ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

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Abbreviations and Acronyms

A	Ala Wai (designating sub-watershed)
BWS	Board of Water Supply
City	City and County of Honolulu
cfs	cubic feet per second
CN	curve number
USACE	United States Army Corps of Engineers
DLNR	State of Hawai'i, Department of Land and Natural Resources
FEMA	Federal Emergency Management Agency
GIS	geographical information system
HEC-HMS	Hydrologic Engineering Center-Hydrologic Modeling System
HEC-SSP	Hydrologic Engineering Center-Statistical Software Package
HEC-GeoHMS	Hydrologic Engineering Center Geospatial Hydrologic Modeling Extension
HEC-GeoRAS	Hydrologic Engineering Center Geospatial River Analysis System Extension
HSG	hydrologic soil group
IDF	Intensity-duration-frequency
ID	Identification number
J	junction
K	Makiki (designating sub-watershed)
LiDAR	light detection and ranging
M	Mānoa (designating sub-watershed)
MP	Mānoa-Pālolo (designating sub-watershed)
MSL	Mean sea level
MWP	Mānoa Watershed Project
NOAA	National Oceanit and Atmospheric Agency
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
P	Pālolo (designating sub-watershed)
SCS	Soil Conservation Service
T_c	time of concentration
TR-55	Technical Release 55
UHM	University of Hawai'i at Mānoa
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
W	Waikīkī (designating sub-watershed)

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Executive Summary

Introduction

In 2001, the United States Army Corps of Engineers (USACE) recommended flood mitigation and ecosystem restoration measures for the Ala Wai Watershed, located on the southeast sector of the island of Oʻahu, Hawaiʻi. As part of this larger goal, USACE contracted Oceanit to develop a Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) for a range of potential storms in the Ala Wai Watershed. HEC-HMS is the USACE hydrologic model. The purpose of this study was to estimate peak flow discharges at particular drainage junctions in the Ala Wai Watershed corresponding to the following storm return periods: 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year. These storm return periods correlate to storm chance exceedance probabilities of 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent, respectively.

Purpose

Whereas this study focuses on the HEC-HMS model, this study uses a total of five different methods to estimate peak flow discharges throughout the Ala Wai Watershed for potential storms ranging in duration and intensity. Estimated peak flow discharges are based on the existing conditions of the Ala Wai Watershed's sub-watersheds of Makiki, Mānoa, and Pālolo valleys; Mānoa- Pālolo and Ala Wai Canals; and Waikīkī. Discharge at junctions of interest throughout these sub-watersheds was studied. Oceanit modeled storms using both rainfall-runoff and peak flow frequency methods for a range of storm scenarios, as follows. The study (1) researched and collected relevant hydrologic data; (2) constructed and calibrated both rainfall-runoff and peak flow frequency hydrologic models; and (3) weighted and compared the results from these models to arrive at estimated peak flow discharges.

Study Area

The Ala Wai Watershed encompasses a drainage area of 10,400 acres (16.2 square miles) of area that are economically significant and densely populated. The existing conditions throughout the Ala Wai Watershed are relevant to its hydrologic analysis, including the character of the watershed's overall climate, topography, geology, vegetation, land use and cover, and water resources. Hawaiʻi's high moisture, orographic rainfall, and northeasterly trade winds create wet conditions in the upper Ala Wai Watershed. The topography of the upper Ala Wai watershed is relatively steep and stony that, in combination with heavy rainfall, provides conditions prone to flash flooding. The lower Ala Wai watershed has finer well-drained soil, but much of it is urbanized, meaning its terrain surfaces are impervious. In terms of streams, the Makiki, Mānoa, and Pālolo streams drain their respective sub-watersheds. Mānoa and Pālolo streams combine to form the Mānoa-Pālolo Canal that empties into the Ala Wai Canal. Runoff and drainage from Waikīkī empties into the Ala Wai Canal as well.

Data Collection Procedure

Data collection for hydrologic analysis included rainfall gage data, stream flow gage data, records of historical storms, maps of storm drainage systems, geospatial data, and field surveys observations. Storms that occurred on December 17–18, 1967; October 30, 2004; and March 31, 2006 were used to calibrate the HEC-HMS model. The City and County of Honolulu drainage maps and University of Hawai'i's utility maps were used to determine the existing storm drainage system. Geospatial information, including LiDAR data and aerial maps established terrain roughness characteristics and stream channel cross sections. Rainfall data was extrapolated to be converted into intensity-duration-frequency (IDF) curves, illustrating rainfall intensities according to their duration.

Hydrologic Analysis Procedure

Hydrologic analysis of sub-watersheds of the Ala Wai Watershed predicted from the application of five hydrologic modeling methods: the HEC-HMS model, USGS regression method, City and County of Honolulu drainage standards Plate 6, Federal Emergency Management Agency Flood Insurance Study, and the HEC Statistics Software Package (SSP). The HEC-HMS model of the Ala Wai Watershed was the focus of this report, and the results from this model were relied on more than other methods.

SCS curve number Loss Method was applied and Clark Unit Hydrograph transform method was applied for non-urbanized areas, and the Kinematic Wave Transform Method was used for urbanized areas. The Ala Wai Canal was assumed to be a reservoir for the purposes of this study because of backwater effects that are possible in the mouth of Ala Wai Canal. Also, according to the TR-55 method, the water flow path was separated into three portions: sheet flow, shallow concentrated flow, and channel flow, which are summed to calculated time of concentration. Manning's *n* values were selected for the land surface characteristics for the Ala Wai Watershed. Curve number calculations were established according to the hydrologic soil group.

Results

Final "best" peak flow discharges were determined by comparing the various derived discharge-frequency curves graphically and by the accuracy or uncertainty of each method. Table ES-1 shows the results of peak flows discharges at the mouth of the Ala Wai Canal.

Peak Flow Discharges at Mouth of Ala Wai Canal								
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
Methodology	**Peak flow discharge (cubic feet per second)**							
HEC-HMS (original Dec 2008)	6,000	10,100	13,390	15,190	16,740	17,670	18,690	20,480
Plate 6						22,500		
FEMA			13,700		23,000	28,200		36,200
HEC-HMS (updated Nov 2010)	8,080	11,900	14,400	16,000	17,800	19,100	20,700	22,200
Final Used (November 2010)	**6,000**	**11,500**	**13,500**	**16,000**	**18,000**	**19,500**	**20,500**	**22,000**

Table ES-1. Peak Flow Discharges at Mouth of Ala Wai Canal (Updated November 2010)

1 Introduction

1.1 Background

In 2001, the United States Army Corps of Engineers (USACE) recommended flood mitigation and ecosystem restoration measures for the Ala Wai Watershed, located on the southeast sector of the island of Oʻahu, Hawaiʻi. These measures constitute the Ala Wai Watershed Project that encompasses a drainage area of approximately 10,400 acres of the valleys of Makiki, Mānoa, and Pālolo, and low-lying areas of Mōʻiliʻili, McCully, and Waikīkī. These areas are economically significant and densely populated, and many have high potential for flooding. Historically, floods have occurred in the Mānoa, Makiki, and Mōʻiliʻili areas due to quick concentration of storm waters that overwhelms the drainage system capacities. Depending on a storm's intensity and duration, the steep slopes of the upper Ala Wai Watershed can create flood conditions due to its steep slopes and impervious surfaces from urbanization. In the past, such as during the severe storm of October 30, 2004, flash flood waters with accumulated debris have caused significant property damage to residential, commercial, and public land (Belt Collins 1998).

Storm runoff in these areas flows through drainage systems that ultimately empty into the Ala Wai Canal. In turn, the Ala Wai Canal flows into the Pacific Ocean. The Ala Wai Canal was constructed in the 1920s, and has experienced heavy sedimentation and economic degradations since its inception (Belt Collins 1998). The proposed flood mitigation measures for the Ala Wai Watershed Project must be based on the best hydrologic and hydraulic data available.

USACE contracted Oceanit to conduct hydrologic analysis for a range of potential storms in the Ala Wai Watershed. This hydrologic study uses five different methods to estimate peak flow discharges throughout the Ala Wai Watershed for potential storms ranging in duration and intensity. Best available predictions are based on the existing conditions of the Ala Wai Watershed's sub-watersheds of Makiki, Mānoa, and Pālolo valleys, Ala Wai Canal, and Waikīkī. Also, the existing conditions of junctions along the Mānoa-Pālolo Canal were considered because of the canal's crucial position as a drainage channel between Mānoa-Pālolo and the Ala Wai Canal, where it empties. Oceanit was directed to model storms using both rainfall-runoff and peak flow frequency methods for a range of storm scenarios, as follows.

1.2 Purpose and Scope

The purpose of this study was to estimate peak flow discharges at particular drainage junctions in the Ala Wai Watershed corresponding to the following storm return periods: 2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year. These storm return periods correlate to storm chance exceedance probabilities of 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent, respectively. The study's scope is solely hydrologic and encompasses the Ala Wai Watershed's sub-watersheds of Makiki, Mānoa, and Pālolo valleys, Ala Wai Canal, and Waikīkī. The study also examines the junctions along the Mānoa-Pālolo Canal.

1.3 Methodology

This hydrologic study provides estimated peak flow discharges for a range of storms for particular junctions throughout the Ala Wai Watershed by applying five hydrologic methods as appropriate

and necessary. The following were completed in this study: (1) relevant hydrologic data was researched and collected; (2) rainfall-runoff models were constructed and calibrated; (3) peak flow discharges based on rainfall intensity-frequency-duration curves were modeled; and (4) these peak flow discharges were weighted and compared to arrive at final results that represent the *best* estimated peak flow discharges.

First, research on the overall existing conditions in the Ala Wai Watershed study area was conducted. Section 2.1 describes these overall existing conditions, and then Sections 2.2 through 2.4 detail the existing conditions in each sub-watershed. Conditions that were necessarily evaluated for hydrologic modeling included the slope, character, elevation, vegetative coverage, acreage, and use of the sub-watershed lands. Many of these conditions were evaluated from review of existing literature, gathering of geospatial data, and inspection during field visits. This data collection is documented in Section 3.5. Sub-basins within each sub-watershed were delineated using the geospatial data (see Section 3.6). Also, Manning's *n* values, which describe land cover and roughness, were selected (see Section 4.1.5). The existing conditions of drainage systems in the study area were primarily collected from the City and County of Honolulu's Storm Drainage System Maps (Section 3.4), and were confirmed during field visits. Primarily, drainage junctions of interest in the Ala Wai Watershed were determined from evaluating the existing drainage facilities.

Second, potential storm rainfall amount determinations were extrapolated from historic rainfall data. The storm rainfall amounts that were the input for the hydrologic model are considered the meteorological model. The rainfall and stream flow data were collected from rain gage and stream flow gage records as available for the study area (see Sections 3.1 through 3.2). Records from three severe storms were collected and later used to calibrate the hydrologic model (see Section 3.3). Rainfall amounts that constitute the frequency storms in the meteorological model were gathered from a study entitled "Rainfall Frequency Study for Oahu" (Giambelluca 1984) known commonly as Report R-73. Rainfall amounts were gathered from Report R-73 for the storm chance exceedance probabilities of 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent. Intensity-Duration-Frequency curves were established for input into the model.

Third, five methods were used to model the Ala Wai Watershed's hydrology. The rainfall-runoff method used was USACE's Hydrologic Engineering Center–Hydrologic Modeling System (HEC-HMS). The peak flow frequency methods used were the United States Geological Survey (USGS) regression equations, the City and County of Honolulu (the City) Plate 6 storm drainage standards, the Federal Emergency Management Agency (FEMA) Flood Insurance Study for the City and County of Honolulu (2004), and Hydrologic Engineering Center–Statistical Software Package (HEC-SSP). The fourth step in this study was, depending on the data available, applying these methods for each sub-watershed or junctions if available for the range of potential storms: chance exceedance probabilities of 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent. The methods used for each junction (by sub-watershed) are shown in Table 1-1 and designated by a checkmark.

Junction	Drainage area (mi^2)	HEC-HMS	USGS Regression Equations	FEMA-FIS	C&C-Plate 6	HEC-SSP
MAKIKI						
JK1	2.33	√	√		√	
JK2	2.49	√	√	√	√	
JK3	2.89	√			√	
MANOA						
JM8	5.97	√	√	√	√	
PALOLO						
JP1	1.15	√	√		√	√
JP2	2.94	√	√		√	
JP3	3.62	√	√	√	√	√
JP4	4.07	√	√		√	
MANOA-PALOLO						
JMP1	10.04	√	√		√	
JMP2	10.34	√	√	√	√	√
JMP3	10.68	√			√	
ALAWAI						
Mouth of Ala Wai Canal	16.22	√		√	√	

Table 1-1. Methods Used by Sub-Watershed Junction

J = junction; K = Makiki; M = Mānoa; P = Pālolo; MP = Mānoa-Pālolo; and mi = miles. A checkmark indicates a method that was used for a particular junction or outlet.

1.3.1 HEC-HMS Analysis

The HEC-HMS model was the primary method of this study. The HEC-HMS method is a precipitation-runoff process model that requires three components including a basin model, a meteorological model, and a control model. The basin model layout was created according to sub-basin delineation and junctions of interest. For the purposes of this study, sub-watershed refers to the larger areas of Makiki, Mānoa, Pālolo, Ala Wai Canal, and Waikīkī; the term "sub-basin" refers to the smaller sub-watersheds within these sub-watersheds to avoid confusion. Also the term "sub-basin" is commonly accepted for the HEC-HMS model delineation of small drainage areas.

1. **Basin Model:** Under the basin model, Ala Wai Watershed was divided into 38 sub-basins. The SCS loss method and Clark Unit Hydrograph transform methods were applied for upper Makiki, Mānoa, and Pālolo valleys because these areas are considered non-urban. The Kinematic Wave Transform Method was applied for the lower Makiki ,Ala Wai Canal, and Waikīkī areas because these areas are considered urban. Selected stream flow routing methods included the Muskingum-Cunge method to account for the peak flow attenuation and the Modified Puls method to account for the backwater effects for reaches collected in the Ala Wai Canal. Ala Wai Canal was modeled as a reservoir. Several basin models were created based on the calibration and determination purposes.

2. **Meteorological Model:** A meteorological model was used to specify how precipitation would be generated for each sub-watershed in the selected basin model. For calibration purposes, hyetographs were used based on the gage weights. For predictive purposes, the frequency storms were used to produce synthetic flood events, according to exceedance probabilities.

3. **Control Model:** A control model was used to set the computation parameters. This study used a five-minute time interval for all computations.

1.3.2 Peak Flow Discharge Results

Ultimately, all five of these accepted hydrologic methods offer the *best* estimated peak flow discharges at particular junctions through Ala Wai Watershed for a range of potential storms. Available results were first weighted by accuracy or uncertainty of method, and then plotted on log-probability graph paper. Selection was completed for a best fit curve function for the peak flow discharge frequency curve at each junction of interest. Final peak flow discharges are presented in Section 5.

1.4 Acknowledgements

The USACE project managers for this study were Mr. Derek Chow and Ms. Cindy Barger. The hydrologic analysis technical team consisted of Mr. Michael Wong with the USACE and Mr. Simon Li of Oceanit. Oceanit's project manager was Dr. Dayananda Vithanage with assistance from Mr. Jay Stone and Ms. Joanne Hiramatsu. Oceanit's technical staff included Ms. Frances Ajo, Mr. Robert Bourke, Mr. Kevin Gooding, Mr. Jonathan Levy, and Mr. Manabu Tagomori. Thank you to the National Climatic Data Center, Board of Water Supply (BWS), and USGS for providing rain and stream gage data pertinent to this study.

2 Study Area Description

The Ala Wai Watershed contains five sub-watersheds that are addressed in this study: Makiki, Mānoa, Pālolo, Ala Wai Canal, and Waikīkī. The Mānoa-Pālolo Canal is also addressed in terms of its drainage junctions. Section 2.1 describes the existing conditions throughout the Ala Wai Watershed, including the overall climate, topography, geology, vegetation, land use, and water resources. These conditions are similar in each of the Ala Wai sub-watersheds that are described in Sections 2.2 through 2.6.

2.1 Ala Wai Watershed

The subject of this hydrology study is the Ala Wai Watershed, which is located on the southeastern sector of the island of Oʻahu, Hawaiʻi as shown in Figure 2-1. The watershed encompasses 10,378 acres, or 16.215 square miles. The Ala Wai Watershed stretches from the Koʻolau Mountains at Puʻu Kōnāhuanui's peak (3,105 feet) down through the three urban valleys of Makiki, Mānoa, and Pālolo, to the low-lying areas of McCully, Mōʻiliʻili, and Waikīkī. Storm runoff in the watershed flows through numerous drainage systems in these areas and ultimately empties into the Ala Wai Canal. The three major sub-watersheds that constitute the Ala Wai Watershed are Makiki, Mānoa, and Pālolo; all three of these sub-watersheds are valley systems of economic significance and dense population. The Makiki, Mānoa, and Pālolo Streams receive flows from each of these valley systems, respectively (see Figure 2-2). Another Ala Wai sub-watershed is at the confluence of the Mānoa and Pālolo Streams, referred to as the Mānoa-Pālolo Canal, which empties storm water runoff into the Ala Wai Canal between the Ala Wai Golf Course and ʻIolani School. The area surrounding the Ala Wai Canal and the adjacent tourist area of Waikīkī comprise another sub-watershed. These major sub-watersheds are shown in Figure 2-2. (According to the existing conditions, sub-basins are delineated within each sub-watershed, and these sub-basin delineations are presented in Section 3, and shown in Figure 3-4.)

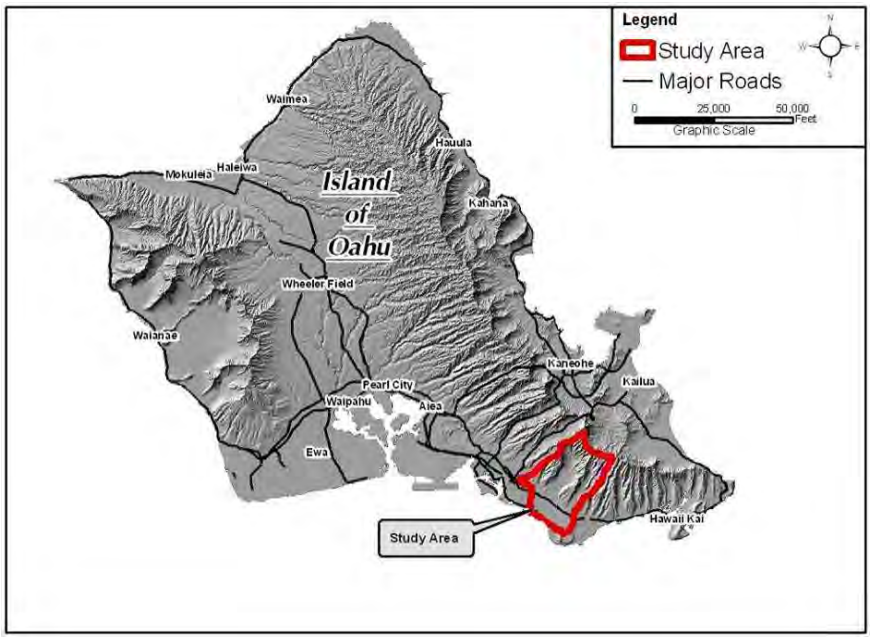

Figure 2-1. Ala Wai Watershed Location Map

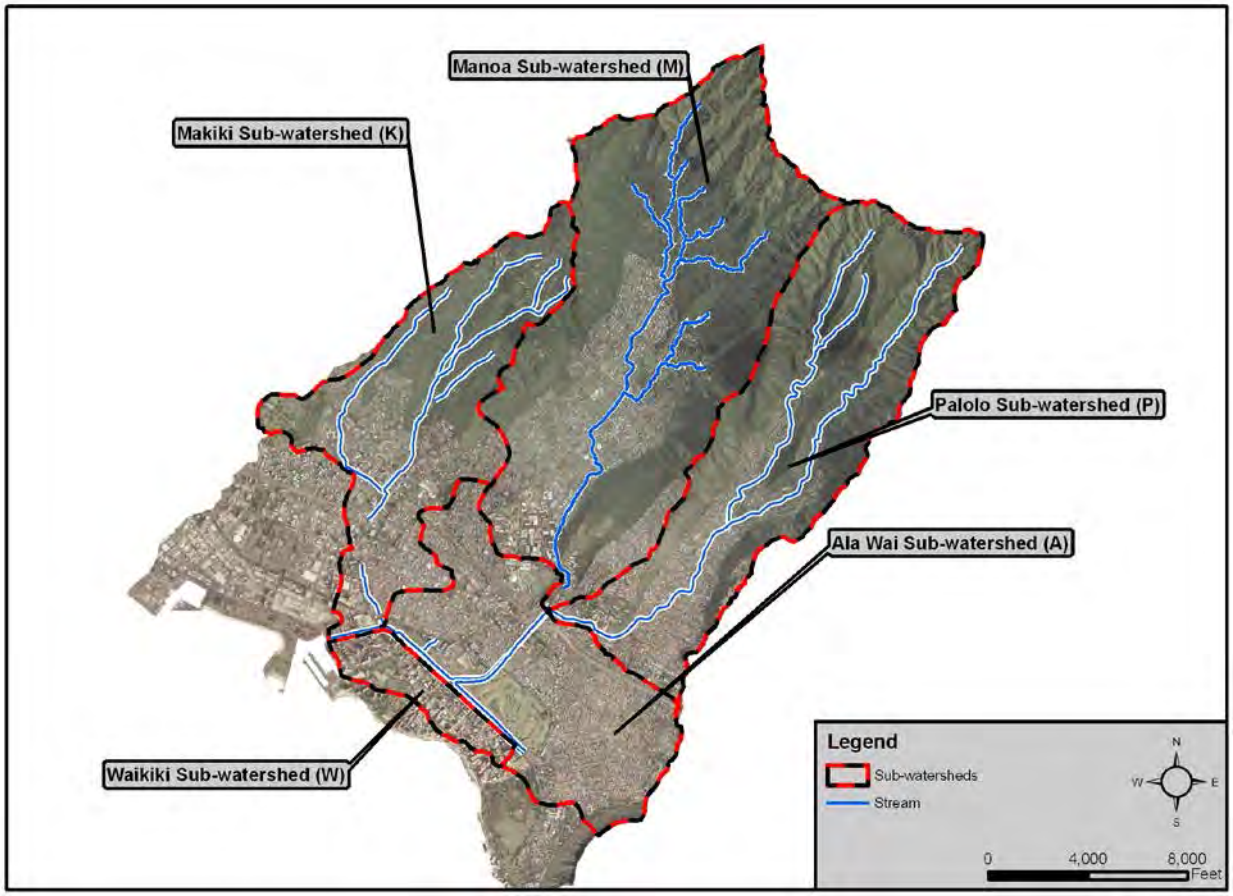

Figure 2-2. Major Streams and Sub-watersheds of Ala Wai Watershed

2.1.1 Climate and Flood Hydrology

Hawai'i's subtropical climate is governed by northeasterly trade winds that regulate weather patterns. The trade winds rise over the Ko'olau Mountain ridges, creating high moisture and orographic rainfall in the mountainous regions. These regions, such as the valley systems of Makiki and Mānoa typically receive more than 160 inches of annual rainfall, whereas the Pālolo valley system receives less annual rainfall (Giambelluca 1984). Generally, rainfall amount decreases as one moves down the valley systems to the southern coast of O'ahu, and so the low-lying areas of the Ala Wai Canal and Waikīkī receive about 30 inches of annual rainfall. The wet winter season occurs from October to April, and the dry summer season occurs from May to September. It should be noted that the three severe storms described for this study occurred in October, December, and March, during the wet winter season. Temperatures on O'ahu fluctuate according to the season, with the winter temperature averaging a high of 77 degrees Fahrenheit (°F) and a low of 64°F. In the summer, temperatures average a high of 81°F and a low of 70°F (NWS 2008).

Floods on Oahu, other than those generated by high ocean waves, are caused by high intensity rainfall. Most major rainstorms that bring flood-producing rainfall are caused by the non-trade wind or Kona wind conditions which occurred during the wet winter season. Rainstorms can bring intense local showers affecting a small area or can blanket the entire island with rain. High-intensity rainfall, small drainage-basin size, steep basin and stream slopes, and little channel storage, produce

floods that are flashy (Wong, 1994). Most drainage basins have rapid response to rainfall characterized by steep triangular hydrographs. Time to peak is usually less than 1 hour and even for large intense storms, the rise and recession of the flood hydrograph usually occurs with 6 hours.

2.1.2 Geology and Soils

The valleys and gulches forming the Ala Wai Watershed are incised into the Koʻolau Volcano. The Koolau lavas are divided into the Koʻolau Basalt and the Honolulu Volcanics. Both of these formations play an important role in the Ala Wai Watershed. The Koʻolau Basalt primarily consists of Pliocene aged shield stage tholeiitic basalt. The Honolulu Volcanics are composed of Pleistocene aged alkalic basalt, basanite, and nephelinite (Lagenheim and Clague, 1987). Holocene and Pleistocene sedimentary caprock is found at the seaward end of the watershed.

The rocks of the Koʻolau Basalt can be divided into three groups, lava flows (aʻa and pahoehoe), pyroclastic deposits, and dikes. The lava flows of the Koʻolau basalt are usually thin bedded with an average thickness of about ten feet (Wentworth and MacDonald, 1953). These beds are composed of aʻa and pahoehoe flows and pyroclastic deposits. Aʻa contains a solid central core between two gravely clinker layers. Pahoehoe flows are usually characterized by a smooth ropy texture. Pyroclastic deposits originate from explosive volcanism. They are composed of friable sand-like ash and indurated tuff deposits. Dikes are thin near vertical sheets of rock that intruded or squeezed into existing lava flows or pyroclastic deposits.

The Honolulu Volcanics erupted much later than the Koʻolau Basalt and overlay the deeply eroded Koʻolau Volcano and its associated alluvial deposits. In Ala Wai they are composed of lava flows and ash and tuff. The lava flows have flow structures similar to the Koʻolau Basalt. The pyroclastic deposits are characterized by easily erodable, sand-like ash and relatively soft and easily erodable tuff. The Sugar Loaf flow which outcrops in cliffs in the UH Quarry poured down from Sugar Loaf on the northwest side of Mānoa Valley and pushed the lower section of Mānoa Stream to the southeast.

The caprock is composed of a wedge of terrestrial and marine sediments. It forms a coastal plain about 8000 feet wide in the Ala Wai area. The caprock is over 1000 feet thick in the seaward areas of the watershed (Wentworth, 1951). Near the ocean, much of the caprock has been covered with artificial fill.

Mānoa and Pālolo valleys are deeply eroded amphitheater shaped valleys that was later backfilled with alluvium and Honolulu Volcanic deposits. The original valleys were probably "V" shaped but the alluvial and volcanic fill material has formed a broad, flat-bottomed valley. The valley fill material is weathered at the surface but despite the heavy rainfall is probably fresh and unweathered in the subsurface. The ridges and valley walls of Mānoa and Pālolo Valleys are generally composed of Koʻolau Basalt (In some areas Honolulu pyroclastics drape the walls). The layered flows of Koʻolau Basalt have eroded into steep weathered cliffs which facilitate rapid runoff. Dikes in the back of the valleys impound groundwater at high elevations which contributes to perennial streamflow.

The altitude within the watershed ranges from mean sea level along the coastal areas, to 40 feet near the confluence of Mānoa and Pālolo Streams, and approximately 2,400 feet in the mountains. Several soil groups are found in the Ala Wai Watershed. The Lualualei-fill land-Ewa association is a

well-drained soil that may be found in the lower elevations. These soils have fine textured or moderately fine-textured subsoil or underlying material. The upper watershed is comprised of rock land-stony steep land association. These soils are generally found on steep to precipitous lands and are well-drained to excessively drained (MacDonald et al. 1970).

2.2 Makiki Sub-Watershed

The Makiki sub-watershed is the westernmost of the Ala Wai Canal drainage sub-watersheds, and drains 1,850 acres or 2.89 square miles of land. Makiki Stream, which is approximately 3.5 miles long, drains the sub-watershed. The stream's tributaries include Kanahā Stream, the main tributary that connects to Makiki Stream via Kanahā Ditch (a long lateral channel of about 6,400 feet), Kānealole Stream, Moleka Stream, and Maunalaha Stream (Townscape 2003). The upper segment of the sub-watershed is in the Koʻolau Mountains and is bordered to the west by the Punchbowl Crater.

Whereas the upper sub-watershed is largely forested and undeveloped, the sub-watershed becomes more urbanized as one moves seaward. The upper Makiki sub-watershed has preservation land uses and is considered non-urbanized in this study. The lower Makiki sub-watershed includes the populated Makiki areas of Wilder Avenue, Mānoa Road, and McCully Street. The urbanized portion of the sub-watershed has residential and commercial land uses. Makiki Stream runoff from urban areas and minor streams ultimately discharges into the Ala Wai Canal between McCully Street and Kalākaua Avenue bridges.

2.3 Mānoa Sub-Watershed

Mānoa sub-watershed is located between the Makiki and Pālolo drainage sub-watersheds and drains 3,822 acres (5.97 square miles) of land from the Koʻolau Mountains to the confluence of Mānoa and Pālolo Streams. The upper sub-watershed has preservation land uses and is considered non-urban. In the upper sub-watershed area, several smaller tributaries feed into the Waihī and Waiakeakua Streams and flow into the Mānoa Stream. Mānoa Stream drains the sub-watershed. The Mānoa Stream passes by Noelani Elementary School, the University of Hawaiʻi at Mānoa (UHM) upper campus, and Kānewai Field, and finally meets the Pālolo Stream to form the Mānoa-Pālolo Canal.

Most of the ground surface in the upper sub-watershed is covered with primarily non-native forest, and the middle segment of the sub-watershed is highly urbanized. The natural path and the characteristics of the Mānoa Stream have been altered significantly. Urban culverts discharge storm runoff into the Mānoa Stream throughout the developed area.

2.4 Pālolo Sub-Watershed

The Pālolo drainage sub-watershed is the easternmost of the Ala Wai Canal drainage sub-watersheds, and drains 2,601 acres (4.07 square miles) of land. The Mānoa sub-watershed borders it to the west, and the Mauʻumae Ridge borders the sub-watershed to the east. The Pālolo sub-watershed drains the Koʻolau Mountains and extends down Pālolo Valley to Waiʻalae Avenue. For the purposes of this study, the upper Pālolo sub-watershed is considered non-urban because it has preservation land use. Pūkele Stream and Waiʻōmaʻo Stream are the sub-watershed's two tributary streams. These streams flow into the Pālolo Stream that drains mostly the urbanized portion of the sub-watershed. The land uses in this area are commercial and residential. The Pālolo Stream meets the Mānoa Stream as the Mānoa-Pālolo Canal. As the Pālolo Stream passes through the urban Pālolo area, the stream is a concrete-lined channel that was part of a flood control project constructed by the City and County of Honolulu.

2.5 Mānoa-Pālolo Canal Junctions

The Mānoa and Pālolo Streams meet as the Mānoa-Pālolo Canal downstream of Kānewai Field and immediately north of Waiʻalae Avenue. The Mānoa-Pālolo Canal discharges into the Ala Wai Canal downstream of the Ala Wai Golf Course. Even though Mānoa-Pālolo Canal drains a segment of the Ala Wai Canal sub-watershed, it does so through large storm drainage outfalls that empty directly into the canal. Thus, only junctions (not areas of the sub-watershed) of the Mānoa-Pālolo Canal were examined for this study, and the large outfalls that enter the canal drain 20,285 acres of land.

2.6 Ala Wai Canal Sub-Watershed

The Ala Wai Canal sub-watershed drainage system is 1805 acres (2.82 square miles) including the Mānoa-Pālolo Canal. Historically, the lower portion of Ala Wai Watershed consisted of wetlands and provided ample storage for heavy runoff from the watershed. Ala Wai Canal was designed to drain the wetlands formed by the streams and create dry land for Waikīkī resort development, and the canal was constructed in the 1920s. At the time of the Ala Wai Canal project, the urban development in the watershed was limited, but today the Waikīkī area is heavily urbanized. Runoff from Makiki, Mānoa, and Pālolo sub-watersheds contains suspended materials from the natural

reaches of these watersheds, and, as a result, Ala Wai Canal has experienced significant sedimentation over the years.

For the purpose of this study, the Ala Wai Canal was modeled as a reservoir using USACE's HEC-HMS. Considering that the canal may be subject to backflow and meets the ocean at mean sea level, a reservoir model is appropriate due to the low elevation and likelihood of water storage. This assumption significantly affected the modeling of the Ala Wai Canal.

2.7 Waikīkī Sub-Watershed

The Waikīkī drainage sub-watershed is the southern-most and coastal area of the Ala Wai Canal drainage sub-watersheds, and drains 298 acres (0.47 square miles) of coastal land. The Waikīkī area is heavily urbanized and not only a vital center of the tourism industry on O'ahu but also a popular residential, shopping, and nightlife area. Historically, the Waikīkī area was swamp land, and thus the sub-watershed is low-lying. The sub-watershed is characterized by impervious surfaces, and storm drainage runoff either flows as overland flow, flows directly into the ocean, or flows through the City drainage system directly into the Ala Wai Canal. The canal is at a similar elevation as the Waikīkī sub-watershed itself.

3 Data Gathered

The character of the land, the historical rainfall data, and historical stream flow data are relevant to the hydrological analysis of the Ala Wai Watershed. Data used for HEC-HMS model calibration included rain gage data, stream flow gage data, stage gage data, and tide gage data records of historical storms, and field surveys. These data were used to create rainfall intensity-duration-frequency curves. Rainfall data were the input for the HEC-HMS rainfall-runoff model calibration.

3.1 Rain Gages

Data sets from thirteen rain gages were used for the Ala Wai Watershed hydrologic analysis. Four of these rain gages are operated by the National Weather Service (NWS), four rain gages are operated by the BWS, three rain gages are operated by USGS, one rain gage is operated by the UHM, and one rain gage is privately operated. The characteristics of each gage are listed in Table 3-1. Figure 3-1 maps these rain gages in or nearby the study area, labeled by their name and identification number (ID). As shown, rain gages are located in a diversity of elevations and locations throughout the greater Ala Wai Watershed.

Typically, rainfall in upper elevations of the sub-watersheds is greater than that of the lower elevations. For the Makiki sub-watershed, the rain gage at the highest elevation is the Tantalus Peak gage at 1,665 feet above mean sea level (MSL). The Mānoa Tunnel rain gage at 650 feet above MSL is the highest for the Mānoa sub-watershed, and the Pālolo Tunnel rain gage is located at 995 feet above MSL. The lowest rain gage for the entire Ala Wai watershed is the Waikīkī Zoo gage at about 5 feet above MSL. It should be noted that three rain gages were located outside the study area. The Waikīkī Zoo rain gage (717.2) was used to represent the Ala Wai Canal and Waikīkī sub-watersheds. The Wihelmina Rise rain gage (721) was used to represent the middle Pālolo sub-watershed, and the Punchbowl Crater rain gage (709) was used to represent the lower Makiki sub-watershed. Figure 3-2 shows the annual rainfall distribution in the Ala Wai Watershed by major sub-watersheds.

Rain gage data sets vary according to whether records are taken in real time (typically 15-minute intervals) or daily. Records were used to extrapolate the rainfall hyetographs for all the sub-watersheds in the calibration basin models. Also, rain gage records provided essential data for three storms that were used to calibrate the HEC-HMS model. Those storms occurred on December 17–18, 1967; October 30, 2004; and March 31, 2006.

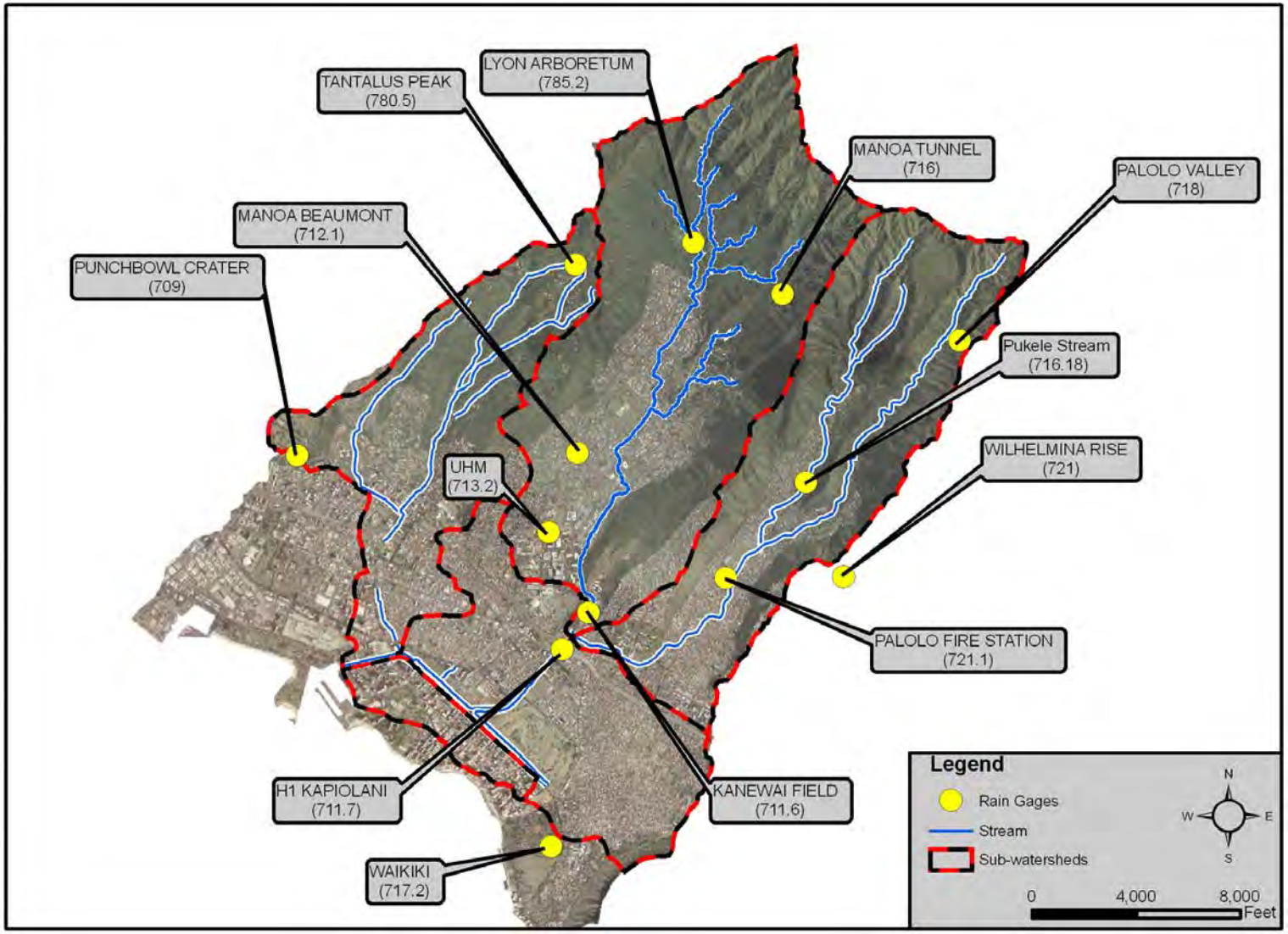

Figure 3-1. Ala Wai Watershed Rain Gages Used by Identification Number

Characteristics of Rain Gages Used

Name	ID	Latitude	Longitude	Elevation (ft)	Records	Real-time recording†	Daily recording*	Operator
Lyon Arboretum	785.2	21°20'08"	157°48'12"	500	1975– Present	√		NWS
Mānoa Tunnel	716	21°19'48"	157°47'36"	650	1927– Present		√	BWS
Kānewai Field	711.6	21°17'47"	157°48'56"	38	1999– Present	√		USGS
Mānoa Beaumont	712.1	21°18' 48"	157°49'00"	200	1947– Present		√	Private
UHM	713.2	21°18'18"	157°49'12"	120	1952– Present		√	UH
Pālolo Fire Stn.	721.1	21°18'00"	157°48'00"	190	1950– Present	√		NWS
Pālolo Tunnel	718	21°20'00"	157°49'00"	995	1926– Present	√		BWS
H-1 Kapiolani	711.7	21°17'22"	157°48'56"	20	2005– Present	√		USGS
Punchbowl Crater	709	21°18'48"	157°50'54"	355	1950– Present		√	NWS
Waikīkī Zoo	717.2	21°16'00"	157°49'00"	5	1957– Present	√		NWS
Wihelmina Rise	721	21°18' 00"	157°47'12"	1100	1927– Present		√	BWS
Pūkele Stream	716.18	21°18'36"	157°47'27"	345	1927– 2005	√		USGS
Tantalus Peak	780.5	21°20'00"	157°49'00"	1665	1927– Present		√	BWS

Table 3-1. Characteristics of Rain Gages Used.

† Real-time recording is by time intervals of 15 minutes. *Daily recording is 24-hour period

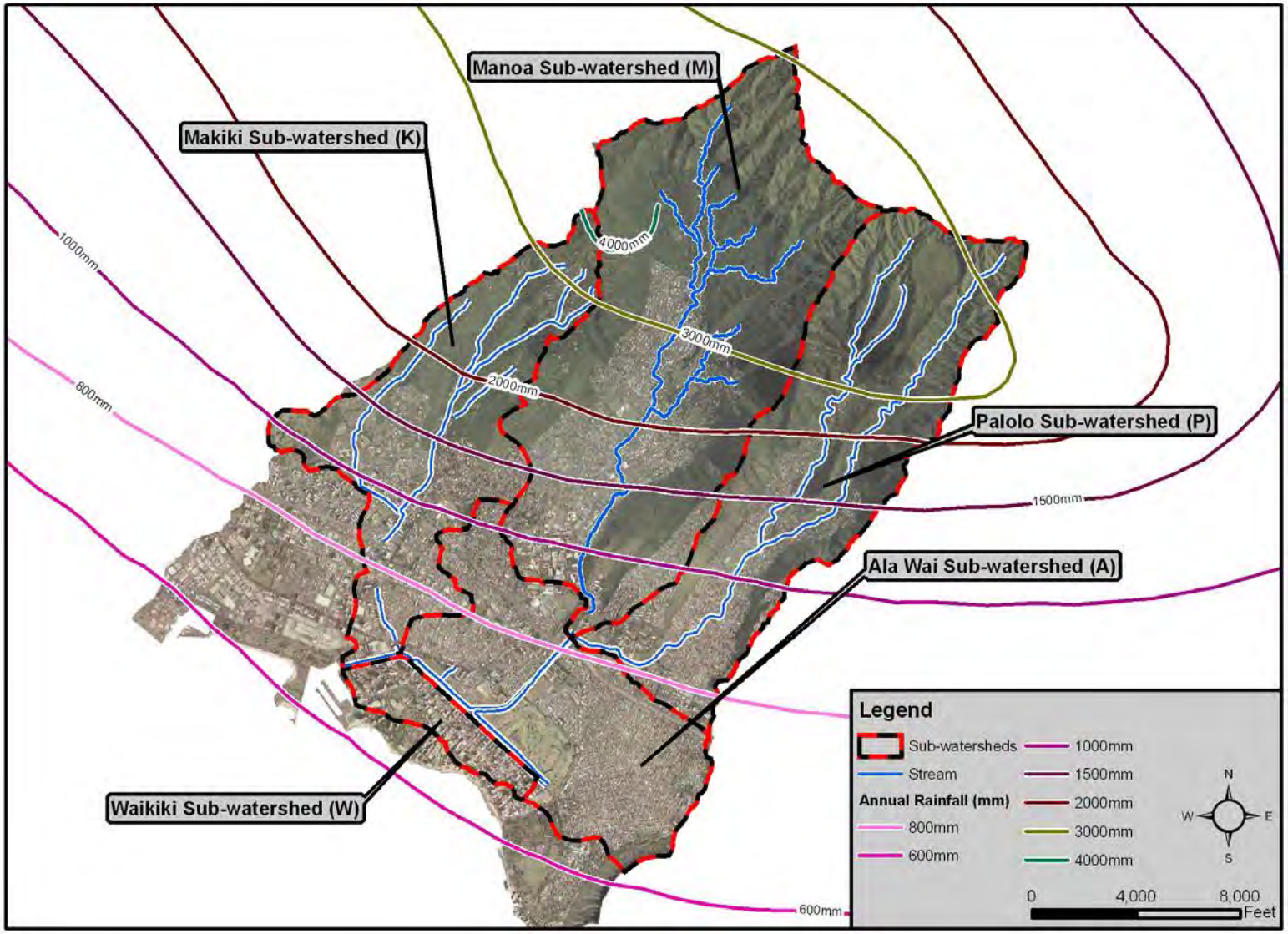

Figure 3-2. Annual Rainfall Distribution for Ala Wai Watershed by Major Sub-watershed

3.2 Stream Flow Gages

Historic stream gage records were used to develop the sub-basin analyses for the HEC-HMS model. Data sets came from nine stream gages throughout the Ala Wai Watershed, and these gages are shown in Figure 3-3 labeled with their USGS identification number. Stream gage data for three storms were essential for calibrating the HEC-HMS model (see calibration discussion in Section 3.8). These three storms occurred in 1967, 2004, and 2006 and are discussed in Section 3.8. Stream gage data for these events are limited depending on whether the gages' record continuously, such as by 15-minute intervals, or whether they simply record peak flow values. The characteristics of the stream gages are given in Table 3-2, and the stream flow gages are shown in Figure 3-3.

3.3 Stage Gages

The Waikīkī and Ala Wai Canal sub-watersheds are located on low-lying coastal land, and data from two stage gages were used in these areas, as shown in Figure 3-4. Stage gage data was essential for calibrating the Ala Wai Canal sub-watershed model detailed in Section 4.6. The nearest stage gage in the ocean was the National Oceanic and Atmospheric Agency's (NOAA's) tide level station 1612340 at Honolulu Harbor, which was used to calibrate the model. The other gage used was USGS 16247130 at Ala Wai Elementary School. These stage gages are located west of the study area as shown in Figure 3-2. Although there are no public published stage records, the local USGS office provided Oceanit with continuous stage data for the October 30, 2004, storm for calibration purposes (see Section 4).

Characteristics of Stream Gages Used									
Gage Location	**Waihī**	**Waiakeakua**	**Lowrey**	**Kānewai**	**Pūkele**	**Waiʻōmaʻo**	**Pālolo**	**Makiki**	**Mānoa-Pālolo**
Gage Number	16238500	16240500	16241500	16242500	1624400	16246000	16247000	16238000	16247100
Gage Location, Latitude	21°19'55"	21°19'52"	21°18'53"	21°17'47"	21°18'36"	21°18'34"	21°17'35"	21°17'02"	21°17'24"
Gage Location, Longitude	157°48'12"	157°48'08"	157°48'41"	157°48'56"	157°47'27"	157°47'11"	157°48'25"	157°50'22"	157°49'17"
Gage Elevation (ft)	289.84	294.5	294.5	38	344.78	373.66	95	10	5
Drainage Area (USGS, mi^2)	1.14	1.06	4.02	5.05	1.18	1.04	3.63	2.23	10.6
Drainage Area (mi^2)	1.19	1.07	4.22	5.643	1.146	1.036	3.62	2.49	10.34
Period of Continuous Record	1913–1983	1913–Present	---	1999–Present	1927–2004	1927–1971	1953–Present	---	1967–Present
Peak Flow Record Only	---	---	2003-2004	---	---	---	---	2003-2004	---
Number of Annual Peaks Available for Analysis	63	88	3	6	59	39	32	2	40

Table 3-2. Characteristics of Stream Gages Used

Characteristics of Stage Gages Used		
Gage Location	**Honolulu Harbor**	**Ala Wai Elementary School**
Gage Number	1612340	16247130
Gage Location, Latitude	21° 18.4'	21°17'16"
Gage Location, Longitude	157° 52.0'	157°49'51"
Gage Elevation (ft)	B.M. ELV. 8.06 Feet	5
Period of Continuous Record	1905-present	2003-2004

Table 3-3. Characteristics of Stage Gages Used

Note: B.M. ELV.= Bench Mark Elevation

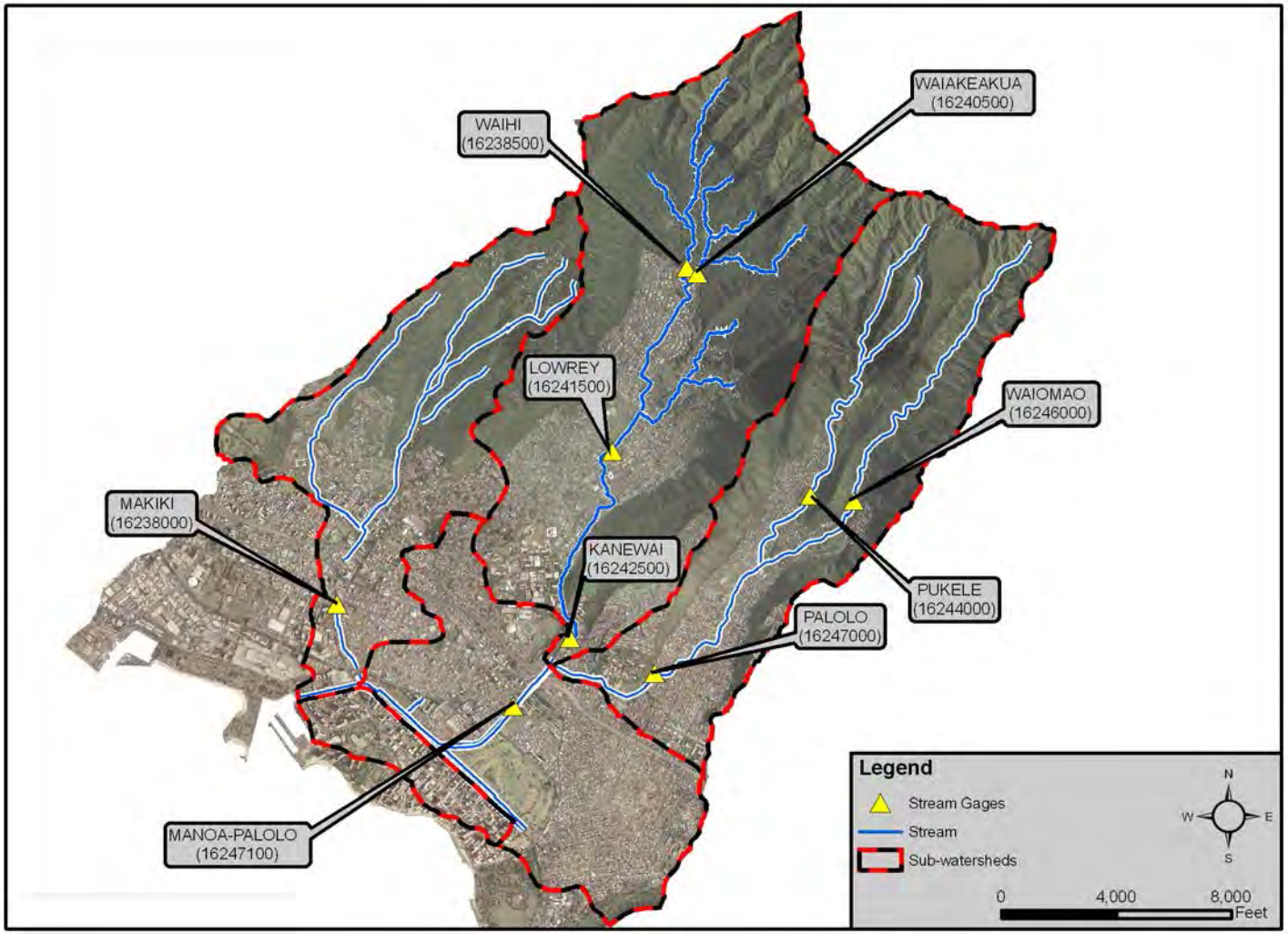

Figure 3-3. Ala Wai Watershed Stream Gages Used by ID Number

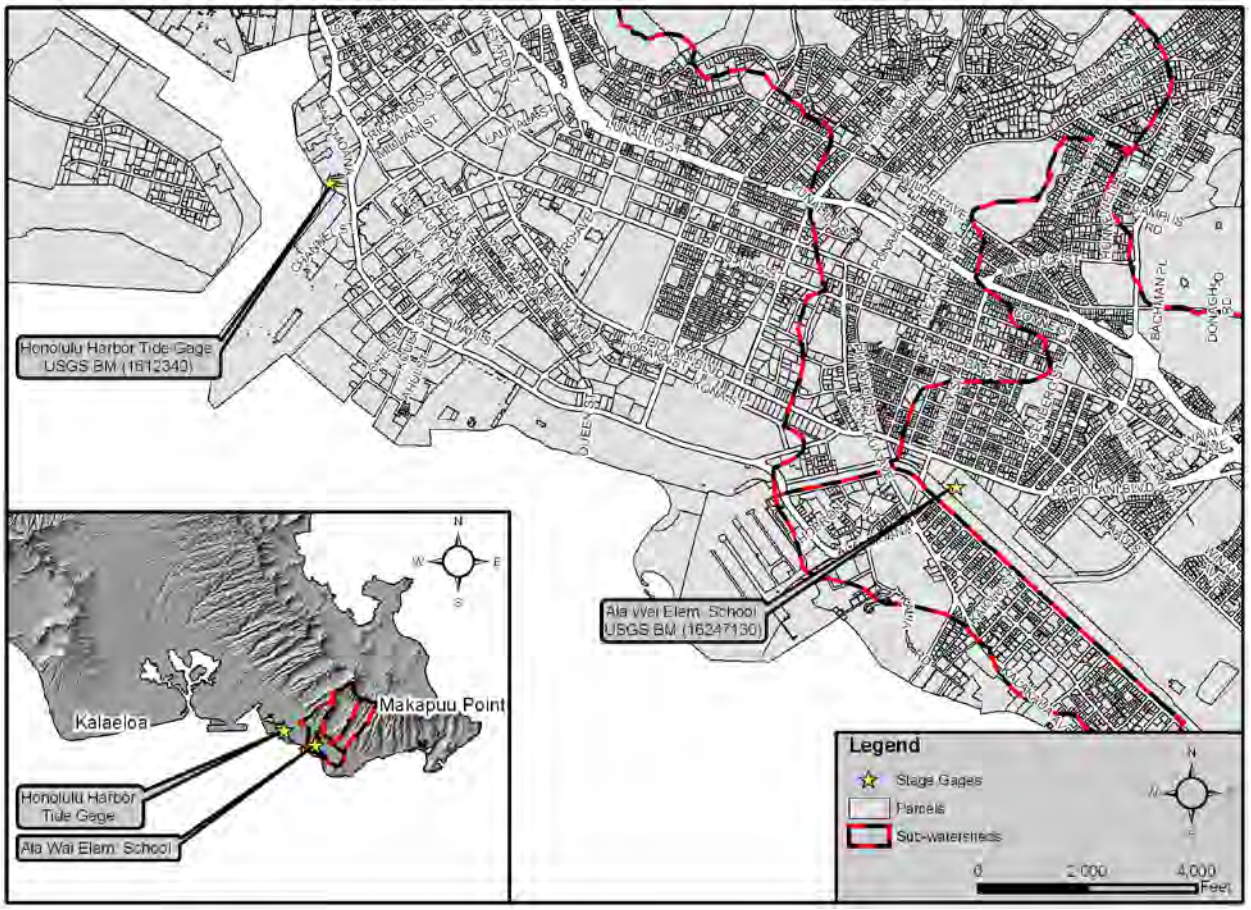

Figure 3-4. Ala Wai Watershed Stage Gages Used (with ID Number)

3.4 Drainage Systems

The City's municipal storm drainage system drains the sub-watersheds of the study area. Runoff from storms flows into the streams or drainage systems throughout the study area. The City's drainage maps were used to identify the locations of the existing storm drainage system. These maps provided information about the characteristics of drainage system segments, including whether the segments are natural or channelized and the size of outlets throughout the system. The drainage systems evaluation results were used in determining the sub-basins boundaries. For example, the boundaries of sub-basin K4 were mainly determined from drainage evaluation.

University of Hawai'i at Mānoa provided utility maps showing the drainage systems through the campus area. Existing conditions of the UHM's storm drainage system, such as the size of relevant culverts, were gathered from these maps. Detailed drainage systems information can be found in the *Final Drainage Evaluation Report Ala Wai Watershed Project* (Oceanit 2008). The drainage systems information within the UHM upper campus was used to determine the boundaries of sub-basin M12. Based on this information, the boundaries of sub-basins M12 were changed slightly. As a result, this sub-watershed's drainage area was different from the Manoa Watershed Study—it changed from 0.672 to 0.749 square miles.

3.5 Geospatial Data

Geospatial information [1] and field survey observations were used to determine hydrologic conditions, such as terrain roughness characteristics and stream channel cross sections. Information collected included LiDAR data and aerial maps. Numerous field visits to the various sub-watersheds of the study area were made over the course of January 2008 until September 2008 to confirm and/or describe any relevant existing condition of a drainage system facility or the existing conditions in a sub-basin.

LiDAR data were inputted into ArcView GIS 3.3 with the HEC-GeoHMS 1.1 extension to create a geospatial model of the Ala Wai Watershed. The HEC-GeoHMS (USACE 2003) model was used to delineate the initial sub-watershed boundaries, calculate sub-watershed areas, and determine flow path lengths and slopes. However, the sub-watersheds within the study area were not completely delineated by the HEC-GeoHMS model alone. The existing drainage infrastructure and the locations of potential conceptual design measures were important factors for sub-watershed delineation. The final sub-watershed delineation was the result of a combination of the HEC-GeoHMS model, an evaluation of the existing storm drainage system, and the potential locations of the conceptual design measures. LiDAR data were used to approximate the boundaries of sub-basins and sub-watersheds. In addition, ArcView GIS 3.3 and drainage maps were used to determine the boundaries of urbanized areas of the sub-watersheds' drainage areas because better resolution was available for evaluation.

3.6 Sub-Basin Delineation

For the purposes of this study, sub-watershed refers to the larger watershed areas of Makiki, Mānoa, Pālolo, and Waikīkī, and the term "sub-basin" refers to the smaller sub-watersheds within these sub-watersheds. These terms are used to avoid confusion. Also the term "sub-basin" is commonly accepted for the HEC-HMS model delineation of small drainage areas. Sub-basins provide clear boundaries for hydrologic study, and sub-basins were delineated according to a couple of assumptions. Sub-basin delineation assumes the following.

> The City's drainage systems can handle the storm runoff for all return periods from 2-year through 500-year storms.

This assumption takes into account all the storm runoff for storms, but not all storm runoff necessarily flows through storm drainage systems. According to the United States Department of Agriculture (1990; Module 206A), "Storm sewers generally handle only a small portion of a large

[1] The aerial images that were used for the hydrologic analysis are from the National Geospatial-Intelligence Agency (NGA) supplied by the USGS. The specifications for these images are 0.3 meter pixel size, rectified natural color image orthoimage. The working image was re-sampled to 1-meter pixel size.

The digital elevation LiDAR data used in this hydrologic analysis were obtained from AIRBORNE 1, with an accuracy of 4 elevation points per square meter. The original data were reprojected to North American Datum (NAD) 83 HARN 1993 Universal Transverse Mercator (UTM) Zone 4 meters. The grid size was 2 meters by 2 meters.

event. The rest of the peak flow travels by street, lawns, and so on to the outlet." This suggests that storm runoff flows along the natural geographic flow path and not necessarily through the storm drainage system. Based on the City's storm drainage standards, the drainage capacities with catchment areas greater than 100 acres should meet 100-year storm drainage standards; the drainage capacities with catchment areas equal to or less than 100 acres should meet 10-year storm drainage standards. Consequently, at junctions with contributing drainage systems, peak discharges may be lower than predicted. Similarly, at junctions where drainage system catchment areas are not considered, actual peak discharges may be higher than predicted.

Some delineations of sub-basins and assumptions about sub-basins were necessary for the low-lying areas of Mānoa-Pālolo Canal, Ala Wai Canal sub-watershed, and Waikīkī sub-watershed. Because Mānoa-Pālolo Canal receives drainage from other sub-watersheds with relatively large drainage systems, only the junctions in the Mānoa-Pālolo Canal were examined and there were no sub-basins delineated around the canal itself. Also, delineation for the Waikīkī sub-watershed was particularly problematic because some of its sub-basins drain directly into the ocean with a relatively small flow directed through the outfalls designated on the drainage maps.

It should be noted that all the hydrologic analysis results in this study for Mānoa sub-watershed were exactly the same as performed in the *Mānoa Watershed Project Final Hydrology Report* (Oceanit 2008) to keep consistency with the previous Mānoa Watershed Project hydrologic study. Another assumption was made about the UHM area in the Mānoa sub-watershed. The drainage area of sub-watershed M12 (UHM upper campus) was changed from the previous 0.672 square miles (Oceanit 2008) to 0.747 square miles. This drainage area determination accounts for the contribution of a 96-inch culvert storm drainage system at Dole Street Bridge. The characteristics of the storm sewer network were collected from the UHM Utility Map (2008).

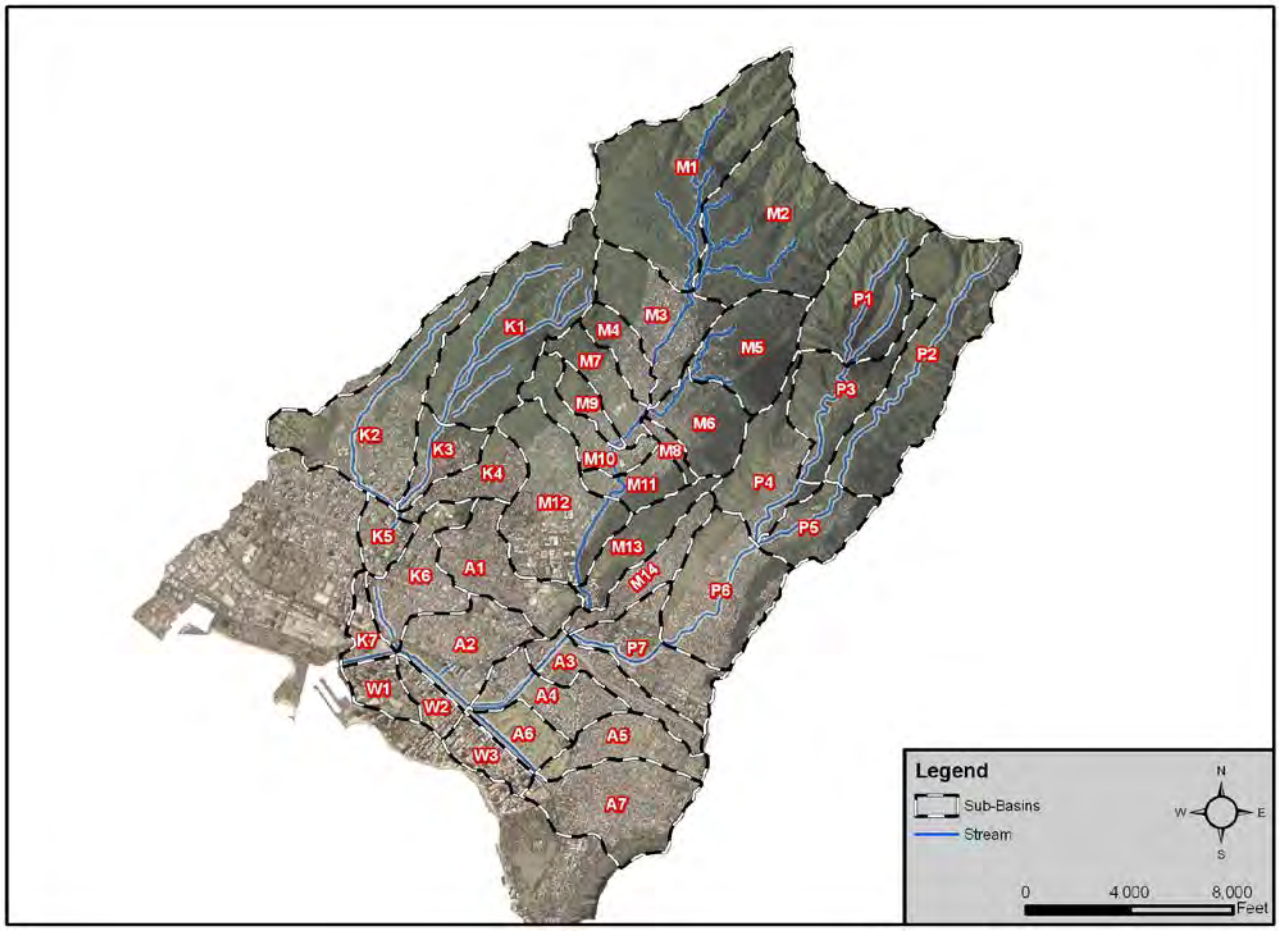

Figure 3-5. Ala Wai Watershed Sub-Basin Delineation

Ala Wai Watershed delineation of sub-basins was based on the junctions that are confluences of study area streams. The following table of sub-basin delineations designates the respective sub-watershed by the following.

- 'J' for junctions, or stream confluences, throughout the watershed
- 'K' for sub-basins in the Makiki sub-watershed
- 'M' for sub-basins in the Mānoa sub-watershed
- 'P' for sub-basins in the Pālolo sub-watershed
- Note that Mānoa-Pālolo Canal sub-watershed has junctions only and not sub-basins because other sub-basins empty into this canal but it does not drain its surrounding area
- 'A' for sub-basins in the Ala Wai sub-watershed; assumed to be a reservoir for the purposes of this study (see earlier discussion in Section 3.6)
- 'W' for sub-basins in the Waikīkī sub-watershed

Ala Wai Watershed Sub-Basin Delineation		
Sub-Basin/Junction	Sub-Basin or Junction Name	Drainage Area (mi^2)
MAKIKI		
KI	Upper Makiki Stream	1.00
K2	Kanahā Stream	0.85
K3	Middle Makiki Stream	0.22
K4	East Mānoa Road	0.25
JK1	Confluence of Makiki and Kanahā Streams	2.33
K5	Lower Makiki Stream	0.16
JK2	USGS Stream Gage near King St. 16238000	2.49
K6	Washington Middle School	0.40
JK3	Confluence of Makiki Stream and Ala Wai Canal	2.89
MĀNOA		
M1	Waihī	1.20
M2	Waiakeakua	1.07
JM1	Confluence of Waihī and Waiakeakua Streams	2.27
M3	Pawaina	0.51
M4	Poelua	0.18
M5	Woodlawn_Ditch 1	0.50
M6	Woodlawn_Ditch 2	0.35
JM2	Confluence of Mānoa Stream & Woodlawn Ditch	3.81
M7	Park	0.25
M8	Kahaloa	0.06
M9	Lowrey	0.11
JM3	Lowrey Ave. Bridge	4.22
M10	Woodlawn	0.26
JM4	Woodlawn Dr. Bridge	4.48
M11	Noelani	0.19
JM5	Mānoa Stream near Noelani Elementary School	4.67
M12	Dole (UHM campus)	0.75
JM6	Dole Street Bridge	5.42
M13	Kānewai	0.30
JM7	Kānewai Field Gage	5.72
M14	Saint Louis Heights	0.25
JM8	Just Upstream of the Confluence of Mānoa & Pālolo Streams	5.97

Table 3-4. Ala Wai Watershed Sub-Basin Delineation

Ala Wai Watershed Sub-Basin Delineation (Continued)		
Sub Basin or Junction Number	Sub Basin or Junction Name	Drainage area (mi^2)
PĀLOLO		
P1	Upper Pūkele Stream	0.67
P3	Middle Pūkele Stream	0.48
JP1	USGS Pūkele Gage 16244000	1.15
P2	Upper Waiʻōmaʻo Stream	1.04
P4	Lower Pūkele Stream	0.45
P5	Lower Waiʻōmaʻo Stream	0.31
JP2	Confluence of Pūkele and Waiʻōmaʻo Streams	2.94
P6	Pālolo Stream	0.68
JP3	USGS Pālolo Gage 16247000	3.62
P7	Waialae Avenue	0.45
JP4	Just Upstream of the Confluence of Mānoa & Pālolo Streams	4.07
MĀNOA-PĀLOLO		
JMP1	Confluence of Mānoa and Pālolo Streams	10.04
A3	H1 Freeway	0.30
JMP2	USGS Stream Gage 16247100	10.34
A4	Date Street	0.34
JMP3	Confluence of Mānoa-Pālolo and Ala Wai Canals	10.68
ALA WAI & WAIKĪKĪ		
A5	Kaimukī	0.32
A7	Diamond Head Drainage System	0.62
A6	Ala Wai Golf Course	0.20
W3	Kuhio	0.18
A1	UHM lower campus and Punahou School	0.45
A2	Mōʻiliʻili	0.47
W2	Kālakaua	0.13
A8	Hawaii Convention Center	0.12
W1	Ala Moana Blvd.	0.16
OUTLET	Mouth of Ala Wai Canal	16.21

Table 3-4 (Continued). Ala Wai Watershed Sub-Basin Delineation

Drainage systems collect the majority of runoff in Waikīkī, and thus, information about these systems was used to delineate the Waikīkī sub-watersheds. Most of the runoff flows through the City's drainage systems and discharges into the Ala Wai Canal. However, a small portion of runoff flows directly into the ocean. This small portion is overland flow or is emptied directly into the ocean by drainage pipes.

3.7 Storm Records Used for Calibration

Calibration of the HEC-HMS model relied on sub-basin analysis that used available records of three storms in December 17-18, 1967; October 30, 2004; and March 31, 2006. However, partial stream flow data were available for some gages and junctions had different recording equipment. Below is a list of the records available by location and storm. The locations refer to the HEC-HMS model layout.

- A partial data set from JM3 (Lowrey Ave. Bridge) from the 2004 storm was used for calibration
- At M2 (Waiakeakua sub-basin), peak flow data were used for the 1967 storm, and real-time data were used for the 2004 and 2006 storms
- At JMP2 (USGS stream gage 17247100 at Kaimukī High School), peak flow data were used for the 1967 storm, and real-time data were used for the 2004 and 2006 storms.
- At JP1 (USGS Pūkele Stream gage), peak flow data from the 1967 storm were used, and real-time data from the 2004 storm were used
- At JP3 (USGS stream gage 17247000 at Pālolo Stream), peak flow data from all three storms were used, but some of these data were discarded because they were clearly inaccurate—comparison to other gage readings downstream during the same storm showed clear inconsistencies

3.7.1 December 1967 Storm

On December 16, 1967, a surface weather front appeared to be stationary west of Hawai'i (DLNR 1968). Torrential rains started falling on O'ahu around the middle of the night on December 17. Many rainfall stations reported excessive rainfall during the storm. Pālolo Valley, Wai'alae-Kāhala, Niu Valley, and Waimānalo suffered extensive flood damage. Rainfall amounts registered in the windward area had a rainfall frequency of about a 25-year storm (DLNR, 1968). The Tantalus Peak rain gage registered 5 inches of rainfall for a 3-hour period ending at 3:00 AM. The Pālolo Tunnel rain gage, maintained by the BWS, recorded 10.06 inches between the middle of the night and 8:00 AM hours, with 2.4 inches from 4:00 AM to 5:00 AM. The rainfall intensity was almost uniformly distributed from the coastal area to the Ko'olau Mountains. The USGS stream gage 16247000 at the Pālolo Stream recorded a record high peak discharge of 4,270 cubic feet per second (cfs); the USGS stream gage 16247100 at the Mānoa-Pālolo Drainage Canal recorded its highest estimated discharge at 10,100 cfs.

3.7.2 October 2004 Storm

A storm on October 30, 2004, that caused flooding in the Mānoa Valley was characterized as about a 20-year storm (NWS 2005). This return period corresponds to a 5% probability of occurrence. The persistent and heavy rainfall created swift and high stream flows that were recorded throughout the Mānoa Stream by various rain and stream gages. The heaviest rainfall happened around 7:30 PM, at which time the Lyon Arboretum rain gage recorded 1.29 inches in 15 minutes. The gage records for the October 2004 storm were used to calibrate the HEC-HMS model.

3.7.3 March 2006 Storm

On March 31, 2006, a strong storm caused the NWS to issue flash flood warnings for O‘ahu because rain fell on already saturated ground. The storm moved over the windward (eastern) half of O‘ahu during the late morning, and rainfall of 1 to 2 inches were recorded within one-hour periods by several NWS gages (NWS 2006). The NWS Waimānalo rain gage recorded over 3 inches of rainfall within a two-hour period. During the six weeks prior to this storm, O‘ahu had experienced heavy rains that saturated lands on the windward side of the island. The March 31 rainfall, coupled with the saturated character of the land, produced flash floods throughout the island (NWS 2006). The Moanalua, Makiki, and Mānoa Streams overtopped their banks, and residents of Mānoa valley were alerted of flash flooding in the area. Various intersections and flooding forced the partial closure of the area’s major highway, H-1 Freeway, and downtown streets were clogged with traffic (Pacific Business News 2006).

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4 Hydrologic Analysis Procedure

Hydrologic analysis of sub-watersheds of the Ala Wai Watershed utilized up to five hydrologic modeling methods. Given the HEC-HMS model layout for the Ala Wai Watershed, the hydrologic analyses for sub-watersheds were completed on the basis of the existing conditions—particularly whether or not sub-watersheds are urbanized. For the sub-watersheds without much urbanized area, hydrologic models were calibrated using the storm records outlined in Section 3.8. The hydrologic model, as shown in Figure 4-1 was based on the sub-watersheds delineated. These sub-watersheds include the upper Makiki, upper Mānoa, and upper Pālolo. Thus, Sections 4.2 through 4.5 outline the necessary parameters that were calculated: rainfall amount, time of concentration, and curve numbers. As mentioned earlier, the Clark Unit Hydrograph was used as the transform method for these areas that are not urbanized.

For the sub-watersheds with more urbanized area, the hydrologic models used the Kinematic Wave Transform Method. Section 4.7 provides the Kinematic Wave Transform Method analyses of the urbanized areas of the Ala Wai Canal and Waikīkī sub-watersheds, alongside the Mānoa-Pālolo Canal junctions considered.

4.1 Hydrologic Model Layout

Stream junctions of interest that are listed in Table 3-3 are illustrated as the final hydrologic model layout as shown below in Figure 4-1.

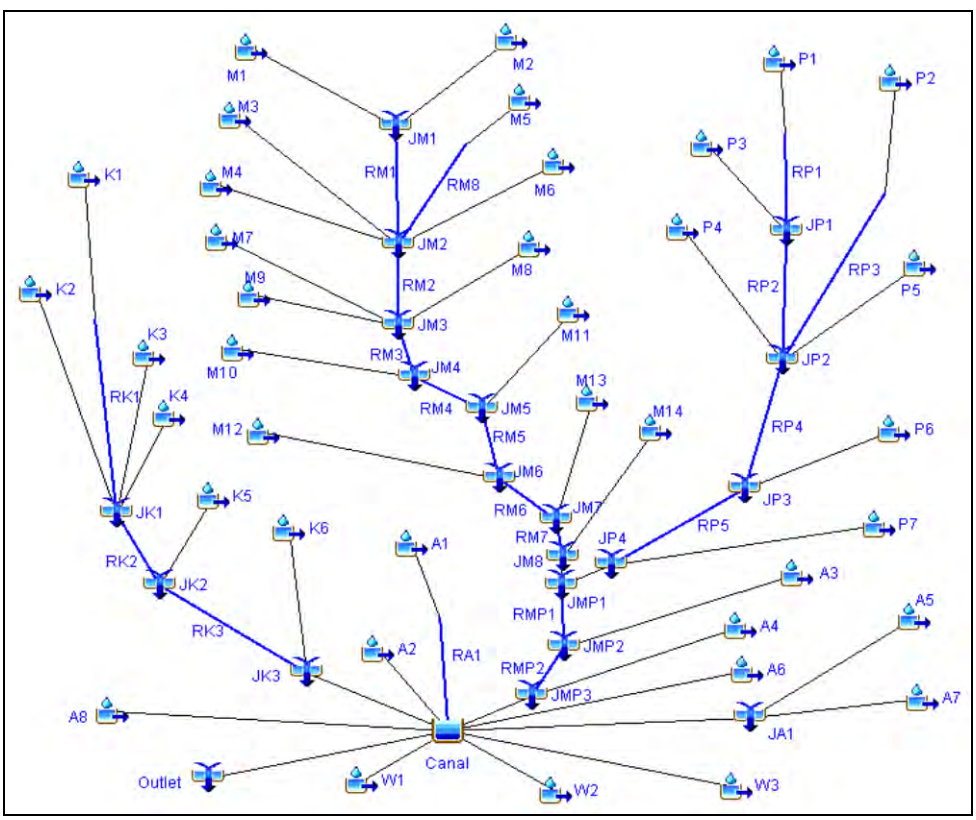

Figure 4-1. Ala Wai Watershed HEC-HMS Model Layout

4.2 Meteorological Model

The storm rainfall amounts that were the input for the hydrologic model are considered the meteorological model. The rainfall and stream flow data were collected from rain gage and stream flow gage records as available for the study area (see Sections 3.1 through 3.2).

4.2.1 Rainfall Amount Determination

Rainfall amount determination was necessary for 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent chance exceedance storms. These amounts were interpolated and/or extrapolated from "Rainfall Frequency Study for O'ahu", Report R-73, by Giambelluca, Lau, Fok and Schroeder (1984). For the 1-, 6-, and 24-hour rainfall amounts for the recurrence periods of 50, 10, 2, and 1 percent chance exceedance, values (shown in Table 4-1) were obtained directly from R-73 (Giambelluca 1984). The rainfall depths from R-73 were plotted, and the resulting smooth curve-function was used to estimate the rainfall depths that were not directly shown in R-73. Thus, for the percent chance exceedance storms less than the 1 percent storm, the rainfall amounts for various durations between 1 hour and 24 hours were determined from the duration nomographs presented in R-73. These curves are shown in Figure 4-3. The 0.5 and 0.2 percent chance exceedance storms' rainfall amounts were estimated by extrapolation using the rainfall depths relationships above the 1 percent chance exceedance storm. Rainfall values less then 1-hour were computed using 1-hour value. According to R-73, the 30-, 15-, and 5-minute rainfall values were determined by multiplying the 1-hour value by 0.714, 0.539, and 0.264, respectively.

Flow in the upper sub-watersheds may be underestimated due to sudden rainfall events that concentrate quickly as runoff because of high amounts of rainfall. Conversely, low rainfall is apparent in the lower sub-watersheds, and the relatively flat topography lends to underestimates of peak flows because runoff along the coastal areas may flow directly into the ocean. Thus, rainfall presented here is an average, based on the center point of the sub-basin and interpolated and extrapolated from the rainfall data available. The center point of each sub-basin was determined using the geospatial data discussed in Section 3.5. It should be noted that the 2001 Ala Wai Flood Study (USACE 2001) used a different approach for determining one rainfall value by averaging rainfall in the upper watershed and lower watershed rather than by averaging by the entire watershed.

Rainfall Intensity Duration Values for the Ala Wai Watershed

Percent Chance Exceedance	Recurrence Interval Year	Duration								
		5-min	15-min	30-min	1-hr	2-hr	3-hr	6-hr	12-hr	24-hr
50%	2	0.40	0.81	1.07	1.50	2.20	2.65	3.50	4.40	5.30
20%	5	0.49	1.00	1.32	1.85	2.80	3.40	4.45	5.70	7.15
10%	10	0.63	1.28	1.70	2.38	3.35	4.10	5.50	7.00	8.60
5%	20	0.70	1.43	1.89	2.65	3.80	4.65	6.25	8.05	10.05
2%	50	0.83	1.70	2.25	3.15	4.35	5.35	7.20	9.45	11.80
1%	100	0.91	1.86	2.46	3.45	4.85	6.00	8.25	10.90	13.65
0.5%	200	1.02	2.08	2.75	3.85	5.35	6.55	9.15	12.10	15.20
0.2%	500	1.16	2.37	3.14	4.40	6.10	7.55	10.40	13.65	17.00

Reference: Giambelluca et al. (1984), DLNR Report R-73

Table 4-1. Determined Rainfall Intensity Duration Values in inches for Ala Wai Watershed, Oahu, Hawaii.
Note: rainfall intensity frequency data determined from maps and nomgraphs in Giambelluca et, 1984, DLNR Report R-73.

4.2.2 Rainfall Intensity-Duration-Frequency Curves

The rainfall-depth duration curves graph in Figure 4-2 shows the rainfall data as determined in average amounts for the percent chance exceedance storms. The rainfall amounts are for a 24-hour period, and were converted to intensity-duration-frequency (IDF) curves to offer rainfall intensities according to the range of storms examined (see Figure 4-3). The IDF curve is a crucial input into the HEC-HMS model analysis.

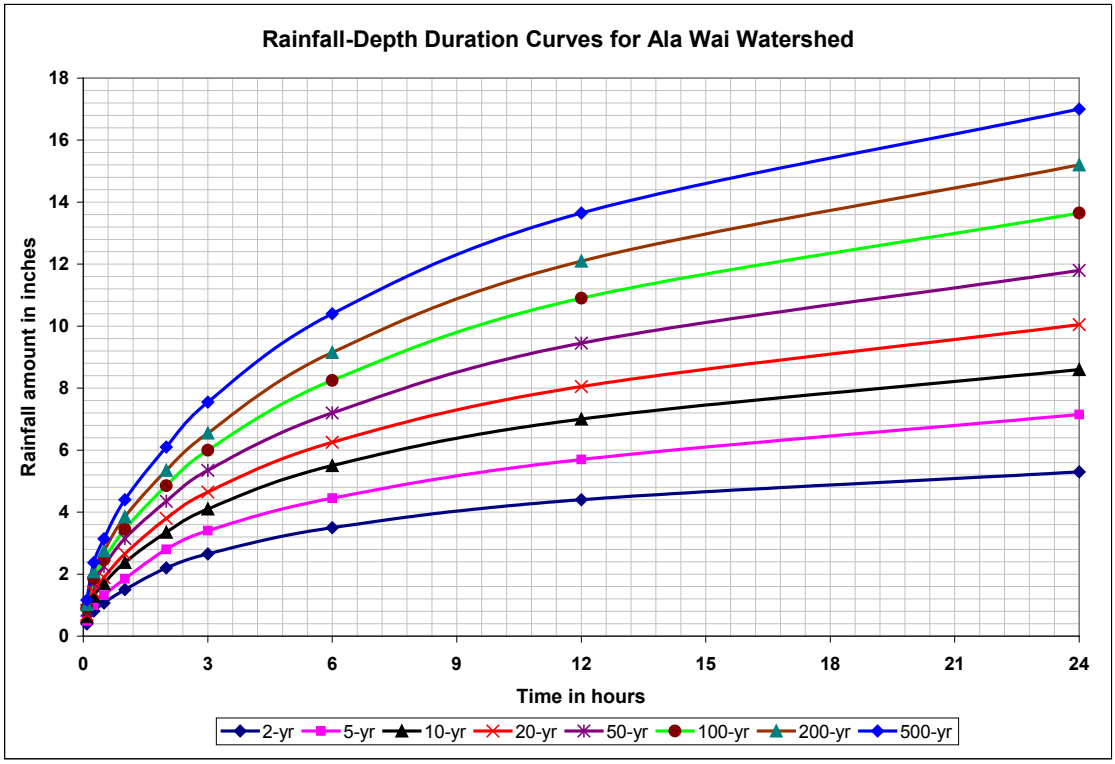

Figure 4-2. Rainfall-Depth Duration Curves for Ala Wai Watershed

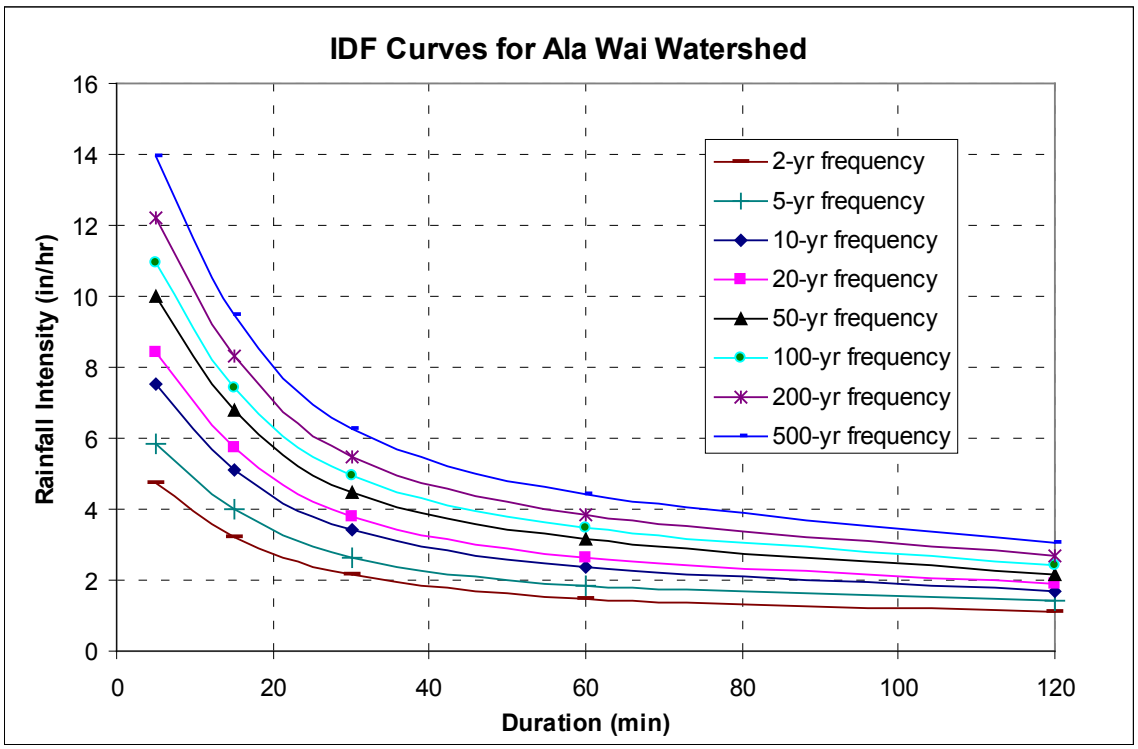

Figure 4-3. IDF curves for Ala Wai Watershed

4.2.3 Time of Concentration Calculation

The Clark Unit Hydrograph requires the parameter of the time of concentration (T_c) for each sub-basin. According to the TR-55 method, three types of flow path constitute the water flow: sheet flow, shallow concentrated flow, and channel flow; these three flows were added together to calculate time of concentration. According to the NRCS's Technical Report 55 (1986), "Time of concentration is the time for runoff to travel from the hydraulically most distant point of watershed to a point of interest within the watershed." The majority of the flow path may be channel flow as appropriate. Calculation of time of concentration is necessary for preparing the transform method for a unit hydrograph. The TR-55 velocity approach method was used to calculate time of concentration; that means the traveling time is a function of watercourse length and the velocity. The average velocity is a function of watercourse, slope, and type of channel.

A certain number of assumptions were made regarding sheet flow. The sheet flow segment describes the time period from raindrop impact until overland flow accumulates to a depth of about 0.1 foot, and one assumption made for time of concentration calculations was that the flow length for the stream reaches analyzed were not longer than 100 feet. The sheet flow segment T_c is calculated using Manning's kinematic solution, dependent on Manning's roughness coefficient *n*, the flow length, the rainfall amount, and the land slope. According to the SCS training material module 206A, "in most watersheds the overland [sheet] flow length is probably about 50 ft." (USDA, 1990) A maximum length of 100 feet is allowed in WinTR-55, and SCS suggests that a visit to the watershed is the best manner of determining the appropriate sheet flow length. Because this study lacked the appropriate observations for sheet flow during site visits, and considering previous studies and engineering judgement, a sheet flow length of 80 feet was set for all sub-watersheds in the Ala Wai Watershed for the calculation of time of concentration.

Overall, the flow length was determined from the City drainage maps and the known characteristics of the stream reach. Also, estimated flow length and land slope data were gathered from the geospatial data collected (see Section 3.5) using ArcView GIS 3.3. LiDAR topographic data and 5-foot elevation contours were used to calculate the slope of each sub-watershed.

4.2.4 Manning's *n* Roughness Coefficients

The surface Manning's roughness coefficients, based on the ground surface conditions, were determined as either 0.4 (woods with light underbrush) or 0.24 (dense grasses) using Table 3-1 from TR-55 (NRCS 1986). Where storm drainage systems are present in the sub-watershed, the appropriate flow path was used to estimate the time of concentration. Drainage pipe flow not under a pressure condition is treated as a portion of channel flow. The wetted perimeter condition assumes the full-flow condition for the drainage system pipes and the natural channel of the streambed. Altogether, the Manning's roughness coefficient for storm drainage facilities was selected as 0.015.

TR-55 Method Time of Concentration Parameters

Sheet Flow Characteristics					Shallow Concentrated Flow			Channel Flow Characteristics					Time of Concentration
Sub-Basin	**Manning's *n***	**Flow Length (ft)**	**Two-Year 24-hour Rainfall (in)**	**Land Slope**	**Surface Description**	**Flow Length (ft)**	**Slope**	**Flow Length (ft)**	**Cross-Section Area (ft^2)**	**Wetted Perimeter(ft)**	**Channel Slope**	**Manning's *n***	**T_C (hr)**
K1	0.4	80	5.3	0.450	Unpaved	1200	0.218	7200	30	19	0.174	0.035	**0.202**
K2	0.4	80	5.3	0.375	Unpaved	1150	0.278	9900	20	18	0.090	0.035	**0.311**
K3	0.24	80	5.3	0.313	Paved	1850	0.305	3100	30	19	0.042	0.035	**0.170**
K4	0.24	80	5.3	0.405	Paved	1450	0.365	5200	7.07	9.42	0.042	0.015	**0.165**
M14	0.24	50	5.3	0.250	Paved	1200	0.150	4150 1200	4.91 160	7.85 48	0.128 0.017	0.015 0.035	**0.152**
P1	0.4	80	5.3	0.260	Unpaved	1600	0.450	4850	40	24	0.159	0.040	**0.189**
P2	0.4	80	5.3	0.200	Unpaved	1850	0.172	9200	40	24	0.090	0.035	**0.313**
P3	0.24	80	5.3	0.306	Unpaved	2300	0.321	5500	48	20	0.061	0.035	**0.203**
P4	0.24	80	5.3	0.280	Unpaved	2800	0.285	1950 2400	3.14 48	6.28 20	0.115 0.0375	0.015 0.035	**0.215**
P5	0.24	80	5.3	0.260	Paved	800	0.285	700 4050	1.77 48	4.7 20	0.236 0.0395	0.015 0.035	**0.163**
P6	0.24	80	5.3	0.270	Paved	1150	0.550	800 5600	4.9 120	7.85 48	0.0625 0.0187	0.015 0.018	**0.168**
P7	0.24	80	5.3	0.180	Paved	700	0.040	3100 3500	4.9 160	7.85 48	0.03 0.02	0.015 0.018	**0.218**

Table 4-2. TR-55 Method Time of Concentration Parameters

Table 4-2 shows the values for sheet flow, shallow concentrated flow, and channel flow that were used to calculate the times of concentration. The times of concentration range from 0.152 hours in the Mānoa 14 sub-basin to 0.313 hours in the Pālolo 2 sub-basin, as shown in Table 4-3.

4.3 Curve Numbers Calculation

Runoff curve numbers, according to the TR-55 method (NRCS 1986), were used to determine the loss method of the HEC-HMS. Soil types in the study area were identified, and assigned to their appropriate hydrologic soil group (HSG in Table 4-3) classification. Geospatial data collected were used to determine land cover appropriate to each sub-basin, and for the various sub-watersheds. The different types of land cover and associated curve numbers are shown in Table 4-3. For the specific sub-basins, curve numbers were multiplied by the areas of the soil types by sub-watershed. For each sub-watershed, the product of these calculations was averaged over the total sub-watershed area to arrive at a composite curve number.

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Calculation of Composite Curve Numbers for Ala Wai Watershed

Sum of WS_Acre		New HydroGrp HSG (All D and blank to C)				Curve Number			Area x CN			Composite
SUB-BASIN	**LAND USE**	**A**	**B**	**C**	**Total**	**A**	**B**	**C**	**A**	**B**	**C**	**CN**
A1	Bare Land	0.0	3.1	1.0	5.0	72	82	87	0.0	253.0	89.8	
	Evergreen Forest	0.5	0.2	0.2	0.8	30	55	70	13.6	11.2	11.2	
	Grassland	3.2	4.7	4.4	12.3	39	61	74	126.4	287.4	323.2	
	High Intensity Developed	13.9	73.8	34.6	122.3	89	92	94	1240.5	6791.8	3249.2	
	Low Intensity Developed	62.6	55.4	22.6	140.7	77	85	90	4821.2	4710.6	2036.1	
	Scrub/Shrub	2.1	3.2	3.4	8.7	30	48	65	63.4	152.5	222.4	
A1 Total		83.3	140.4	66.2	289.9	A1 Composite CN						**84**
A2	Bare Land		1.6	6.1	7.7	72	82	87	0.0	132.6	527.6	
	Cultivated Land			0.2	0.2	77	86	91	0.0	0.0	20.2	
	Evergreen Forest		0.1	0.4	0.6	30	55	70	0.0	6.9	30.8	
	Grassland		4.1	12.5	16.6	39	61	74	0.0	250.9	926.5	
	High Intensity Developed		106.5	109.9	216.4	89	92	94	0.0	9799.5	10327.7	
	Low Intensity Developed		13.0	19.8	32.8	77	85	90	0.0	1105.8	1781.7	
	Scrub/Shrub		2.1	7.2	9.2	30	48	65	0.0	99.5	465.2	
	Water		0.1	15.1	15.1	98	98	98	0.0	8.0	1476.0	
A2 Total			127.5	171.1	298.7	A2 Composite CN						**90**
A3	Bare Land		1.9	0.0	1.9	72	82	87	0.0	157.9	0.0	
	Evergreen Forest		0.2	0.0	0.2	30	55	70	0.0	12.2	0.0	
	Grassland		5.6	0.0	5.6	39	61	74	0.0	342.0	0.0	
	High Intensity Developed		143.8	0.0	143.8	89	92	94	0.0	13229.4	0.0	
	Low Intensity Developed		38.5	0.0	38.5	77	85	90	0.0	3276.0	0.0	
	Scrub/Shrub		3.8	0.0	3.8	30	48	65	0.0	183.9	0.0	
A3 Total			193.9	0.0	193.9	A3 Composite CN						**89**
A4	Bare Land		3.0	0.9	3.9	72	82	87	0.0	244.7	79.4	
	Evergreen Forest		0.2	0.1	0.2	30	55	70	0.0	8.8	4.4	
	Grassland		23.6	6.0	29.6	39	61	74	0.0	1440.7	441.8	
	High Intensity Developed		122.7	5.0	127.8	89	92	94	0.0	11290.6	472.8	
	Low Intensity Developed		29.1	7.6	36.8	77	85	90	0.0	2477.6	685.8	
	Scrub/Shrub		7.9	6.5	14.3	30	48	65	0.0	378.5	419.3	
	Water		0.2	3.6	3.8	98	98	98	0.0	18.0	349.9	
A4 Total			186.7	29.6	216.3	A4 Composite CN						**85**
A5	Bare Land		1.2	0.2	1.4	72	82	87	0.0	98.4	19.3	
	Evergreen Forest		0.2	0.0	0.2	30	55	70	0.0	12.2	0.0	
	Grassland		12.2	2.2	14.5	39	61	74	0.0	745.9	165.1	
	High Intensity Developed		131.9	0.8	132.7	89	92	94	0.0	12138.5	72.6	
	Low Intensity Developed		48.7	4.7	53.4	77	85	90	0.0	4140.4	422.9	
	Scrub/Shrub		0.9	0.6	1.5	30	48	65	0.0	43.8	38.8	
	Water			0.4	0.4	98	98	98	0.0	0.0	38.4	
A5 Total			195.2	8.9	204.1	A5 Composite CN						**88**
A6	Bare Land		2.7	5.0	7.7	72	82	87	0.0	223.0	437.4	
	Evergreen Forest			0.5	0.5	30	55	70	0.0	0.0	32.1	
	Grassland		52.8	18.6	71.3	39	61	74	0.0	3219.5	1372.7	
	High Intensity Developed			5.1	5.1	89	92	94	0.0	0.0	478.9	
	Low Intensity Developed		0.1	3.1	3.1	77	85	90	0.0	5.9	275.9	
	Scrub/Shrub		4.5	15.0	19.5	30	48	65	0.0	215.9	977.5	
	Water		1.2	17.5	18.7	98	98	98	0.0	116.1	1714.1	
A6 Total			61.2	64.7	126.0	A6 Composite CN						**72**
A7	Bare Land		1.5	2.5	3.9	72	82	87	0.0	120.8	214.5	
	Evergreen Forest		2.0	0.1	2.1	30	55	70	0.0	111.6	4.2	
	Grassland	0.2	12.8	1.1	14.1	39	61	74	7.7	783.5	79.1	
	High Intensity Developed	0.0	238.4	3.8	242.3	89	92	94	3.5	21935.1	361.6	
	Low Intensity Developed	0.3	67.2	10.3	77.9	77	85	90	25.4	5715.0	928.2	
	Scrub/Shrub	0.8	15.5	38.1	54.4	30	48	65	24.3	744.6	2478.1	
	Water		0.0	2.2	2.2	98	98	98	0.0	0.3	211.5	
A7 Total		1.4	337.5	58.0	396.9	A7 Composite CN						**85**
A8	Bare Land			0.1	0.1	72	82	87	0.0	0.0	12.4	
	Grassland		0.1	0.4	0.6	39	61	74	0.0	8.7	32.9	
	High Intensity Developed		28.8	37.8	66.6	89	92	94	0.0	2647.5	3556.8	
	Low Intensity Developed		1.4	3.0	4.4	77	85	90	0.0	120.1	271.4	
	Scrub/Shrub		0.7	2.4	3.1	30	48	65	0.0	32.0	159.0	
	Water			4.3	4.3	98	98	98	0.0	0.0	424.2	
A8 Total			31.0	48.2	79.2	A8 Composite CN						**92**
K1	Evergreen Forest	268.5	1.4	66.9	336.8	30	55	70	8056.1	75.6	4681.3	
	Grassland	3.3		1.4	4.8	39	61	74	129.7	0.0	106.4	
	Low Intensity Developed	30.9	0.0	3.9	34.9	77	85	90	2382.0	0.7	354.0	
	Scrub/Shrub	216.6		48.9	265.5	30	48	65	6499.0	0.0	3178.2	
K1 Total		519.4	1.4	121.1	642.0	K1 Composite CN						**40**
K2	Bare Land	0.7		0.4	1.1	72	82	87	48.0	0.0	38.7	
	Evergreen Forest	97.2		51.4	148.6	30	55	70	2917.0	0.0	3595.5	
	Grassland	69.3	0.5	19.5	89.3	39	61	74	2702.9	27.6	1443.9	
	High Intensity Developed	34.4	29.8	14.5	78.7	89	92	94	3062.2	2742.4	1363.0	
	Low Intensity Developed	103.2	10.2	43.3	156.7	77	85	90	7949.2	863.6	3901.4	
	Scrub/Shrub	47.3	0.0	22.5	69.8	30	48	65	1419.1	1.1	1461.9	
K2 Total		352.2	40.4	151.7	544.3	K2 Composite CN						**62**

Table 4-3. Calculation of Composite Curve Numbers for Ala Wai Watershed

Calculation of Composite Curve Numbers for Ala Wai Watershed (Continued)

Sum of WS_Acre		New HydroGrp HSG (All D and blank to C)				Curve Number			Area x CN			Composite
SUB-BASIN	**LAND USE**	**A**	**B**	**C**	**Total**	**A**	**B**	**C**	**A**	**B**	**C**	**CN**
K3	Evergreen Forest	17.1	7.3	4.4	28.9	30	55	70	513.0	404.0	309.3	
	Grassland	5.7	2.2	0.7	8.6	39	61	74	221.6	131.5	52.9	
	High Intensity Developed	2.3	11.1	0.0	13.4	89	92	94	203.6	1024.5	0.0	
	Low Intensity Developed	55.4	18.0	2.9	76.3	77	85	90	4267.4	1533.9	258.1	
	Scrub/Shrub	7.7	1.2	7.1	16.0	30	48	65	230.3	58.4	462.2	
K3 Total		88.2	39.9	15.1	143.2	K3 Composite CN						**68**
K4	Bare Land	1.1		0.0	1.1	72	82	87	77.3	0.0	3.3	
	Evergreen Forest	3.1	0.3	0.0	3.4	30	55	70	93.4	15.9	0.0	
	Grassland	13.7	1.0	0.3	15.0	39	61	74	532.7	61.0	25.7	
	High Intensity Developed	4.8	6.2	0.0	11.0	89	92	94	426.9	573.0	2.0	
	Low Intensity Developed	100.1	9.9	0.0	110.0	77	85	90	7708.3	837.6	0.0	
	Scrub/Shrub	18.9	1.1	0.0	20.0	30	48	65	566.2	52.9	0.0	
K4 Total		141.6	18.5	0.4	160.5	K4 Composite CN						**68**
K5	Bare Land		0.4	0.0	0.4	72	82	87	0.0	36.5	0.0	
	Evergreen Forest		0.4	0.0	0.4	30	55	70	0.0	20.8	0.0	
	Grassland		4.4	0.0	4.4	39	61	74	0.0	266.0	0.0	
	High Intensity Developed		73.3	0.0	73.3	89	92	94	0.0	6748.0	0.0	
	Low Intensity Developed		21.6	0.0	21.6	77	85	90	0.0	1839.8	0.0	
	Scrub/Shrub		3.2	0.0	3.2	30	48	65	0.0	154.1	0.0	
K5 Total			103.4	0.0	103.4	K5 Composite CN						**88**
K6	Bare Land	0.3	0.7	0.2	1.2	72	82	87	21.0	54.7	19.3	
	Evergreen Forest	2.6		0.0	2.6	30	55	70	77.6	0.0	0.0	
	Grassland	0.3	7.6	3.2	11.2	39	61	74	12.2	466.6	237.3	
	High Intensity Developed	3.1	141.2	53.6	197.9	89	92	94	271.8	12991.1	5041.6	
	Low Intensity Developed	7.6	22.3	3.9	33.8	77	85	90	581.9	1898.8	349.7	
	Scrub/Shrub	4.6	5.8	0.3	10.6	30	48	65	137.4	276.9	18.8	
	Water			0.0	0.0	98	98	98	0.0	0.0	1.4	
K6 Total		18.4	177.6	61.3	257.3	K6 Composite CN						**87**
M1	Evergreen Forest	124.6	48.4	80.4	253.4	30	55	70	3738.1	2661.3	5628.2	
	Grassland	3.2	6.2	4.2	13.7	39	61	74	125.3	379.7	313.8	
	High Intensity Developed		0.7	0.9	1.5	89	92	94	0.0	63.5	80.5	
	Low Intensity Developed	0.3	7.6	5.4	13.4	77	85	90	26.2	643.0	490.4	
	Scrub/Shrub	51.6	40.2	393.3	485.1	30	48	65	1547.7	1929.2	25565.2	
M1 Total		179.7	103.1	484.3	767.1	M1 Composite CN						**56**
M10	Bare Land	0.6		1.1	1.7	72	82	87	44.8	0.0	96.3	
	Evergreen Forest	19.6		0.5	20.1	30	55	70	588.4	0.0	32.0	
	Grassland	5.2	0.1	3.0	8.3	39	61	74	201.0	7.9	222.3	
	High Intensity Developed	4.5	3.5	17.5	25.5	89	92	94	400.8	323.4	1641.2	
	Low Intensity Developed	40.3	4.3	33.4	77.9	77	85	90	3103.4	362.7	3003.1	
	Scrub/Shrub	24.9		9.2	34.1	30	48	65	746.9	0.0	600.2	
M10 Total		95.1	7.9	64.6	167.6	M10 Composite CN						**68**
M11	Bare Land			0.4	0.4	72	82	87	0.0	0.0	32.6	
	Evergreen Forest		1.0	11.4	12.3	30	55	70	0.0	52.6	795.4	
	Grassland	0.0	4.8	0.8	5.6	39	61	74	0.6	292.0	56.8	
	High Intensity Developed		1.2	4.7	5.9	89	92	94	0.0	108.6	445.2	
	Low Intensity Developed	5.1	17.4	23.8	46.2	77	85	90	389.1	1480.0	2139.9	
	Scrub/Shrub		1.2	49.9	51.1	30	48	65	0.0	57.4	3246.6	
M11 Total		5.1	25.5	91.0	121.6	M11 Composite CN						**75**
M12	Bare Land	2.9	0.5	0.6	4.0	72	82	87	208.8	37.5	54.7	
	Evergreen Forest	12.9	2.3	4.9	20.1	30	55	70	387.8	125.0	344.2	
	Grassland	20.5	9.6	6.8	36.9	39	61	74	799.3	588.6	500.5	
	High Intensity Developed	12.9	59.2	5.0	77.1	89	92	94	1150.7	5446.9	469.0	
	Low Intensity Developed	151.6	61.9	9.5	222.9	77	85	90	11674.1	5257.5	851.8	
	Scrub/Shrub	49.0	15.9	53.1	118.0	30	48	65	1471.2	761.7	3452.9	
M12 Total		249.9	149.3	79.9	479.1	M12 Composite CN						**70**
M13	Bare Land		1.0	0.2	1.2	72	82	87	0.0	78.0	19.4	
	Evergreen Forest		31.1	46.5	77.6	30	55	70	0.0	1712.6	3254.3	
	Grassland		1.0	3.1	4.0	39	61	74	0.0	60.4	226.4	
	High Intensity Developed		7.4	3.1	10.5	89	92	94	0.0	684.6	288.0	
	Low Intensity Developed		14.4	11.7	26.2	77	85	90	0.0	1226.4	1056.9	
	Scrub/Shrub		17.9	51.3	69.2	30	48	65	0.0	858.6	3334.6	
M13 Total			72.8	115.9	188.7	M13 Composite CN						**68**

Table 4-3 (Continued). Calculation of Composite Curve Numbers for Ala Wai Watershed

Calculation of Composite Curve Numbers for Ala Wai Watershed (Continued)

Sum of WS_Acre		New HydroGrp HSG (All D and blank to C)				Curve Number			Area x CN			Composite
SUB-BASIN	**LAND USE**	**A**	**B**	**C**	**Total**	**A**	**B**	**C**	**A**	**B**	**C**	**CN**
M14	Bare Land		1.2	0.7	1.9	72	82	87	0.0	99.5	63.2	
	Evergreen Forest		0.3	0.2	0.4	30	55	70	0.0	14.0	13.3	
	Grassland		6.3	1.7	8.1	39	61	74	0.0	387.3	126.8	
	High Intensity Developed		47.7	4.1	51.8	89	92	94	0.0	4389.8	387.0	
	Low Intensity Developed		76.8	12.4	89.2	77	85	90	0.0	6526.7	1118.4	
	Scrub/Shrub		7.6	3.5	11.2	30	48	65	0.0	366.4	229.7	
M14 Total			139.9	22.7	162.7	M14 Composite CN						**84**
M2	Evergreen Forest		92.1	91.6	183.7	30	55	70	0.0	5063.4	6414.8	
	Grassland		0.4	12.3	12.7	39	61	74	0.0	26.3	910.0	
	Low Intensity Developed		0.2	2.5	2.7	77	85	90	0.0	15.3	227.4	
	Scrub/Shrub		29.0	458.6	487.6	30	48	65	0.0	1392.0	29806.5	
M2 Total			121.7	565.0	686.7	M2 Composite CN						**64**
M3	Bare Land		0.2	0.0	0.2	72	82	87	0.0	18.2	0.0	
	Evergreen Forest	6.6	14.7	12.0	33.4	30	55	70	199.3	810.7	841.2	
	Grassland	7.9	20.1	3.3	31.3	39	61	74	309.9	1227.1	242.7	
	High Intensity Developed	13.4	20.7	5.2	39.3	89	92	94	1191.5	1907.7	488.2	
	Low Intensity Developed	20.5	54.6	14.0	89.1	77	85	90	1578.9	4637.3	1262.7	
	Scrub/Shrub	36.6	37.7	57.1	131.3	30	48	65	1096.7	1809.9	3709.0	
M3 Total		85.0	148.1	91.6	324.7	M3 Composite CN						**66**
M4	Evergreen Forest	2.1	0.3	1.7	4.1	30	55	70	63.1	15.2	117.1	
	Grassland	2.9	0.1	3.5	6.6	39	61	74	113.1	8.9	261.2	
	High Intensity Developed	14.7	0.1	7.0	21.7	89	92	94	1306.2	6.4	656.1	
	Low Intensity Developed	20.1	0.2	11.3	31.6	77	85	90	1547.9	16.3	1015.4	
	Scrub/Shrub	25.1	0.0	25.5	50.6	30	48	65	752.3	0.6	1655.4	
M4 Total		64.9	0.7	48.9	114.5	M4 Composite CN						**66**
M5	Bare Land		0.2	0.0	0.2	72	82	87	0.0	18.2	0.0	
	Evergreen Forest		56.1	27.3	83.3	30	55	70	0.0	3083.8	1909.6	
	Grassland		4.2	0.0	4.2	39	61	74	0.0	254.6	0.0	
	High Intensity Developed		1.2	0.0	1.2	89	92	94	0.0	113.0	0.0	
	Low Intensity Developed		27.5	0.0	27.5	77	85	90	0.0	2336.1	0.0	
	Scrub/Shrub		40.4	163.1	203.6	30	48	65	0.0	1940.8	10603.9	
M5 Total			129.6	190.4	320.0	M5 Composite CN						**63**
M6	Bare Land		0.2	0.0	0.2	72	82	87	0.0	18.2	0.0	
	Evergreen Forest		18.2	7.8	25.9	30	55	70	0.0	999.4	543.3	
	Grassland		9.1	0.6	9.7	39	61	74	0.0	554.6	42.6	
	High Intensity Developed		2.9	1.5	4.5	89	92	94	0.0	269.8	144.3	
	Low Intensity Developed		67.7	5.2	72.9	77	85	90	0.0	5754.8	471.5	
	Scrub/Shrub		40.0	72.8	112.8	30	48	65	0.0	1919.1	4730.1	
M6 Total			138.1	87.9	226.0	M6 Composite CN						**68**
M7	Bare Land	0.4		1.1	1.5	72	82	87	32.0	0.0	95.3	
	Evergreen Forest	13.7		1.8	15.5	30	55	70	411.9	0.0	123.5	
	Grassland	2.8		24.1	26.9	39	61	74	110.2	0.0	1780.6	
	High Intensity Developed	9.5		5.2	14.7	89	92	94	843.2	0.0	489.6	
	Low Intensity Developed	13.9		22.8	36.7	77	85	90	1072.0	0.0	2049.7	
	Scrub/Shrub	25.7		36.4	62.1	30	48	65	771.4	0.0	2366.4	
M7 Total		66.1		91.3	157.4	M7 Composite CN						**64**
M8	Bare Land		0.4	0.0	0.4	72	82	87	0.0	29.9	1.9	
	Evergreen Forest			1.7	1.7	30	55	70	0.0	0.0	117.6	
	Grassland		0.7	1.3	2.1	39	61	74	0.0	44.1	98.4	
	High Intensity Developed		0.5	3.2	3.7	89	92	94	0.0	44.3	300.0	
	Low Intensity Developed		10.4	7.8	18.2	77	85	90	0.0	881.5	703.6	
	Scrub/Shrub		1.0	8.0	9.0	30	48	65	0.0	47.0	523.2	
M8 Total			12.9	22.1	35.0	M8 Composite CN						**80**
M9	Bare Land	0.4		0.5	0.8	72	82	87	25.7	0.0	39.4	
	Evergreen Forest	2.3		1.2	3.5	30	55	70	68.7	0.0	87.4	
	Grassland	2.7		2.4	5.1	39	61	74	106.2	0.0	176.6	
	High Intensity Developed	0.5		5.3	5.8	89	92	94	40.7	0.0	497.7	
	Low Intensity Developed	5.0		21.2	26.1	77	85	90	382.1	0.0	1903.9	
	Scrub/Shrub	6.2		23.9	30.0	30	48	65	184.9	0.0	1551.0	
M9 Total		17.0		54.4	71.4	M9 Composite CN						**71**
P1	Evergreen Forest		27.6	8.6	36.1	30	55	70	0.0	1517.2	598.6	
	Grassland		0.2	12.0	12.2	39	61	74	0.0	12.0	891.1	
	Scrub/Shrub		11.9	365.5	377.5	30	48	65	0.0	573.4	23759.2	
P1 Total			39.7	386.1	425.8	P1 Composite CN						**64**

Table 4-3 (Continued). Calculation of Composite Curve Numbers for Ala Wai Watershed

Calculation of Composite Curve Numbers for Ala Wai Watershed (Continued)

Sum of WS_Acre		New HydroGrp HSG (All D and blank to C)				Curve Number			Area x CN			Composite
SUB-BASIN	LAND USE	A	B	C	Total	A	B	C	A	B	C	CN
P2	Bare Land		0.4	0.0	0.4	72	82	87	0.0	29.9	0.0	
	Evergreen Forest		37.9	51.3	89.2	30	55	70	0.0	2084.9	3590.3	
	Grassland		0.9	19.3	20.1	39	61	74	0.0	52.6	1425.9	
	High Intensity Developed		1.5	0.0	1.5	89	92	94	0.0	133.5	0.0	
	Low Intensity Developed		9.1	0.0	9.1	77	85	90	0.0	769.4	1.4	
	Scrub/Shrub		29.8	513.0	542.8	30	48	65	0.0	1432.6	33343.5	
P2 Total			79.5	583.6	663.0	P2 Composite CN						**65**
P3	Bare Land		0.1	0.0	0.1	72	82	87	0.0	11.7	0.0	
	Evergreen Forest		65.4	36.3	101.7	30	55	70	0.0	3599.5	2538.8	
	Grassland		6.7	3.5	10.2	39	61	74	0.0	407.5	258.1	
	High Intensity Developed		3.8	0.0	3.8	89	92	94	0.0	351.0	0.0	
	Low Intensity Developed		9.9	0.6	10.6	77	85	90	0.0	841.7	58.5	
	Scrub/Shrub		43.1	138.1	181.2	30	48	65	0.0	2070.0	8973.6	
P3 Total			129.1	178.5	307.6	P3 Composite CN						**62**
P4	Bare Land		1.2	1.7	2.9	72	82	87	0.0	95.5	150.2	
	Evergreen Forest		5.2	31.6	36.8	30	55	70	0.0	284.5	2215.1	
	Grassland		6.4	9.7	16.1	39	61	74	0.0	390.0	714.8	
	High Intensity Developed		17.8	12.2	30.1	89	92	94	0.0	1642.0	1147.2	
	Low Intensity Developed		26.6	25.1	51.8	77	85	90	0.0	2262.4	2263.2	
	Scrub/Shrub		12.4	138.0	150.3	30	48	65	0.0	593.0	8969.7	
P4 Total			69.5	218.4	287.9	P4 Composite CN						**72**
P5	Bare Land		0.2	0.1	0.4	72	82	87	0.0	18.2	12.4	
	Evergreen Forest		6.9	6.9	13.9	30	55	70	0.0	381.6	486.4	
	Grassland		1.8	4.2	6.0	39	61	74	0.0	107.7	310.4	
	High Intensity Developed		3.9	5.7	9.6	89	92	94	0.0	362.7	534.8	
	Low Intensity Developed		19.6	41.4	61.0	77	85	90	0.0	1667.5	3721.7	
	Scrub/Shrub		10.7	94.2	104.9	30	48	65	0.0	514.0	6121.2	
P5 Total			43.2	152.5	195.7	P5 Composite CN						**73**
P6	Bare Land		1.3	5.3	6.6	72	82	87	0.0	106.2	462.5	
	Evergreen Forest			1.0	1.0	30	55	70	0.0	0.0	73.1	
	Grassland		3.4	28.5	31.9	39	61	74	0.0	206.4	2109.5	
	High Intensity Developed		35.3	172.3	207.6	89	92	94	0.0	3248.2	16199.2	
	Low Intensity Developed		19.2	79.2	98.4	77	85	90	0.0	1631.9	7131.8	
	Scrub/Shrub		1.3	89.4	90.7	30	48	65	0.0	60.4	5813.3	
P6 Total			60.4	375.9	436.3	P6 Composite CN						**85**
P7	Bare Land		1.0	0.0	1.0	72	82	87	0.0	84.6	0.0	
	Cultivated Land			0.2	0.2	77	86	91	0.0	0.0	20.2	
	Evergreen Forest		0.2	0.2	0.4	30	55	70	0.0	12.2	15.6	
	Grassland		12.1	1.3	13.4	39	61	74	0.0	738.4	93.7	
	High Intensity Developed		145.3	50.3	195.6	89	92	94	0.0	13369.2	4724.6	
	Low Intensity Developed		47.7	13.6	61.2	77	85	90	0.0	4052.5	1221.0	
	Scrub/Shrub		12.2	0.6	12.8	30	48	65	0.0	585.6	41.8	
P7 Total			218.6	66.2	284.7	P7 Composite CN						**88**
W1	Evergreen Forest	0.6		5.4	6.0	30	55	70	18.7	0.0	377.5	
	Grassland	0.2		8.8	9.0	39	61	74	8.7	0.0	652.2	
	High Intensity Developed	9.4		60.2	69.6	89	92	94	833.4	0.0	5661.4	
	Low Intensity Developed	3.5		15.2	18.8	77	85	90	271.3	0.0	1371.0	
	Water			0.0	0.0	98	98	98		0.0	2.9	
W1 Total		13.7		89.7	103.4	W1 Composite CN						**89**
W2	Evergreen Forest	0.1		1.0	1.1	30	55	70	4.3	0.0	69.0	
	Grassland			0.8	0.8	39	61	74	0.0	0.0	56.5	
	High Intensity Developed	8.4		63.0	71.4	89	92	94	749.3	0.0	5918.8	
	Low Intensity Developed	1.0		8.5	9.4	77	85	90	74.7	0.0	762.1	
	Scrub/Shrub			0.0	0.0	30	48	65	0.0	0.0	0.1	
	Water			0.0	0.0	98	98	98		0.0	2.2	
W2 Total		9.5		73.2	82.7	W2 Composite CN						**92**
W3	Bare Land	0.3		0.0	0.3	72	82	87	20.7	0.0	0.0	
	Evergreen Forest	0.9		0.9	1.7	30	55	70	26.4	0.0	60.3	
	Grassland	0.1	0.0	0.0	0.1	39	61	74	3.8	0.7	0.0	
	High Intensity Developed	57.7	0.1	41.6	99.5	89	92	94	5137.5	12.1	3910.8	
	Low Intensity Developed	4.3		5.5	9.9	77	85	90	334.2	0.0	497.4	
	Water			0.6	0.6	98	98	98		0.0	54.4	
W3 Total		63.3	0.1	48.5	112.0	W3 Composite CN						**90**
Grand Total		2053.8	3344.7	4978.0	10377.3	Ala Wai Watershed Composite CN						**70**

Table 4-3 (Continued). Calculation of Composite Curve Numbers for Ala Wai Watershed

4.4 Mānoa-Pālolo Model Calibration

The final HEC-HMS model for the Ala Wai Watershed consisted of 38 sub-basins. The model used the SCS runoff curve number method as the loss method to be consistent with the previous Mānoa Watershed Project hydrologic study. The model for the Ala Wai Watershed used the Clark Unit Hydrograph as the transform method for the sub-basins that are not fully urbanized. The Clark Unit Hydrograph was used as the transform method for the sub-basins in Makiki Valley (K1-K4), Mānoa Valley (M1 to M14), and Pālolo Valley (P1 to P7). The urbanized sub-basins of lower Makiki, Ala Wai Canal, and Waikīkī applied the Kinematic Wave Transform Method. Because there are insufficient rainfall and stream flow data in the low-lying areas of the Ala Wai Watershed, it was difficult to calibrate the sub-basin parameters within in the Ala Wai Canal and Waikīkī sub-watersheds. Most of the parameters of the Kinematic Wave Transform Method were based on physical measurements; it is assumed that the peak discharges of the urbanized sub-basins are correct. The actual calibration models are those of Mānoa and Pālolo valleys, a pilot calibration model for Makiki valley, and a reservoir calibration model for Ala Wai Canal. This last model represents the calibration for the entire watershed. Figure 4-4 shows the calibration model layout for the Ala Wai Watershed.

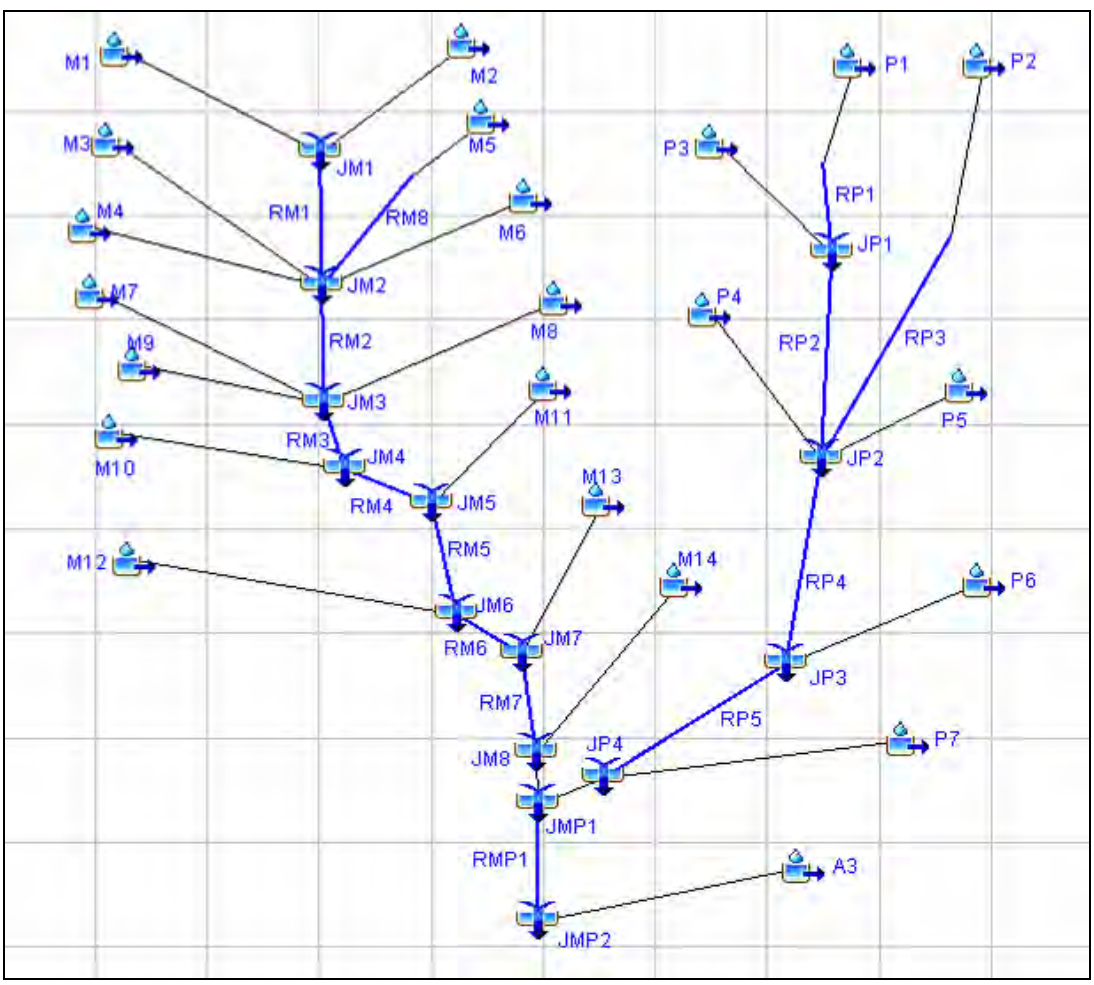

Figure 4-4. HEC-HMS Mānoa-Pālolo Calibration Model Layout

4.4.1 October 2004 Storm Calibration for Mānoa-Pālolo Area

The calibration for the storm of October 30, 2004, was based on the method used in the previous Mānoa Watershed Project hydrologic study. The calibration parameters used for the Mānoa sub-watershed in the Mānoa Watershed Project hydrologic study were used for the HEC-HMS model in the Ala Wai Watershed hydrologic study. The gage weights for sub-basins in Mānoa valley were the same as those used in the Mānoa Watershed Project described earlier. The main task of the calibration for the Ala Wai Watershed hydrologic study focused on the Pālolo sub-watershed and the area downstream of Kānewai Field gage, to the USGS stream gage 16247100. This stream gage is located on Kaimukī High School and had full stream flow records for the event. Gage weights were used for calibration purposes. The Thiessen polygon method was initially applied to determine the gage weight for each sub-basin. Figure 4-5 shows the Thiessen polygons for the October 2004 storm for the Ala Wai Watershed. The Thiessen polygon method does not account for orthographic rainfall effect in mountain areas. After taking into consideration the rainfall pattern, data quality, and storm movement and distribution, the final gage weights and relevant 24-hour rainfall of the October 2004 storm for each sub-basin were determined as shown in Table 4-4. (Note: 'MP' is used to abbreviate the Mānoa-Pālolo area.)

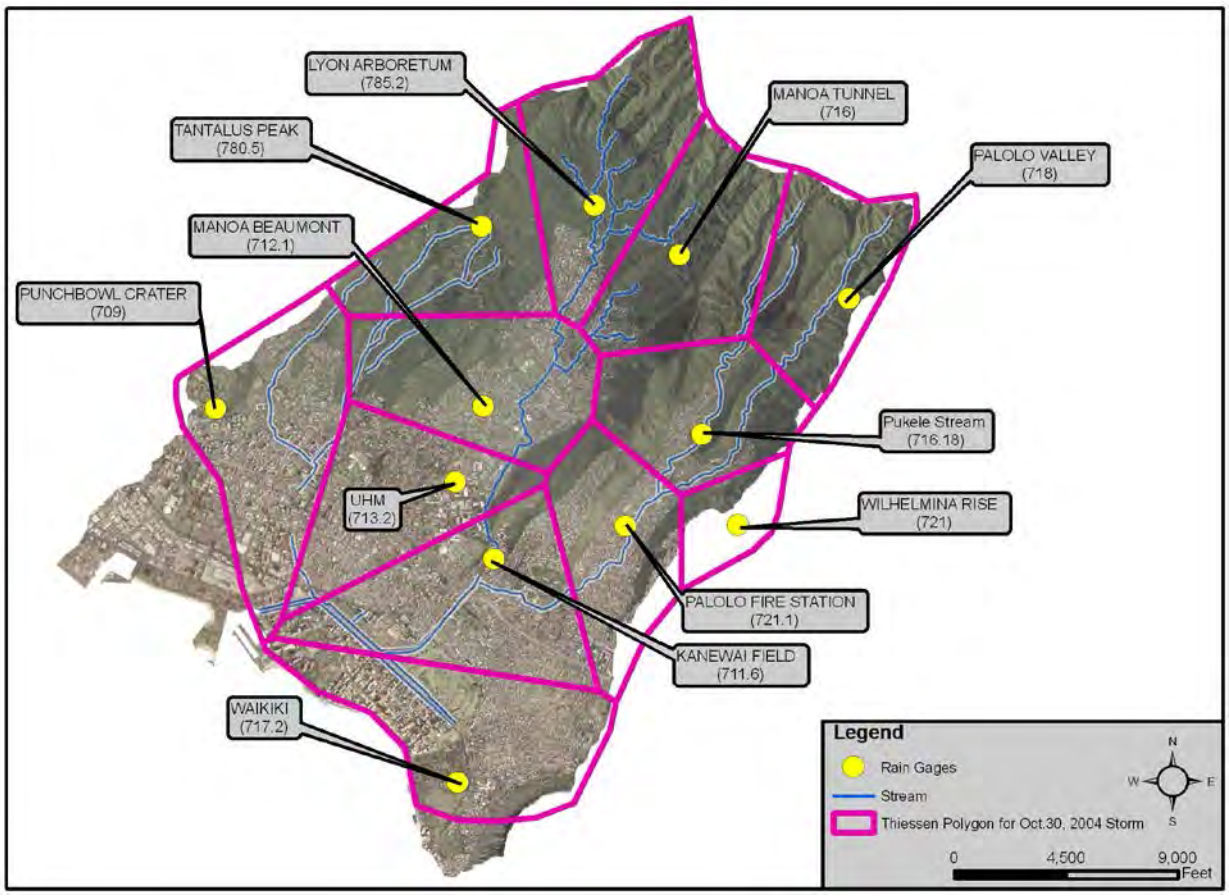

Figure 4-5. Rain Gages and Thiessen Polygons for the October 30, 2004

Meteorological Model: Gage Weights for October 30, 2004, Storm for MP

Gage weights	Thiessen Polygon (Gages in red are real time recording)											
Sub-basin	**Lyon Arboretum**	**Manoa Tunnel**	**Kanewai**	**Manoa Beaumont**	**UHM**	**Palolo Fire Sta**	**Palolo Valley**	**Pūkele**	**Tantalus Peak**	**Waikiki**	**Wilhemina Rise**	**24hr Rain (in)**
ID	785.2	716	711.6	712.1	713.2	721.1	718	Pukele	780.5	717.2	721	
Total Rainfall (in)	10.08	11.14	1.67	4.62	2.4	2.13	6.21	4.07	7.8	0.05	1.64	(in)
A3			0.7			0.2				0.1		1.60
M1	0.8	0.2										10.29
M2	0.3	0.5					0.2					9.84
M3	0.6	0.2							0.2			9.84
M4	0.5	0.2							0.3			9.61
M5	0.3	0.4					0.3					9.34
M6	0.4	0.3		0.1				0.2				8.65
M7	0.4			0.3					0.3			7.76
M8	0.3			0.4				0.3				6.09
M9	0.3			0.4					0.3			7.21
M10	0.3			0.4					0.3			7.21
M11	0.3			0.4				0.3				6.09
M12			0.1	0.5	0.4							3.44
M13			0.3	0.2	0.2	0.3						2.57
M14			0.5			0.5						1.9
P1		0.3					0.5	0.2				7.26
P2		0.1					0.6	0.3				6.06
P3		0.1					0.3	0.6				5.42
P4		0.2				0.1		0.7				5.29
P5						0.1		0.5			0.4	2.9
P6						0.9					0.1	2.08
P7			0.5			0.5						1.9

Table 4-4. Meteorological Model: Gage Weights for October 30, 2004, Storm for MP

The HEC-HMS meteorological model's parameters were calibrated using the October 30, 2004, storm data. Table 4-5 lists the final parameters for the HEC-HMS model in the Mānoa and Pālolo sub-watersheds. The parameters of the calibrated times of concentration are close to those calculated using the TR-55 method. The meteorological model used storm hydrographs for calibration and frequency based rainfall to compute the synthetic flood events.

	Loss Method --- SCS Curve Number		Transform--Clark Unit Hydrograph	
Sub-basin	Initial Abstraction (inch)	Curve Number	Time of Concentration (hour)	Storage Coefficient (hour)
A3 (Plane 1)	0.75	83	Kinematic Wave Transform	
A3 (Plane 2)	0.10	98		
M1	0.60	62	0.24	0.42
M10	0.60	76	0.26	0.60
M11	0.60	75	0.50	0.30
M12	0.30	73	0.25	0.65
M13	0.60	68	0.27	0.40
M14	1.00	84	0.15	0.30
M2	0.60	64	0.23	1.10
M3	0.60	69	0.25	0.70
M4	0.60	73	0.23	0.80
M5	0.60	63	0.31	0.90
M6	0.60	68	0.25	0.85
M7	0.60	71	0.19	1.50
M8	0.60	80	0.16	1.80
M9	0.60	75	0.17	1.50
P1	2.20	64	0.10	0.40
P2	1.20	65	0.30	0.55
P3	3.20	62	0.10	0.68
P4	1.20	72	0.10	0.30
P5	1.20	73	0.16	0.30
P6	1.20	85	0.10	0.25
P7	1.20	88	0.18	0.30

Table 4-5. Calibrated Model Parameters for October 2004 Storm for MP

At junctions JP1 and JMP2, the observed rainfall from the October 2004 storm and the modeled stream flows are shown in Figures 4-6 and 4-7. The modeled peak flows occur slightly after the observed peak flows; and the peak flow for junction JP1, Pūkele Stream gage, was modeled at a higher amount than the observed peak flow in 2004. The time of concentration values may be too high in this case. For the October 2004 storm, real-time data from M2, partial data from JM3, partial real-time data from JM7, real-time data from JP1, peak flow data from JP3, and continuous data from JMP2 were used. Because the HEC-HMS model was calibrated using the October 2004 storm

data in the Mānoa Watershed Project hydrologic study (Oceanit 2008), the parameters for all Mānoa sub-basins except M14 in the Ala Wai Watershed hydrologic study were kept the same as they were in the Mānoa Watershed Project study.

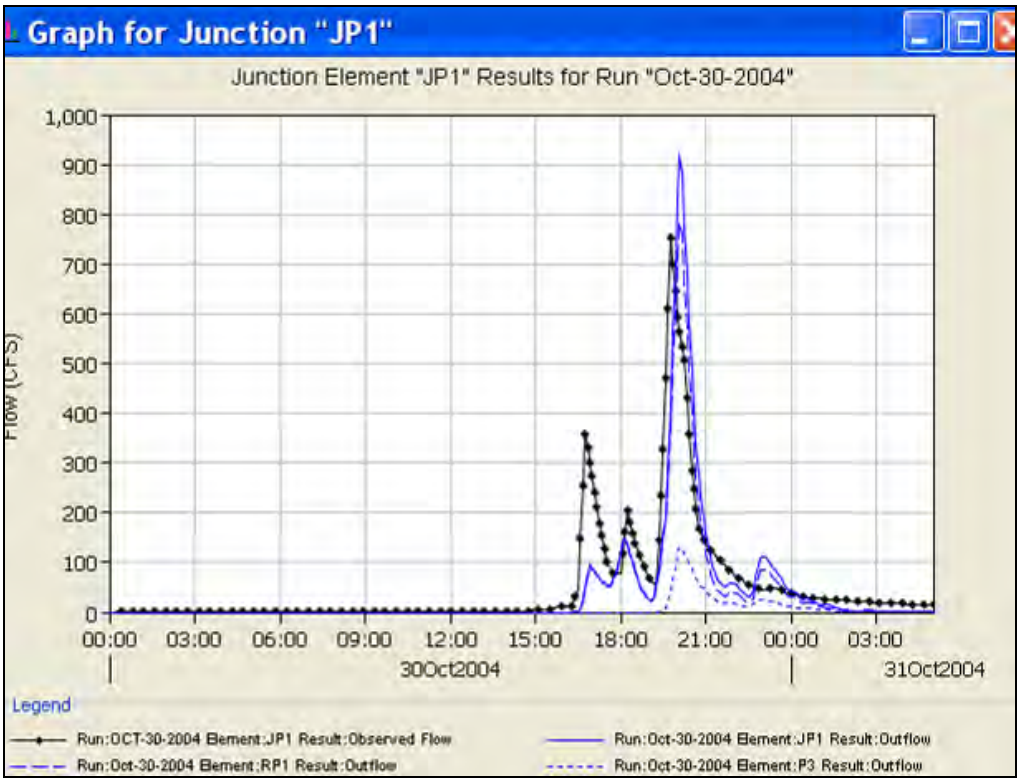

Figure 4-6. Observed and Modeled Stream Flows at Junction JP1 (Pūkele Gage [2440]) October 2004 Storm

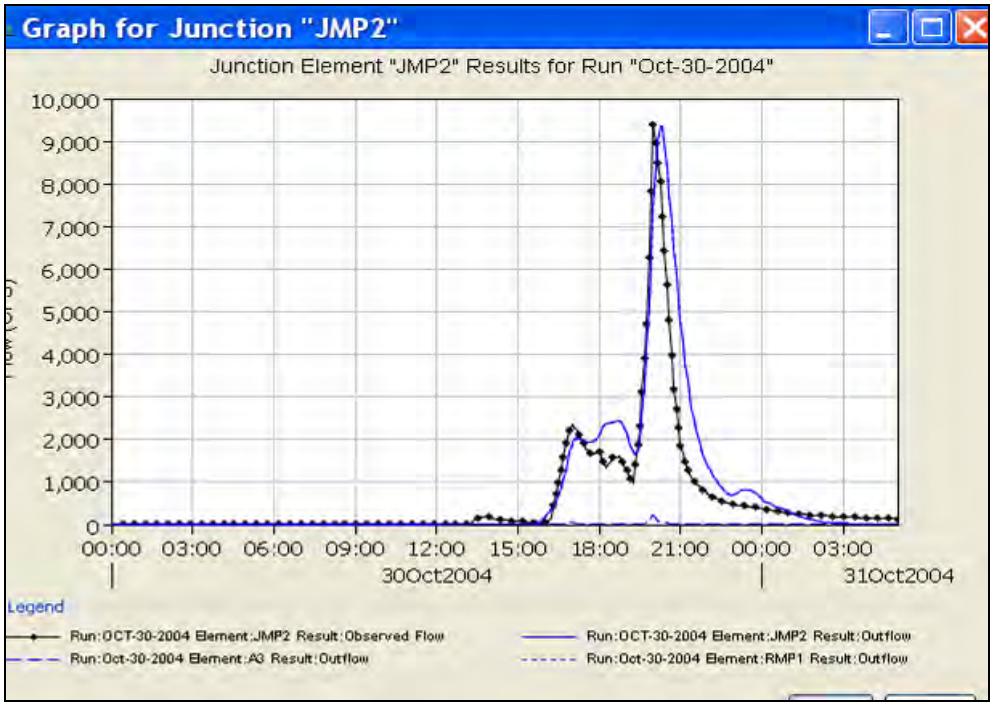

Figure 4-7. Observed and Modeled Flows at Junction JMP2 (Mānoa-Pālolo Gage [2471]) October 2004 Storm

4.4.2 December 1967 Storm Calibration for Mānoa-Pālolo Area

The calibration for the storm of December 17–18, 1967, was based on the method used in the previous Mānoa Watershed Project hydrologic study. The calibration parameters in the Mānoa Watershed Project study for the Mānoa sub-watershed were not changed. The gage weights for sub-basins in the Mānoa sub-watershed were the same as that in the Mānoa Watershed Project study. The Thiessen polygon method was initially applied to determine the gage weight for each sub-basin. Figure 4-8 shows the Thiessen polygons for the December 1967 storm for the Ala Wai Watershed. After taking into consideration the rainfall pattern, data quality, and storm movement and distribution, the final gage weights and relevant 24-hour rainfall of the December 1967 storm for each sub-basin were determined as shown in Table 4-6. (Note: 'MP' is used to abbreviate the Mānoa-Pālolo area.)

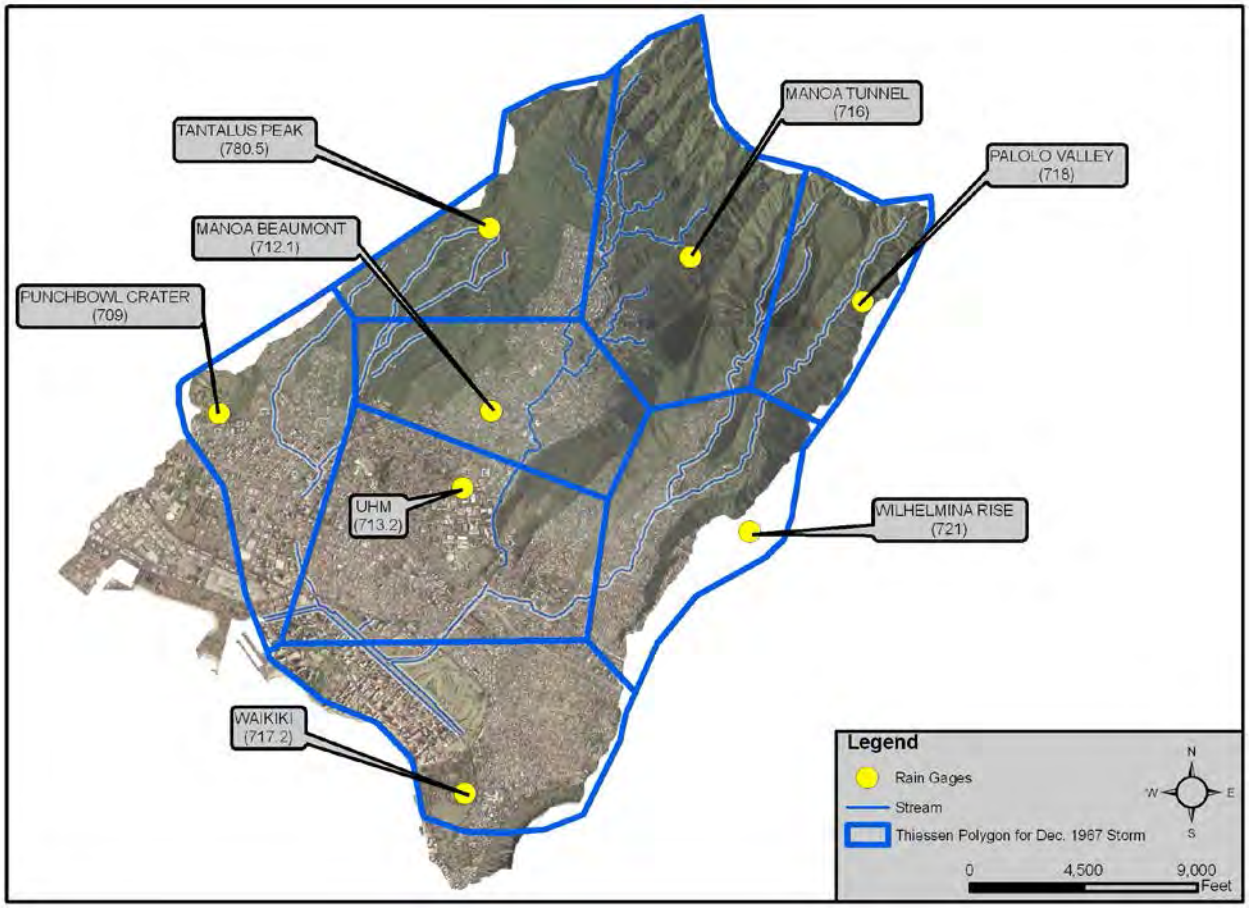

Figure 4-8. Rain Gages and Thiessen Polygons for December 1967 Storm for MP

The gage weights for the December 1967 storm, shown in Table 4-6, were calculated by considering the Thiessen polygons shown in Figure 4-8, the rainfall pattern, and the storm movement and distribution.

Meteorological Model: Gage Weights for December 17–18, 1967, Storm for MP								
Gage weights	Thiessen Polygon							
Sub-Basin	Mānoa Tunnel	Mānoa Beaumont	UHM	Pālolo Valley	Tantalus Peak	Waikīkī	Wilhemina Rise	24-hr Rain (in)
ID	716	712.1	713.2	718	780.5	717.2	721	
Total Rainfall (in)	10.42	9.43	9.5	10.88	8.1	8.21	9.56	
A3			0.6		0.1	0.3		8.97
M1	0.4				0.6			9.03
M2	0.6			0.2	0.2			10.05
M3	0.2	0.2			0.6			8.83
M4	0.2	0.2			0.6			8.83
M5	0.5			0.3	0.2			10.09
M6	0.3	0.5			0.2			9.46
M7		0.6			0.4			8.90
M8		0.8			0.2			9.16
M9		0.7			0.3			9.03
M10		0.8			0.2			9.16
M11		0.6	0.2		0.2			9.18
M12		0.4	0.5		0.1			9.33
M13		0.2	0.7		0.1			9.35
M14		0.2	0.6		0.1		0.1	9.35
P1	0.5			0.4	0.1			10.37
P2				0.7	0.1		0.2	10.34
P3	0.3			0.4	0.1		0.2	10.2
P4	0.3				0.1		0.6	9.68
P5					0.1		0.9	9.41
P6			0.2		0.1		0.7	9.4
P7			0.45		0.1	0.15	0.3	9.18

Table 4-6. Meteorological Model: Gage Weights for December 17–18, 1967, Storm for MP

The meteorological model used storm hydrographs for calibration and frequency based rainfall to compute the synthetic flood events. For creating the peak discharges for various return periods, the frequency storm with an intensity position at 50% was used in computing the peaks and hydrographs. Table 4-7 lists the final parameters for the HEC-HMS model in the Mānoa and Pālolo sub-watersheds. The parameters of the calibrated time of concentrations are close to those calculated using the TR-55 method. At junctions JP1, JP3, and JMP2, the modeled stream flows for the December 1967 storm show a series of stream flow peaks as shown in Figures 4-9 to 4-11. For the December 1967 storm, peak flow data from M2, data from JP1, peak flow data from JP3, and continuous data from JMP2 were used.

	Loss Method --- SCS Curve Number		Transform--Clark Unit Hydrograph	
Sub-basin	Initial Abstraction (inches)	Curve Number	Time of Concentration (hour)	Storage Coefficient (hour)
A3 (Plane 1)	1.50	83	Kinematic Wave Transform	
A3 (Plane 2)	0.15	98		
M1	0.70	62	0.22	0.30
M10	0.70	76	0.26	0.25
M11	0.70	75	0.19	0.25
M12	0.70	73	0.26	0.22
M13	0.70	68	0.26	0.30
M14	1.80	84	0.10	0.68
M2	0.50	64	0.22	0.22
M3	0.70	69	0.22	0.30
M4	0.70	73	0.22	0.30
M5	0.70	63	0.23	0.30
M6	0.70	68	0.22	0.30
M7	0.70	71	0.18	0.30
M8	0.70	80	0.15	0.30
M9	0.70	75	0.17	0.30
P1	1.20	64	0.21	0.30
P2	1.80	65	0.30	0.20
P3	1.20	62	0.16	0.25
P4	0.72	72	0.25	0.23
P5	0.65	73	0.30	0.34
P6	0.73	85	0.24	0.31
P7	1.80	88	0.10	0.80

Table 4-7. Calibrated Model Parameters for December 1967 Storm for MP

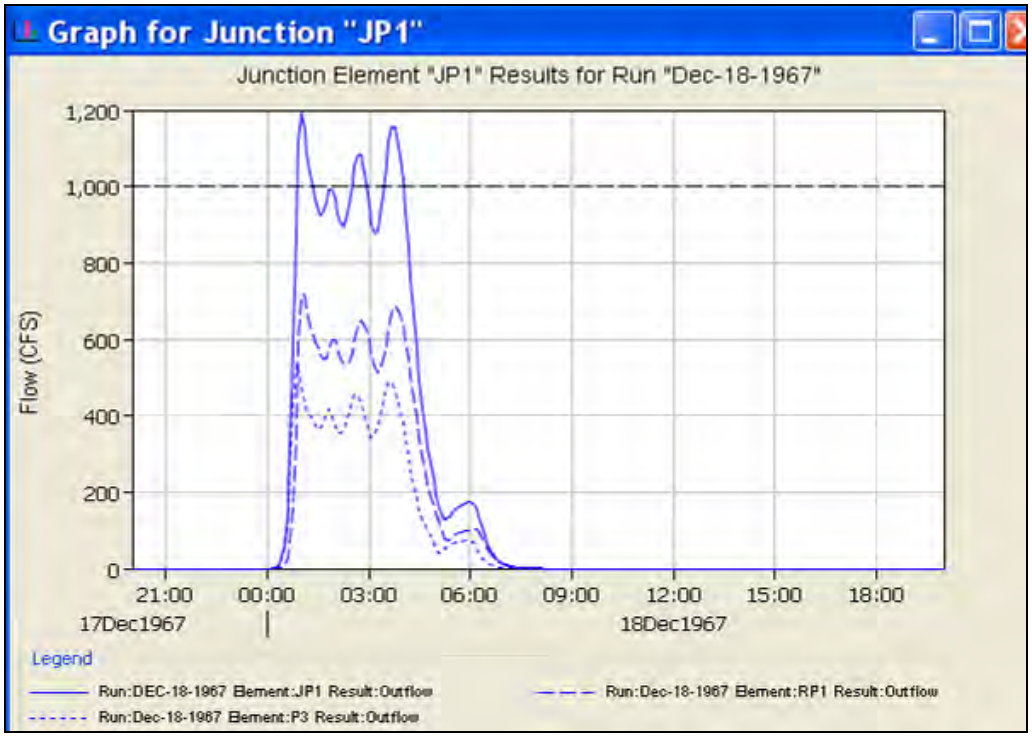

Figure 4-9. Modeled Stream Flows at Junction JP1 (Pūkele Gage [2440]) December 1967 Storm

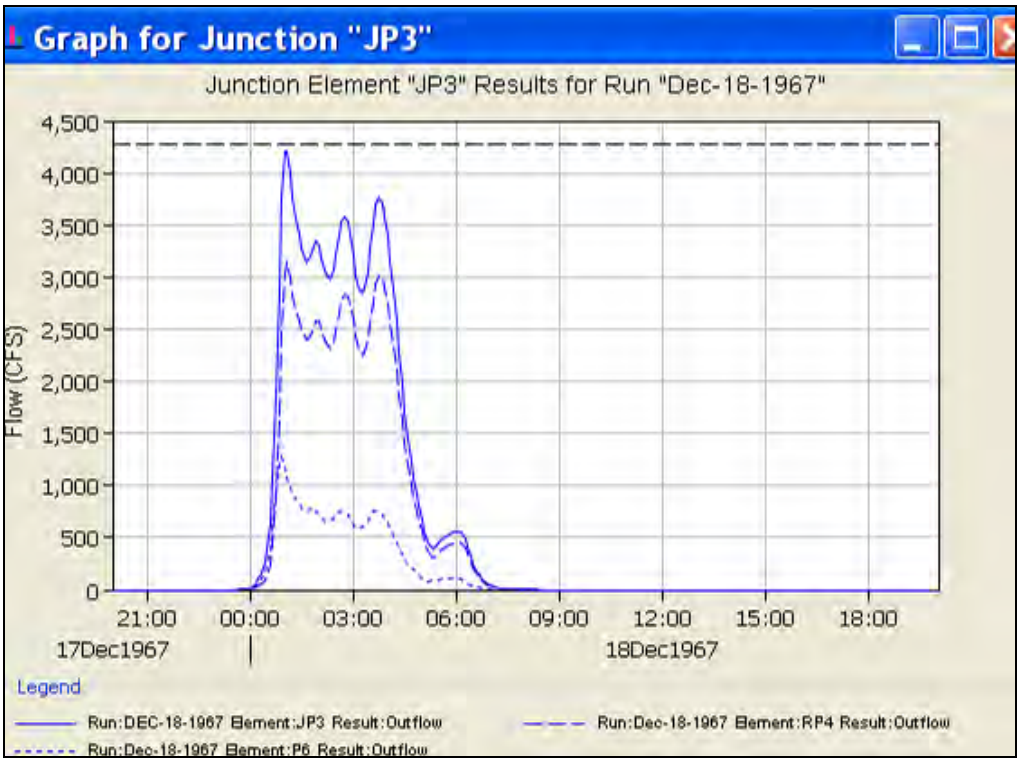

Figure 4-10. Modeled Stream Flows at JP3 (USGS Pālolo Gage [16247000]) December 1967 Storm

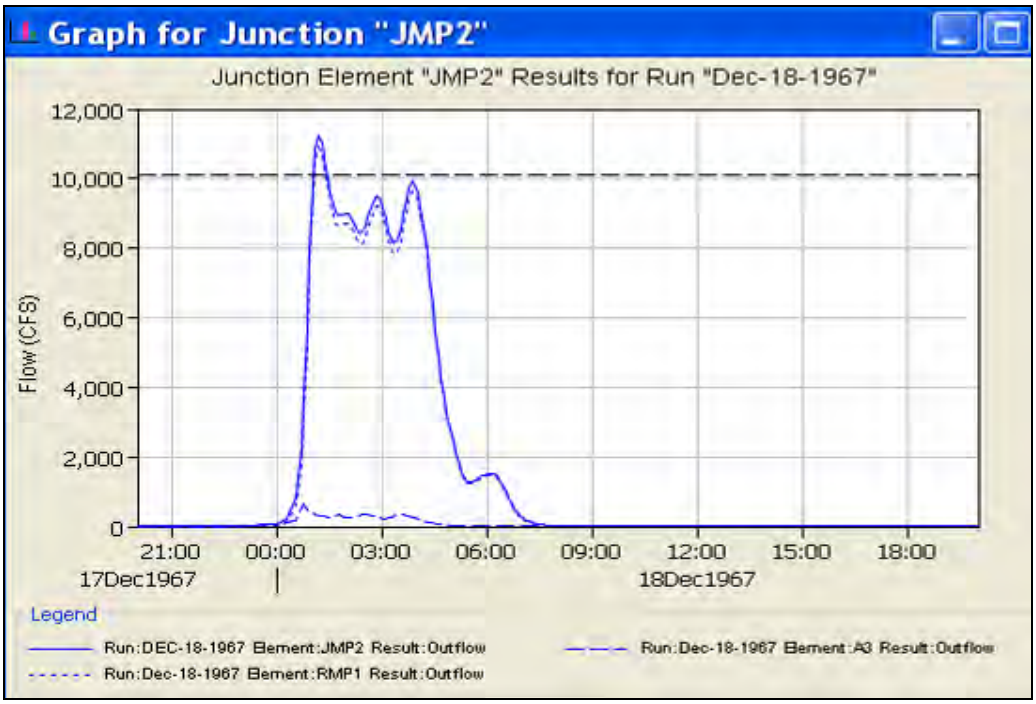

Figure 4-11. Modeled Stream Flows at JMP2 (USGS Stream Gage [16247100]) December 1967 Storm

4.4.3 March 2006 Storm Calibration for Mānoa-Pālolo Area

The Thiessen polygon method was initially applied to determine the gage weight. Figure 4-12 shows the Thiessen polygons for the March 31, 2006, storm for the Ala Wai Watershed. After taking into consideration the rainfall pattern, data quality, and storm movement and distribution, the final gage weights and relevant 24-hour rainfall of the March 2006 storm for each sub-basin were determined as shown in Table 4-8. The March 31, 2006, storm is a significant example because the storm produced a small amount of rain that generated a large amount of runoff because the soils in the study area were already saturated from six weeks of heavy rains. (Note: 'MP' is used to abbreviate the Mānoa-Pālolo area.)

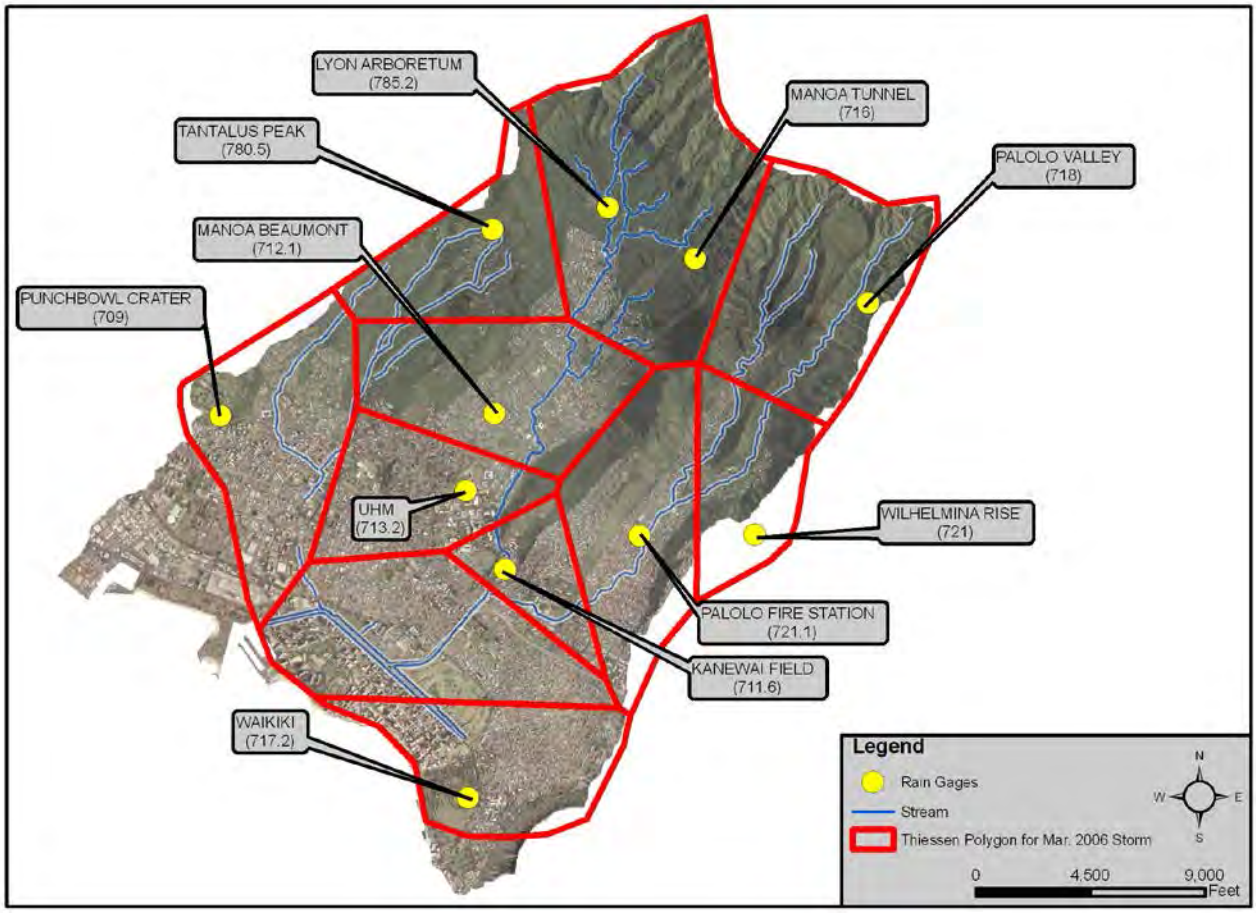

Figure 4-12. Rain Gages and Thiessen Polygons for March 2006 Storm for MP

Meteorological Model: Gage Weights for March 31, 2006 Storm for MP

Gage weights	Thiessen Polygon									
Sub-Basin	**Lyon Arboretum**	**Kānewai**	**Mānoa Beaumont**	**UHM**	**Pālolo Fire Stn.**	**Pālolo Valley**	**Tantalus Peak**	**Wilhemina Rise**	**H-1 at Kapiolani**	**24hr Rain (in)**
ID	785.2	711.6	712.1	713.2	721.1	718	780.5	721	711.7	
Total Rainfall (in)	3.35	3.49	3.25	4.75	3.00	2.84	2.60	3.49	3.53	
A3		0.1			0.1				0.8	3.47
M1	0.9						0.1			3.27
M2	0.9					0.1				3.30
M3	0.6		0.3				0.1			3.25
M4	0.1		0.6				0.3			3.07
M5	0.9				0.1					3.31
M6	0.1		0.7		0.2					3.21
M7	0.1		0.6				0.3			3.07
M8			0.8		0.2					3.20
M9	0.1		0.8	0.1						3.41
M10		0.1	0.8				0.1			3.21
M11			0.7	0.1	0.2					3.35
M12		0.2	0.3	0.5						4.05
M13		0.5		0.2	0.3					3.60
M14		0.5			0.4				0.1	3.30
P1	0.2					0.8				2.94
P2	0.1					0.7		0.2		3.02
P3	0.1				0.1	0.5		0.3		3.10
P4					0.6	0.1		0.3		3.13
P5					0.2			0.8		3.39
P6		0.1			0.8			0.1		3.10
P7		0.6			0.3				0.1	3.35

Table 4-8. Meteorological Model: Gage Weights for March 2006 Storm for MP

The HEC-HMS meteorological model's parameters were calibrated using the March 31, 2006, storm data. Table 4-9 lists the final parameters for the HEC-HMS model in the Mānoa and Pālolo sub-watersheds. The parameters of the calibrated time of concentrations are close to those calculated using the TR-55 method. The meteorological model used storm hydrographs for calibration and frequency based rainfall to compute the synthetic flood events.

	Loss Method --- SCS Curve Number		Transform Method --- Clark Unit Hydrograph	
Sub-basin	Initial Abstraction (inches)	Curve Number	Time of Concentration (hour)	Storage Coefficient (hour)
A3 (Plane 1)	0	92	Kinematic Wave Transform	
A3 (Plane 2)	0	98		
M1	0	88	0.20	0.10
M10	0	92	0.18	0.10
M11	0	92	0.10	0.10
M12	0	92	0.20	0.10
M13	0	90	0.10	0.10
M14	0	90	0.12	0.10
M2	0	70	0.32	0.12
M3	0	92	0.20	0.10
M4	0	92	0.10	0.10
M5	0	72	0.20	0.10
M6	0	75	0.15	0.10
M7	0	80	0.15	0.10
M8	0	92	0.10	0.10
M9	0	92	0.10	0.10
P1	0	64	0.10	0.10
P2	0	65	0.10	0.10
P3	0	62	0.10	0.10
P4	0	72	0.10	0.10
P5	0	73	0.10	0.10
P6	0	85	0.10	0.11
P7	0	90	0.10	0.10

Table 4-9. Calibrated Model Parameters for March 2006 Storm

The modeled stream flow for the March 2006 storm in M2 and at JMP2 show a small flow peak flow followed by a higher peak flow, as shown in Figures 4-13 and 4-14. The modeled peak flows are higher and earlier than the observed flows; however, the highest peaks match well. Due to the extremely saturated soil within the study area during this storm, the sub-basins' curve numbers were allowed to change to match the peak at JMP2 for calibration.

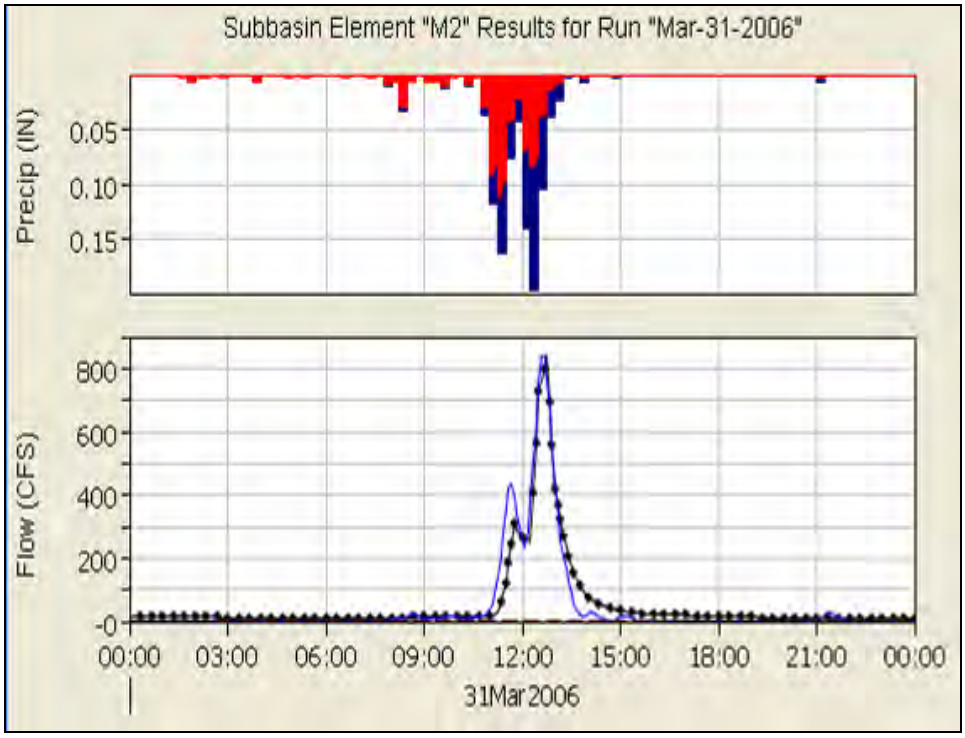

Figure 4-13. Observed and Modeled Stream Flows at Waiakeakua Stream (Sub-basin M2), March 2006 Storm

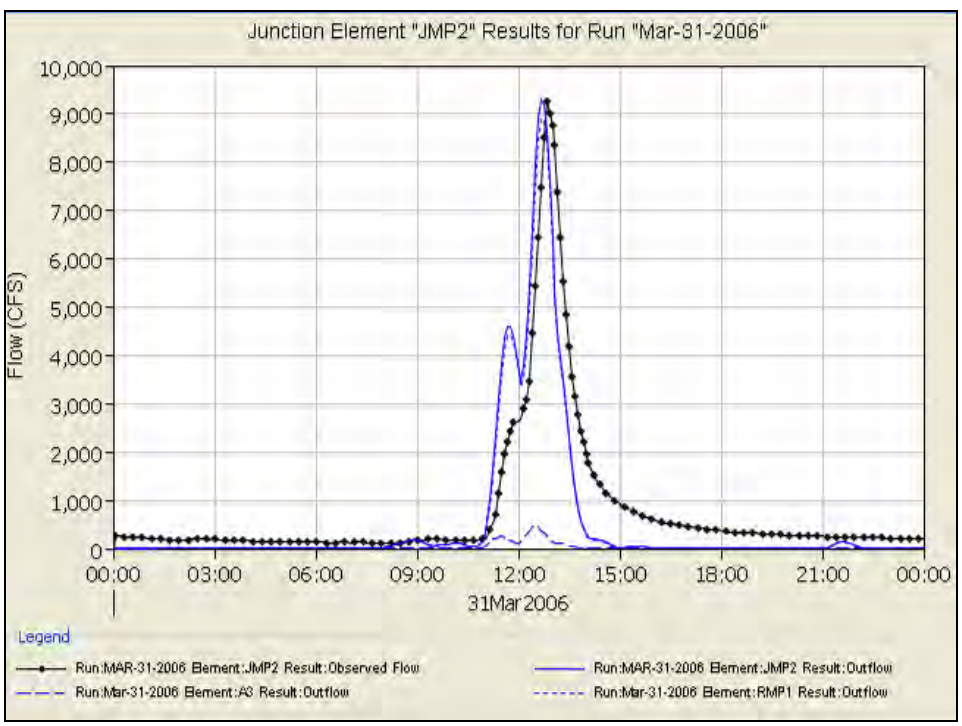

Figure 4-14. Observed and Modeled Stream Flows at JMP2 (USGS Stream Gage [16247100]), March 2006 Storm

4.4.4 Final Loss and Transform Parameters for Mānoa-Pālolo Area

The loss method was determined by using the NRCS runoff CN method to take advantage of the results from the Mānoa Watershed Project hydrologic study. The parameters of initial abstraction were optimized for the Waiakeakua sub-basin and then were assigned to all the other sub-basins. Impervious parameters were set to zero because the percentage of the sub-basin that is impervious is specified in the CN. The optimization was used in each individual calibration (see Section 4.2). The final model parameters were the weighted average ones.

There is more confidence with the storms of October 30, 2004, and December 17–18, 1967, and less confidence with the storm of March 31, 2006. More weighting values were given to the calibrated parameters of the storm events of October 2004 and December 1967. The calibrated parameters of the October 2004 and December 1967 storm events were assigned twice the weight of the calibrated parameters for the March 31, 2006, storm. The finalized calibrated parameters of the HEC-HMS model were weighted as (2*2004 + 2*1967 + 1* 2006)/5. The weighted averaged loss method and transform method parameters for the Mānoa-Pālolo area are listed in Tables 4-10 and 4-11.

Curve Number Loss Method Calibration: Manoa-Palolo basin model								
	October-30-2004		December-18-1967		March-31-2006		Weighted Average	
Sub-basin	Initial Abstraction (inch)	Curve Number	Initial Abstraction (inch)	Curve Number	Initial Abstraction (inch)	Curve Number	Initial Abstraction (inch)	Curve Number
A3 (Plane 1)	0.75	83	1.50	83	0	92	**0.90**	**85**
A3 (Plane 2)	0.10	98	0.15	98	0	98	**0.10**	**98**
M1	0.60	62	0.70	62	0	88	**0.52**	**67**
M10	0.60	76	0.70	76	0	92	**0.52**	**79**
M11	0.60	75	0.70	75	0	92	**0.52**	**78**
M12	0.30	73	0.70	73	0	92	**0.40**	**77**
M13	0.60	68	0.70	68	0	90	**0.52**	**72**
M14	1.00	84	1.80	84	0	90	**1.12**	**85**
M2	0.60	64	0.50	64	0	70	**0.44**	**65**
M3	0.60	69	0.70	69	0	92	**0.52**	**74**
M4	0.60	73	0.70	73	0	92	**0.52**	**77**
M5	0.60	63	0.70	63	0	72	**0.52**	**65**
M6	0.60	68	0.70	68	0	75	**0.52**	**69**
M7	0.60	71	0.70	71	0	80	**0.52**	**73**
M8	0.60	80	0.70	80	0	92	**0.52**	**82**
M9	0.60	75	0.70	75	0	92	**0.52**	**78**
P1	2.20	64	1.20	64	0	64	**1.36**	**64**
P2	1.20	65	1.80	65	0	65	**1.20**	**65**
P3	3.20	62	1.20	62	0	62	**1.76**	**62**
P4	1.20	72	0.72	72	0	72	**0.77**	**72**
P5	1.20	73	0.65	73	0	73	**0.74**	**73**
P6	1.20	85	0.73	85	0	85	**0.77**	**85**
P7	1.20	88	1.80	88	0	90	**1.20**	**88**

Table 4-10. Final HEC-HMS Model Loss Method Parameters

Clark Unit Hydrograph Transform Method Calibration: Manoa-Palolo basin model								
	October-30-2004		December-18-1967		March-31-2006		Average Values	
Sub-basin	T_c (Hour)	S_c (Hour)	T_c (Hour)	S_c (Hour)	T_c (Hour)	S_c (Hour)	T_c (Hour)	S_c (Hour)
M1	0.24	0.42	0.22	0.30	0.20	0.10	**0.22**	**0.31**
M2	0.23	1.10	0.22	0.22	0.32	0.12	**0.24**	**0.55**
M3	0.25	0.70	0.22	0.30	0.20	0.10	**0.23**	**0.42**
M4	0.23	0.80	0.22	0.30	0.10	0.10	**0.20**	**0.46**
M5	0.31	0.90	0.23	0.30	0.20	0.10	**0.26**	**0.50**
M6	0.25	0.85	0.22	0.30	0.15	0.10	**0.22**	**0.48**
M7	0.19	1.50	0.18	0.30	0.15	0.10	**0.18**	**0.74**
M8	0.16	1.80	0.15	0.30	0.10	0.10	**0.14**	**0.86**
M9	0.17	1.50	0.17	0.30	0.10	0.10	**0.16**	**0.74**
M10	0.26	0.60	0.26	0.25	0.18	0.10	**0.24**	**0.36**
M11	0.50	0.30	0.19	0.25	0.10	0.10	**0.30**	**0.24**
M12	0.25	0.65	0.26	0.22	0.20	0.10	**0.24**	**0.37**
M13	0.27	0.40	0.26	0.30	0.10	0.10	**0.23**	**0.30**
M14	0.15	0.30	0.10	0.68	0.12	0.10	**0.12**	**0.41**
P1	0.10	0.40	0.21	0.30	0.10	0.10	**0.14**	**0.30**
P2	0.30	0.55	0.30	0.20	0.10	0.10	**0.26**	**0.32**
P3	0.10	0.68	0.16	0.25	0.10	0.10	**0.12**	**0.39**
P4	0.10	0.30	0.25	0.23	0.10	0.10	**0.16**	**0.23**
P5	0.16	0.30	0.30	0.34	0.10	0.10	**0.20**	**0.28**
P6	0.10	0.25	0.24	0.31	0.10	0.11	**0.16**	**0.25**
P7	0.18	0.30	0.10	0.80	0.10	0.10	**0.13**	**0.46**

Table 4-11. Final HEC-HMS Transform Method Parameters
Note: T_c is the time of concentration, S_c is the storage coefficient

4.5 Makiki Model Calibration

Data from the USGS Makiki Stream Gage (16238000) at King Street Bridge was used to calibrate the Makiki HEC-HMS model. This gage measured two peaks in 2004. One peak was 487 cfs recorded on February 28, 2004, and the other peak was 1,000 cfs recorded on October 30, 2004. There were no sufficient rainfall data for February 28, 2004, so the 1,000 cfs peak on October 30, 2004, was used to calibrate the Makiki HEC-HMS model. The Thiessen polygons for October 30, 2004, in the Makiki sub-watershed can be seen in Figure 4-15, and they are the same as those for the Mānoa-Pālolo calibration of the October 30, 2004 storm. Because there was no timing rainfall gage within the Makiki sub-watershed, the Lyon Arboretum rainfall gage (785.2) was selected as the time weight gage for all sub-basins in the sub-watershed (see Table 3.1 for rainfall gage information). (Note: 'K' is used to abbreviate for the Makiki sub-watershed.)

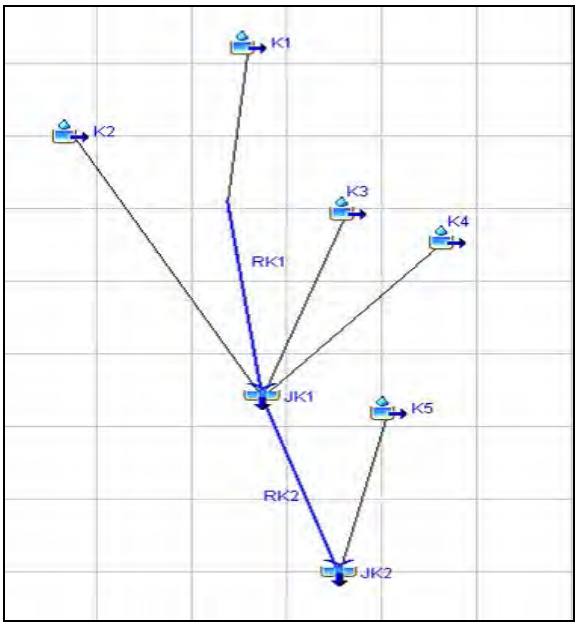

Figure 4-15. HEC-HMS Makiki Sub-Watershed Calibration Model Layout

4.5.1 October 2004 Storm Calibration for the Makiki Sub-Watershed

Due to the limited data available for the Makiki sub-watershed, the October 30, 2004, storm data were the only storm data used to calibrate the Makiki meteorological model. The calibration was based on the peak discharge of 1,000 cfs at King Street Bridge (USGS stream gage 16238000). Figure 4-5 shows the Thiessen polygons for the October 2004 storm for the Ala Wai Watershed. The Thiessen polygon method does not account for orthographic rainfall effect in mountain areas. The rainfall pattern, data quality, and storm movement and distribution were taken into consideration for the final gage weights. For the Makiki sub-watershed, the final gage weights for the 24-hour rainfall of the October 2004 storm were calculated and are given in Table 4-12.

Gage Weights for Makiki Sub-Watershed October 30, 2004, Storm						
Gage Weights	Thiessen Polygons (Gages in red recorded)					
Sub-Basin ID	Lyon Arboretum	Mānoa Beaumont	UHM	Tantalus Peak	Punchbowl Crater	24-hr Rain (inch)
	785.2	712.1	713.2	780.5	709	
Total Rainfall (in)	**10.08**	**4.62**	**2.4**	**7.8**	**0.05**	
K1	0.1	0.3		0.5	0.1	**6.39**
K2	0.1			0.2	0.7	**3.23**
K3	0.1	0.4	0.2		0.3	**3.62**
K4	0.1	0.4	0.4		0.1	**3.91**
K5	0.1		0.3		0.6	**2.30**

Table 4-12. Gage Weights for October 2004 Storm Makiki Sub-Watershed

The HEC-HMS meteorological model's parameters were calibrated using the October 30, 2004, storm data for the Makiki sub-watershed. Table 4-13 lists the calibrated parameters for the HEC-HMS model in the Makiki sub-watershed. The parameters of the calibrated times of concentration are close to those calculated using the TR-55 method. The meteorological model used storm hydrographs for calibration and frequency-based rainfall to compute the synthetic flood events. The final model parameters for the Makiki sub-watershed are given in Table 4-14.

Sub-basin	Initial Loss (inch)	Curve Number	Time of Concentration (hour)	Storage Coefficient (hour)
K1	1	42	0.18	0.45
K2	1	62	0.23	0.25
K3	1	68	0.12	0.2
K4	1	68	0.12	0.25
K5 (Plane 1)	0.7	85		
K5 (Plane 2)	0.1	98		

Table 4-13. Calibrated Parameters of Makiki Sub-Watershed

Sub-basin	Initial Loss (inch)	Curve Number	Time of Concentration (hour)	Storage Coefficient (hour)
K1	1	42	0.18	0.45
K2	1	62	0.23	0.35
K3	1	68	0.12	0.32
K4	1	68	0.12	0.35
K5 (Plane 1)	0.7	85		
K5 (Plane 2)	0.1	98		

Table 4-14. Finalized Parameters in HEC-HMS Model Makiki Sub-Watershed

The calibrated and final parameters of the HEC-HMS Model for the Makiki sub-watershed only differ by a few storage coefficients. These differences are due to the differing use and character of land in upper versus lower Makiki. The land use of the upper Makiki sub-watershed, a natural area with preservation land use, is similar to those of the upper Mānoa and Pālolo sub-watersheds. This similarity is reflected in the storage coefficient calculated. That is, the calibrated Clark Unit Hydrograph storage coefficient of the K1 sub-basin is 0.45 hour (hr), as shown in Tables 4-13 and 4-14, and the calibrated Clark Unit Hydrograph storage coefficients of sub-basins M5, P2, and M2, are 0.50, 0.32, and 0.57 hr respectively. In contrast, for lower Makiki sub-basins of K2, K3, and K4, the storage coefficients were increased slightly to match the calibrated storage coefficients in the Mānoa and Pālolo sub-watersheds. Figure 4-16 shows the modeled stream flows for JK2.

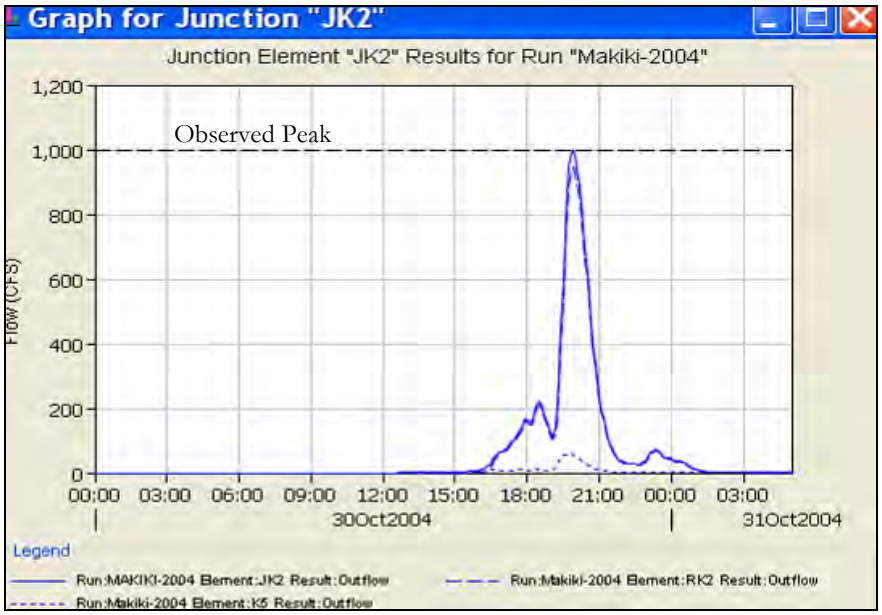

Figure 4-16. Modeled Stream Flows at JK2 (King Street Bridge, USGS stream gage 16238000)

4.6 Kinematic Wave Transform Method Parameters

The Kinematic Wave Transform Method was used for the urbanized sub-basins. The Kinematic Wave technique is widely accepted for use in urbanized runoff modeling (USACE, 2001) because the parameters for various elements constituting the model are directly related to measurable, physical basin features. Parameters such as storm drain catchment length, drainage area, roughness, slope, and channel geometry are used to define the flow of water over basin surfaces into the stream channel. For the urbanized sub-basins, two overland flow plane elements were used to represent pervious land areas such as lawns and gardens and impervious areas such as streets and roofs. In this study, a sub-basin was modeled by combining two overland planes, a collector channel, and a main channel. The lengths, slopes, and roughness coefficients of the overland flow planes were based on the average of several values within the sub-watershed. Table 4-15 lists the values of the flow planes. Urbanized watersheds typically have various storm drainage systems, man-made channels, and natural channels. To model complex urban systems in a manageable fashion, the concept of typical collector channels was employed. The collector system was formulated from average parameters, in the sub-watershed. Tables 4-16 and 4-17 summarize the values of the collector channels and main channels.

In order to use the composite runoff curve number in a kinematic wave model, the sub-watershed must be divided into its pervious and impervious components. A curve number of 98 was used for the impervious areas (USACE 1973). The following equation can be applied to calculate the adjusted pervious curve number. The adjusted pervious curve number was used as the loss rate for the pervious areas.

$$X = \frac{CNc - 98 \times f}{1 - f}$$

Where $X = Adjusted\ \ pervious\ curve\ number$

$CNc = Composite\ curve\ number$

$f = total\ \ percent\ impervious, 0 \le f \le 1$

Kinematic Wave Transform Flow Planes for Urbanized Sub-Basins					
Subwatershed	Intial Abstraction (inch)	CN	Area (%)	Composite CN	Adjusted Pervious CN
A1 (Plane 1)	1.00	78	70	84	78
A1 (Plane 2)	0.10	98	30		
A2 (Plane 1)	0.75	86	65	90	86
A2 (Plane 2)	0.05	98	35		
A3 (Plane 1)	0.90	83	60	89	83
A3 (Plane 2)	0.10	98	40		
A4 (Plane 1)	0.75	76	60	85	76
A4 (Plane 2)	0.10	98	40		
A5 (Plane 1)	0.75	81	60	88	81
A5 (Plane 2)	0.10	98	40		
A6 (Plane 1)	1.00	69	90	72	69
A6 (Plane 2)	0.10	98	10		
A7 (Plane 1)	1.00	76	60	85	76
A7 (Plane 2)	0.10	98	40		
A8 (Plane 1)	0.75	86	50	92	86
A8 (Plane 2)	0.10	98	50		
K5 (Plane 1)	1.00	85	75	88	85
K5 (Plane 2)	0.10	98	25		
K6 (Plane 1)	1.20	80	60	87	80
K6 (Plane 2)	0.10	98	40		
W1 (Plane 1)	0.80	83	60	89	83
W1 (Plane 2)	0.10	98	40		
W2 (Plane 1)	1.00	86	50	92	86
W2 (Plane 2)	0.10	98	50		
W3 (Plane 1)	0.95	82	50	90	82
W3 (Plane 2)	0.10	98	50		

Table 4-15. Kinematic Wave Transform Flow Planes for Urbanized Sub-Basins

Kinematic Wave Collector Channels

Sub-basin	Length (ft)	Slope (ft/ft)	Manning's n	Area (mi^2)	Shape	Diameter (ft)	Width (ft)	Side Slope (xH:1V)
A1 (Sub-Collector)								
A1 (Collector)	1200	0.015	0.016	0.0207	Circle	3		
A2 (Sub-Collector)								
A2 (Collector)	2500	0.01	0.015	0.03	Circle	4		
A3 (Sub-Collector)								
A3 (Collector)	2800	0.06	0.018	0.03	Circle	3		
A4 (Sub-Collector)								
A4 (Collector)	2200	0.004	0.014	0.03	Circle	4		
A5 (Sub-Collector)								
A5 (Collector)	1200	0.035	0.018	0.03	Circle	2.5		
A6 (Sub-Collector)								
A6 (Collector)	750	0.006	0.06	0.01	Trapezoid		2	10
A7 (Sub-Collector)								
A7 (Collector)	1200	0.035	0.018	0.03	Circle	1.5		
A8 (Sub-Collector)								
A8 (Collector)	2400	0.003	0.015	0.03	Circle	4		
K5 (Sub-Collector)								
K5 (Collector)	1000	0.005	0.016	0.02	Circle	2		
K6 (Sub-Collector)								
K6 (Collector)	2600	0.005	0.018	0.035	Circle	3		
W1 (Sub-Collector)								
W1 (Collector)	1200	0.0015	0.015	0.025	Circle	1.5		
W2 (Sub-Collector)								
W2 (Collector)	800	0.0025	0.015	0.015	Circle	3		
W3 (Sub-Collector)								
W3 (Collector)	900	0.002	0.015	0.015	Circle	3		

Table 4-16. Kinematic Wave Collector Channels

Kinematic Wave Main Channels

Sub-basin	Route Upstream	Length (ft)	Slope (ft/ft)	Shape	Manning's n	Diameter (ft)	Width (ft)	Slope (xH:1V)
A1	No	1200	0.067	Circle	0.016	3		
A2	Yes	3600	0.001	Trapezoid	0.015		255	0
A3	Yes	800	0.0075	Trapezoid	0.03		50	5
A4	Yes	3100	0.001	Trapezoid	0.035		50	5
A5	No	5800	0.021	Circle	0.015	4		
A6	No	3650	0.001	Trapezoid	0.022		255	0
A7	No	6200	0.0267	Circle	0.015	4		
A8	Yes	2200	0.0015	Trapezoid	0.015		155	0
K5	Yes	700	0.056	Trapezoid	0.035		20	0
K6	Yes	3050	0.049	Trapezoid	0.035		20	0
W1	No	2800	0.0015	Circle	0.016	2		
W2	No	1500	0.0028	Circle	0.014	3		
W3	No	2100	0.0028	Circle	0.015	3		

Table 4-17. Kinematic Wave Main Channels

4.7 Reservoir and Reach Modeling

A number of assumptions were made during hydrologic modeling using the HEC-HMS method. These assumptions were made regarding the reservoir, reach, and junction modeling for the Ala Wai Watershed study area. Building upon the other sub-watershed model calibration, this final model represents the calibration of the entire watershed.

4.7.1 Ala Wai Canal as Reservoir

In order to consider backwater effect caused by the ocean tides, the Ala Wai Canal was modeled as a reservoir by assuming there is an imaginary boundary between the mouth of Canal and the ocean. "A reservoir is an element with one or more inflow and one computed outflow and is modeled by the assumption that water surface in the reservoir is level" (USACE 2008). The routing method was selected as the outflow structure. The size and type of imaginary outlet structure were mainly selected based on the cross section at the mouth of Ala Wai Canal. Noda and Associates (1994) study showed that the channel is a rectangular shape with a dimension of 152 feet x 14 feet near Ala Moana Bridge. The GeoRAS model also created similar cross sections at the mouth of the canal. The inlet elevation for this outlet structure was selected as -6.2 feet which was obtained from the October 30, 2004 storm calibration; then the rise of structure should be about 8 ft. The span of the structure was selected as 152 ft to match the field measurement. Figure 4-17 lists the reservoir model settings and Figure 4-18 shows its related outflow structure. There is no tide gage at the Ala Wai Canal mouth, the tide gage in Honolulu Harbor (NOAA tide level station 1612340) was used to represent the tail water effect. Consequently, the specified stage method was used to represent the main tail water. The elevation-storage function for the reservoir (Ala Wai Canal) was estimated by applying the bathymetric survey data for Ala Wai Canal conducted by Oceanit (2008) and the LiDAR data for surrounding areas, as show in Table 4-18 and Figure 4-18.

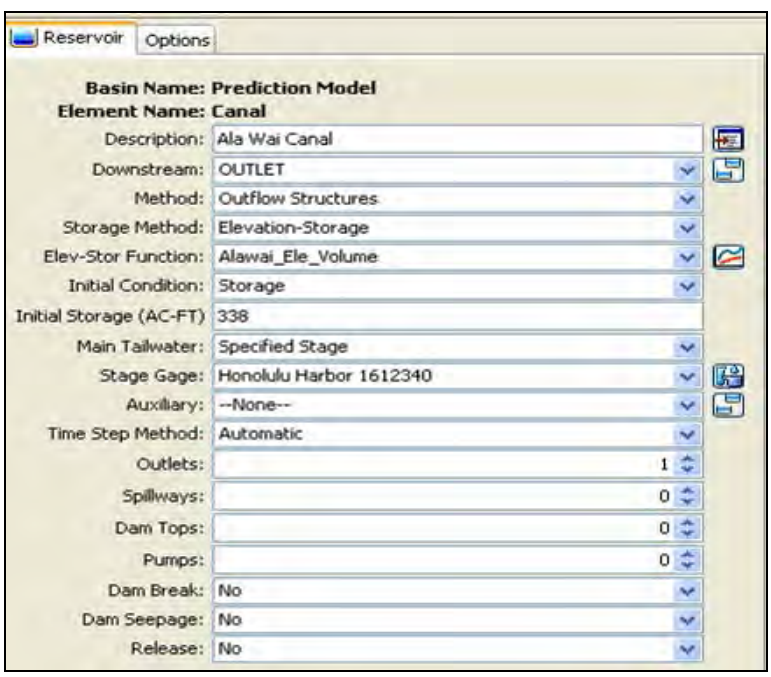

Figure 4-17. Model Settings for Reservoir (Ala Wai Canal)

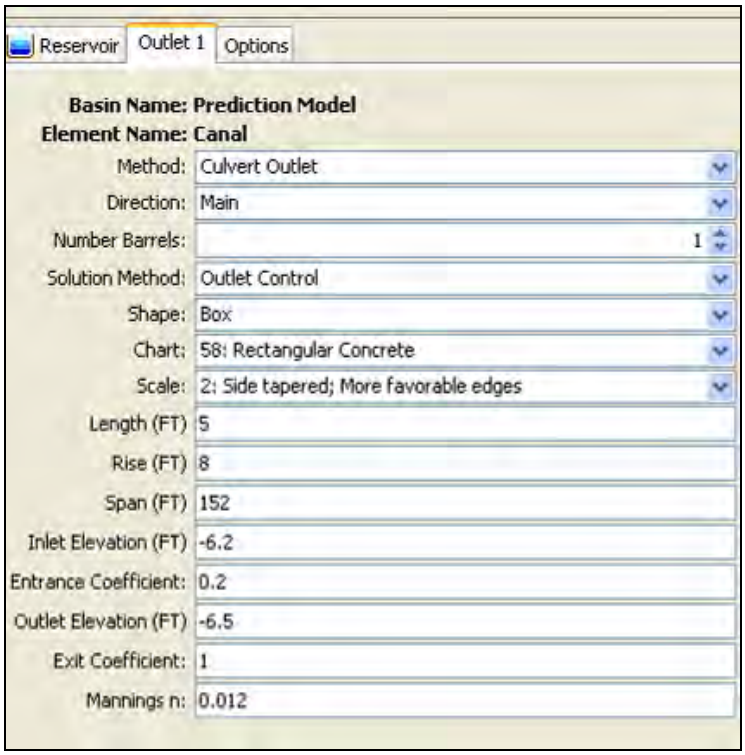

Figure 4-18 Model Settings for the Outflow Structure of Ala Wai Reservoir

Elevation-Storage Function Data

Elevation (ft)	Storage (acre-ft)	Elevation (ft)	Storage (acre-ft)	Elevation (ft)	Storage (acre-ft)
-15.5	0	-7.5	46.21	1	374.51
-15	0.01	-7	58.81	1.5	399.14
-14.5	0.03	-6.5	72.87	2	424.53
-14	0.09	-6	88.32	2.5	451.72
-13.5	0.22	-5.5	105.22	3	481.35
-13	0.43	-5	123.38	3.5	516.12
-12.5	0.74	-4.5	142.62	4	565.43
-12	1.2	-4	162.89	4.5	649.36
-11.5	1.89	-3.5	183.98	5	790.16
-11	2.99	-3	205.54	5.5	994.63
-10.5	4.89	-2.5	227.5	6	1260.41
-10	8.01	-2	249.61	6.5	1576.57
-9.5	12.49	-1.5	271.72	7	1930.93
-9	18.44	-1	293.83	7.5	2313.63
-8.5	25.97	-0.5	315.94	8	2718.57
-8	35.25	0	338.05		
-7.5	46.21	0.5	350.41		

Table 4-18. Elevation-Storage Curve Function Data

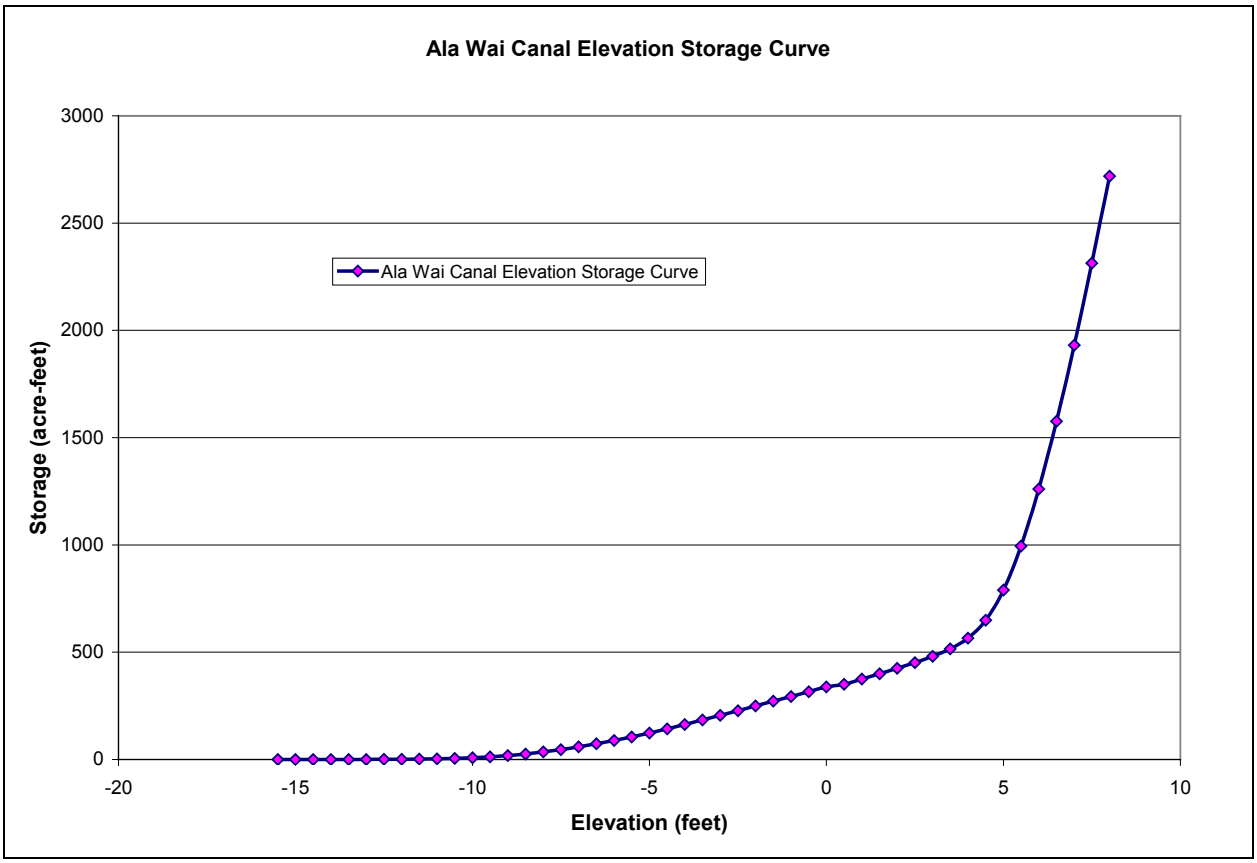

Figure 4-19. Elevation Storage Curve for Ala Wai Canal

The reservoir model was calibrated using the observed stage in the Ala Wai Canal from the October 2004 and December 1967 storm events. For modeling of the 2004 storm, the recorded stream flow hydrograph at USGS stream gage 16247100 was used to represent the inflow from upstream of Manoa and Palolo Streams; and Makiki calibrated model hydrograph at JK2 (USGS stream gage 16238000) was used to represent the inflow from Makiki area. Figure 4-20 illustrates the HEC-HMS model layout for October 30, 2004 storm calibration. Figure 4-21 shows the modeled and observed stages in Ala Wai Canal. The stage peak time matched very well at about 20:15pm with only 0.1 foot difference between the observed stage and the modeled stage.

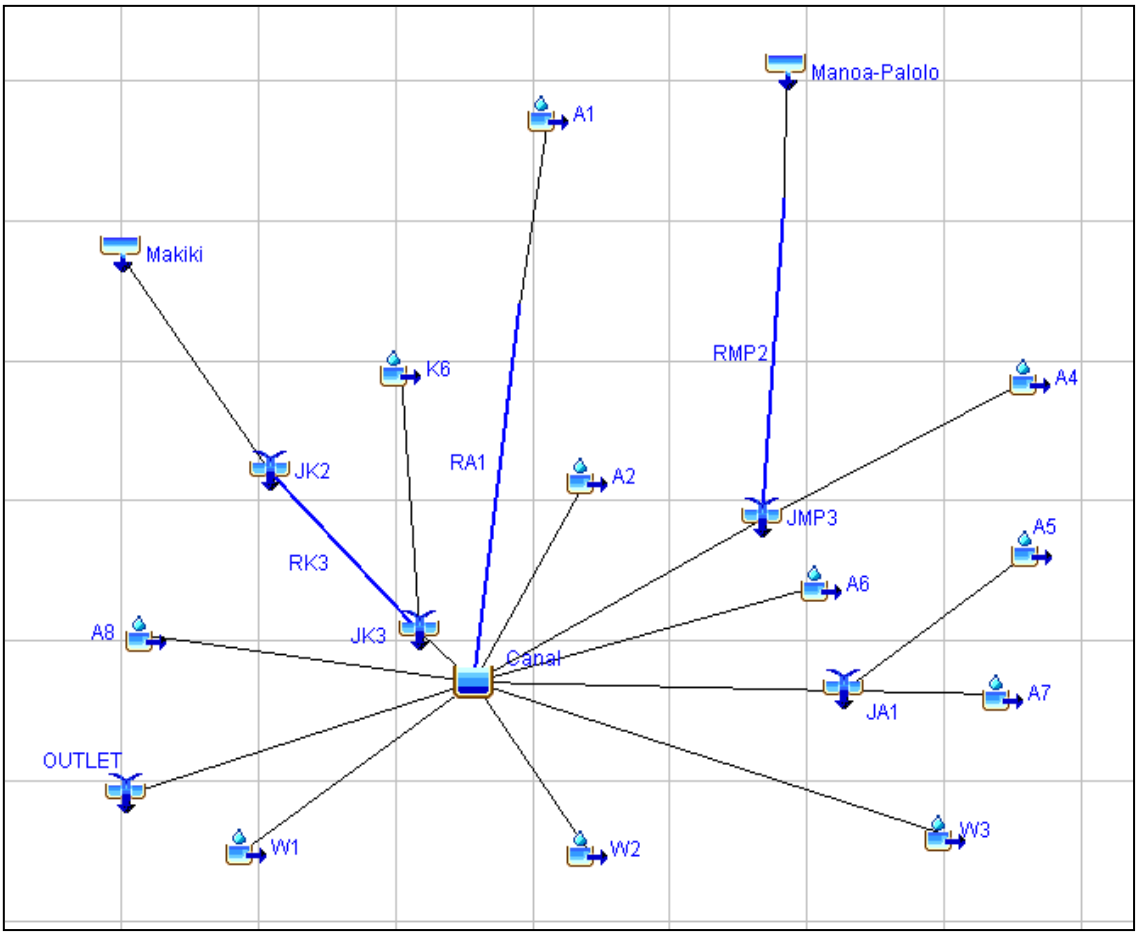

Figure 4-20. Model Layout for 2004

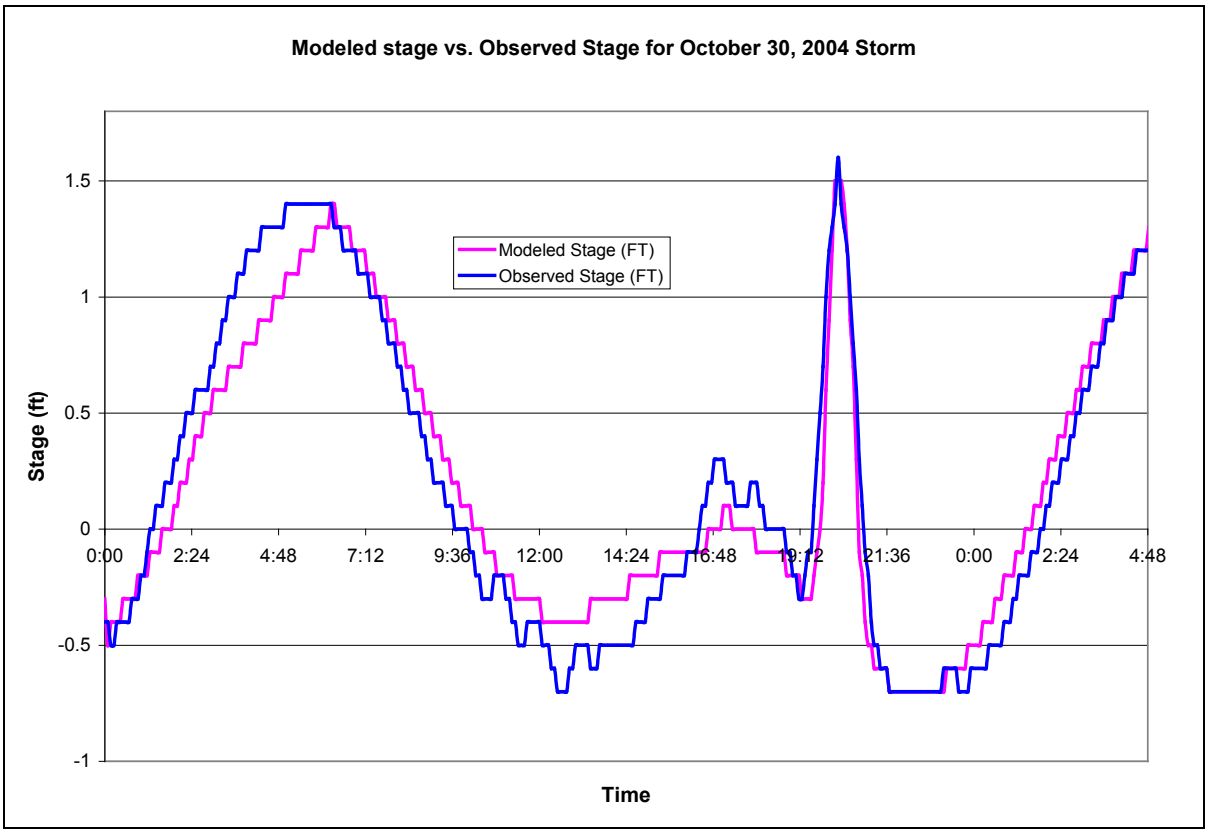

Figure 4-21. Calibrated Water Elevation vs. Observed Stage for Ala Wai Canal on October 30, 2004 Storm

For modeling of the December 17—18, 1967 storm, the calibrated Mānoa-Pālolo model hydrograph at USGS stream gage 16247100 was used to represent the upstream inflow. The finalized Makiki model described in Section 4.5 was used to represent the Makiki sub-watershed. Figure 4-22 shows the HEC-HMS model layout for calibrating this storm. The DLNR post flood report (1968) noted that Ala Wai Canal in Waikiki overflowed at the confluence with Mānoa-Pālolo Drainage Canal. Ala Wai Boulevard and adjacent streets near the confluence were flooded with water up to two feet deep (DLNR, 1968). The modeled peak stage was about 4.4 feet, or about 2.2 feet above Ala Wai Boulevard. Figure 4-23 shows the modeled stage in feet.

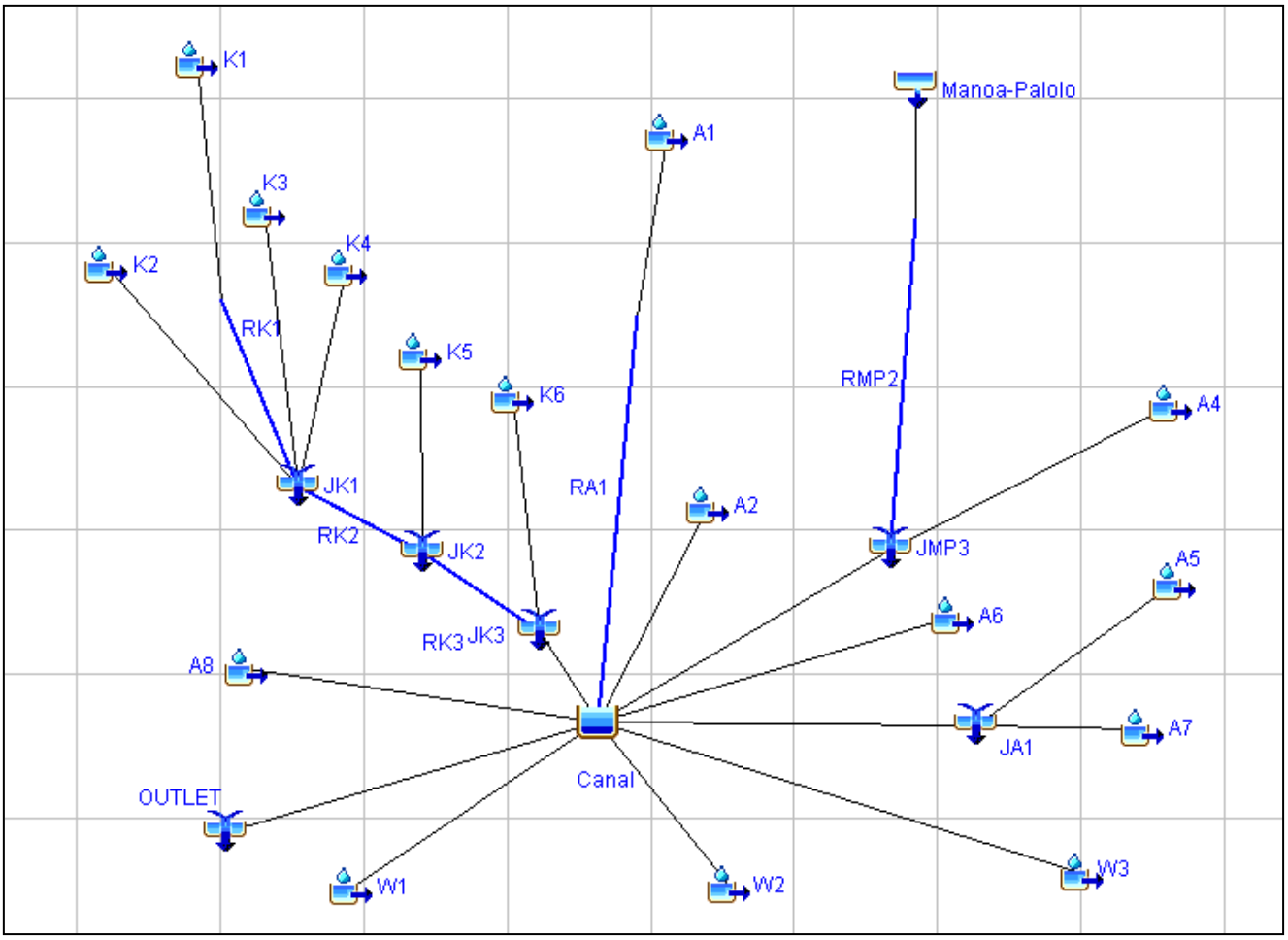

Figure 4-22. Model Layout for 1967

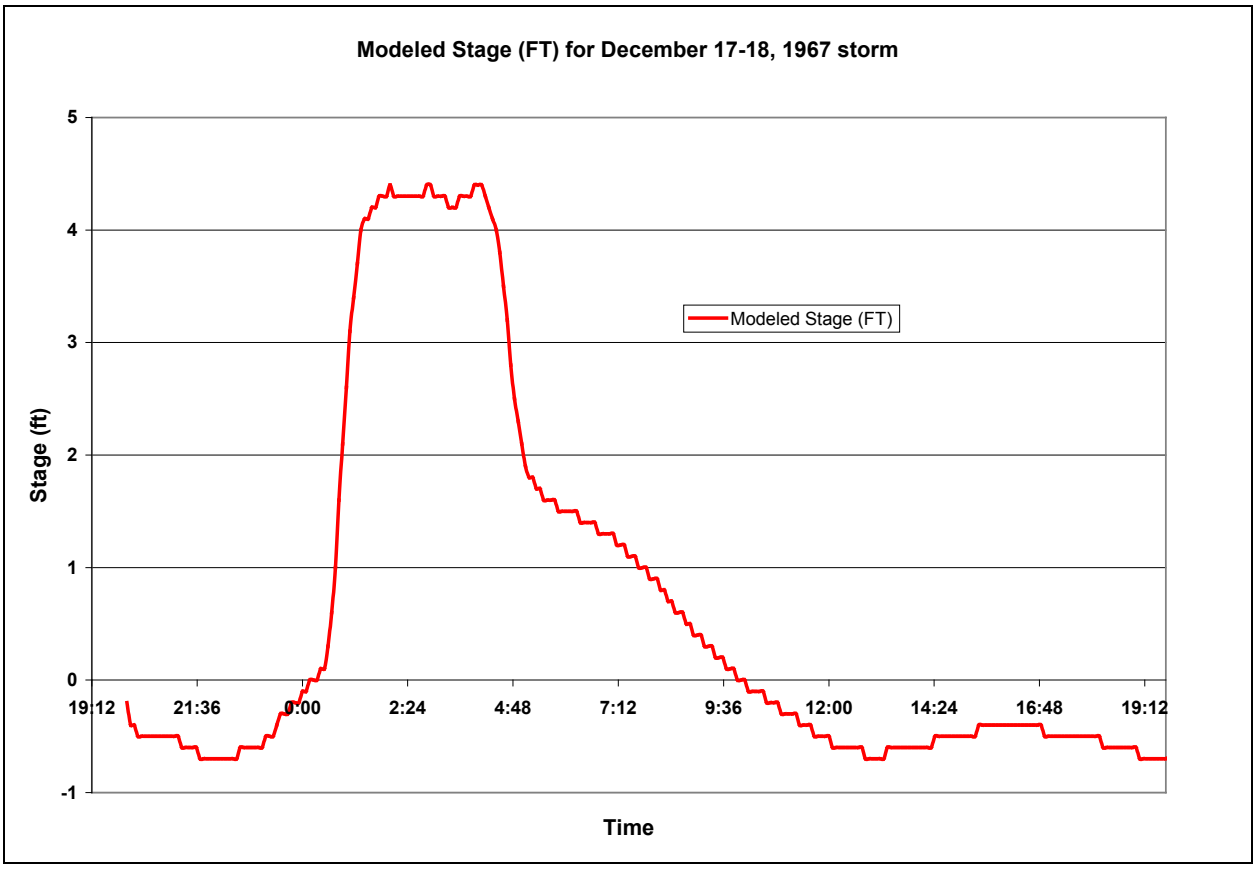

Figure 4-23. Calibrated Water Elevation at Ala Wai Canal for December 17-18, 1967 Storm

4.7.2 Reaches: Muskingum-Cunge and Modified Puls Channel Routing

The Muskingum-Cunge channel routing parameters were used and included the Manning's *n* values, length, slope, and cross-sections. The Manning's *n* values for the stream channel and its banks were determined using Chow's (1959) guidelines and channel conditions. The length of each reach was determined using GIS Arcview 3.3 maps; the slopes were estimated using contours generated from LiDAR data; and the widths were determined from field measurements and the cross-sectional data obtained from GeoRAS. The channel routing parameters are shown in Table 4-19.

Muskingum-Cunge Channel Routing for HEC-HMS Model

Reach	Length (ft)	Slope (ft)	Manning's n	Shape	Width (ft)	Side Slope (xH:V)
RK1	4350	0.0415	0.05	Trapezoid	10	2
RK2	2650	0.0101	0.03	Trapezoid	20	2
RM7	1180	0.008	0.035	Trapezoid	50	2
RMP1	1900	0.0053	0.04	Trapezoid	50	2
RP1	5900	0.056	0.046	Trapezoid	15	2
RP2	3300	0.015	0.04	Trapezoid	15	2
RP3	4350	0.04	0.04	Trapezoid	12	2
RP4	5950	0.0185	0.0162	Rectangle	30	
RP5	4300	0.0186	0.0162	Rectangle	30	

Table 4-19. Muskingum-Cunge Channel Routing for HEC-HMS Model

The Modified Puls Routing Method was used for the Ala Wai Canal modeling to take backwater effects into consideration. The Modified Puls Routing Method is also called storage routing or level pool routing and is most often applied to reservoir routing. Because the Ala Wai Canal was modeled as a reservoir, the stream reaches that discharge into the reservoir were modeled using the Modified Puls Routing Method. The storage-discharge functions for reaches RMP2 (Mānoa-Pālolo Canal) and RK3 (Makiki Stream) were defined based on the elevation-discharge measurements of stream gages 16247100 at the Mānoa-Pālolo Canal and 16238000 at King Street bridge. The storage-discharge function for reach RA1 (Alanaio Stream) was defined by using Manning's equation. Figure 4-24 shows the locations of these three reaches. Figures 4-25, 4-26, and 4-27 Show the storage-discharge curves for these three reaches, respectively.

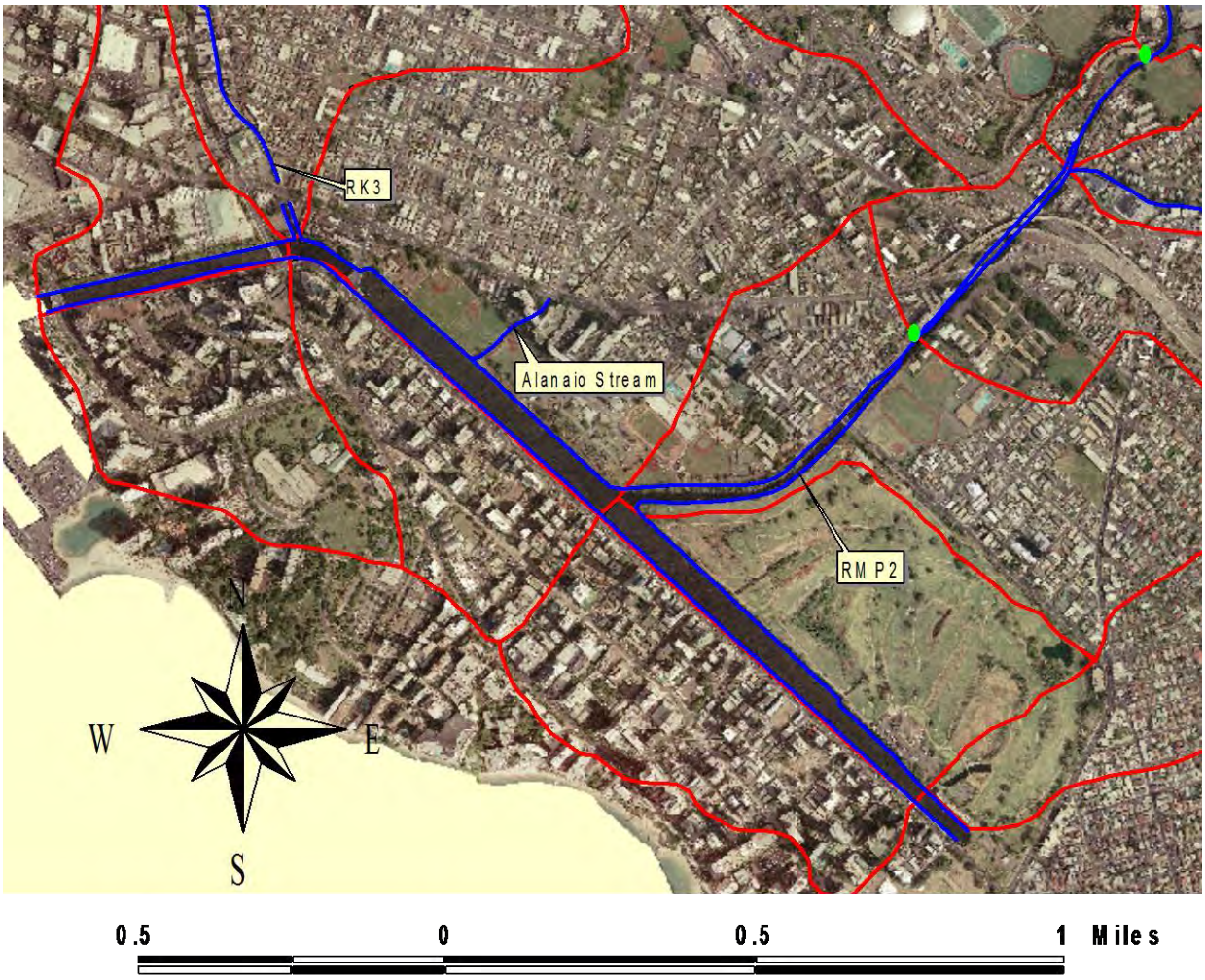

Figure 4-24. Reach locations for Modified Puls Routing Method

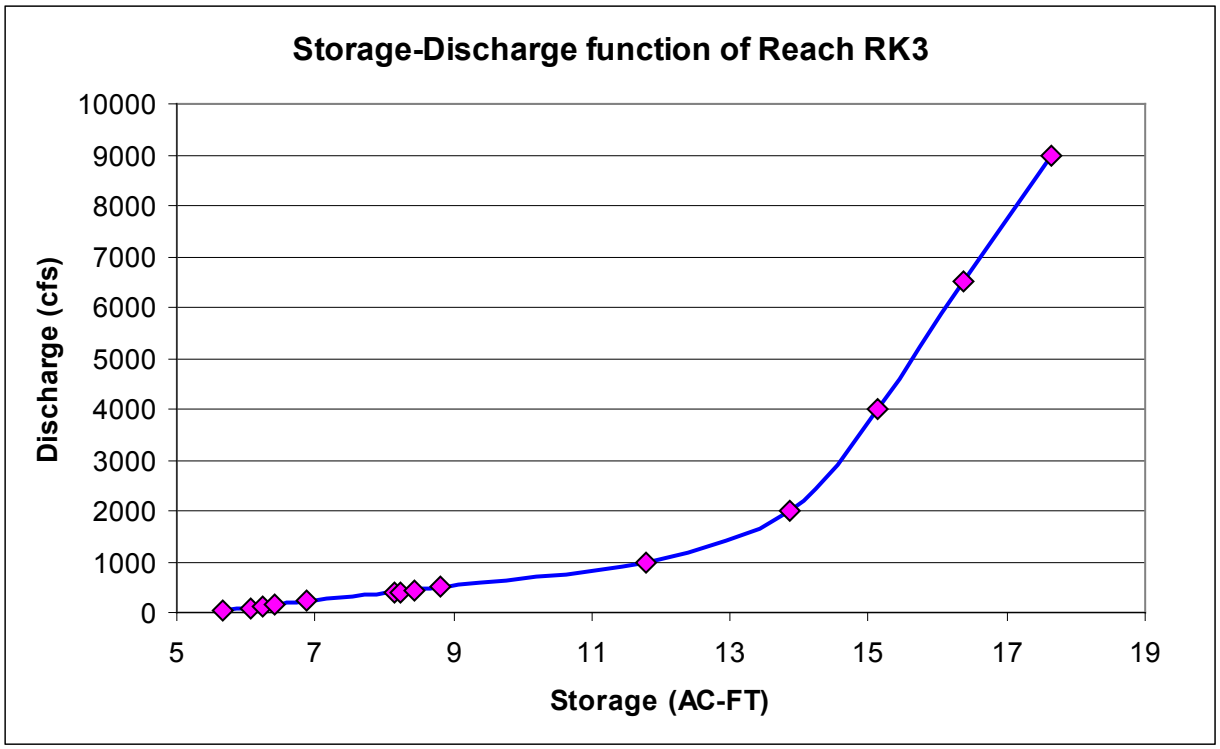

Figure 4-25. Storage-Discharge Curve for Reach RK3

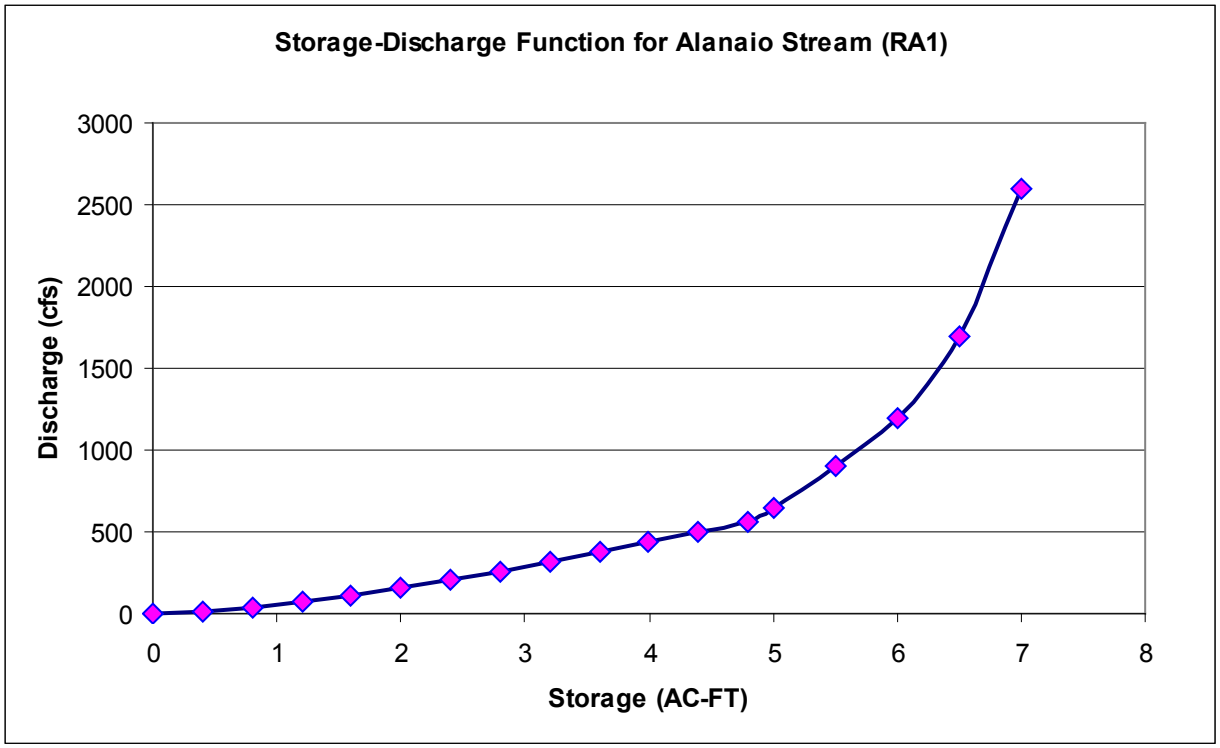

Figure 4-26. Storage-Discharge for Reach RA1

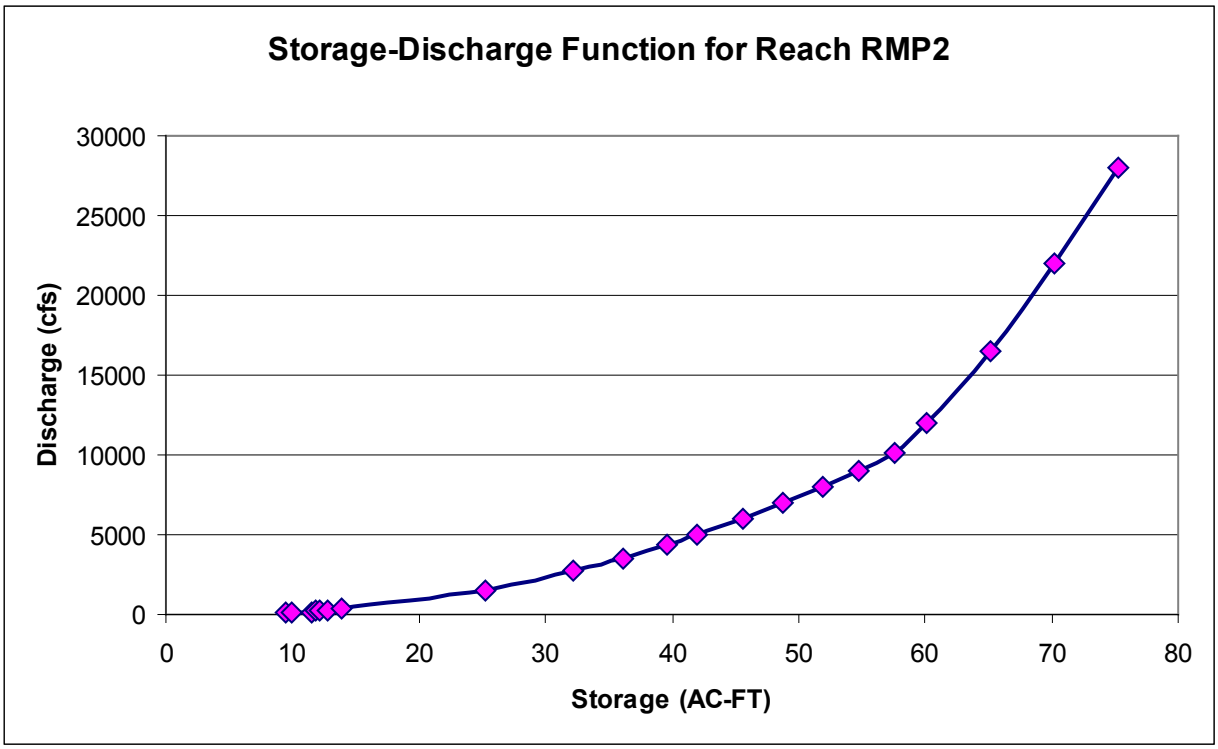

Figure 4-27. Storage-Discharge for Reach RMP2

4.8 Inflow Hydrographs at Kānewai Gage

For consistency with the previous Mānoa Watershed Project hydrologic study, the final results from that study were used to represent the whole Mānoa sub-watershed at the Kānewai Field stream gage. Inflow hydrographs were obtained from the HEC-HMS model of the Mānoa Watershed Project study for the storm chance exceedances of 50 through 0.2 percent. Table 4-20 lists the peak discharges at the Kānewai Field stream gage (USGS 16242500). Figures 4-28 and 4-29 provide the modeled stream flow at Kānewai Field, based on the results from the Mānoa Watershed Project hydrologic study (Oceanit 2008).

Peak Discharges at Kānewai Field Stream Gage from Mānoa Watershed Project								
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceeded	50%	20%	10 %	5%	2%	1%	0.5 %	0.2 %
Peak Discharges (cfs)	2,500	4,300	6,000	7,600	9,500	10,700	12,000	14,000

Table 4-20. Peak discharges at Kānewai Field Stream Gage from Mānoa Watershed Project Hydrologic Study

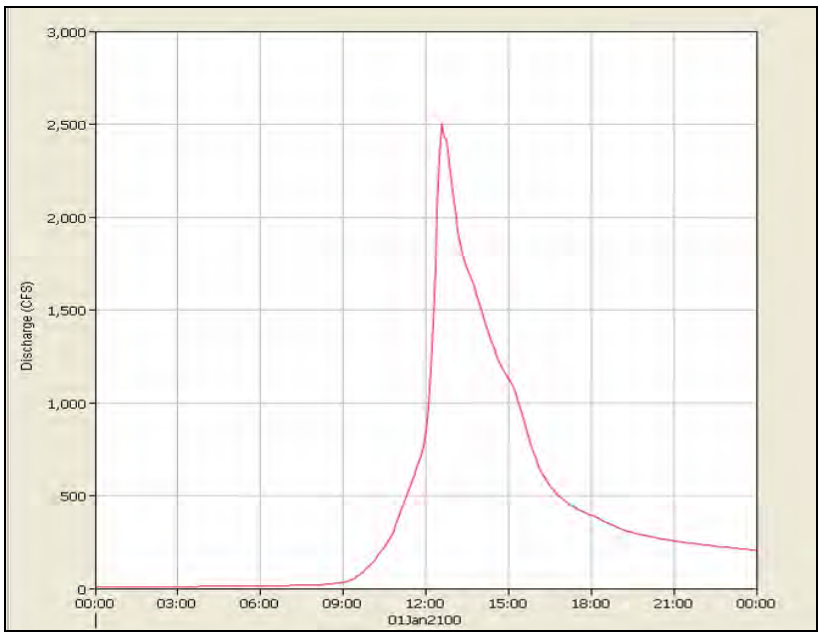

Figure 4-28. Inflow Hydrograph for the 50-percent Chance Flood Used to Represent the Manoa Sub-Watershed in the Ala Wai Watershed HEC-HMS Model (at Kānewai Field)

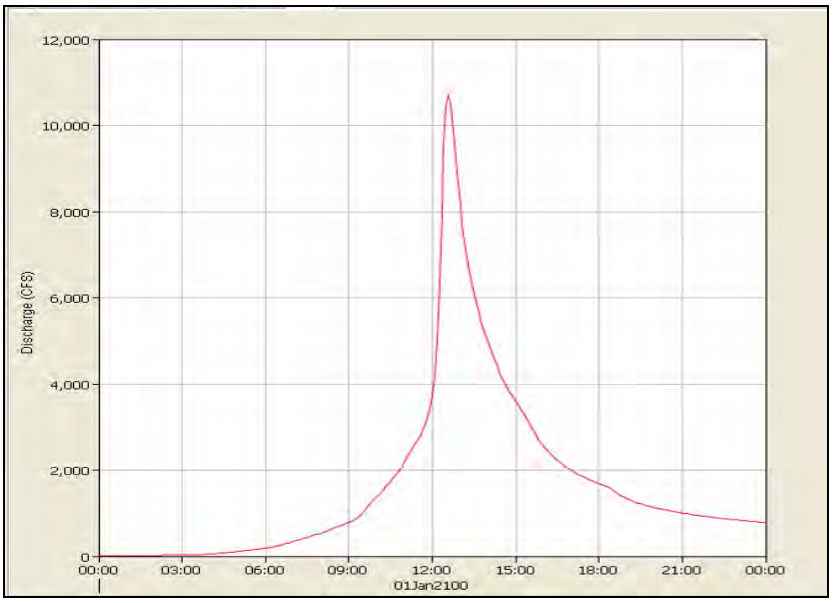

Figure 4-29. Inflow Hydrograph for the 1-percent Chance Flood Used to Represent the Manoa Sub-Watershed in the Ala Wai Watershed HEC-HMS Model (at Kānewai Field)

4.9 Peak Flow Results

For predicting the peak discharges for various return periods, the frequency storm with an intensity position at 50 percent was used in computing the peaks and hydrographs. The HEC-HMS model predicted peak discharges at various junctions in the Ala Wai Watershed are listed in Table 4-21. The final HEC-HMS model layout is shown below in Figure 4-30.

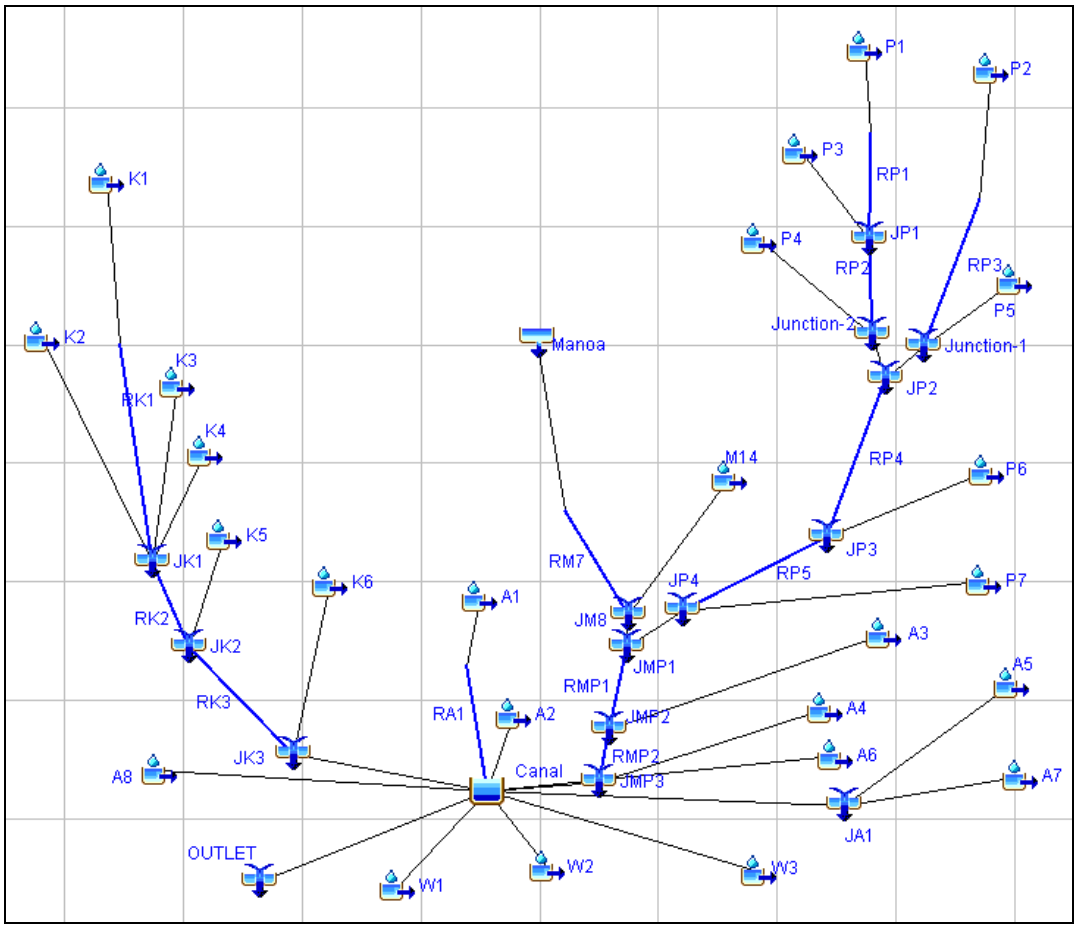

Figure 4-30. Ala Wai Watershed HEC-HMS Model

HEC-HMS Model Results—Peak Flow Discharges at Junctions

Table 4-20 HEC-HMS Model Peak Flow Discharges at Junctions

	Peak flow discharge (cfs)							
Return Period (yr)	2	5	10	20	50	100	200	500
Percent Chance Exceedance	50%	20%	10%	5%	2%	1%	0.5%	0.2%
JK1	570	1,200	1,890	2,400	3,150	3,740	4,380	5,240
JK2	660	1,360	2,110	2,650	3,440	4,060	4,730	5,630
JK3	890	1,770	2,690	3,340	4,280	5,000	5,790	6,850
JM8	2,560	4,450	6,210	7,860	9,810	11,100	12,400	14,500
JP1	320	730	1,150	1,460	1,900	2,220	2,590	3,110
JP2	940	2,030	3,190	4,010	5,180	6,040	6,980	8,320
JP3	1,330	2,710	4,170	5,180	6,620	7,670	8,850	10,500
JP4	1,550	3,120	4,720	5,810	7,400	8,550	9,860	11,600
JMP1	4,020	7,170	10,300	12,900	16,100	18,500	20,900	24,400
JMP2	4,090	7,340	10,500	13,000	16,300	18,700	21,100	24,700
JMP3	4,220	7,450	10,700	13,300	16,600	18,900	21,400	24,900
Ala Wai Canal	6,000	10,100	13,400	15,200	16,700	17,700	18,700	20,500

Table 4-21. HEC-HMS Model Predicted Peak Discharges at Junctions

4.10 USGS Regression Equations and City and County's Plate 6

Regional regression equations developed by the USGS (Wong, 1994) for estimating peak discharges for the 50-, 20- 10-, 4-, 2-, and 1-percent chance exceedance probabilities at gaged and ungaged sites were used to calculate peak flows in the sub-watersheds. The equations for Leeward O'ahu were used for the sub-watersheds in this study. The drainage area (DA) and median annual rainfall (P) in these equations are independent parameters. These regression equations are valid for ungaged sites when (1) the drainage areas are between 0.03 and 45.7 square miles; (2) where less than 36 percent of the area is urbanized; and (3) the median rainfall is between 29 and 239 inches. The median annual rainfall for each sub-watershed was determined from DLNR (1982). The median annual rainfall amounts for the junctions were calculated by the weighting mean method with respect to the sub-watershed areas. The equations used bias-correction factors along with the accuracy of the estimates in equivalent years of record (Wong, 1994). The peak discharges calculated using these regression equations and Plate 6 of the City's drainage standards (2000) for each junction are presented in Table 4-22. The accuracy of these results is 16 years for the 1 percent chance exceedance event and 15 years for the other storm events.

The City storm drainage standards (2000) specify the use of the rational method for drainage areas of 100 acres or less and Plate 6 for drainage areas greater than 100 acres, and this method was used for some of the sub-basins in the Ala Wai Watershed study area. Plate 6 is an envelope curve developed from maximum known peaks and regression analysis of 100-year peak flows. This curve is assumed to represent a 100-year peak flow but actually has a slightly higher return period (Wong 1994). The accuracy of this curve is based not on the average years of recorded data but by the

standard error of regression. The accuracy of data used for peak determination of the 100-year envelope is unknown. In the absence of accurate data, an equivalent years of record of 10 years is assigned (Interagency Advisory Committee on Water Data 1982).

Plate 6 was applied to calculate the 100-year peak discharges in all sub-basins because the corresponding drainage areas exceed 100 acres. Plate 6 provides three curves relating to the peak discharge of the 100-year return period storm (1 percent chance exceedance probability). Curve B from Plate 6 was used for the Mānoa sub-watershed.

USGS Regression Equations and Plate 6 Calculation in cfs

RP	Equation with BFC	JK1	JK2	JM8	JP1	JP2	JP3	JP4	JMP1	JMP2	Years of Record
2	Q_2=3.635 $(DA)^{0.634}$ $P^{1.08}$	660	670	1660	650	1040	1040	1040	2120	2110	**4.2**
5	Q_5=27.58 $(DA)^{0.642}$ $P^{0.773}$	1340	1370	3100	1160	1930	2020	2060	4060	4080	**5.8**
10	Q_{10}=77.32 $(DA)^{0.646}$ $P^{0.621}$	1960	2000	4330	1580	2700	2870	2970	5760	5800	**8.2**
25	Q_{25}=225.7 $(DA)^{0.646}$ $P^{0.464}$	2900	2980	6120	2200	3830	4150	4330	8240	8320	**11.4**
50	Q_{50}=440.7 $(DA)^{0.645}$ $P^{0.368}$	3840	3960	7870	2810	4940	5410	5690	10680	10810	**13.7**
100	Q_{100}=788.3 $(DA)^{0.643}$ $P^{0.286}$	4680	4840	9330	3320	5880	6500	6860	12740	12910	**15.8**
	Plate 6 (100-yr)	5300	5600	11000	3200	6500	7700	8100	15500	16000	**10**

Table 4-22. USGS Regression Equations and Plate 6 Calculation

4.11 FEMA Flood Insurance Study

The hydrologic and hydraulic analysis for the original Flood Insurance Study (FIS) for the City and County of Honolulu was performed by R.M. Towill Corporation in 1976. FEMA revised the previous FIS for the City and published the most updated FIS in 1979.

For Makiki Stream, USGS regression equations were used to obtain peak flow discharges for the 10-, 50-, and 100-year flooding events (FEMA, 2004). The 500-year flood was determined by a regression equation utilizing the same basic data and regression techniques as applied by USGS. These regression equations applied the ratio of the drainage area covered by forests and vegetation to total drainage area in percent instead of the median rainfall that current USGS regression equations applied to determine the peaks. Figure 18 in FIS (FEMA, 2004) was the results that only applied to one place with the drainage area as about 2.49 square miles. This drainage area is equal to the drainage area of junction JK2; in other words, only junction JK2 is available to have FEMA flood insurance analysis peak flow discharges.

For Palolo Stream, peak discharges were based on a statistical analysis results by using the 25-year recording annual peaks at USGS Gaging Station 16247000. The analysis followed the standard log-Pearson type III method procedures as outlined by the Water Resources Council. So the FEMA FIS analysis for Palolo Stream is only applied to junction JP3 that USGS gage 16247000 located.

For Manoa-Palolo and Ala Wai Canals, the peak discharges were determined by using SCS hydrograph method. Probably because of the higher proportion of urbanized areas, the SCS method resulted in slightly higher peak discharges.

For JM8, which is part of Manoa sub-watershed, same analysis was used as previous Manoa watershed study conducted by Oceanit (2008).

Table 4-23 shows the FEMA flood insurance study analysis for Makiki, Palolo, Manoa-Palolo Canal and Ala Wai Canal.

Peak Flow Discharges in cfs Calculated by FEMA				
Return Period (yr)	10	50	100	500
Percent Chance Exceedance	10%	2%	1%	0.2%
JK2	1,850	3,250	3,950	5,950
JM8	7,600	11,500	13,600	17,000
JP3	2,790	4,510	5,340	7,530
JMP2	12,000	19,200	23,000	28,500
Ala Wai Canal	13,700	23,000	28,200	36,200

Table 4-23. Peak Flow Discharges Calculated by FEMA

4.12 Flow Frequency Analysis

HEC-SSP version 1.0 Beta was used to perform the flow frequency analysis. This software is limited to performing flood flow frequency analysis based on Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" (Interagency Advisory Committee on Water Data 1982). Three USGS stream gages that have sufficient data to perform the flow frequency analysis are within the study area. The USGS stream gage 16247100 at the Mānoa-Pālolo Canal (Junction JMP2), adjacent to the Kaimukī High School, has a drainage area of 10.34 square miles. Thirty-eight effective annual peaks were used in the HEC-SSP model to predict the peaks for the various return periods at this junction. The USGS Pālolo Stream gage 16247000 (Junction JP3) has a drainage area of 3.62 square miles. Thirty-two effective annual peaks were used at this junction. The USGS Pūkele Stream (tributary of Pālolo Stream) gage 16244000 (Junction JP1) has a drainage area of 1.15 square miles. Fifty-nine effective annual peaks were used at this junction. The following figures and tables show the flow frequency results from HEC-SSP model (Figures 4-31-33 and Tables 4-24 through 4-26).

At USGS Gaging Station 16247000, there are 32 effective annual peaks available to perform the statistical frequency analysis. The continuous recorded annual peaks are from 1953 to 1979 and from 2003 to 2007, but no data is available between 1980 and 2002. The recorded annual peaks from 2003 to 2007 seem incorrect for the following two reasons.

(1) On October 30, 2004, the recorded peak at this gage was 776 cfs. The tributary stream gage upstream (Pukele) recorded a 753 cfs peak, and another tributary (Waiomao Stream) received the same rain as Pukele Stream received. At USGS gage 16247100 downstream, the recorded peak was 9380 cfs and the Manoa Stream at Kanewai gage recorded a peak at 5860 cfs. Thus, the peak flow at the Palolo gage should be in a range of 1500 to 3000 cfs rather than the 776 recorded because it received similar rainfall as Manoa.

(2) The peak for March 31, 2006 storm at Palolo Stream Gage was 1390 cfs, at downstream gage USGS 16247100, the recorded peak was 9320 cfs, the rainfall was uniformly distributed into the study area, the Palolo valley should have generated a range 2000 to 3000 cfs peak flow. Since there was possible channel conditions changed during the last 50 years, the data in this gage may be lower than actual stream flows, as a result, the HEC-SSP and FEMA analysis (used 25-year annual peaks) got lower peak discharges.

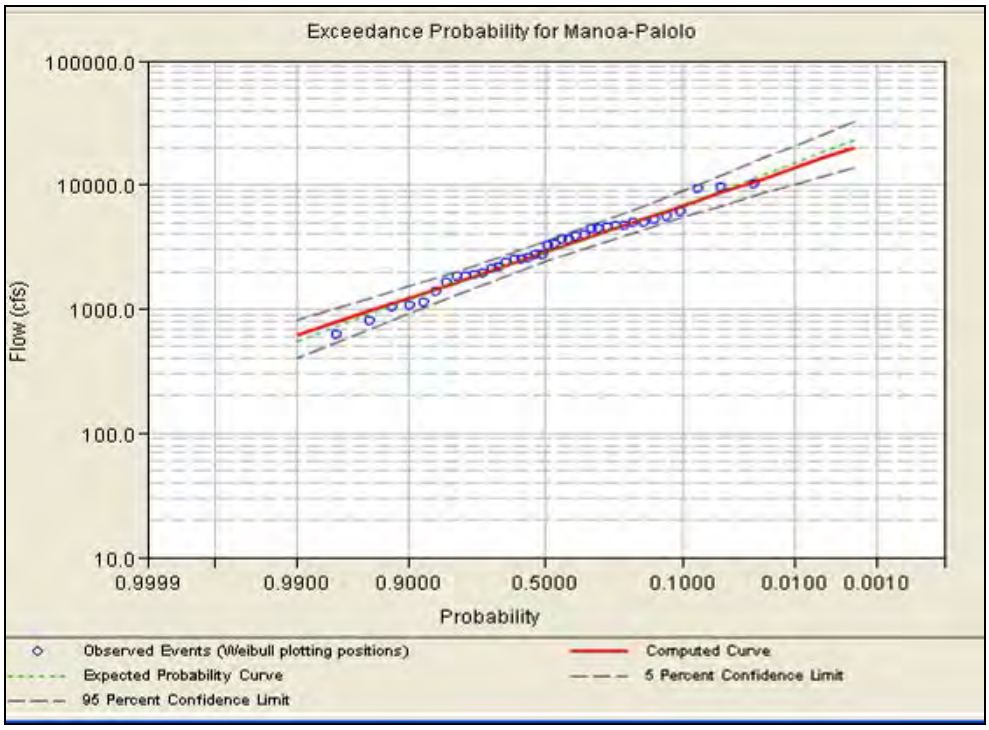

Figure 4-31. Exceedance Probability for Mānoa-Pālolo Canal Stream Gage JMP2 (USGS Stream Gage[16247100])

Percent Chance Exceedance	Return Period (year)	Computed Flow (cfs)	Confidence Limits Flow (cfs)	
			0.05	0.95
0.2	500	19,800	32,538	13,949
0.5	200	16,200	25,443	11,719
1	100	13,700	20,783	10,143
2	50	11,400	16,677	8,654
5	20	8,670	12,017	6,804
10	10	6,800	9,013	5,475
20	5	5,070	6,407	4,179
50	2	2,880	3,459	2,404

Table 4-24. Flood Flow Frequency Results for Mānoa-Pālolo Canal Stream Gage JMP2 (USGS Stream Gage [16247100])

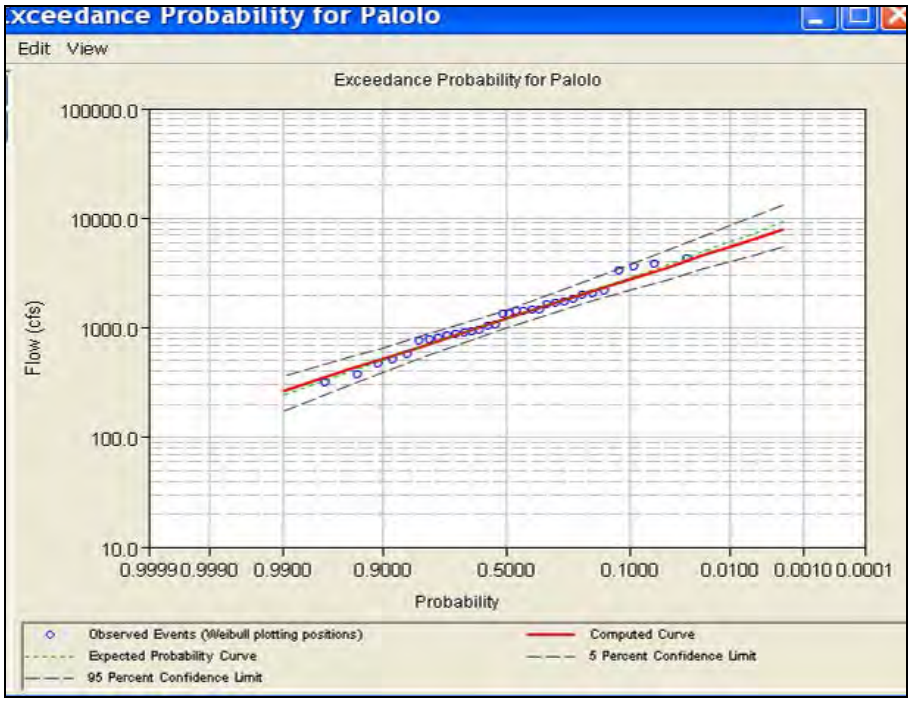

Figure 4-32. Exceedance Probability for Pālolo Stream Gage JP3 (USGS Pālolo Gage [16247000])

Percent Chance Exceedance	Return Period (year)	Computed Flow (cfs)	Confidence Limits Flow (cfs)	
			0.05	0.95
0.2	500	7,820	13,366	5,422
0.5	200	6,430	10,478	4,589
1	100	5,470	8,578	3,996
2	50	4,580	6,900	3,433
5	20	3,510	4,991	2,725
10	10	2,780	3,757	2,212
20	5	2,090	2,683	1,705
50	2	1,210	1,466	997

Table 4-25. Flood Flow Frequency Results for Pālolo Stream Gage JP3 (USGS Pālolo Gage [16247000])

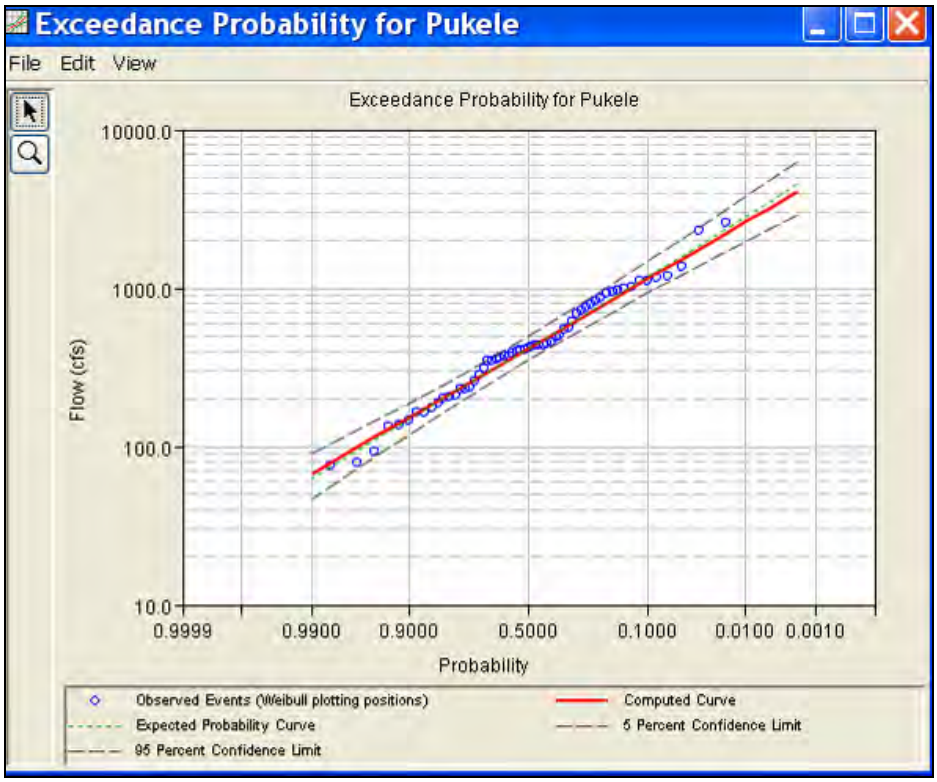

Figure 4-33. Exceedance Probability for Pūkele Stream Gage JP1 (USGS Pūkele Gage [16244000])

Percent Chance Exceedance	Return Period (year)	Computed Flow (cfs)	Confidence Limits Flow (cfs)	
			0.05	0.95
0.2	500	4,050	6,330	2,880
0.5	200	3,190	4,800	2,330
1	100	2,620	3,820	1,960
2	50	2,110	2,980	1,620
5	20	1,530	2,060	1,210
10	10	1,150	1,490	930
20	5	810	1,010	680
50	2	420	500	350

Table 4-26. Flood Flow Frequency Results for Pūkele Stream JP1 (USGS Pūkele Gage [16244000])

5 Results of Hydrologic Model

All of the hydrologic analysis methodologies estimate peak flow discharges (cfs) for return periods (percent chance exceedance storms) by junction; the methodologies include the HEC-HMS modeling, the USGS regression method, City Plate 6, FEMA Flood Insurance Study, and the HEC-SSP model. Each of these methodologies provides a predictive measure for peak discharges, and used together they offer a clear and accurate depiction of where peak flows will occur during 50, 20, 10, 5, 2, 1, 0.5, and 0.2 percent chance exceedance storms.

5.1 Determination of Final Peak Flow Discharges

The USACE Engineer Manual (EM) 1110 – 2 -1619 (1996, Table 4-5, page 4-5) provides guidelines to assign accuracies to flood frequency estimates determined by various methods in term of equivalent years of record. It is assumed that the estimates with higher equivalent years of record are more reliable than those with lower equivalent years of record. Based on the guidelines, the HEC-SSP model is the most reliable with equivalent years of record 59, 32, and 38 for junctions JP1, JP3, and JMP2, respectively. The HEC-HMS model was calibrated to three historical storms for Manoa and Palolo sub-watersheds, two historical storms for Ala Wai Canal reservoir model, and one historical storm event for Makiki sub-watershed. Although there was no calibration to the urbanized sub-basins, the parameters physical measurable Kinematic Wave transform method was applied. An equivalent record length of 20 years was assigned to the results generated by HEC-HMS model based on guidelines provided in EM110-2-1619 (USACE, 1996).

FEMA flood insurance study within Ala Wai watershed area applied various methods to determine the peak discharges, based on the analysis done with equivalent record lengths of 15 years and were assigned to FEMA results in junctions JK2, JM8, JMP2, and Ala Wai Canal. An equivalent record length of 25 years was assigned to FEMA results in junction JP3 in response to its statistic analysis using 25-year recorded annual peaks. The weighting factors for the HEC-HMS modeling, the USGS regression, City Plate 6, FEMA Flood Insurance Study, and the HEC-SSP methodologies are shown in Table 5-1.

Weighting Factors for Peak Discharges Development								
Methodology	Accuracy in Equivalent Years of Record							
Percent Chance Exceedance	50%	20%	10%	5%	2%	1%	0.5%	0.2%
HEC-HMS	20	20	20	20	20	20	20	20
Regression	15	15	15	15	15	16		
Plate 6						10		
FEMA			15 25(JP3)		15 25(JP3)	15 25(JP3)		15 25(JP3)
HEC-SSP	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)	59(JP1) 32 (JP3) 38(JMP2)

Table 5-1. Weighting Factors Used To Develop Final Peak Flow Values

Determination of the final peak flow discharges at junctions of interest for the sub-watersheds studied was conducted in three steps: (1) the peak flow discharge values produced by each method were weighted; (2) all the available peak flow discharge values were plotted on log probabilistic graph paper by percent chance exceedance; and (3) the best fit curve of the peak flow discharges was graphed assuming watershed linearity, that is, that the peak flow discharge-frequency curves should be defined by a single function (illustrated as a smooth curve) for each sub-watershed.

The determination of final peak flow discharges assumes that the sub-watersheds examined in this study exhibit linearity, meaning that a single function may describe the runoff from a sub-watershed. Sub-watershed linearity is based on the concept that peak flow discharge frequency curves serve their descriptive purpose as continuous, smooth curves. Thus, even after peak flow discharges were weighted and plotted on log-probabilistic graph paper, the best curve fit for these discharge values was plotted. The best fit curve was the final step in determining peak flow discharge values at the junctions of interest

5.2 Makiki Peak Flow Discharges

Peak flow discharges at junctions of interest in the Makiki sub-watershed were weighted according to the process detailed in Section 5.1, plotted on log-probabilistic graph paper, and a best fit curve was analyzed. Table 5-2 provides peak flow discharge results for the Makiki sub-watershed at junctions of interest by methodology, the weighted values, and the 'FINAL' best fit values.

Methodology	Peak flow discharge (cfs)							
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
JK1 (Confluence of Makiki and Kanaha Streams, A=2.328 mi^2)								
HEC-HMS	570	1,200	1,890	2,400	3,150	3,740	4,380	5,240
Regression	660	1,350	1,960	2,900	3,840	4,680		
Plate 6						5,300		
Weighted	610	1,260	1,920	2,620	3,450	4,410	4,380	5,240
FINAL	**650**	**1,300**	**1,900**	**2,550**	**3,400**	**4,100**	**4,800**	**5,700**
JK2 (USGS Stream Gage at King St. 16238000, A= 2.49 mi^2)								
HEC-HMS	660	1,360	2,110	2,650	3,440	4,060	4,730	5,630
Regression	670	1,370	2,000	2,980	3,960	4,850		
Plate 6						5,600		
FEMA			1,850		3,250	3,950		5,950
Weighted	660	1,360	2,000	2,790	3,540	4,490	4,730	5,770
FINAL	**660**	**1,330**	**1,960**	**2,580**	**3,500**	**4,250**	**4,950**	**5,900**
JK3 (Confluence of Makiki Stream and Ala Wai Canal, A=2.892 mi^2)								
HEC-HMS	890	1,770	2,690	3,340	4,280	5,000	5,790	6,850
Plate 6						6,100		
Weighted	890	1,770	2,690	3,340	4,280	5,370	5,790	6,850
FINAL	**760**	**1,600**	**2,400**	**3,200**	**4,300**	**5,250**	**6,100**	**7,200**

Table 5-2. Peak Flow Discharges at Makiki Junctions by Methodology

The junction near the confluence of the Makiki Stream and Ala Wai Canal (JK3) received the highest amount of peak flow discharge in the Makiki sub-watershed. This was expected, because JK3 represents the flow exiting the entire Makiki sub-watershed. The peak discharge values attained by the Plate 6 and Regression methods appear higher than the peak discharge values attained through HEC-HMS modeling, as seen in Figures 5-1 through 5-3. As mentioned in Section 5.1, the peak discharge values were not only weighted, but also the final values were determined by the best fit curve shown in Figures 5-1 through 5-3. This best fit curve takes into account all of the methods used. In short, the final best fit curve was used to calculate the final peak discharges. Figures 5-1 through 5-3 graph the peak flow discharge by methodology over the percent chance exceedance for Makiki junctions of interest.

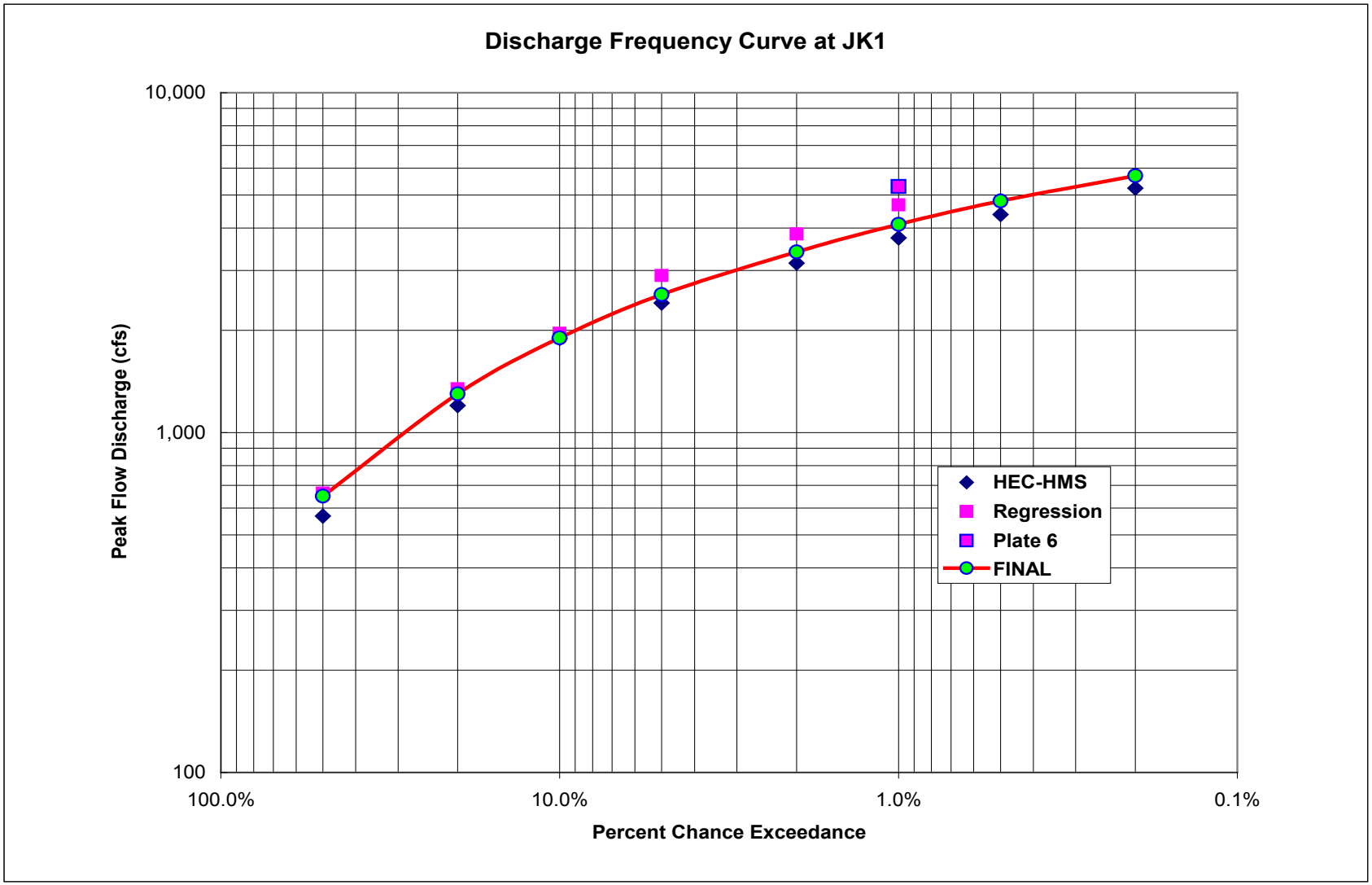

Figure 5-1. Final Discharge Frequency Curve at JK1 (Confluence of Makiki and Kanahā Streams)

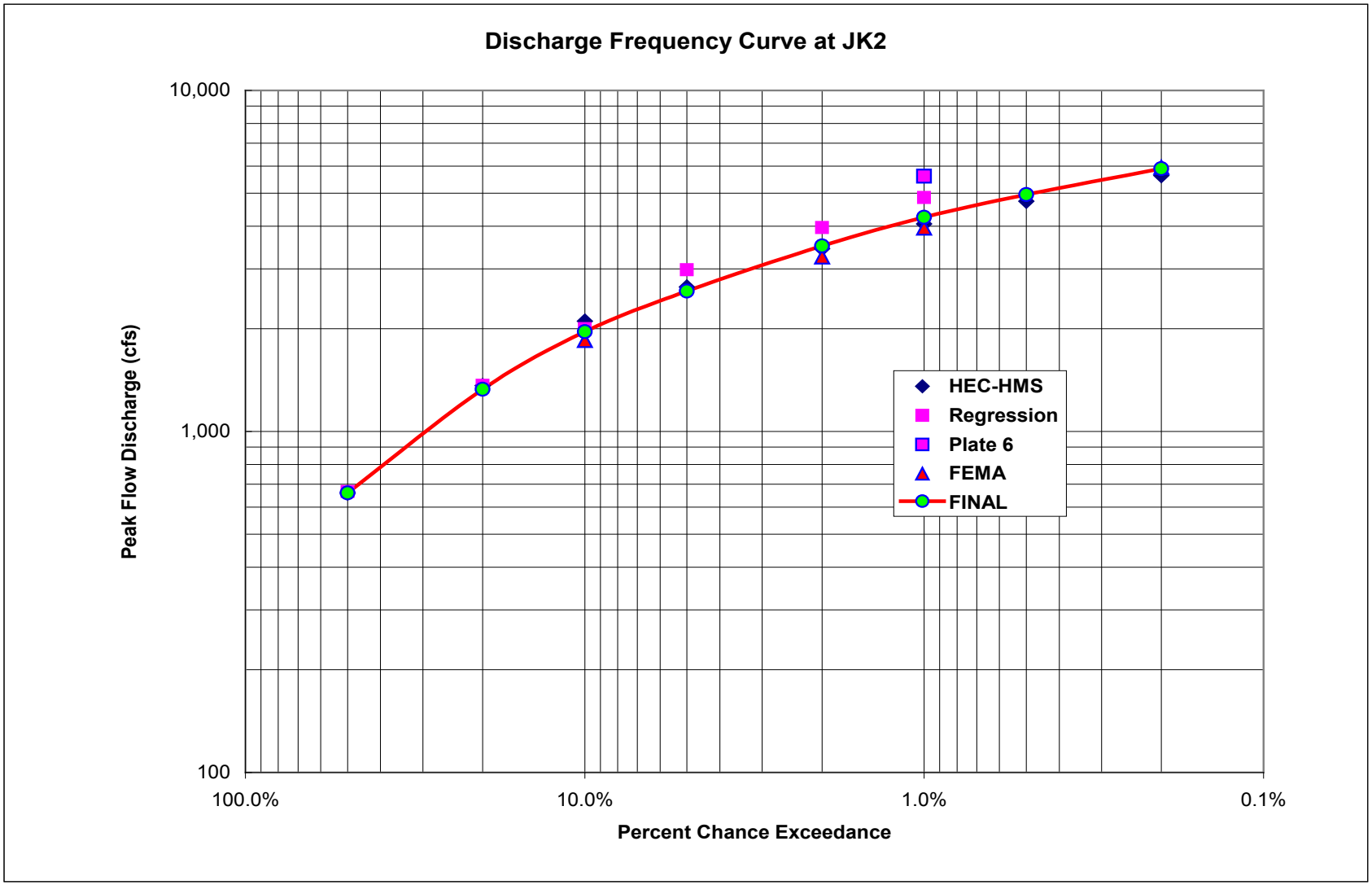

Figure 5-2. Final Discharge Frequency Curve at JK2 (USGS Stream Gage [16238000])

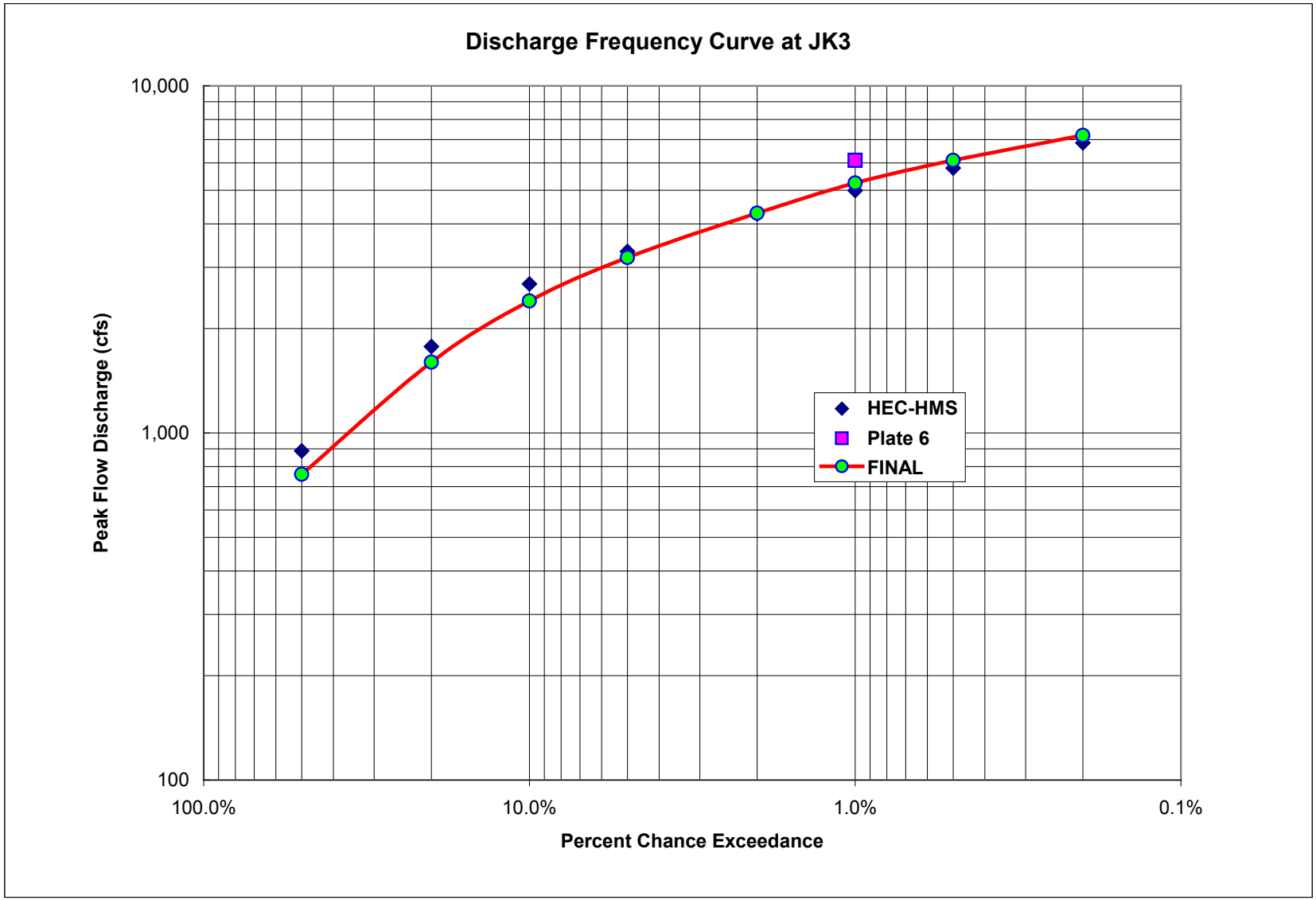

Figure 5-3. Final Discharge Frequency Curve at JK3 (Confluence of Makiki Stream and Ala Wai Canal)

5.3 Mānoa Peak Flow Discharges

Peak flow discharges for the Mānoa sub-watershed were determined in a previous study, and these values were used for the current study. The HEC-HMS peak flow discharges calculated in the Mānoa Watershed Project hydrology report (Oceanit 2008) at the junction just upstream of the confluence of the Mānoa and Pālolo Streams (JM8) were used. This junction, JM8, is where flow exits the Mānoa sub-watershed, and thus this peak discharge value accounts for all the runoff exiting the Mānoa sub-watershed. Table 5-3 provides the peak flow discharge results by methodology and the 'FINAL' values,. The final peak flow discharges from this study are plotted in Figure 5-4.

Methodology	Peak flow discharge (cfs)							
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
JM8 (Right above Confluence of Manoa and Palolo Streams, A=5.972 mi^2)								
HEC-HMS	2,560	4,450	6,210	7,860	9,810	11,100	12,400	14,500
Regression	1,660	3,100	4,330	6,120	7,870	9,330		
Plate 6						11,000		
FEMA			7,600		11,500	13,600		17,000
Weighted	2,180	3,870	6,060	7,110	9,730	11,200	12,400	15,600
FINAL	**2,600**	**4,450**	**6,150**	**7,800**	**9,700**	**11,000**	**12,400**	**14,400**

Table 5-3. Peak Flow Discharges at Mānoa Junctions by Methodology

The junction that is just upstream of the confluence of the Mānoa and Pālolo streams (JM8) receives the highest amount of peak flow discharge in the Mānoa sub-watershed. Figure 5-4 illustrates the peak flow discharge results at the Mānoa junctions of interest.

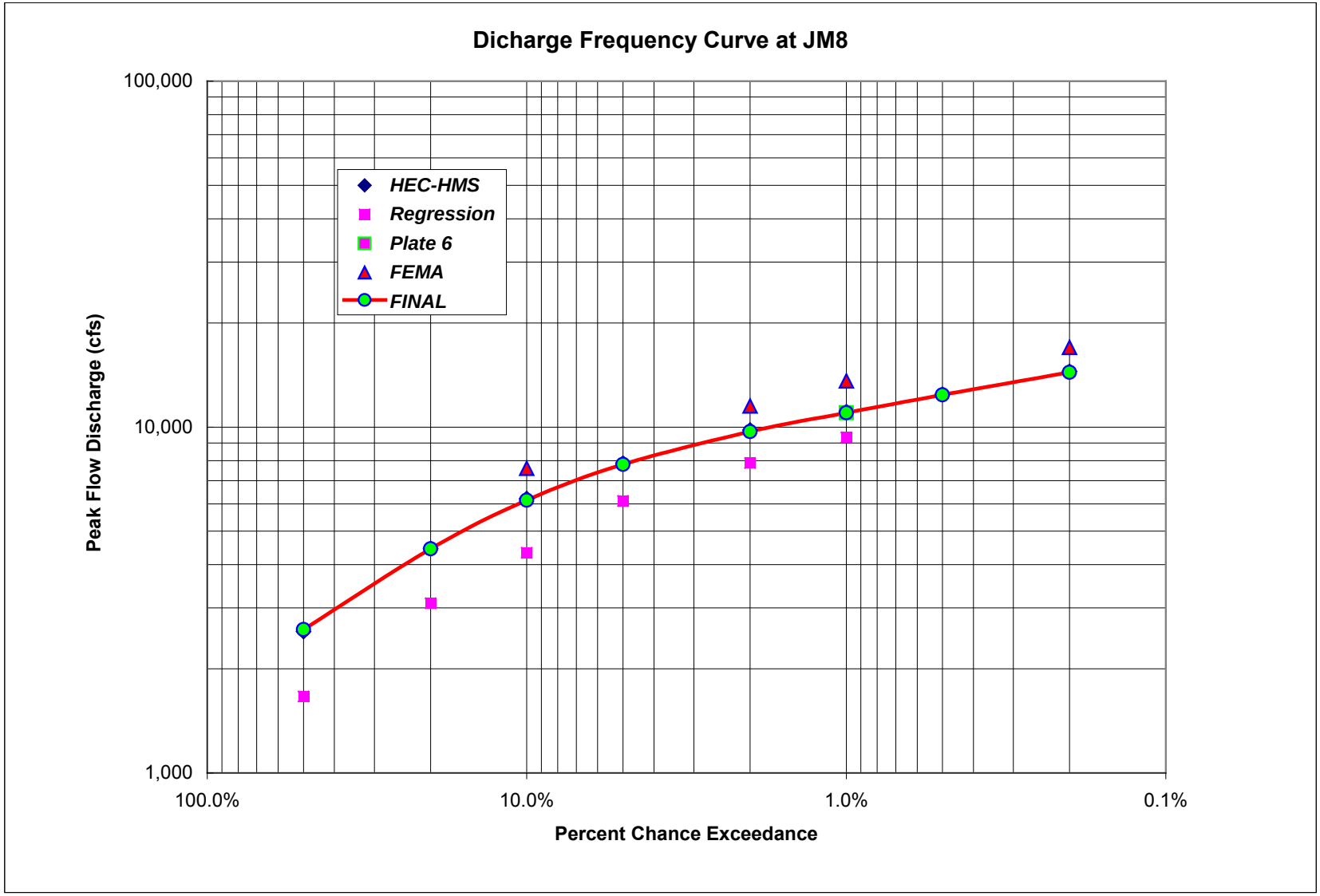

Figure 5-4. Final Discharge Frequency Curve at Junction JM8 (Upstream of the Confluence of Mānoa & Pālolo Streams)

5.4 Pālolo Peak Flow Discharges

Pālolo peak flow discharges at junctions of interest were determined through the process described in Section 5.1. Table 5-4 provides peak flow discharge results for the sub-watershed by methodology and weighted followed by 'FINAL' values.

Methodology	Peak flow discharge (cfs)							
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
JP1 (Pukele Stream Gage 16244000, A= 1.146 mi^2)								
HEC-HMS	320	730	1,150	1,460	1,900	2,220	2,590	3,110
Regression	650	1,160	1,580	2,200	2,810	3,320		
Plate 6						3,400		
HEC-SSP	420	810	1,150	1,530	2,110	2,620	3,190	4,050
Weighted	440	850	1,220	1,620	2,180	2,720	3,040	3,810
FINAL	**400**	**800**	**1,150**	**1,550**	**2,100**	**2,500**	**2,900**	**3,400**
JP2 (Confluence of Pukele and Waiomao Streams, A=2.938 mi^2)								
HEC-HMS	940	2,030	3,190	4,010	5,180	6,040	6,980	8,320
Regression	1,035	1,930	2,700	3,828	4,940	5,880		
Plate 6						6,200		
Weighted	980	1,990	2,980	3,930	5,080	6,020	6,980	8,320
FINAL	**950**	**1,850**	**2,700**	**3,650**	**4,900**	**5,900**	**6,900**	**8,000**
JP3 (Palolo Stream Gage 16247000, A=3.62 mi^2)								
HEC-HMS	1,330	2,710	4,170	5,180	6,620	7,670	8,850	10,500
Regression	1,040	2,020	2,870	4,150	5,410	6,500		
Plate 6						7,700		
FEMA			2,790		4,510	5,340		7,530
HEC-SSP	1,210	2,090	2,780	3,510	4,580	5,470	6,430	7,820
Weighted	1,210	2,260	3,100	4,150	5,140	6,240	7,360	8,410
FINAL	**1,200**	**2,100**	**3,000**	**4,000**	**5,500**	**6,500**	**7,500**	**8,600**
JP4 (Right above the confluence of Manoa and Palolo Streams, A= 4.065 mi^2)								
HEC-HMS	1,550	3,120	4,720	5,810	7,400	8,550	9,860	11,600
Regression	1,040	2,060	2,970	4,330	5,690	6,860		
Plate 6						8,100		
Weighted	1,330	2,660	3,970	5,180	6,660	7,870	9,860	11,600
FINAL	**1,250**	**2,200**	**3,100**	**4,200**	**5,700**	**6,900**	**7,900**	**9,100**

Table 5-4. Peak Flow Discharges at Pālolo Junctions by Methodology

The junction that is just upstream the confluence of the Mānoa and Pālolo streams (JP4) receives the highest amount of peak flow discharge in the Pālolo sub-watershed, as it is situated at the downstream (*makai*) end of the watershed and drainage system. In the Pālolo sub-watershed, at the Pūkele Stream gage junction (JP1), the regression method calculates higher flow discharge values than other methods, and the HEC-HMS model seems to underestimate the peak flow discharges for many of the storms under study; the discharge frequency curve fit closely mirrors the findings of the

HEC-SSP analysis which applied 59 historical annual peaks. However, at the next junction downstream, the confluence of the Pūkele and Waiʻōmaʻo Streams (JP2), all the methodologies used provide similar peak flow discharge values. The HEC-SSP analysis was not used for this junction. The discharge frequency curve for the junction at the Pālolo Stream gage (JP3) seems to be higher than HEC-SSP findings at lower exceedance probabilities, this is probably due to the shorter historical annual peak records and the incontinuous and incorrect records. Downstream at the junction just upstream of the confluence of the Mānoa and Pālolo Stream (JP4), the frequency curve fit is close to the low regression equation values. All of these results are illustrated by junction for the Pālolo sub-watershed in Figures 5-5 through 5-8. These figures graph the peak flow discharge by method over the percent chance exceedance storm.

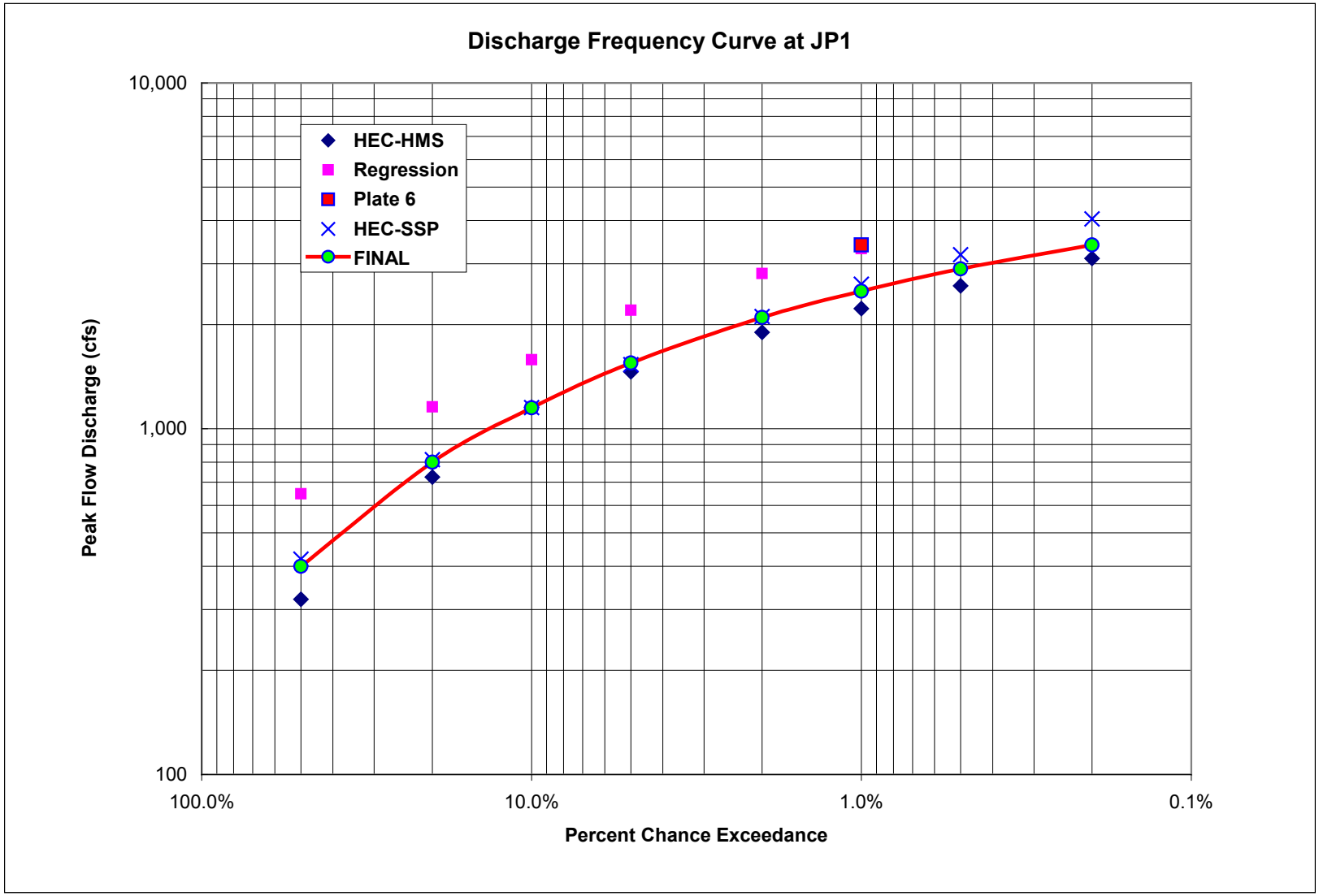

Figure 5-5. Final Discharge Frequency Curve at JP1 (USGS Pūkele Gage [16244000])

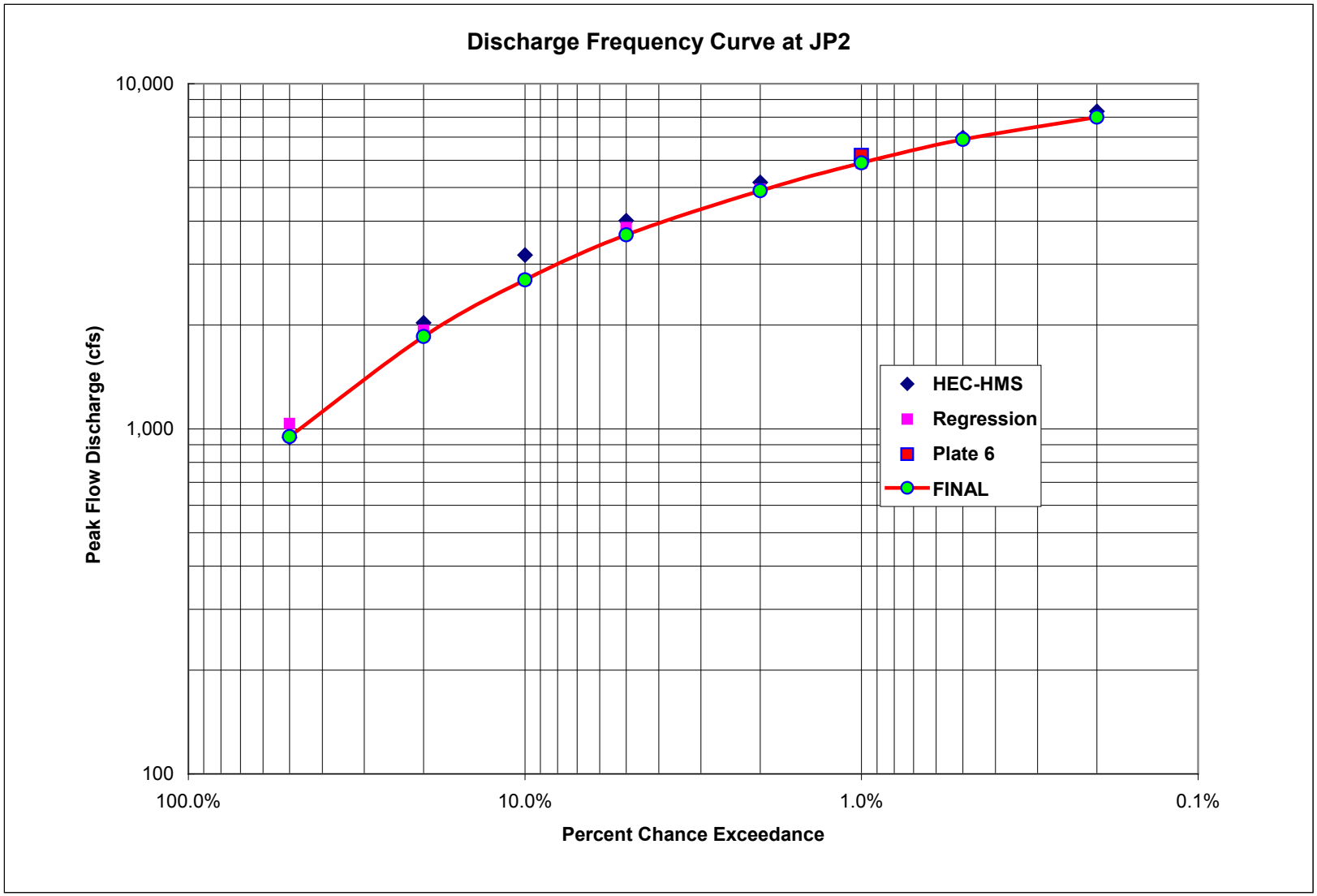

Figure 5-6. Final Discharge Frequency Curve at JP2 (Confluence of Pūkele and Waiʻōmaʻo Streams)

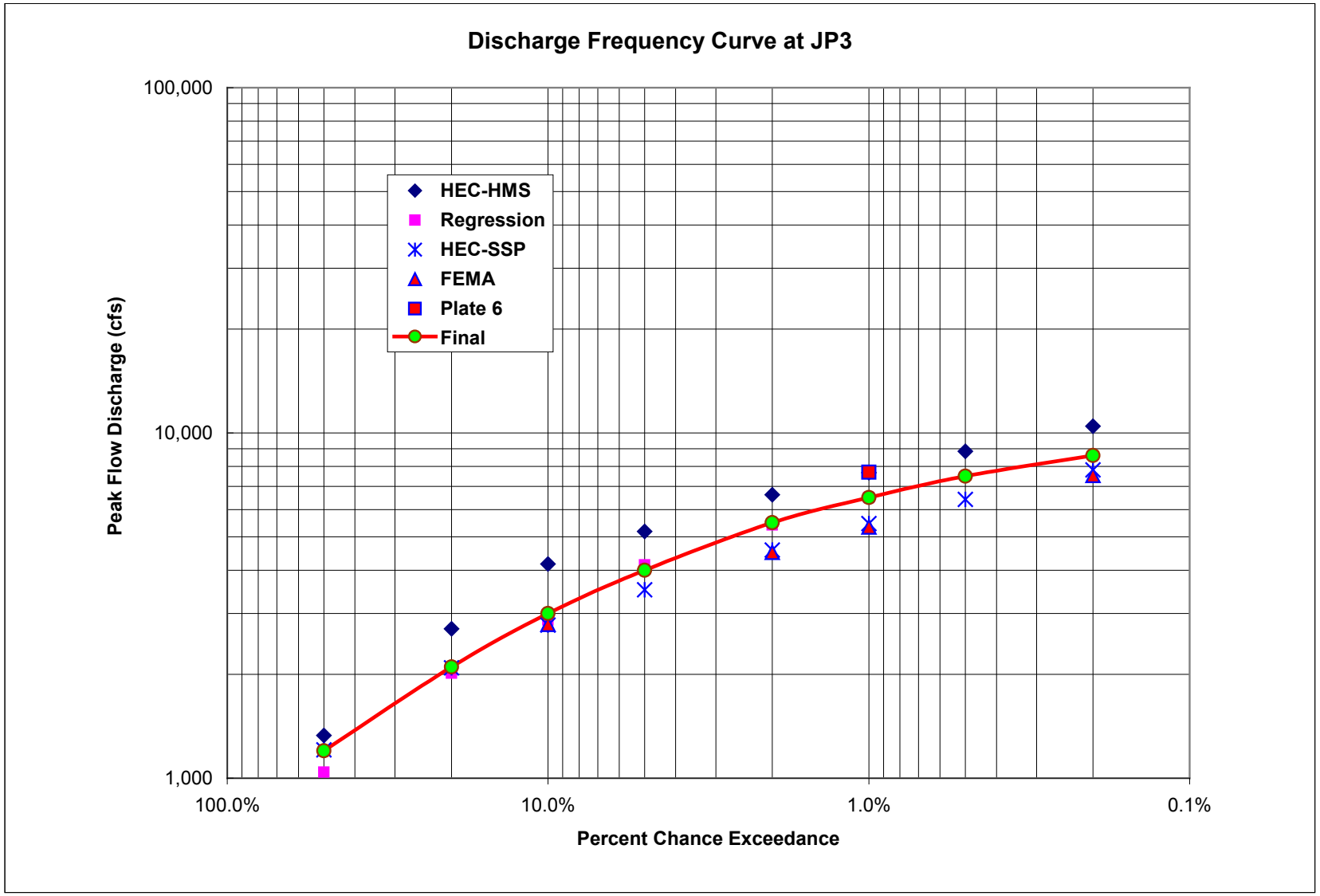

Figure 5-7. Final Discharge Frequency Curve at JP3 (USGS Pālolo Gage [16247000])

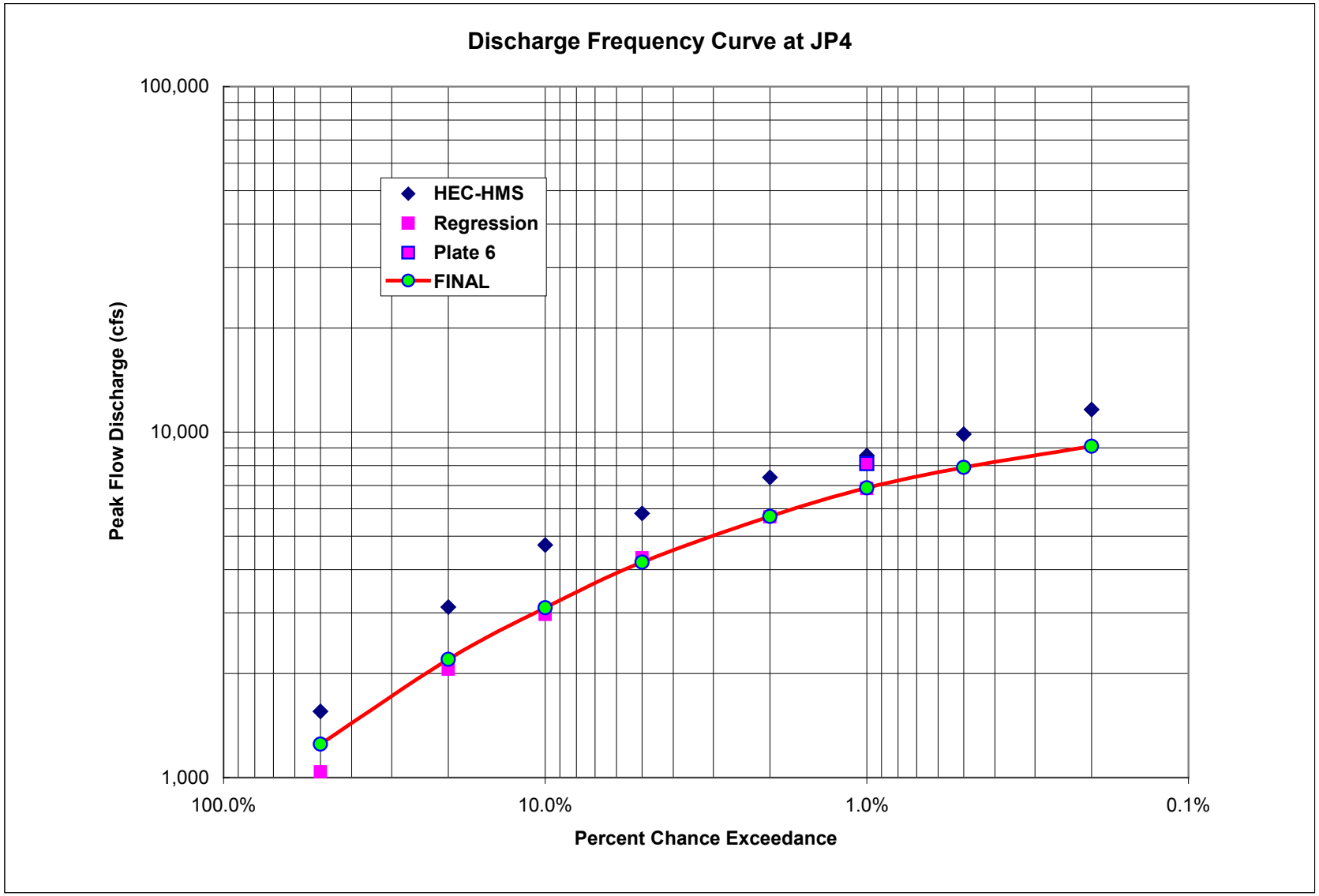

Figure 5-8. Final Discharge Frequency Curve at JP4 (Upstream of the Confluence of Mānoa & Pālolo Streams)

5.5 Mānoa-Pālolo Peak Flow Discharges

Weighting of methodologies were used where peak flow discharges for multiple methodologies were available. Table 5-5 provides peak flow discharge results for the Mānoa-Pālolo Canal by methodology and then as 'FINAL' values through the weighting process described.

Methodology	Peak flow discharge (cfs)							
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
JMP1 (Confluence of Manoa and Palolo Streams, A= 10.037 mi^2)								
HEC-HMS	4,020	7,170	10,300	12,900	16,100	18,500	20,900	24,400
Regression	2,120	4,060	5,760	8,240	10,700	12,700		
Plate 6						15,500		
Weighted	3,210	5,840	8,360	10,900	13,800	15,800	20,9000	24,400
FINAL	**3,350**	**6,000**	**8,400**	**10,900**	**14,100**	**16,500**	**18,700**	**21,800**
JMP2 (Manoa-Palolo Stream Gage 16247100, A= 10.34 mi^2)								
HEC-HMS	4,090	7,340	10,500	13,000	16,300	18,700	21,100	24,700
Regression	2,110	4,080	5,800	8,320	10,800	12,900		
Plate 6						16,000		
FEMA			12,000		19,200	23,000		28,500
HEC-SSP	2,883	5,065	6,800	8,670	11,400	13,700	16,200	19,800
Weighted	3,070	5,520	8,470	9,890	13,900	16,400	18,100	23,200
FINAL	**3,400**	**6,100**	**8,500**	**11,150**	**14,400**	**16,800**	**19,000**	**22,100**
JMP3 (Right above the confluence of Manoa-Palolo and Ala Wai Canals, A=10.678 mi^2)								
HEC-HMS	4,220	7,450	10,700	13,300	16,600	18,900	21,400	24,900
Plate 6						16,500		
Weighted	4,220	7,450	10,660	13,260	16,560	18,100	21,400	24,900
FINAL	**3,450**	**6,200**	**8,700**	**11,400**	**14,700**	**17,100**	**19,300**	**22,400**

Table 5-5. Peak Flow Discharges at Mānoa-Pālolo Junctions by Methodology

The junction directly upstream of the confluence of the Mānoa-Pālolo and Ala Wai Canals (JMP3) receives the highest amount of peak flow discharge in the Mānoa-Pālolo Canal sub-watershed. This junction is located at the downstream (*makai*) end of the watershed and drainage system, and so it is not surprising that peak flow discharge would occur at the 'bottom' of the sub-watershed as the water flows down toward sea level. For the Mānoa-Pālolo Canal junctions studied (JMP1 and JMP3), the HEC-HMS modeling results provide higher peak flow discharges than the other methodologies used, particularly the Regression method and HEC-SSP calculation. At junction JMP2 (USGS gage 16247100), the final *best* estimates are lower than HEC-SSP findings but parallel to those values. Noda and Associates (1994) used 24 historical annual peaks to determine the peak flow discharges; their result for 100 year was at 12,429 cfs, whereas in this study, HEC-SSP provided 13,700 cfs. These results are illustrated in the final discharge frequency curves Figures 5-9 through 5-11. These figures show the peak flow discharge by method and junction, and dependent on the percent chance exceedance storm.

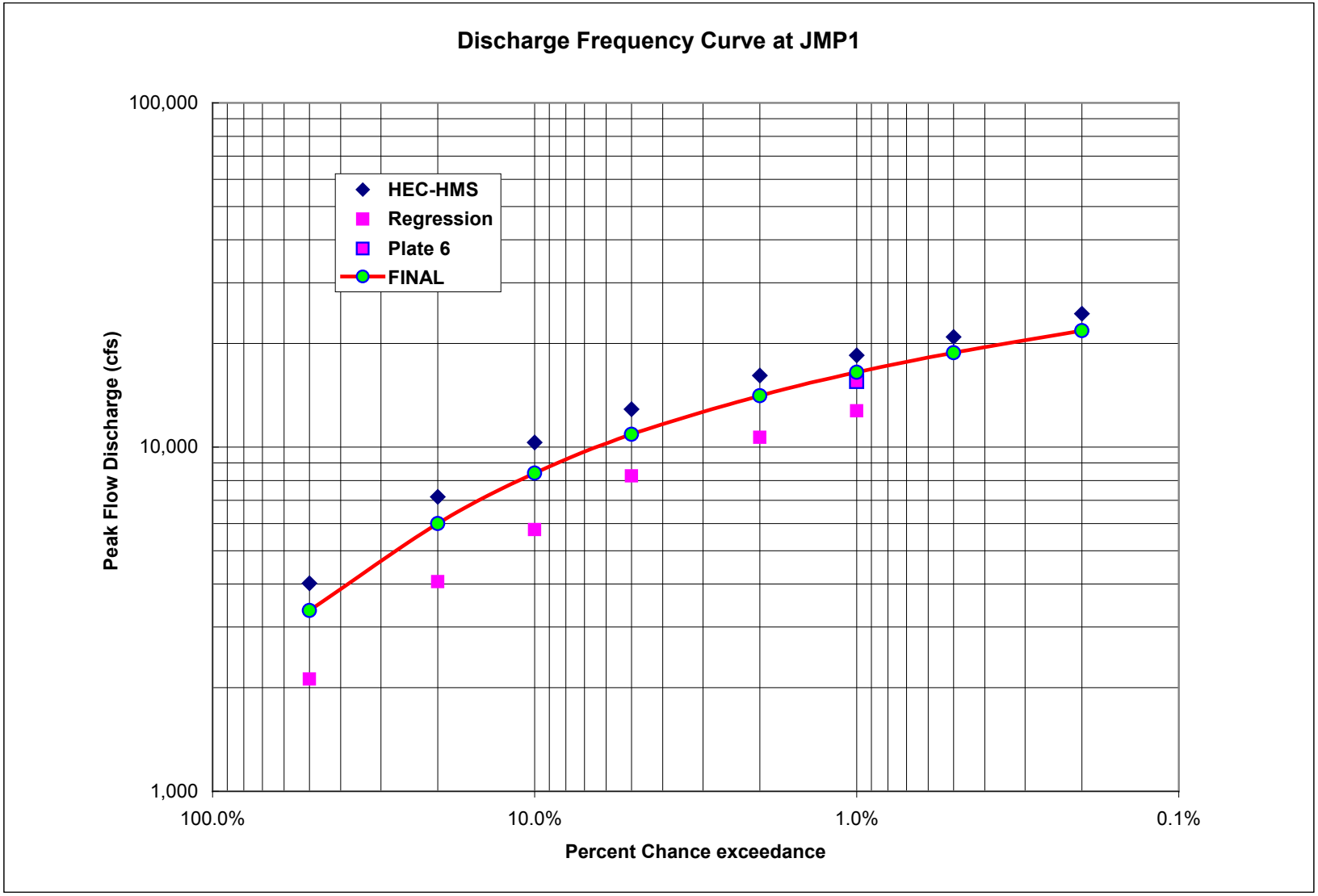

Figure 5-9. Final Discharge Frequency Curve at JMP1 (Confluence of Mānoa & Pālolo Streams)

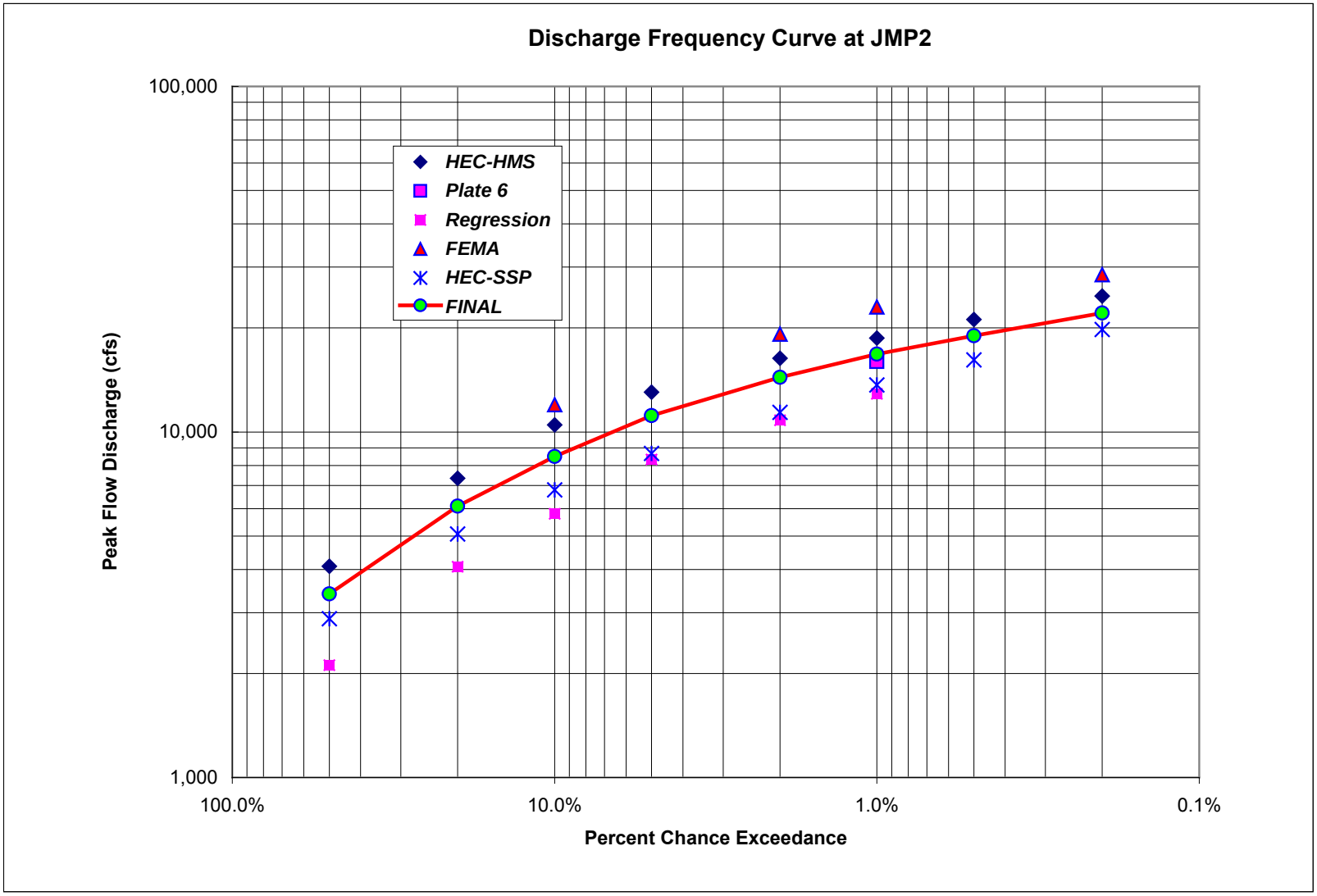

Figure 5-10. Final Discharge Frequency Curve at JMP2 (USGS Stream Gage [16247100])

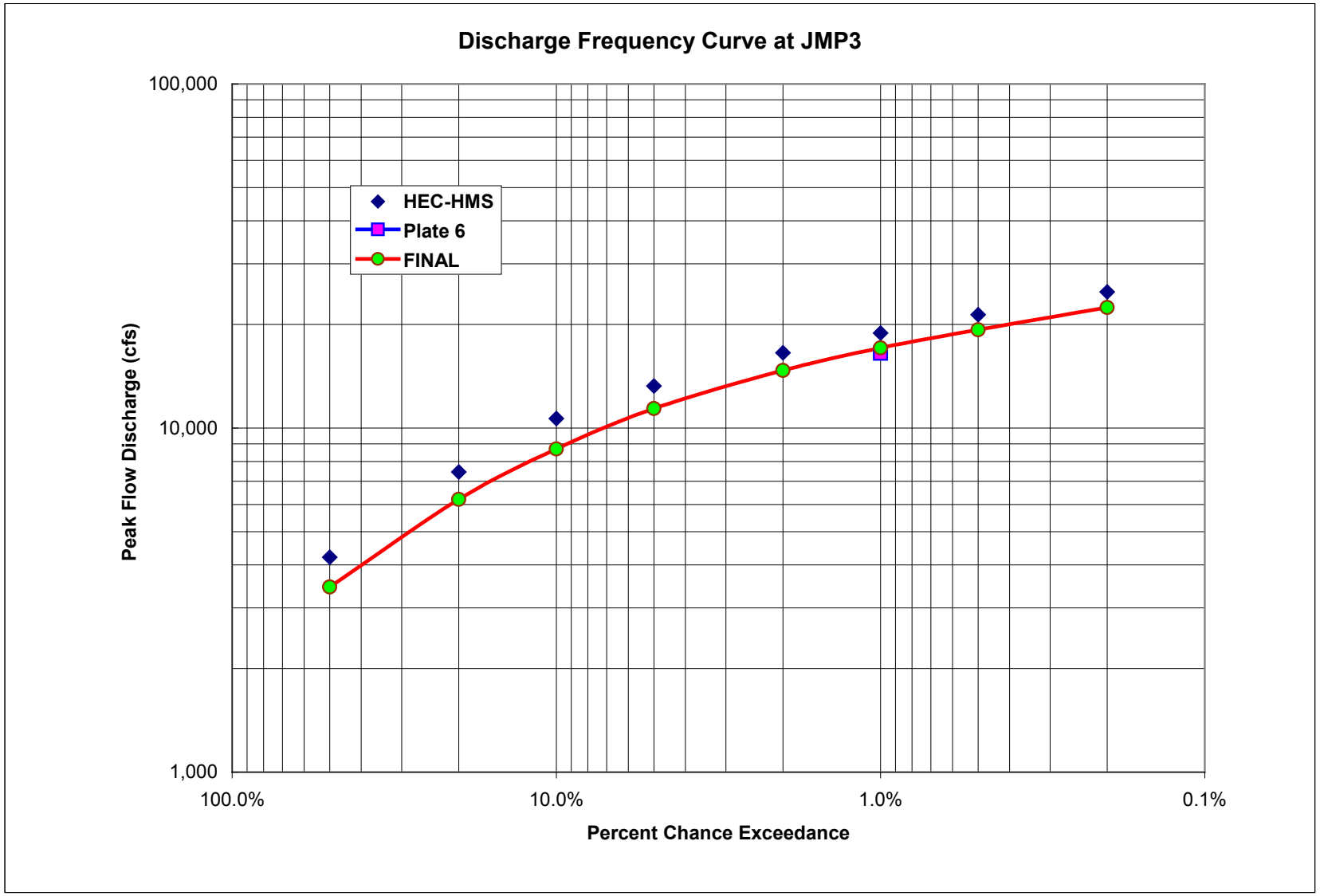

Figure 5-11. Final Discharge Frequency Curve at JMP3 (Confluence of Mānoa -Pālolo and Ala Wai Canals)

5.6 Ala Wai Canal Peak Flow Discharges

As mentioned earlier, Ala Wai Canal was modeled as a reservoir, considering backwater effects caused by the tides due to the sub-watershed location near mean sea level. The reservoir model treated Ala Wai Canal and the adjacent lower area as a detention basin. As the modeled flood wave passes through the reservoir, storage occurs that can greatly reduce the peak flow. The magnitude of this reduction depends on the boundary setting of the modeled reservoir. The storage-elevation function for the Ala Wai Canal reservoir model was determined using bathymetric survey data for the channel and LiDAR data for the surrounding area (Section 4.6.1). No other method accounted for analysis of the surrounding storage area; consequently, the flow peaks determined by other methods are much higher than those determined by the reservoir model. In conclusion, the HEC-HMS results that modeled Ala Wai Canal as a reservoir are considered the most accurate.

Table 5-6 provides peak flow discharge results for Ala Wai Canal sub-watersheds by methodology and then weighted followed by 'FINAL' values through the best fit curve process.

Methodology	Peak flow discharge (cfs)							
Return Period (yr)	**2**	**5**	**10**	**20**	**50**	**100**	**200**	**500**
Percent Chance Exceedance	**50%**	**20%**	**10%**	**5%**	**2%**	**1%**	**0.5%**	**0.2%**
Ala Wai Canal (Mouth of Ala Wai Canal, A=16.215 mi^2)								
HEC-HMS	6,000	10,100	13,400	15,200	16,700	17,700	18,700	20,500
Plate 6						22,500		
FEMA			13,700		23,000	28,200		36,200
Weighted	6,000	10,100	13,500	15,200	19,400	22,300	18,700	27,200
FINAL	**6,000**	**9,500**	**12,500**	**15,200**	**17,500**	**18,500**	**19,500**	**20,500**

Table 5-6. Peak Flow Discharges at the Ala Wai Canal Mouth by Methodology

The inflows to Ala Wai Canal increased, whereas the outflow did not increase significantly. For example, at the 50-year frequency storm, inflow was estimated as 24,850 cfs from HEC-HMS model, and the outflow from the Ala Wai Canal was estimated as 16,700 cfs with a peak elevation of 5.4 feet. At the 100-year frequency storm, HMS model shows that inflow was 28,200 cfs, and outflow was 17,700 cfs at a peak elevation at 5.8 feet. The canal will be overtopped at this storm condition and the water will be stored in the adjacent areas. Figure 5-12 shows the peak flow discharge over the percent chance exceedance by methodology at the mouth of the Ala Wai Canal.

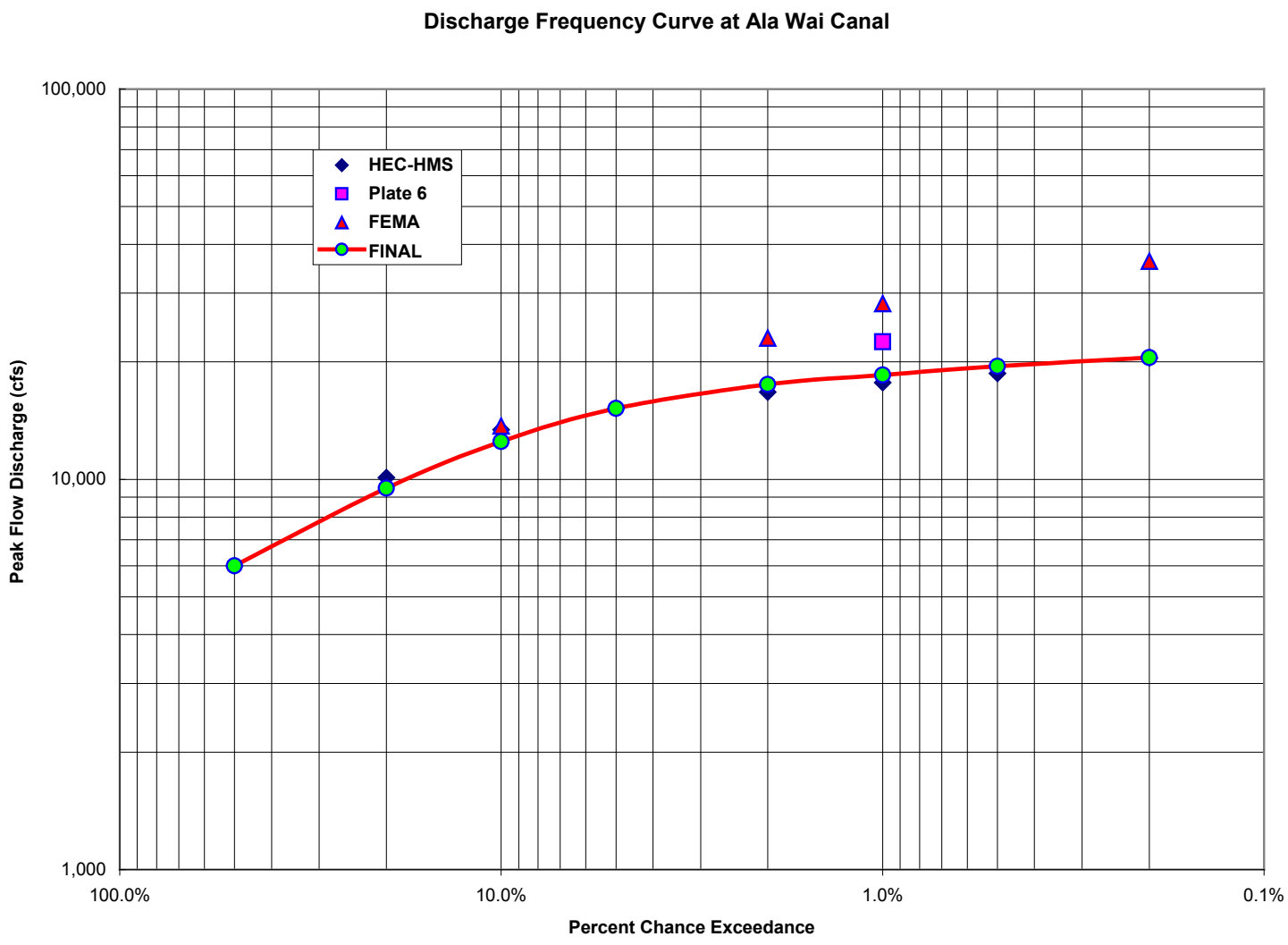

Figure 5-12. Final Discharge Frequency Curve at the Mouth of the Ala Wai Canal

5.7 Peak Flow Discharge Update (November 2010)

As discussed in Hydraulic Appendix, peak flow values were updated and adjusted based on new rainfall-frequency-intensity data. When the hydrologic studies for Manoa and Ala Wai Watersheds were conducted, the 1984 rainfall frequency data for Oahu was used in the rainfall-runoff modeling (Giambelluca and others, 1984). In March 2009, the updated rainfall frequency data for the State of Hawaii was released as the Precipitation Frequency Data Server (PFDS) which is part of National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 4, Version 2.0, Hawaiian Islands, released March 30, 2009. Atlas 14 is official documentation of precipitation frequency estimates for the United States. Documentation can be found at: http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume4.pdf, last accessed September 28, 2009 while the actual; server is located at: http://hdsc.nws.noaa.gov/hdsc/pfds/hi/hi_pfds.html. This tool computes the rainfall frequency and intensity with 90 percent confidence limits for the 1- to 100-year storms for durations from 5 minutes to 60 days. The updated rainfall frequency values are presented in Table 5-7. A comparison between the previous (Table 4-1) and newer rainfall frequency duration values, indicated that the newer intensity values were higher than the older data by an average of 4 to 13 percent depending on the rainfall recurrence interval and duration. In general, the shorter frequency time periods had a larger change then the longer rainfall time periods. To provide consistency with using the HEC-RAS model for the future without project and alternative modeling, the peak-flow data was updated to account for the impacts of the new higher rainfall frequency-duration data for the Ala Wai Watershed. The peak-flow input data was changed from the previous computed input flow data from both the Manoa and Ala Wai hydrologic studies by an average of 9.8 percent. The average percent range varied from minus 7 percent for the Manoa Stream 10-percent chance flood to plus 36 percent for the non-Manoa Stream 50-percent chance floods (Table 5-8). Because the peak flow data was not solely based on the HEC-HMS rainfall-runoff modeling but also other methods such as flood-frequency analysis, the peak flow adjustments were not just based on modifying the previous HEC-HMS results but also incorporating the graphical adjustments used in this and the previous Manoa Stream study (Oceanit, 2008b).

The updated adjusted peak discharge values by junction are listed in Table 5-8. These values were then adjusted by location, as described in the Hydraulic appendix for use in the HEC-RAS model. The uncertainty of the peak flow discharge values, as discussed in Section 5.1, is based on the equivalent years of record. The final equivalent years of record (EYOR) used in the risk and uncertainty HEC-FDA model is based on stream reach and is presented in Table 5-9. The Makiki Watershed with the least amount of available data was given the lowest EYOR of 18 years, while the remaining sub-watersheds were assigned values from 25 to 30 years. The highest values were from sub-basins where the peak flow discharges were almost entirely based on gaged data; Pukele and Waiomao Streams.

Percent Chance Exceedance	Return Period (years)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.38	0.66	0.97	1.40	1.87	2.12	2.74	3.35	3.92
50	2	0.47	0.80	1.19	1.72	2.33	2.71	3.49	4.29	5.18
20	5	0.61	1.04	1.54	2.22	3.04	3.54	4.58	5.68	6.96
10	10	0.72	1.24	1.83	2.64	3.61	4.21	5.46	6.80	8.39
5	20	0.81	1.49	2.11	3.05	4.15	4.94	6.28	8.00	9.95
4	25	0.89	1.52	2.25	3.24	4.42	5.16	6.69	8.36	10.42
2	50	1.02	1.75	2.59	3.74	5.09	5.94	7.69	9.61	12.05
1	100	1.16	1.99	2.95	4.25	5.78	6.74	8.74	10.92	13.77
0.5	200	1.31	2.25	3.34	4.82	6.53	7.61	9.86	12.30	15.60
0.2	500	1.53	2.62	3.88	5.61	7.57	8.82	11.42	14.23	18.18

Rainfall Intensity Frequency data determined from NOAA Atlas 14 Precipitation Frequency Data Server using watershed centroid of 21.3092 N, 157.8071 W. Values for the 5-percent chance storm are interpolated.

Revision of data in Table 4-1

Table 5-7. Updated Rainfall Intensity Frequency Data for the Ala Wai Watershed, Oahu, Hawaii

Model & Junction	Return Period (yr)	2	5	10	20	50	100	200	500
	Percent Chance Exceedance	50%	20%	10%	5%	2%	1%	0.50%	0.20%
Manoa Watershed Model	JM1	1,200	2,000	2,600	3,350	4,500	5,400	6,200	7,600
	JM2	1,940	3,200	4,200	5,280	7,140	8,350	9,400	11,400
	JM3	2,080	3,450	4,350	5,450	7,200	8,410	9,500	11,600
	JM4	2,200	3,650	4,600	5,700	7,500	8,700	10,000	12,500
	JM5	2,320	3,800	4,800	6,100	7,900	9,360	11,000	12,900
	JM6	2,500	4,100	5,200	6,530	8,800	10,200	12,000	14,200
	JM7	2,700	4,300	5,600	6,900	9,250	10,700	13,000	15,000
	JM8	2,900	4,600	6,100	8,200	10,400	12,500	14,500	17,400
Ala Wai Watershed Model	JK1	800	1,500	2,100	2,770	3,800	4,700	5,500	6,600
	JK2	900	1,550	2,200	2,800	3,850	4,800	5,600	6,700
	JK3	1,040	1,850	2,600	3,400	4,700	5,900	6,800	8,500
	JP1	440	850	1,200	1,600	2,280	2,800	3,350	4,200
	JP2	1,100	2,100	3,000	3,930	5,430	6,700	8,020	9,990
	JP3	1,350	2,420	3,400	4,340	5,900	7,420	9,000	11,000
	JP4	1,450	2,580	3,500	4,560	6,350	7,900	9,400	12,000
	JMP1	4,200	7,100	9,200	12,000	16,000	18,500	22,100	26,500
	JMP2	4,500	7,300	9,500	12,400	16,200	19,400	22,500	26,900
	JMP3	4,600	7,350	9,700	12,800	16,500	20,000	23,000	27,700
	Ala Wai	8,000	11,500	13,500	16,000	18,000	19,500	20,500	22,000

Table 5-8. Updated Peak Flow Discharges for the Ala Wai Watershed by HEC-HMS Model Junction

Table 5-9. Peak Flow Discharge Frequency Data and Uncertainty in Equivalent Years of Record used in HEC-FDA, Ala Wai Watershed, Oahu, Hawaii

Stream or Sub-Watershed	HEC-HMS Model Sub-Basin or Junction	HEC-RAS Reach Name	HEC-FDA Reach Name	HEC-FDA Analytical Frequency Curve Data (Log Units)			EYOR
				Mean	Std. Dev.	Skew	
Ala Wai, Waikiki	Ala Wai	Ala Wai Lower	ALA 1	3.7983	0.3143	-2.2259	30
		Ala Wai Middle	ALA 2	3.6600	0.2052	0.1873	
		Ala Wai Upper	ALA 3	2.9714	0.2164	-0.7680	
Makiki	K2	Kanaha Ditch	KAH 1 KAH 2	2.4673	0.2954	0.106	18
	----	Kanaha Split	KAO 1	2.2952	0.3480	-0.0938	
	JK3	Makiki Lower	MAK 1	2.9345	0.1638	1.2305	
	JK2		MAK 2	2.8820	0.1609	1.7006	
	JK1	Makiki Upper	MAK 3	2.6086	0.2634	0.2515	
	K1, K3		MAK 4	2.3121	0.3323	0.1887	
Manoa	JM7, JM 8	Manoa Stream Main Reach	MAN 1	3.4780	0.2340	0.4426	25
	JM 6		MAN 2	3.3770	0.2299	0.2732	
	JM 4, JM 5		MAN 3 MAN 4	3.3297	0.2339	0.2878	
	JM 3		MAN 5	3.3000	0.2444	0.2758	
	JM 1, JM 2		MAN 6 MAN 7	3.0954	0.2436	0.4493	
	----	UH_Split	UNI 1 UNI 2	0.699	0.7764	0.0153	18
Manoa-Palolo Canal	JMP 1 to JMP 3	Palolo Lower	MPC 1 MPC 2	3.6356	0.2482	0.280	30
Palolo	JP1 to JP 4	Palolo Main	PAL 1 to PAL 4	3.1354	0.3063	0.136	27
	JP1	Pukele Tributary	PUK 1	2.8005	0.3424	-0.057	44
	P2, P5	Waiomao Ditch	WAI 1	2.8129	0.2976	-0.021	35

EYOR = Equivalent Years of Record; ----, not a separate sub-basin in HEC-HMS model

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

SECTION 209 OF FLOOD CONTROL ACT OF 1962
(PUBLIC LAW 87-874)
APPENDIX A2

EXISTING WITHOUT-PROJECT HYDRAULIC AND WITH-PROJECT HYDROLOGIC AND HYDRAULIC

U.S. ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
FORT SHAFTER, HAWAII
June 2015

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX A

EXISTING WITHOUT-PROJECT HYDRAULIC AND
WITH-PROJECT HYDROLOGIC AND HYDRAULIC

1 INTRODUCTION

Through a cooperative effort undertaken by the State of Hawaii Department of Land and Natural Resources (DLNR) Engineering Division and the U.S. Army Corps of Engineers (USACE) as part of the *Ala Wai Canal Project, O'ahu, Hawai'i, Draft Feasibility Study Report with Integrated Environmental Impact Statement* (Draft Feasibility Report/EIS) , a hydrologic and hydraulic study of the Ala Wai Watershed was initiated in 2001 and was amended in 2006. A large portion of this Watershed is highly susceptible to flooding. The purpose of this study is to determine the feasibility of flood damage reduction alternatives for the Ala Wai Watershed. This Draft Feasibility Report/EIS presents a description of the analytical approach, analyses performed, and the results obtained for a detailed without-project hydraulic study and a with-project hydrologic and hydraulic study of the approximately 19 square miles of the Ala Wai Watershed. Results of this study include water surface profiles for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% Annual Chance Exceedance (ACE) storm events for the existing without-project conditions, future without-project conditions, and for several respective with-project alternatives.

2 GENERAL

2.1 Scope of Work

An analysis of the Watershed and stream hydrology and hydraulics was performed using the USACE's Hydrologic Engineering Center's-Hydrologic Modeling System (HEC-HMS) in conjunction with the Hydrologic Engineering Center's-River Analysis System (HEC-RAS). The results of this modeling effort were used to develop depth-duration-frequency rating curves for each portion of the study. The Watershed was first analyzed under current development conditions assuming no implementation of any flood damage reduction alternatives. These scenarios were then modified to include an initial array of five project alternatives aimed at reducing flood damages at different areas in the Watershed. Three alternatives are described in this Appendix, Alternatives 1A, 2A, and 3A. 10% level of designs were created for Alternatives 2A and 3A.

The study area extends from the ridge of the Ko'olau Mountains to the nearshore waters of Mamala Bay and includes Makiki, Manoa, and Palolo streams. These streams all drain to the

Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands, thus allowing development of the Waikiki district.

2.2 Previous Hydrologic and Hydraulic Models and Studies

Varieties of studies have been previously conducted in the Ala Wai Watershed and were reviewed as part of this project. These studies include the following:

- **Federal Emergency Management Agency's National Flood Insurance Program Study (FEMA, 1979).** The Federal Emergency Management Agency (FEMA) contracted the USACE to determine flood hazards for the McCully and Moiliili areas that encompass the Ala Wai Canal and the Manoa-Palolo Drainage Canal. This study delineated the 1-percent ACE (100-year) floodplains and was completed in February 1979. The discharge of 28,300 cubic feet per second (cfs) at the canal mouth was used to delineate the 1-percent ACE floodplains.
- **Ala Wai Canal Improvement Project, Storm Water Capacity Study (Edward K. Noda and Associates, 1994).** The State of Hawaii contracted Edward K. Noda and Associates to conduct this study to determine the hydraulic effects associated with dredging the Ala Wai Canal. This study concluded that by lowering the canal invert elevation to -12.0 and -10.0 feet mean lower low water at strategic locations, the maximum 1-percent ACE (100-year) flood elevation would be at approximately 5.0 feet mean sea level near the top of the ocean side canal bank. The 1-percent ACE flow used in this study was 22,389 cfs at the mouth of the canal.
- **Ala Wai Flood Study (USACE, 2001).** Conducted under the Planning Assistance to States Program (Section 22, WRDA of 1974), this study investigated and recommended appropriate solutions to resolve flooding from the Ala Wai Canal. The Land Division of DLNR was the non-Federal sponsor of the study. The analysis demonstrated that there are possible structural measures that could be implemented to mitigate flooding by increasing the flood carrying capacity of the Canal. Specific measures included dredging, levees and floodwalls, and detention/sedimentation basins. The study indicated that dredging would increase the flood capacity of the channel, but would not provide full protection against a 1-percent ACE (100-year) flood.
- **Ala Wai Watershed Analysis (Townscape Inc. and Dashiell, 2003).** The purpose of this effort was to review existing literature and evaluate existing data to identify the water resource problems, studies, and recommended actions to improve Watershed health, as related to water supply, flood control, and ecosystem restoration. This document was prepared as a component of the USACE/DLNR Ala Wai Watershed Feasibility Study.
- **Hydrology and Hydraulics Study, Flood of October 30, 2004, Mānoa Stream (USACE, 2006).** A storm on October 30, 2004, caused significant flooding in Mānoa Valley, especially in areas adjacent to Mānoa District Park and Woodlawn Drive Bridge. A post-flood analysis was conducted using rainfall-runoff and stream hydraulic computer modeling (older HEC-2 model), the results of which were used to assess the feasibility of several short-term flood mitigation measures. Alternatives analyzed included construction of levees or floodwalls along sections of the channel between Mānoa District Park and Woodlawn Drive and installation of an artificial channel between East

Mānoa Road and Woodlawn Drive. Of these alternatives, the channel drop structure at Woodlawn Drive Bridge was determined to have the best potential for increasing the capacity with the least amount of maintenance, aesthetic, bridge structure, and drainage impacts to mitigate. DLNR was the non-Federal sponsor of the study.

- **Final Hydrology Report, Manoa Watershed Project (Oceanit, 2008a).**

  The Natural Resources Conservation Service (NRCS) contracted Oceanit through the USACE to develop conceptual designs and prepare a feasibility report, watershed plan, and a preliminary draft environmental impact statement (PDEIS) for alternate flood hazard reduction schemes aimed at preventing similar flooding in the future. Several rainfall runoff models and frequency-based methods were used to estimate the peak discharges at various junctions in the Watershed. Rainfall runoff models included Technical Release 55 (TR-55) from the NRCS, Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) from the USACE, and FLO-2D, a distributed model. Fequency-based methods included the Plate 6 of the City and County of Honolulu (CCH) drainage standards, USGS regression equations, and FEMA peak discharge-frequency drainage area curves. Peak discharges calculated using the above methods were compared, and best estimates of the peak discharges for the following return periods were determined: 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE.

- **Final Hydraulic Analysis Report, Manoa Watershed Project (Oceanit, 2008b).** The NRCS contracted Oceanit through the USACE to explore alternatives for flood reduction along the Manoa Stream corridor. In order to qualify the effects of each proposed alternative, the existing extent of flood inundation must be known. The Hydrologic Engineering Center-River Analysis System (HEC-RAS) was used to analyze the extent of the inundated areas from Manoa Stream for these eight storm events: 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE (2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year). The 50-, 5-, 1-, and 0.2-percent ACE storms were mapped. Peak flow data at critical junctions along the stream were supplied by the Final Hydrology Report, Manoa Watershed Project (Oceanit, 2008a). The hydraulic analysis was conducted without debris blockages at bridge openings.

- **Technical Summary Report, Mānoa Watershed Project (Oceanit, 2008c).** Following the October 30, 2004, flooding event in Mānoa Valley new LiDAR data was obtained. NRCS initiated the Mānoa Watershed Project, which included development of hydrologic and hydraulic models using HEC-HMS and HEC-RAS, and design of conceptual flood reduction measures, based on the work completed as part of the Mānoa Stream Hydrology and Hydraulics Study (USACE, 2006). The intent of the project was to prepare a Watershed Plan and EIS under the NRCS Watershed Program (PL83-566). However, the funds needed to complete the EIS were not received, and thus the scope of the project was reduced to technical reports and conceptual measures to mitigate flooding. The results of this effort were eventually incorporated, with expansion of the hydrology and hydraulics modeling, into the Ala Wai Watershed Project.

- **Final Hydrology Report, Ala Wai Watershed Project (Oceanit, 2008d).**

  This study estimated peak flow discharges at particular drainage junctions in the Ala Wai Watershed corresponding to the following storm return periods: 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE (2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year). Updates were added on November 2010.

- **Final Drainage Evaluation Report, Ala Wai Watershed Project (Oceanit, 2008e).** This study evaluates the existing Ala Wai Watershed drainage facilities to determine the existing capacity of the drainage system. The existing discharge capacity is compared with the 2000 CCH's Storm Drainage Standards to determine whether or not each drainage facility (mostly culverts can pass a 10-, 50-, or 100-year storm, depending on the drainage area serviced by the outlet.

- **Conceptual Engineering Report, Ala Wai Canal Flushing System & Ala Wai Golf Course Detention System (Mitsunaga & Associates, Inc., 2014).** The DLNR proposes to improve the water quality of the Ala Wai Canal to standards acceptable for water recreational activities including canoeing, kayaking, fishing and minimal power boating. The specific objectives of the proposed project are to: decrease sources of pollution through detention ponds and/or filters on tributaries to the canal and improve Watershed management, increase water flow and circulation in the canal while addressing environmental concerns, and define and implement maintenance management practices for the canal. This Conceptual Engineering Report developed alternatives to address the diversion of the off-site storm water through Ala Wai Golf Course and a flushing system or the Ala Wai Canal.

3 WITHOUT PROJECT HYDRAULIC MODELINGOverview

The HEC-RAS (Hydrologic Engineering Center - River Analysis System) computer program, version 4.1.0 was used for hydraulic modeling (U.S. Army Corps of Engineers, 2010). This HEC-RAS model (Figure A-1) was created by joining separate HEC-RAS models of Makiki, Manoa, and Palolo Streams and Manoa-Palolo Drainage and Ala Wai Canals together. The HEC-RAS model of Manoa Stream is documented in Oceanit (2008b) and the separate models for the Makiki and Palolo Streams and the Manoa-Palolo Drainage and Ala Wai Canals were originally created by Oceanit and West Consultants by July 2009 and then corrected and merged together by the USACE by November 2009. In 2013 the merged model was then updated again to be more accurate. This model consisted of 8 rivers, 13 reaches, 1,287 cross sections, 476 of which are interpolated, 49 bridges (this includes culverts), 2 inline weirs, and 16 lateral weirs.

3.1.1 Study Reach Descriptions

The Makiki Stream portion of the HEC-RAS model starts from the confluence with the Ala Wai Canal to a point approximately 2.0 miles upstream and includes the Kanaha Ditch Tributary from its confluence with Makiki Stream to a point approximately 0.8 miles upstream. Due to the dominate effect of the Ala Wai Canal during high flows, the downstream reach of Makiki Stream downstream of Fern Street was not modeled in detail; both the Kapiolani Boulevard and pedestrian walkway bridges were ignored in the model. The stream channels of both Makiki and Kanaha Streams have been highly modified with concrete and confined from the point when they

enter the urbanized area and include sections when the stream channel is confined to sections entirely underground.

The Manoa HEC-RAS model was modified from the Oceanit (2008b) by adding the potential for split flow to leave Manoa Stream near Woodlawn Drive Bridge and enter the University of Hawaii at Manoa Campus. Also the Dole Street Bridge was added to the model for completeness, although its effect on flow is very minimal as the low chord of the bridge is still about 10 ft higher than the 0.2-percent ACE flood water-surface elevation. The Manoa Stream reach extends from the confluence with Manoa-Palolo Drainage Canal upstream about 3.1 miles to the point where the Waihi and Waiakeakua Stream tributaries meet. The Manoa Stream channel is mostly natural with some segments modified by concrete channel or stream bank hardening.

The Palolo Stream Main reach extends upstream approximately 1.9 miles from the confluence with the Manoa-Palolo Drainage Canal. Upstream of Palolo Stream, the Pukele Stream and Waiomao Stream tributaries were modeled, extending 1.1 and 0.9 miles upstream. The Palolo Stream Main reach Channel is mostly confined to one large concrete channel.

The Manoa-Palolo Drainage Canal is called the Palolo Stream Lower reach in the model and extends about 0.9 miles from the Ala Wai Canal to the confluence of the Manoa and Palolo Stream. This canal consists of a modified channel with segments of natural bed and banks, but mostly hardened stream banks.

The Ala Wai Canal section is modeled using three reaches from the mouth of the to the Makiki Stream confluence (Lower), from Makiki Stream to the Manoa-Palolo Drainage Canal confluence (Middle), and from the Manoa-Palolo Drainage Canal confluence to the upstream end (Upper). The reach lengths are approximately 2,490, 3,365, and 4,260 feet respectively. The Ala Wai Canal channel has a natural bottom with hardened banks and has tidal influence. Bathymetric data was collected by Oceanit in 2008 and used to compute the cross-section data for the canal.

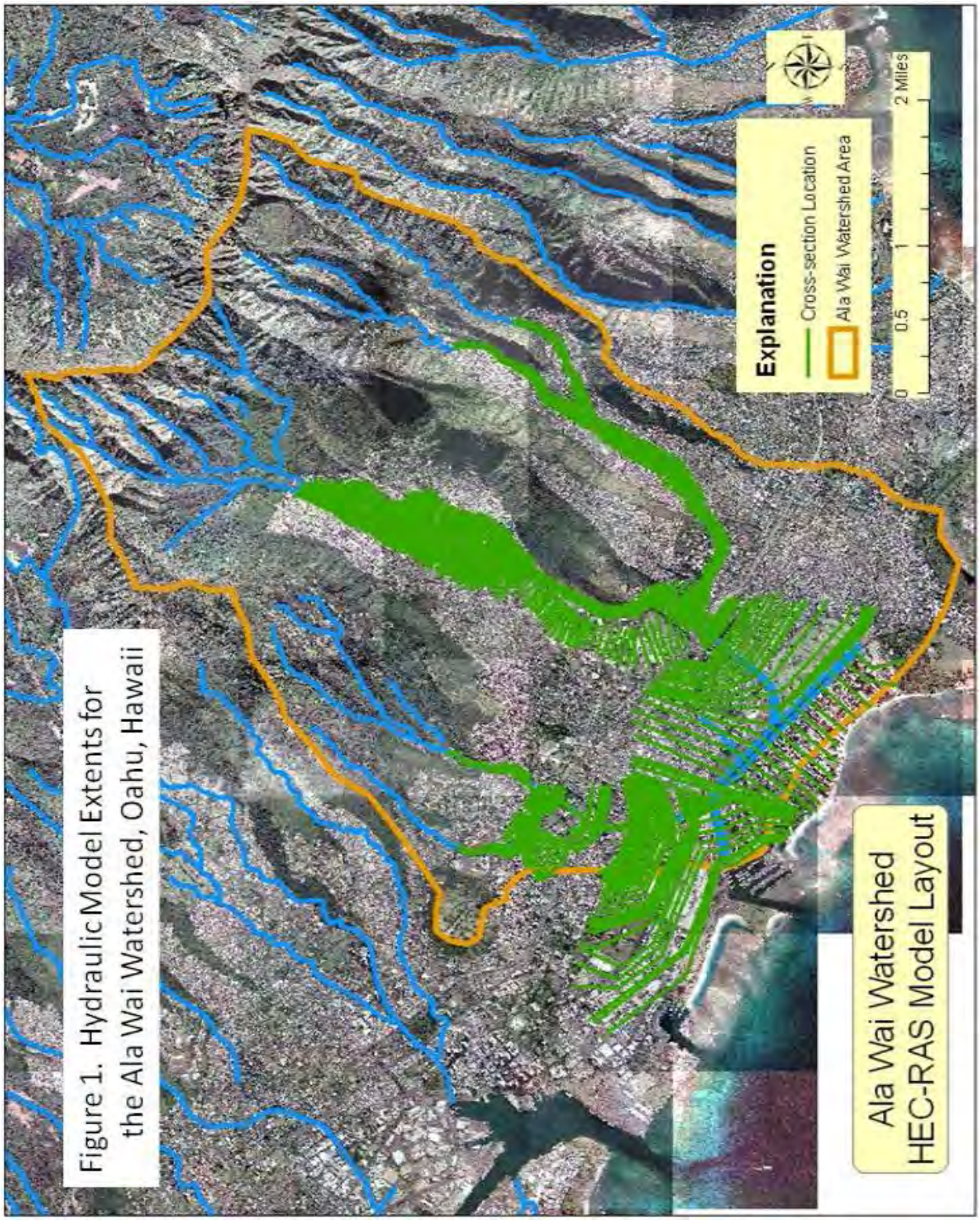

Figure A-1: Hydraulic Model Extents for the Ala Wai Watershed, Oahu, Hawaii

3.1.2. Terrain Data

Topographic data for the hydraulic model is primarily based on airborne light detection and ranging (LIDAR) data. The LIDAR data was collected, processed, and verified by Oceanit and their sub consultants in late 2006 and early 2007. The LIDAR data has an accuracy of 45 cm (1.5 ft) horizontal, 37 cm (1.2 ft) vertical and was processed with 1.4 m (5 ft) horizontal point spacing. Datum of data is NAD 1983 HARN projected into Stateplane_Hawaii_3_FIPS_5103_Feet horizontal and mean sea level vertical. The bare ground LIDAR data was then converted into a Triangular Irregular Network (TIN) format using Geographical Information Systems (GIS) software. The TIN format is needed for using HEC-GeoRAS version 10.1 for ArcGIS version 10.1 to extract the necessary spatial and elevation data for the hydraulic model (USACE, 2011). The HEC-RAS model schematic layout is illustrated in Figure A-2.

Further refinement to the extracted topographic data especially along and near the stream channels and in other critical areas with large amounts of vegetation overgrowth was done with the HEC-RAS program. Therefore, the Manning's n-values were adjusted and refined where needed. At selected stream cross-section locations conventional land surveys or site investigations and field measurements were done to determine channel inverts, top of bank locations, bridge dimensions, and other elements relevant to hydraulic modeling. This information was collected and originally entered into the HEC-RAS model by Oceanit and their sub-consultants. Most of the refinements to the cross-sections in the model were based on channel and bridge plans, especially in the Makiki and Palolo areas where the majority of the streams have been channelized. For the upper Manoa Stream area, where much of the stream channel is privately owned, cross-section adjustments were done based on field observations or measurements and not surveyed cross-sections. Cross-section data in the Ala Wai Canal were based on the bathymetric survey data collected in 2008.

3.1.3. Cross-Section Modeling

Cross-section locations for the HEC-RAS model were determined by the channel slope, channel shape, and location of structures. In general cross-sections were spaced about 100 to 500 feet apart for the Ala Wai and Manoa-Palolo Drainage Canals, about 25 feet apart for the Lower Makiki Stream and Palolo Stream Main reaches, and about 50 to 100 ft apart for all the other stream reaches. Near hydraulic structures, such as bridges and culverts, cross-sections were located closer together. Cross-sections in the area of stream confluences or junctions had to be modified to prevent the cross-section lines from crossing each other. These cross-sections were bent, or "doglegged" to insure the overbank areas were not double-counted or were purposely ignored in the case of Makiki Stream near the Ala Wai Canal. Makiki Stream at the mouth of the stream is heavily influenced from the water surface elevation of the Ala Wai Canal. This backwater effect completely overcomes the downstream cross-sections of Makiki Stream and can give erroneous results if the cross-section length is cut short to avoid crossing any adjacent section lines. For this reason, it was decided to start the Makiki reach just upstream of Kapiolani Boulevard. This provided a balance between the influence of the canal water surface elevation and the necessity to properly model more frequency flow events.

Ineffective flow areas were defined at cross-sections to separate areas of active conveyance from adjacent low lying areas that do not contribute to downstream conveyance due to either the presence of high ground along the reach or the expansion/contraction from another control upstream or downstream, such as a bridge or culvert opening. Levee stations were also used to confine flow to channels for lower flow rates especially where the ground elevations were lower than the top of channel. The contraction coefficients for majority of the cross-sections were 0.1, 0.3 was used near bridges and culverts. The expansion coefficient was set to 0.3 for most cross-sections except near bridges, culverts or lateral structures where a value of 0.5 was used to account for the potential for greater losses.

An important component of hydraulic modeling is the selection of Manning's n-values (roughness coefficients). Manning's n-values were determined from previous studies and several site surveys conducted by Oceanit to characterize the channel roughness. Reasonable values are usually determined from site visits and the use of guides such as Barnes (1967) or Arcement (1989). Manning's n-values were further refined based on model calibration. Previous modeling on Manoa Stream (Oceanit, 2008b) was calibrated to the 2004 flood event on Manoa Stream. Previous modeling of the Ala Wai Canal (U.S. Army Corps of Engineers, 2001 and 2005) was calibrated to the limited data of the 1967 event on Palolo Stream and Manoa-Palolo Drainage Canal. Makiki and Kanaha Streams do not have any calibration or gaged data to aid in calibration or model comparison, but are mostly concrete lined channels so the n-values should be stable. Calibrated n-values are assumed to also account for any sediment or debris "bulking" during those storm events. Manning's n-values for the Ala Wai Watershed HEC-RAS model are presented by modeled River and Reach in Table A-1.

The range of Manning's n-values used can be roughly characterized by channel description. Natural stream channels with minimal vegetation in the channel, steep banks, trees and brush on banks, and bottoms consisting of gravels, cobbles, and few large boulders were given values from 0.03 to 0.04. Natural channel sections that were uniform and contained smooth graveled beds were given a value of 0.025. The Ala Wai Canal was given an n-value of 0.03. Lined or concrete channels were given a value of 0.018 and smooth overbank areas in parks or the golf course were given values of 0.06. The majority of overbank areas in mixed urban areas or overland flow (split flow) areas were given values of 0.1 to 0.125. Previous channel n-values used were 0.04 for the natural channels with 0.06 for all overbank areas (M&E Pacific, 1977) to 0.027 to 0.04 for the Ala Wai Canal and 0.25 for the urban overbank areas (U.S. Army Corps of Engineers, 2005).

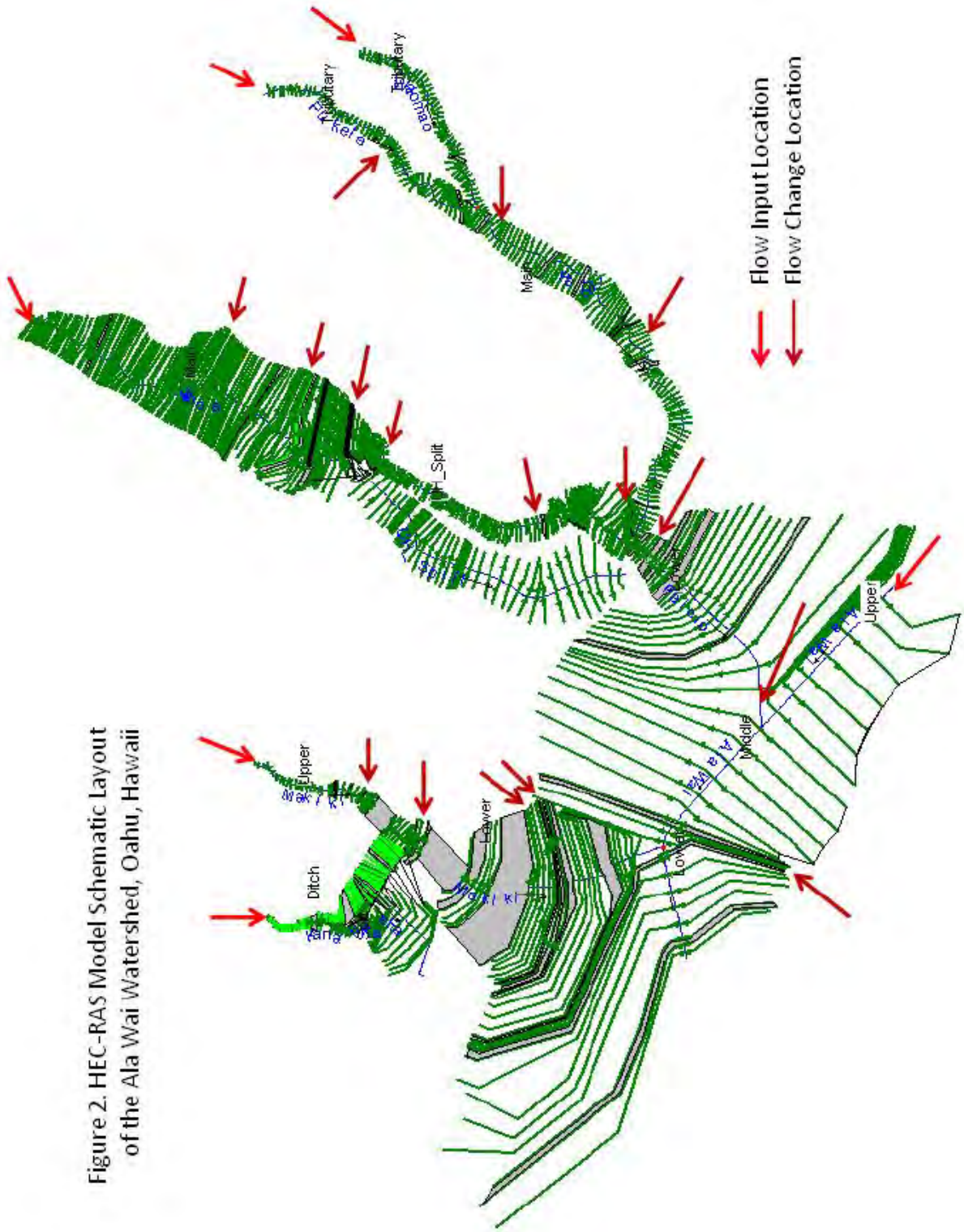

Figure A-2: HEC-RAS Model Schematic Layout of the Ala Wai Watershed, Oahu, Hawaii

Table A-1. Manning's n-values for roughness used in the Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii

Table 1. **Manning's n-values for roughness used in the Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii**

Model Stream Names		Model Cross-section Location Range		Channel Section		
River	Reach	From	To	Left Overbank	Main Channel	Right Overbank
Ala Wai	Upper	6370	9724	0.125	0.03	0.125
Ala Wai	Middle	2580	5825	0.125	0.03	0.06 to 0.125
Ala Wai	Lower	33	2324	0.125	0.03	0.125
Kahana	Ditch	3238	4372	0.125	0.04	0.125
Kahana	Ditch	3	3084	0.125	0.025	0.125
Kahana	Split	809	3508	0.125	0.1	0.125
Makiki	Upper	6319	10768	0.125	0.025	0.125
Makiki	Lower	5952	6286	0.125	0.025	0.125
Makiki	Lower	2632	4725	0.125	0.025 to 0.06	0.125
Makiki	Lower	639	2560	0.125	0.025	0.125
Manoa	Main	10592	16506	0.125	0.04	0.125
Manoa	Main	9792	10566	0.125	0.025	0.125
Manoa	Main	8775	9691	0.125	0.018	0.125
Manoa	Main	7734	8699	0.125	0.025	0.125
Manoa	Main	7190	7653	0.125	0.03	0.125
Manoa	Main	6129	7149	0.125	0.035	0.125
Manoa	Main	84	6054	0.125	0.04	0.125
Palolo	Main	8951	15326	0.125	0.018	0.125
Palolo	Main	7102	8838	0.125	0.03	0.125
Palolo	Main	5303	7000	0.125	0.018	0.125
Palolo	Lower	1813	5198	0.125	0.025	0.125
Palolo	Lower	859	1356	0.125	0.025	0.06 to 0.125
Pukele	Tributary	2004	5958	0.125	0.04	0.125
Pukele	Tributary	146	1893	0.125	0.018	0.125
UH_Split	UH_Split	132	6929	0.125	0.125	0.125
Waiomao	Tributary	514	4900	0.125	0.04	0.125
Waiomao	Tributary	110	414	0.125	0.018	0.125

3.1.4. Bridge and Culvert Modeling

Geometric data (culvert diameters and dimensions, culvert length, bridge span, etc.) for all bridges and culverts was obtained by Oceanit and entered into the HEC-RAS model. In many cases, like along Palolo Stream, bridges over concrete channels do not constrict the flow until the flow overtops the banks and thus, have minimal impact to most of the smaller flow frequency results. In other cases, like Woodlawn Drive Bridge in Manoa, a significant constriction occurs

at the smaller flow frequency results. The HEC-RAS model results take these factors into account. A list of bridges and culverts are presented in Table A-2.

For the Ala Wai Watershed HEC-RAS model all bridges and culverts were modeled using the energy method for low flow if no bridge piers were present. Where bridges had piers, the energy and momentum method was selected and the highest energy answer was then used in the HEC-RAS model for the resulting computations. For the momentum method, the coefficient of drag for the piers was 1.20 at all piers except 1.60 was used at East Manoa Road and Waialae Avenue Bridges, 2.0 was used at the double box culvert at 10th Avenue. For situations where the water surface elevation reaches the low chord of the bridge, the pressure and weir method was selected at all bridges except for those bridges crossing the Ala Wai Canal, Manoa-Palolo Drainage Canal, and Dole Street Bridge on Manoa Stream which used the energy only method due to the flat slopes of these reaches or in the case of Dole Street, where the low chord was 10 feet higher than the 0.2-percent ACE flood elevation.

For determining blocked bridge potential from debris, both from large boulders or floating vegetation, the type of bridge, bridge location, and historical performance was used to determine the percent blockage which was used for all flow modeling. In general, concrete lined channels with supercritical flow tend to wash debris downstream quickly and maintain a “self-cleaning” condition. Most urban debris and trash is small in size with bicycles being the largest observed. Such sized debris has a low potential to create a blockage. In small steep channels, large vegetative debris also has low potential for downstream movement as such debris gets trapped or lodged across the channel and only after being broken up by the force of water will smaller pieces begin to be transported downstream.

The first bridge or culvert in the HEC-RAS model below the forest reserve or undeveloped areas was given a 25% reduction in open area blockage to represent the potential for sediment or debris to constrict these openings. Other percent reductions used were 15% and 45% (Table A-2). Two bridges in Manoa, East Manoa Road and Woodlawn Drive have had serious debris problems during the 2004 flood event so were given blocked areas equivalent to those determined from that event. All blockages were modeled in the HEC-RAS model by creating obstructions to a height from the channel bed to an elevation that represents the percent reduction in area. This was done by culvert blockage routines for culverts or cross-section obstructions for bridges in the HEC-RAS model.

Table A-2. Bridge and Culvert Location and Information used in the Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii

Table 2. **Bridge and Culvert Location and Information used in the Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii**

Model Stream Names		Model Cross-section Location	Name of Crossing	Type of Structure	Bed Material under Crossing	Percent Blockage used for Debris
River	Reach					
Ala Wai	Middle	3020	McCully St	Bridge w/piers	Natural	----
Ala Wai	Lower	2280	Kalakaua Ave	Bridge w/piers	Natural	----
Ala Wai	Lower	370	Ala Moana Blvd	Bridge w/piers	Natural	----
Kanaha	Ditch	3168	Nehoa St	Box Culvert	Concrete	25
Kanaha	Ditch	2346	Lewalani Dr	Box Culvert	Concrete	----
Kanaha	Ditch	1713	Liholiho St	Bridge	Concrete	----
Kanaha	Ditch	1533	Private Dr upstream of Kewalo	Bridge	Concrete	----
Kanaha	Ditch	1386	Kewalo St	Bridge	Concrete	----
Kanaha	Ditch	798	Keeamoku St	Bridge	Concrete	----
Kanaha	Ditch	237	Makiki St	Arch Culvert	Concrete	----
Kanaha	Ditch	102	Underground section just upstream of Makiki Stream confluence	Bridge	Concrete	----
Makiki	Upper	8575	Makiki St	Bridge	Concrete	25
Makiki	Upper	8290	Oneele Pl	Bridge	Natural	----
Makiki	Upper	7974	Private Dr just downstream of Oneele Pl	Bridge	Natural	----
Makiki	Upper	7330	Nehoa St and underground section	Box Culvert	Concrete	----
Makiki	Lower	6272	Anapuni St	Box Culvert	Concrete	----
Makiki	Lower	6029	Wilder St	Bridge	Concrete	----
Makiki	Lower	5337	Underground Section just downstream of Wilder St	Box Culvert	Concrete	----
Makiki	Lower	4544	Wooden Deck Bridge downstream of underground section	Bridge	Natural	----
Makiki	Lower	3639	Underground Section at S. Beretania St	Box Culvert	Concrete	10
Makiki	Lower	2547	Private Drive just upstream of Phillip St	Bridge	Natural	----
Makiki	Lower	2435	Phillip St	Bridge	Concrete	----

Table 2. **Bridge and Culvert Location and Information used in the Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii ---- Continued**						
Model Stream Names		**Model Cross-section Location**	**Name of Crossing**	**Type of Structure**	**Bed Material under Crossing**	**Percent Blockage used for Debris**
River	**Reach**					
Makiki	Lower	2228	Covered section just downstream of Phillip St	Bridge	Concrete	---
Makiki	Lower	1311	Fern St	Bridge	Concrete	---
Manoa	Main	14686	Pawaina St	Bridge	Natural	---
Manoa	Main	10461	Kahaloa Dr	Bridge	Concrete	---
Manoa	Main	9273	Lowrey Ave	Bridge	Concrete	---
Manoa	Main	8749	East Manoa Rd	Bridge w/piers	Concrete	25
Manoa	Main	7756	Woodlawn Dr	Bridge	Natural	45
Manoa	Main	2520	Dole St	Bridge w/piers	Natural	---
Palolo	Main	15248	Kiwila Rd	Box Culvert	Concrete	---
Palolo	Main	13489	Kahlua Rd	Bridge	Concrete	---
Palolo	Main	12621	Paalea Ave	Box Culvert	Concrete	---
Palolo	Main	11053	Private Rd	Bridge	Concrete	---
Palolo	Main	10863	Private Rd	Bridge	Concrete	---
Palolo	Main	9873	Palolo Ave	Arch Culvert	Concrete	---
Palolo	Main	7515	3rd Ave	Arch Culvert	Concrete	---
Palolo	Main	6578	St Louis Dr	Arch Bridge	Concrete	---
Palolo	Main	6059	Footbridge	Bridge	Concrete	---
Palolo	Main	5343	Koali Rd	Bridge	Concrete	---
Palolo	Lower	5110	Waialae Ave	Bridge w/piers	Natural	---
Palolo	Lower	4732	H-1 Highway	Bridge w/piers	Natural	---
Palolo	Lower	4501	South King St	Bridge w/piers	Natural	---
Palolo	Lower	4031	Kapiolani Blvd	Bridge w/piers	Natural	---
Palolo	Lower	2317	Date St	Bridge	Natural	---
Pukele	Tributary	3172	Palolo Ave/10th Ave	Box Culvert	Natural	25
Pukele	Tributary	355	Ahe St	Box Culvert	Concrete	---
Waiomao	Tributary	1924	10th Pl	Box Culvert	Concrete	25
Waiomao	Tributary	1268	10th Ave	Double Box Culverts	Concrete	10

3.1.5. Peak Flow Data

Peak flow data from the Manoa and Ala Wai hydrologic studies (Oceanit, 2008a and 2008d) were used after adjusting these peak flow values with updated rainfall-frequency data at the hydrologic model junctions. Peak flow data for the 50-year Future Climate Change Scenarios can be found in Appendix R. The peak flow frequency data was then adjusted from the hydrologic model junctions to corresponding cross-section locations in the HEC-RAS model

where the flow would enter the stream channel in order to capture the change in flow that would occur during each of the frequency based events. There were areas where flow left the main stream channel and followed a new path downhill. To account for these split flow areas, lateral weirs were set to enter the split flow reach at specific stream stations. The HEC-RAS program calculates the weir flow leaving the stream and into the split flow "stream" channel. In the flow file the initial flow for the split flow reaches were set to 1 cubic foot per second (cfs) and the split flow optimization algorithm was used to balance the amount of flow being diverted depending on the value of the peak flow frequency. The peak-flow values used and the input model locations are presented in Table A-3. The 1-percent ACE peak flow for the Ala Wai Canal in this model was 19,500 cfs. Previous estimates of the 1-percent ACE peak flow value at the mouth of the Ala Wai Canal have ranged from 22,900 cfs (Edward K. Noda and Associates, Inc., 1994) to 28,200 cfs (Federal Emergency Management Agency, 2004).

Table A-3. Input Peak Flow Discharges in cubic feet per second for Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii

Table 3. **Input Peak Flow Discharges in cubic feet per second for Ala Wai watershed HEC-RAS Model, Honolulu, Hawaii**

Model Stream Names		Model Input Cross-section Location	Percent Chance Flood							
River	Reach		50%	20%	10%	5%	2%	1%	0.5%	0.2%
Ala Wai	Upper	9724	1,000	1,400	1,800	2,300	3,040	3,600	4,320	5,300
Ala Wai	Middle	5825	4,500	7,300	9,500	12,400	16,200	19,400	22,500	26,900
Ala Wai	Lower	2324	8,000	11,500	13,500	16,000	18,000	19,500	20,500	22,000
Kanaha	Ditch	4372	270	500	700	930	1,240	1,500	1,790	2,200
Kanaha	Split	3508	1	1	1	1	1	1	1	1
Makiki	Upper	10768	200	390	560	770	1,080	1,360	1,680	2,150
Makiki	Upper	7674	300	580	800	1,100	1,500	1,900	2,300	2,900
Makiki	Lower	6286	700	1,300	1,800	2,490	3,420	4,230	4,950	5,940
Makiki	Lower	3189	810	1,390	1,980	2,520	3,460	4,320	5,040	6,030
Makiki	Lower	1465	880	1,570	2,210	2,890	3,990	5,010	5,780	7,220
Manoa	Main	16506	1,200	2,000	2,600	3,350	4,500	5,400	6,200	7,600
Manoa	Main	10968	1,940	3,200	4,200	5,280	7,140	8,350	9,400	11,400
Manoa	Main	9274	2,080	3,450	4,350	5,450	7,200	8,410	9,500	11,600
Manoa	Main	7839	2,200	3,650	4,600	5,700	7,500	8,700	10,000	12,500
Manoa	Main	6175	2,320	3,800	4,800	6,100	7,900	9,360	11,000	12,900
Manoa	Main	2477	2,500	4,100	5,200	6,530	8,800	10,200	12,000	14,200
Manoa	Main	1807	2,700	4,300	5,600	6,900	9,250	10,700	13,000	15,000
Manoa	Main	1230	2,900	4,600	6,100	8,200	10,400	12,500	14,500	17,400
Palolo	Main	15526	1,100	2,100	3,000	3,930	5,430	6,700	8,020	9,990
Palolo	Main	9520	1,350	2,420	3,400	4,340	5,900	7,420	9,000	11,000
Palolo	Main	7552	1,450	2,580	3,500	4,560	6,350	7,900	9,400	12,000
Palolo	Lower	5198	4,200	7,100	9,200	12,000	16,000	18,500	22,100	26,500
Pukele	Tributary	5958	440	850	1,200	1,600	2,280	2,800	3,350	4,200
Pukele	Tributary	3629	640	1,200	1,720	2,300	3,090	3,730	4,450	5,400
UH_Split	UH_Split	6929	1	1	1	1	1	1	1	1
Waiomao	Tributary	4900	650	1,140	1,580	2,050	2,700	3,200	3,800	4,700

3.1.6. Split Flow Assumptions

During the development of the Ala Wai Watershed HEC-RAS model, potential locations where peak-flow discharges leave the defined stream channels and do not return were identified by model results, previous models (USACE, 2005) or from knowledge of previous flood events. These locations were modeled in HEC-RAS through the use of lateral weirs (structures) and the split-flow optimization routine in steady flow models. In sections of the model where overtopping flow would move parallel to the stream channel or downhill, no lateral weirs were used. Two locations, along Kanaha and Manoa Streams, were modeled as "stream reaches" to account for the floodplain impacts of these flows and at Waikiki the flow was allowed to leave the model to go into the ocean. The use of split-flow optimization reduces the flow in the stream channel downstream of the lateral weir location if peak-flows leave the channel.

Kanaha Ditch is a cross slope man-made drainage channel that carries runoff to the Makiki Stream. Between Nehoa Street and Lewalani Drive flood waters in the model overtop the right bank (looking downstream) and would tend to flow away from the ditch to the south (**Figure A-3**).

A number of lateral weirs were created in the HEC-RAS model along the right bank of the Kanaha Ditch Reach. Those weirs were set at the top of the right bank elevations of the ditch and the overflow was assigned to specific cross-sections in the split-flow reach where it was presumed to flow. Weir flow coefficients were set between 1 and 2.2. For all lateral weirs in the model, the weir flow coefficient was determined depending on the round roughness conditions near those areas which would represent the most likely overflow conditions. The Kanaha Split reach extends about 2,600 ft down slope past Wilder Avenue to the H-1 Freeway area. Elevation data provided indicates that the flood extent would not cross the freeway. The model of this split flow reach does not account for the collection of the overtopping flows to be collected by the local storm drain system.

The Manoa Stream split flow reach is called the UH Split reach in the model. This reach was added along Manoa Stream up- and downstream of Woodlawn Drive Bridge. Lateral weirs were added along the right bank of Manoa Stream to account for the overtopping flows which inundated the University of Hawaii campus in 2004. Weir flow coefficients were set at 2.0. The UH Split reach extends for about 6,900 ft from Woodlawn Drive to the lower campus quarry area where it is assumed that the flow would pond and not flow back into Manoa Stream or to the Manoa-Palolo Drainage Canal. Again, in the model this split-flow reach does not account for the collection of the overtopping flows in the reach to be collected by the local storm drain systems.

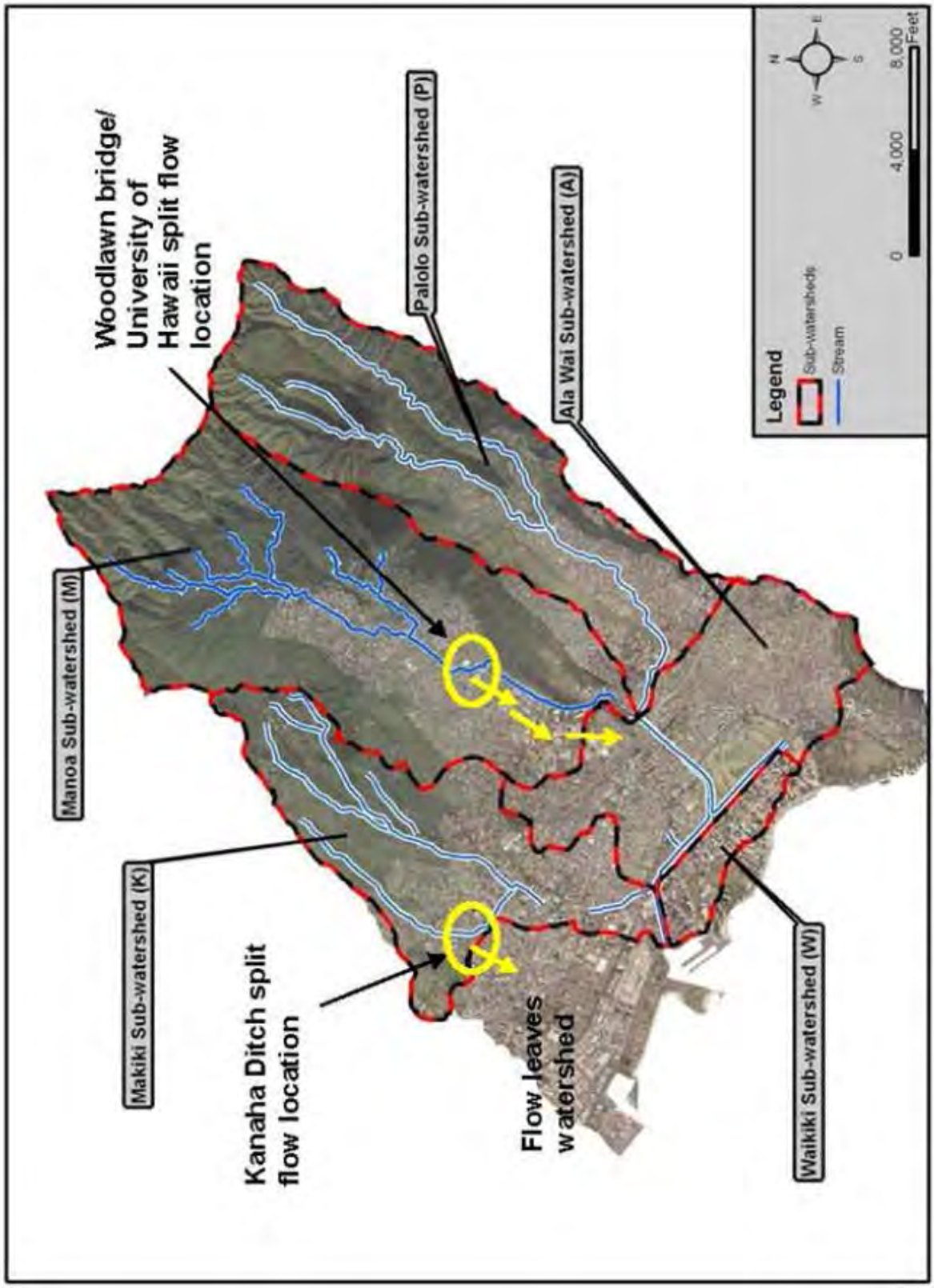

Figure 3. Location of the Split Flow Reaches in the Ala Wai Watershed, Oahu, Hawaii

Figure A-3: Location of the Split Flow Reaches in the Ala Wai Watershed, Oahu, Hawaii

Along the left overbank of the Ala Wai Canal, from its upstream end down to about McCully Street, flow overtops the "ridge-line" along Waikiki and leaves the model by entering the ocean. This overtopping of the natural topography begins to occur at approximately elevation 6 feet. The flow leaving the system effectively reduces the discharge in the lower end of the canal. To account for the overtopping, lateral weirs were inserted into the model along the Middle and Upper Ala Wai Canal Reaches. Since these weirs are located in an urban environment, weir flow is influenced by the proximity of buildings, automobiles, etc. A weir coefficient of 1 was used here. The lateral weirs were set to allow the flow to leave the system (model).

Table 4 shows all of the lateral structures, the 10-, 2-, 1-, and 0.2-percent (10-, 50-, 100-, and 500-Year) ACE events are shown. The flow upstream (Q US), total flow leaving the structure (Q Leaving Total), and the downstream flow (Q DS) are shown in this table.

Table A-4. Lateral Structure Output Table A-in cubic feet per second for Without-Project Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii

River	Reach	River Sta	Profile	Q US (cfs)	Q Leaving Total (cfs)	Q DS (cfs)
Pukele	Tributary	236	10 yr	1720	0	1720
Pukele	Tributary	236	50 yr	3090	0	3090
Pukele	Tributary	236	100 yr	3730	35.88	3694.12
Pukele	Tributary	236	500 yr	5400	458.08	4941.92
Manoa	Main	7946	10 yr	4350	0	4600
Manoa	Main	7946	50 yr	7200	3.44	7496.56
Manoa	Main	7946	100 yr	8410	18.16	8681.84
Manoa	Main	7946	500 yr	11600	267.87	12232.04
Manoa	Main	7706	10 yr	4600	0	4600
Manoa	Main	7706	50 yr	7496.56	63.23	7433.33
Manoa	Main	7706	100 yr	8681.84	139.71	8542.13
Manoa	Main	7706	500 yr	12232.04	549.47	11682.68
Manoa	Main	1821	10 yr	5200	0	6100
Manoa	Main	1821	50 yr	8733.33	0	10333.33
Manoa	Main	1821	100 yr	10042.13	0	12342.13
Manoa	Main	1821	500 yr	13382.68	106.84	16475.84
Kanaha	Ditch	3000	10 yr	700	238.67	479.67
Kanaha	Ditch	3000	50 yr	1240	635.96	639.94
Kanaha	Ditch	3000	100 yr	1500	814.04	691.99
Kanaha	Ditch	3000	500 yr	2200	1569.19	630.74
Kanaha	Ditch	2770	10 yr	479.67	112.5	366.45
Kanaha	Ditch	2770	50 yr	639.94	257.05	369.09
Kanaha	Ditch	2770	100 yr	691.99	419.42	259.73
Kanaha	Ditch	2770	500 yr	630.74	3841.41	2.2
Kanaha	Ditch	2150	10 yr	366.45	0	366.45
Kanaha	Ditch	2150	50 yr	369.09	0	278.63
Kanaha	Ditch	2150	100 yr	259.73	599.11	2.1
Kanaha	Ditch	2150	500 yr	2.2	8515.67	2.2

Table A-4. Lateral Structure Output Table A-in cubic feet per second for Without-Project Ala Wai Watershed HEC-RAS Model, Honolulu, Hawaii

River	Reach	River Sta	Profile	Q US (cfs)	Q Leaving Total (cfs)	Q DS (cfs)
Kanaha	Ditch	1660	10 yr	366.45	9.75	357.75
Kanaha	Ditch	1660	50 yr	278.63	226.44	52.39
Kanaha	Ditch	1660	100 yr	2.1	942.36	1.5
Kanaha	Ditch	1660	500 yr	2.2	3334.33	2.2
Kanaha	Ditch	1500	10 yr	357.75	69.47	297.29
Kanaha	Ditch	1500	50 yr	52.39	836.33	1.24
Kanaha	Ditch	1500	100 yr	1.5	1839.66	1.5
Kanaha	Ditch	1500	500 yr	2.2	4403.5	2.2
Kanaha	Ditch	1300	10 yr	297.29	56.86	239.88
Kanaha	Ditch	1300	50 yr	1.24	1995.39	1.24
Kanaha	Ditch	1300	100 yr	1.5	3928.1	1.5
Kanaha	Ditch	1300	500 yr	2.2	8720.99	2.2
Kanaha	Ditch	1170	10 yr	239.88	64.99	178.05
Kanaha	Ditch	1170	50 yr	1.24	1275.16	1.24
Kanaha	Ditch	1170	100 yr	1.5	2448.04	1.5
Kanaha	Ditch	1170	500 yr	2.2	5336.15	2.2
Kanaha	Ditch	990	10 yr	178.05	53.02	125.83
Kanaha	Ditch	990	50 yr	1.24	877.81	1.24
Kanaha	Ditch	990	100 yr	1.5	1667.37	1.5
Kanaha	Ditch	990	500 yr	2.2	3605.37	2.2
Kanaha	Ditch	700	10 yr	125.83	7.8	118.06
Kanaha	Ditch	700	50 yr	1.24	1153.07	1.24
Kanaha	Ditch	700	100 yr	1.5	2403.33	1.5
Kanaha	Ditch	700	500 yr	2.2	5556.16	2.2
Kanaha	Ditch	500	10 yr	118.06	0	118.06
Kanaha	Ditch	500	50 yr	1.24	552.51	1.24
Kanaha	Ditch	500	100 yr	1.5	1546.69	1.5
Kanaha	Ditch	500	500 yr	2.2	4262.07	2.2
Ala Wai	Upper	9720	10 yr	1800	1119.61	686.11
Ala Wai	Upper	9720	50 yr	3040	4838.43	3.04
Ala Wai	Upper	9720	100 yr	3600	7239.85	3.6
Ala Wai	Upper	9720	500 yr	5300	12105.42	5.3
Ala Wai	Middle	5800	10 yr	8386.11	595.42	7794.97
Ala Wai	Middle	5800	50 yr	13093.33	2057.69	11035.64
Ala Wai	Middle	5800	100 yr	15642.13	2823.31	12818.82
Ala Wai	Middle	5800	500 yr	20675.85	4158.09	16517.75

3.1.7. Boundary Conditions

Since the Ala Wai Watershed HEC-RAS model is a steady state hydraulic model, only peak flow data and boundary conditions for each event to be modeled were required. In a steady flow model, peak-flow hydrographs traveling from one stream to the next are assumed to occur peak to peak. Boundary conditions for upstream junctions or tributary streams are based on the model results from the downstream reach. The downstream boundary condition for the entire model is the mouth of the Ala Wai Canal where the starting water-surface elevation of 1.08 feet which is the Mean Higher High Water (MHHW) level at the Honolulu Harbor tide gage. The starting water-surface elevation for the Kanaha Split reach was set to normal depth (slope=0.0171). The starting water-surface elevation for the UH Split reach was set to normal depth (slope=0.0019). The starting water-surface elevations for the remaining streams were determined as a result of the hydraulic calculations of the stream junctions. All junctions were set to compute water-surface elevations using the Energy Method.

4. WITHOUT PROJECT MODEL RESULTS AND FLOOD INUNDATION MAPPING

The HEC-RAS model was used to determine the water-surface elevations and floodplain extents for the 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent ACE floods (2-5-, 10-, 20-, 50-, 100-, 200-, and 500-year recurrence intervals). Floodplain extents for the 10-, 50-, 100-, and 500-year recurrence intervals are shown on Figures A-4 through A-7. The water-surface elevation data for the 8 flood events are used in the HEC-FDA (Flood Damage Analysis) program to determine flood damages for the economic analyses. The HEC-FDA program uses the water-surface elevations in determining flood damages and not the flood maps, so any irregularities in the presented maps has no impact on the damage calculations.

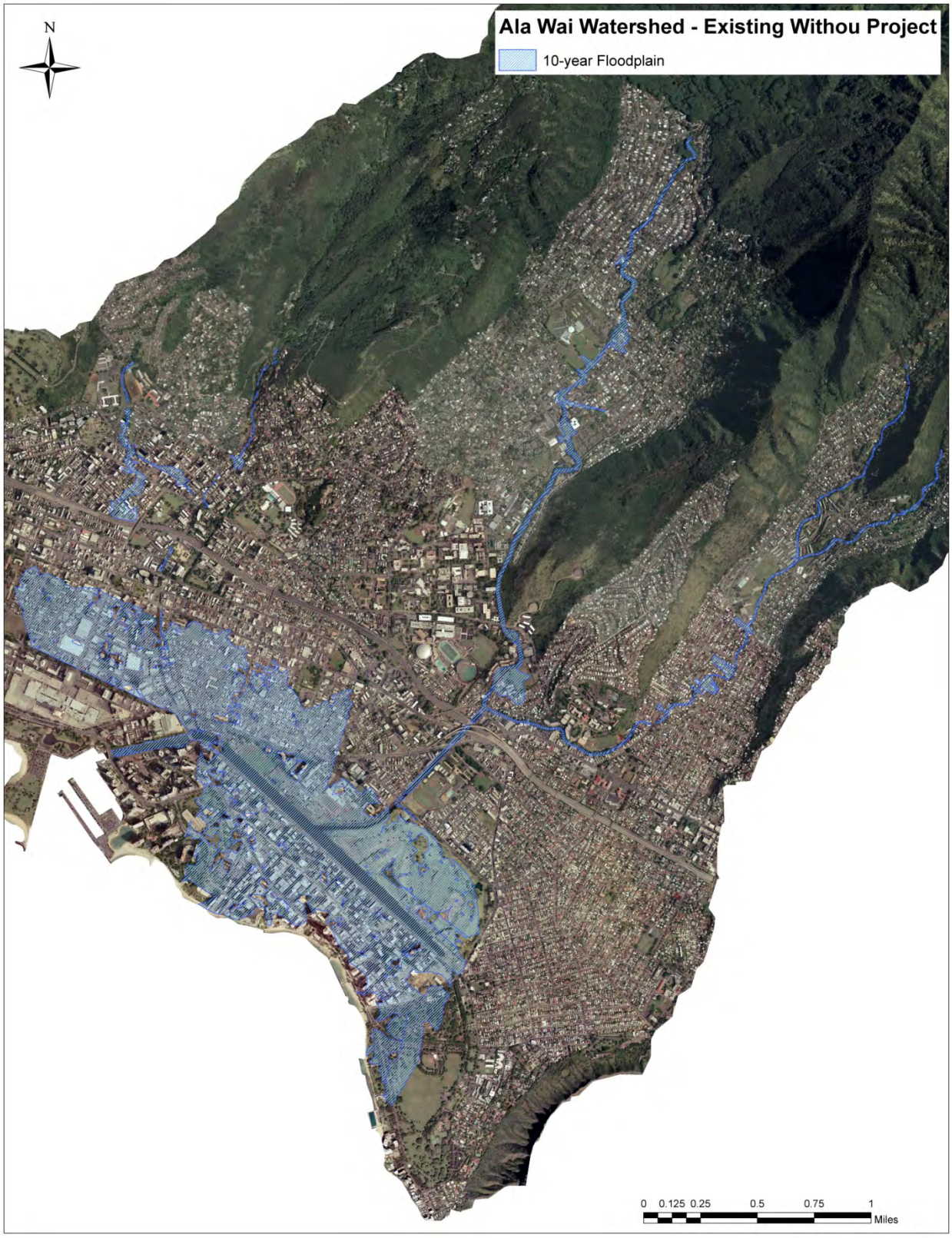

Figure A-4: Floodplain Outlines for the 10-Percent ACE (10-year) Flood, Ala Wai Watershed, Oahu, Hawaii

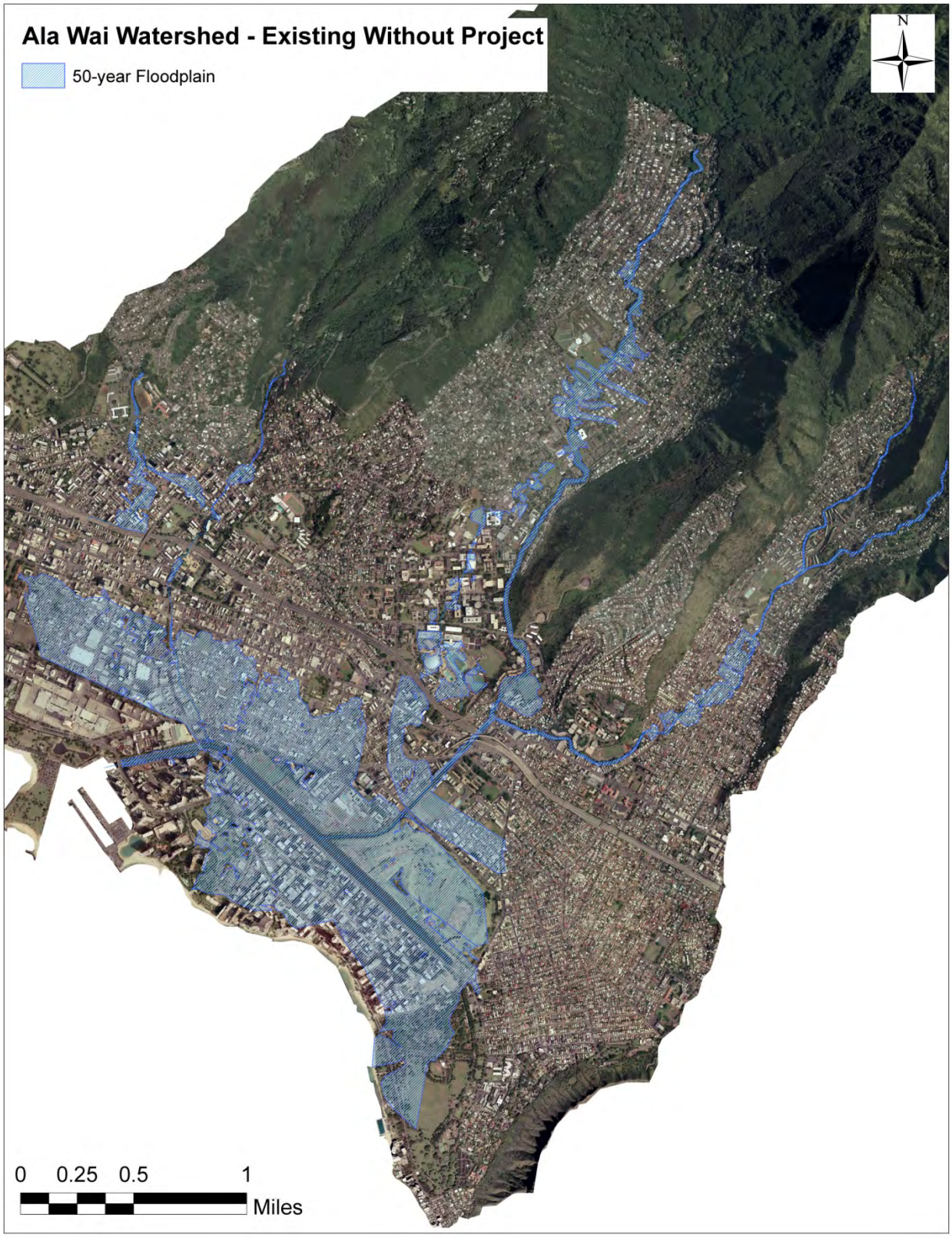

Figure A-5: Floodplain Outlines for the 2-Percent ACE (50-year) Flood, Ala Wai Watershed, Oahu, Hawaii

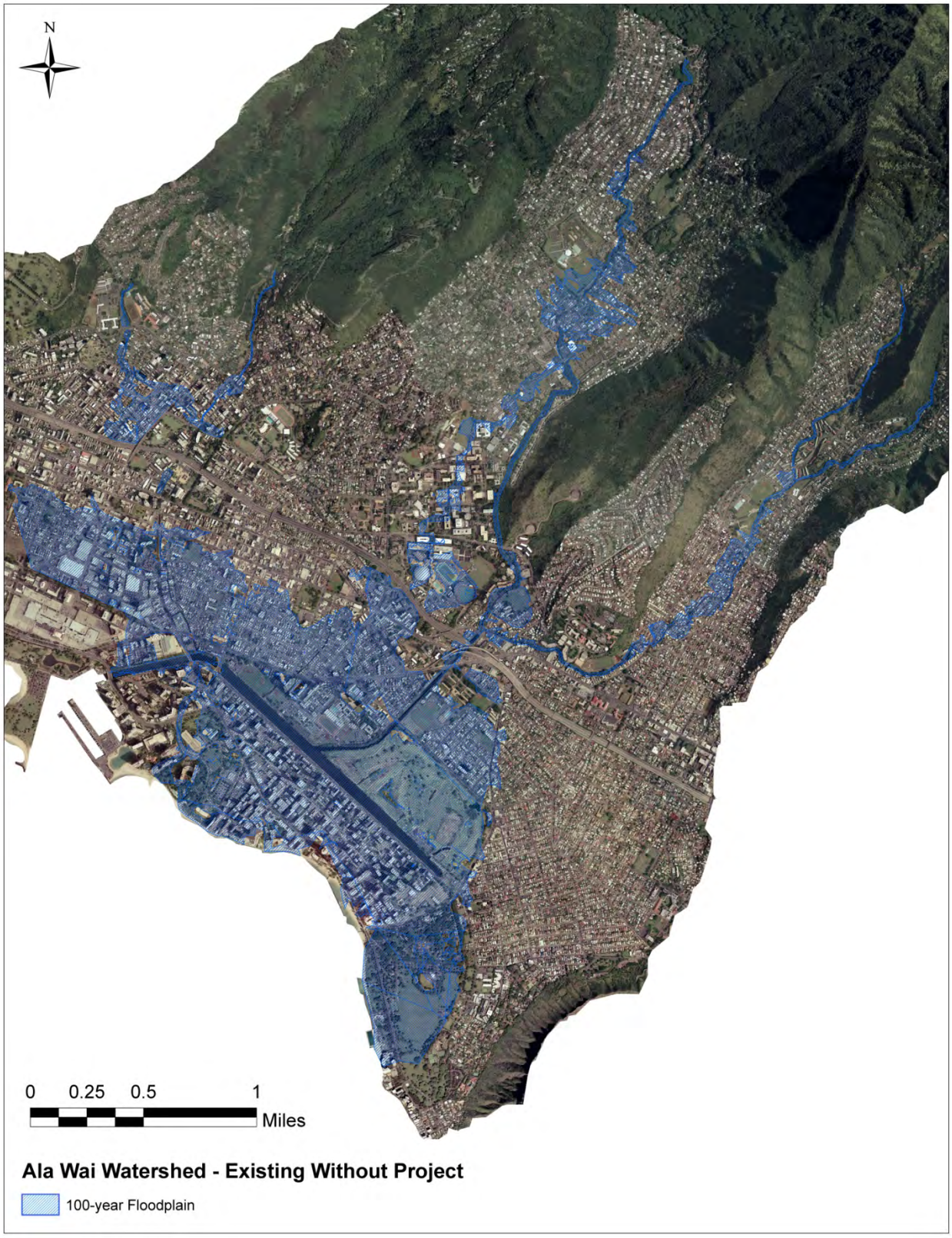

Figure A-6: Floodplain Outlines for the 1-Percent ACE (100-year) Flood, Ala Wai Watershed, Oahu, Hawaii

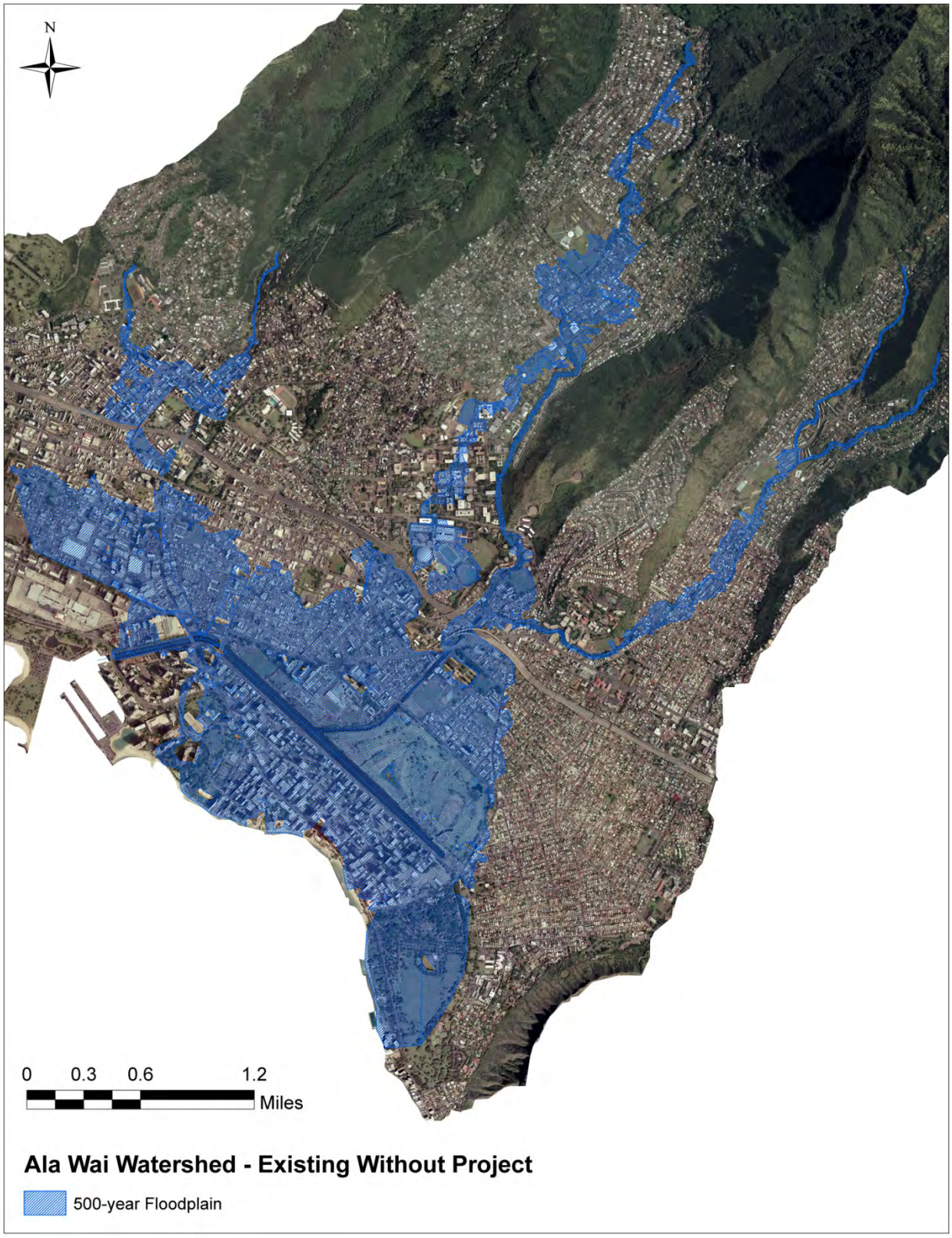

Figure A-7: Floodplain Outlines for the 0.2-Percent ACE (500-year) Flood, Ala Wai Watershed, Oahu, Hawaii

4.1. Model Limitations

The HEC-RAS model was designed as a steady flow model using a mixed flow regime solution. As such, a number of warning messages appeared in several reaches indicating an unbalanced solution at cross sections resulting in critical depth or non-convergence. In steep reaches this message typically indicates the model is defaulting to critical depth because a super-critical flow answer is possible. The subcritical regime provides a conservative estimate of water-surface elevations for evaluating flooding but a mixed flow solution is more accurate. A mixed flow regime uses both subcritical and supercritical regimes. In less steep reaches, the primary reason for warning messages is probably due to the sharp contrast in Manning's n values between the channel at 0.018 to 0.04 and the overbanks at 0.125. The convergence problem seems to be most pronounced at bridges and culverts where the bridge deck and presence of weirs complicate the model solution process. Slight adjustments to ineffective flow limits helped reduce the non-convergences, but there are some locations where the messages could not be avoided for all storm events. One such location is the Makiki Stream between Anapuni Street and Wilder Street (cross sections 6316 to 5952).

Other warning messages such as conveyance ratios exceeding the 0.7 to 1.4 guidelines, velocity head differences exceeding 0.5 ft and energy losses greater than 1.0 ft between cross sections are due to the cross section geometry of the study area and cannot be avoided. Cross-section spacing can help with the steady flow solution. Average cross-section spacing for the various reaches in the Ala Wai Watershed HEC-RAS model is presented in Table A-5. In general, cross-section spacing from 50 to 100 ft in steep reaches and from 250 to 750 ft in flat reaches is adequate. In concrete channels such as Makiki Lower and Palolo Main reaches cross-sections were spaced at least 25 ft apart, this is to gain accuracy.

The use of split flow reaches to model areas where there is no flow under normal conditions are difficult to model accurately. The HEC-RAS model as with all hydraulic models, require a flow value to be used for each reach. Zero flow is not an allowable input value. For the Kanaha and UH Split reaches a flow value of 1 cfs was used as the initial input. Even with just a 1 cfs flow there will be a water-surface elevation, when in some cases there should be no water at all. For the 50- to 10-percent ACE floods, when flow is not leaving the main channel, the model results would indicate flood depths, although very low, when none would be present. This is a model artifact which needs to be accounted for when making flood inundation maps or using the data in HEC-FDA. For HEC-FDA, the water-surface elevation input data was changed to ground elevation at certain locations and flood events based on logic.

Table A-5. Cross-section Spacing in the Ala Wai Watershed HEC-RAS Model, Oahu, Hawaii

HEC-RAS River, and Reach Names	Avg Cross-section Spacing in Feet
Ala Wai Canal, Upper, Middle, and Lower	286
Kanaha, Ditch (includes interpolated)	47
Kanaha, Split	87
Makiki Stream, Upper	107
Makiki Stream, Lower	31
Manoa Stream, Main	61
Palolo Stream, Main	96
Palolo Stream, Lower (includes Manoa-Palolo Drainage Canal)	180
Pukele Stream, Tributary	97
UH_Split, UH_Split	160
Waiomao Stream, Tributary	90

4.2. Flood Inundation Mapping

The flood inundation maps in Figures A-4 to A-7 were generated by the HEC-GeoRAS software using TIN (Triangulated Irregular Network) elevation data and the maximum water-surface elevation profiles computed by HEC-RAS. A raster cell size of 5 feet was used to create the inundation outlines. HEC-GeoRAS converts the TIN elevation data and the maximum water-surface elevation data to raster layers with a 5 foot by 5 foot grid size before comparing them to one another. HEC-GeoRAS evaluates whether the water-surface elevation grid has a higher elevation than the ground-surface elevation grid. If the water-surface elevation was higher than the ground-surface elevation, the cell was considered inundated. The results were in raster datasets of the inundation depths. The inundation depth grid was then converted to a floodplain polygon coverage showing the maximum extents of flooding. The automated delineation process creates areas of no inundation, as the example figure, Figure A-8, shows areas or polygons where inundation is included or not included. As you can see in the figure there are some locations where inundation is not connected to the main inundation extents.

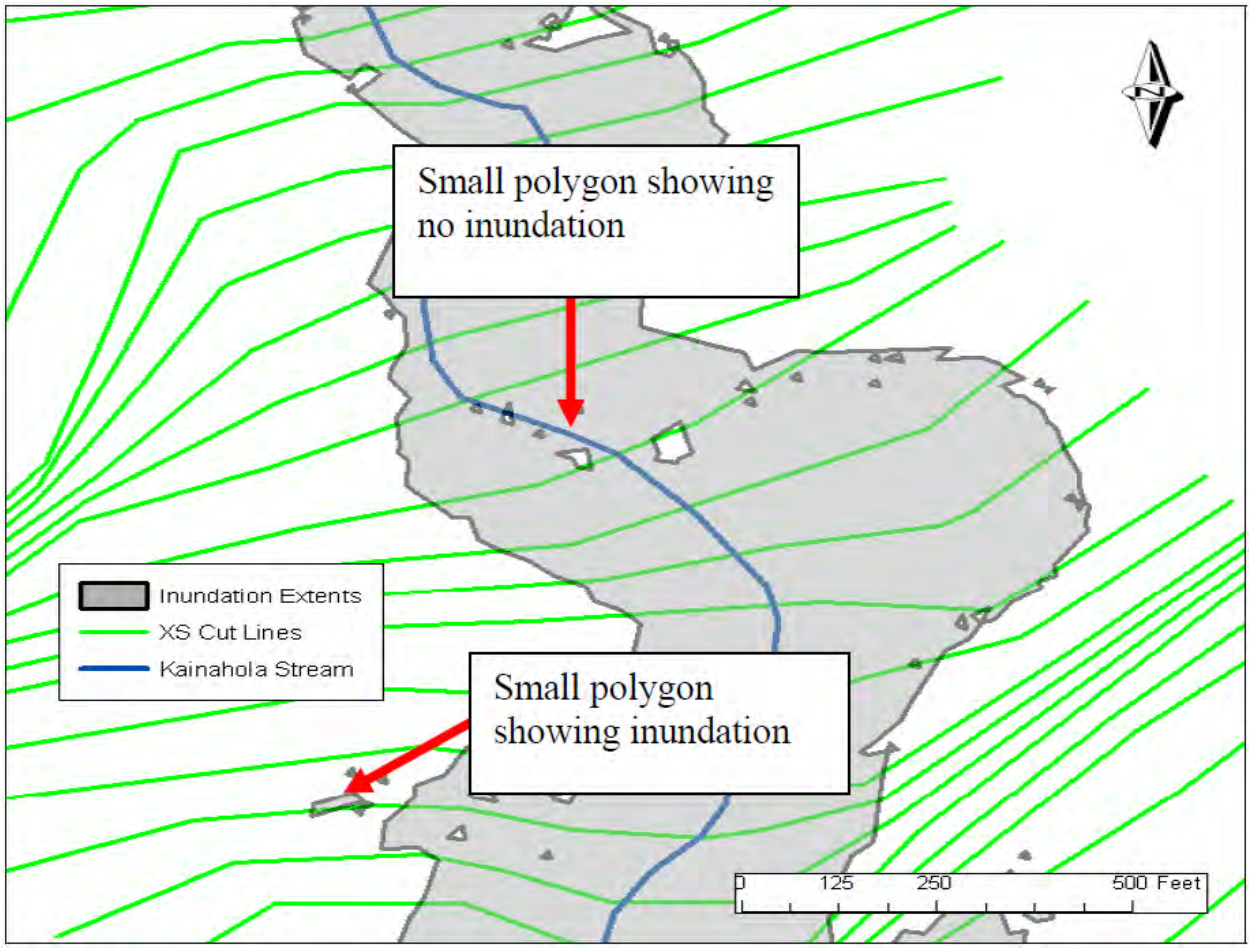

Figure A-8: Example of Inundation Extents Coverage Created by HEC-GeoRAS

Some non-connected areas of inundation, as described above, are an initial limitation of the mapping process because the computed water-surface is limited to the extents of the cross-sections; however, final mapping results should involve engineering judgment to modify the floodplain boundaries based on modeling assumptions and topographic data. If floodplain mapping is needed from the model results, then manual edits were done to either fill-in or remove areas where flooding is or is not likely to occur. An example of Figure A-8 with manual edits is shown on Figure A-9.

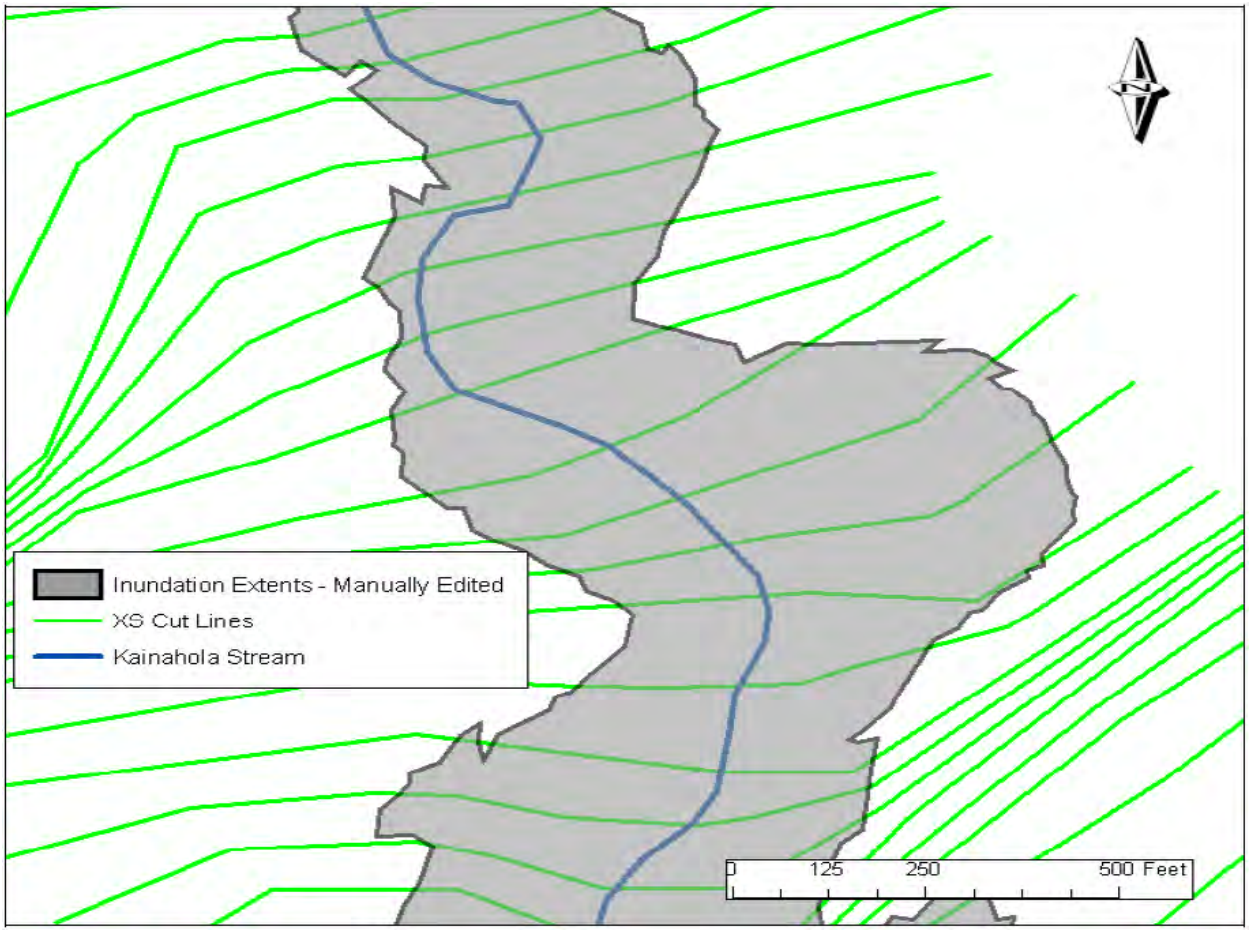

Figure A-9: Example of Inundation Extents Coverage Manually Edited

4.3. Model Results

The inclusion of the lateral weirs along the Waikiki area of the Ala Wai Canal reaches resulted in a reduction in peak flow downstream of McCully Street at the 1-percent ACE (100-year) flood event; a total of approximately 5,500 cfs leaves the system and flows into the ocean. With consideration of the effects of floodplain storage and backwater along Makiki Stream, the peak flow at the mouth of the canal is reduced to about 12,000 cfs from its upstream peak of 21,600 cfs. This results in a greatly reduced flood inundation area between Kalakaua Avenue and Ala Moana Boulevard. Based on the peak flow values computed for this study the Ala Wai Canal has about a 20- to 10-percent ACE (5- to 10-year) flood event capacity before overtopping. This is less than the 10-percent ACE (10-year) flood event capacity documented in Edward K. Noda and Associates, Inc. (1994) even with the dredging done in 2008. One reason for a reduced capacity may be due to the use of MHHW as a downstream boundary condition for all flood events and the use of a steady flow HEC-RAS model which tends to be more conservative then the in-house model used by Edward K. Noda and Associates, Inc. (1994). The Kalakaua Avenue Bridge was the main reason for high water-surface elevations in the upstream sections of the canal.

The flooding along lower Makiki Stream is mainly due to the high water-surface elevations of the Ala Wai Canal being such that the Makiki Stream cannot drain. Water backs up into Makiki and overtops the channel and floods the surrounding area. The flooding occurs between King Street and Kapiolani Boulevard. The elevations along Kapiolani Boulevard are slightly higher than the surrounding ground, and as a result, act as a berm or weir preventing most of the flow from flooding the downstream area. A small area in the vicinity of Kaheka Street allows flow to flow over Kapiolani Boulevard and eventually into the lower area of the parking facility of the Ala Moana Center. Channel capacities for the model reaches are listed in Table A-6. The split reaches don't have any capacities because they are not actual streams they are just the natural ground. The flooding inundation extents for lower Makiki Stream on Figures A-4 to A-7 are somewhat overestimated due to the small existing channel sizes and large floodplain areas modeled. The flood mapping routines will fill in the entire cross-section width even though water may not actually flow into those areas for other factors such as walls and buildings which are not always representative in the model.

Table A-6. Approximate Average Bankfull Channel Capacities and Beginning Level of Damages by Annual Probability for Stream Reaches in the HEC-RAS Model for the Ala Wai Watershed, Oahu, Hawaii

River	Reach	Average Bankfull Peak Discharge Capacity (cfs)	Percent Chance Flood	Recurrence Interval (yrs)
Ala Wai	Lower	12,200	10	10
Ala Wai	Middle	6,900	20	5
Ala Wai	Upper	1,300	20	5
Kanaha	Ditch	350	20	5
Kanaha	Split	N/A	N/A	N/A
Makiki	Upper	1,200	5	20
Manoa	Main	3,500 to 7,600	20 to 2	5 to 50
Palolo	Main	3,400 to 6,000	5 to 2	20 to 50
Palolo	Lower	15,400	5	20
Pukele	Tributary	2,700	2	50
UH_Split	UH_Split	N/A	N/A	N/A
Waiomao	Tributary	2,600	2	50

The flooding along Kanaha Ditch is similar to the flooding along Makiki Stream. The water-surface elevation at the confluence of the ditch causes a backwater effect in the ditch and does not allow it to drain. Water overtops the channel and flows down slope. Water flows across Wilder Street and floods the area approximately bounded by Kewalo Street and Keeamoku Street. Water is stopped by the H1 Freeway where it will pond and presumably make its way into the stormwater drainage systems.

Another issue with the flood modeling in the Makiki area is the discharge contained in the stream channel where floodwalls exist. These floodwalls are built upon the stream channel walls (**Photo 1**) and may or may not prove suitable to contain large flood events. It was assumed in the HEC-RAS model that none of these types of levee-like structures would fail during any of the model runs. Photo 2 shows that some locations may not prove adequate and the resulting flood inundation areas may be larger than shown on Figures A-4 to A-7.

As can be seen for the flood inundation maps (Figures A-4 to A-7), the floodplain boundaries for the lower Makiki Stream, the Manoa-Palolo Drainage Canal, and the Ala Wai Canal are shown in some areas as reaching the Watershed boundaries. This result could be overly conservative if the hydrograph volume is insufficient to produce such flooding. Also, the flood inundation limits reach the model boundary such as at the upper end of the Ala Wai Canal. Flooding at these locations will more than likely flow into Kapiolani Park and then into the ocean. A manually edited map should account for this possibility.

Results of the detailed modeling of Palolo Stream indicate a channel capacity capable of holding a 2-percent ACE (50-year) flood event between Palolo Avenue Bridge and Kahlua Road Bridge. The capacity downstream is between the 5- to 2-percent ACE (20- to 50-year) flood events.

As previously documented (USACE, 2005; Oceanit, 2008b) the Manoa Stream has channel capacity limitations between Kahaloa Drive Bridge and Woodlawn Drive Bridge which creates a flooding hazard for the nearby residences and the University of Hawaii campus.

Flood depths for the 1-percent ACE flood event around the Ala Wai Canal, Manoa-Palolo Drainage Canal, and lower Makiki Streams (Figure A-6) are about 1.5 to 3 feet deep on average for the out of channel floodplain. Flood depths are about 2 to 3 feet deep on average for the split flow reaches of Kanaha Split and the UH_Split overland flooding. In the upper Makiki, Manoa and Palolo Streams, flood depths can get up to 5 feet depending on the location.

5. WITH PROJECT HYDROLOGIC MODELING

5.1. Detention Analysis

In order to determine the effectiveness of detention basins throughout the Watershed, the HEC-HMS model, the Technical Summary Report, Manoa Watershed Project (Oceanit, 2008c), and other hydrologic analysis were used to study different detention basin scenarios.

5.1.1 Preliminary Analysis

Initially, 12 different sites were selected throughout the Watershed. Figure A-10 shows the locations of the proposed detention basins. Each detention basin was designed to maximize effectiveness while remaining within reasonable vertical and horizontal limitations. Each basin was examined to determine the potential flow reduction. Basins were analyzed for all eight storm events.

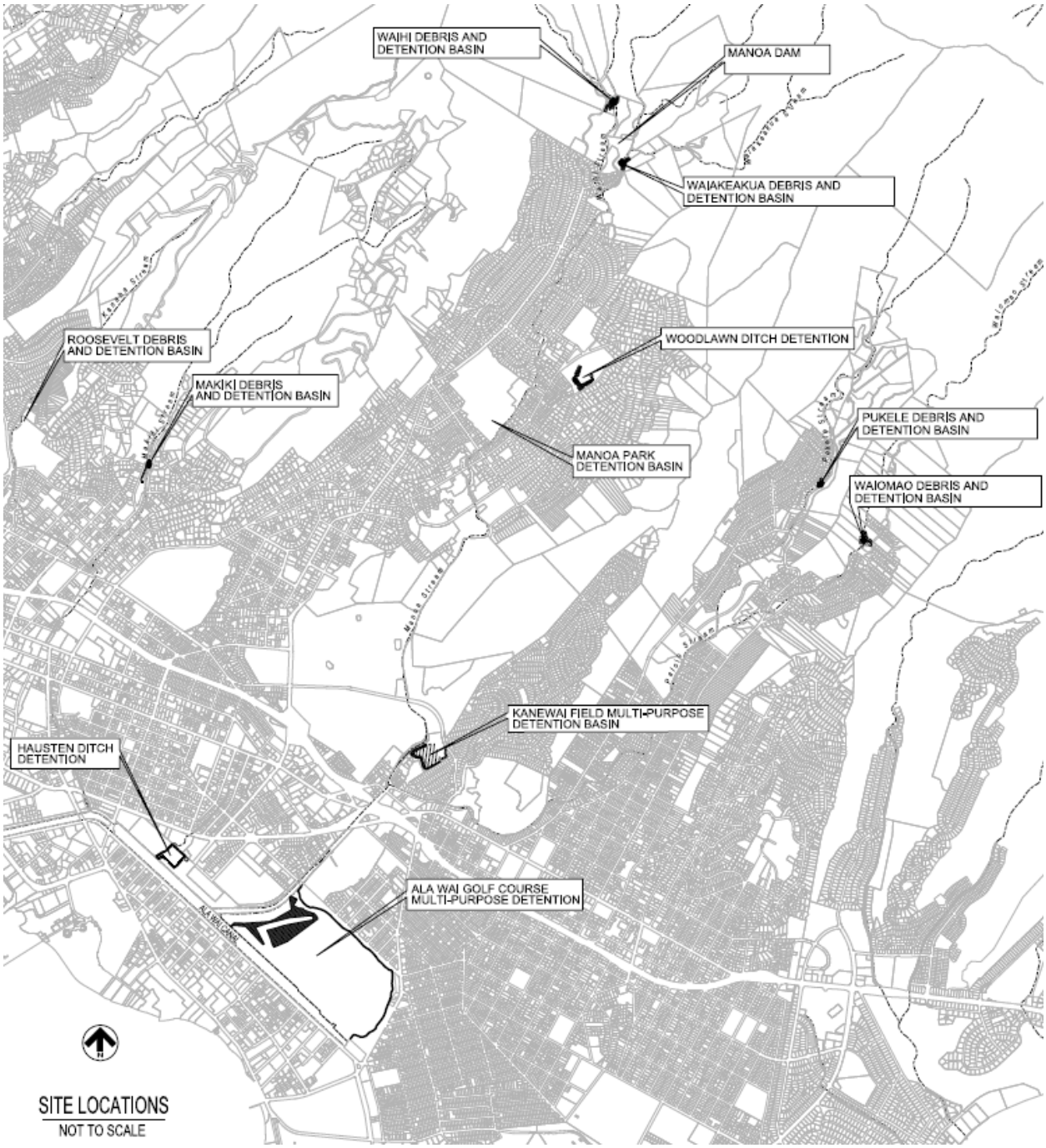

Figure A-10: Preliminary Detention Basin Locations

Roosevelt Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into Kanaha Stream. The design assumes a downstream capacity of 1,254 cfs and 20 foot high berms with an emergency spillway. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Kanaha Stream. In addition, the basin is

designed to use existing open space (i.e. no residential houses). There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 946 cfs to pass through into Kanaha Stream.

Makiki Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into Makiki Stream. The design assumes a downstream capacity of 450 cfs and 24 foot high berms with an emergency spillway. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Makiki Stream. In addition, the basin is designed to use existing open space (i.e. no residential houses). There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 390 cfs, the 20-percent ACE (5-year) storm, to pass through into Makiki Stream.

Hausten Ditch Detention

This basin is designed to temporarily contain water while the slide gates at Hausten Ditch Bridge are up. The slide gates will be down during a flood event to prevent water from Ala Wai Canal flowing back into Hausten Ditch. In addition, the basin is designed to use existing open space (i.e. no residential houses).

Ala Wai Golf Course Multi-Purpose Detention

This multi-purpose detention basin is designed to contain water on the golf course and prevent flood waters from leaving. There will be earthen berms constructed on the north and east sides of the golf course, the berms will basically follow the existing golf cart road. The berms have an average height of 3 feet.

A sediment basin would be located in the vicinity surrounding holes 12 to 18 of the Ala Wai Golf Course. Flows from the Manoa-Palolo Drainage Canal would be diverted into the sediment basin, which would help reduce the amount of sediment deposited into the Ala Wai Canal. Flows would reenter into the Canal at two locations, a new outlet connected to the sediment basin and an existing outlet.

Manoa Dam

This dam is designed to contain all of the predicted upstream storm water. Through modeling and rain data, it was determined that the dam needed to retain about 17,000,000 cubic feet of water behind the residential neighborhoods of Manoa. This large quantity of water severely restricted the dam location and forced a maximum height of 50 feet. Two spillways capable of handling 3,450 cfs each located above the river bed. The spillways were sized to allow overflow for a 0.2-percent ACE (500-year) storm, with a peak flow of 6,900 cfs. There are two outlets, one into Waihi Stream and one at the junction of Luaalea and Waiakeakua Stream. The Waihi Stream 5x7 foot culvert has a capacity of 1,770 cfs and the Waiakeakua Stream 5x6 foot culvert has a capacity of 1,890 cfs, representing flows from a 20-percent ACE (5-year) storm. Flows greater than this will cause water to back up and be retained behind the dam (Oceanit, 2008c). In addition, the structure is to not interfere with existing farms and houses near the basin site.

Waihi Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into the Manoa residential area. The design assumes a maximum downstream capacity of 3,000 cfs and a maximum 24 foot height and minimum containment of 125,000 cubic feet. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Manoa Stream. In addition, the structure is to not interfere with existing farms and houses near the basin site.

There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 2,000 cfs, the 20-percent ACE (5-year) storm, to pass through into Manoa Stream. The emergency spillway would begin to overflow when the retention capacity of 125,000 cubic feet is exceeded.

Waiakeakua Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into the Manoa residential area. The design assumes a maximum downstream capacity of 3,000 cfs and a maximum 20 foot height and minimum containment of 346,000 cubic feet. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Manoa Stream. In addition, the structure is to not interfere with existing farms and houses near the basin site.

There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 1,475 cfs, the 20-percent ACE (5-year) storm, to pass through into Manoa Stream. The emergency spillway can handle an extra 3,150 cfs should such high flows occur.

Woodlawn Ditch Detention Basin

The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Woodlawn Ditch will eventually flow into Manoa Stream. The design assumes a maximum downstream capacity of 2,750 cfs and a maximum 20 foot height, there is also a 3x80 foot concrete-lined emergency spillway. The design assumes that slightly less than 750 cfs will flow into Woodlawn Ditch while the remaining flow will be contained in the detention basin during a flood event.

There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 977 cfs out into Woodlawn Ditch.

Manoa Park Detention Basin

The basin is designed to use existing open space (i.e. no residential houses, use of park land) to create a detention basin that is both useful and aesthetically pleasing to the community. The detention basin is designed to handle an inflow of 4,250 cfs; additional flows up to 2,490 cfs will require the use of the emergency spillway. The berm has a maximum eight of 13 feet and it would border three sides of Manoa District Park. The intake pipes from Poelua Place lies underground and has a bubble-up structure located in the south east corner of the park, covered by a concrete pad to ease in clean-up procedures. The bubble-up structure intakes both 10x10

foot box culverts and has a 2 foot diameter concrete outlet pipe for slow drainage back into Manoa Stream. Any water that does not immediately drain is bubbled into the basin. The basin has graded contours to allow water to accumulate to the southeast corner of the park at the drainage. For aesthetics and for clean-up the three surrounding berms have bleachers on the inside. The new landscaped park has room to contain two baseball fields and a soccer field.

Kanewai Field Multi-Purpose Detention Basin

The basin is designed to use existing open space (park land) to temporarily contain floodwaters. The intake into Kanewai Field is intended to handle 3,960 cfs of the stream inflow and outflow. The existing drainage pipe is able to drain 62 cfs. Kanewai Field will be surrounded by a 7 feet high earthen berm, but protecting the existing structures. On the northwest end of the basin, adjacent to Manoa Stream, the berm is graded down to a 3x60 foot spillway that will allow water to flow into the basin when the river level is high and out of the basin once the high flows have passed.

Pukele Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into Pukele Stream. The design assumes a downstream capacity of 1,700 cfs and a 24-foot high berm with an emergency spillway. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Makiki Stream. There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 300 cfs, to pass through into Pukele Stream.

Waiomao Debris and Detention Basin

This basin is designed as both a way to temporarily contain water and stop the flow of debris into Waiomao Stream. The design assumes a downstream capacity of 1,540 cfs and a 24-foot high berm with an emergency spillway. The basin is not designed to permanently contain water, but to detain large volumes of water to slow the rate into Makiki Stream. There is an arch culvert under the berm; it is 12 feet long and 4 feet, 1 inch high. The outlet allows about 400 cfs, to pass through into Pukele Stream.

6. WITH PROJECT HYDRAULIC MODELING

6.1. Detention Analysis

For each of the detention scenarios modeled (See With Project Hydrologic Modeling Section) the HEC-RAS model was modified with the revised flows.

6.2. Debris Catchment Analysis

In order to determine the effectiveness of debris catchments throughout the Watershed, the HEC-RAS model, the Technical Summary Report Manoa, Watershed Project (Oceanit, 2008c), and other analysis were used to study different debris catchment scenarios.

6.2.1. Preliminary Analysis

Initially, seven different sites were selected throughout the Watershed. Figure A-11 shows the locations of the proposed debris catchment sites. Each debris catchment was designed to maximize effectiveness while remaining in a viable location within reasonable vertical and horizontal limitations.

Waiakeakua Debris Catchment

This structure is designed to catch large debris. It allows all flood flows to pass through the debris poles. It is assumed that the largest river flow will be below the maximum height of the poles and will span the length of the debris catchment structure. The structure consists of a 2-foot thick concrete pad that spans 140 feet across the stream and the floodplain with a width of 8 feet. Steel posts 8 inches in diameter and between 4 to 7 feet high are evenly spaced at 4 feet along the center of the concrete pad.

Waihi Debris Catchment

This structure is designed to catch large debris. It allows all flood flows to pass through the debris poles. It is assumed that the largest river flow will be below the maximum height of the poles and will span the length of the debris catchment structure. The structure consists of a 2-foot thick concrete pad that spans 140 feet across the stream and the floodplain with a width of 8 feet. Steel posts 8 inches in diameter and between 4 to 7 feet high are evenly spaced at 4 feet along the center of the concrete pad (Oceanit, 2008c).

Poelua Place Debris Basin

This basin is designed to provide a capture point for large debris before they reach bridges downstream. In addition, the debris basin will slow the velocity of floodwaters. The debris basin is intended to capture debris in flows larger than a 50-percent ACE (2-year) stream flow and allow passage of all flows.

The debris basin consists of two separate structures. On the east side is the actual basin. The old oxbow lot will be dug down to reclaim the bend in the stream. A small berm surrounding the basin protects the existing neighborhoods from any water that may spill out of the basin. Water carrying large debris enters the northern end of the basin, curves around, and reenters the stream at the south end. Any large debris floating atop the flood waters are caught by a debris catcher consisting of five 8 inch diameter steel posts secured by a concrete pad.

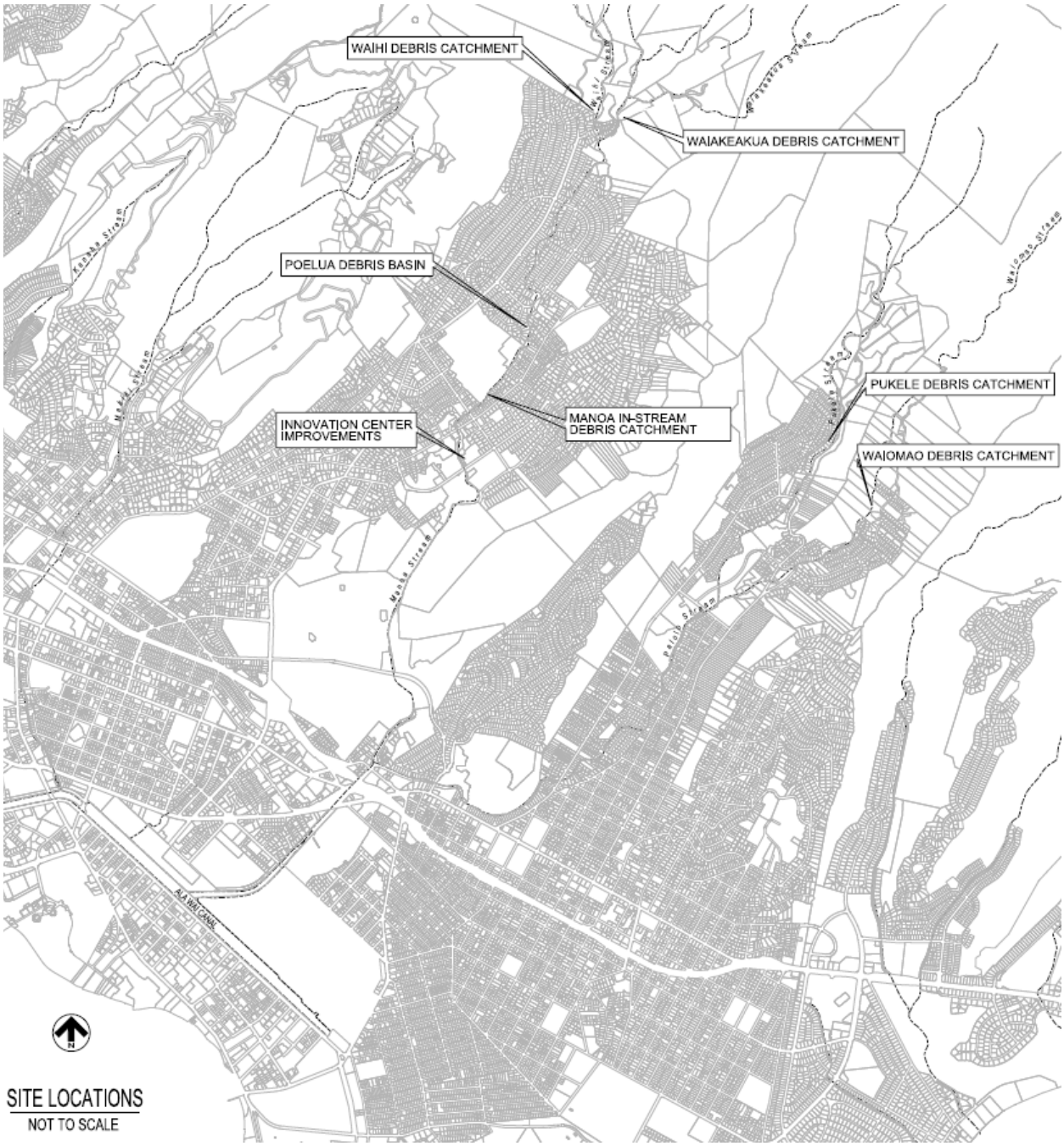

Figure A-11: Preliminary Debris Catchment Locations

Manoa In-Stream Debris Catchment

This structure is designed to catch large debris. It allows all flood flows to pass through the debris poles. It is assumed that the largest river flow will be below the maximum height of the poles and will span the length of the debris catchment structure. The structure consists of a 2-foot thick concrete pad that spans 60 feet across the stream and the floodplain with a width of 8

feet. Steel posts 8 inches in diameter and between 4 to 7 feet high are evenly spaced at 4 feet along the center of the concrete pad.

Innovation Center Improvements

The basis of this design is to restore the original floodplain between East Manoa Road Bridge and Woodlawn Bridge to lower the volume of floodwaters entering downstream of Woodlawn Bridge. A new floodplain will be created. The floodplain is intended to be inundated and capture debris when flows exceed the 50-percent ACE (2-year) storm flow. Water on the floodplain will re-enter the stream after is passes through the debris catchers (Oceanit, 2008c). The debris catchers consists of a 1-foot thick concrete pad that spans 250 feet parallel to the stream and the floodplain with a width of 6 feet. Steel posts 8 inches in diameter and 4 feet high are evenly spaced at 6 feet along the center of the concrete pad.

Waiomao Debris Catchment

This structure is designed to catch large debris. It allows all flood flows to pass through the debris poles. It is assumed that the largest river flow will be below the maximum height of the poles and will span the length of the debris catchment structure. The structure consists of a 2-foot thick concrete pad that spans 50 feet across the stream and the floodplain with a width of 8 feet. Steel posts 8 inches in diameter and between 4 to 7 feet high are evenly spaced at 4 feet along the center of the concrete pad.

Pukele Debris Catchment

This structure is designed to catch large debris. It allows all flood flows to pass through the debris poles. It is assumed that the largest river flow will be below the maximum height of the poles and will span the length of the debris catchment structure. The structure consists of a 2-foot thick concrete pad that spans 25 feet across the stream and the floodplain with a width of 8 feet. Steel posts 8 inches in diameter and between 4 to 7 feet high are evenly spaced at 4 feet along the center of the concrete pad.

6.3. Floodwall Analysis

In order to determine the effectiveness of floodwalls throughout the Watershed, the HEC-RAS model, the Technical Summary Report, Manoa Watershed Project (Oceanit, 2008c), and other analysis were used to study different floodwall scenarios.

6.3.1. Preliminary Analysis

Initially, 3 different sites were selected throughout the Watershed. Figure A-12 shows the locations of the proposed floodwall sites. Each floodwall system was designed to maximize effectiveness while remaining in a viable location within reasonable vertical and horizontal limitations.

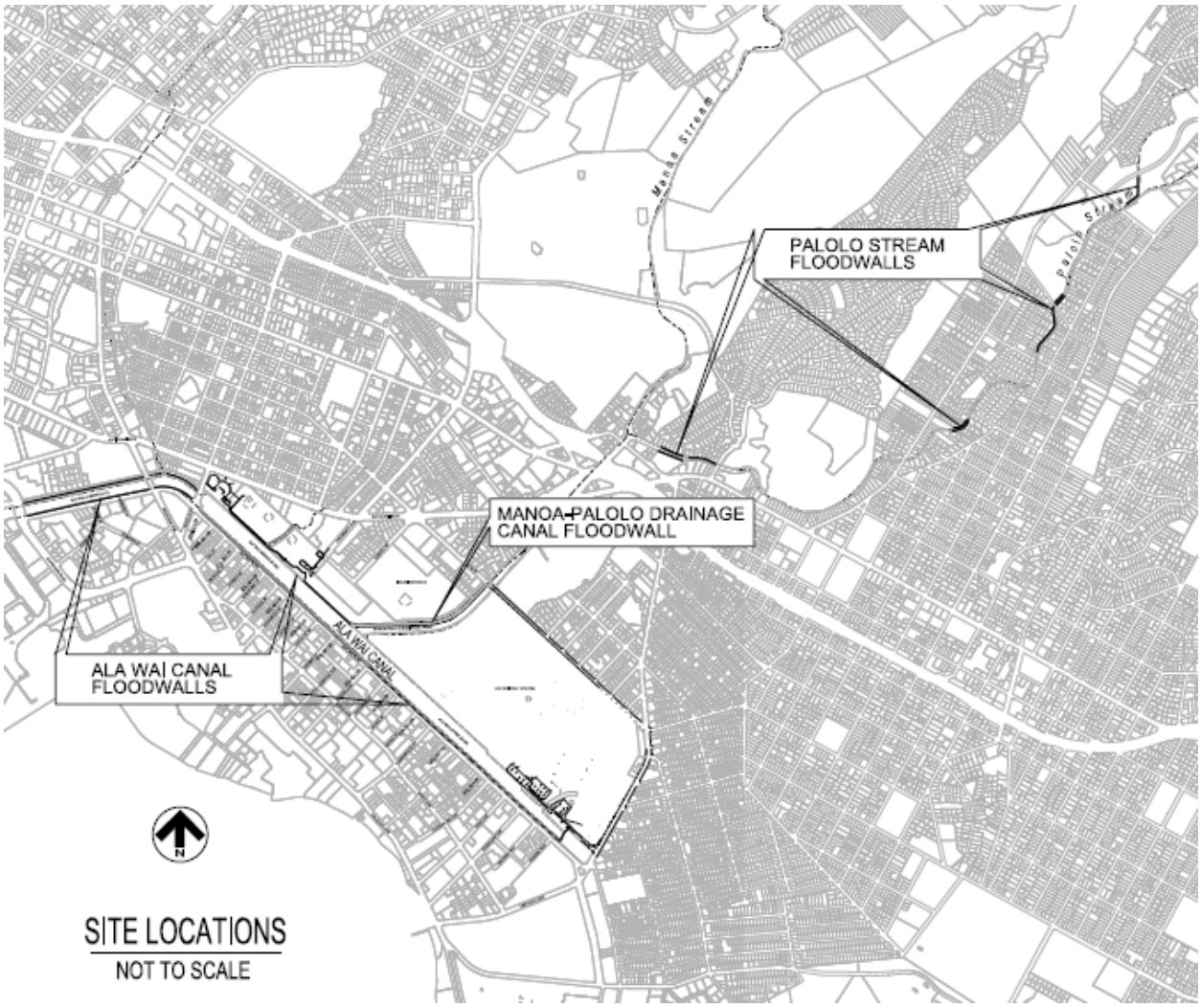

Figure A-12: Preliminary Floodwall Locations

Palolo Stream Floodwalls

The Palolo Stream Floodwall system is designed to keep the 1-percent ACE (100-year) flow within the existing concrete stream channel with 90% Assurance. The floodwalls will be constructed out of reinforced concrete.

Manoa-Palolo Drainage Canal Floodwall

The Manoa-Palolo Drainage Canal Floodwall system is designed to keep the 1-percent ACE (100-year) flow from flooding the right bank with 90% Assurance. The floodwall will be constructed out of reinforced concrete and will run along the right bank from Date Street to the Ala Wai Canal.

Ala Wai Canal Floodwalls

The Ala Wai Canal Floodwall system is designed to keep the 1-percent ACE (100-year) flow within the existing channel with 90% Assurance. The entire floodwall system will be constructed out of reinforced concrete. At the upstream end the floodwall system will connect to the Ala Wai Golf Course Levee and run along the left bank of the Ala Wai Canal. There will be no floodwall on the right bank of the Canal next to the golf course. The floodwall system will continue to run along both banks all the way to the Ala Moana Boulevard Bridge.

7. ALTERNATIVES

After doing analysis on the different detention basins combined with other measures such as debris catchments and floodwalls alternatives were developed. See Section 3.6, *Formulation of Alternative Plans*, in the Draft Feasibility Report/EIS . This section explains which measures were used for three different alternatives.

7.1. Alternative 1A

Alternative 1A in Table A-7 was developed using the Manoa Dam to detain as much flow as it could without using other detention measures along Manoa Stream. The emphasis of this alternative was the Manoa Dam because majority of the flows that reach the Ala Wai Canal are from Manoa Stream. The Manoa Dam would be constructed to allow debris to be caught during storm events to prevent debris from the upper Watershed from entering Manoa Stream. An in-stream debris catchment was also used in this alternative to catch debris that entered the stream downstream of the dam. This measure is located right below Manoa District Park.

Waiomao Debris and Detention Basin and Pukele Debris and Detention Basins were also used in this alternative above Palolo Stream. These two measures were used to lower the peak flow in Palolo Stream, these measures also prevented debris from entering the concrete lined Palolo Stream. The two debris and detention basins did not lower the 1-percent ACE (100-year) storm enough to provide 90% Assurance so floodwalls were also added to this alternative in certain areas to attain 90% Assurance for the 1-percent ACE (100-year) event. A floodwall was also added on the right bank of the Manoa-Palolo Drainage Canal to prevent flooding in and around Iolani School.

The Roosevelt Debris and Detention Basin was used in the Makiki Watershed to lower the peak flow. This measure also catches debris to prevent it from entering Makiki Stream. Floodwalls were analyzed in Makiki but they were not feasible because of the required heights.

Even with the Manoa Dam, floodwalls along the Ala Wai Canal are still needed to prevent the 1-percent ACE (100-year) storm event from flooding Waikiki and Moiliili. The Hausten Ditch Detention was used in conjunction with the Ala Wai Canal Floodwall system to prevent interior drainage from flooding Moiliili when slide gates are closed at the Hausten Ditch Pedestrian Bridge.

Table A-7. Input Peak Flow Discharges in cubic feet per second for Ala Wai Watershed HEC-RAS for Alternative 1A Model, Honolulu, Hawaii

Model Stream Names			Percent ACE Flood							
River	Reach	Model Input Cross-section Location	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Ala Wai	Upper	9724	1000	1400	1800	2300	3040	3600	4320	5300
Ala Wai	Middle	5825	4430	6880	8850	10900	13800	16200	19000	23200
Ala Wai	Lower	2324	7040	10400	12900	14600	16400	17600	18800	21000
Kanaha	Ditch	4372	133	178	202	230	382	534	702	946
Kanaha	Split	3508	1	1	1	1	1	1	1	1
Makiki	Upper	10768	204	385	558	766	1080	1360	1680	2150
Makiki	Upper	7674	300	580	800	1100	1500	1900	2300	2900
Makiki	Lower	6286	532	912	1250	1640	2210	2690	3240	4130
Makiki	Lower	3189	654	1100	1470	1910	2530	3060	3650	6530
Makiki	Lower	1465	943	1580	2170	2890	3830	4630	5370	6530
Manoa	Main	16506	980	1260	1400	1500	1620	1690	2960	4630
Manoa	Main	10968	1730	2430	2970	3520	4300	4910	5560	7760
Manoa	Main	9274	1940	2740	3370	4030	4950	5650	6420	8550
Manoa	Main	7839	2110	3010	3710	4430	5500	6310	7170	9010
Manoa	Main	6175	2230	3200	3960	4750	5900	6750	7720	9260
Manoa	Main	2477	2670	3910	4870	5890	7370	8460	9660	11400
Manoa	Main	1807	2820	4150	5200	6310	7930	9120	10400	12300
Manoa	Main	1230	2970	4380	5510	6680	8410	9680	11100	13100
Palolo	Main	15526	644	1180	1630	2090	3070	4030	5090	6620
Palolo	Main	9520	1110	1880	2550	3260	4250	5110	6450	8320
Palolo	Main	7552	1450	2410	3210	4070	5250	6190	7500	9580
Palolo	Lower	5198	4270	6660	8560	10500	13400	15700	18600	22700
Pukele	Tributary	5958	187	399	568	758	1100	1470	1890	2500
Pukele	Tributary	3629	341	636	922	1230	1630	2060	2650	3490
UH_Split	UH_Split	6929	1	1	1	1	1	1	1	1
Waiomao	Tributary	4900	349	584	799	994	1520	1980	2480	3160

7.2. Alternative 2A

The emphasis for Alternative 2A in Table A-8 was not to detain water in the un-urbanized areas. Therefore, there were no detention basins or dams in the upstream areas of Manoa Stream but the Woodlawn Ditch Detention Basin, the Manoa Park Detention Basin, and the Kanewai Field Multi-Purpose Detention Basin were used in this alternative. Because there were no debris and detention basins in the upstream area a debris catchment will be constructed at Waiakeakua Stream and Waihi Stream. An in-stream debris catchment will also be constructed at Poelua Place; this is just upstream of the Manoa Park Detention Basin's intake so the debris catchment prevents debris from going down stream of that location including preventing debris from clogging up the intake. An in-stream debris catchment will also be constructed next to the Innovation Center just upstream of Woodlawn Bridge.

No detention measures were used in the Palolo Watershed; there just isn't any land available along Palolo Stream. The floodwall from Alternative 1 was also added on the right bank of the Manoa-Palolo Drainage Canal to prevent flooding in and around Iolani School.

The Makiki Debris and Detention Basin and the Roosevelt Debris and Detention Basins were used in the Makiki Watershed because that was the only measure that could be used to lower flows in that Watershed. Same as Alternative 1, the floodwalls were analyzed in Makiki but they were not feasible because of the required heights.

Floodwalls along the Ala Wai Canal are also needed to prevent the 1-percent ACE (100-year) storm event from flooding Waikiki and Moiliili. The Hausten Ditch Detention was used in conjunction with the Ala Wai Canal Floodwall system to prevent interior drainage from flooding Moiliili when slide gates are closed at the Hausten Ditch Pedestrian Bridge. The Ala Wai Golf Course Multi-Purpose Detention was also used in conjunction with the Ala Wai Canal Floodwall system.

Table A-8. Input Peak Flow Discharges in cubic feet per second for Ala Wai Watershed HEC-RAS for Alternative 2A Model, Honolulu, Hawaii

Model Stream Names			Percent ACE Flood							
River	Reach	Model Input Cross-section Location	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Ala Wai	Upper	9724	809	809	809	809	809	809	1670	2650
Ala Wai	Middle	5825	4500	5630	6440	7410	10400	12900	16100	20740
Ala Wai	Lower	2324	8000	9830	10440	11010	12200	13400	14100	15800
Kanaha	Ditch	4372	133	178	202	230	382	534	702	946
Kanaha	Split	3508	1	1	1	1	1	1	1	1
Makiki	Upper	10768	200	200	200	320	630	910	1230	1700
Makiki	Upper	7674	300	390	440	650	1050	1450	1850	2450
Makiki	Lower	6286	700	768	942	1340	2090	2810	3410	4240
Makiki	Lower	3189	810	858	1120	1370	2130	2900	3500	4330
Makiki	Lower	1465	880	968	1350	1740	2660	1180	4240	5520
Manoa	Main	16506	1200	2000	2600	3350	4500	5400	6200	7600
Manoa	Main	10968	1940	3200	4200	5280	7140	8350	9400	11400
Manoa	Main	9274	2080	2080	2080	2080	2950	4160	5250	7350
Manoa	Main	7839	2200	2200	2200	2200	2200	2680	3980	6480
Manoa	Main	6175	2320	2320	2400	2600	2600	3340	4980	6880
Manoa	Main	2477	2500	2500	2500	3030	3500	4180	5980	8180
Manoa	Main	1807	2700	2700	2700	3400	3950	4680	6980	8980
Manoa	Main	1230	2900	2900	2900	2900	4300	5680	7680	10600
Palolo	Main	15526	1100	2100	3000	3930	5430	6700	8020	9990
Palolo	Main	9520	1350	2420	3400	4340	5900	7420	9000	11000
Palolo	Main	7552	1450	2580	3500	4560	6350	7900	9400	12000
Palolo	Lower	5198	4200	5430	6140	7012	10224	12000	15714	20340
Pukele	Tributary	5958	440	850	1200	1600	2280	2800	3350	4200
Pukele	Tributary	3629	640	1200	1720	2300	3090	3730	4450	5400
UH_Split	UH_Split	6929	1	1	1	1	1	1	1	1
Waiomao	Tributary	4900	650	1140	1580	2050	2700	3200	3800	4700

7.3. Alternative 3A

This alternative 3A in Table A-9 was created to lower as much flow as possible without using the Manoa Dam, a more effective and logical approach to flood protection. The Waiakeakua Debris and Detention Basin along with the Waihi Debris and Detention Basin and the Woodlawn Ditch Detention Basin were used along Manoa Stream. The in-stream debris catchment below Manoa District Park would also be a part of this alternative to catch debris that enters the stream downstream of Waiakeakua and Waihi Streams. The debris catchment at the Innovation Center was initially part of this alternative but after doing incremental justification the Kanewai Field Multi-Purpose Detention Basin was a better overall measure to use in this alternative instead.

The Waiomao Debris and Detention Basin and the Pukele Debris and Detention Basin were both used for the Palolo Watershed. After doing further analysis the floodwalls along Palolo Stream were too costly and infeasible. Further analysis was also done on the floodwall along the Manoa-Palolo Drainage Canal and that measure was not incrementally justified.

The Makiki Watershed initially used the Makiki Debris and Detention Basin and the Roosevelt Debris and Detention Basins but after incremental justification the Roosevelt Debris and Detention Basin was not justified. As in Alternatives 1 and 2, the floodwalls were analyzed in Makiki but they were not feasible because of the required heights.

Floodwalls along the Ala Wai Canal are also needed in this alternative to prevent the 1-percent ACE (100-year) storm event from flooding Waikiki and Moiliili. The Hausten Ditch Detention was used in conjunction with the Ala Wai Canal Floodwall system to prevent interior drainage from flooding Moiliili when slide gates are closed at the Hausten Ditch Pedestrian Bridge. The Ala Wai Golf Course Multi-Purpose Detention was also used in conjunction with the Ala Wai Canal Floodwall system. This alternative became our TSP.

Table A-9. Input Peak Flow Discharges in cubic feet per second for Ala Wai Watershed HEC-RAS for Alternative 3A Model, Honolulu, Hawaii

Model Stream Names			Percent ACE Flood							
River	Reach	Model Input Cross-section Location	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Ala Wai	Upper	9724	809	809	809	900	1640	2200	2920	3900
Ala Wai	Middle	5825	4500	7130	7710	9037	10027	11717	13827	14000
Ala Wai	Lower	2324	7530	9230	8710	9937	10927	11767	15327	18000
Kanaha	Ditch	4372	270	500	700	930	1240	1500	1790	2200
Kanaha	Split	3508	1	1	1	1	1	1	1	1
Makiki	Upper	10768	200	390	390	390	630	910	1230	1700
Makiki	Upper	7674	300	580	640	720	1050	1450	1850	2450
Makiki	Lower	6286	700	780	1040	1190	1610	2120	2780	3810
Makiki	Lower	3189	810	1390	1130	1370	1640	2210	2870	3900
Makiki	Lower	1465	880	1500	1360	1740	2170	2900	3610	5090
Manoa	Main	16506	1200	2000	2000	2000	2000	2000	2000	2000
Manoa	Main	10968	1940	3200	3600	3930	4640	4950	5200	5800
Manoa	Main	9274	2080	3450	3750	4100	4700	5010	5300	6000
Manoa	Main	7839	2200	3650	3650	3650	3227	3527	4027	5127
Manoa	Main	6175	2320	3800	3850	4050	3627	4187	5027	6127
Manoa	Main	2477	2500	4100	4250	4480	4527	5027	6027	7427
Manoa	Main	1807	2700	4300	4650	4850	4977	5527	7027	8227
Manoa	Main	1230	2900	4600	4600	5327	5327	6527	7727	9827
Palolo	Main	15526	644	1180	1630	2090	3070	4030	5090	6620
Palolo	Main	9520	1110	1880	2550	3260	4250	5110	6450	8320
Palolo	Main	7552	1450	2410	3210	4070	5250	6190	7500	9580
Palolo	Lower	5198	4200	6930	7410	8637	9827	10817	13427	16507
Pukele	Tributary	5958	187	399	568	758	1100	1470	1890	2500
Pukele	Tributary	3629	341	636	922	1230	1630	2060	2650	3490
UH_Split	UH_Split	6929	1	1	1	1	1	1	1	1
Waiomao	Tributary	4900	349	584	799	994	1520	1980	2480	3160

Table A-10. Input Peak Flow Discharge Comparison in cubic feet per second for Ala Wai Watershed HEC-RAS for Existing Conditions and TSP Model, Honolulu, Hawaii

Model Stream Names			Percent ACE Flood							
			Existing Conditions				TSP			
River	Reach	Model Input Cross-section Location	10%	2%	1%	0.2%	10%	2%	1%	0.2%
Ala Wai	Upper	9724	1800	3040	3600	5300	809	1640	2200	3900
Ala Wai	Middle	5825	9500	16200	19400	26900	7710	10027	11717	14000
Ala Wai	Lower	2324	13500	18000	19500	22000	8710	10927	11767	18000
Kanaha	Ditch	4372	700	1240	1500	2200	700	1240	1500	2200
Kanaha	Split	3508	1	1	1	1	1	1	1	1
Makiki	Upper	10768	560	1080	1360	2150	390	630	910	1700
Makiki	Upper	7674	800	1500	1900	2900	640	1050	1450	2450
Makiki	Lower	6286	1800	3420	4230	5940	1040	1610	2120	3810
Makiki	Lower	3189	1980	3460	4320	6030	1130	1640	2210	3900
Makiki	Lower	1465	2210	3990	5010	7220	1360	2170	2900	5090
Manoa	Main	16506	2600	4500	5400	7600	2000	2000	2000	2000
Manoa	Main	10968	4200	7140	8350	11400	3600	4640	4950	5800
Manoa	Main	9274	4350	7200	8410	11600	3750	4700	5010	6000
Manoa	Main	7839	4600	7500	8700	12500	3650	3227	3527	5127
Manoa	Main	6175	4800	7900	9360	12900	3850	3627	4187	6127
Manoa	Main	2477	5200	8800	10200	14200	4250	4527	5027	7427
Manoa	Main	1807	5600	9250	10700	15000	4650	4977	5527	8227
Manoa	Main	1230	6100	10400	12500	17400	4600	5327	6527	9827
Palolo	Main	15526	3000	5430	6700	9990	1630	3070	4030	6620
Palolo	Main	9520	3400	5900	7420	11000	2550	4250	5110	8320
Palolo	Main	7552	3500	6350	7900	12000	3210	5250	6190	9580
Palolo	Lower	5198	9200	16000	18500	26500	7410	9827	10817	16507
Pukele	Tributary	5958	1200	2280	2800	4200	568	1100	1470	2500
Pukele	Tributary	3629	1720	3090	3730	5400	922	1630	2060	3490
UH_Split	UH_Split	6929	1	1	1	1	1	1	1	1
Waiomao	Tributary	4900	1580	2700	3200	4700	799	1520	1980	3160

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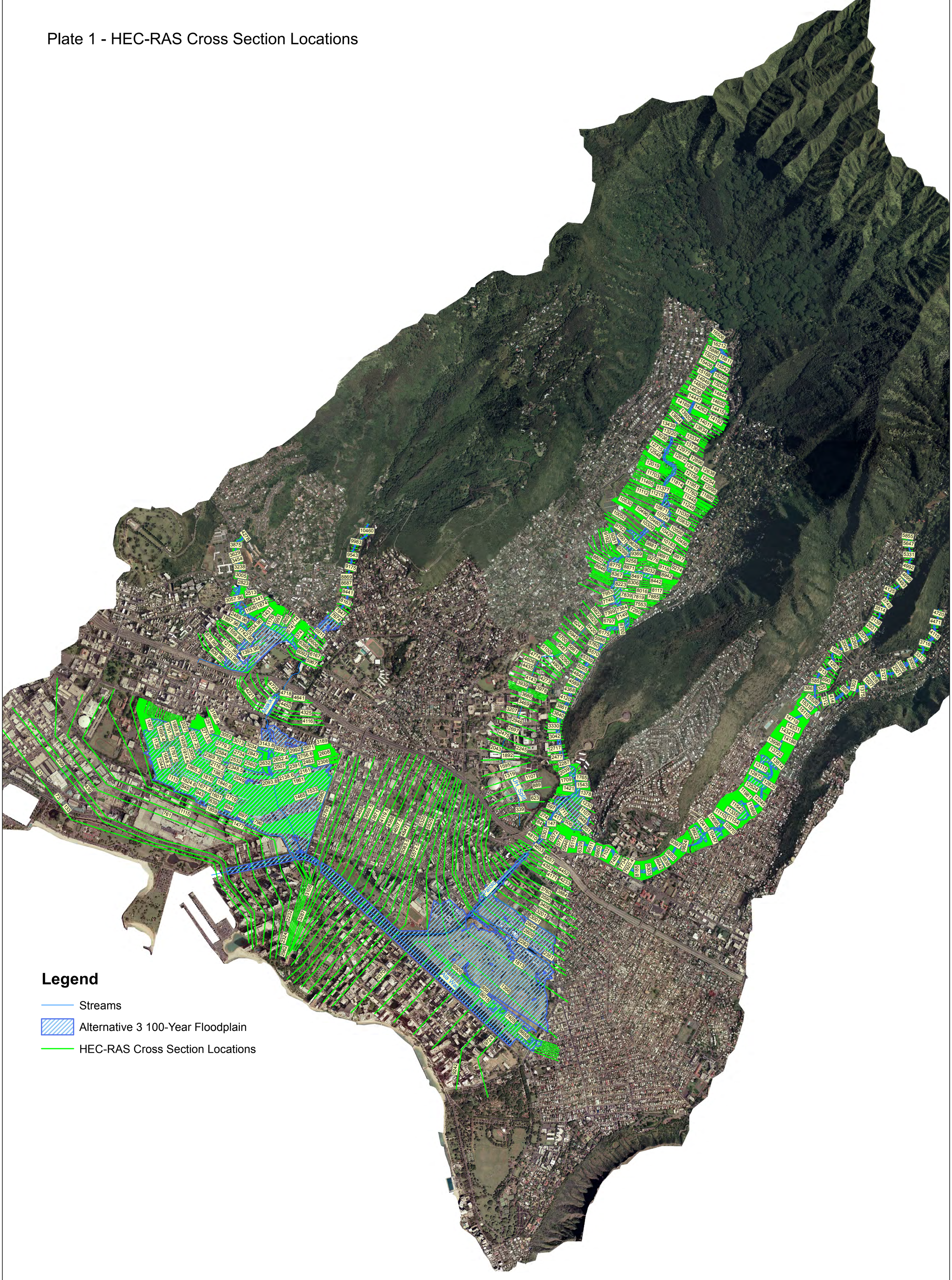
Plate 1 - HEC-RAS Cross Section Locations



DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

Plate 2 - HEC-RAS Cross Section Plots

Ala Wai Lower, Cross Section 1477

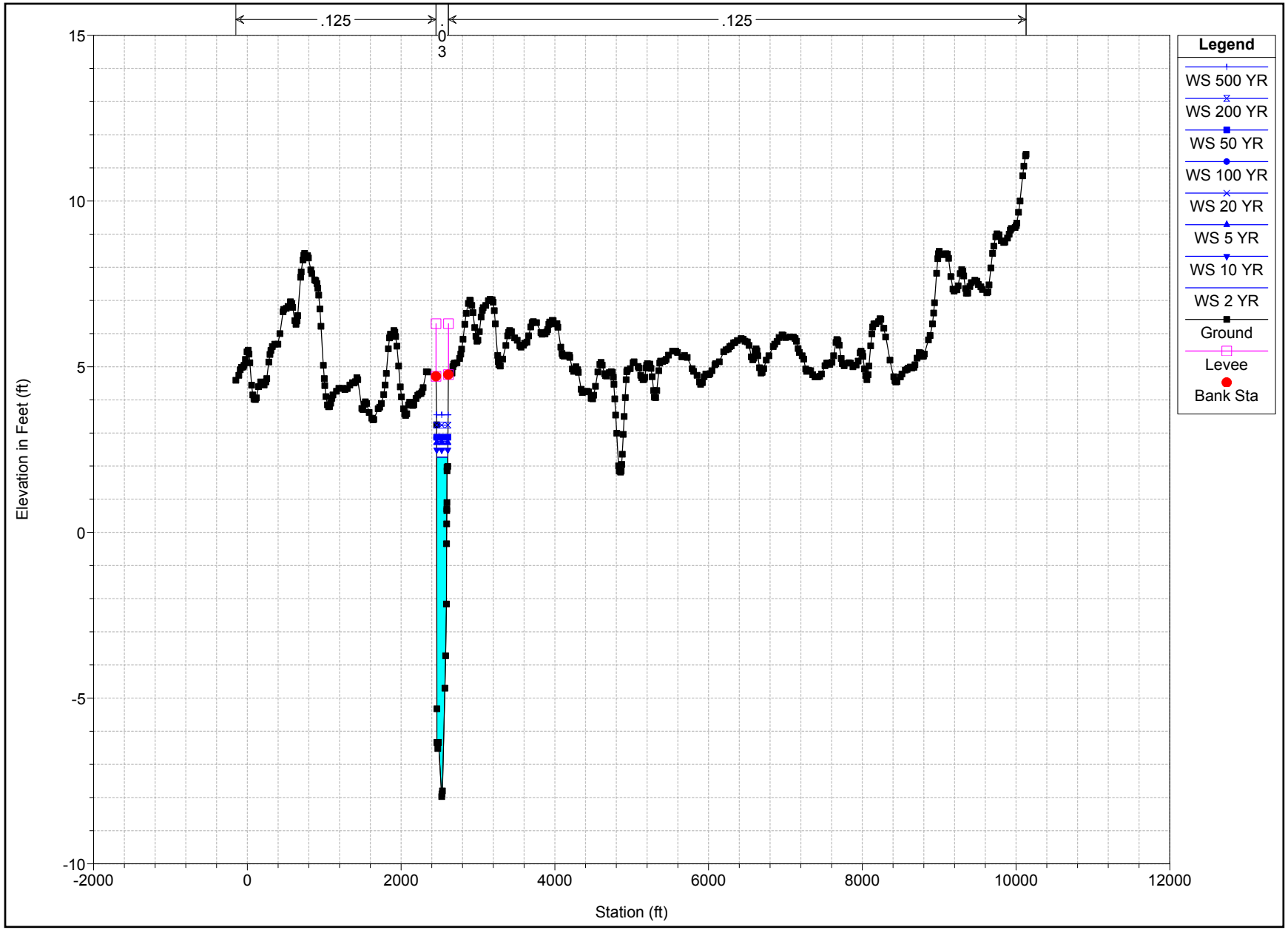


Plate 2 - HEC-RAS Cross Section Plots

Ala Wai Middle, Cross Section 4847

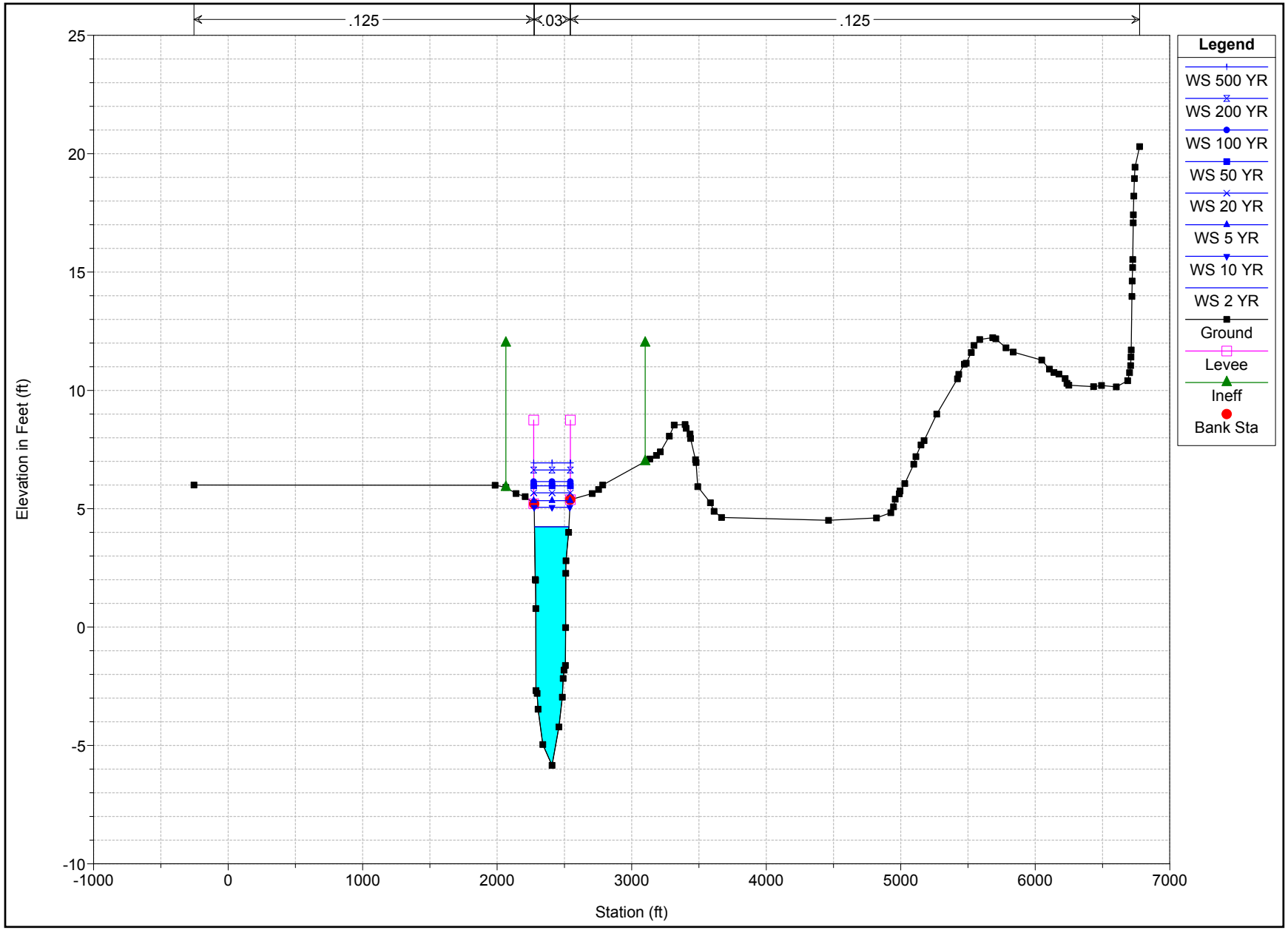


Plate 2 - HEC-RAS Cross Section Plots

Ala Wai Upper, Cross Section 8015

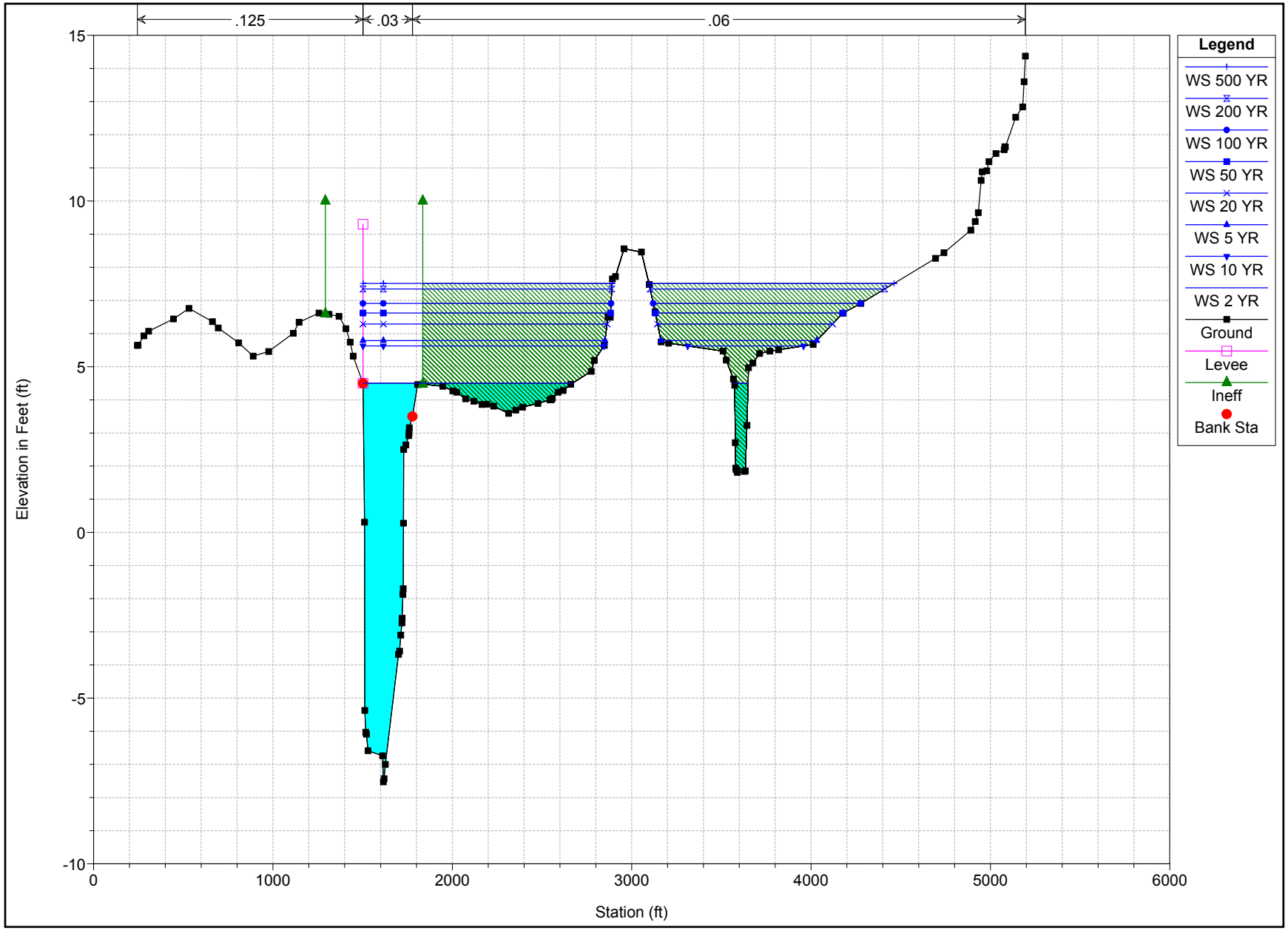


Plate 2 - HEC-RAS Cross Section Plots

Kanaha Ditch, Cross Section 1874

Plate 2 - HEC-RAS Cross Section Plots

Kanaha Ditch, Cross Section 3005

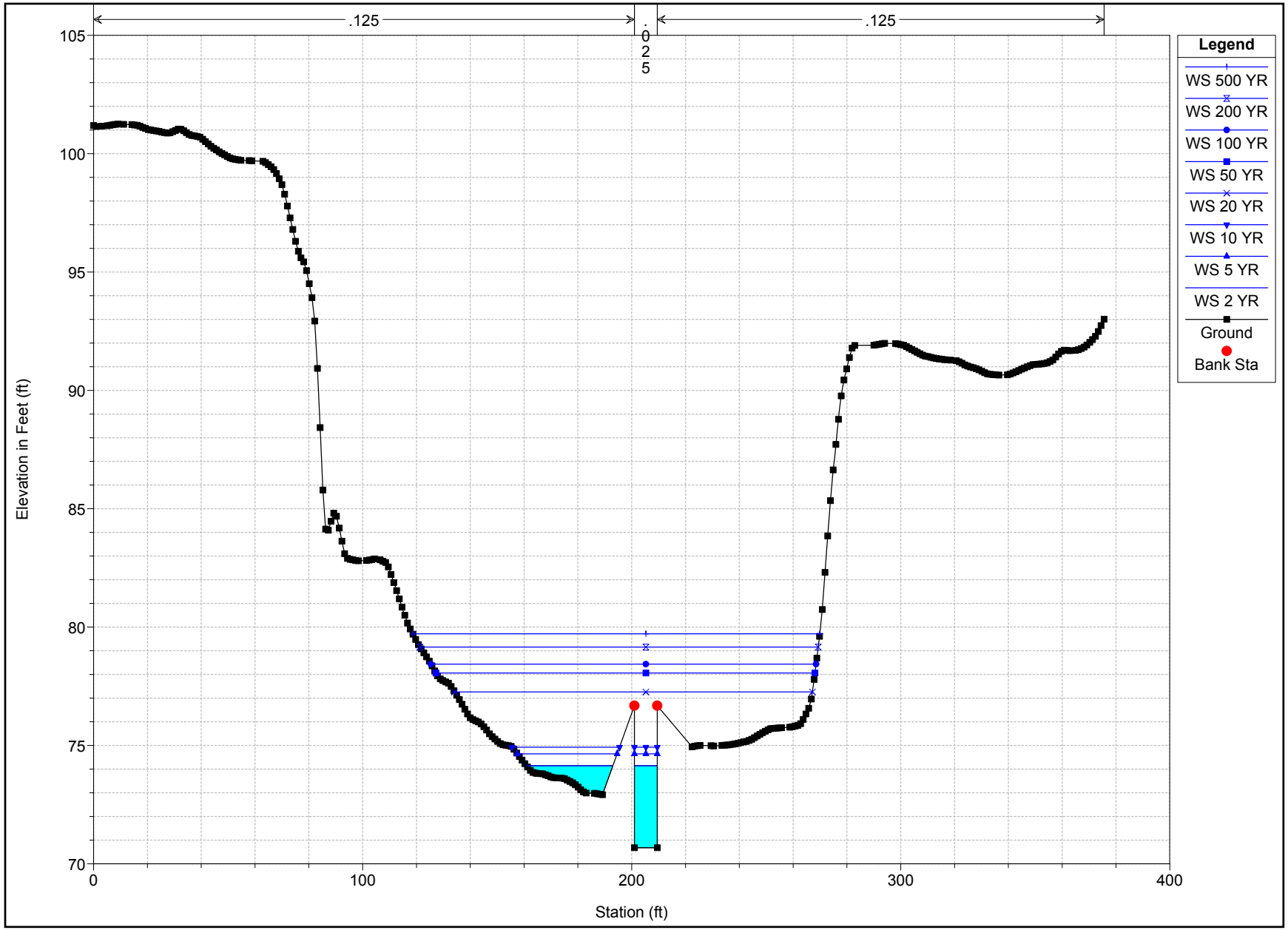


Plate 2 - HEC-RAS Cross Section Plots

Kanaha Split, Cross Section 1393.96

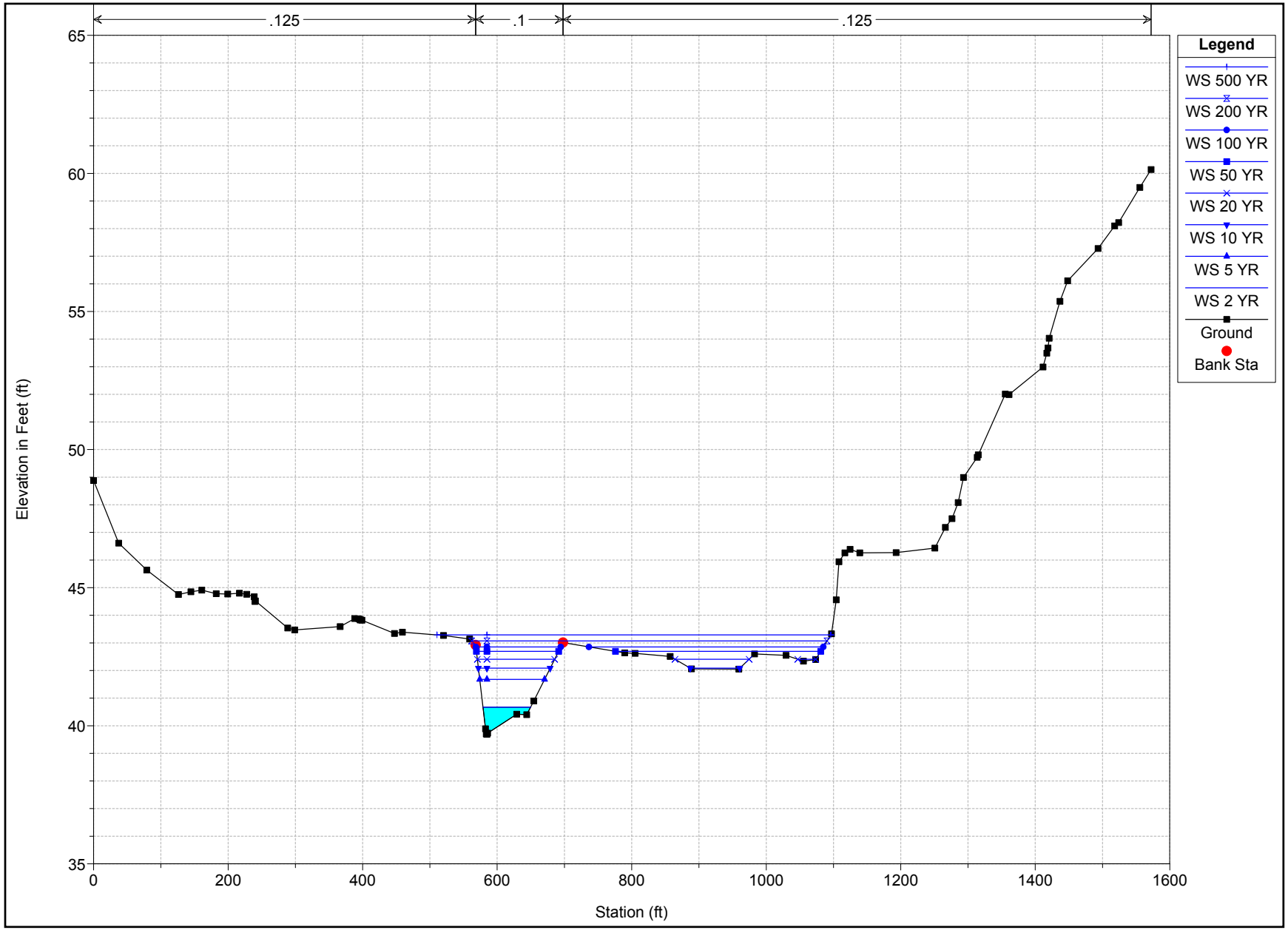


Plate 2 - HEC-RAS Cross Section Plots

Makiki Lower, Cross Section 4325

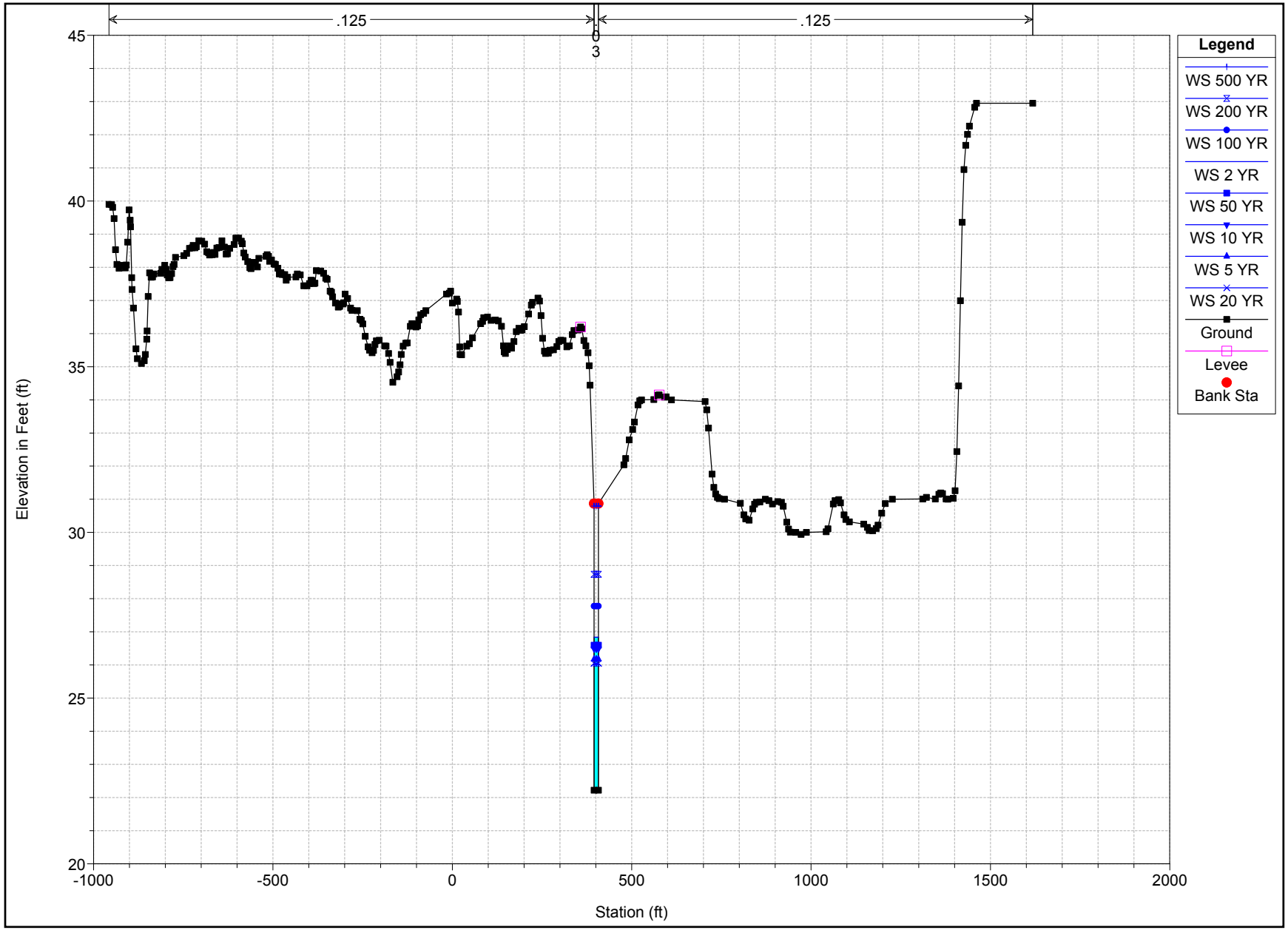


Plate 2 - HEC-RAS Cross Section Plots

Makiki Upper, Cross Section 6606

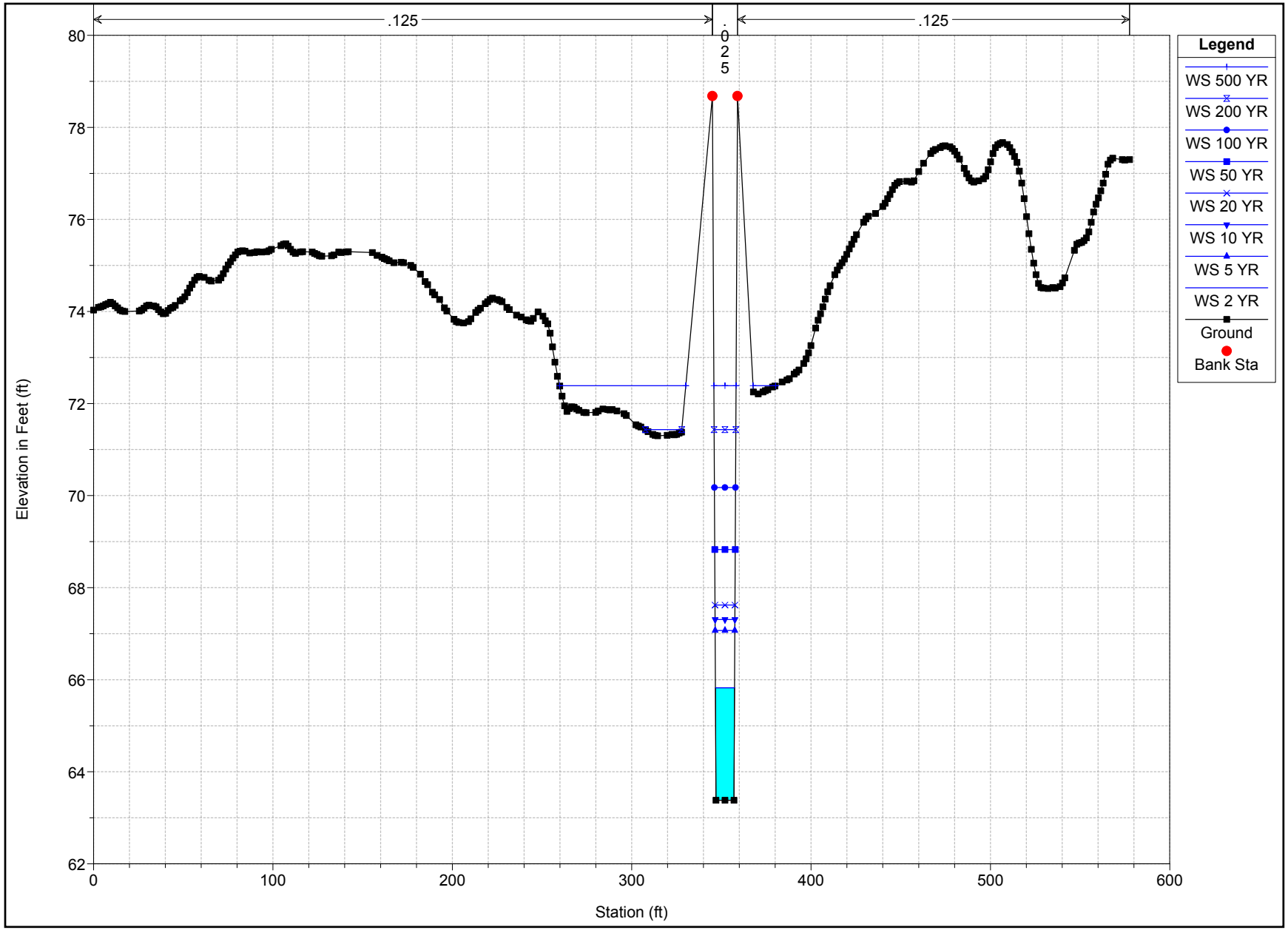


Plate 2 - HEC-RAS Cross Section Plots

Makiki Upper, Cross Section 9666

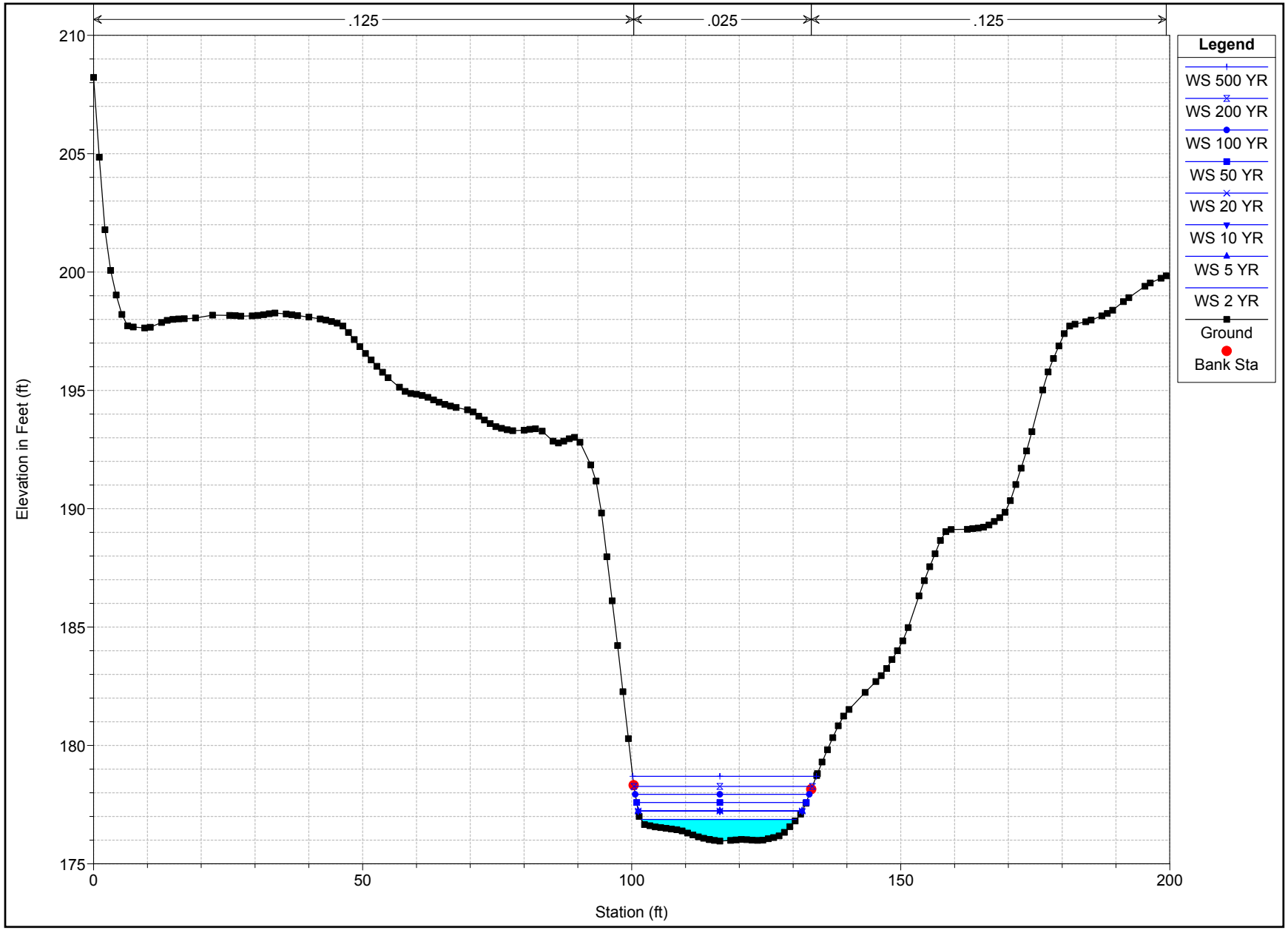


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 948

Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 5461

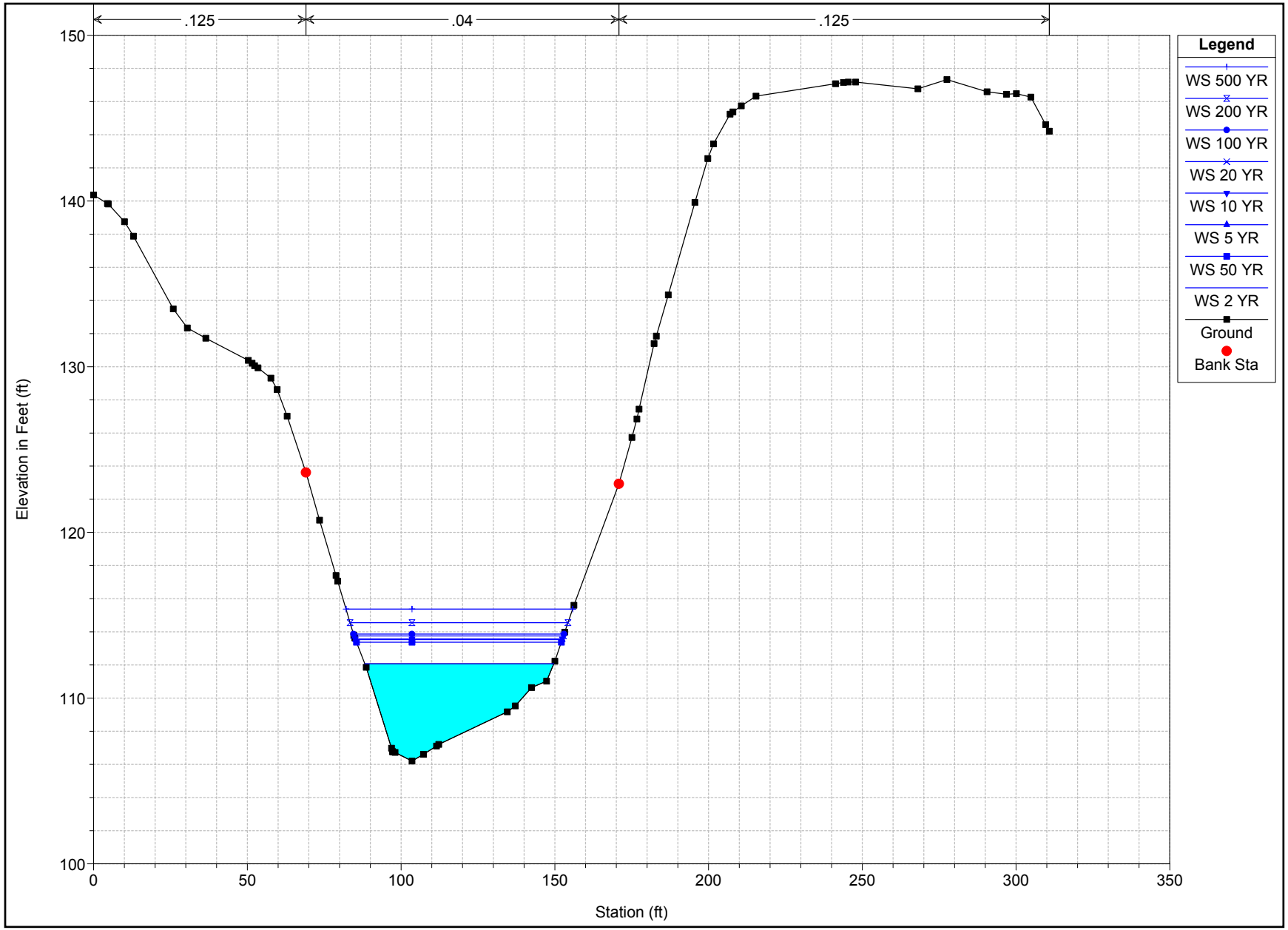


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 8367

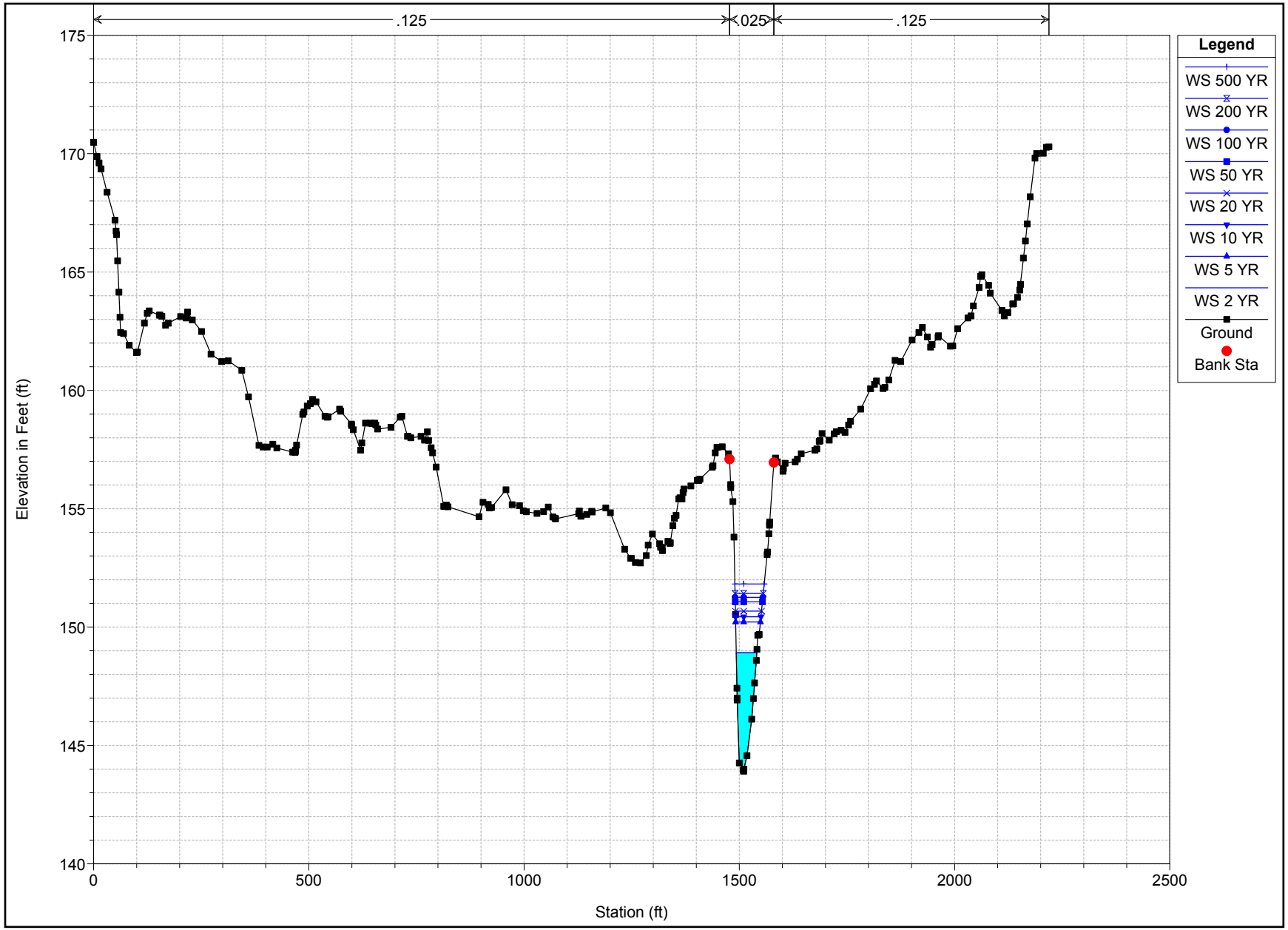


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 9032

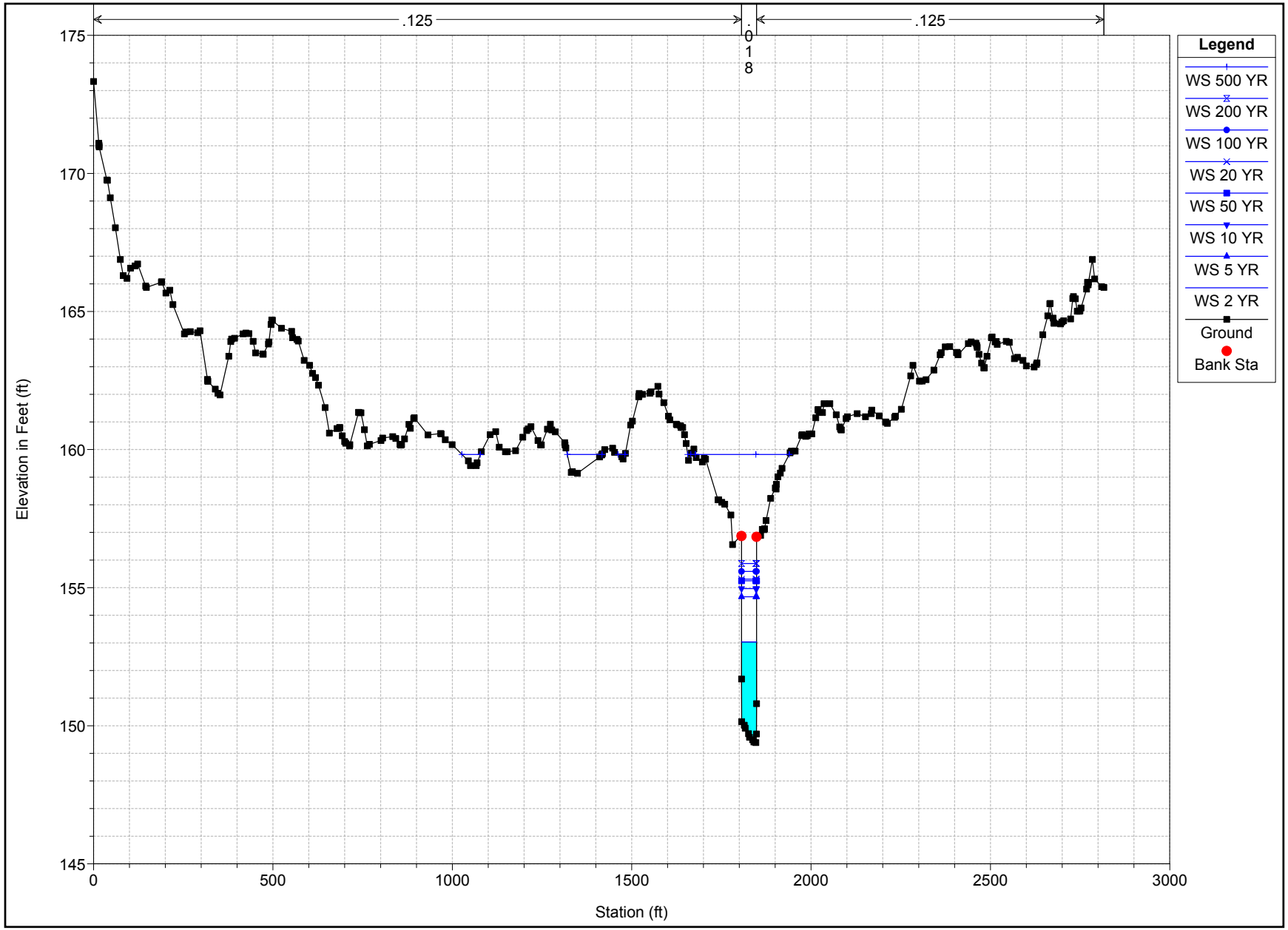


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 10309

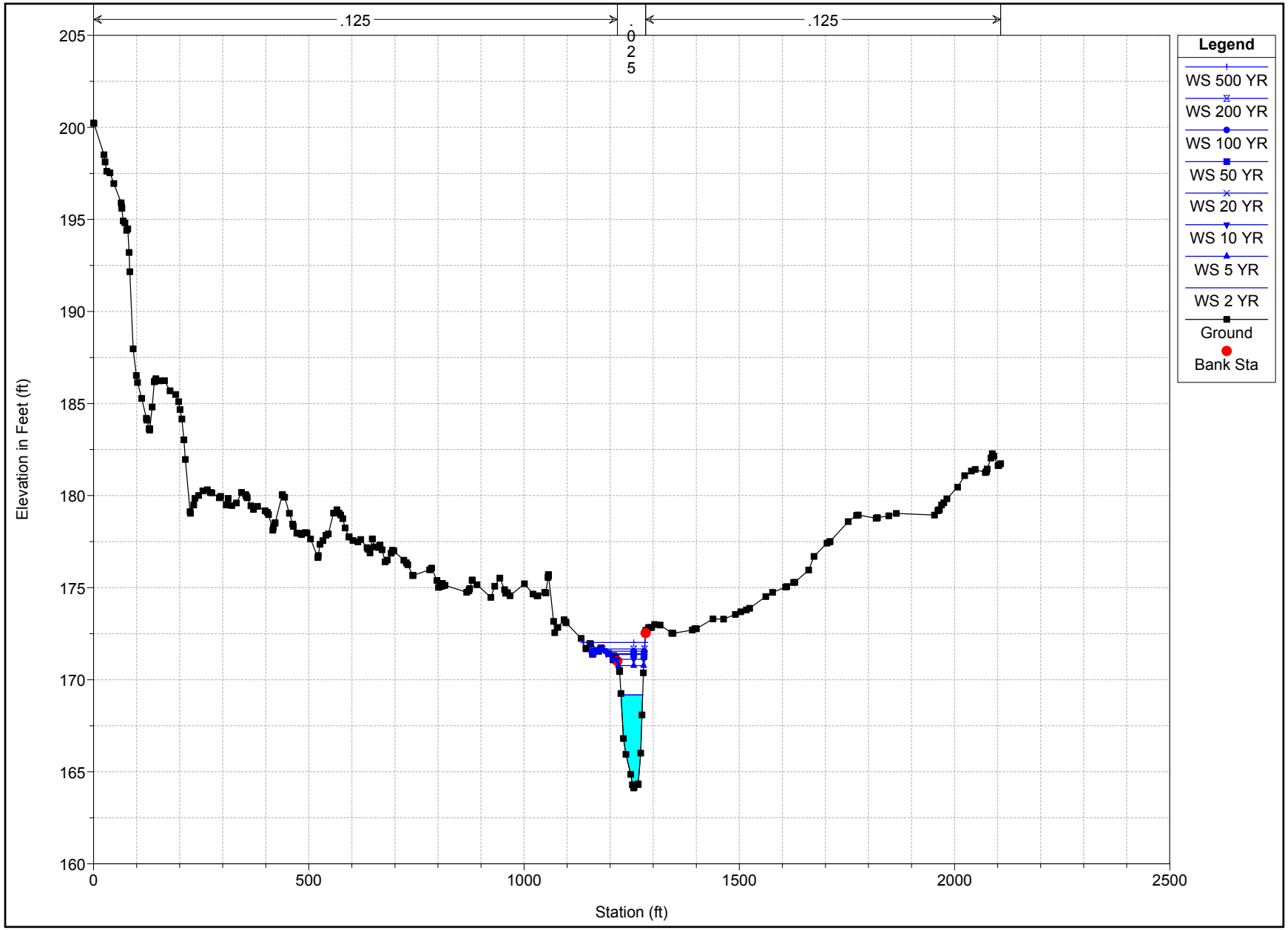


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 13136

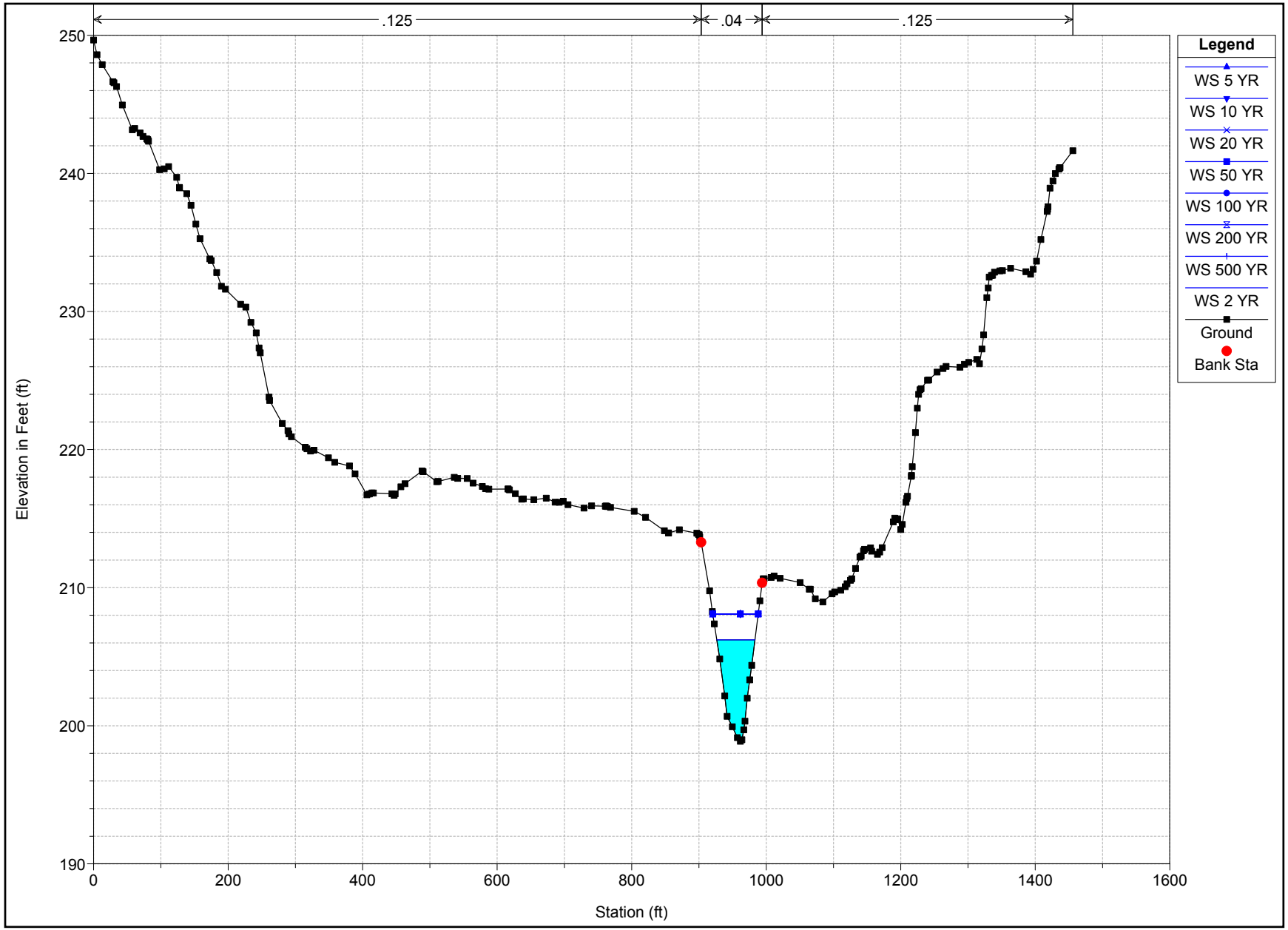


Plate 2 - HEC-RAS Cross Section Plots

Manoa Main, Cross Section 15753

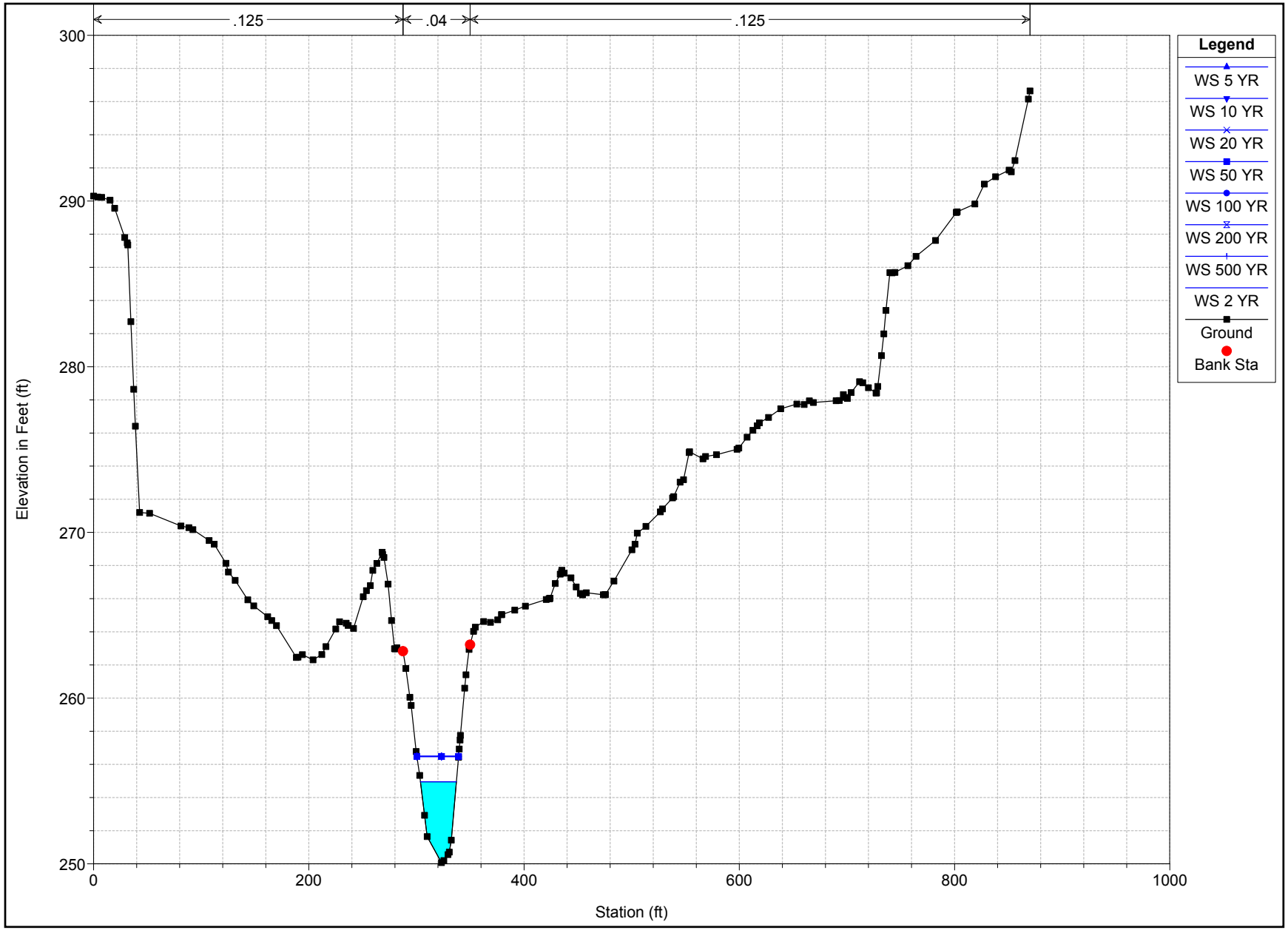


Plate 2 - HEC-RAS Cross Section Plots

Palolo Lower, Cross Section 1813

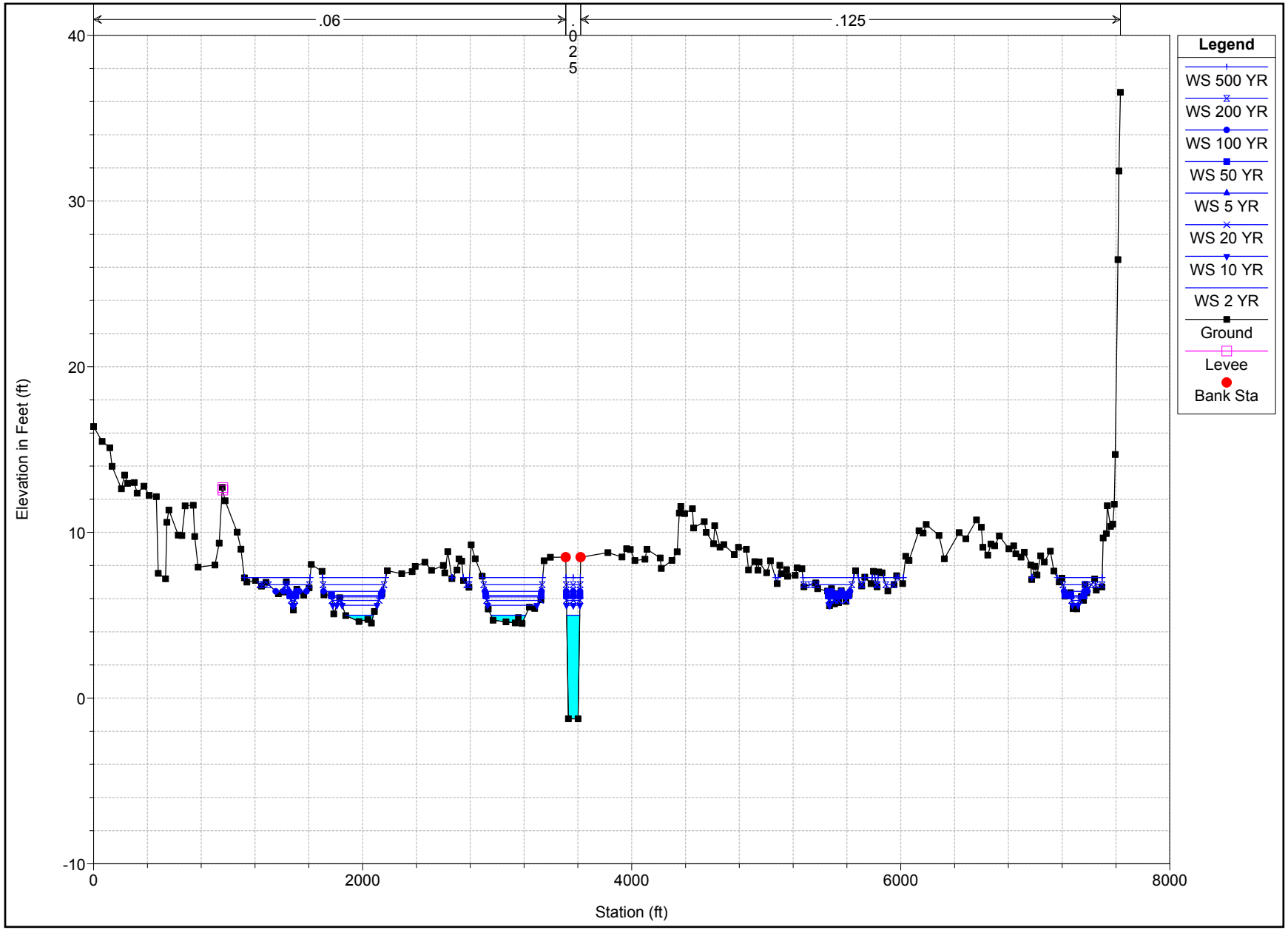


Plate 2 - HEC-RAS Cross Section Plots

Palolo Lower, Cross Section 3406

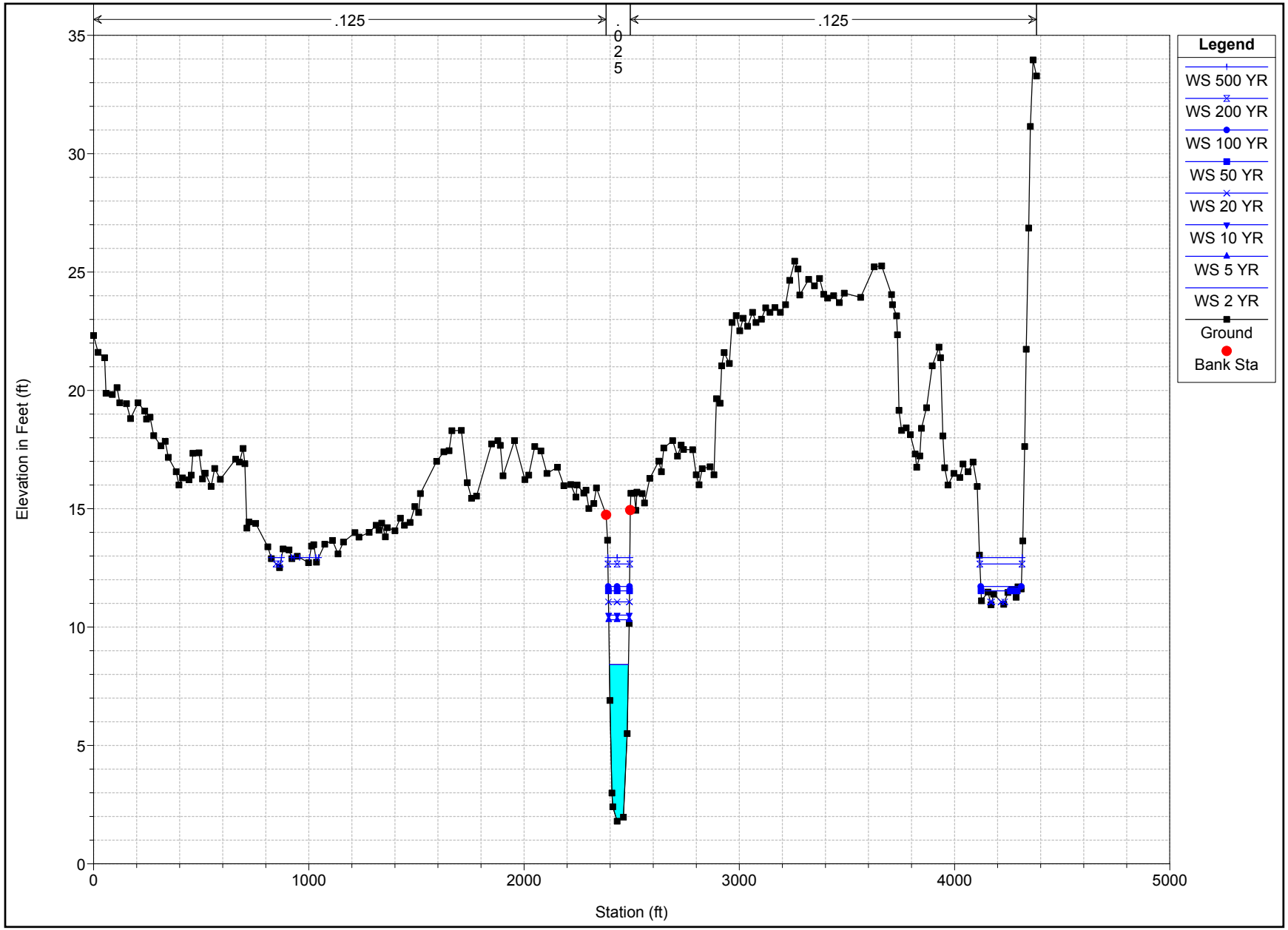


Plate 2 - HEC-RAS Cross Section Plots

Palolo Main, Cross Section 6376

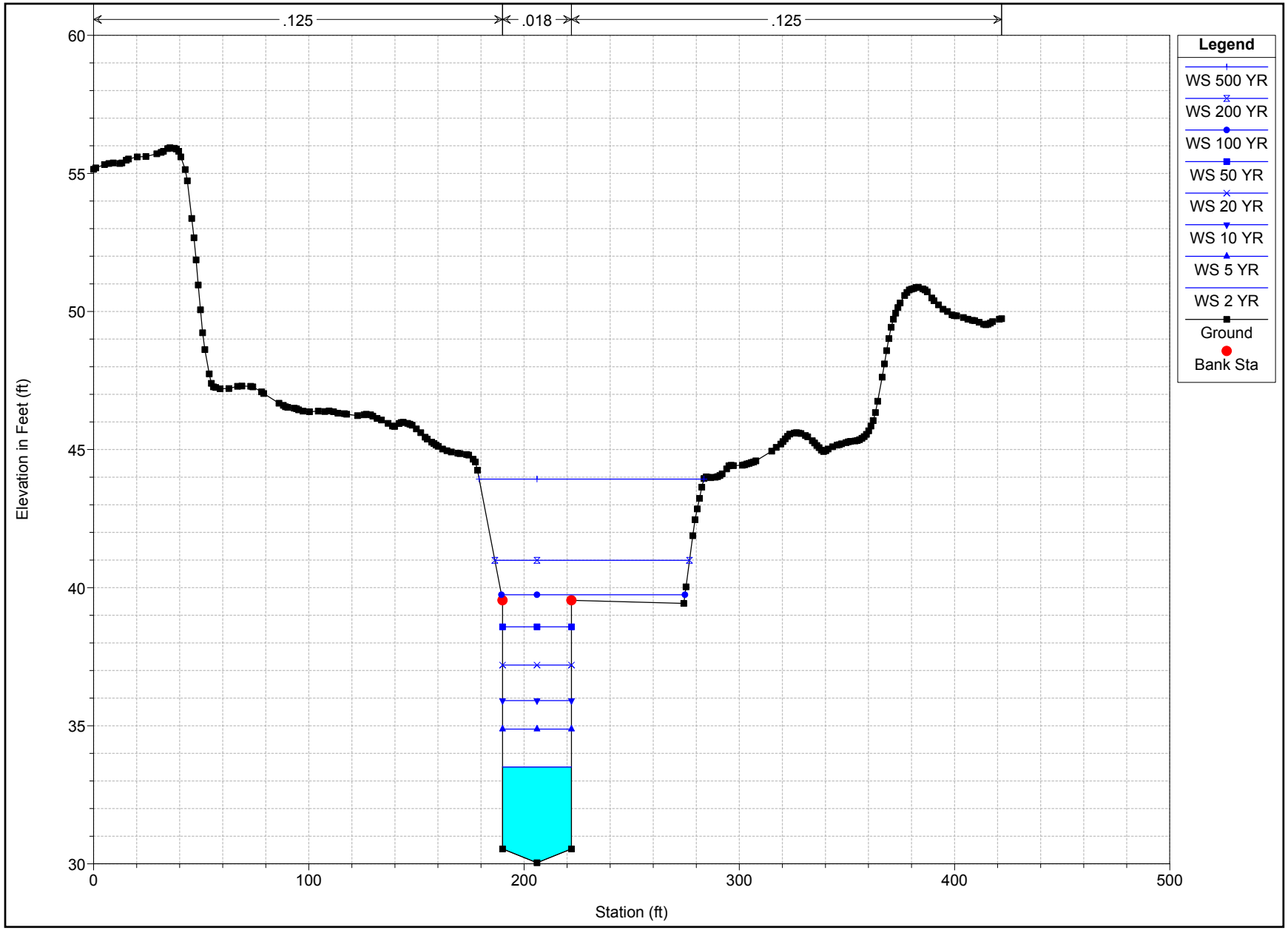


Plate 2 - HEC-RAS Cross Section Plots

Palolo Main, Cross Section 8574

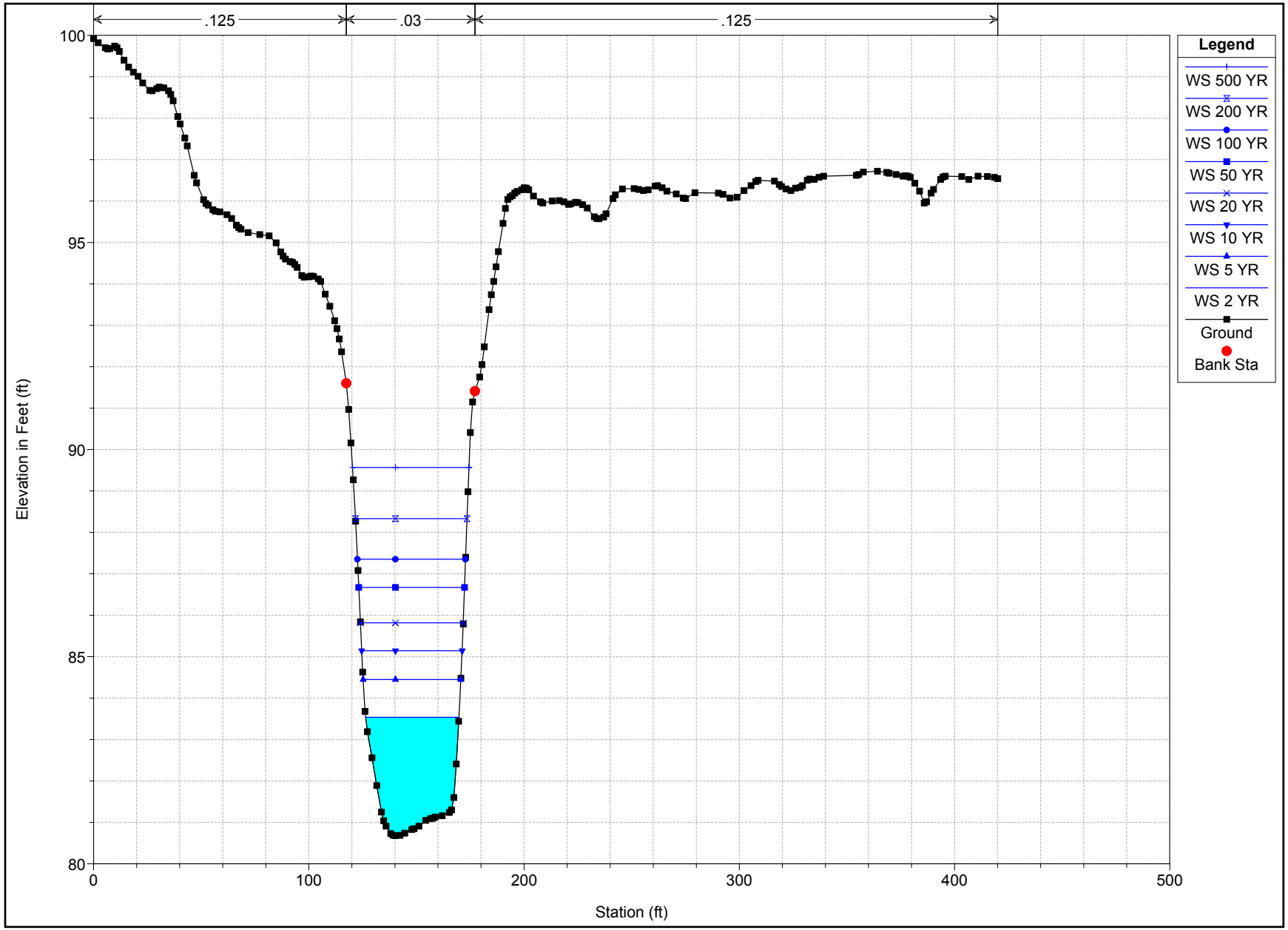


Plate 2 - HEC-RAS Cross Section Plots

Palolo Main, Cross Section 11649

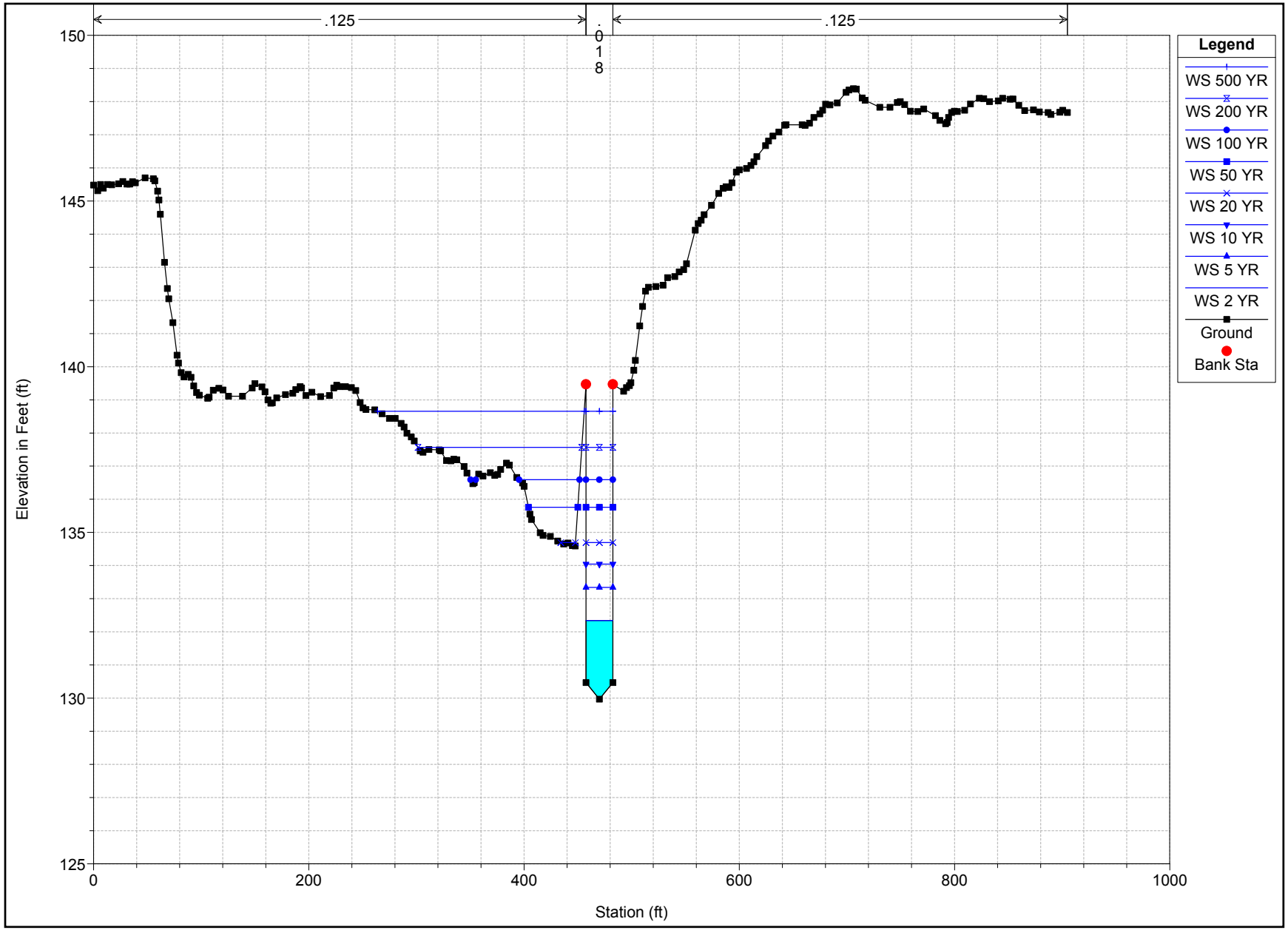


Plate 2 - HEC-RAS Cross Section Plots

Palolo Main, Cross Section 14619

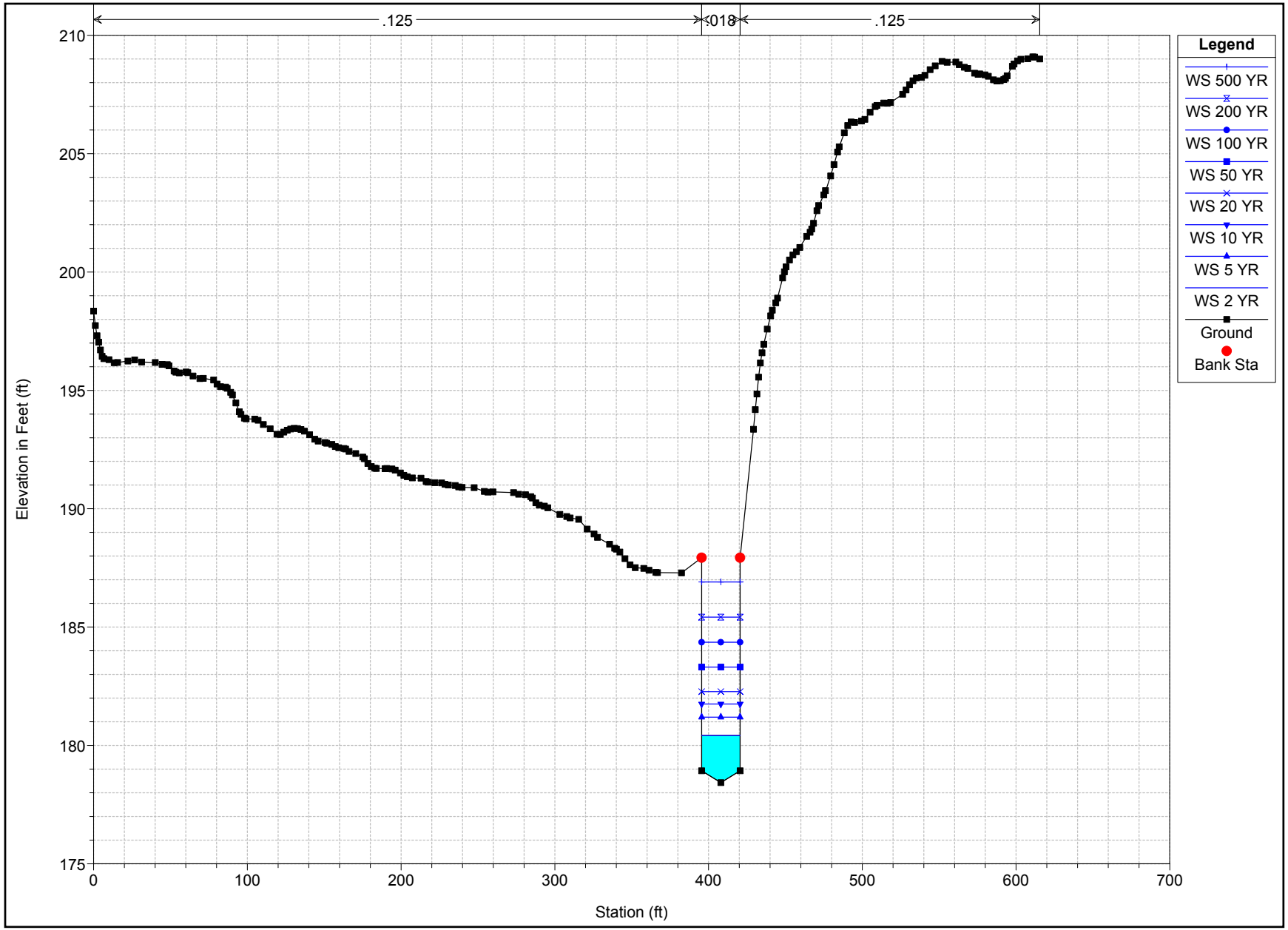


Plate 2 - HEC-RAS Cross Section Plots

Pukele Tributary, Cross Section 2184

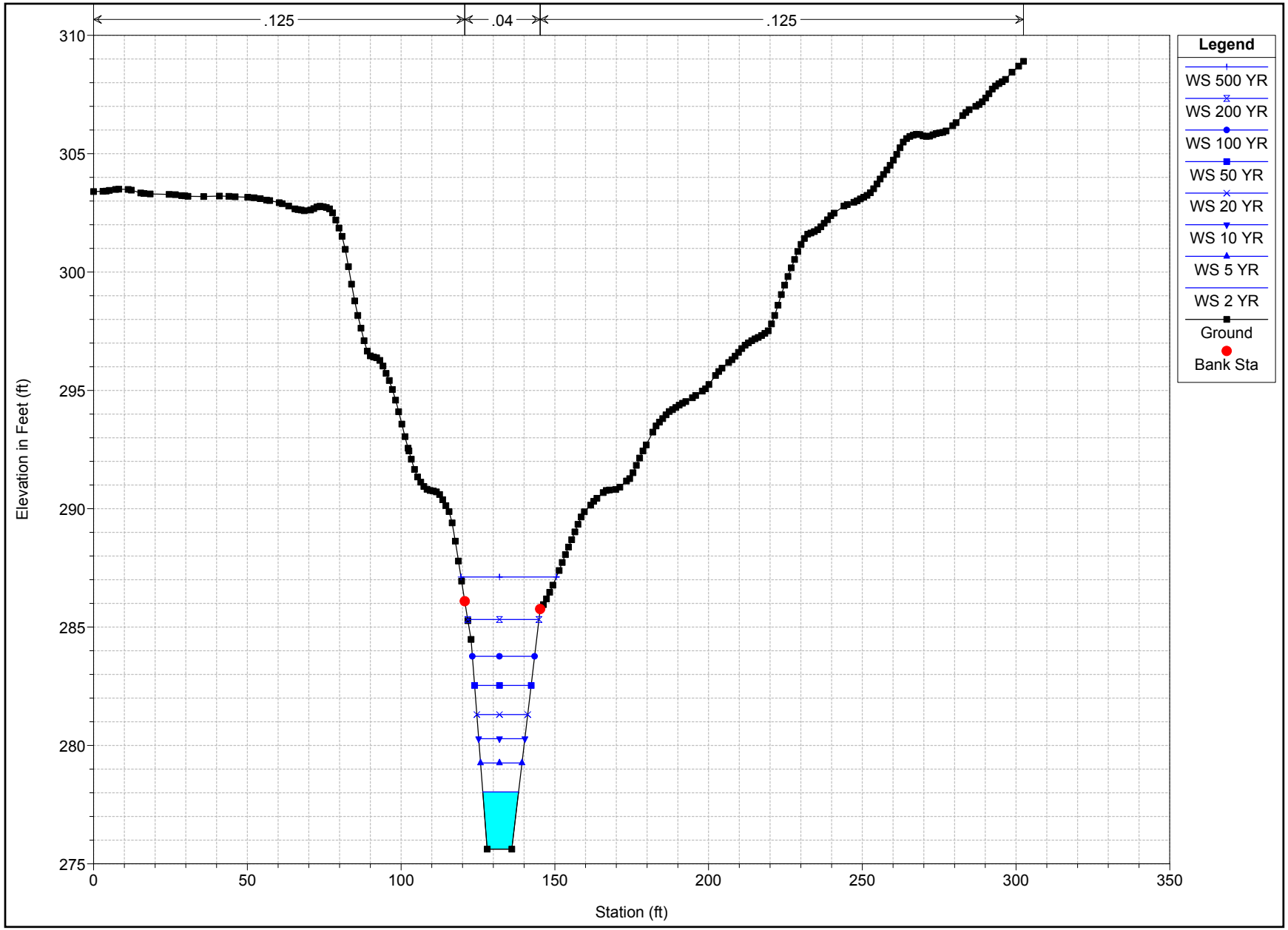


Plate 2 - HEC-RAS Cross Section Plots

UH Split, Cross Section 1107

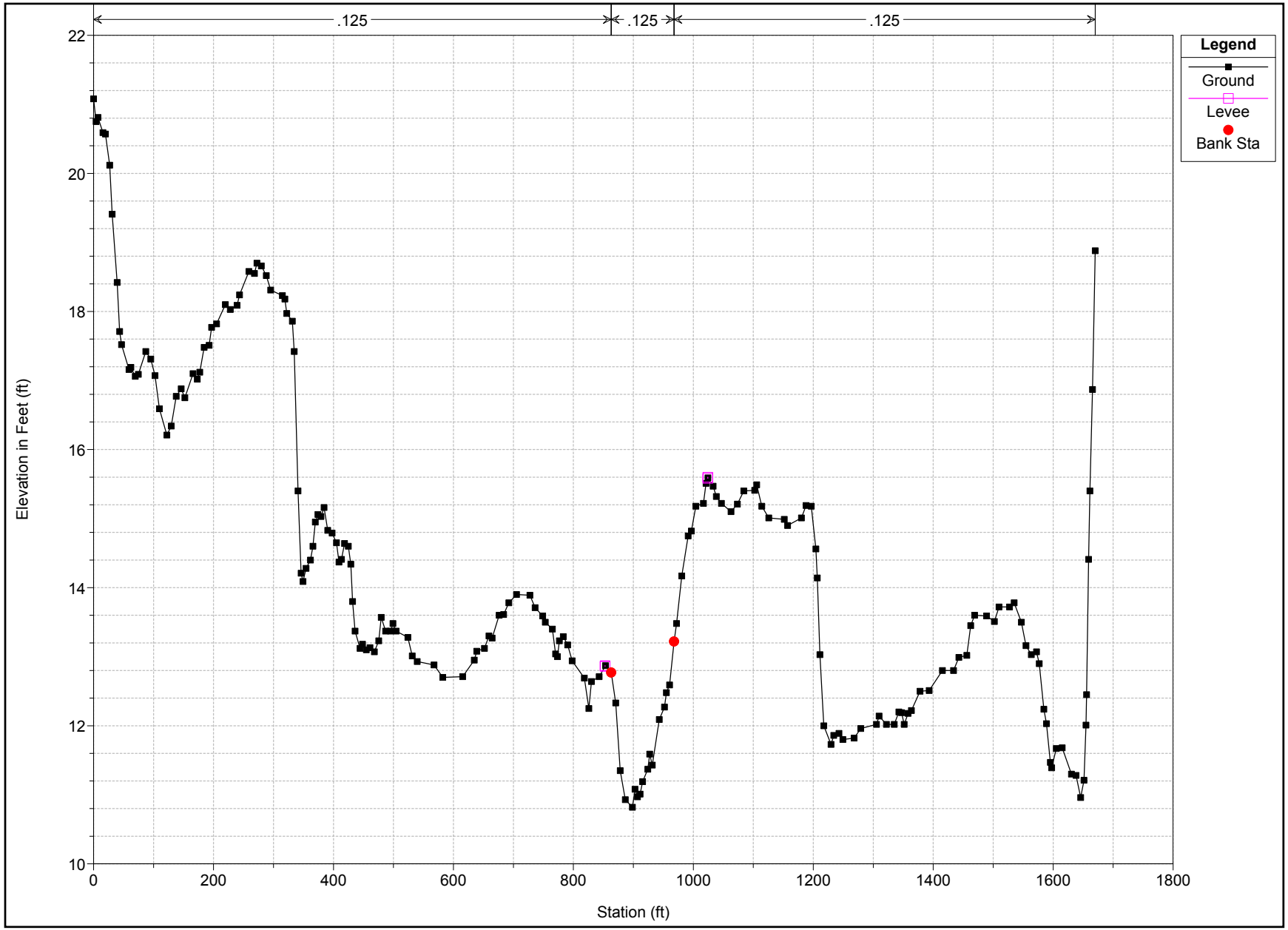


Plate 2 - HEC-RAS Cross Section Plots

UH Split, Cross Section 4606

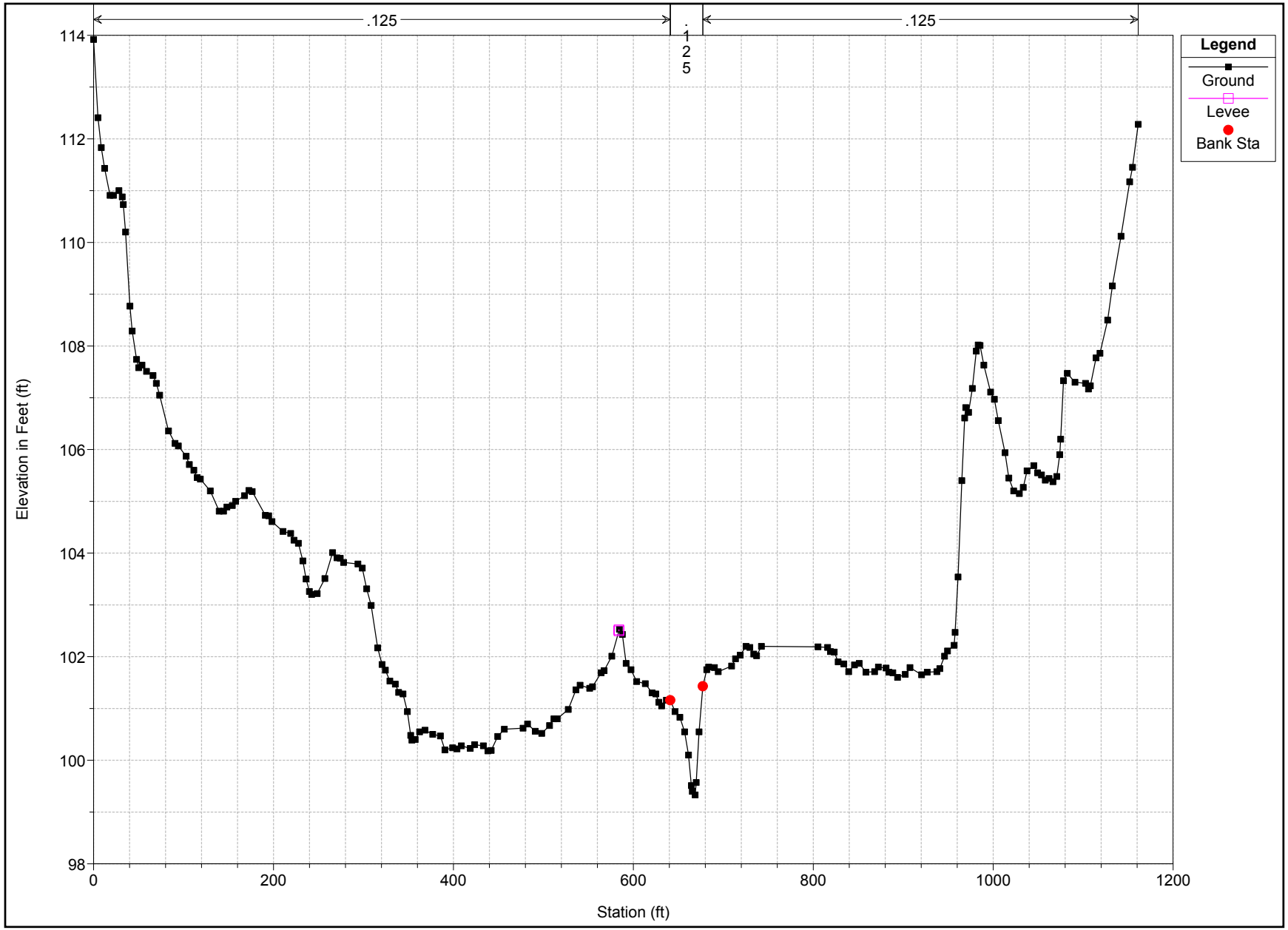


Plate 2 - HEC-RAS Cross Section Plots

Waiomao Tributary, Cross Section 1724

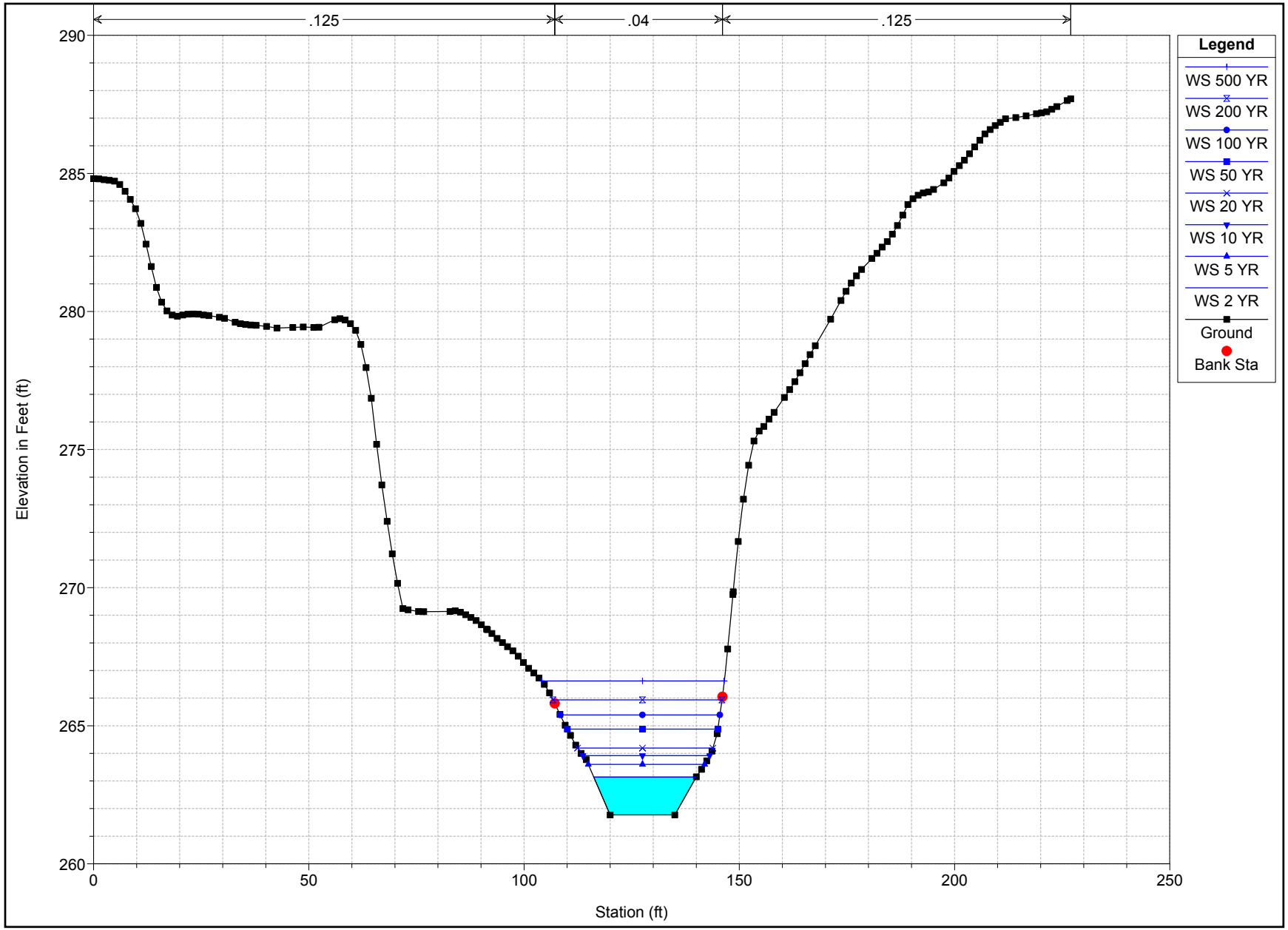


Plate 3 - Without Project Hydraulic Profiles

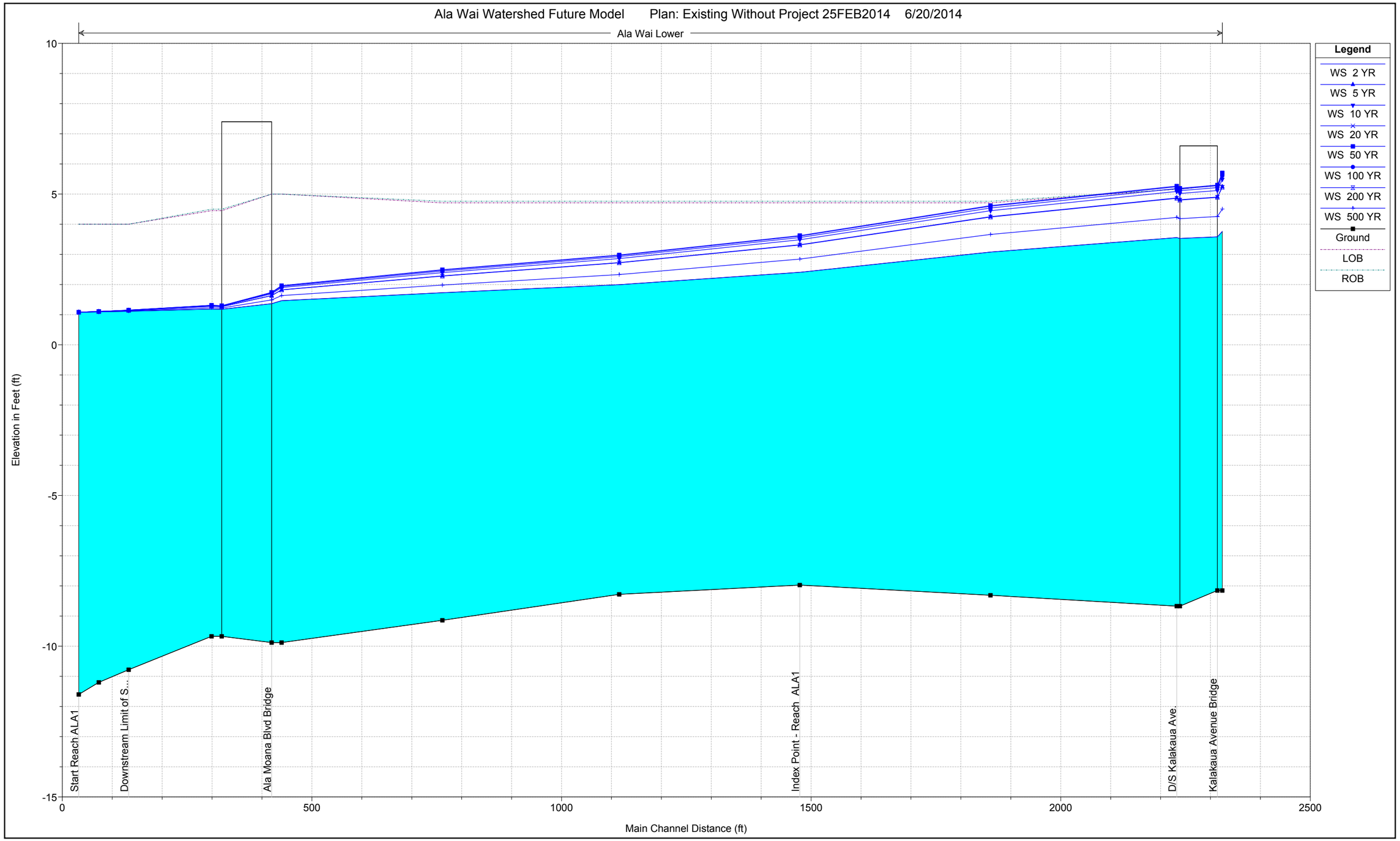


Plate 3 - Without Project Hydraulic Profiles

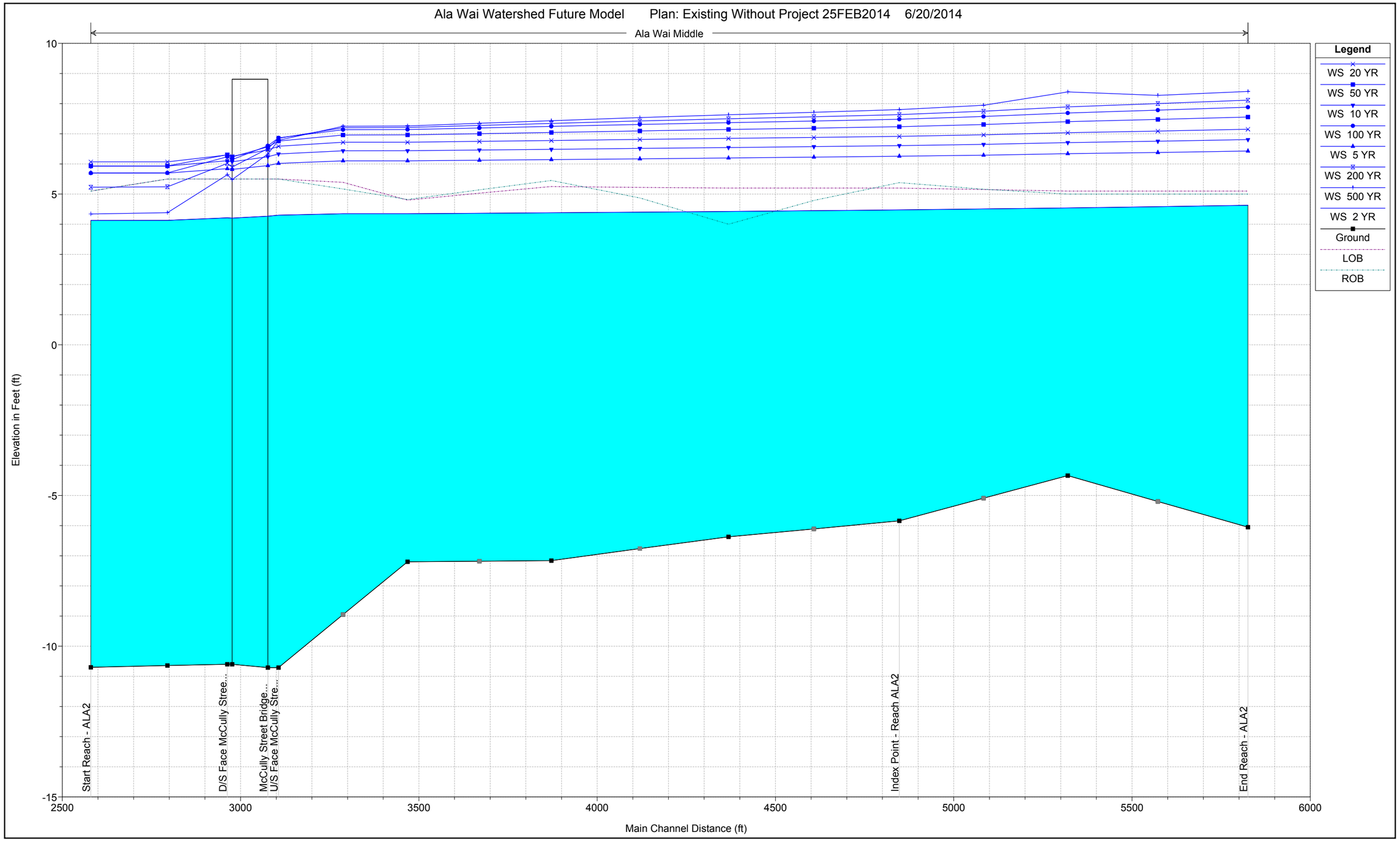


Plate 3 - Without Project Hydraulic Profiles

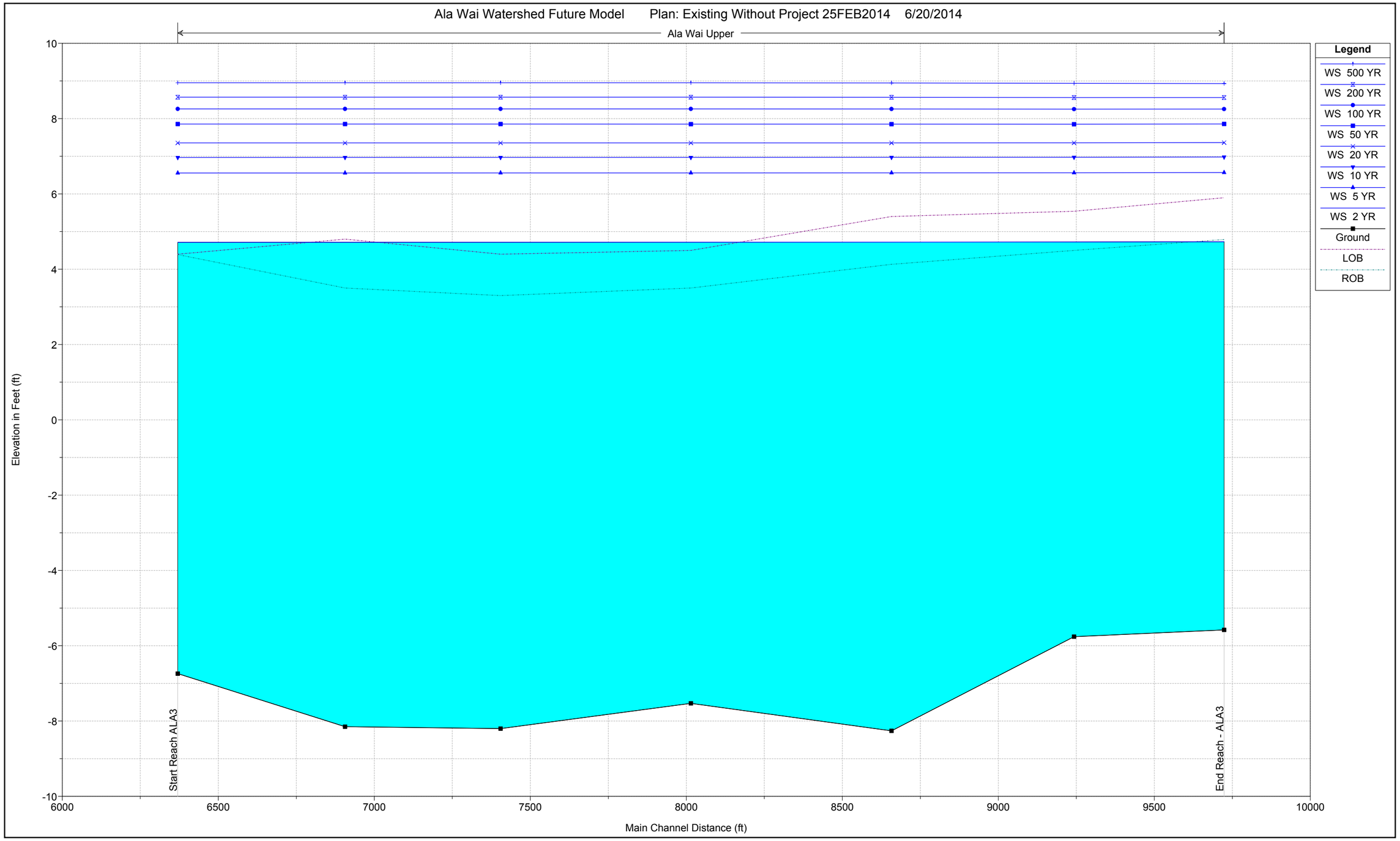


Plate 3 - Without Project Hydraulic Profiles

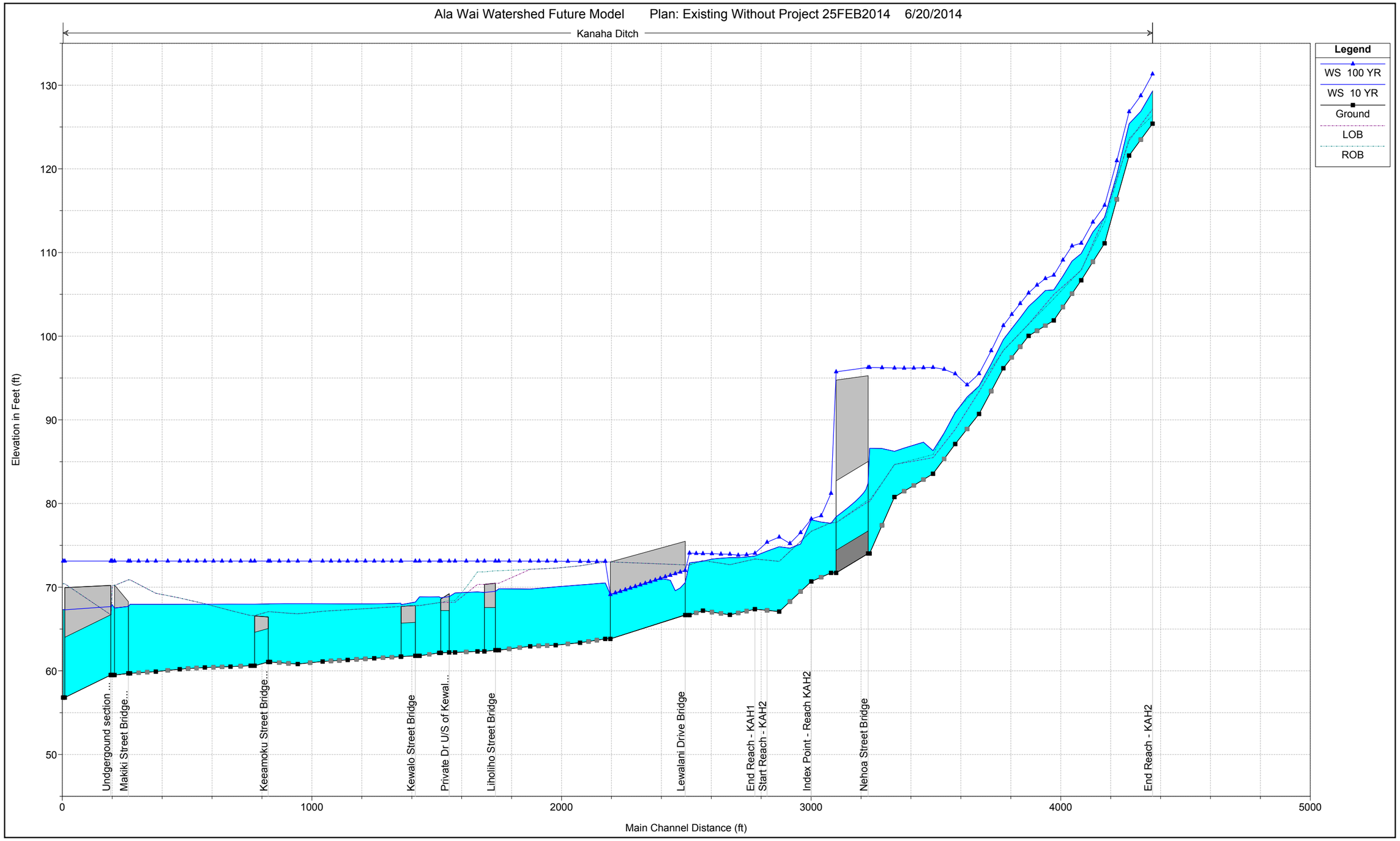


Plate 3 - Without Project Hydraulic Profiles

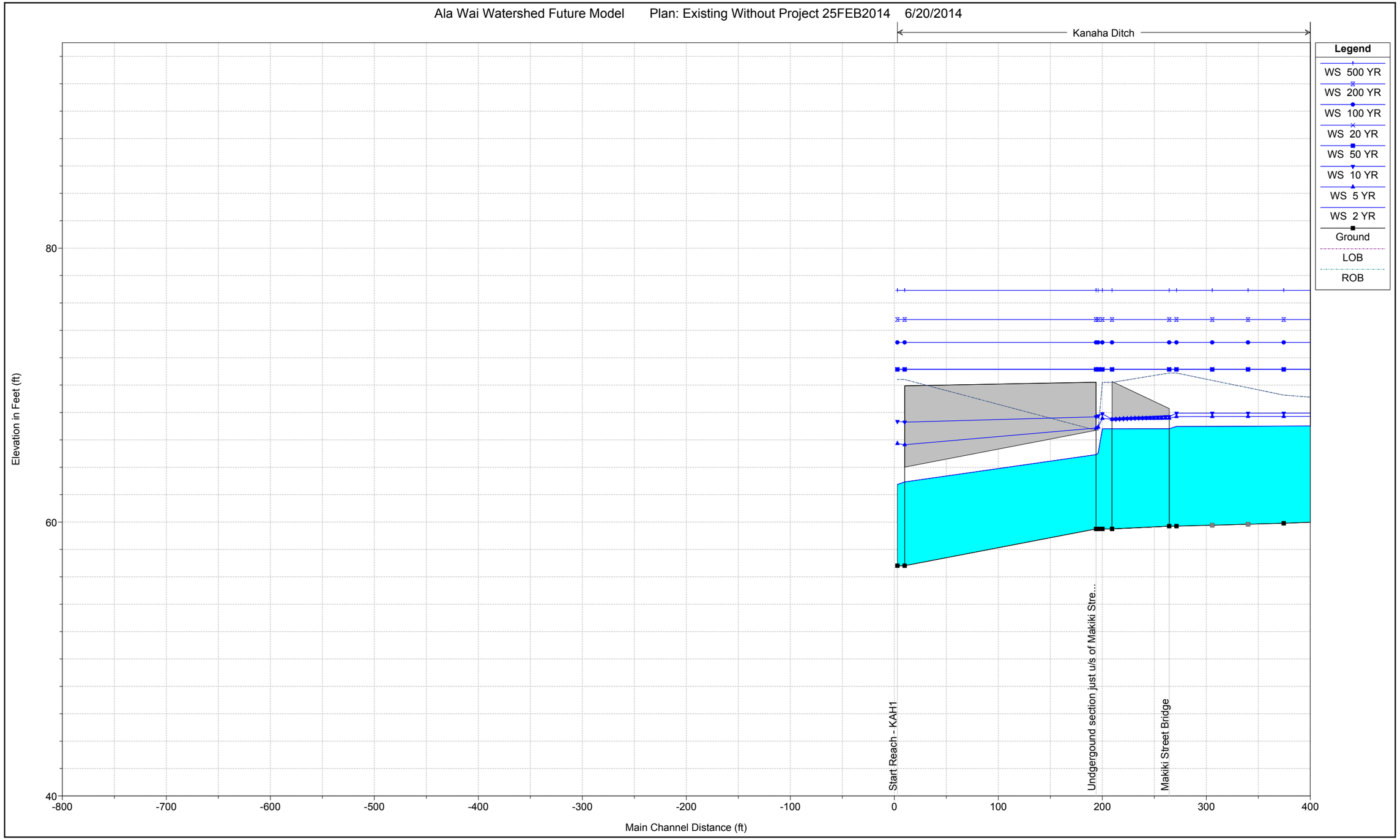


Plate 3 - Without Project Hydraulic Profiles

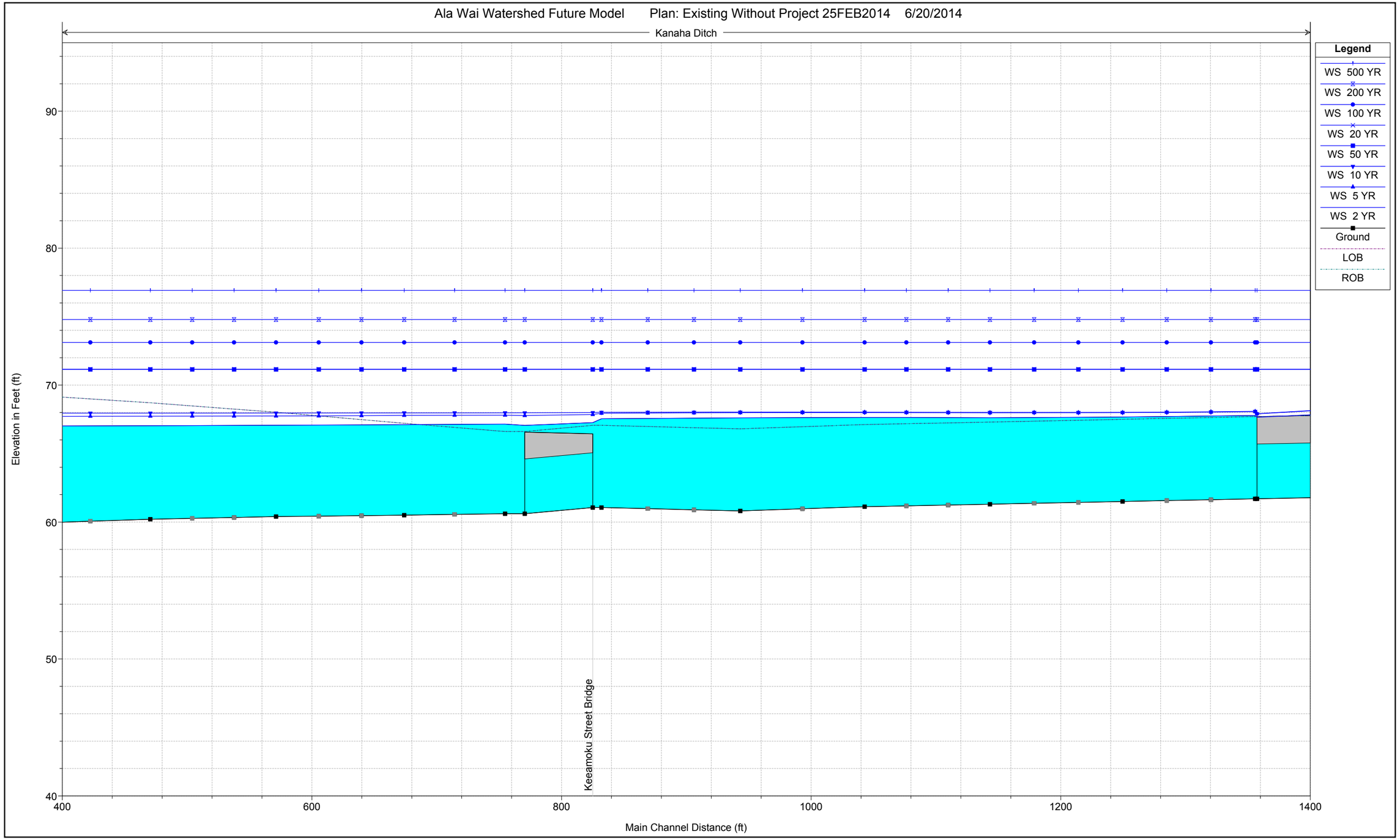


Plate 3 - Without Project Hydraulic Profiles

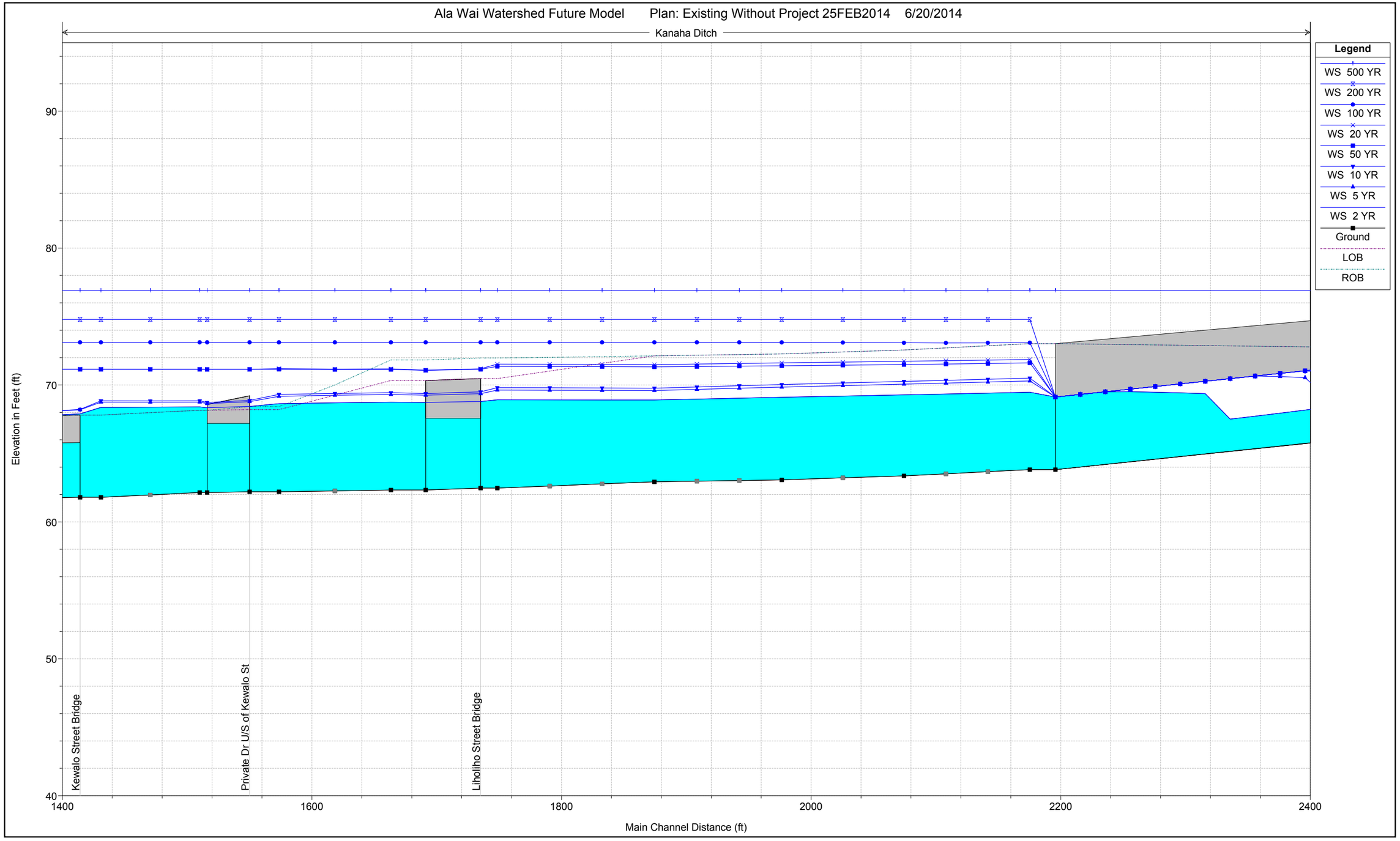


Plate 3 - Without Project Hydraulic Profiles

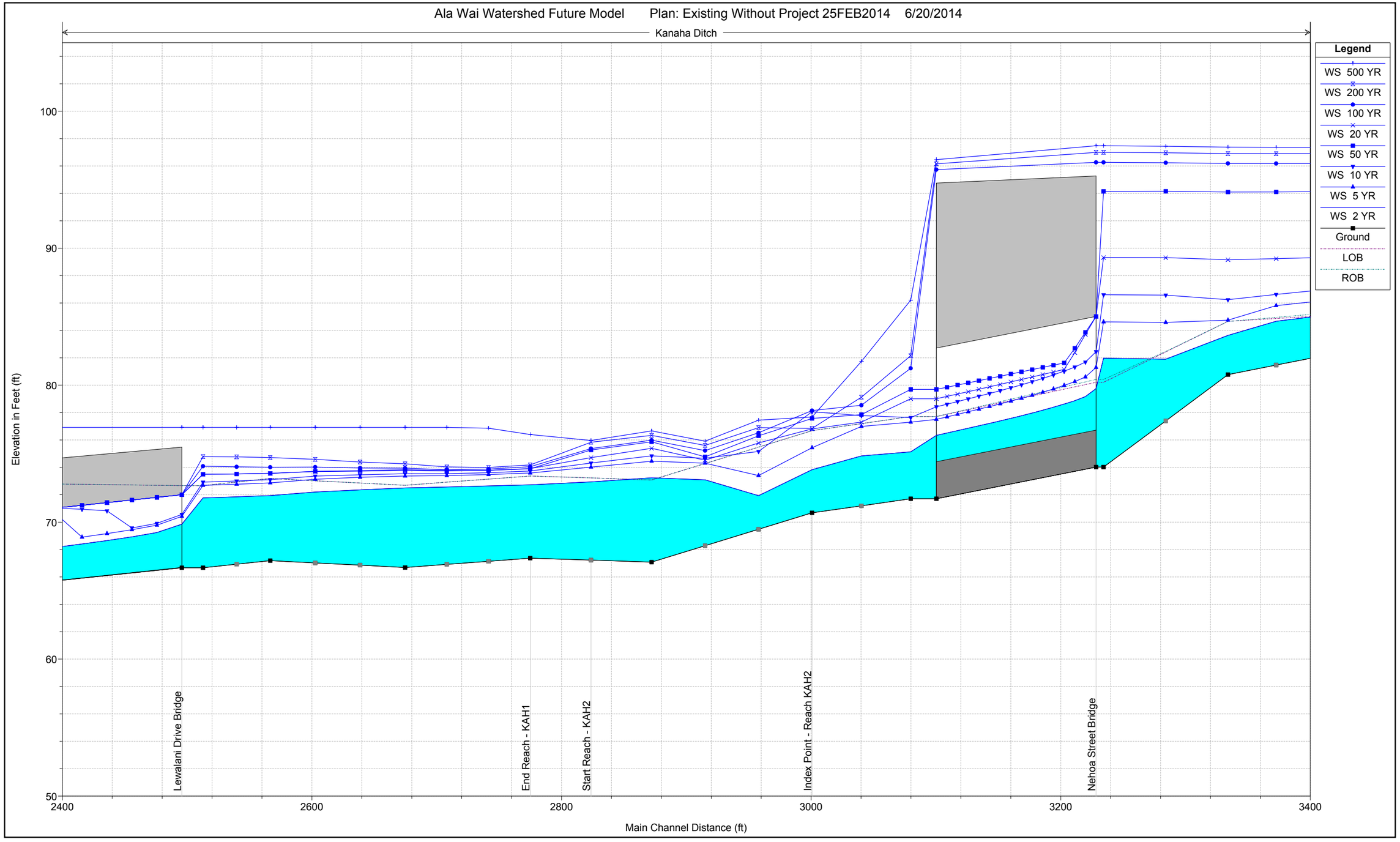


Plate 3 - Without Project Hydraulic Profiles

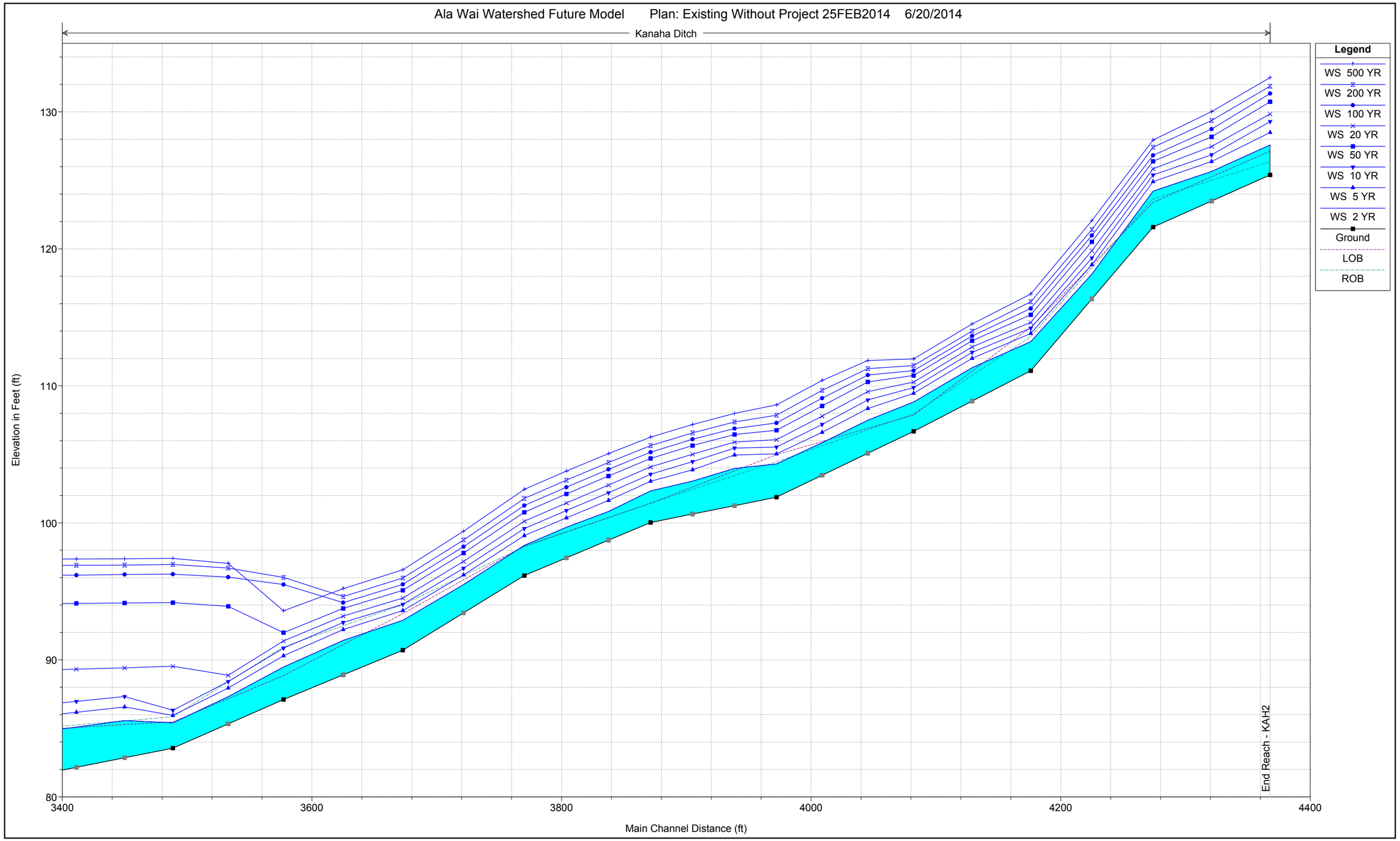


Plate 3 - Without Project Hydraulic Profiles

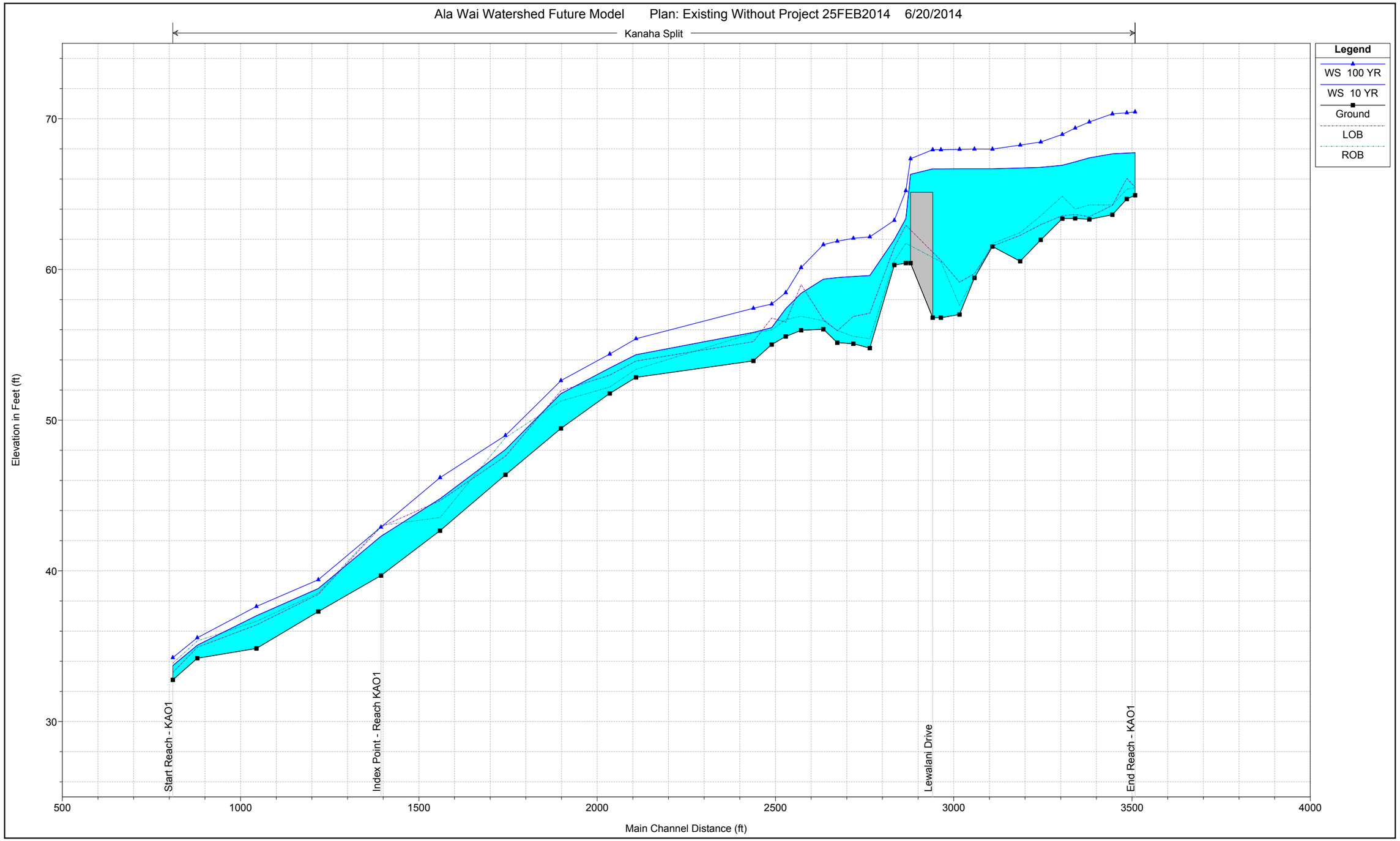


Plate 3 - Without Project Hydraulic Profiles

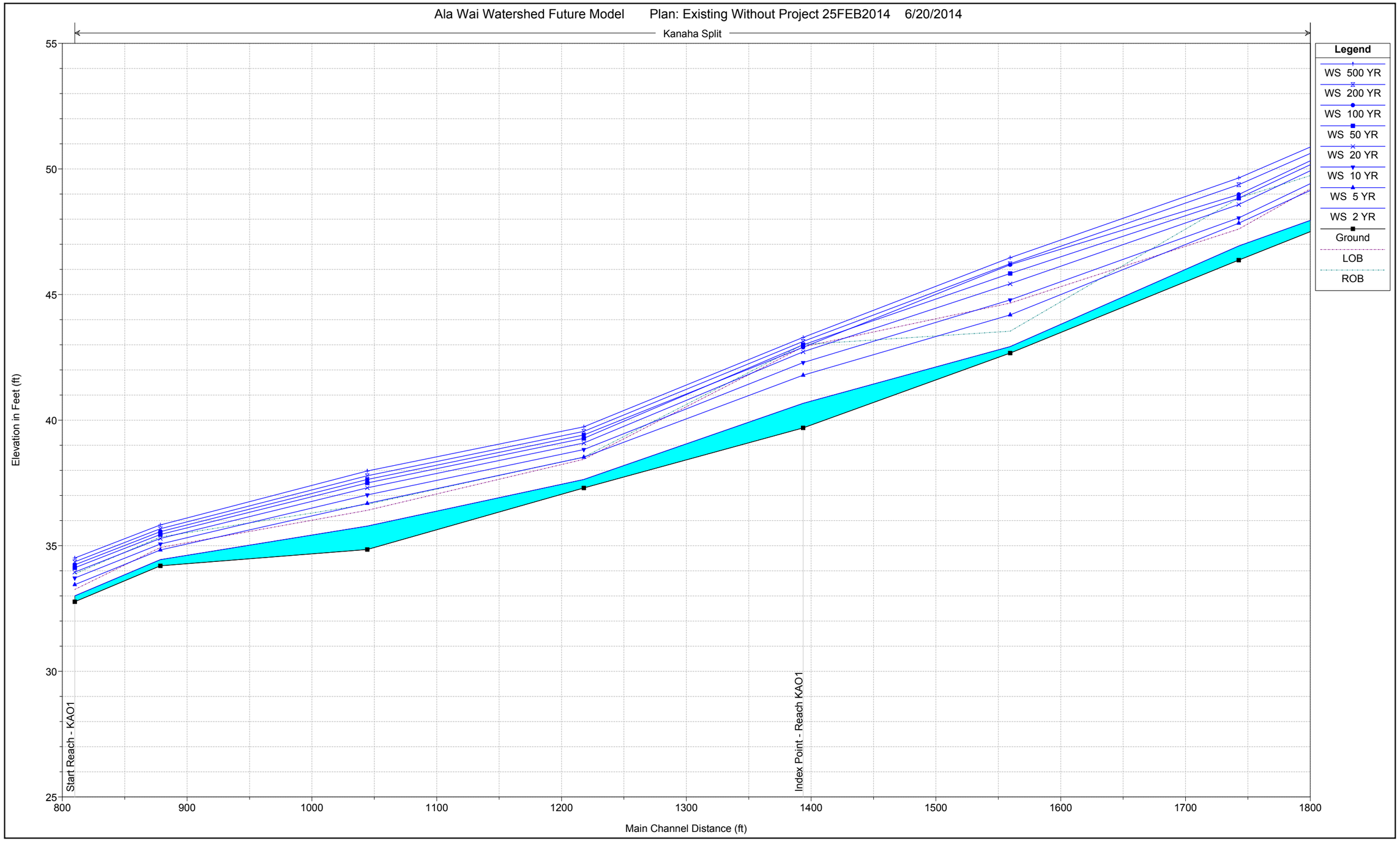
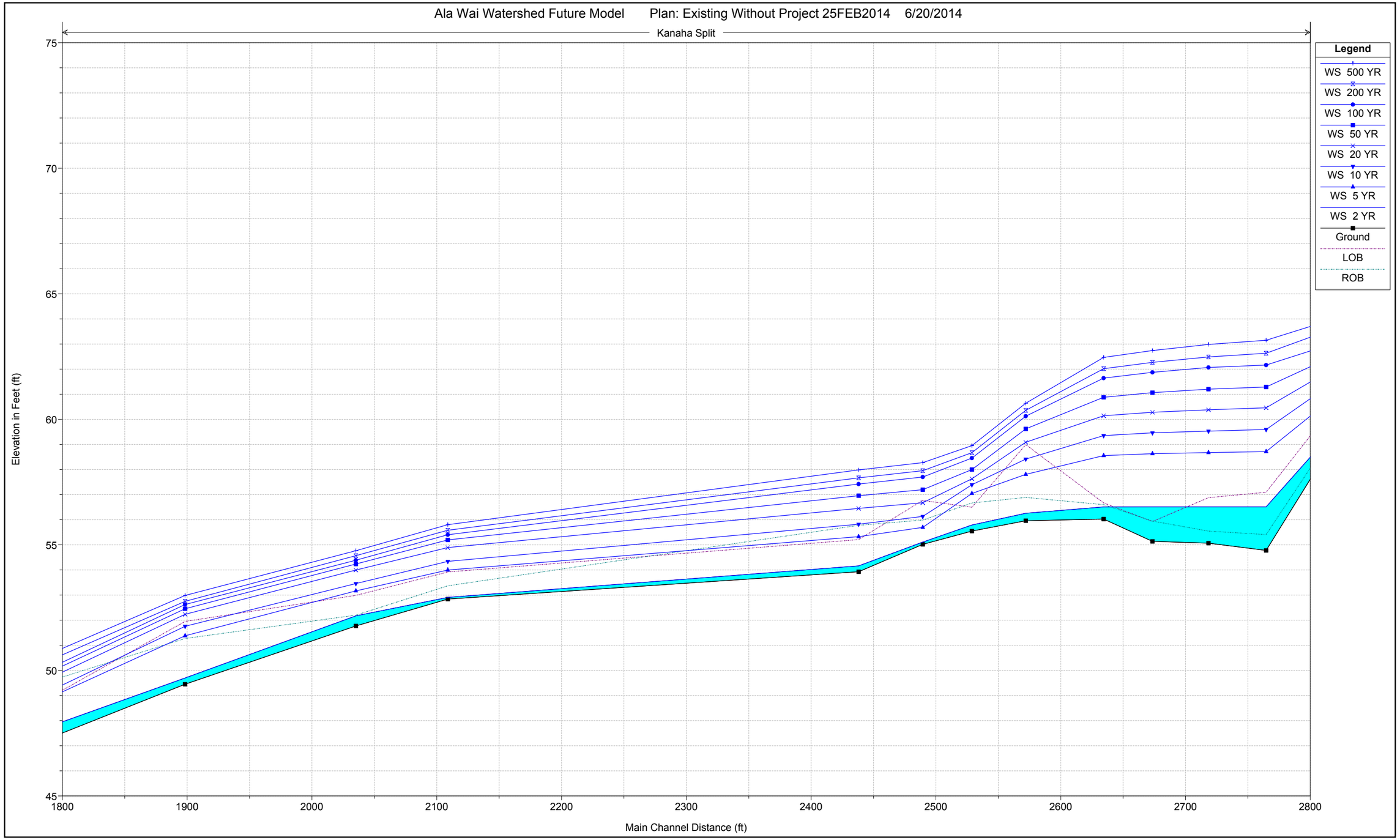


Plate 3 - Without Project Hydraulic Profiles



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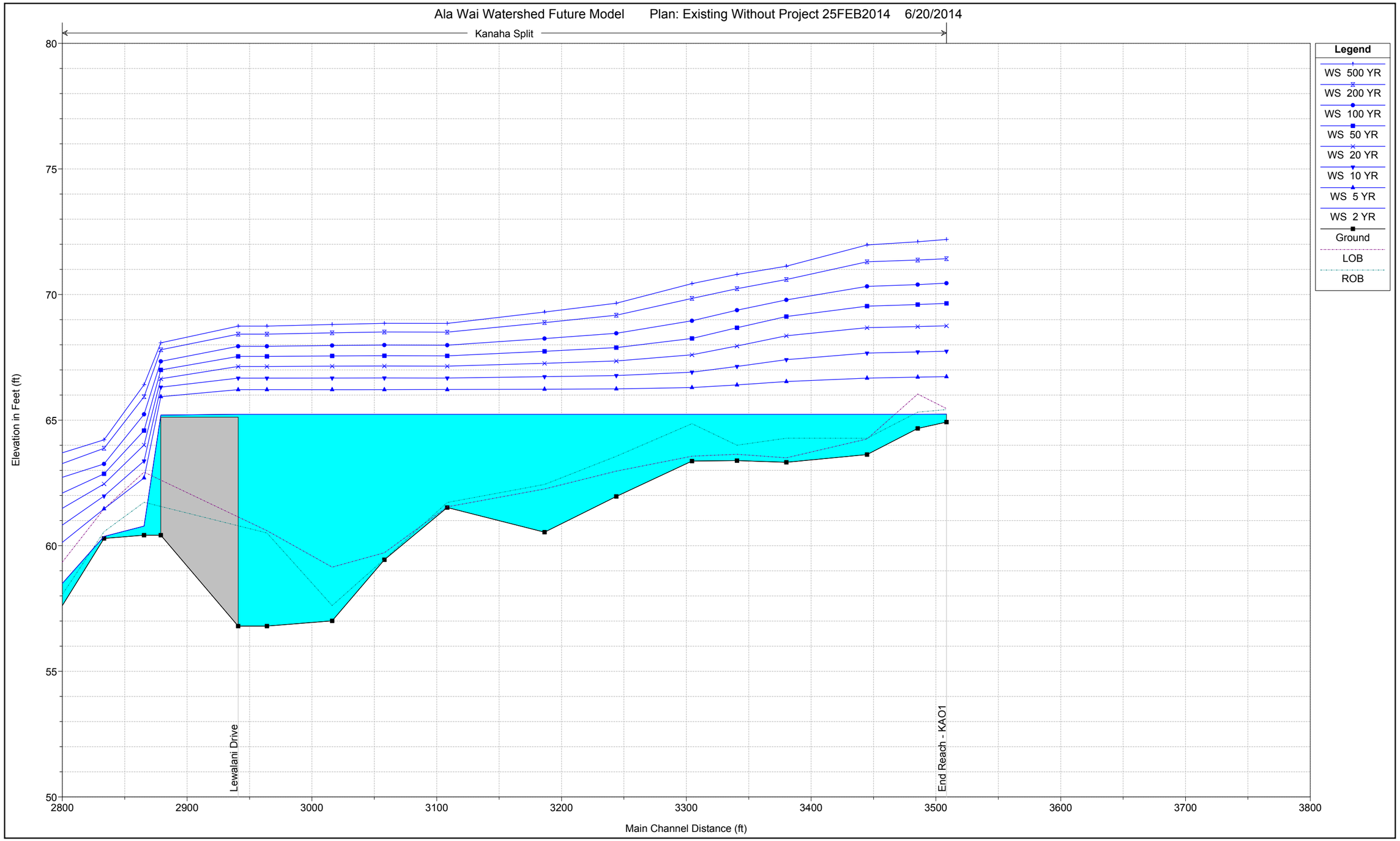

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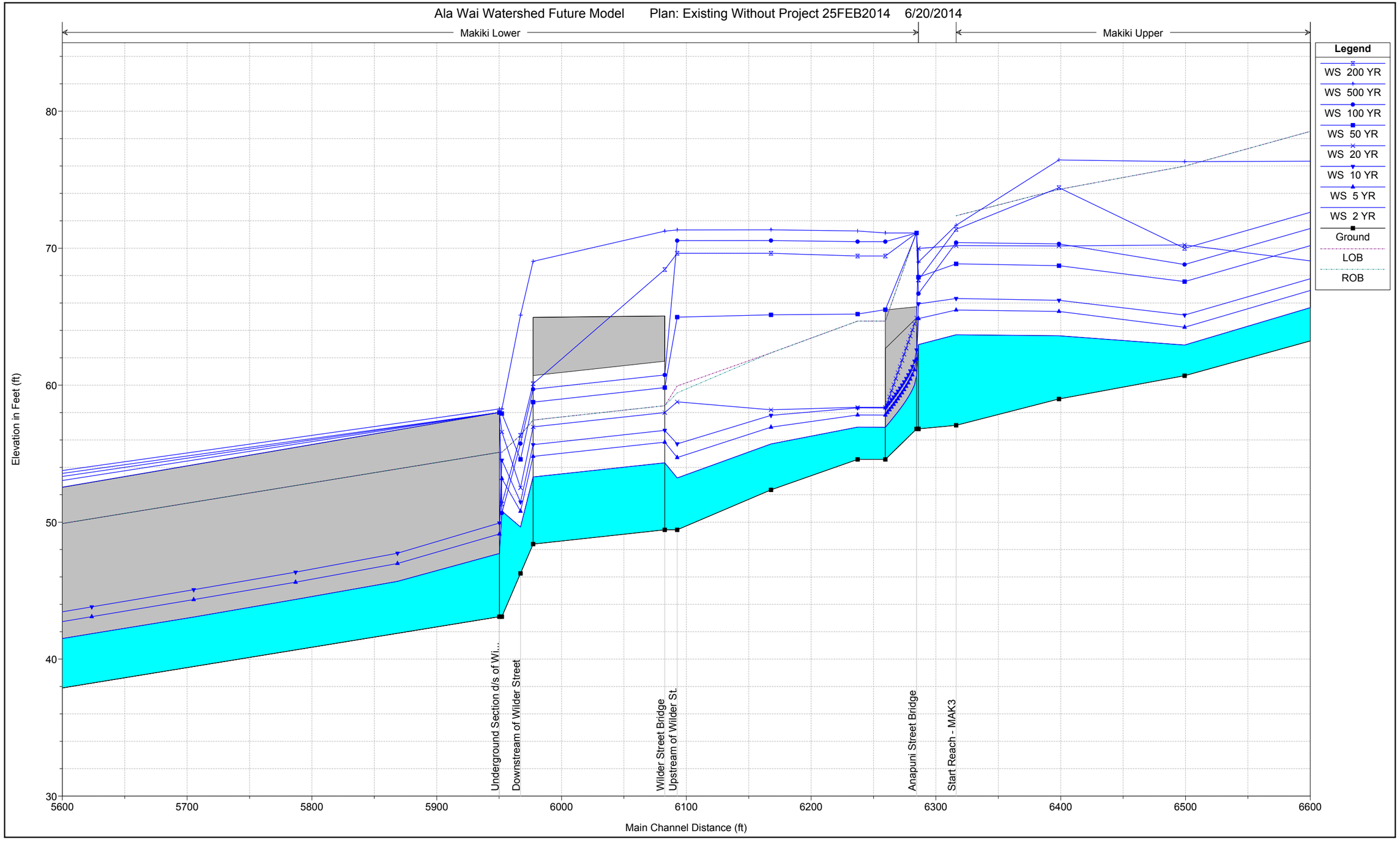


Plate 3 - Without Project Hydraulic Profiles

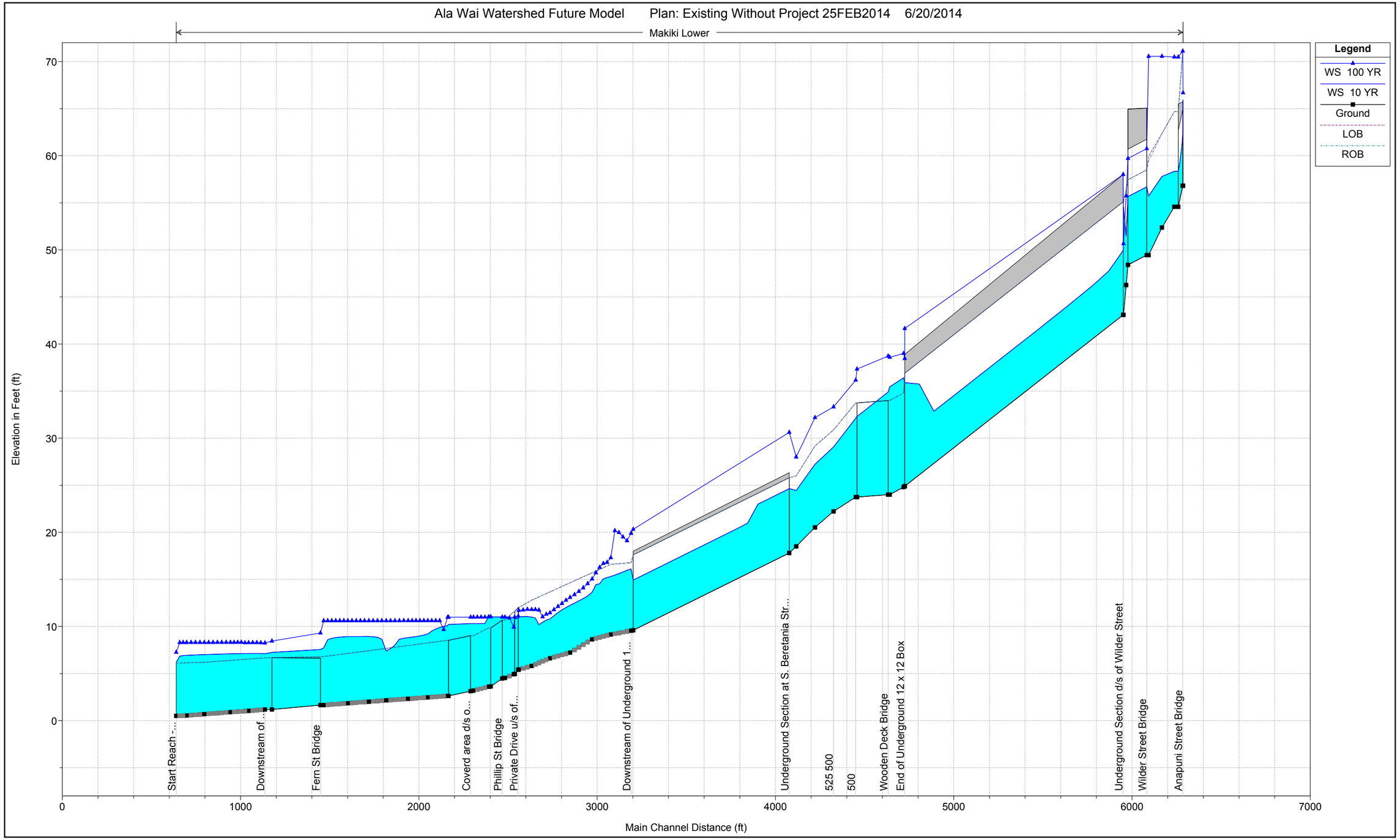


Plate 3 - Without Project Hydraulic Profiles

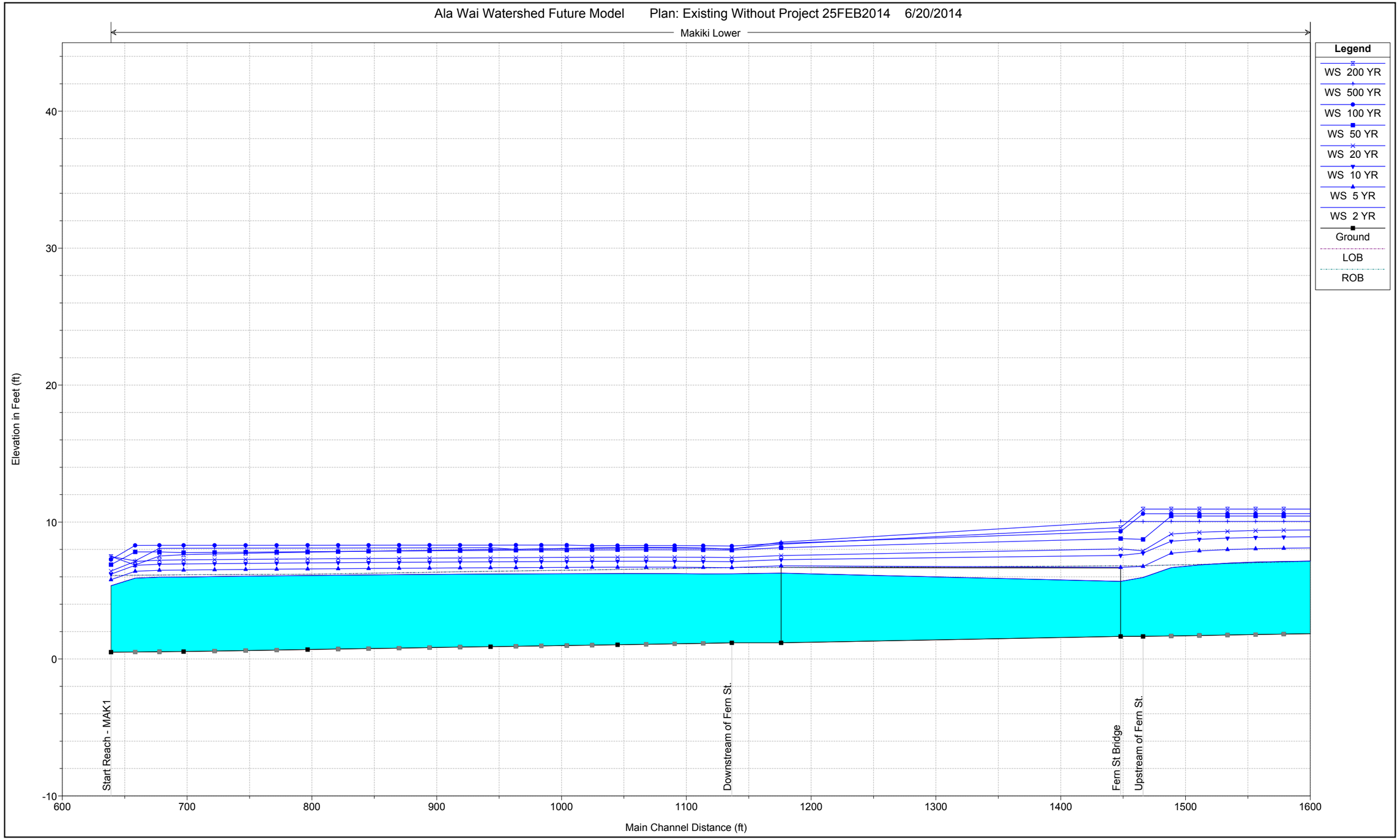


Plate 3 - Without Project Hydraulic Profiles

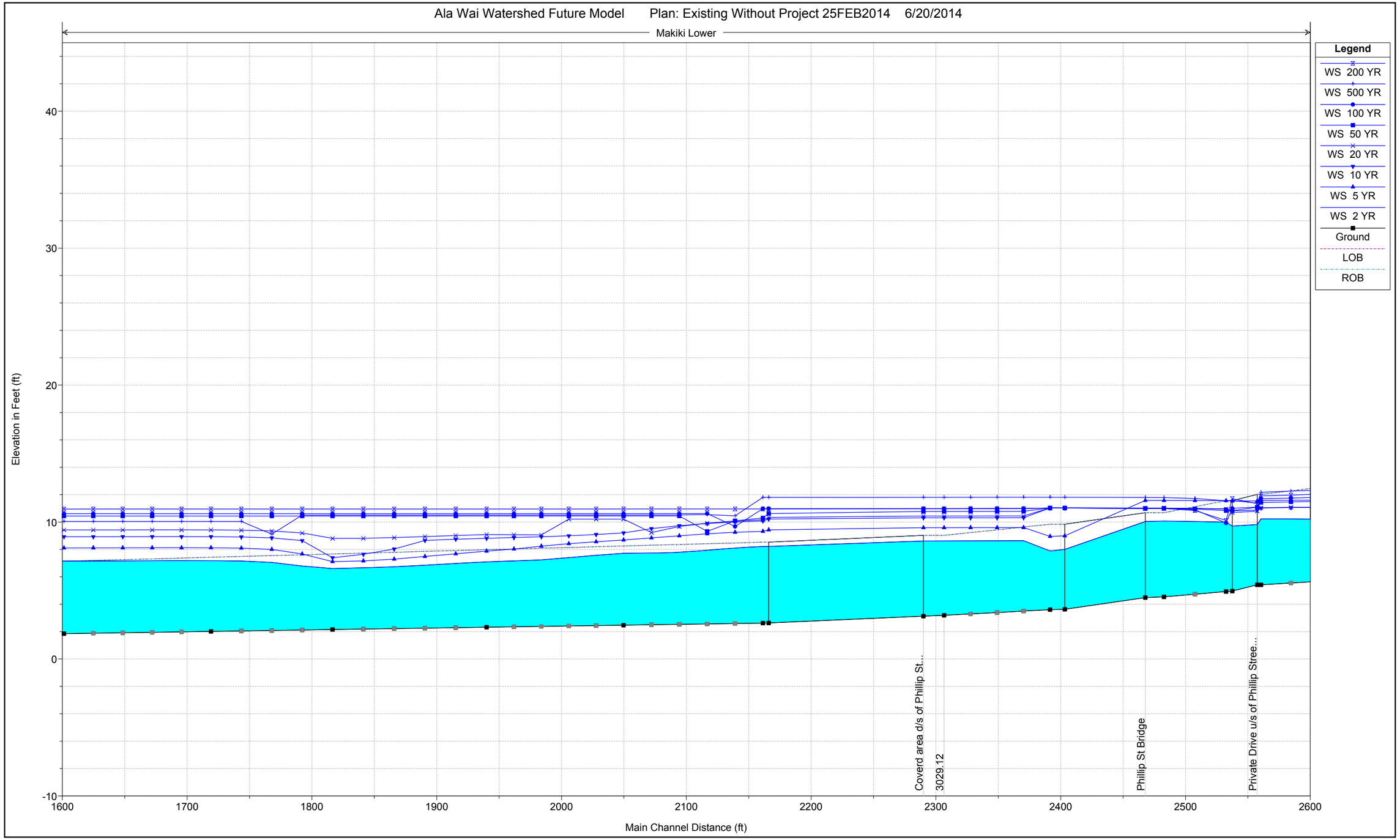


Plate 3 - Without Project Hydraulic Profiles

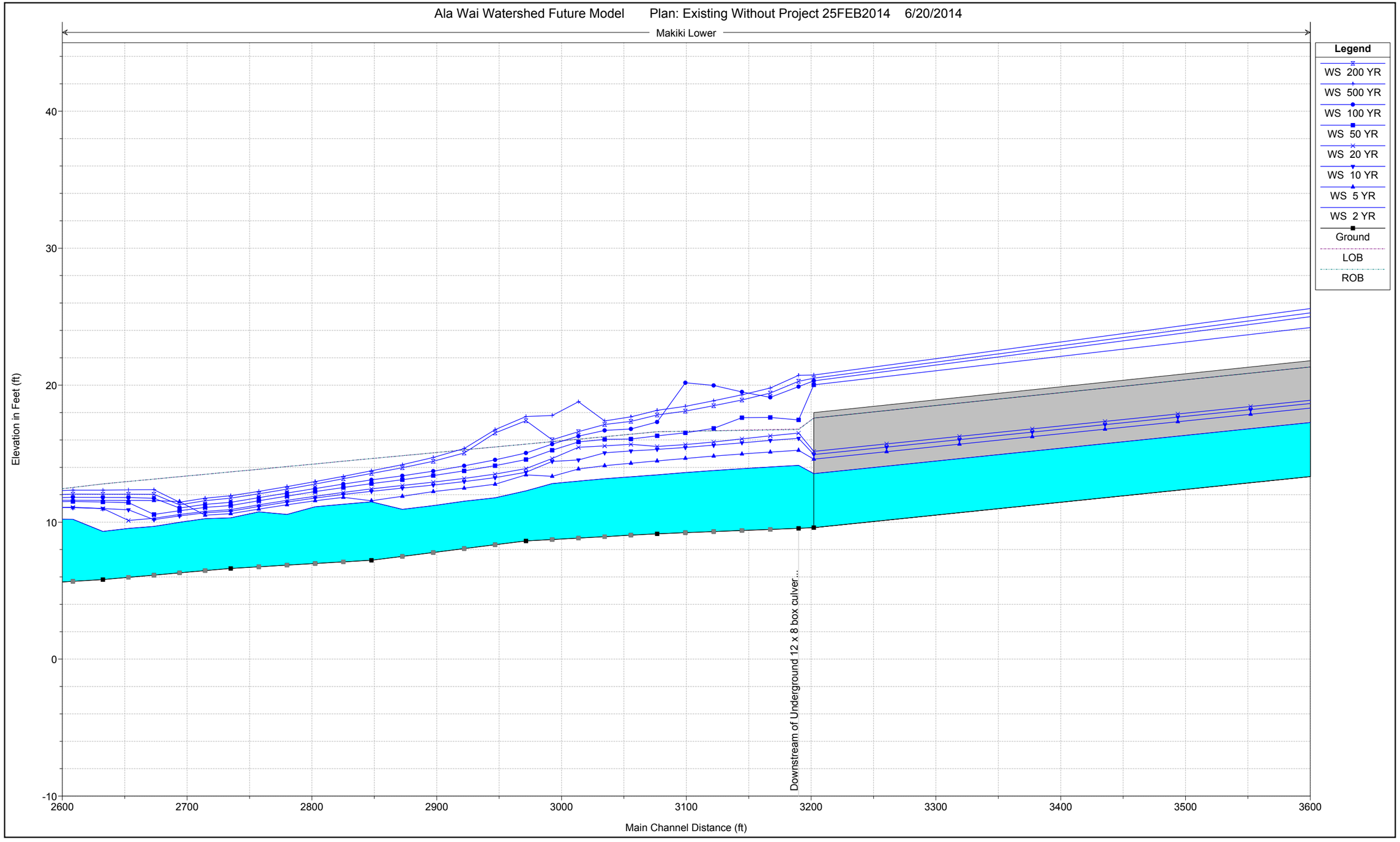


Plate 3 - Without Project Hydraulic Profiles

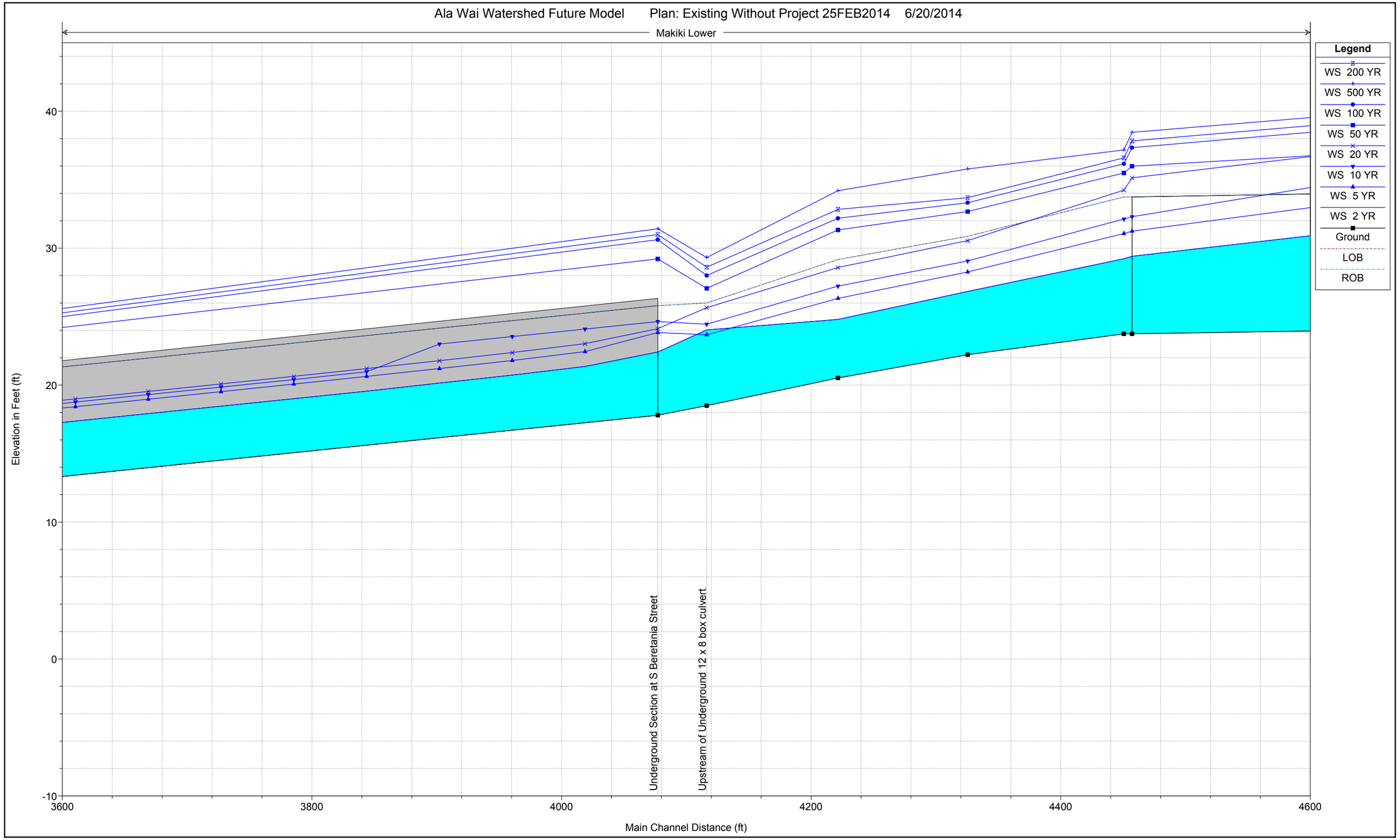
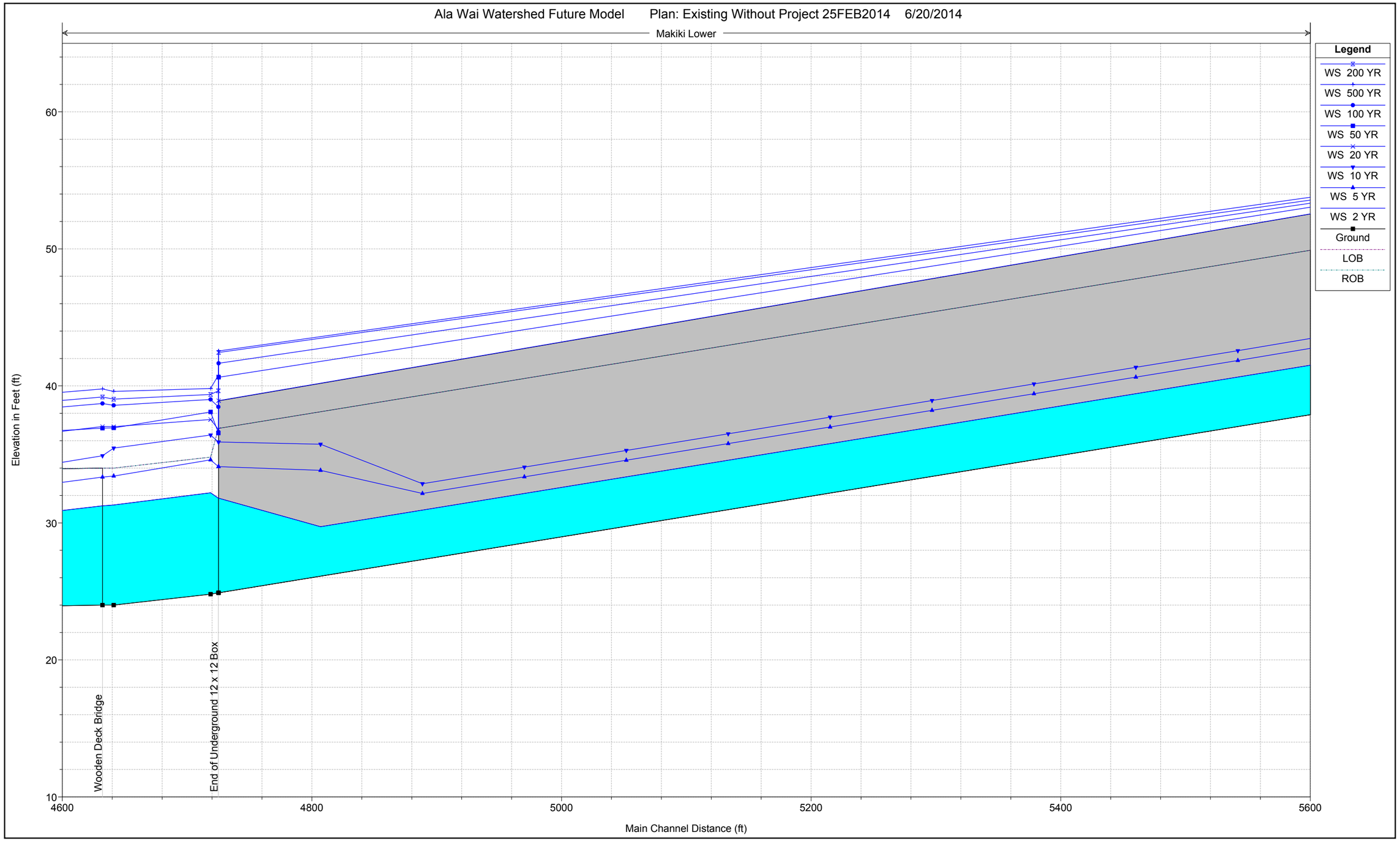


Plate 3 - Without Project Hydraulic Profiles



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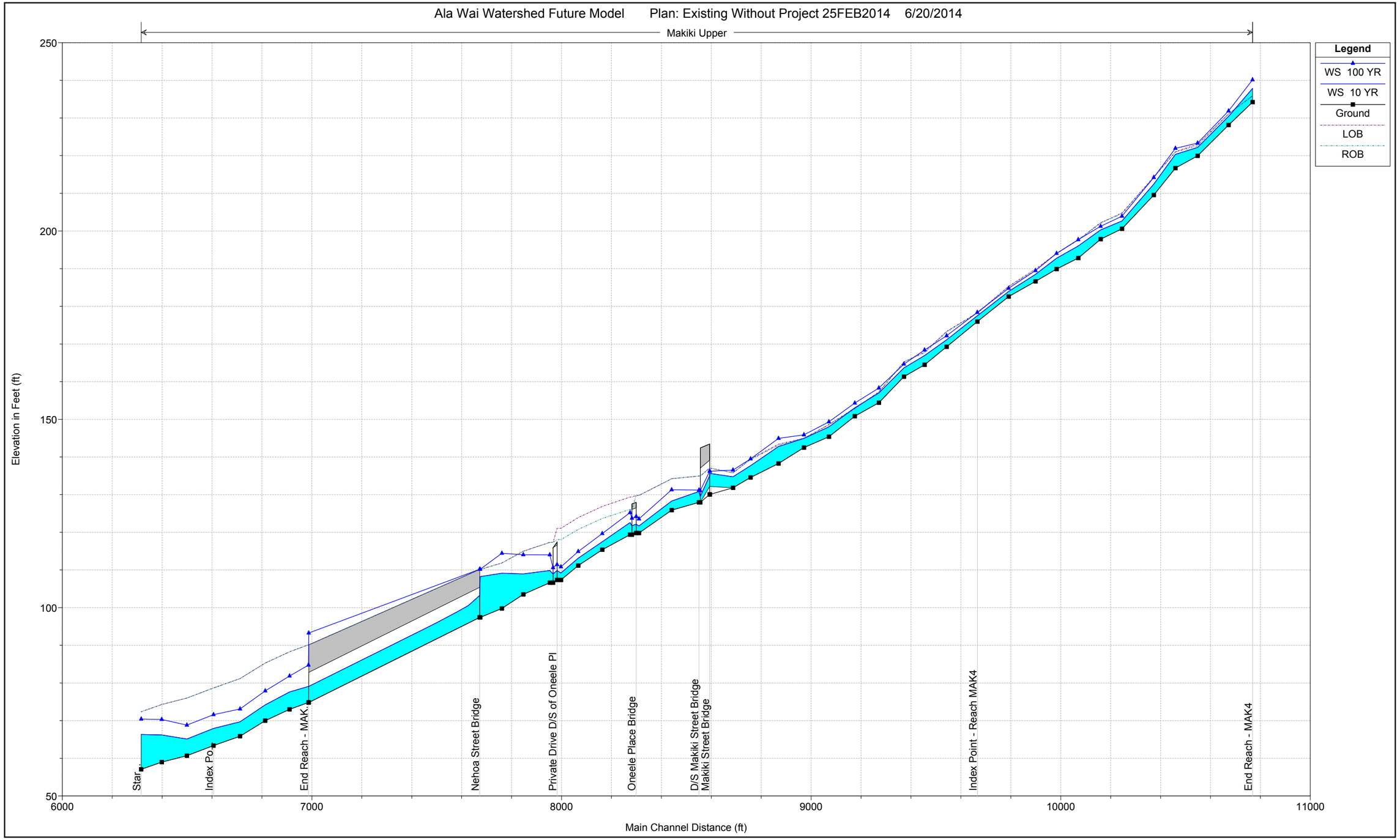


Plate 3 - Without Project Hydraulic Profiles

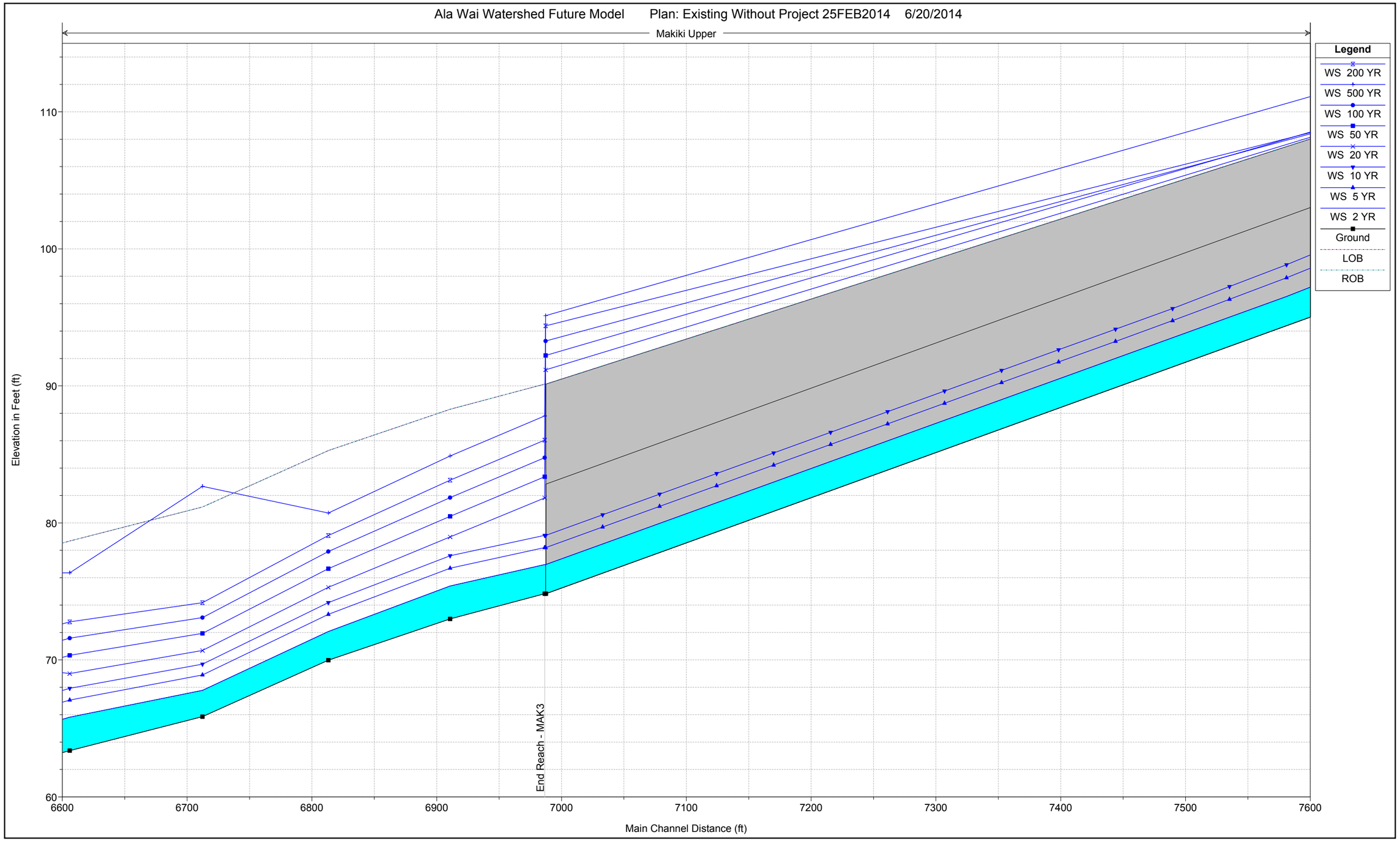


Plate 3 - Without Project Hydraulic Profiles

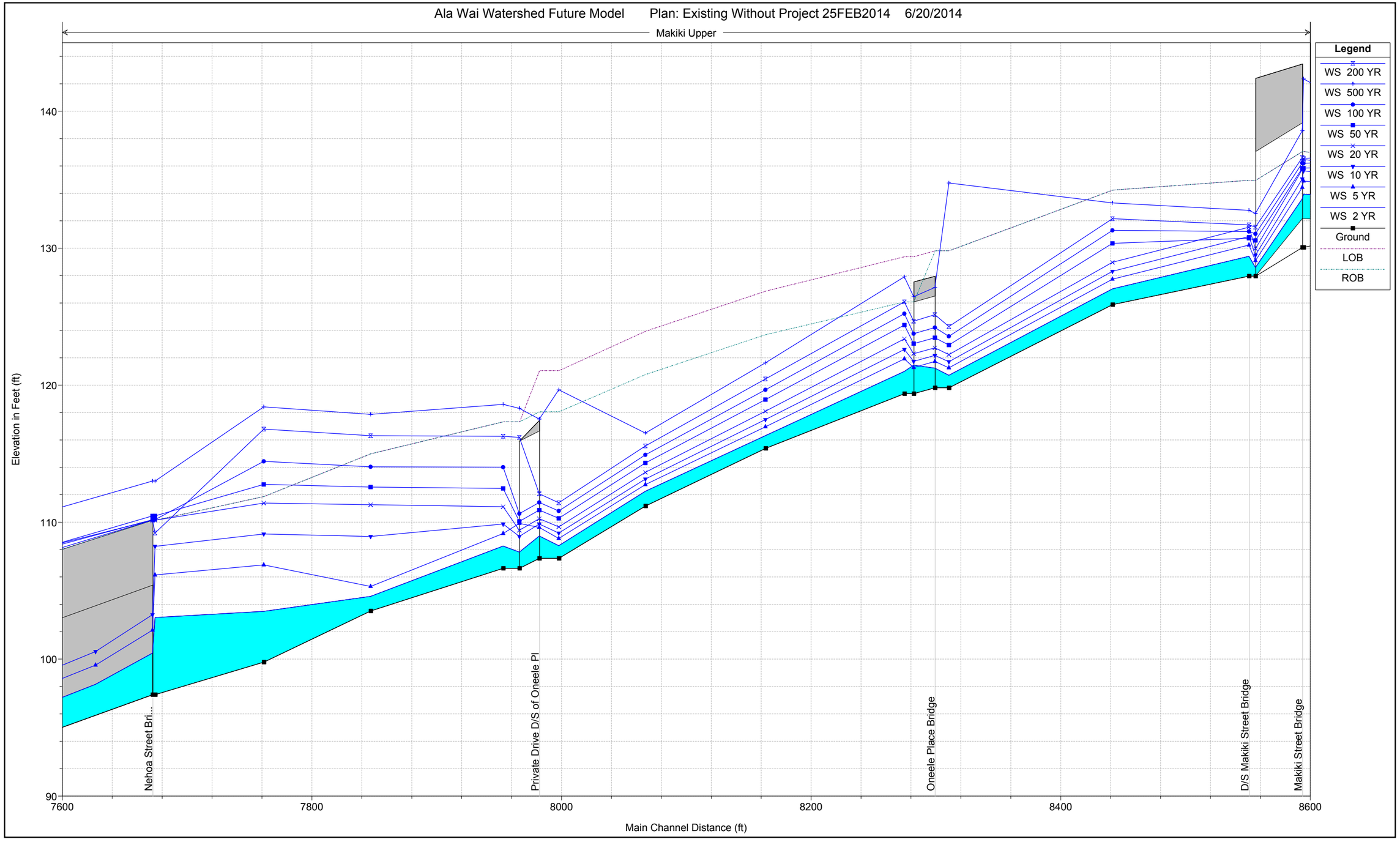


Plate 3 - Without Project Hydraulic Profiles

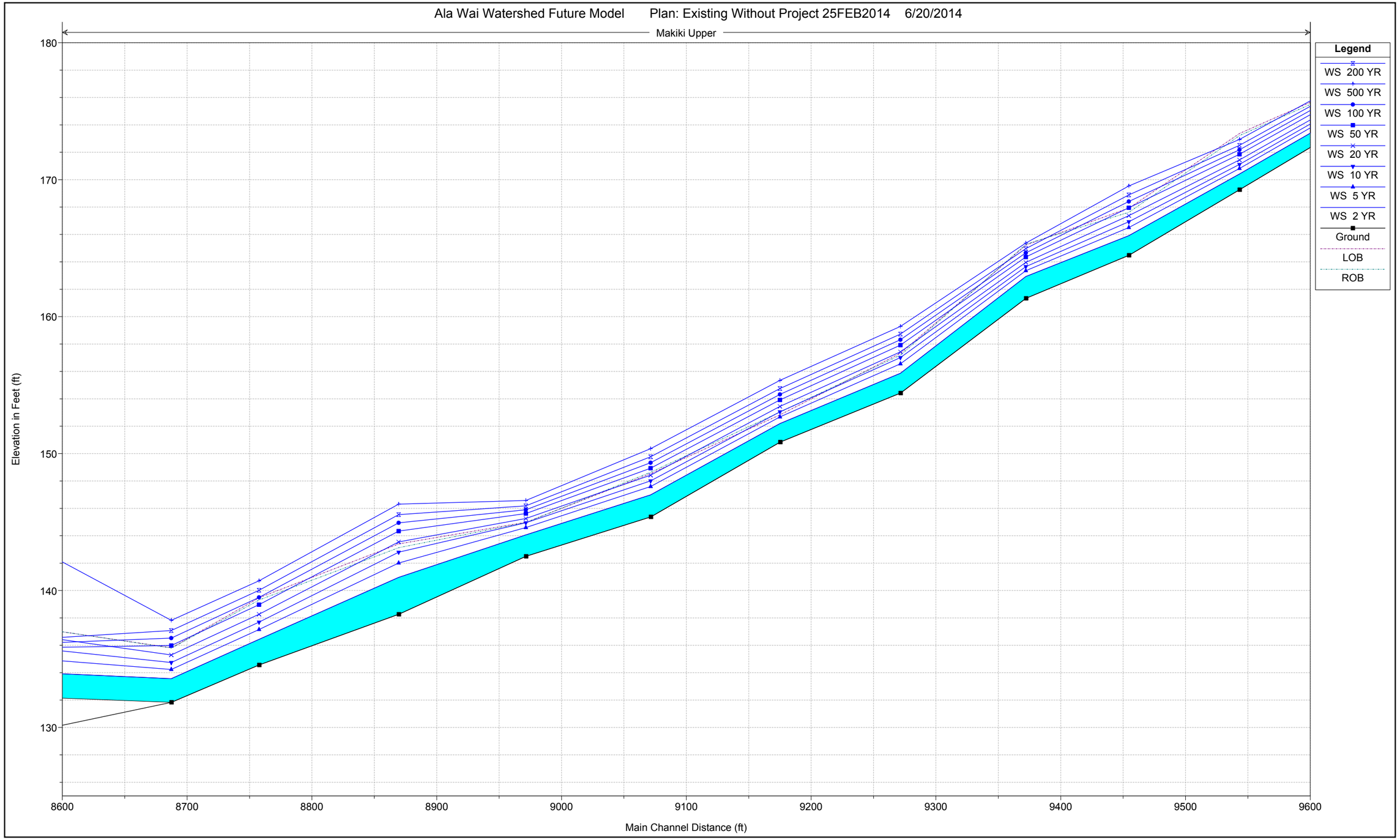
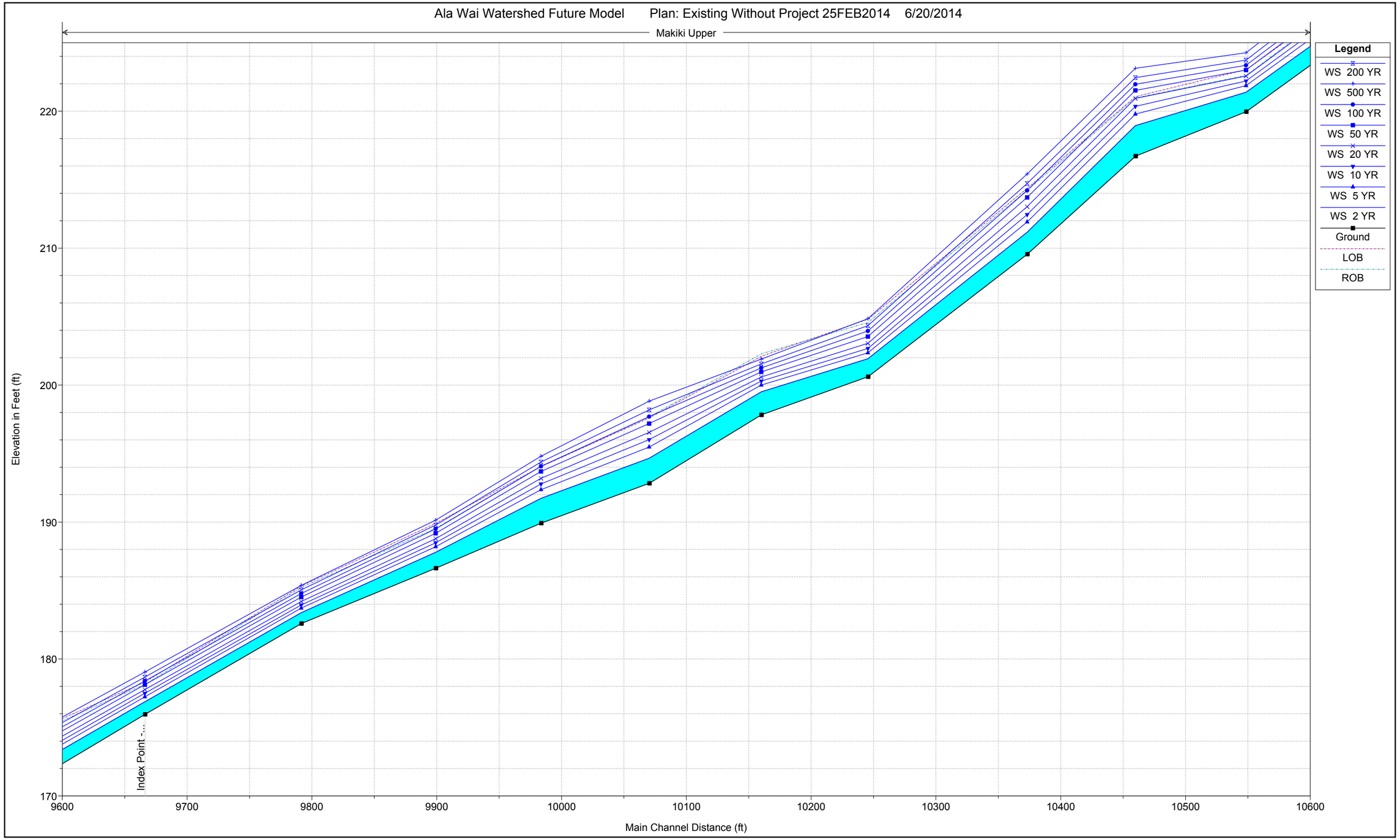


Plate 3 - Without Project Hydraulic Profiles



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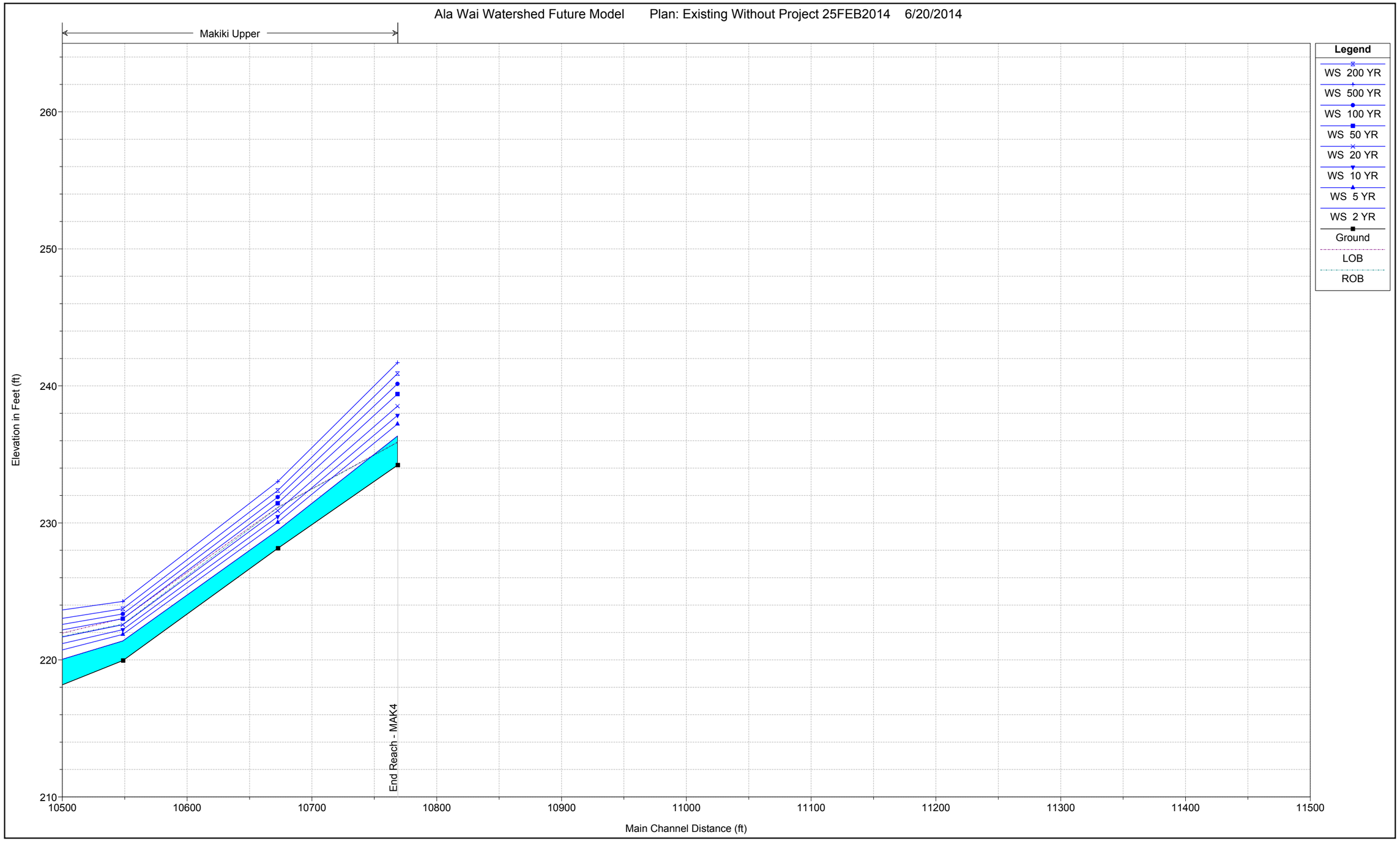
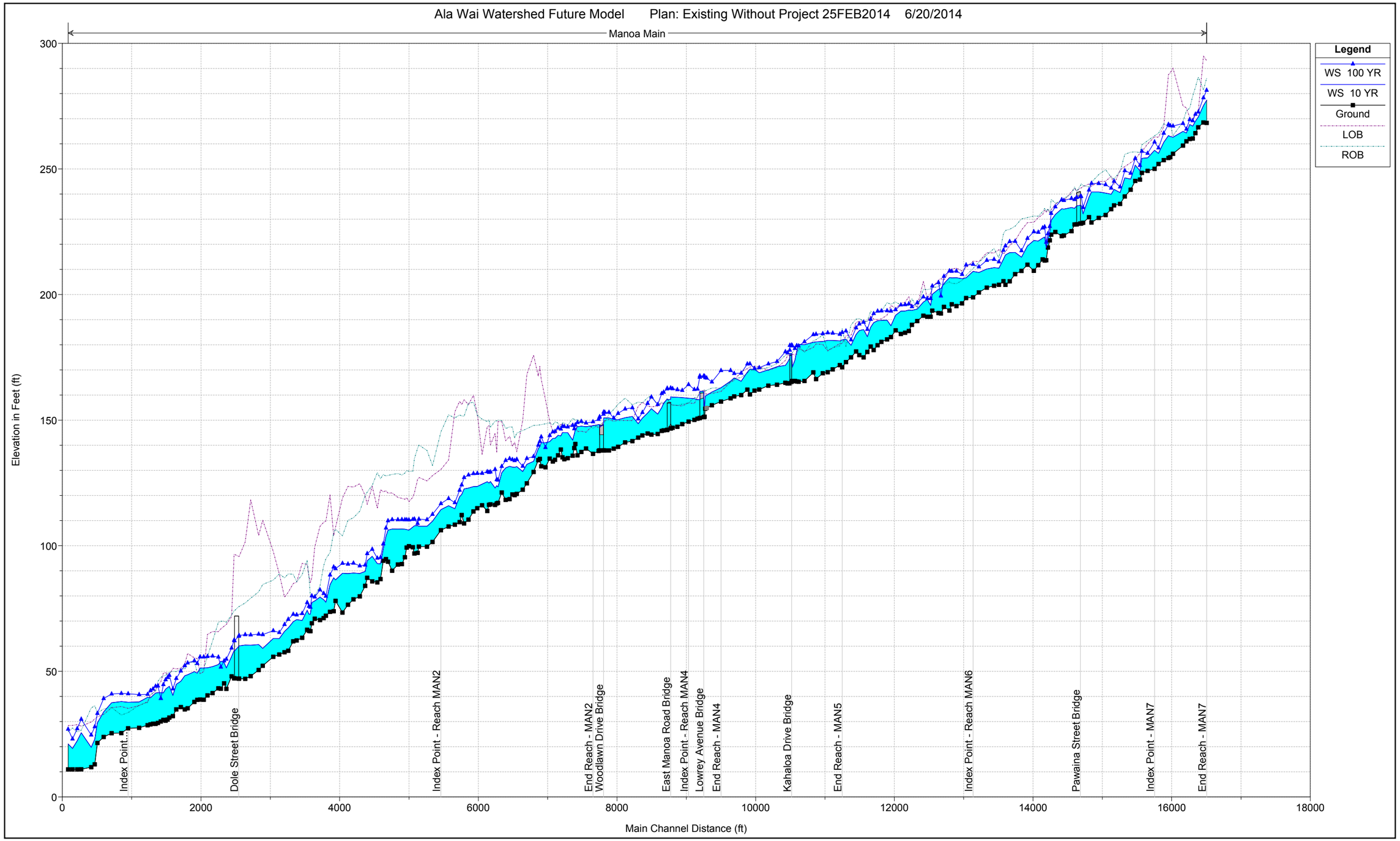


Plate 3 - Without Project Hydraulic Profiles



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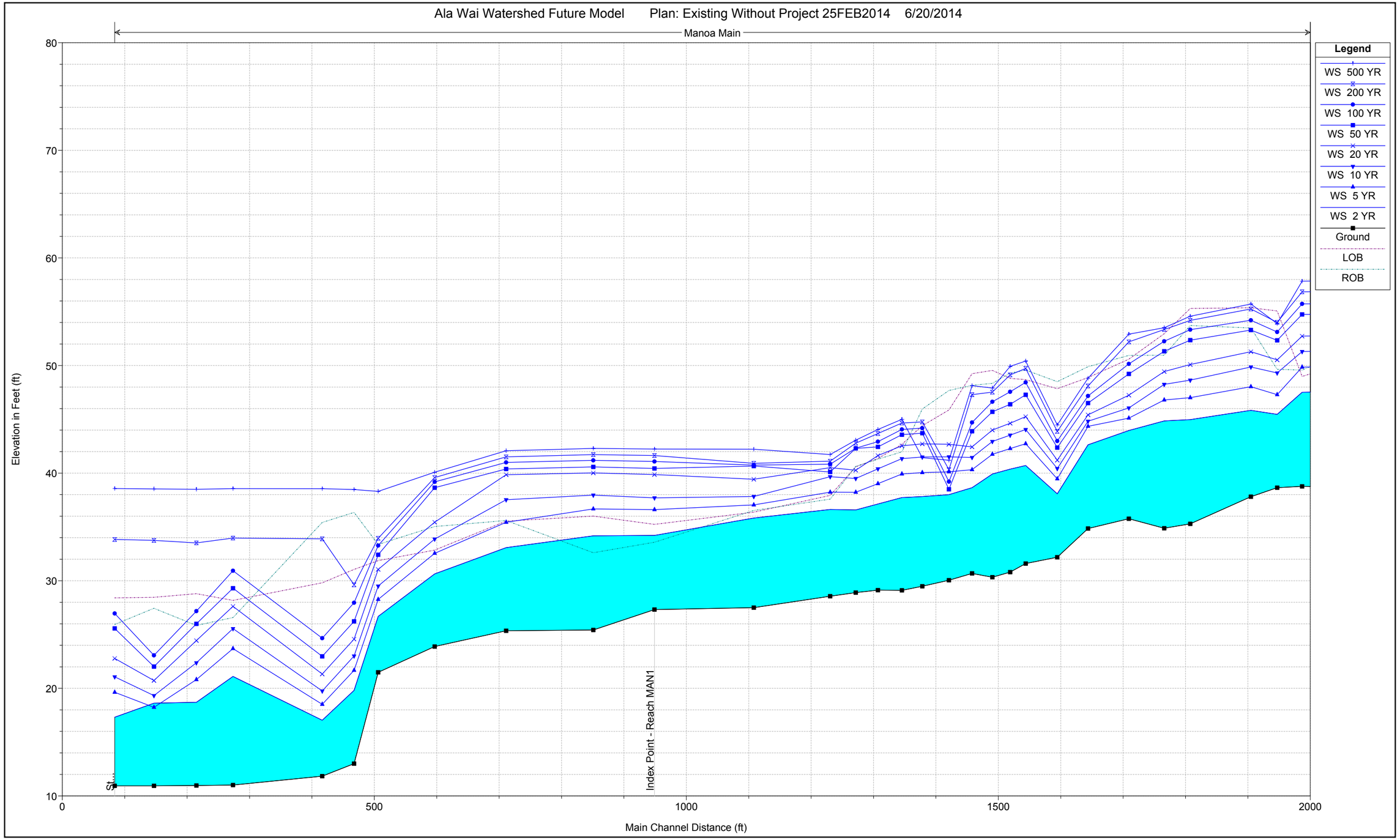
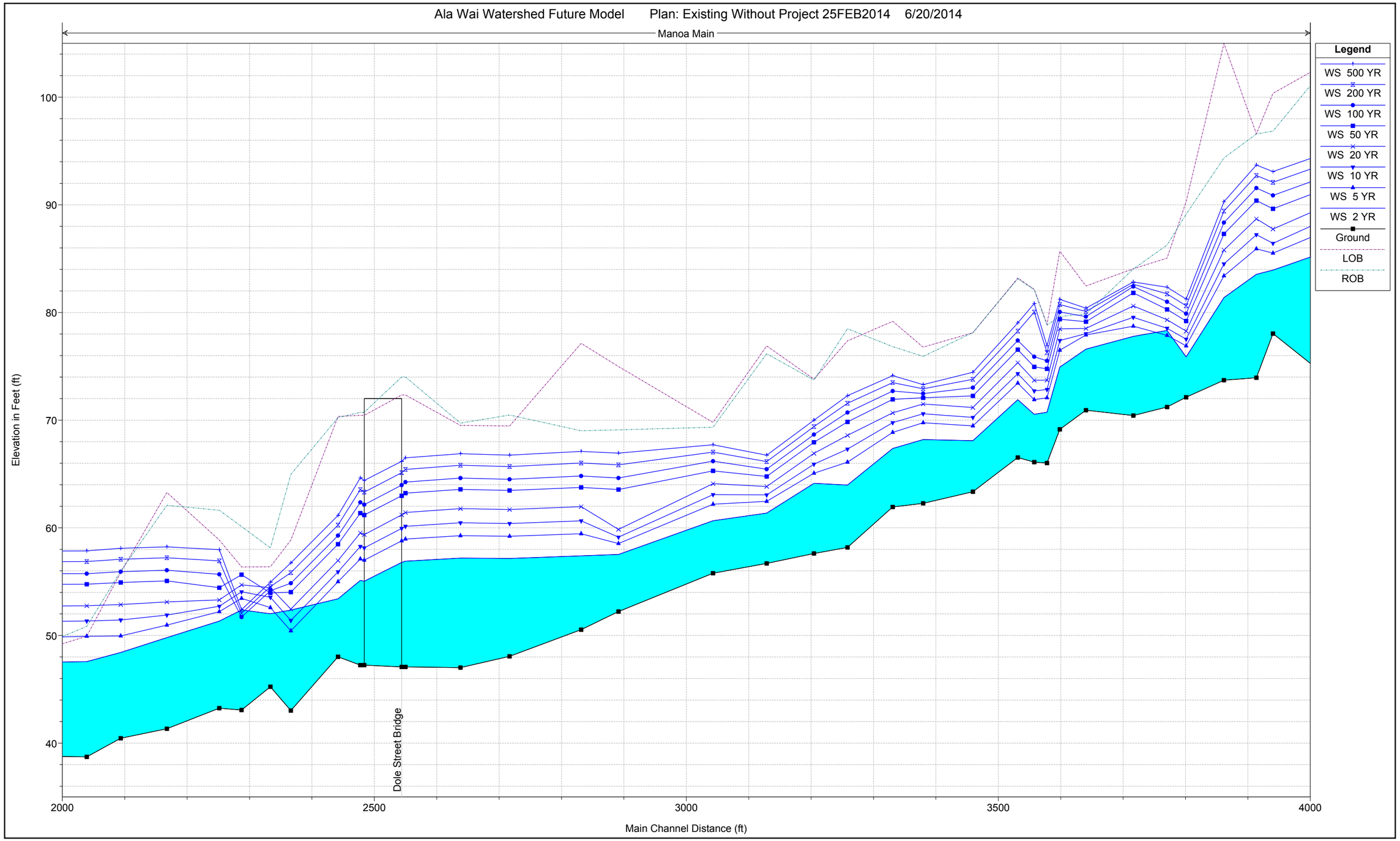


Plate 3 - Without Project Hydraulic Profiles



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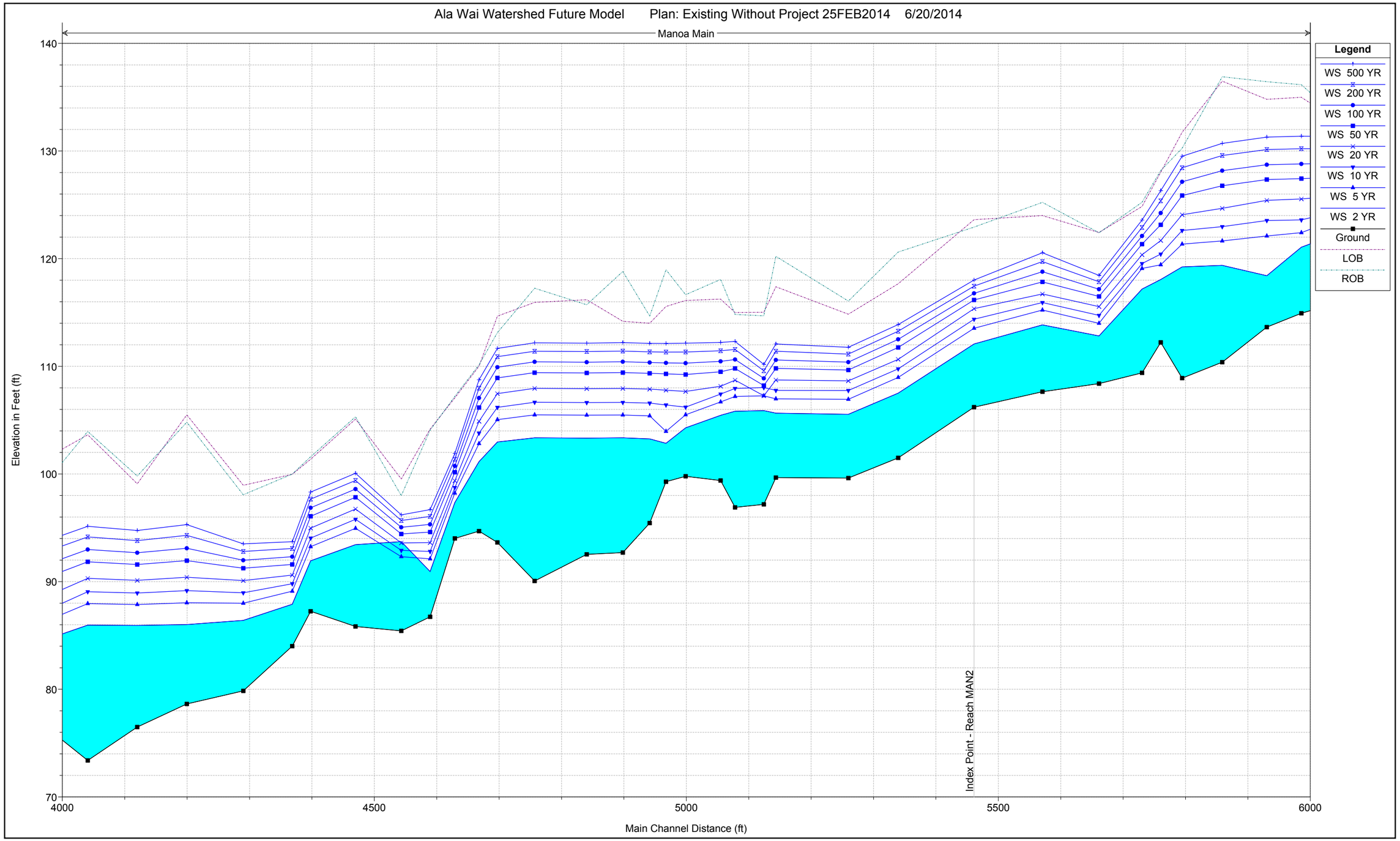


Plate 3 - Without Project Hydraulic Profiles

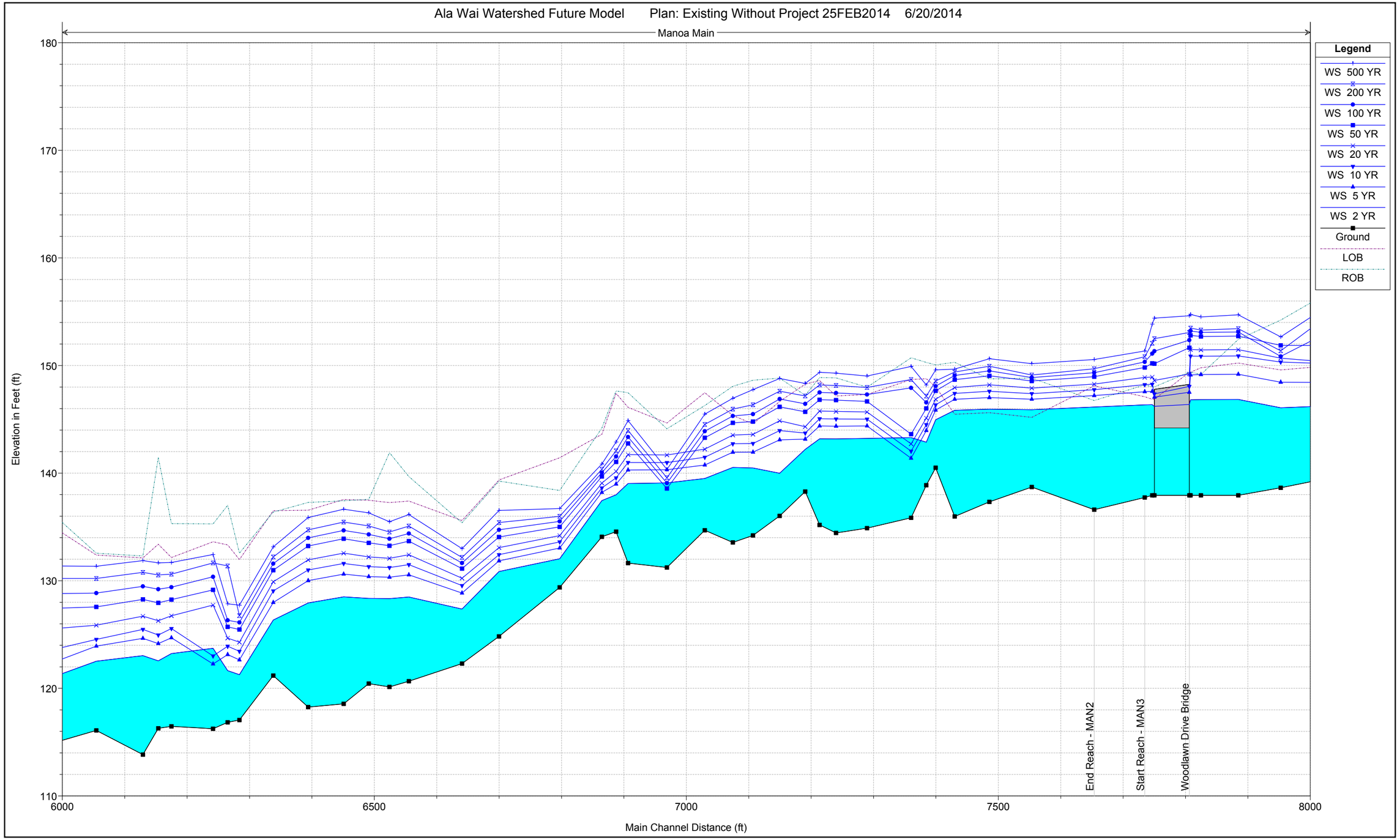


Plate 3 - Without Project Hydraulic Profiles

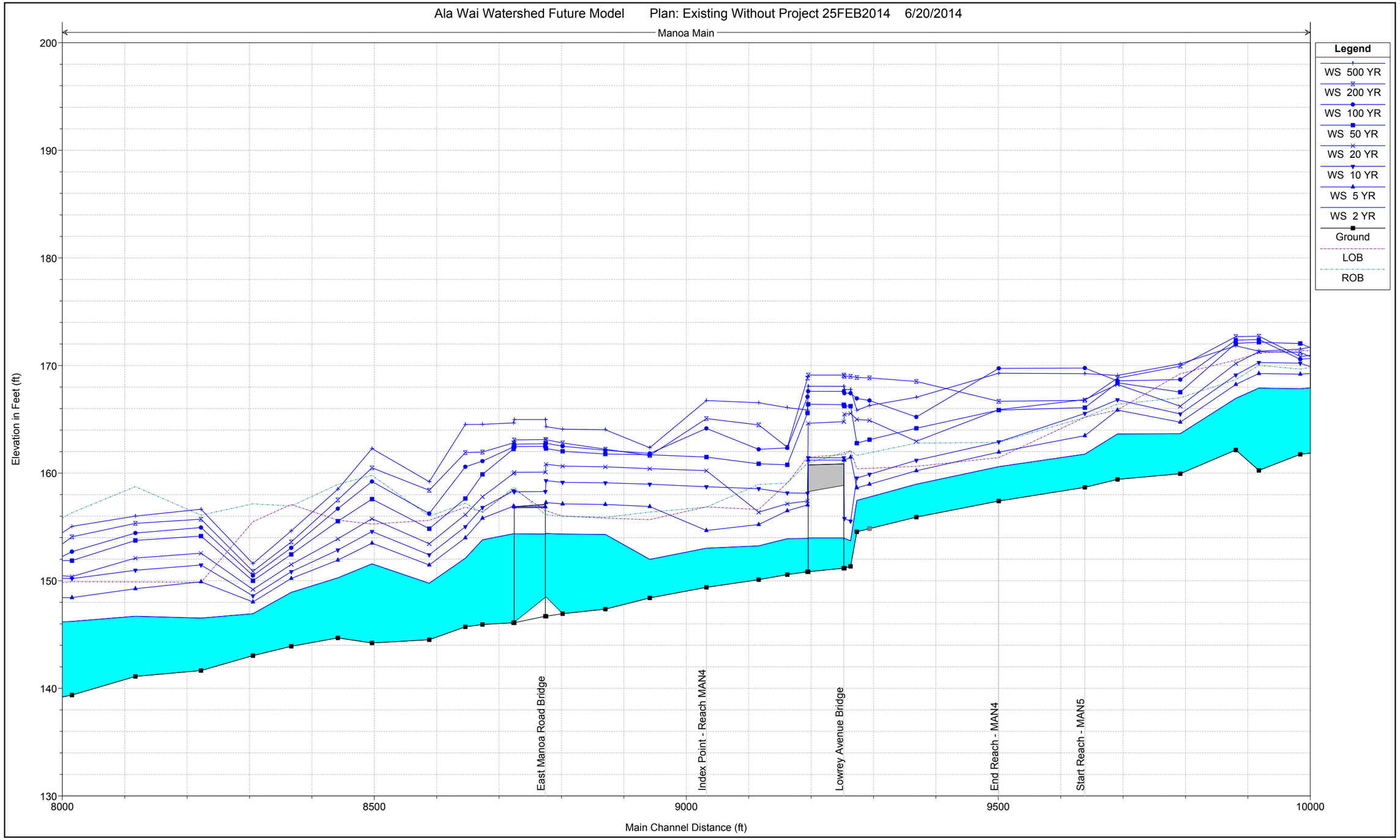


Plate 3 - Without Project Hydraulic Profiles

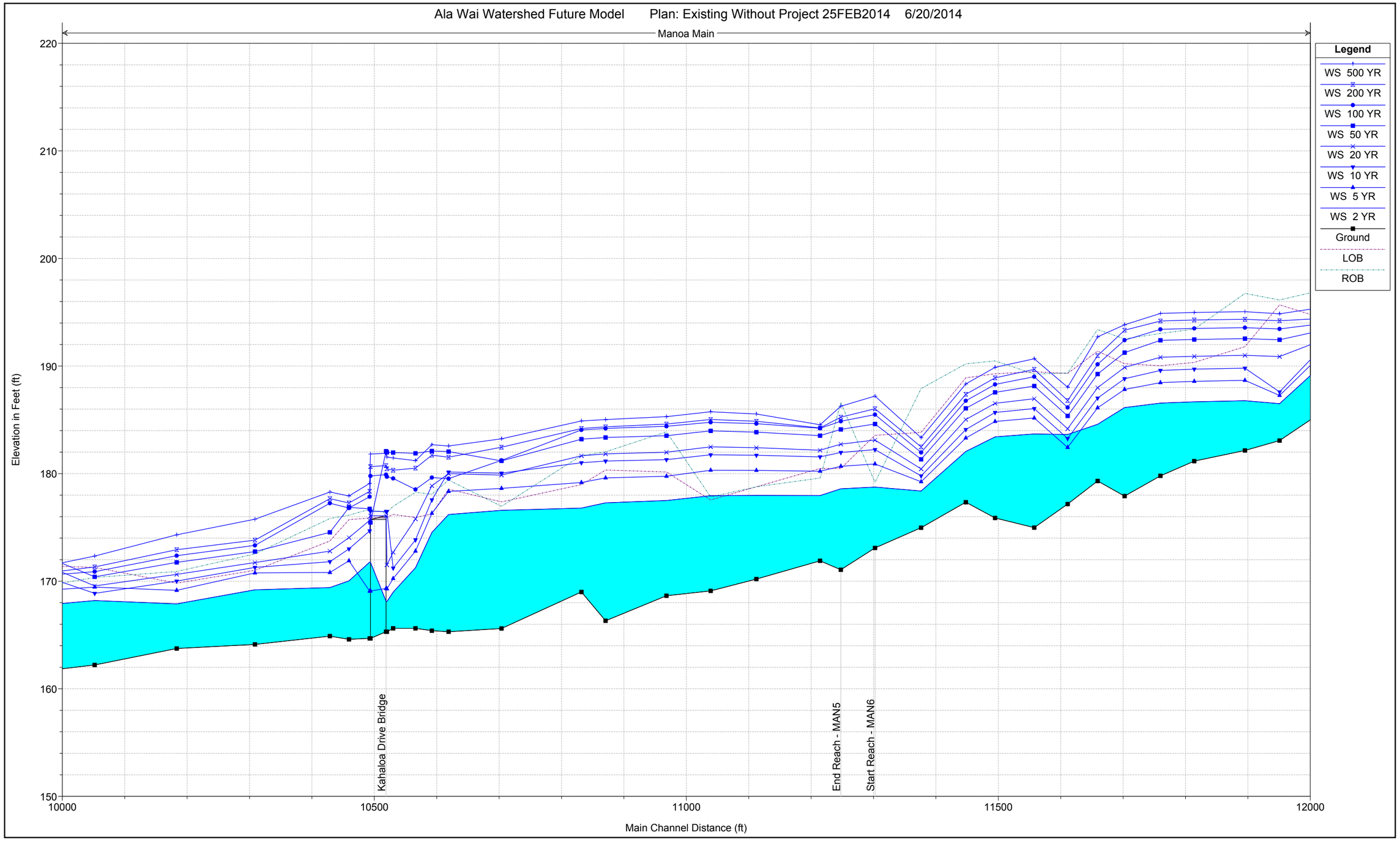


Plate 3 - Without Project Hydraulic Profiles

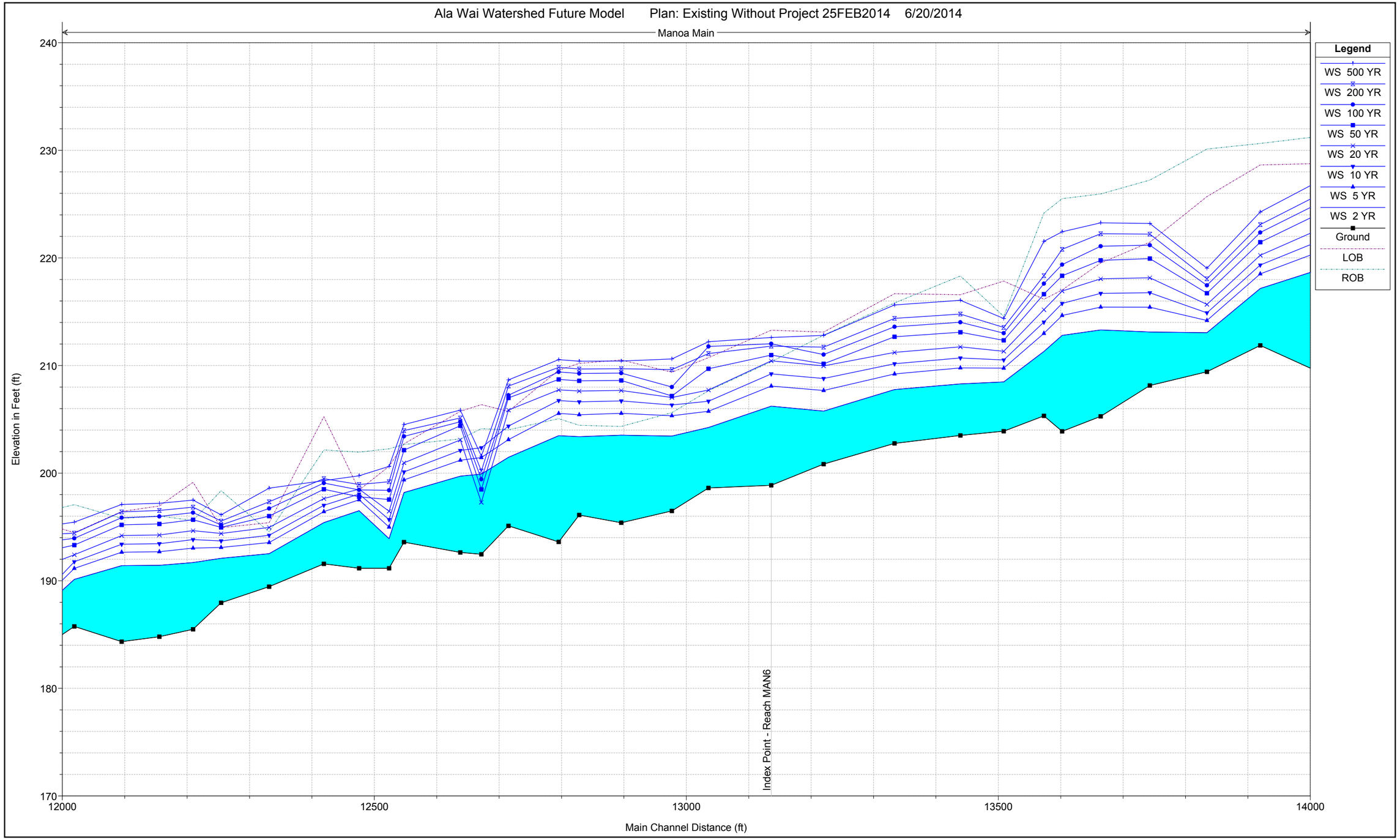


Plate 3 - Without Project Hydraulic Profiles

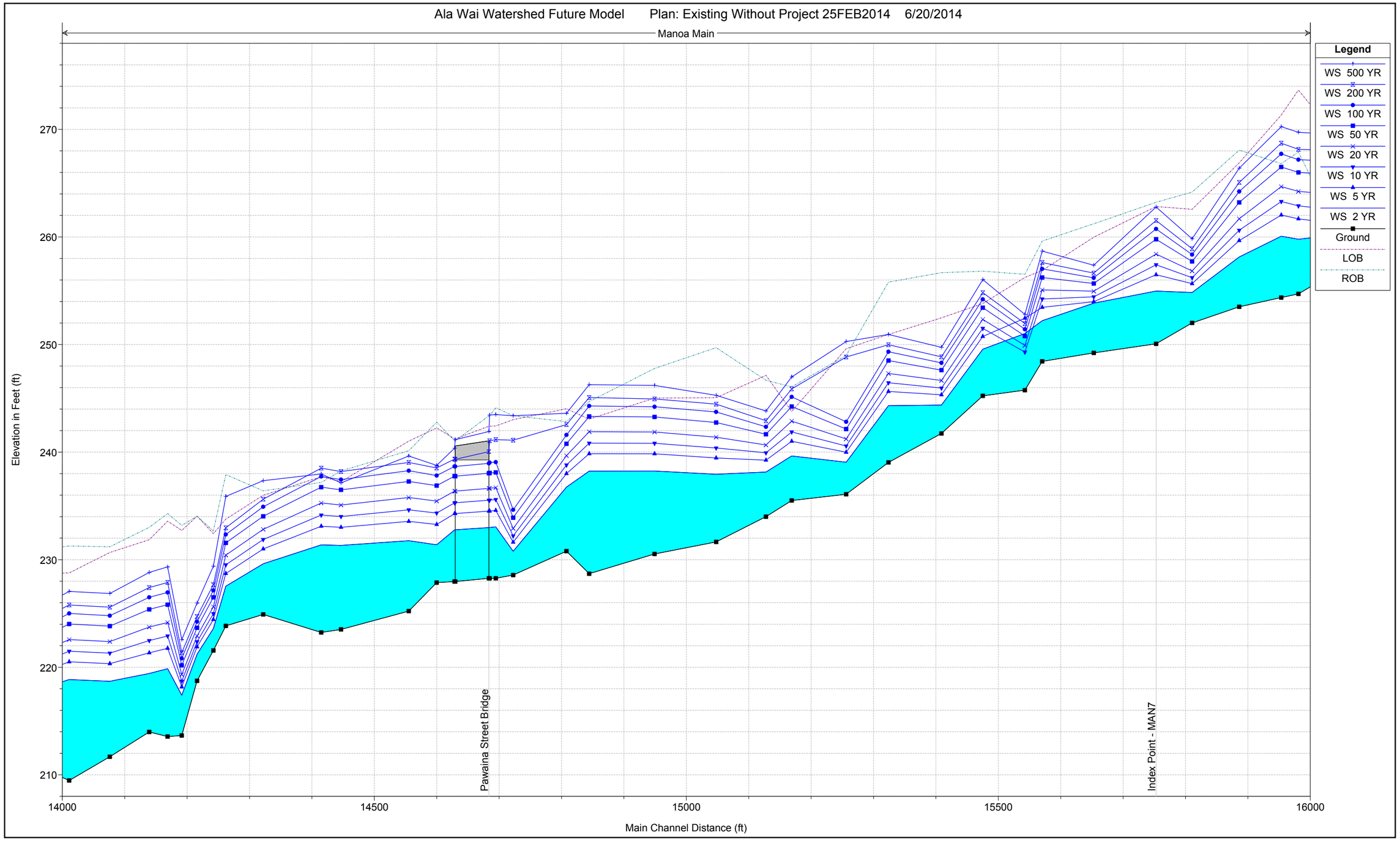


Plate 3 - Without Project Hydraulic Profiles

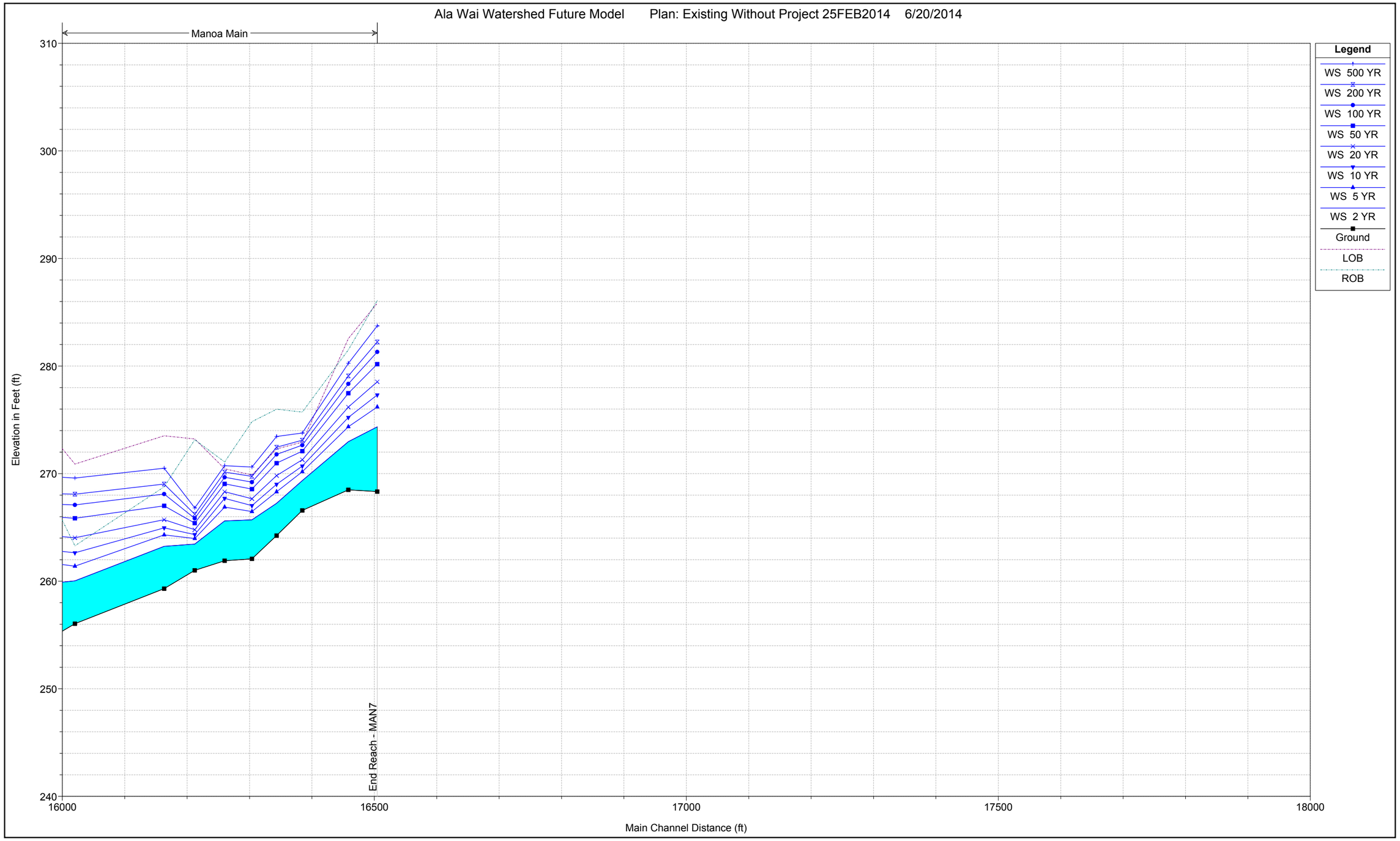
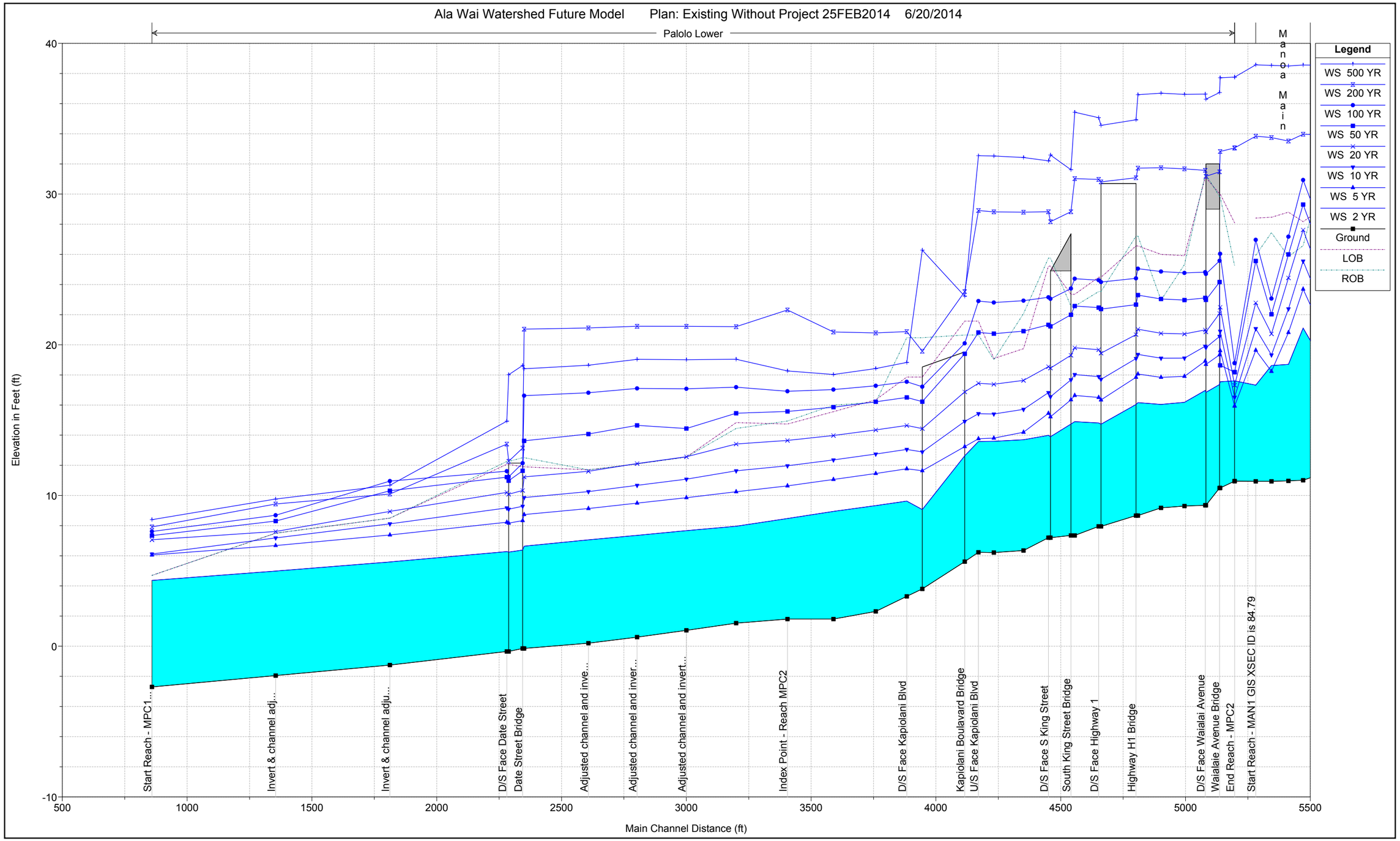


Plate 3 - Without Project Hydraulic Profiles



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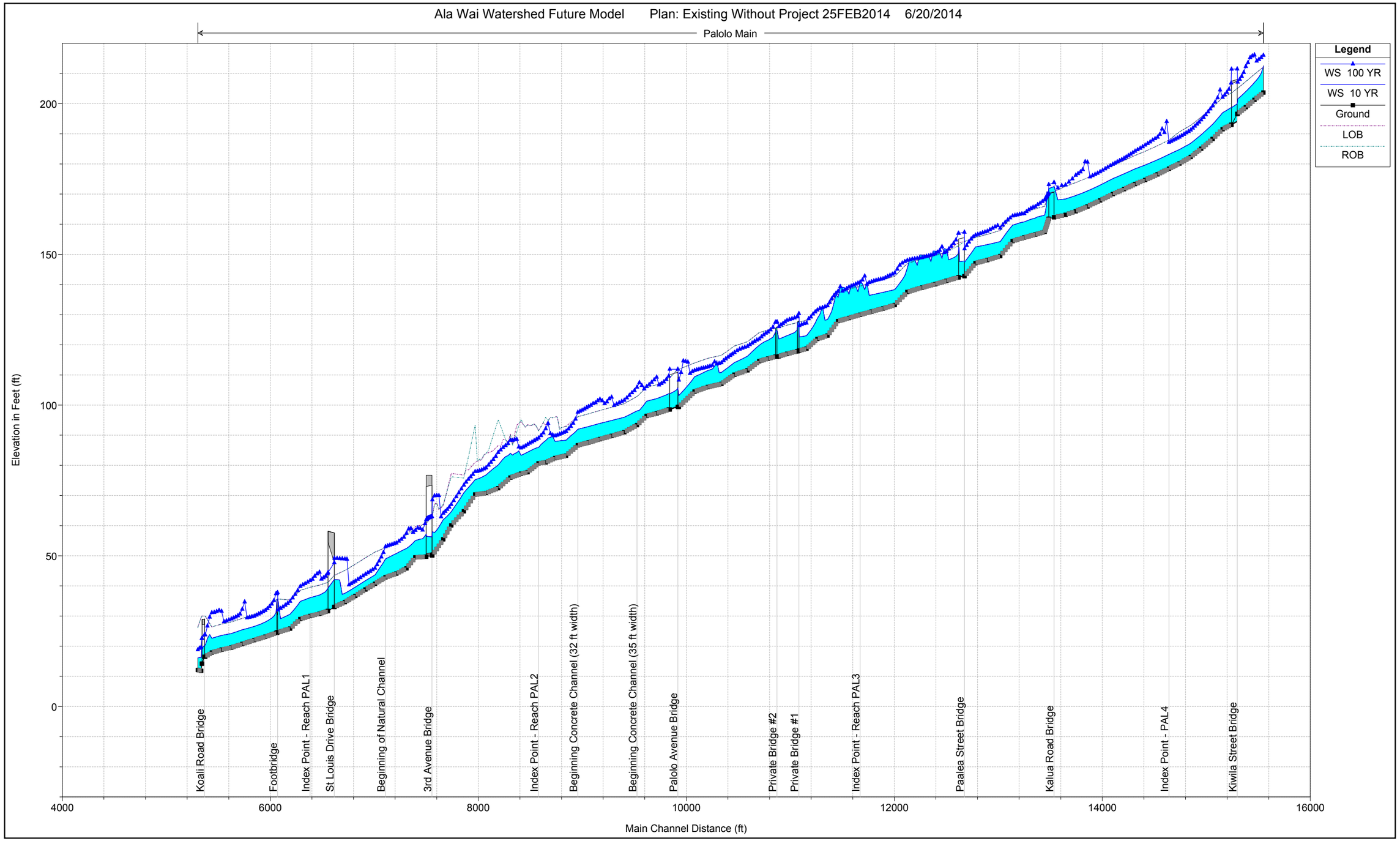


Plate 3 - Without Project Hydraulic Profiles

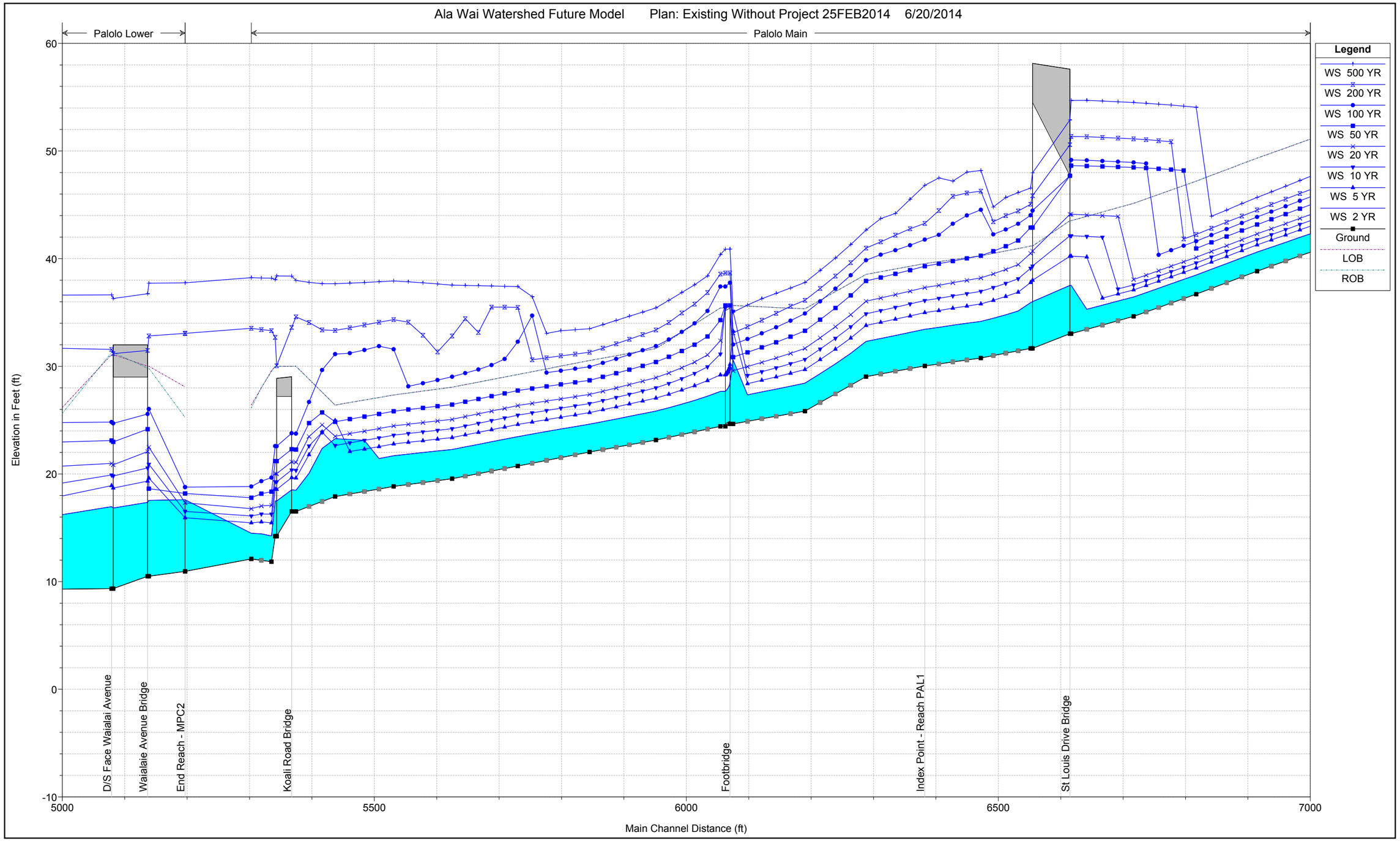
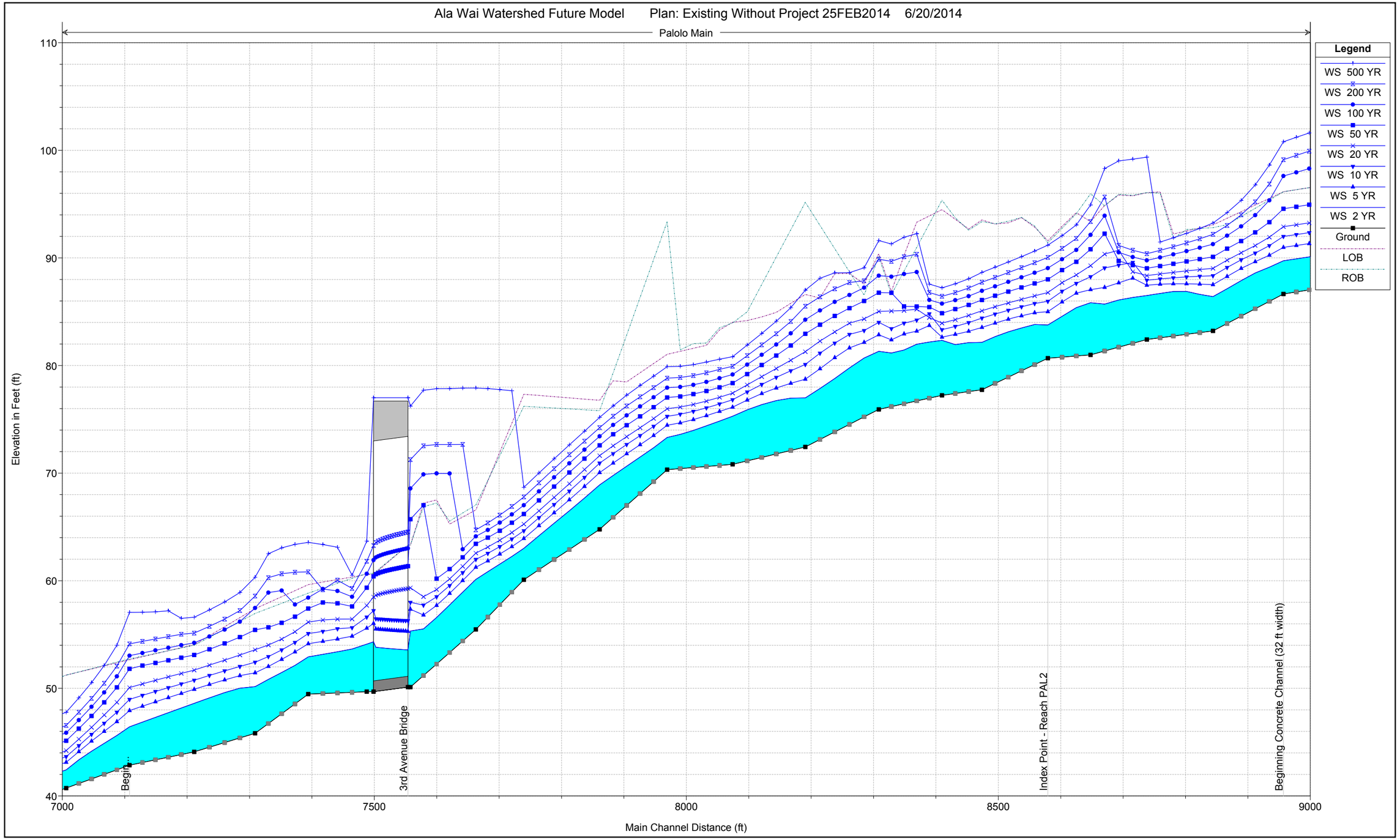


Plate 3 - Without Project Hydraulic Profiles



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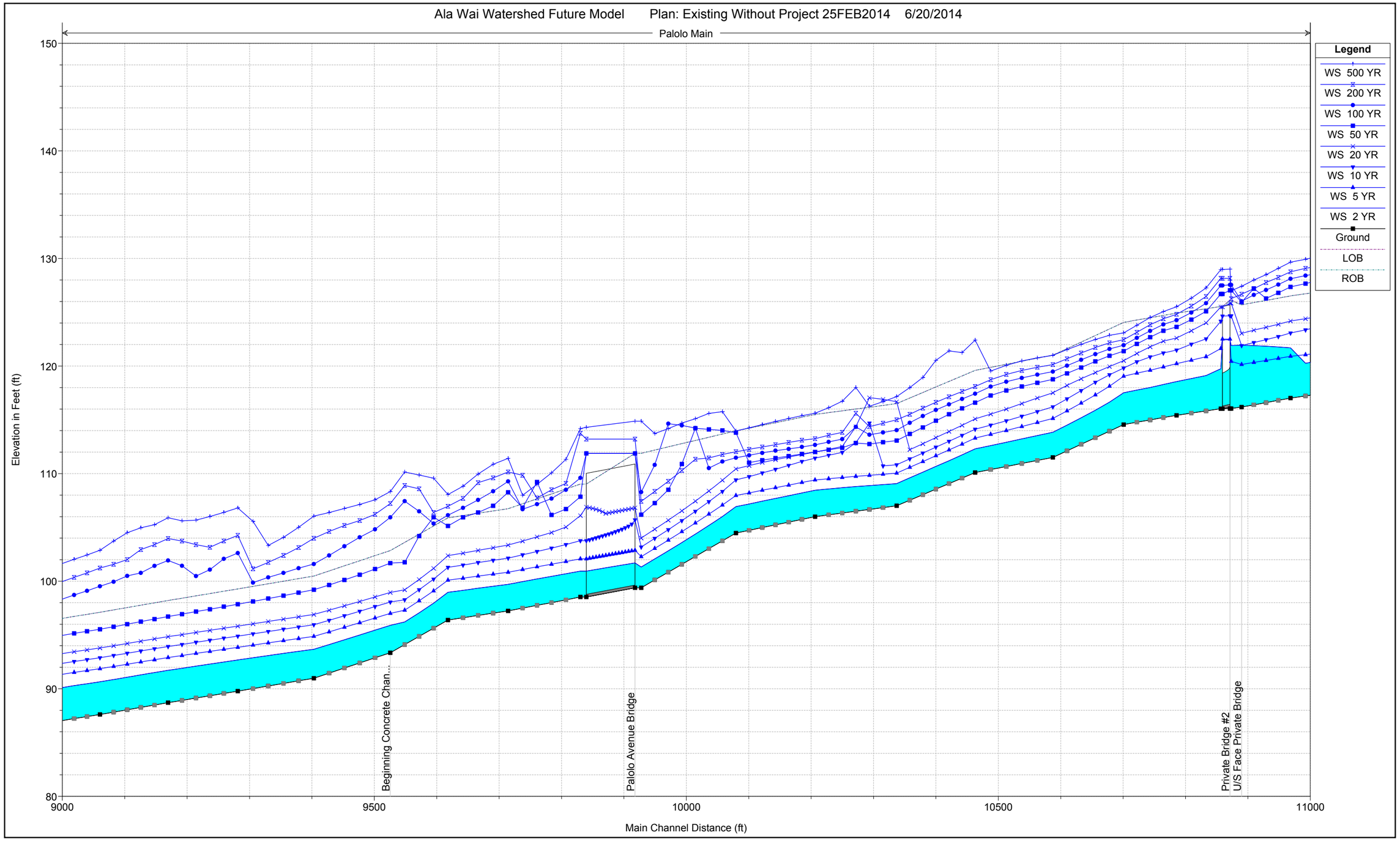

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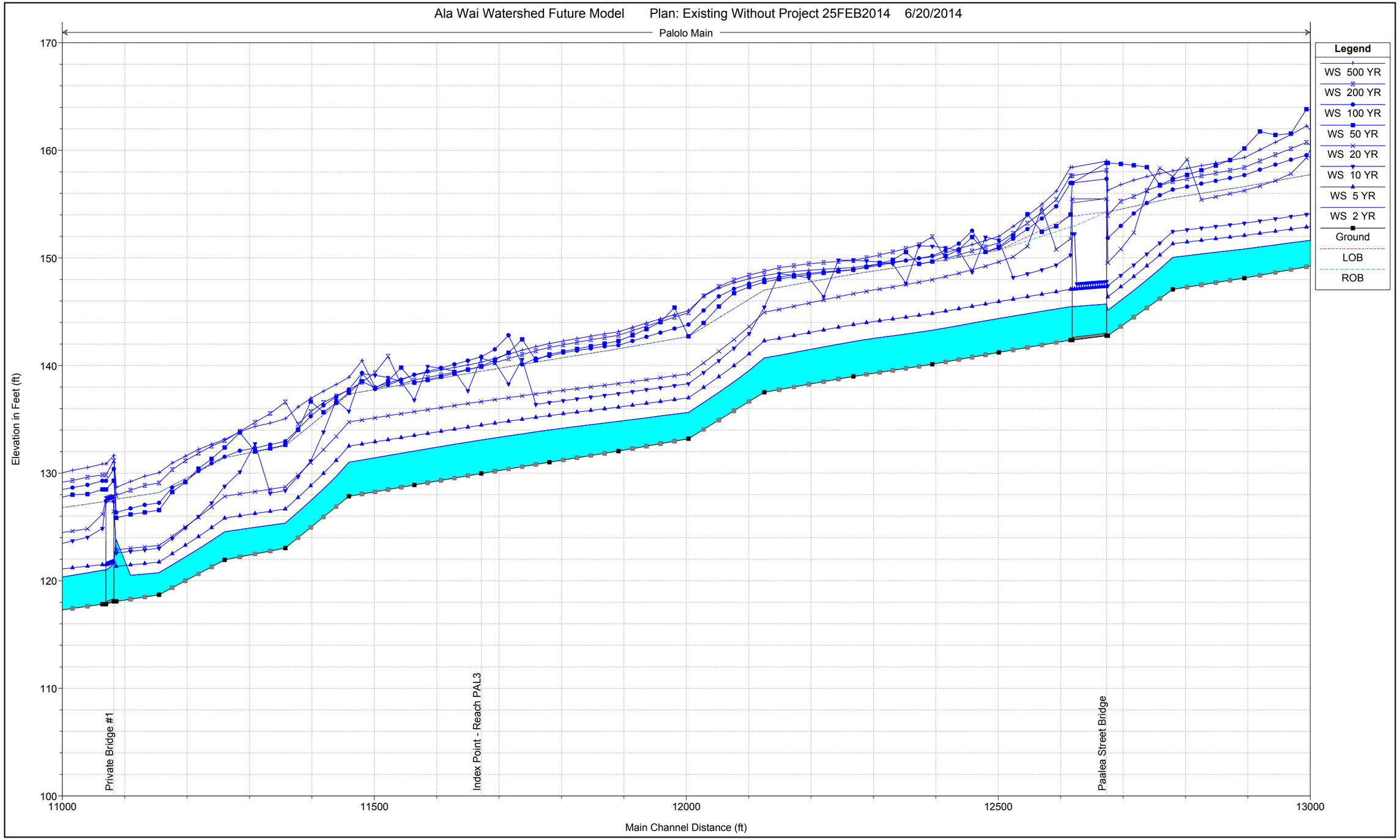

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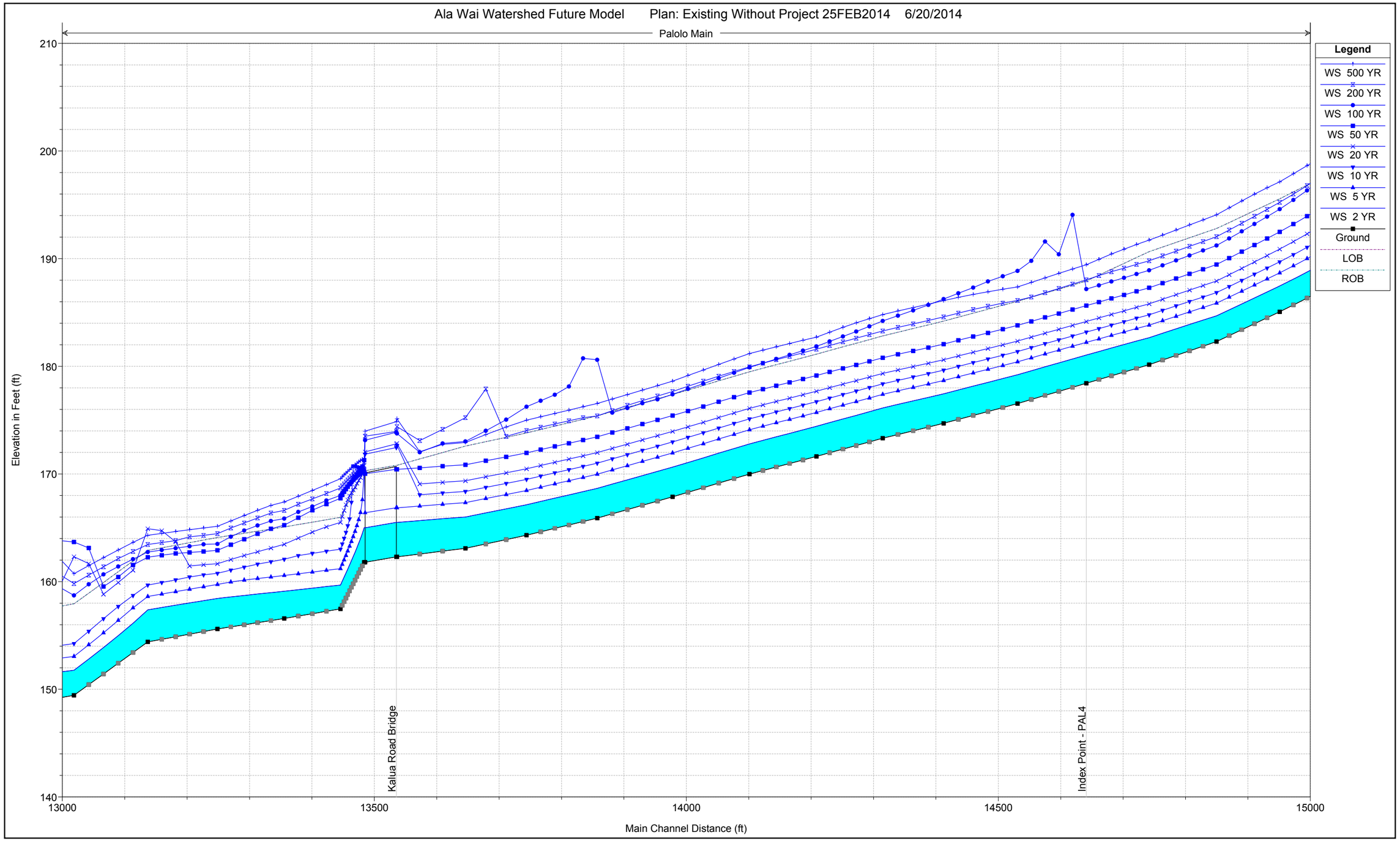

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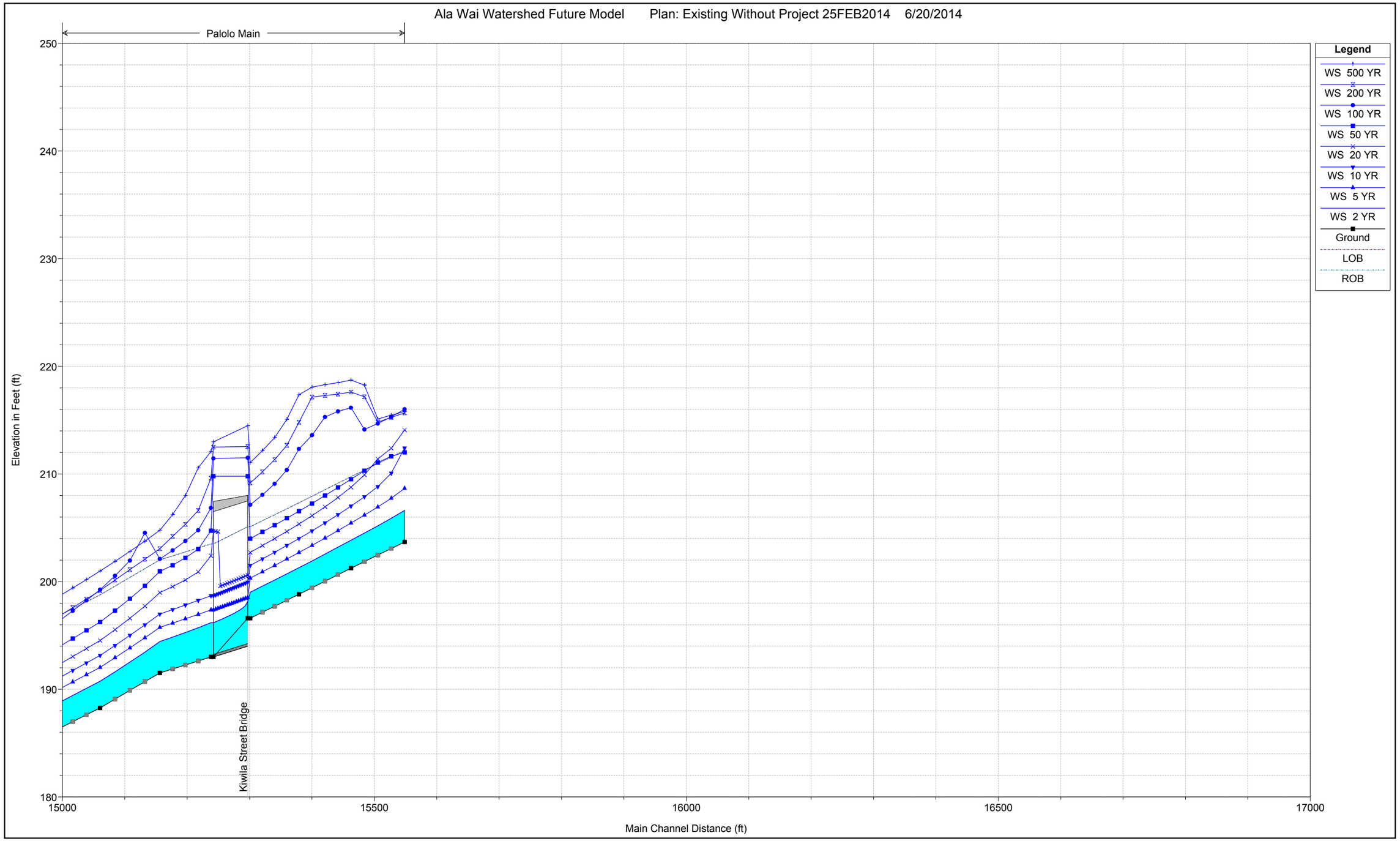

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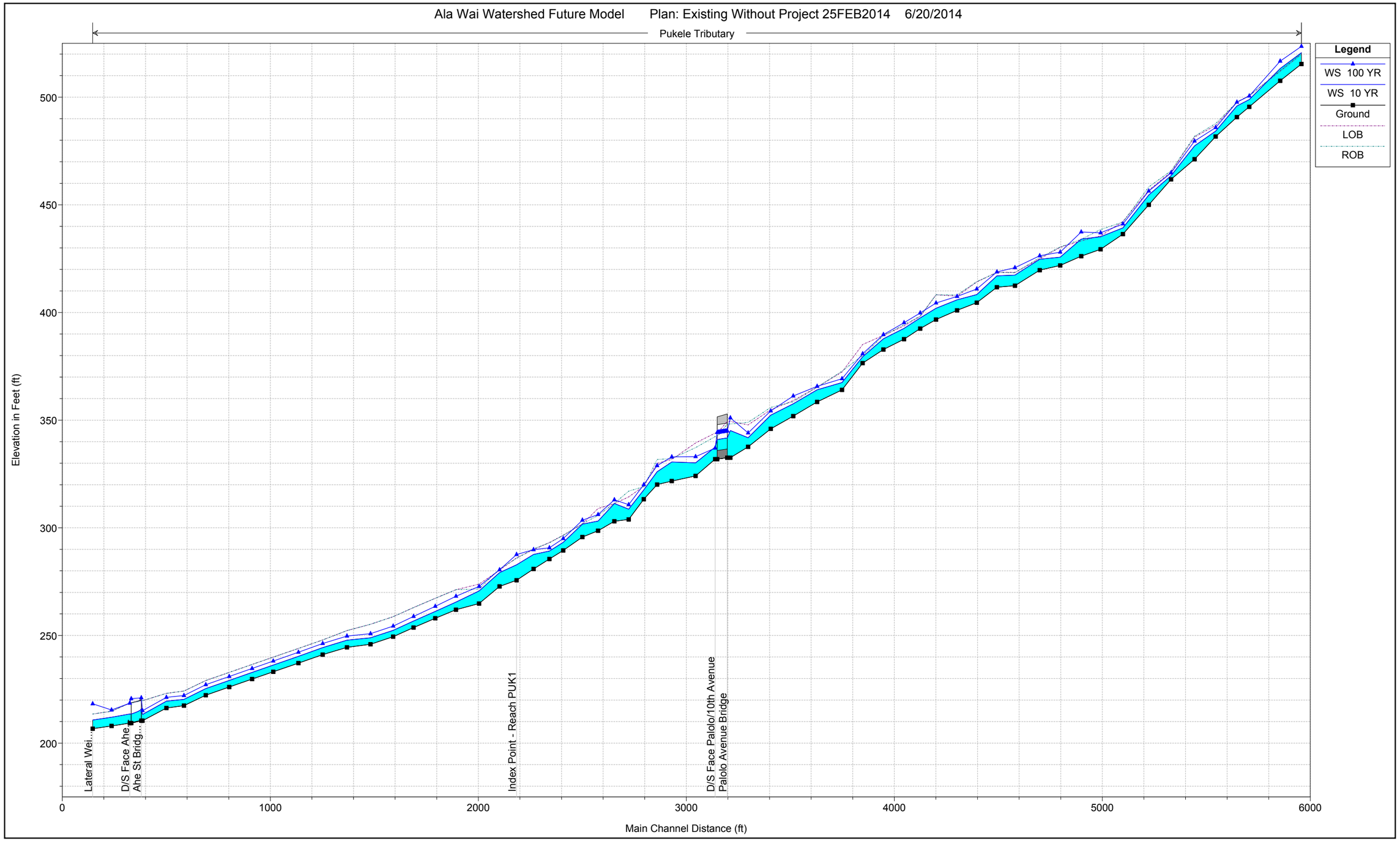

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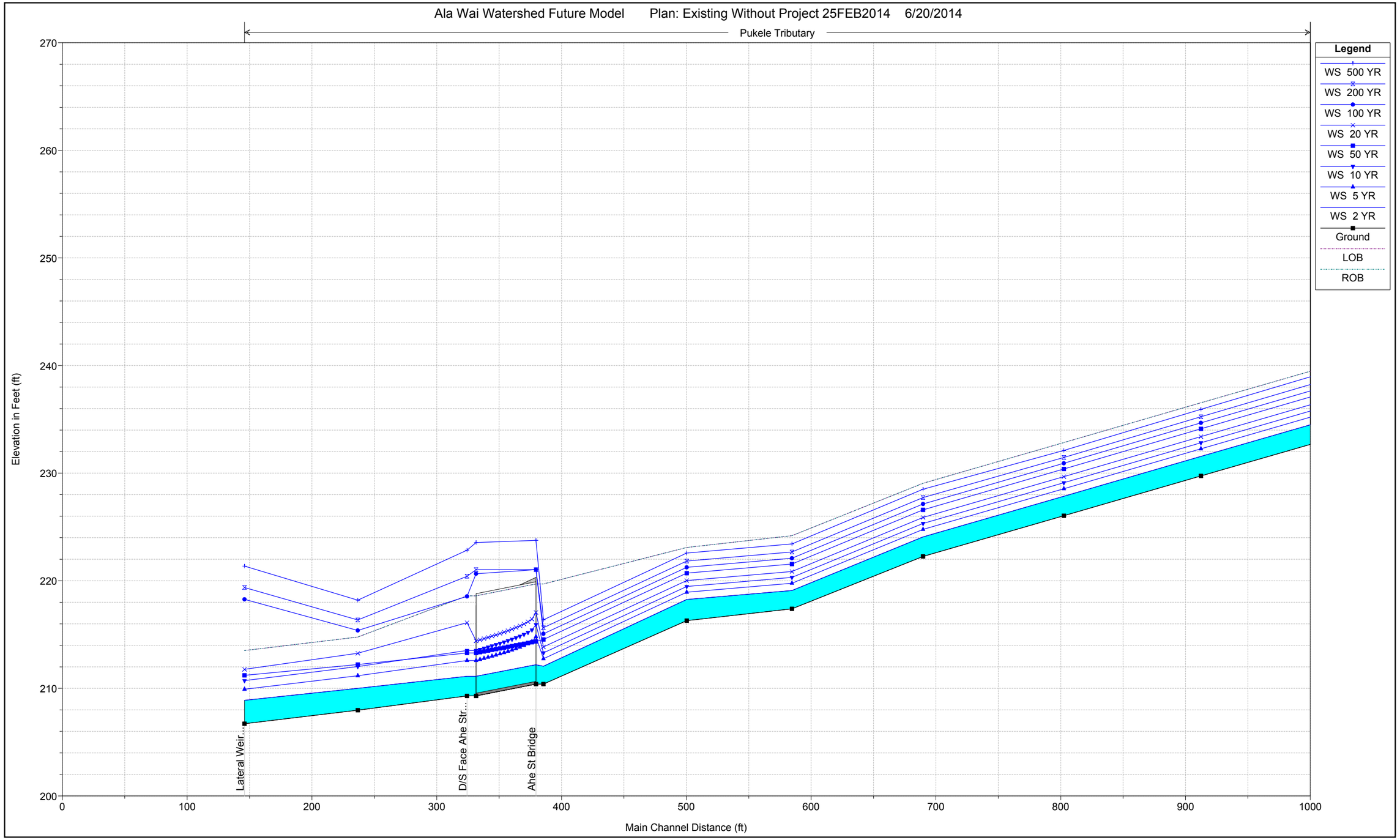

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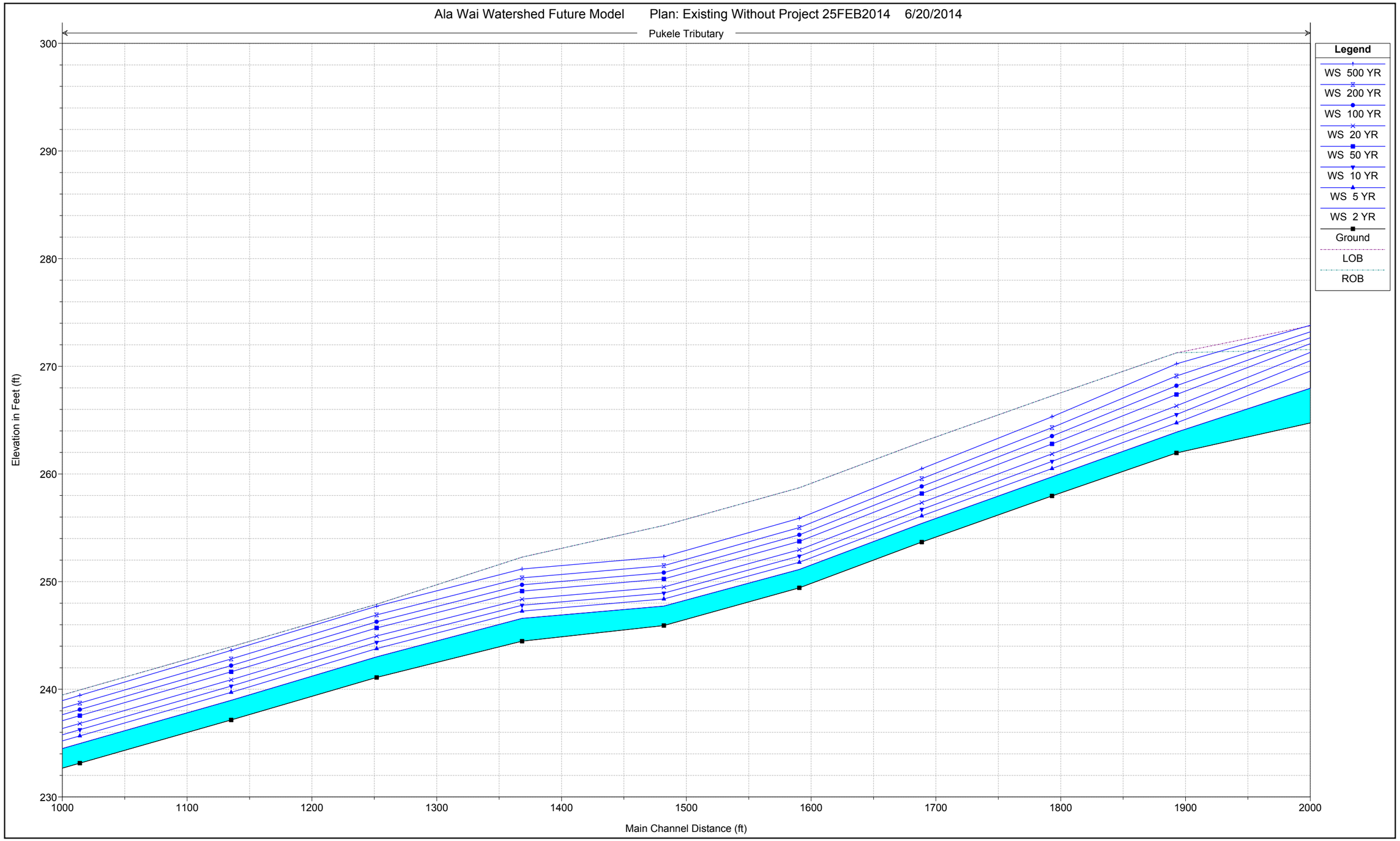

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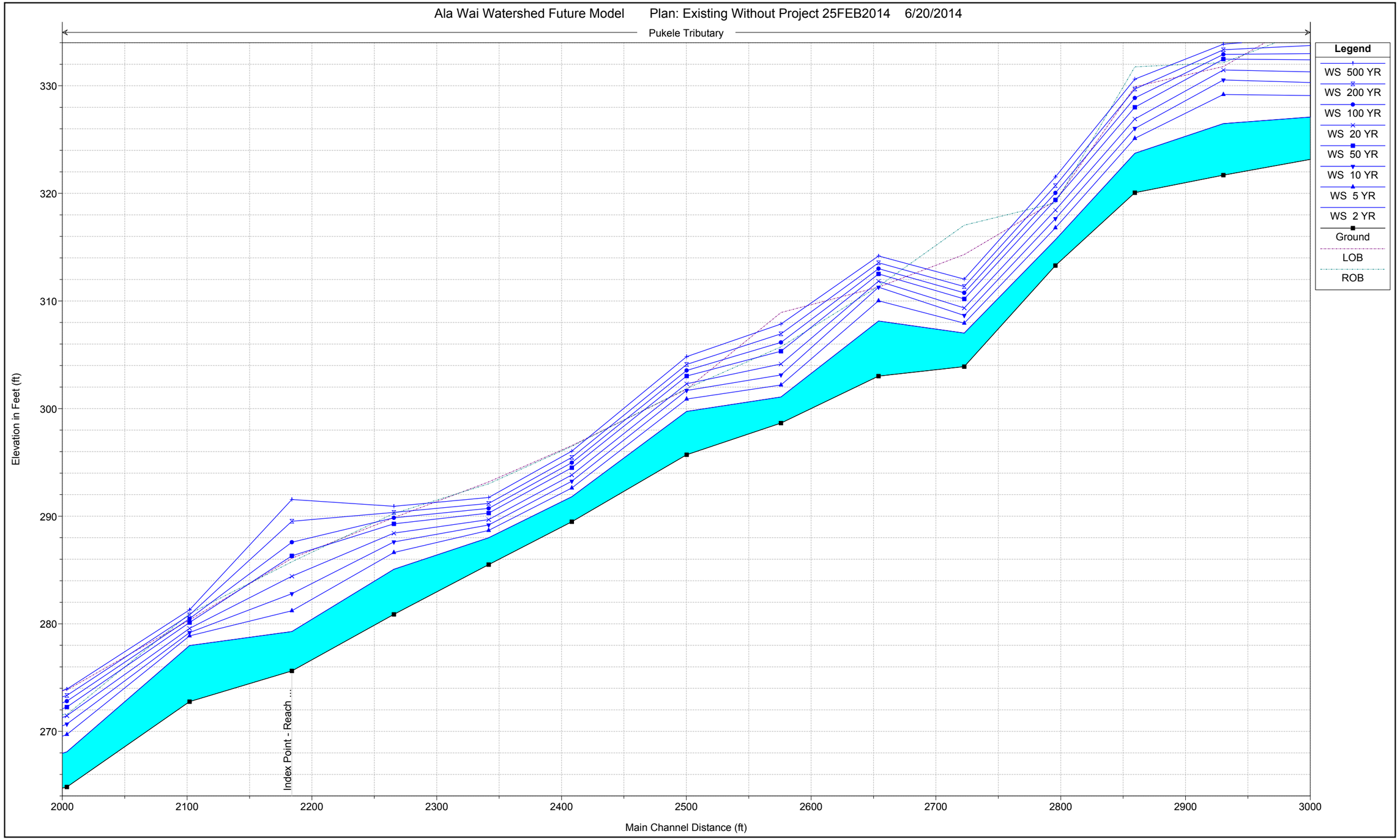

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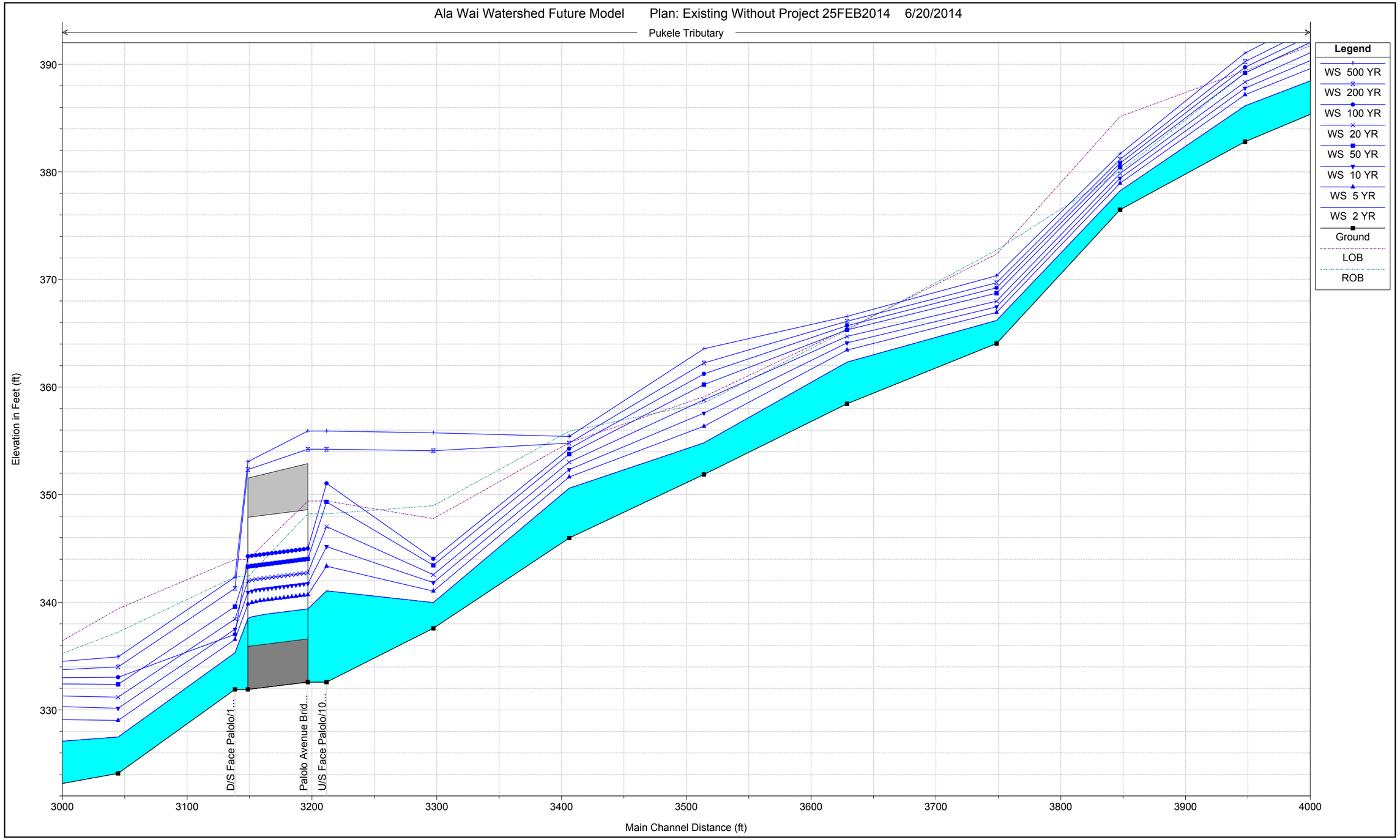

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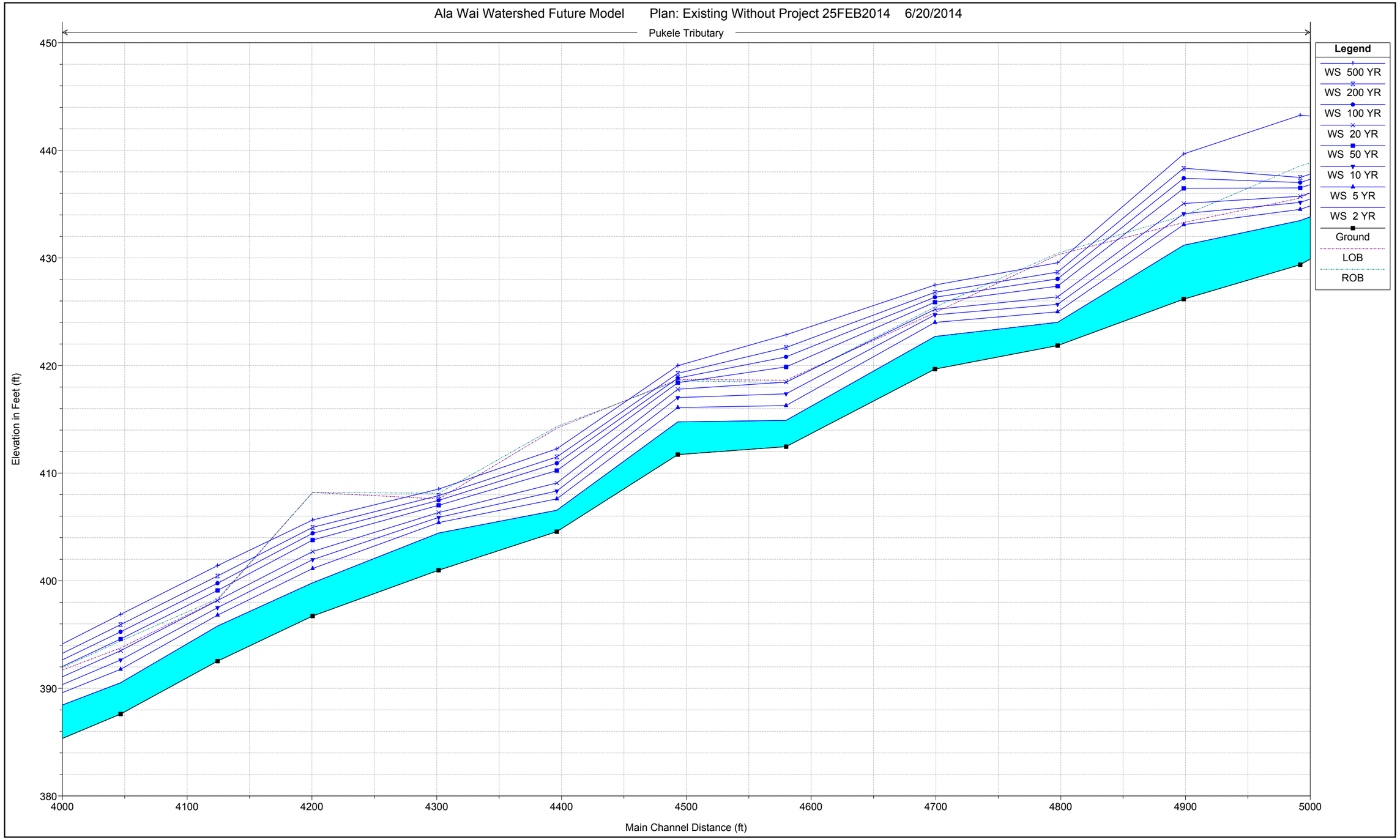

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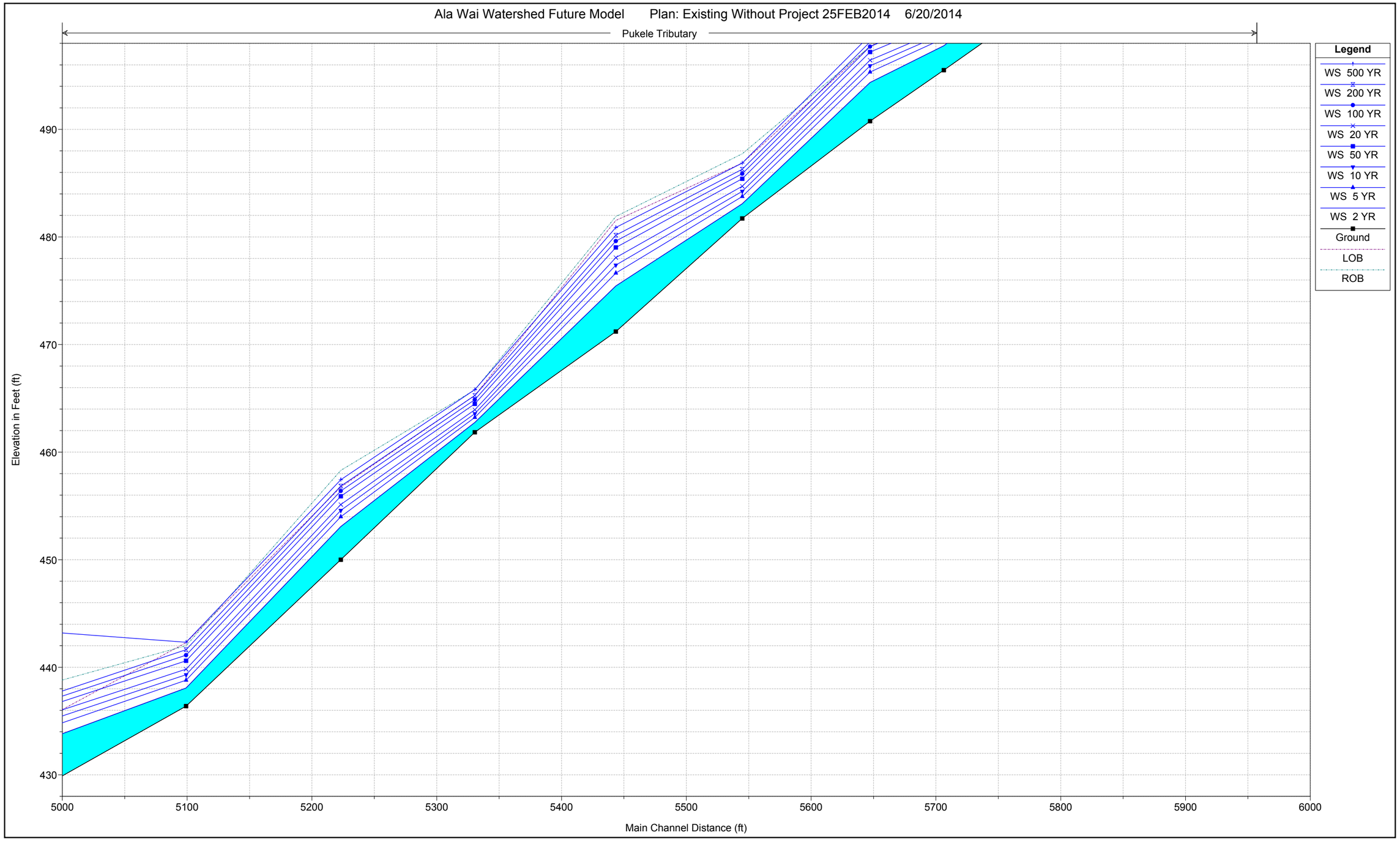

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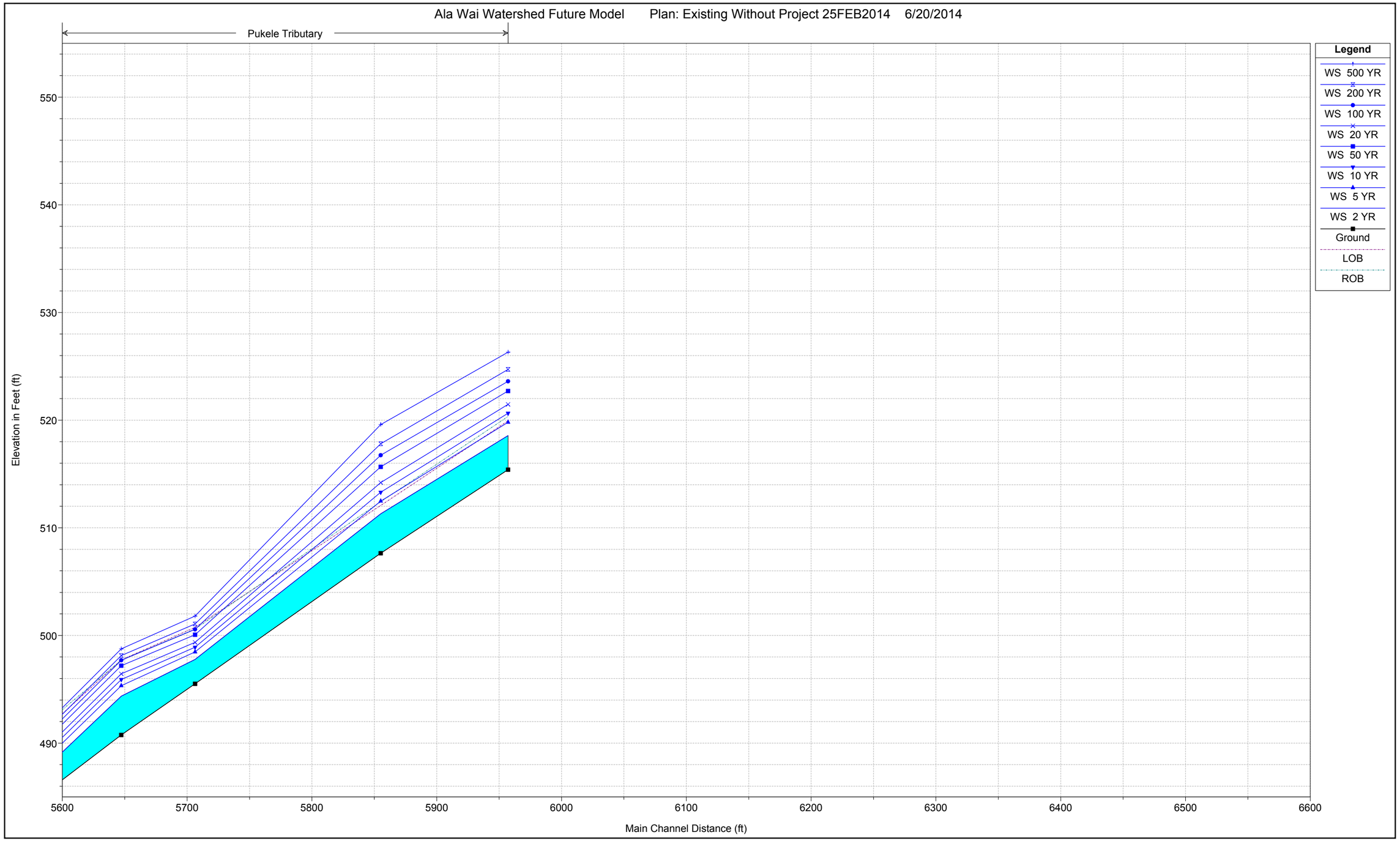

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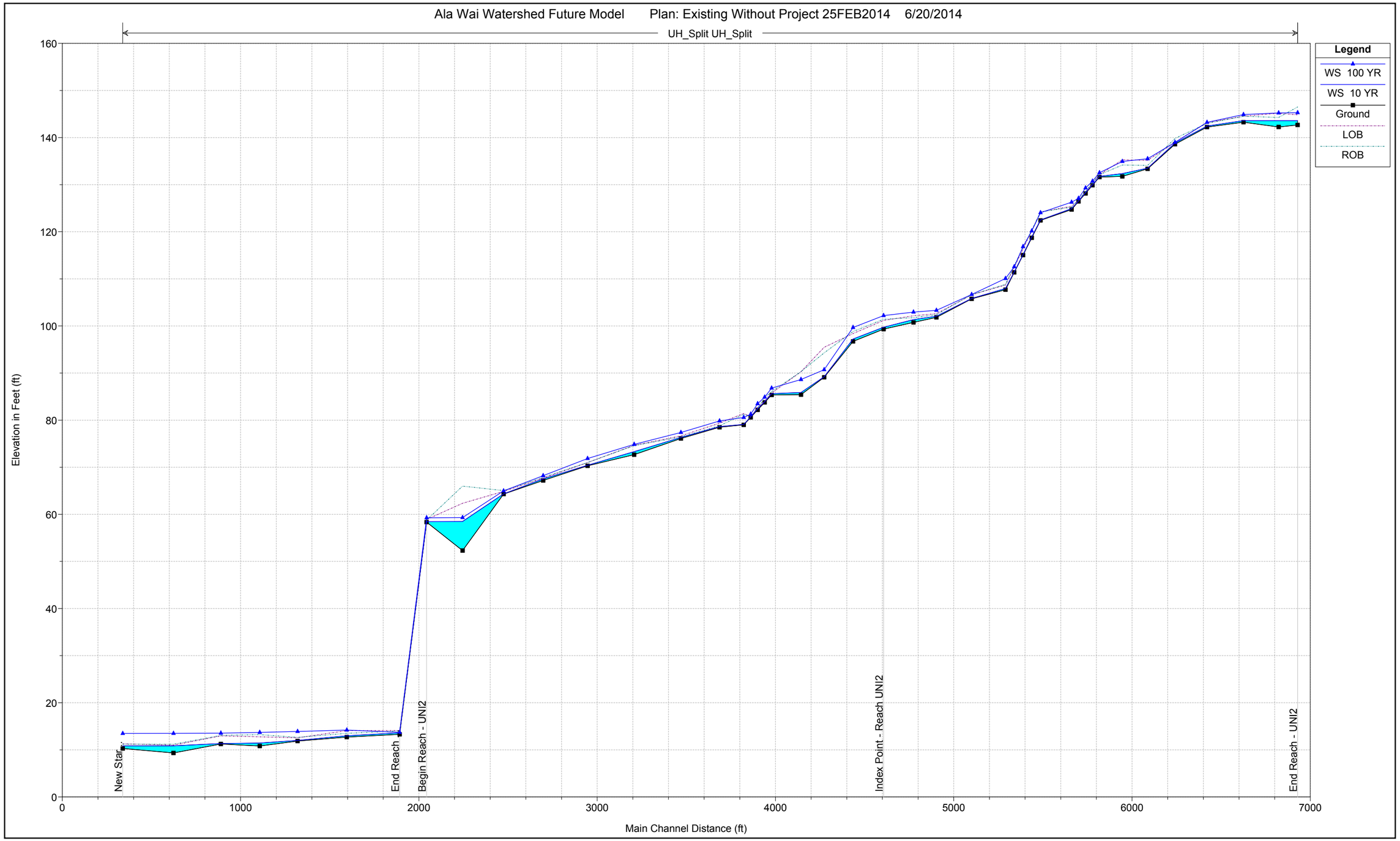

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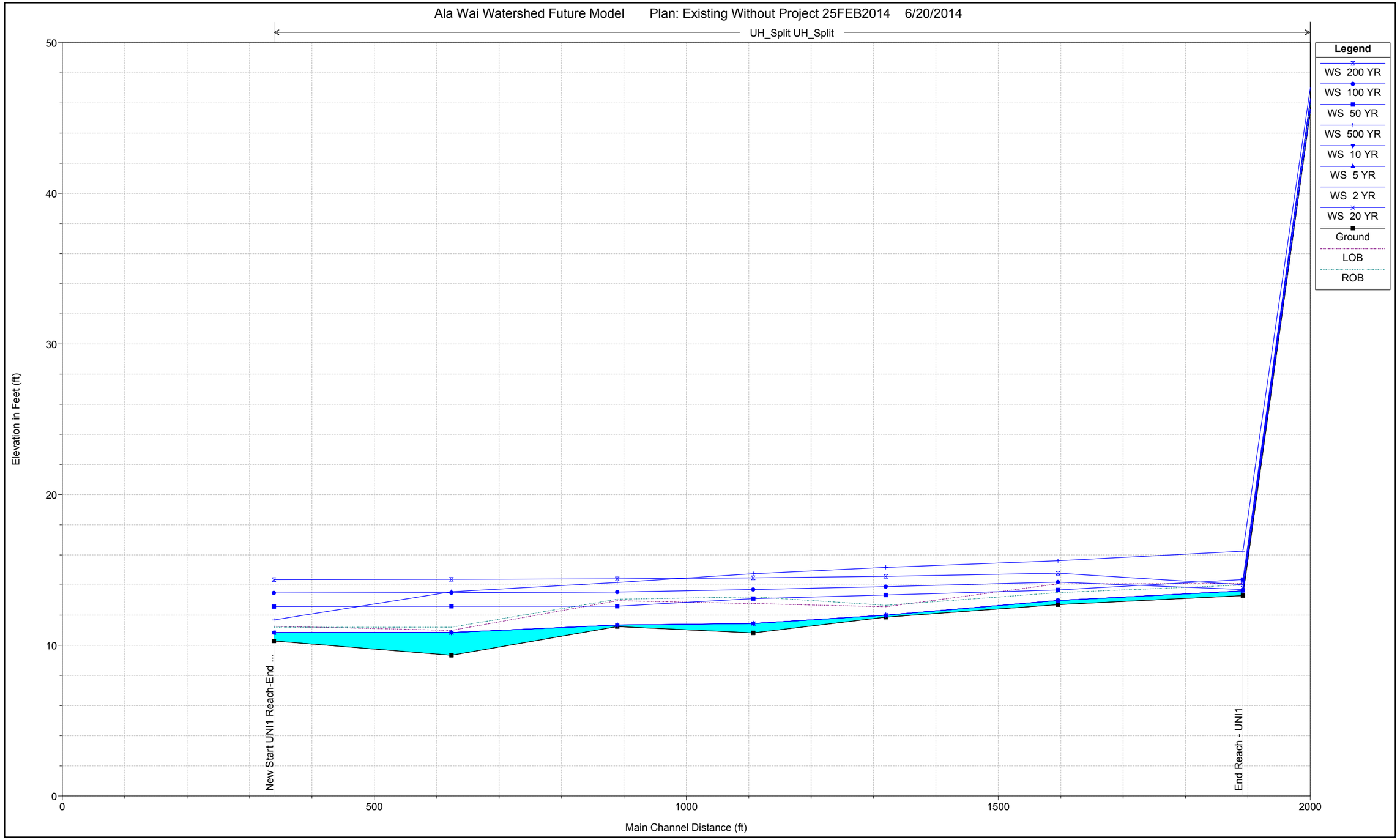

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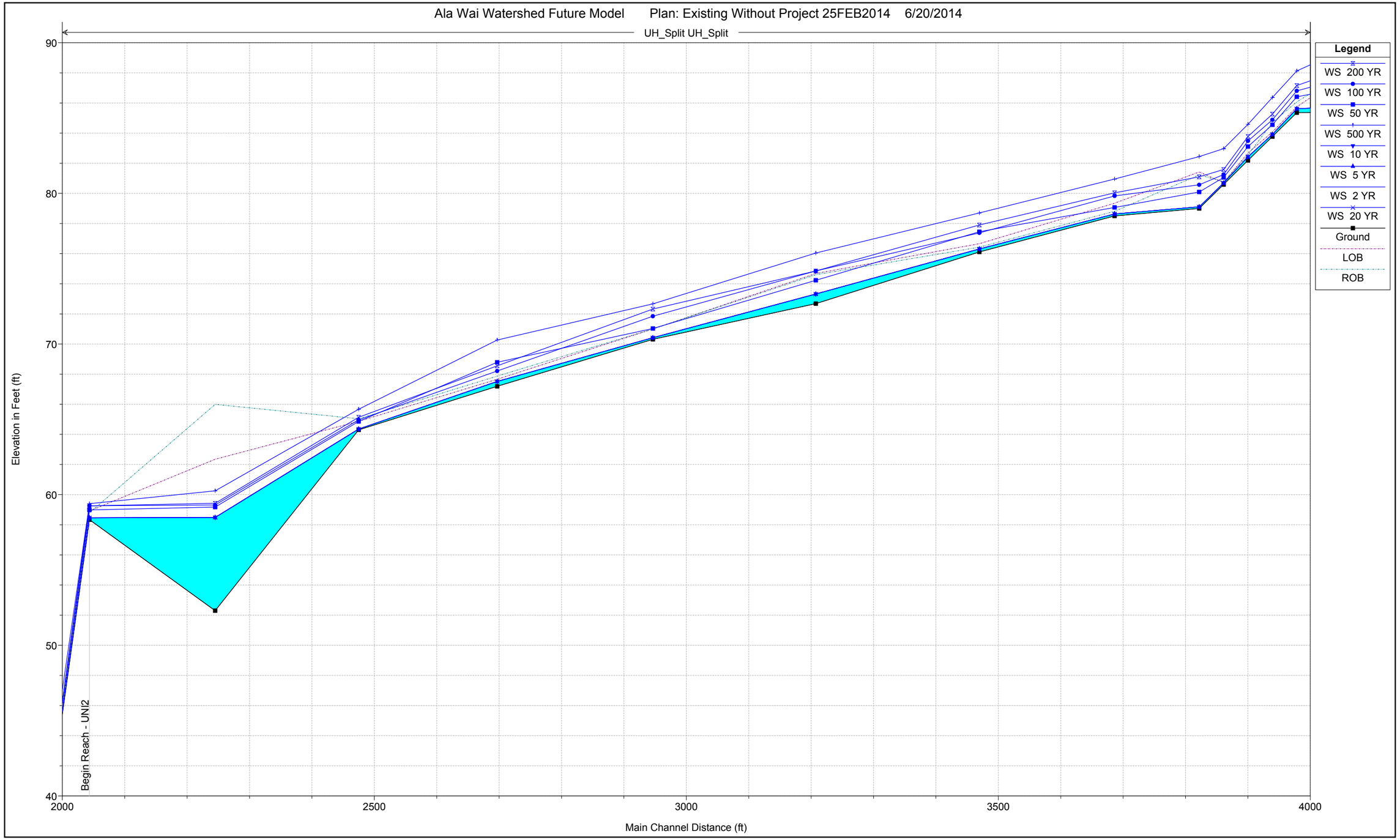

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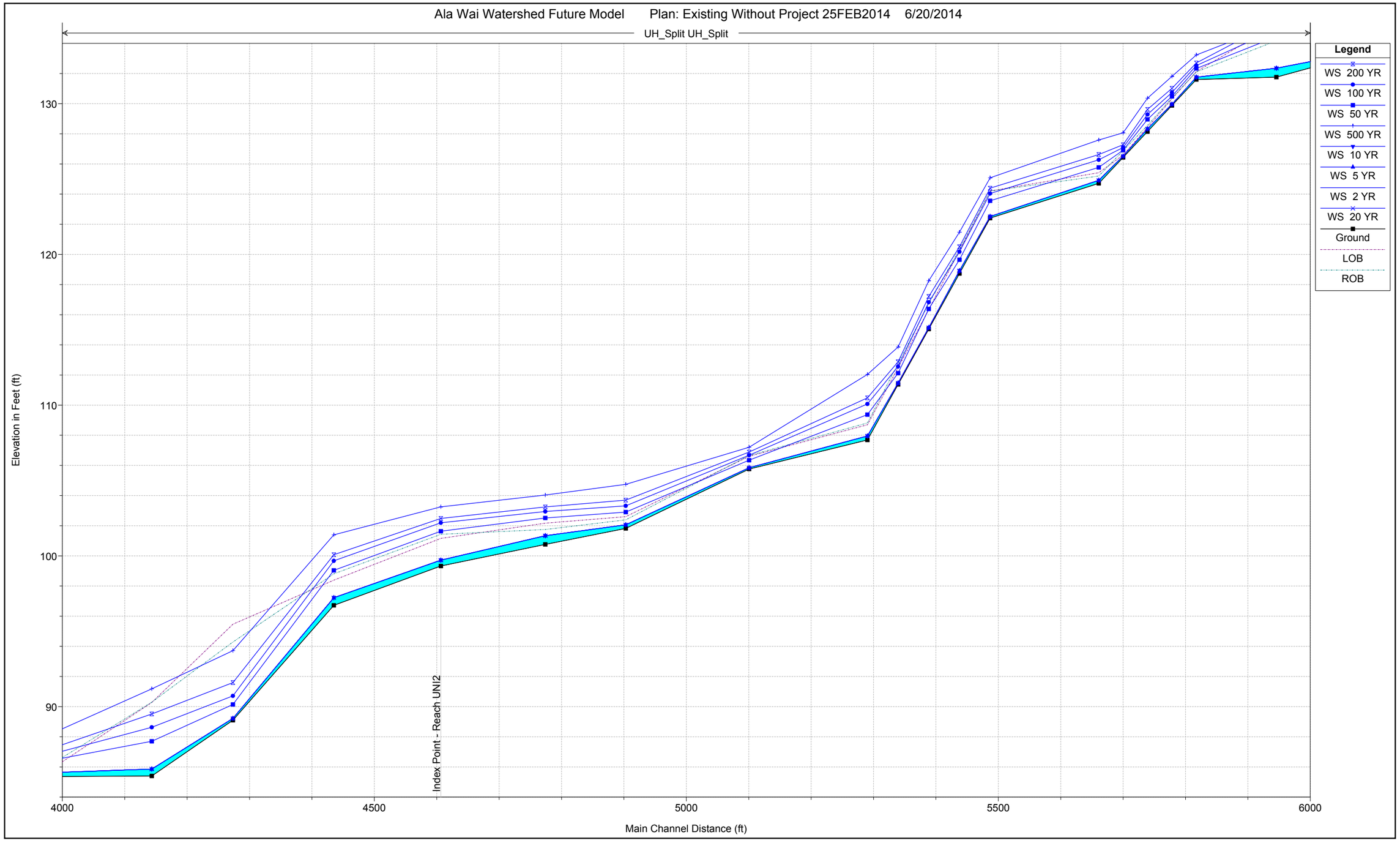

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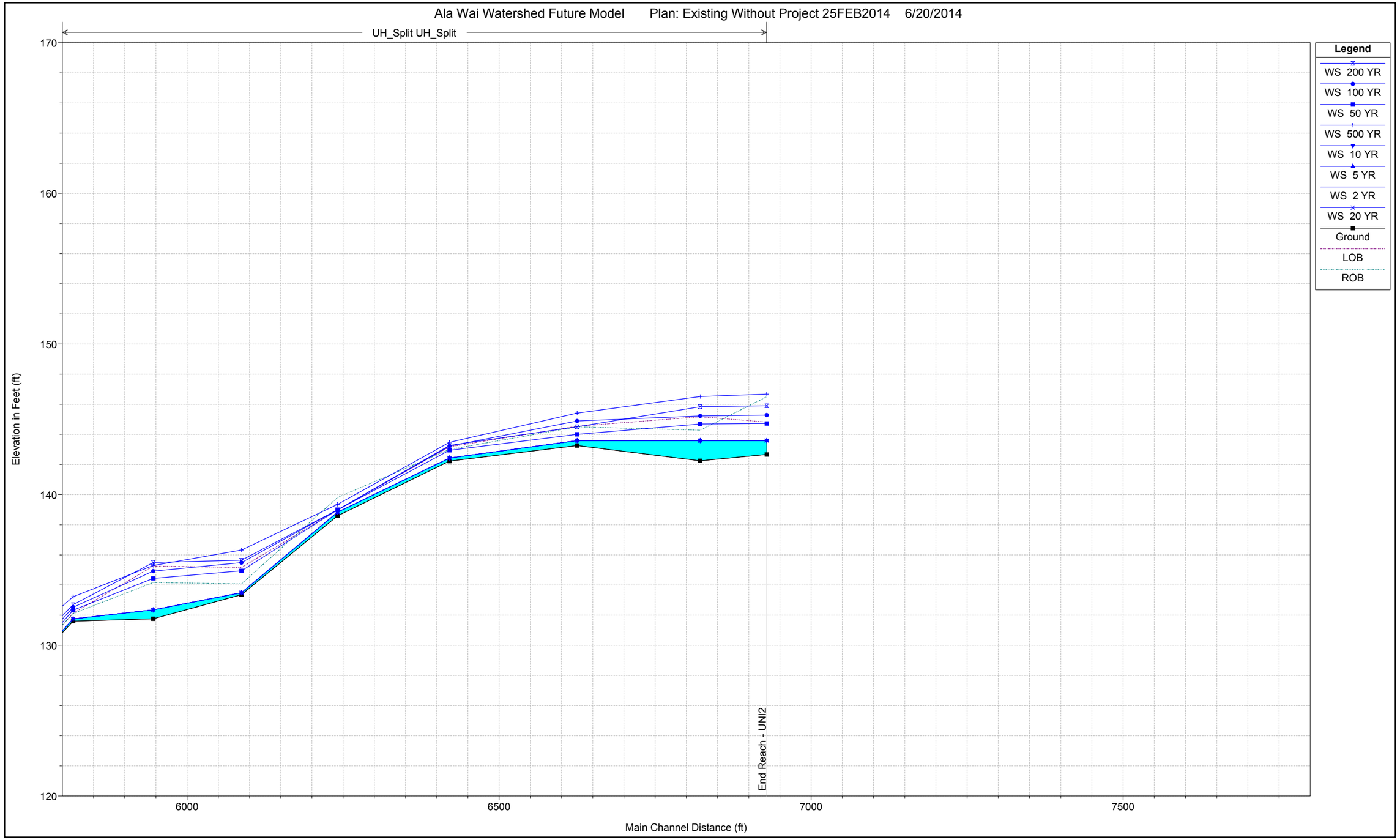

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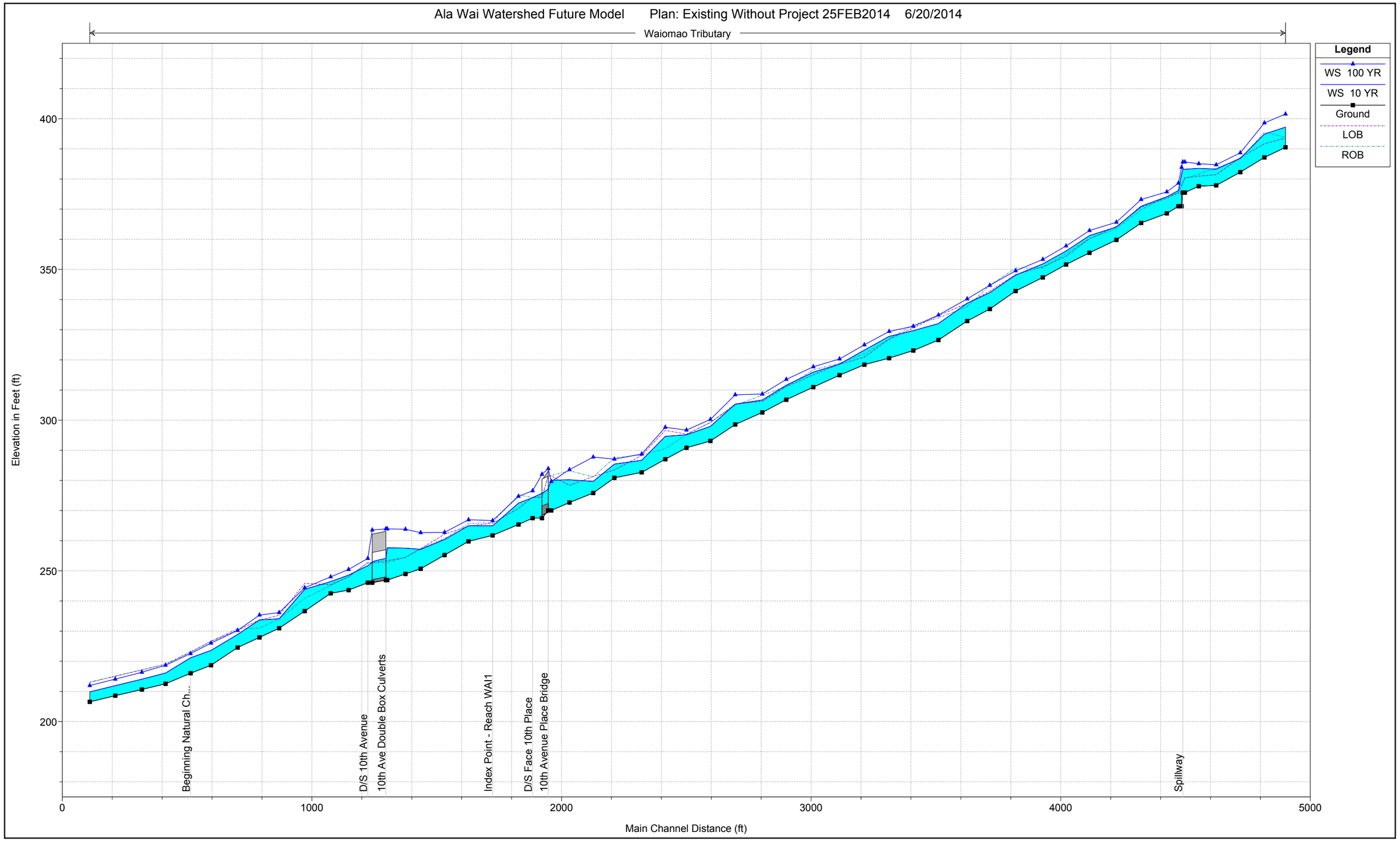

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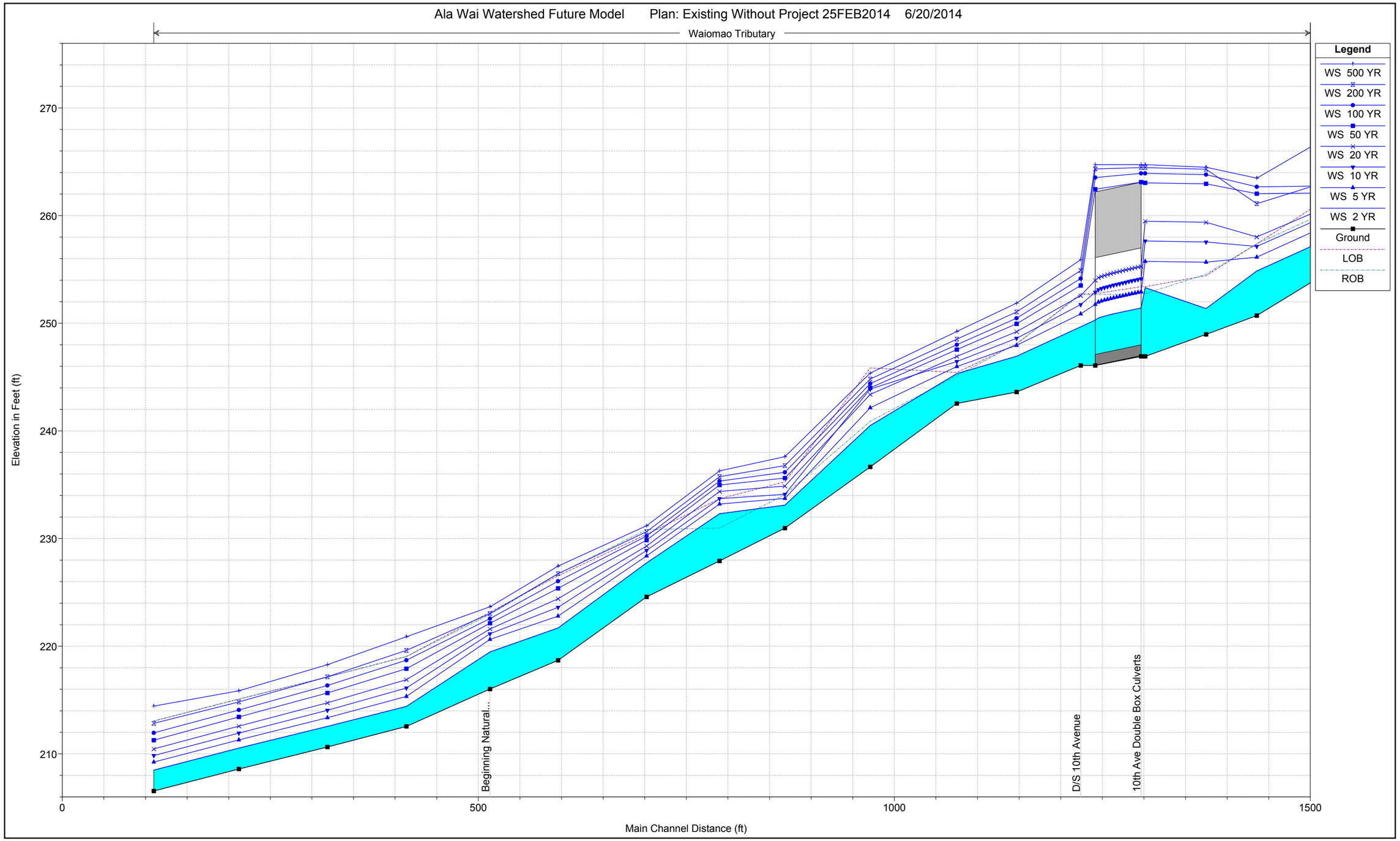

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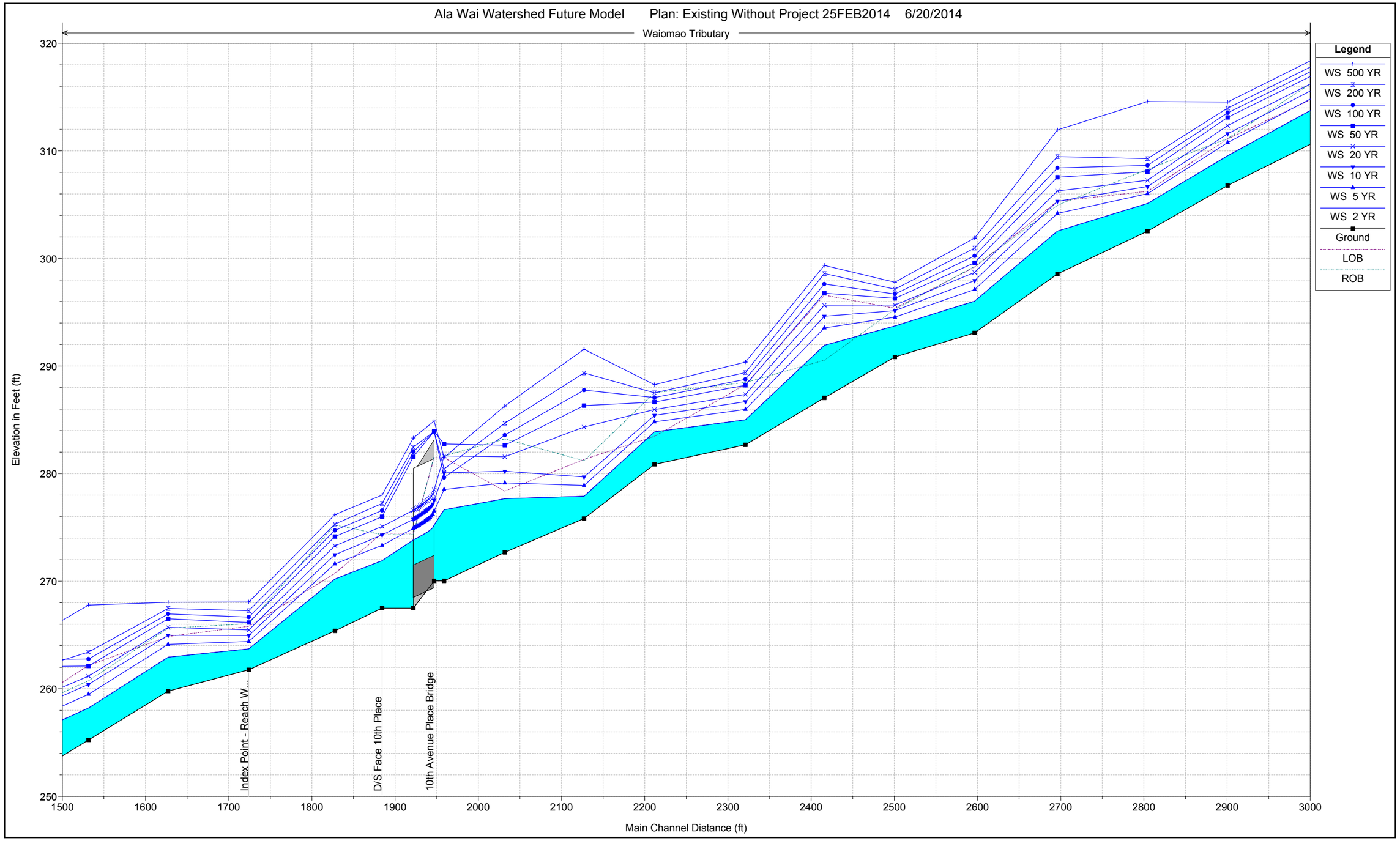

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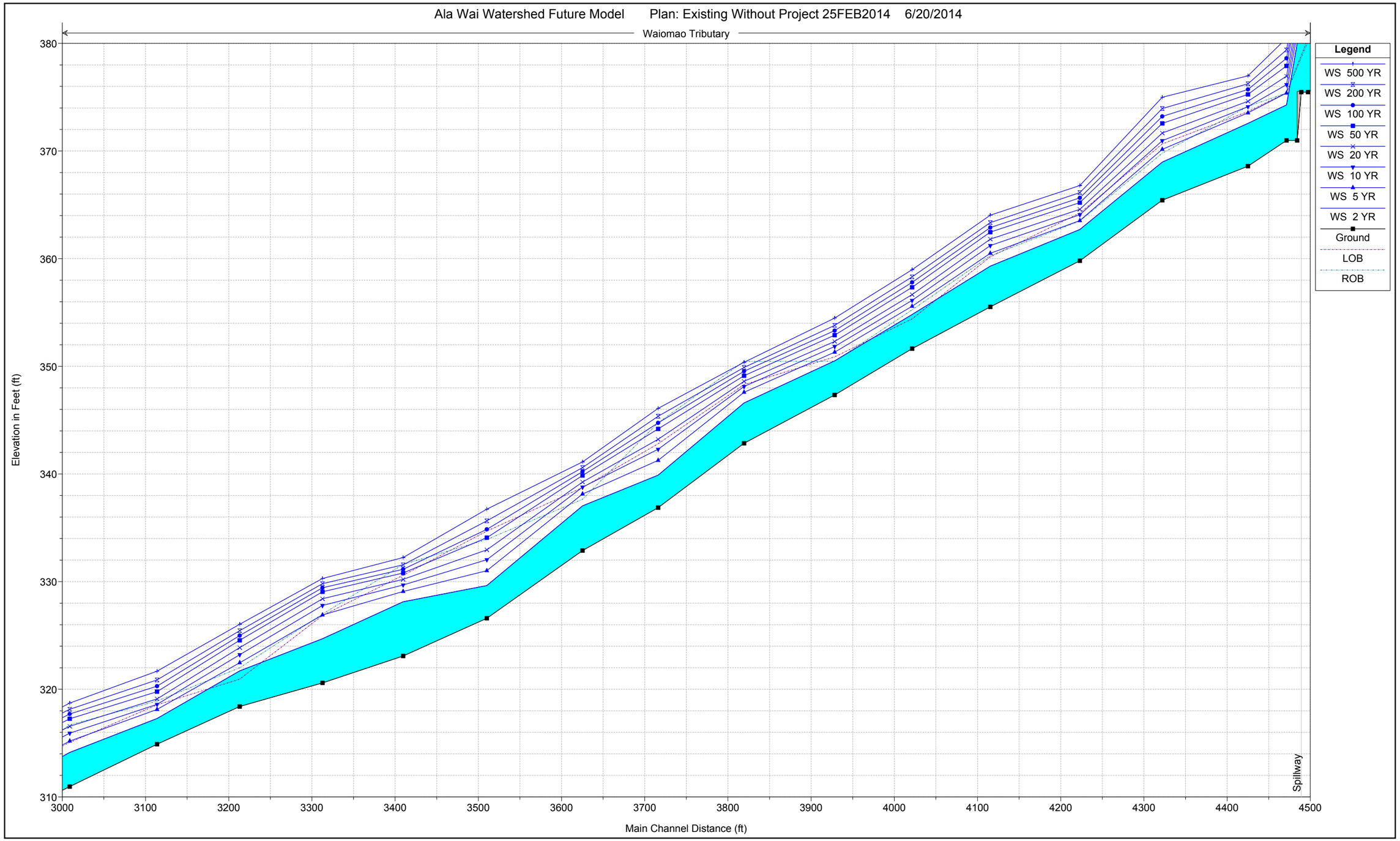

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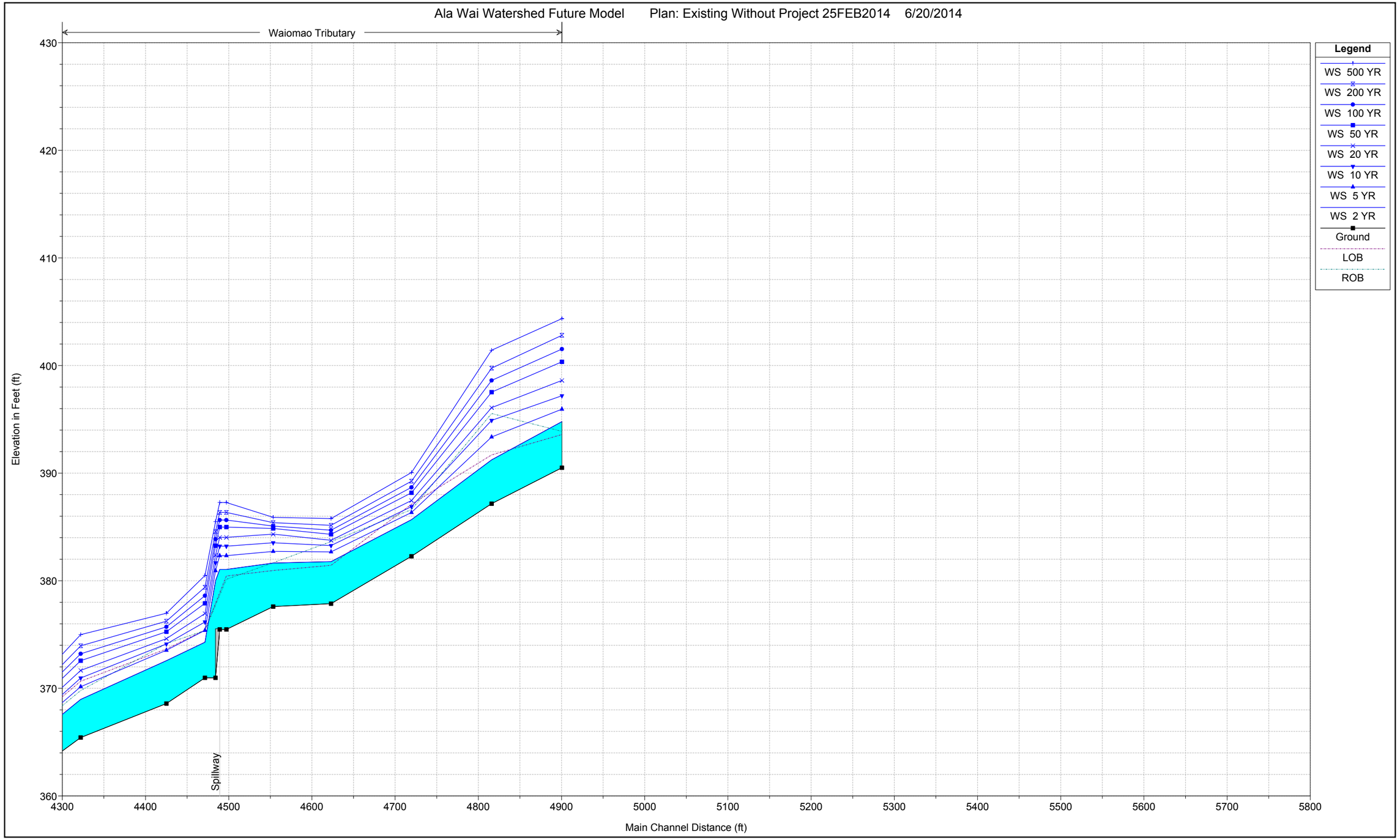
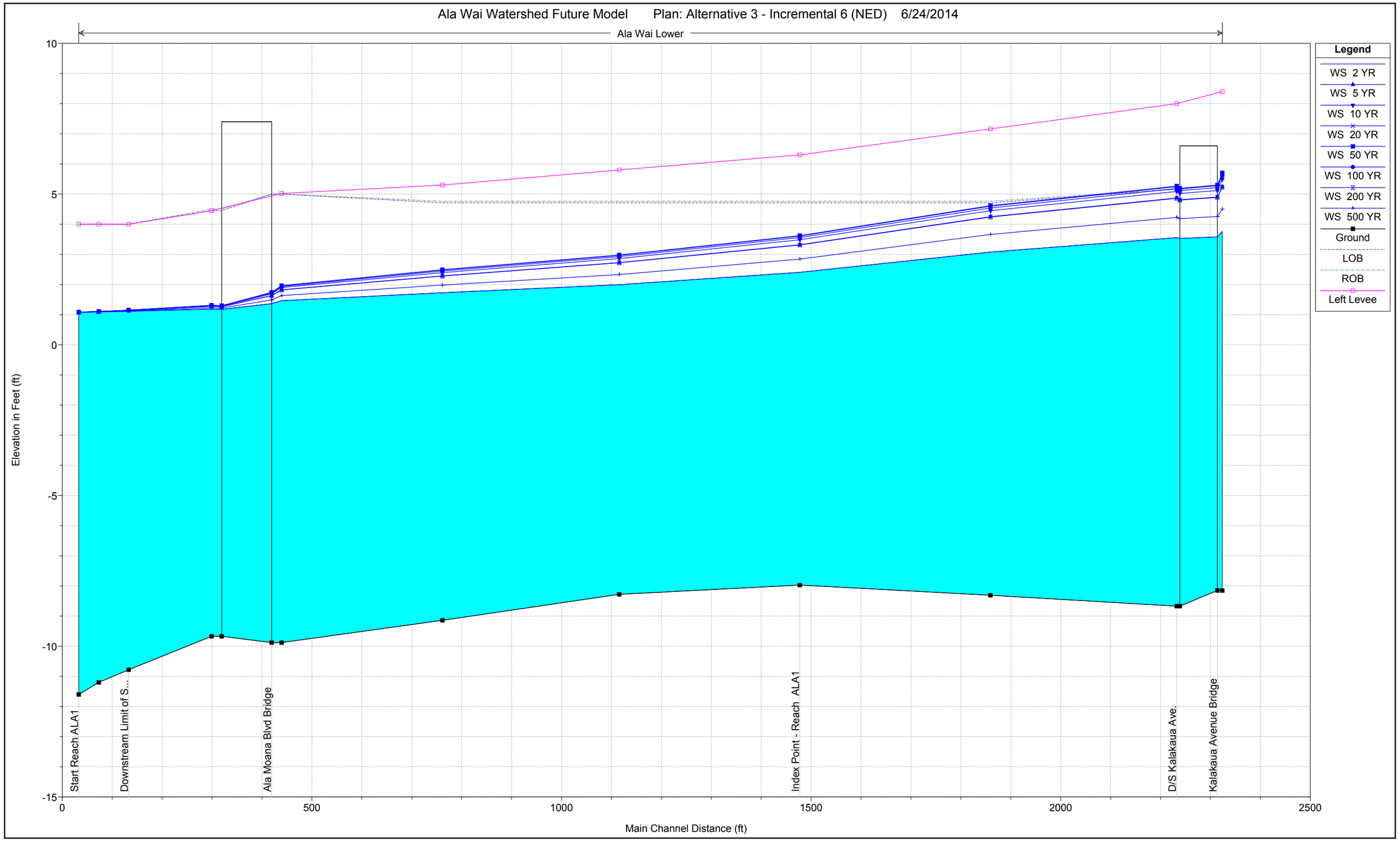


Plate 4 - Alternative 3 Hydraulic Profiles



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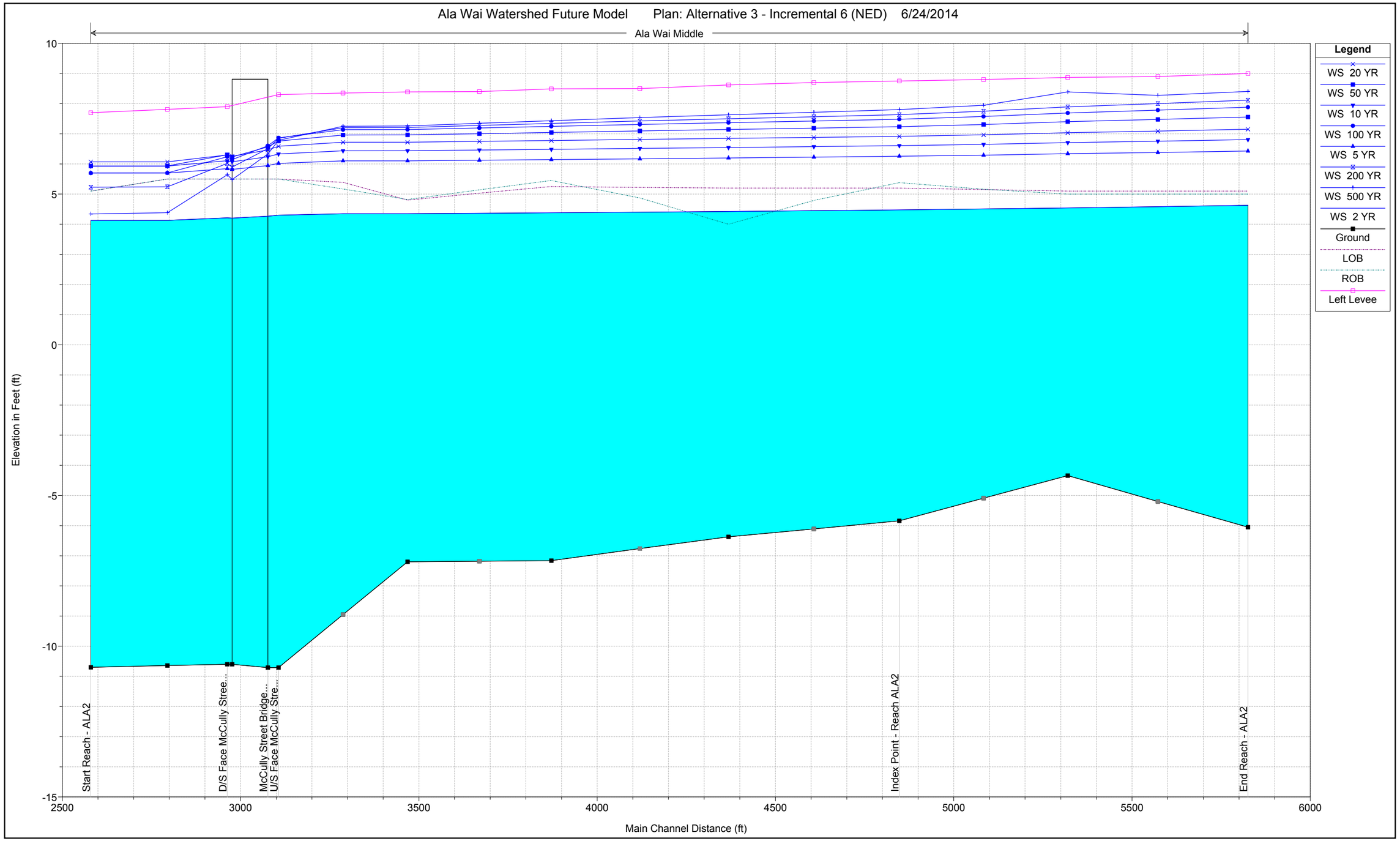

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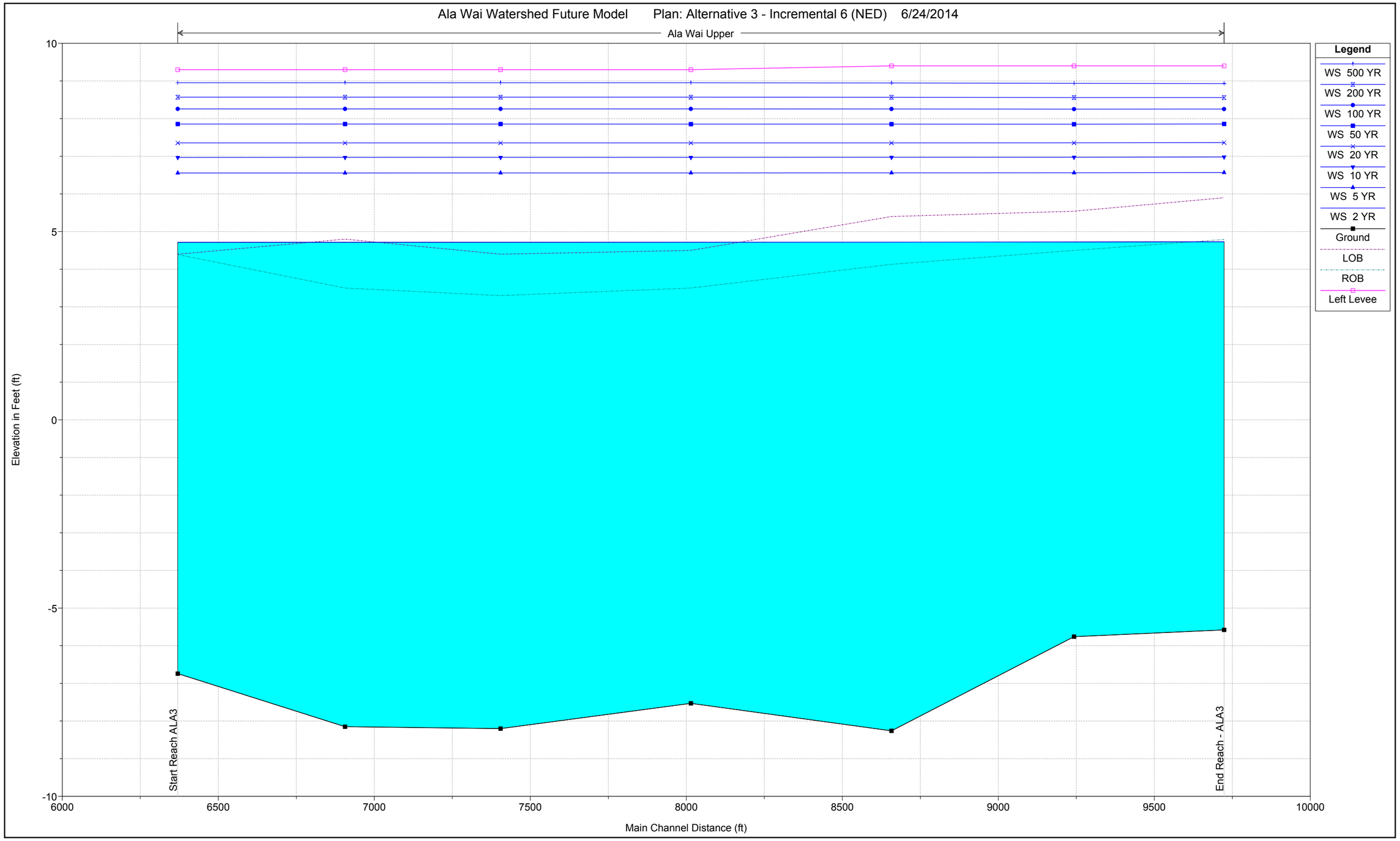

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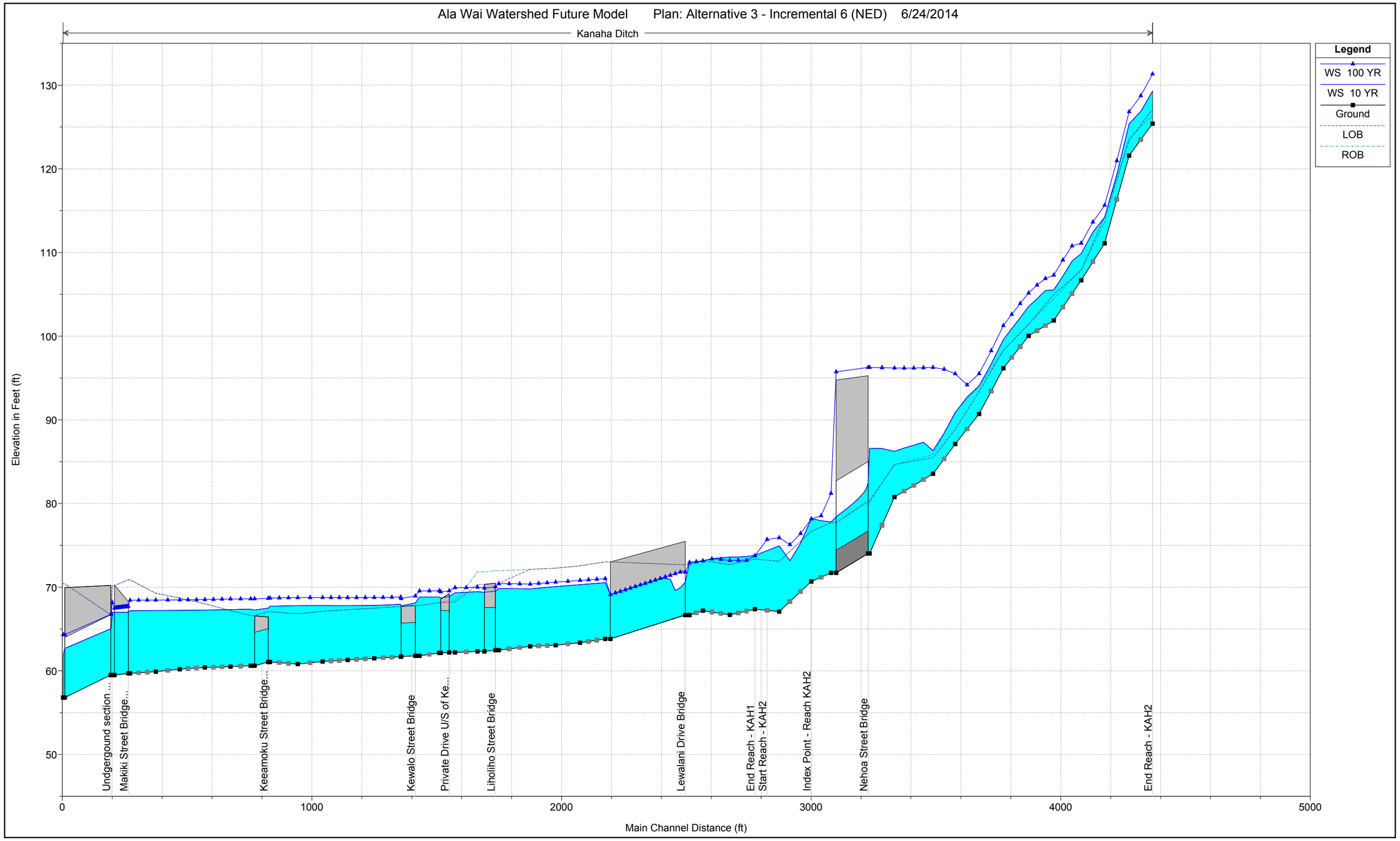

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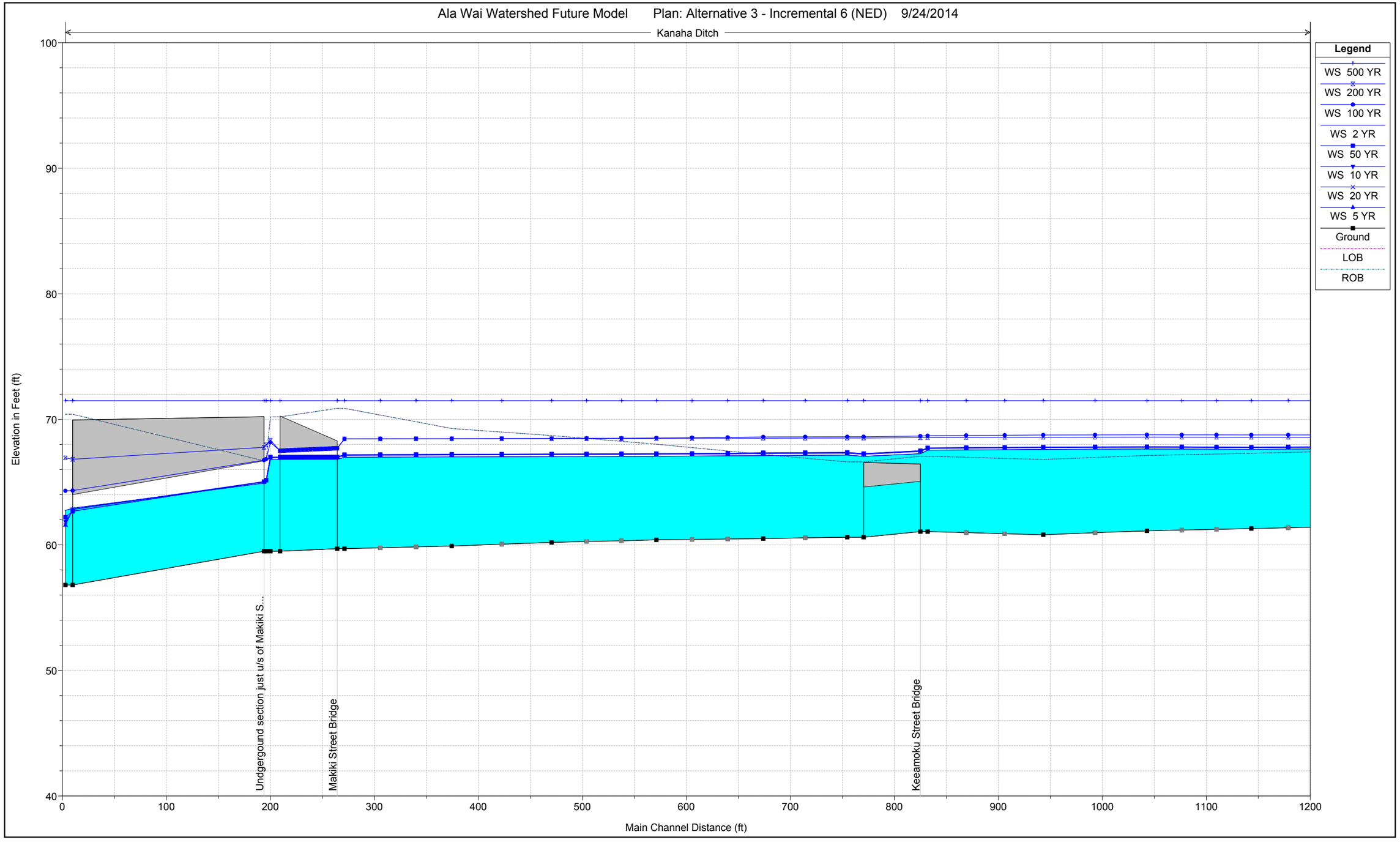

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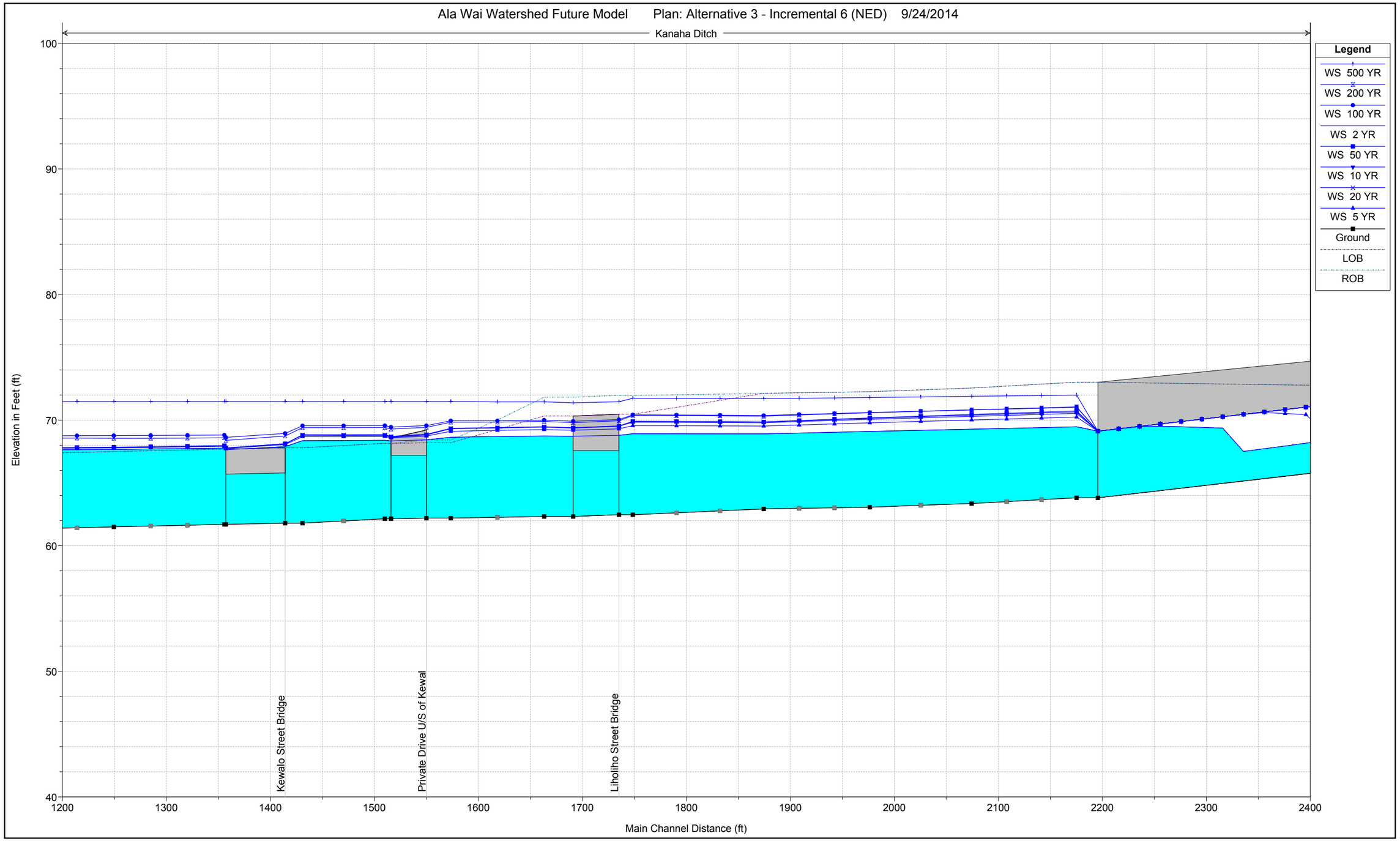

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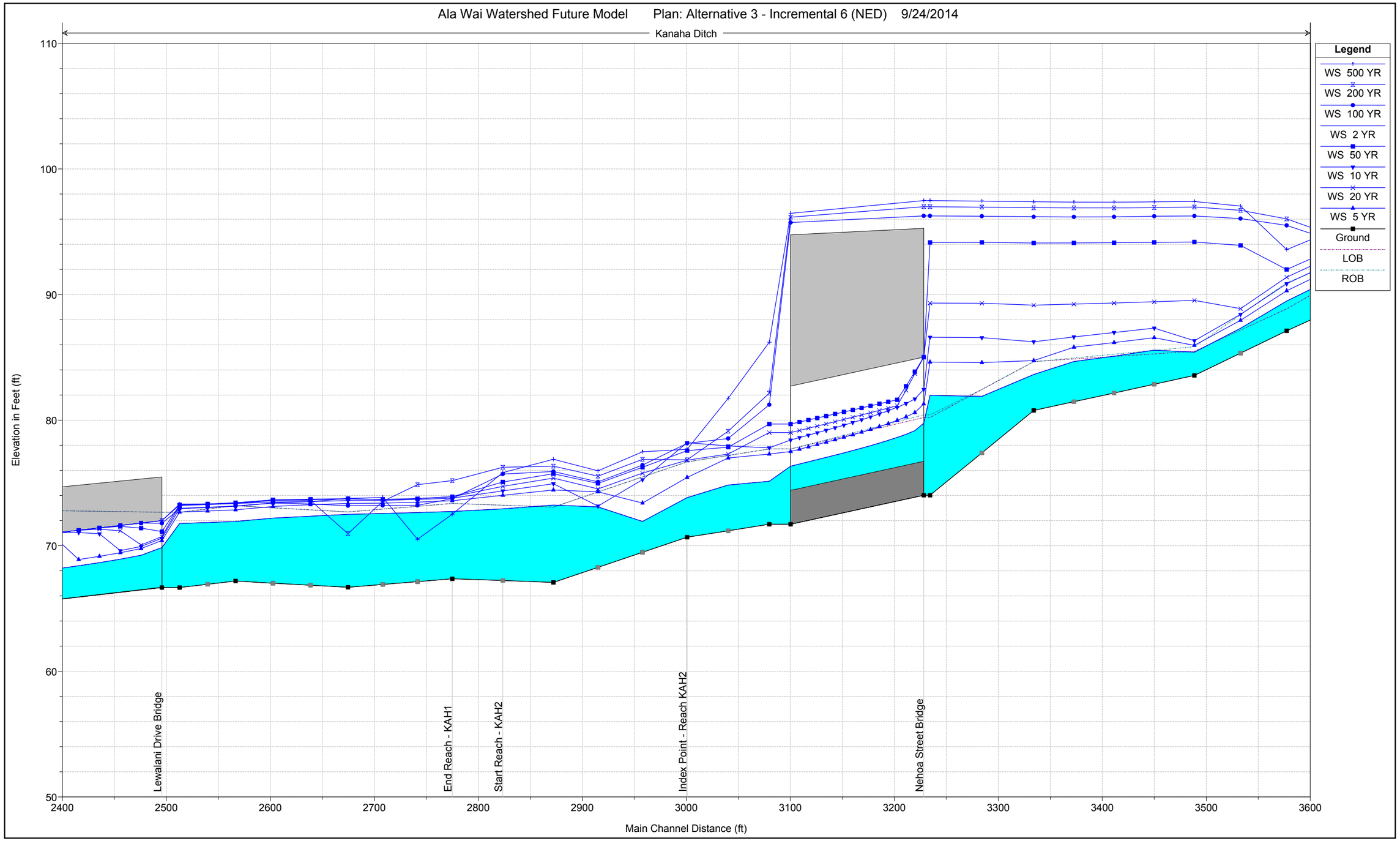

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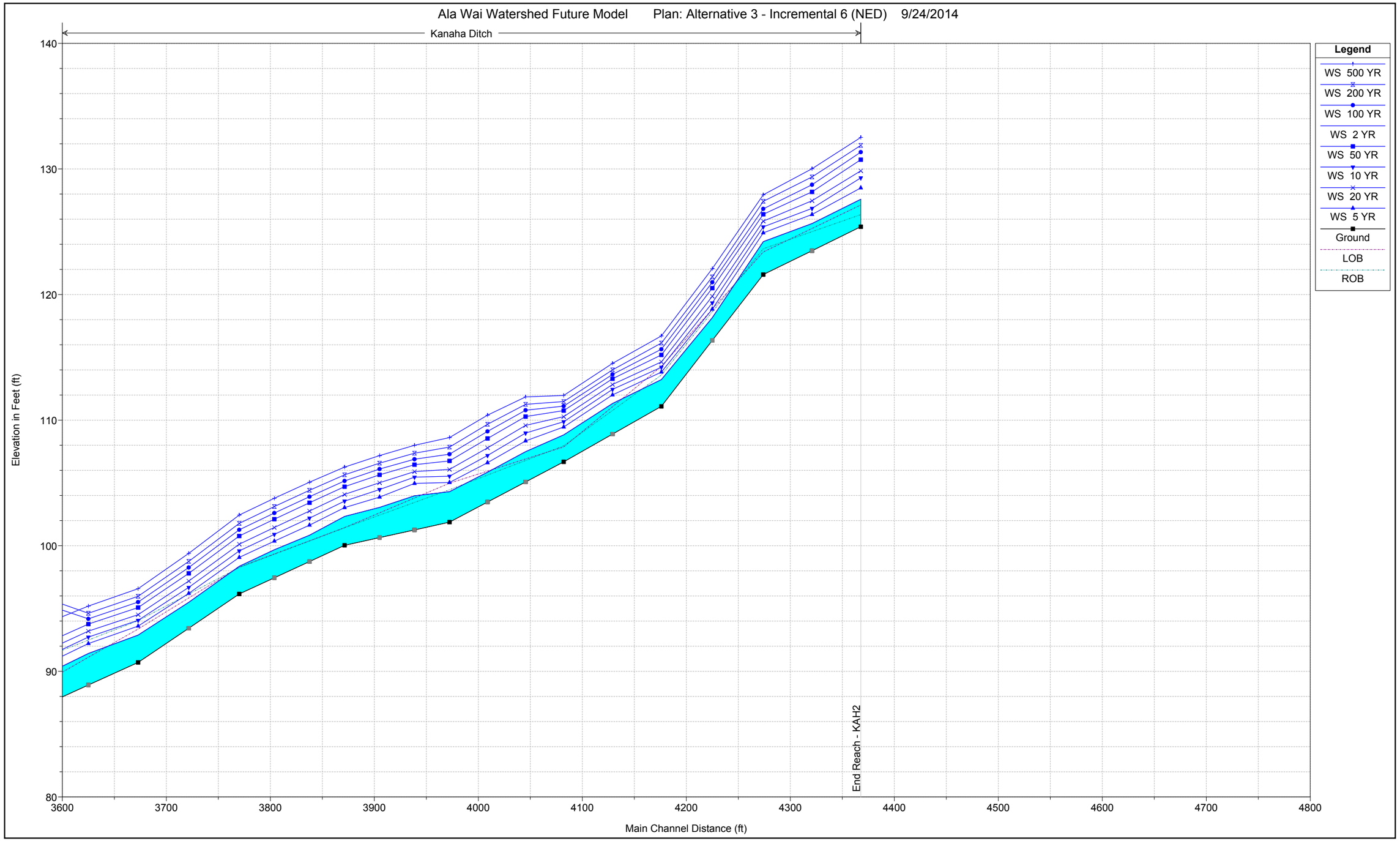

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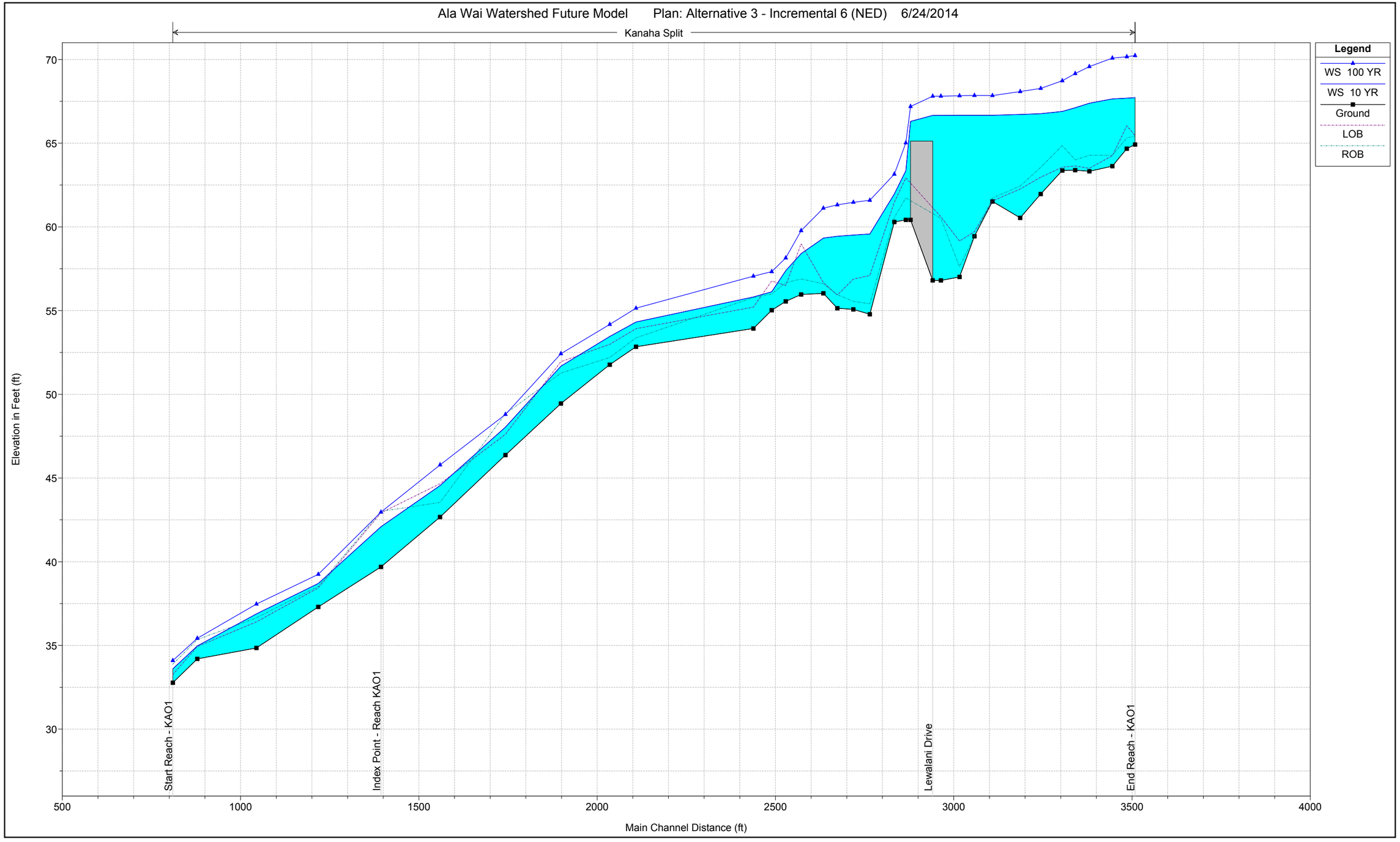

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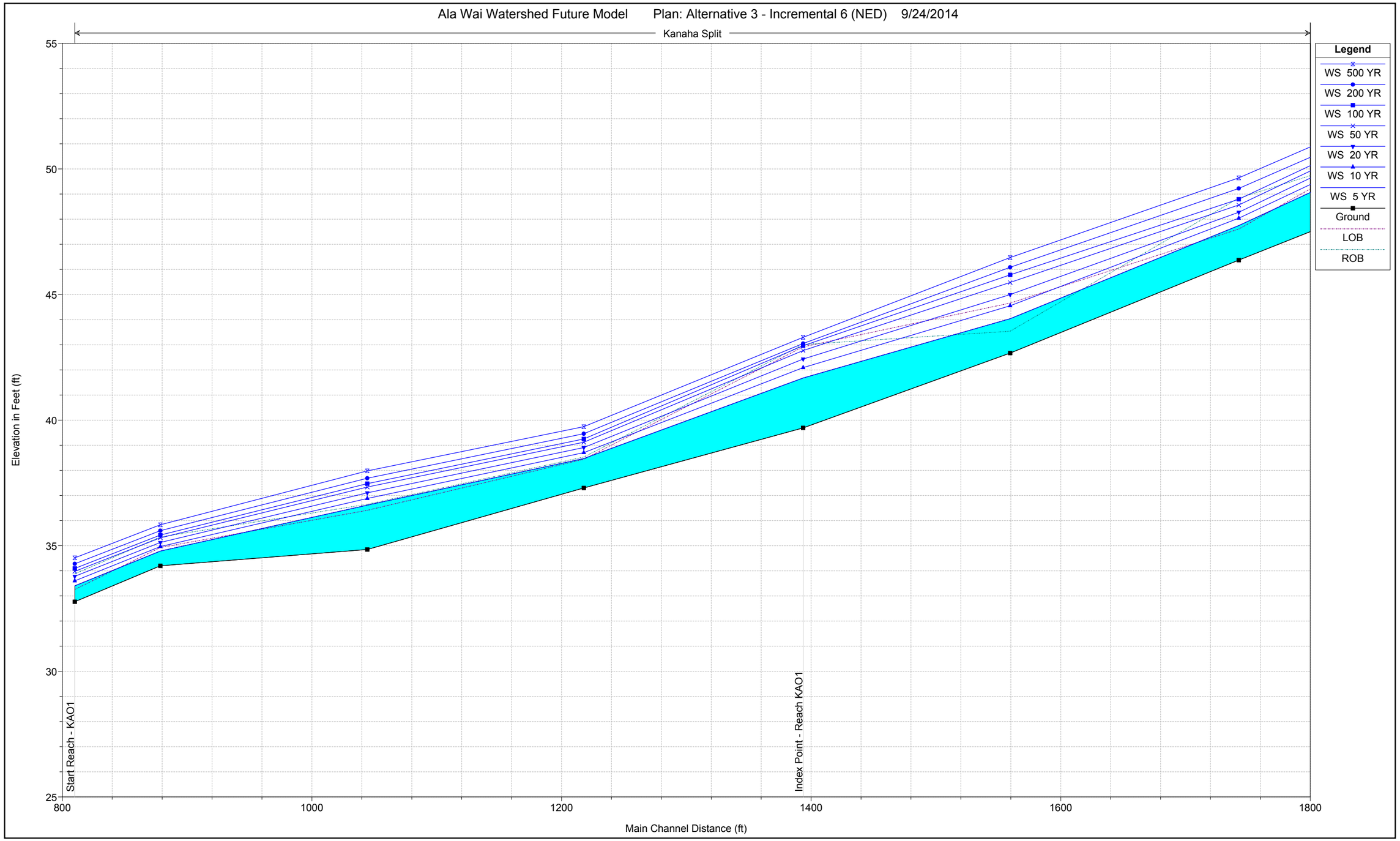

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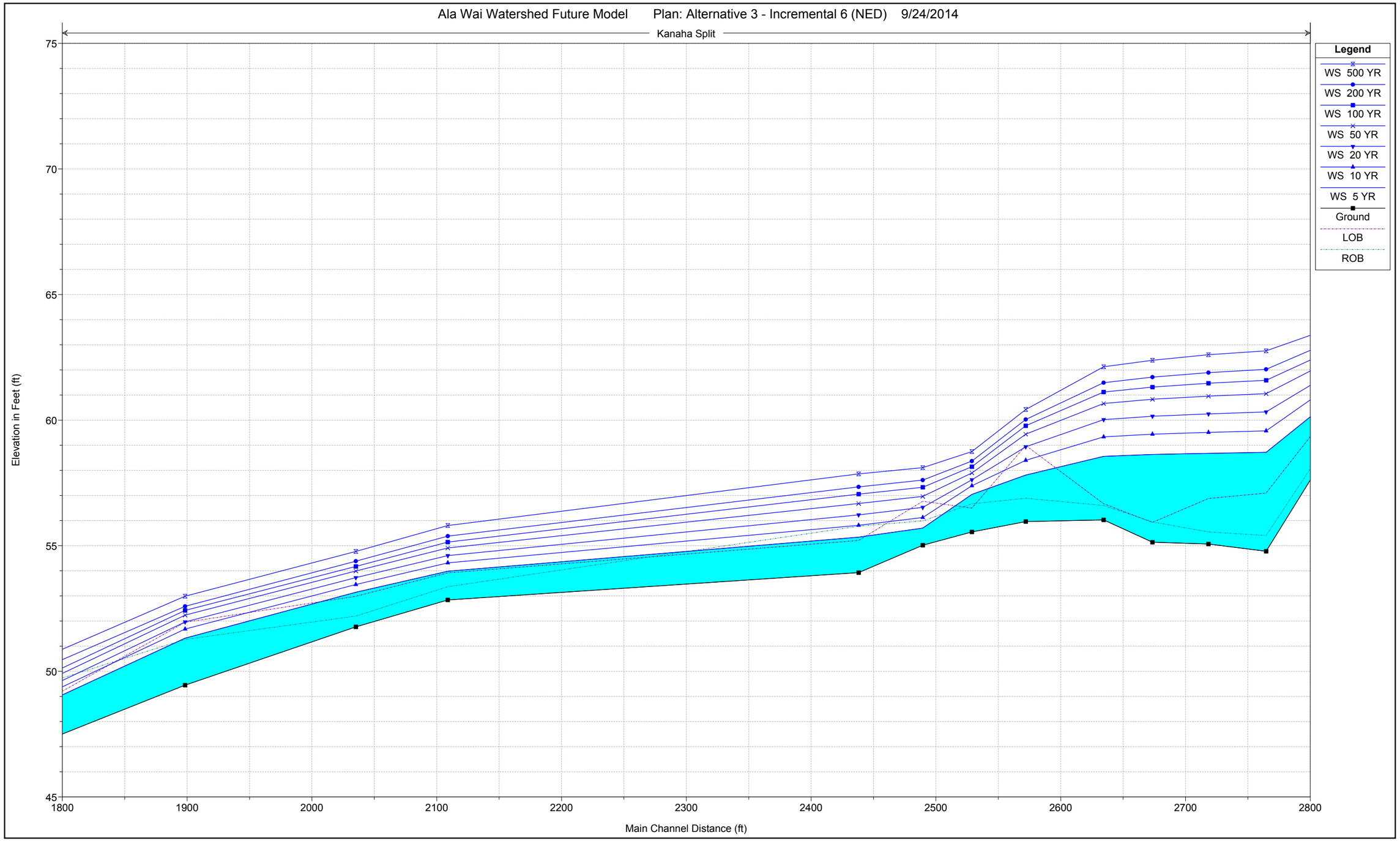

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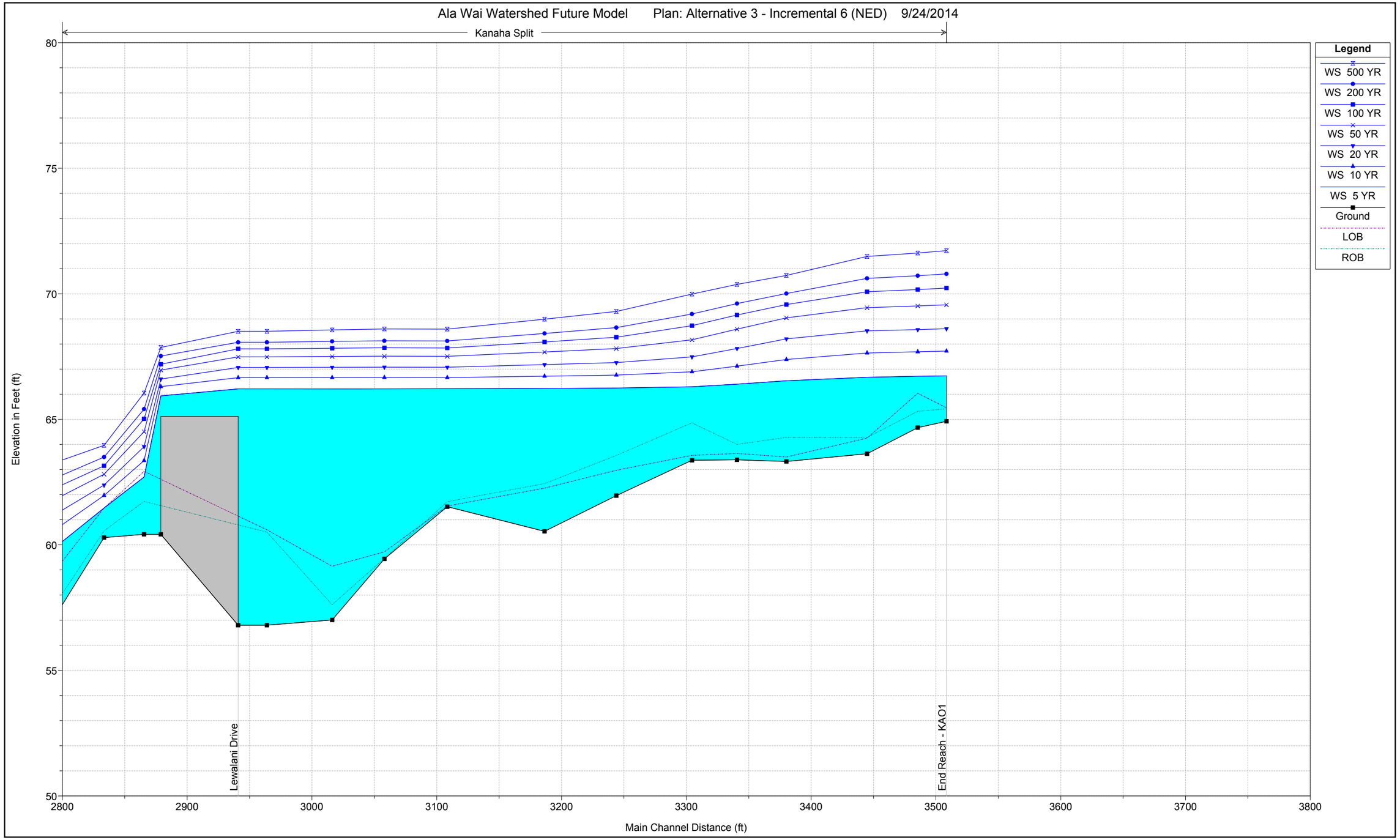

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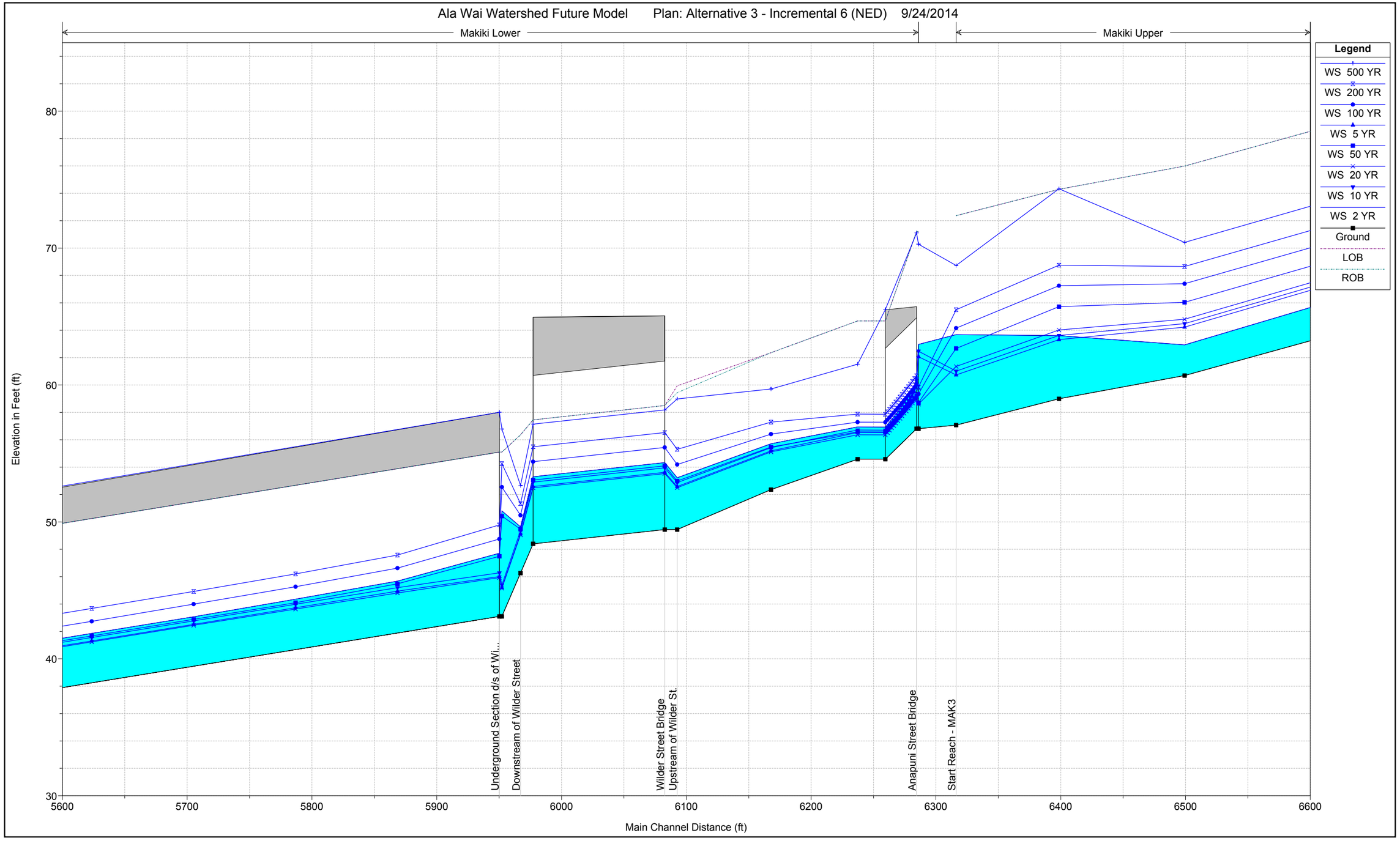

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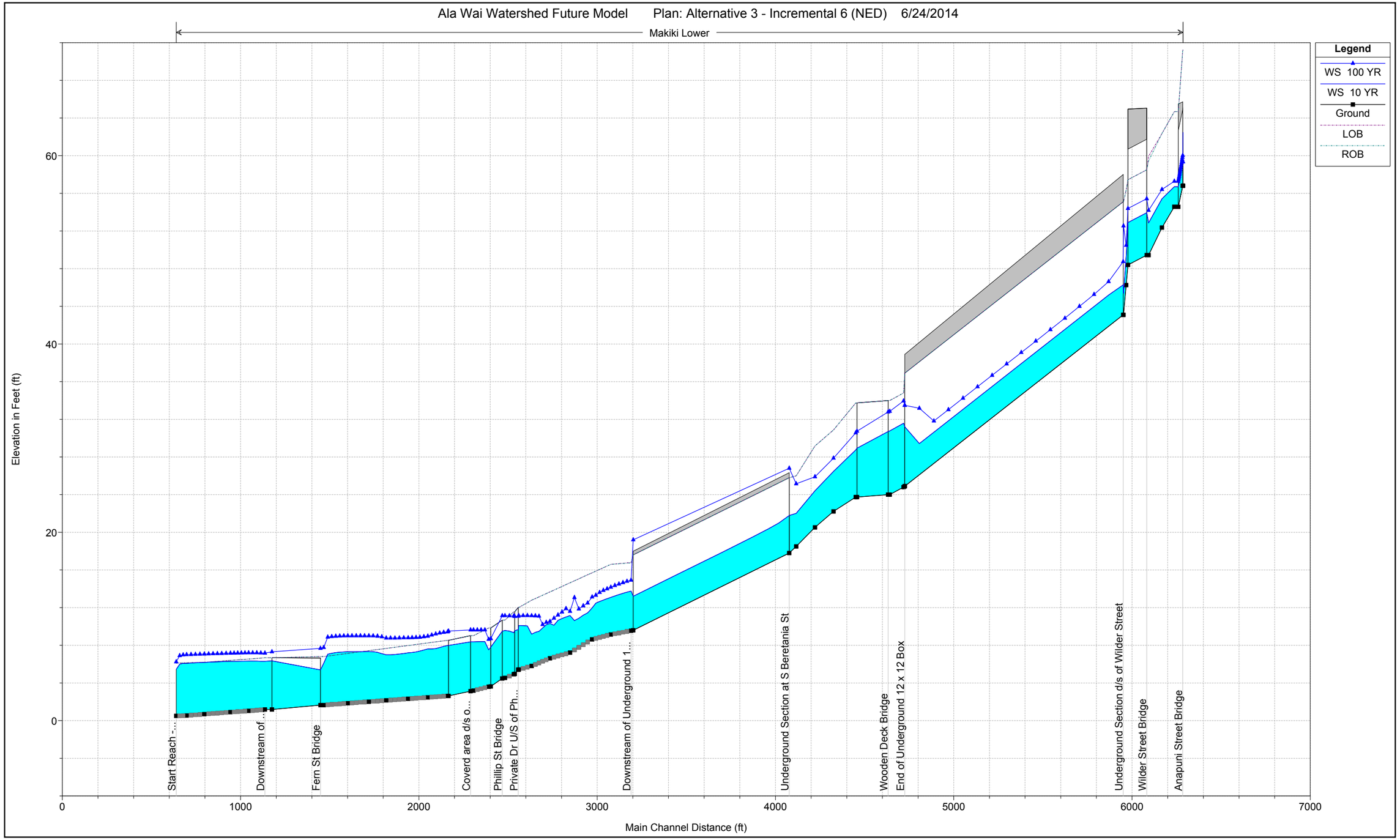

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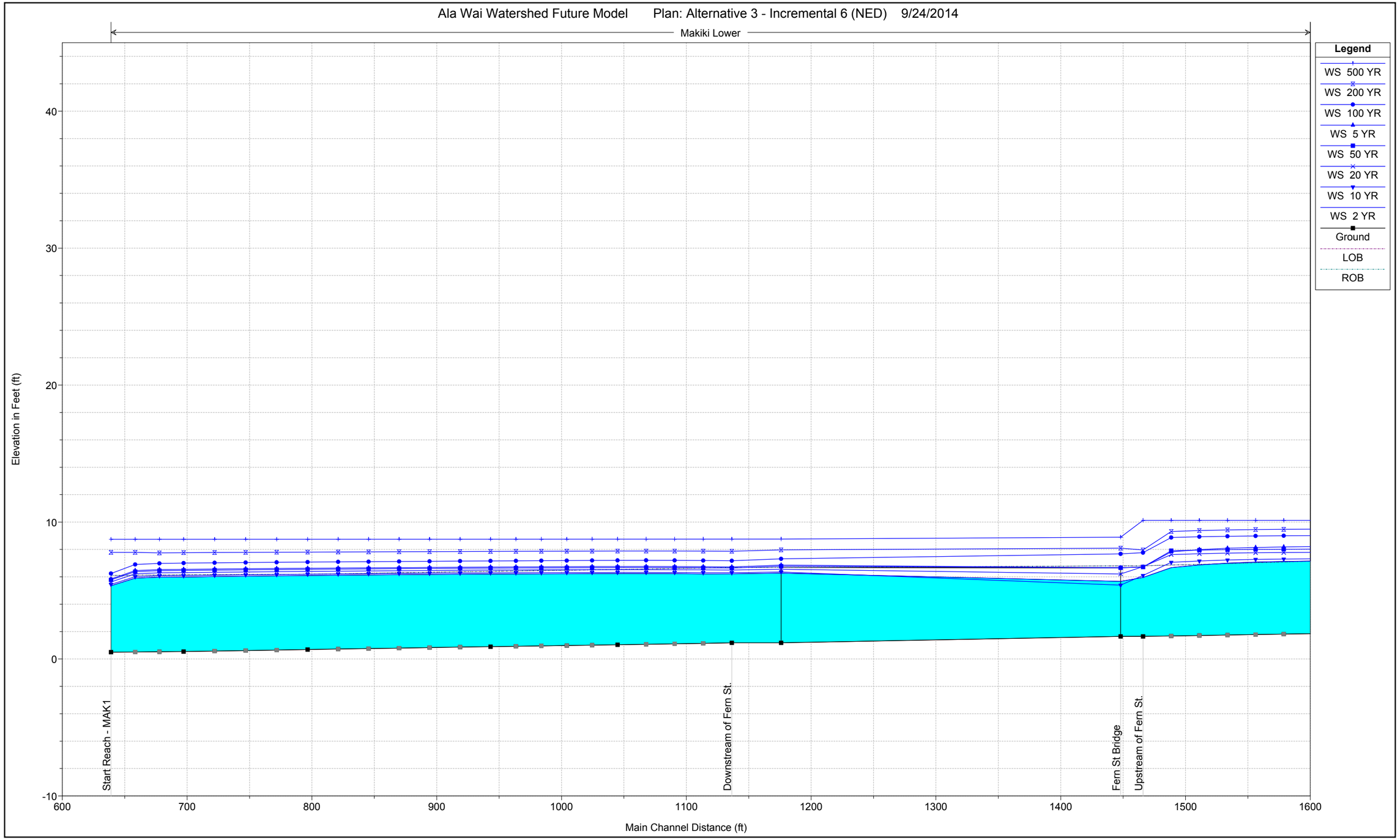

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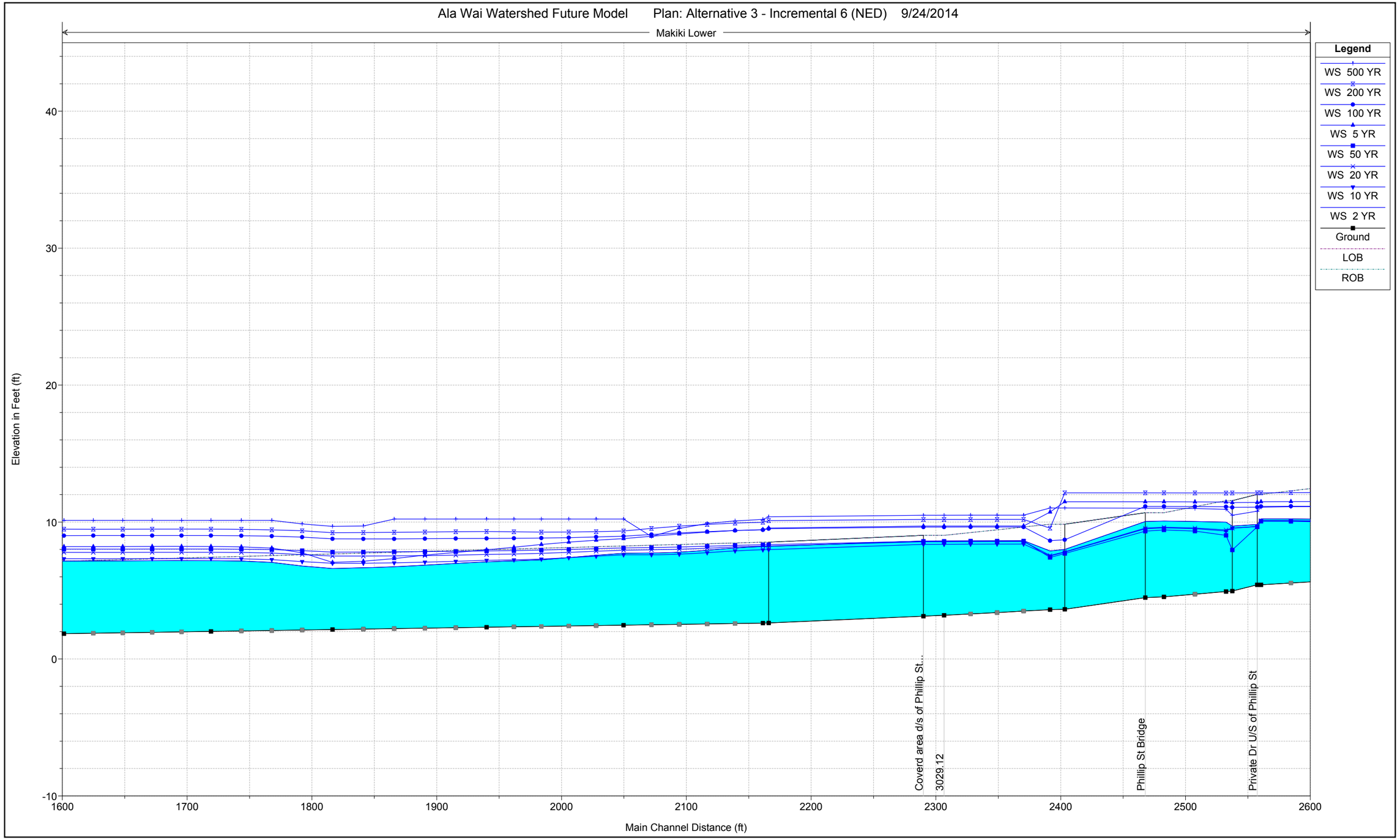

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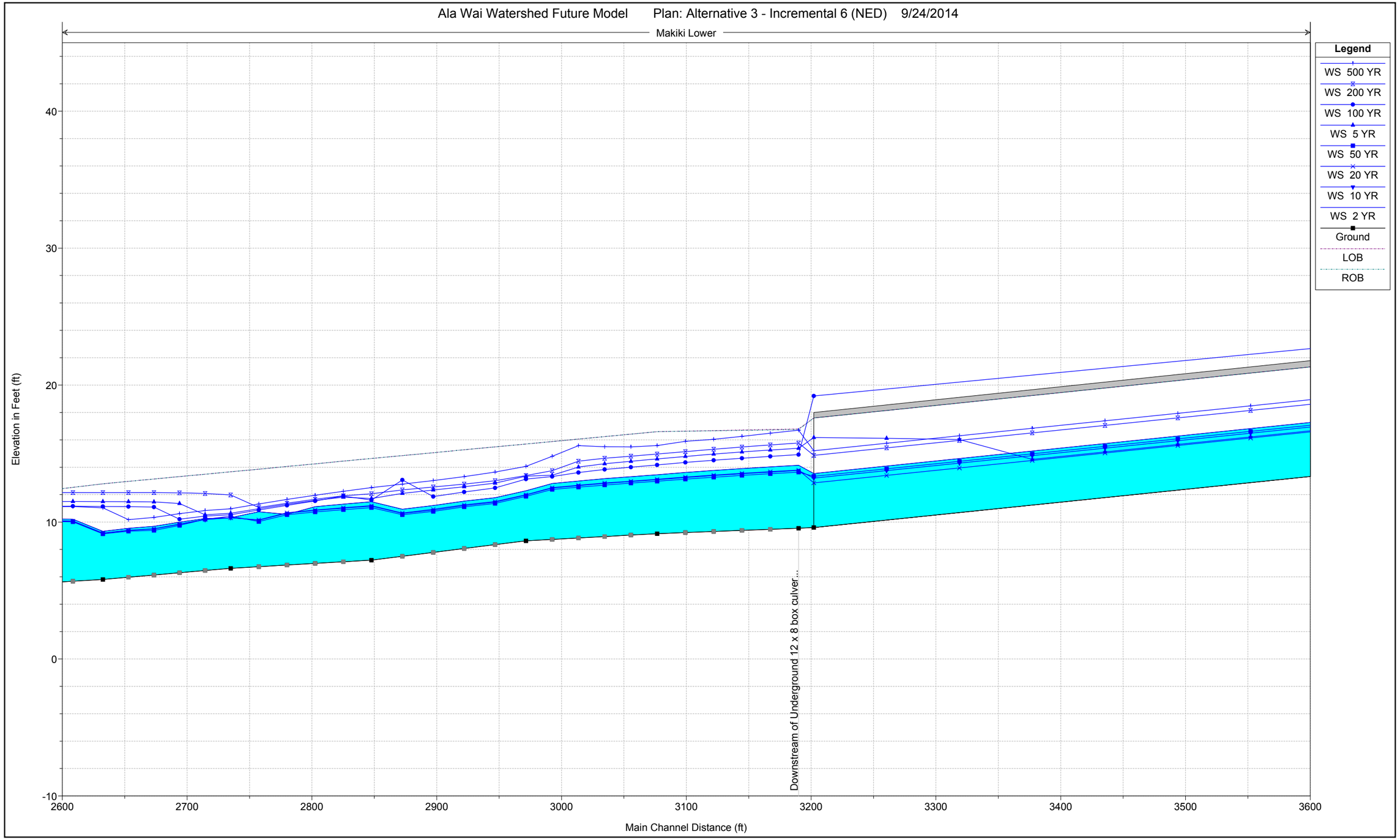

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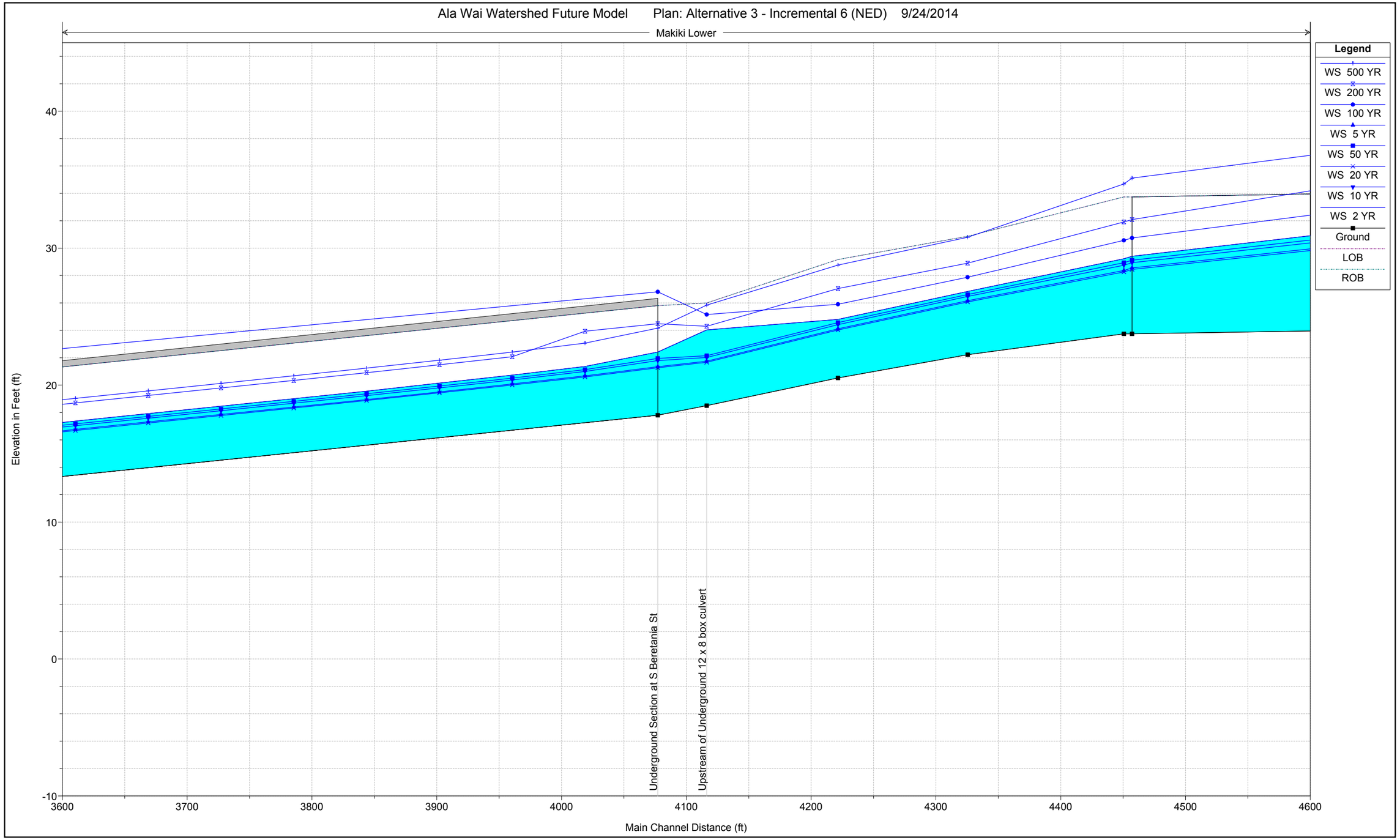

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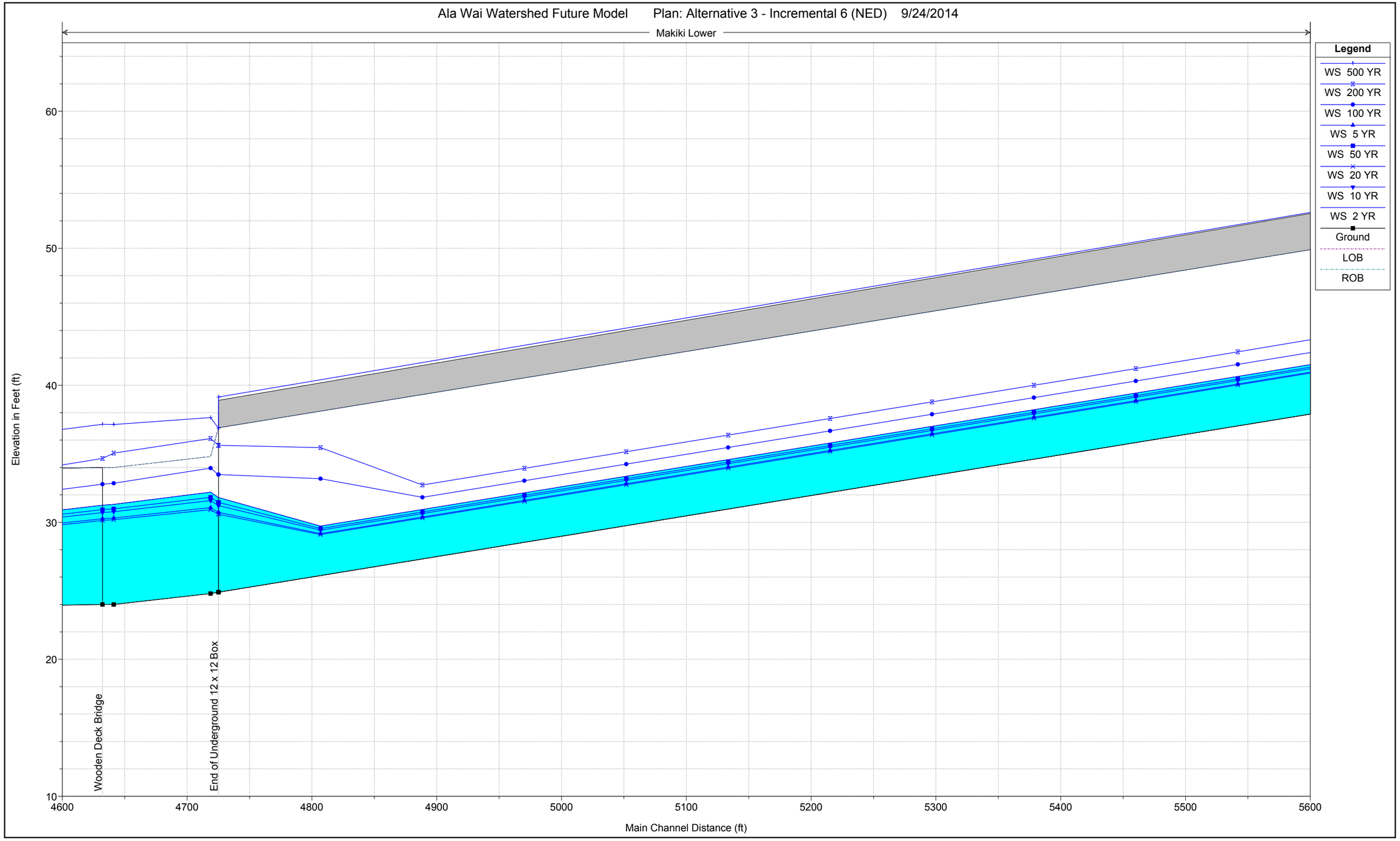

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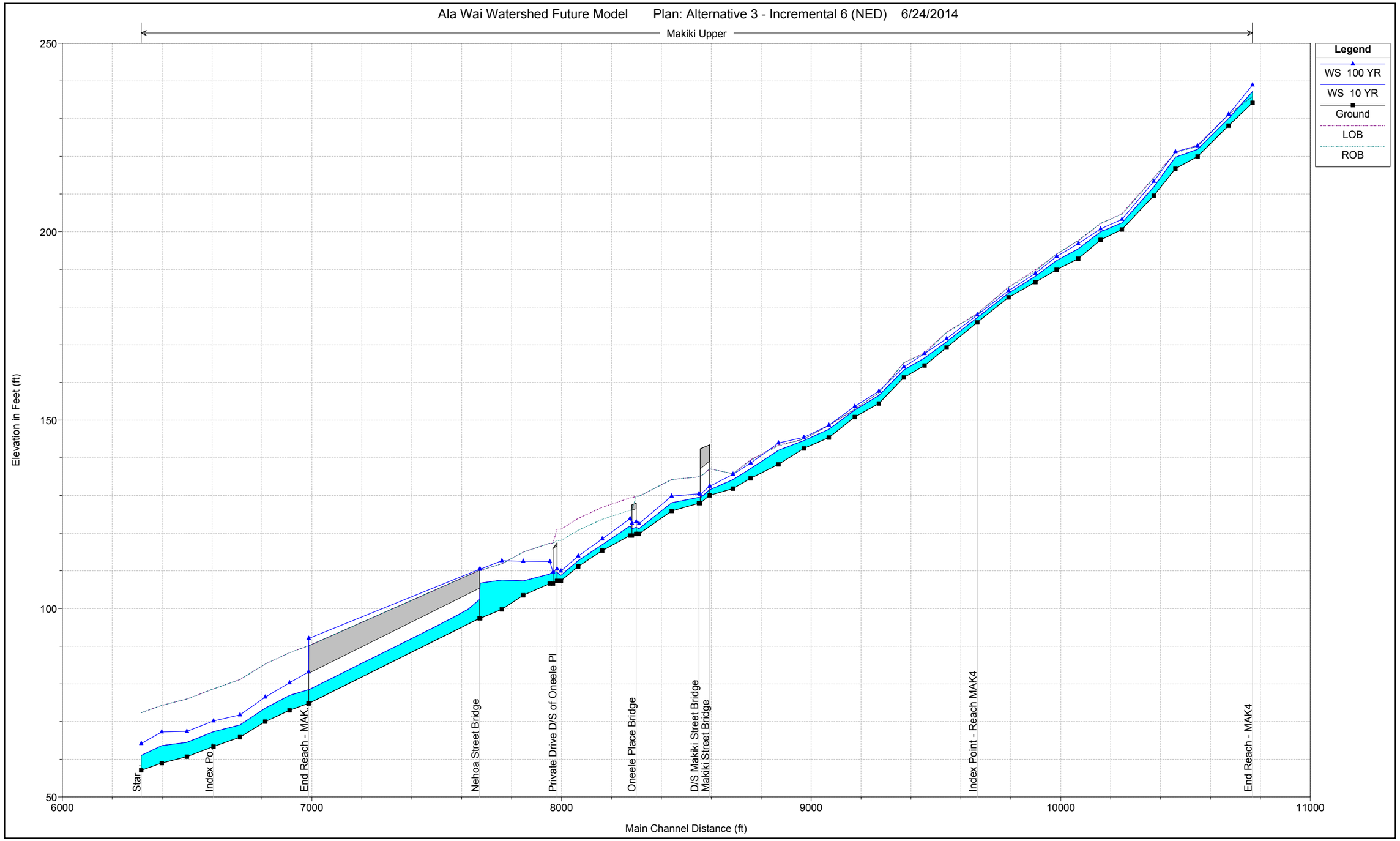

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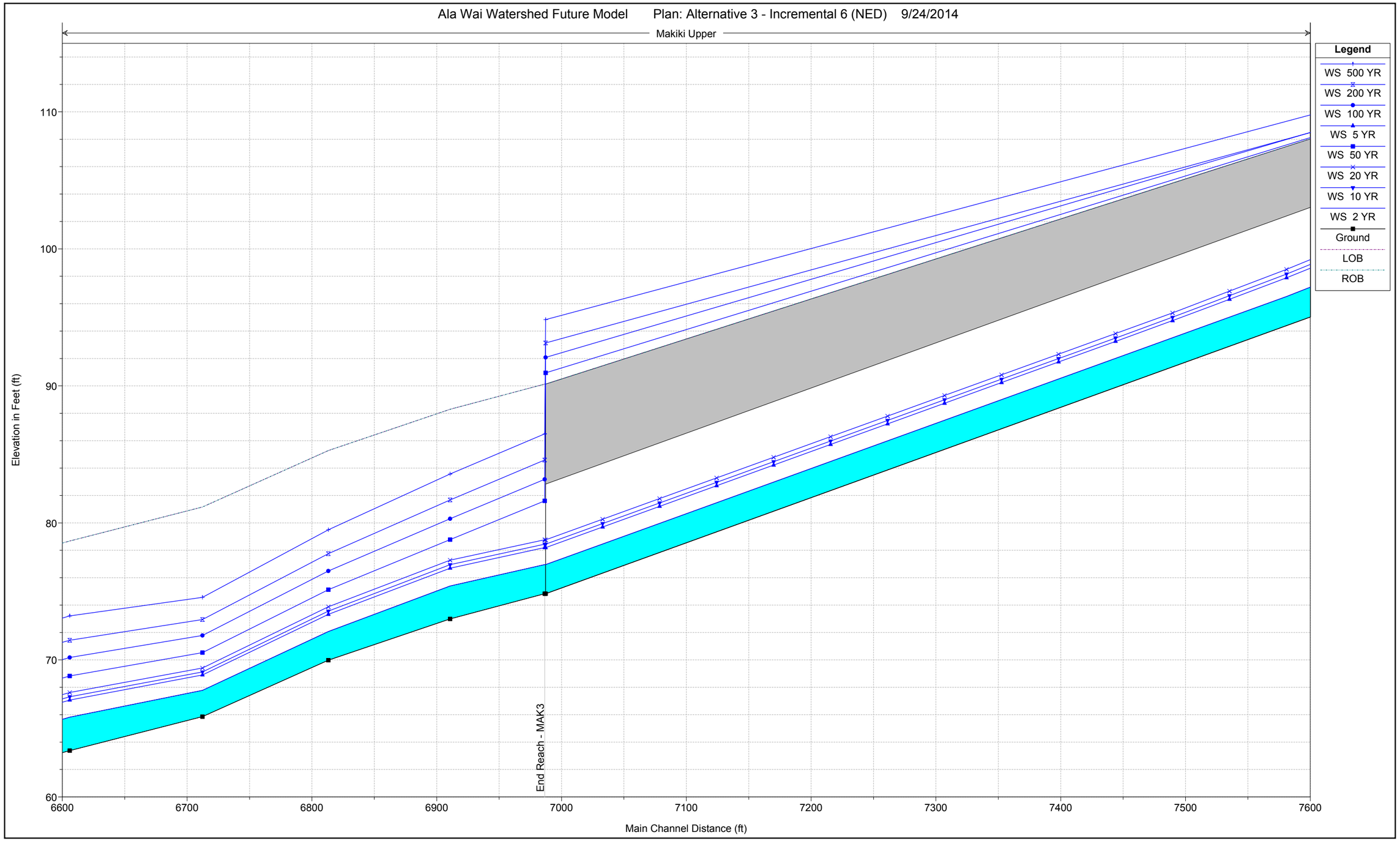

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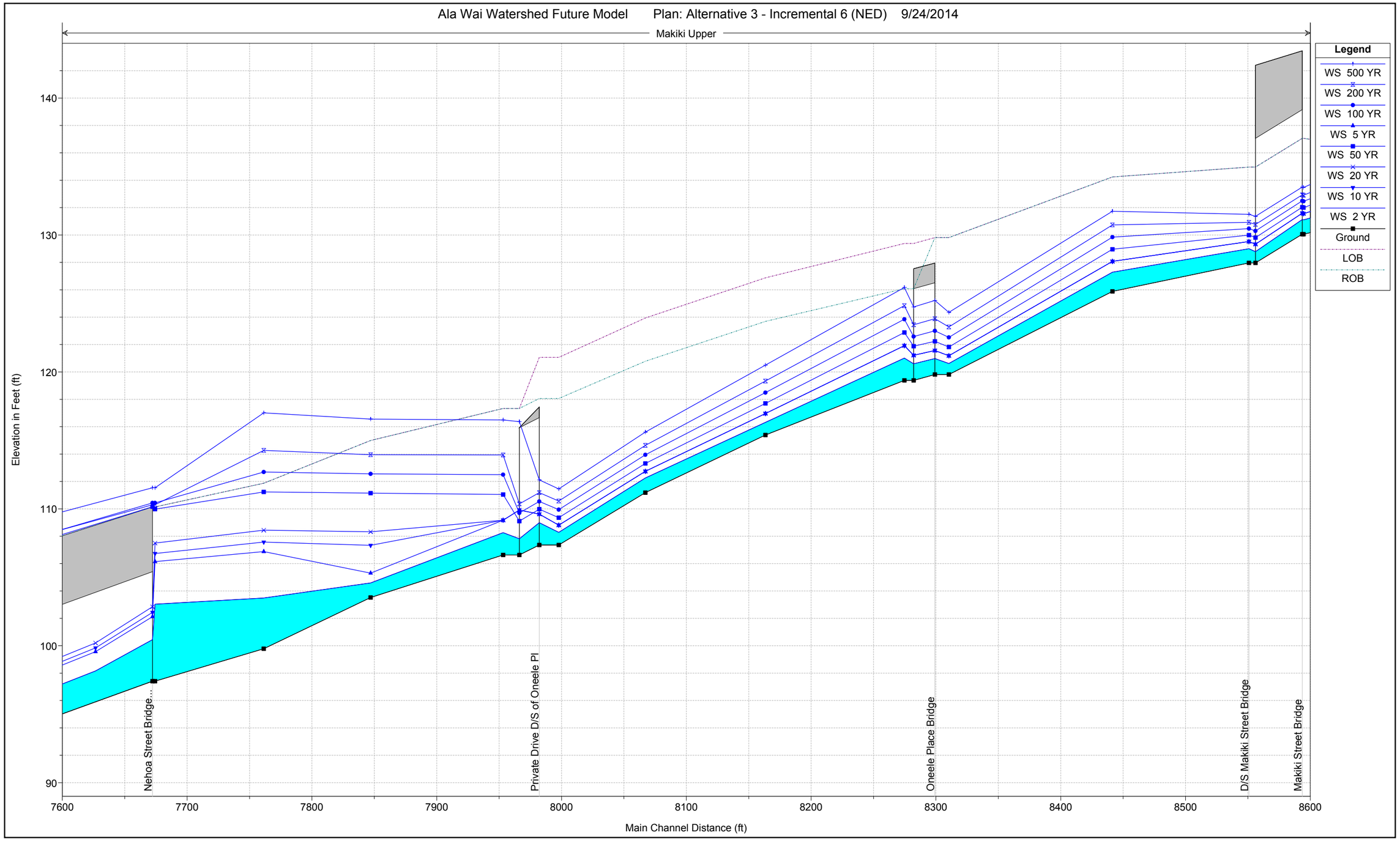

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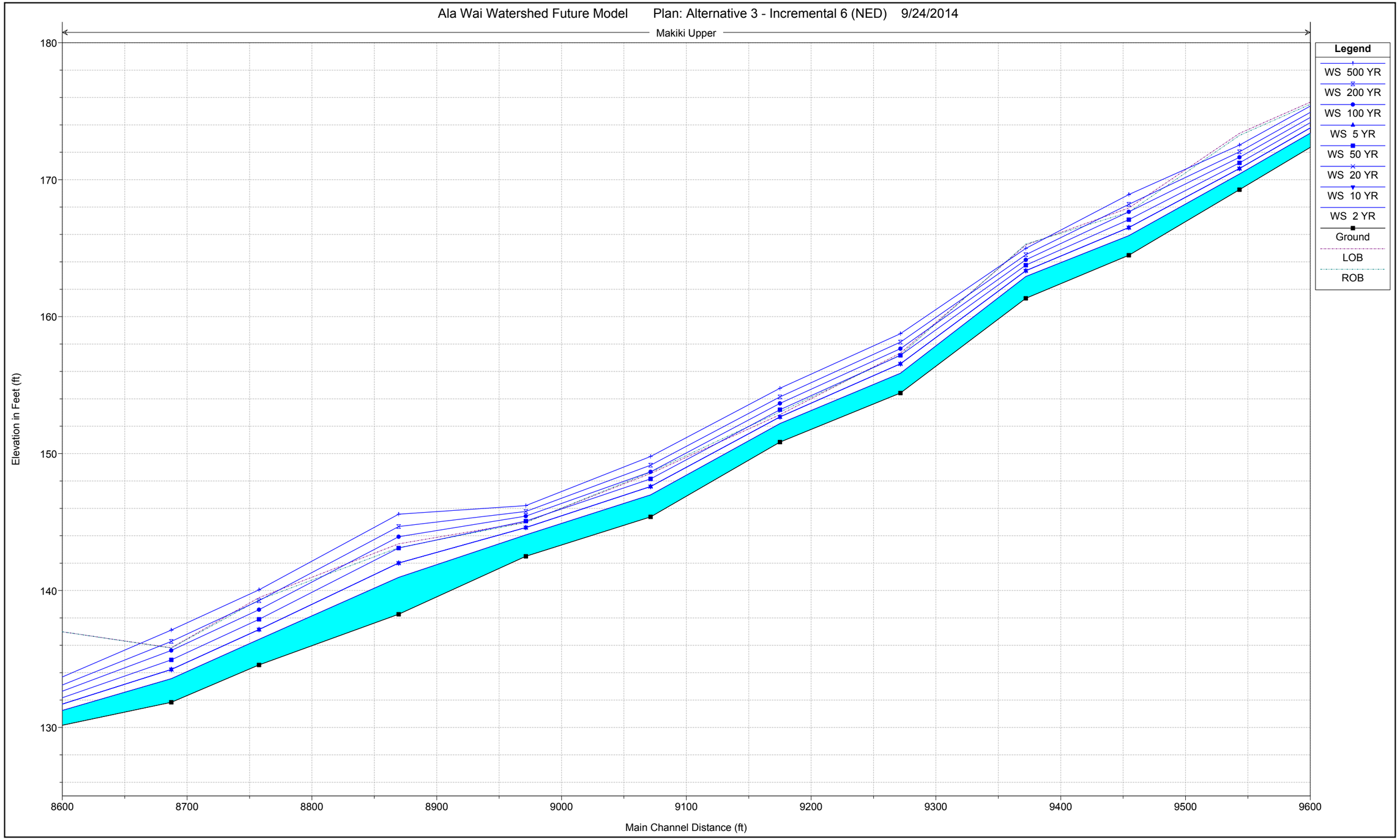

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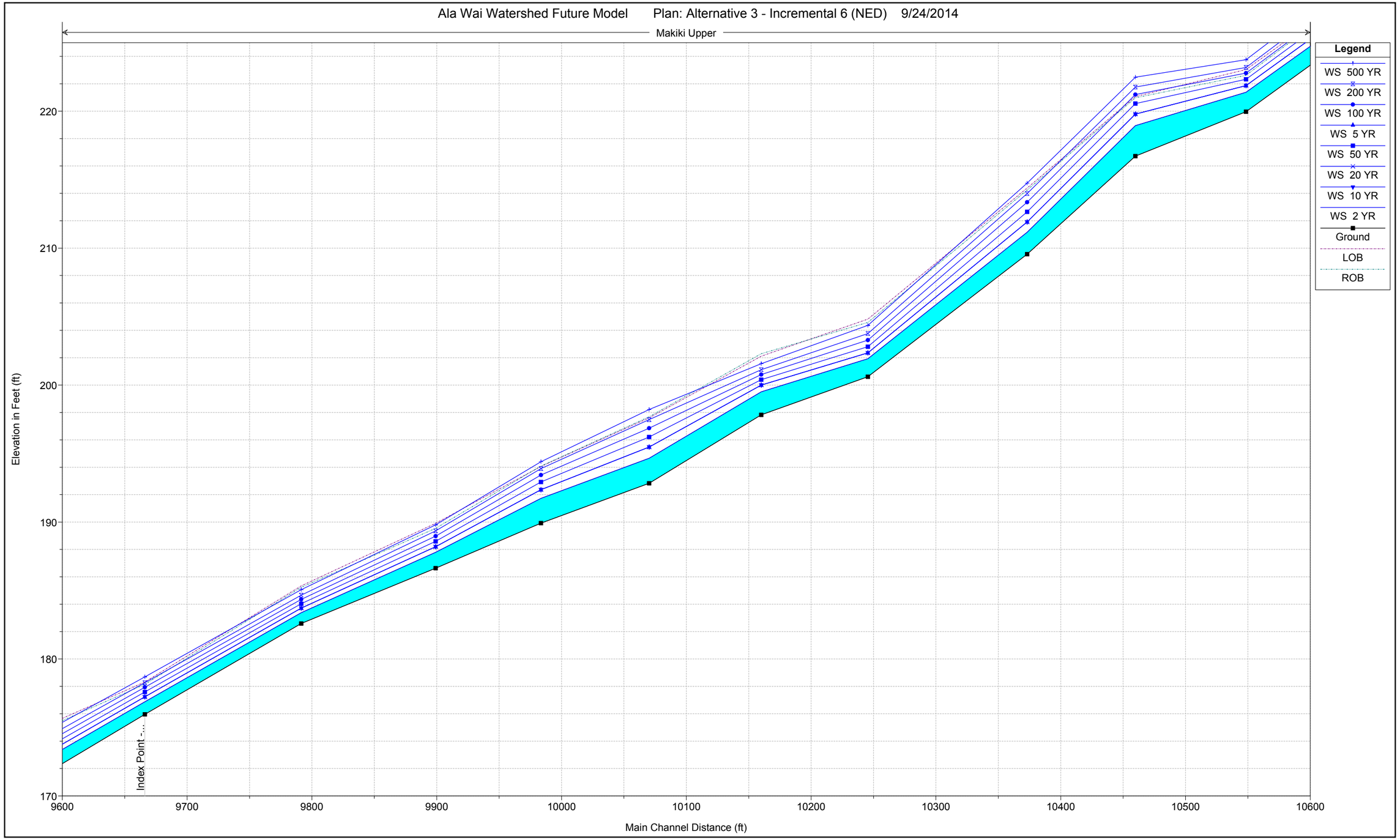

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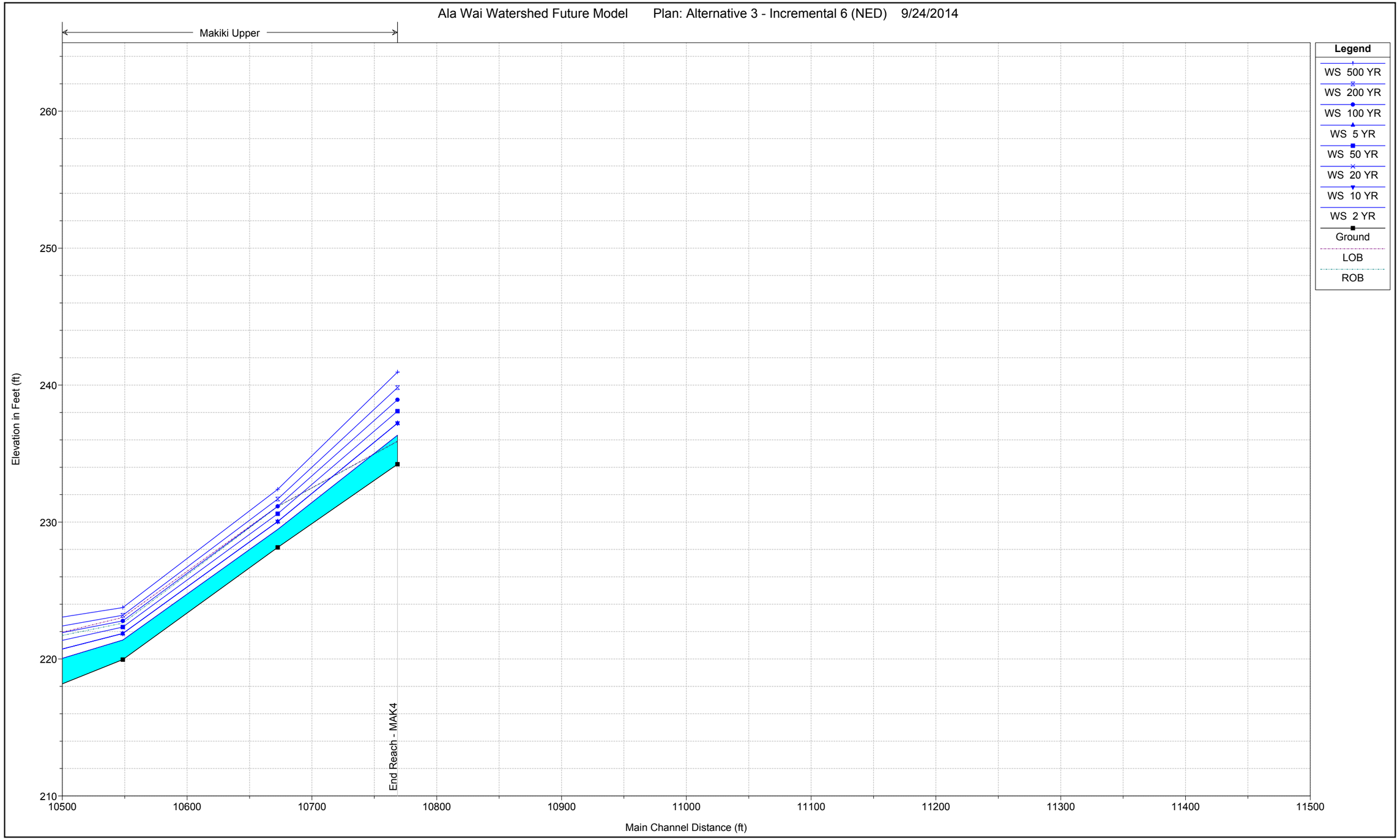

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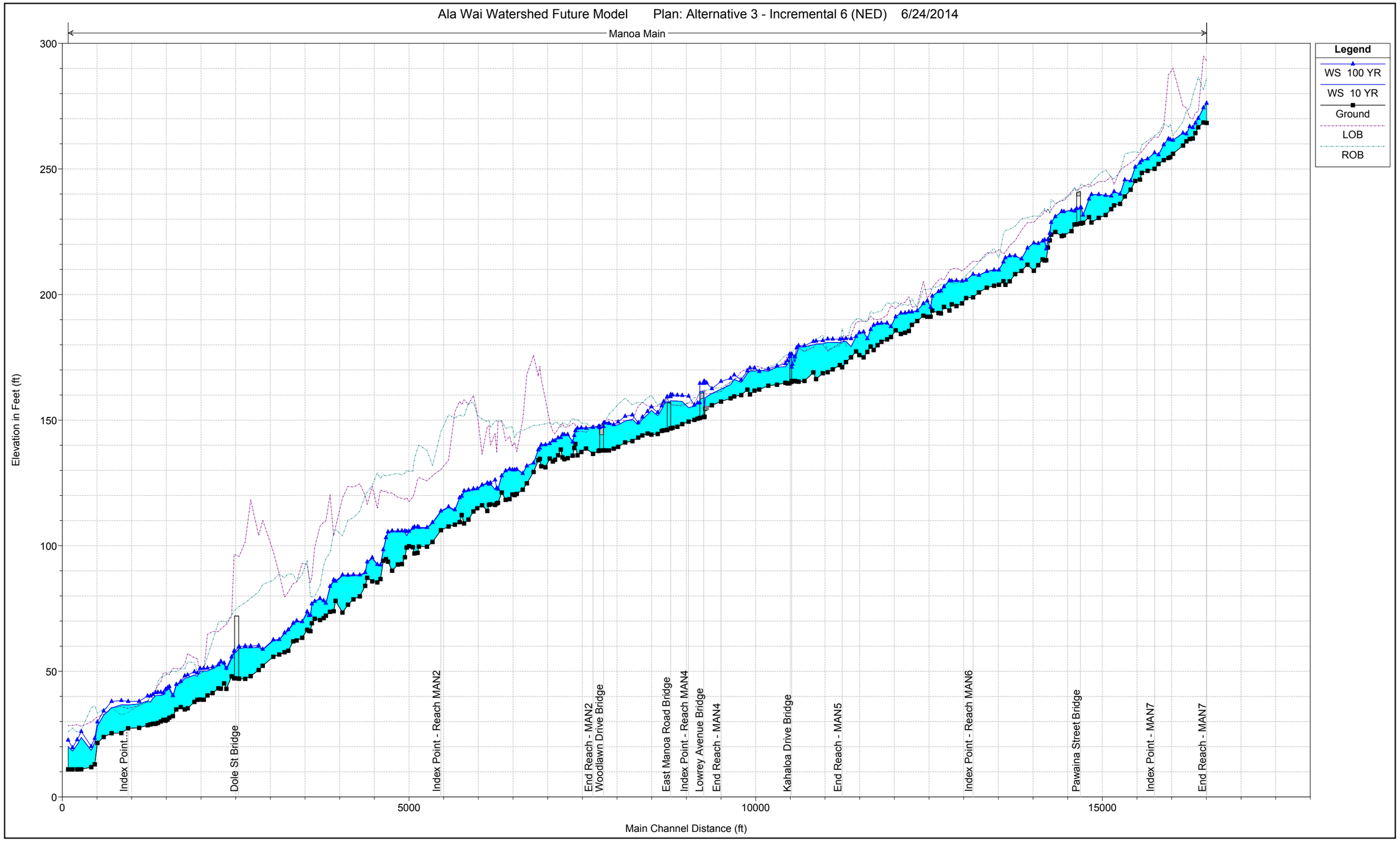

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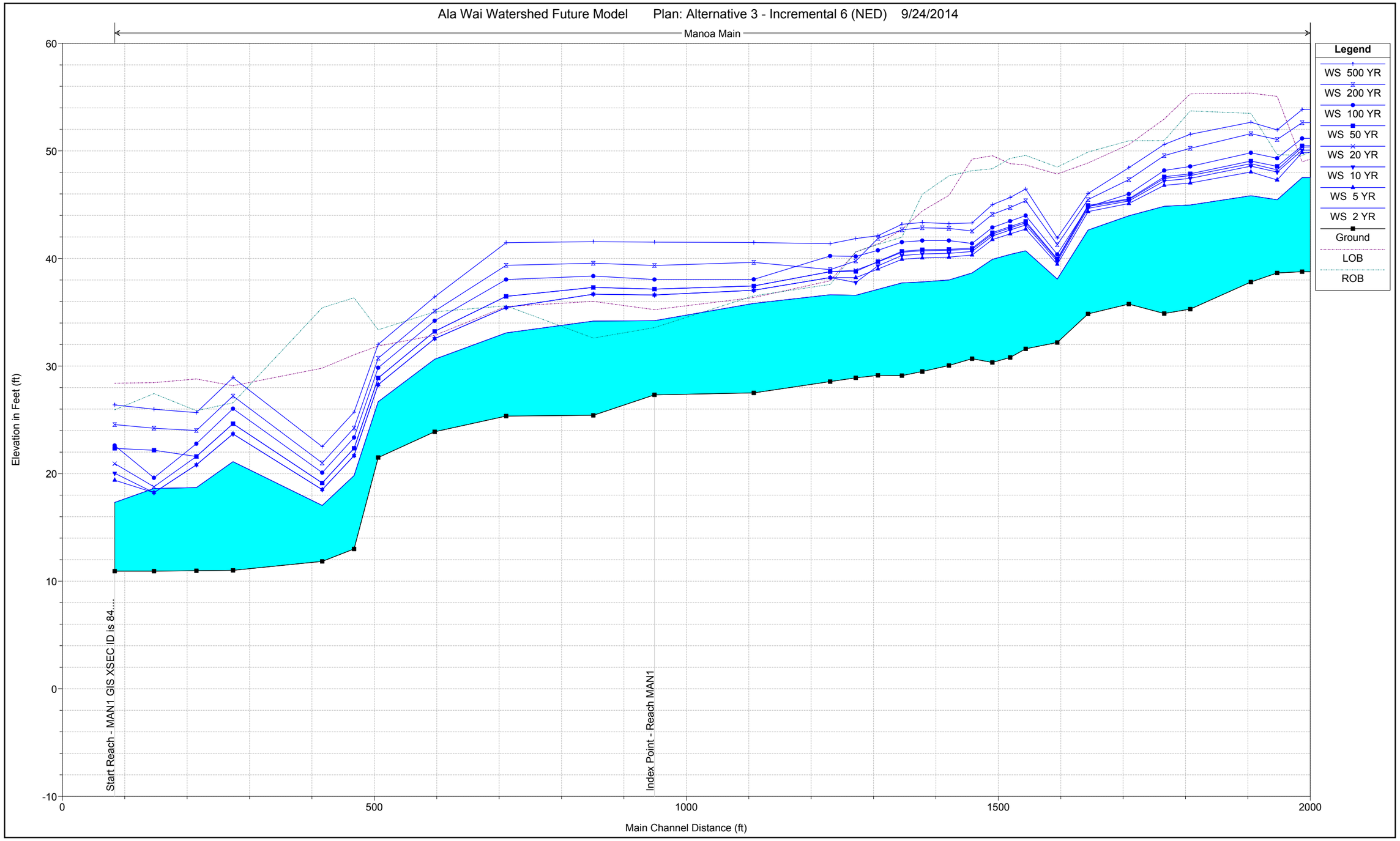

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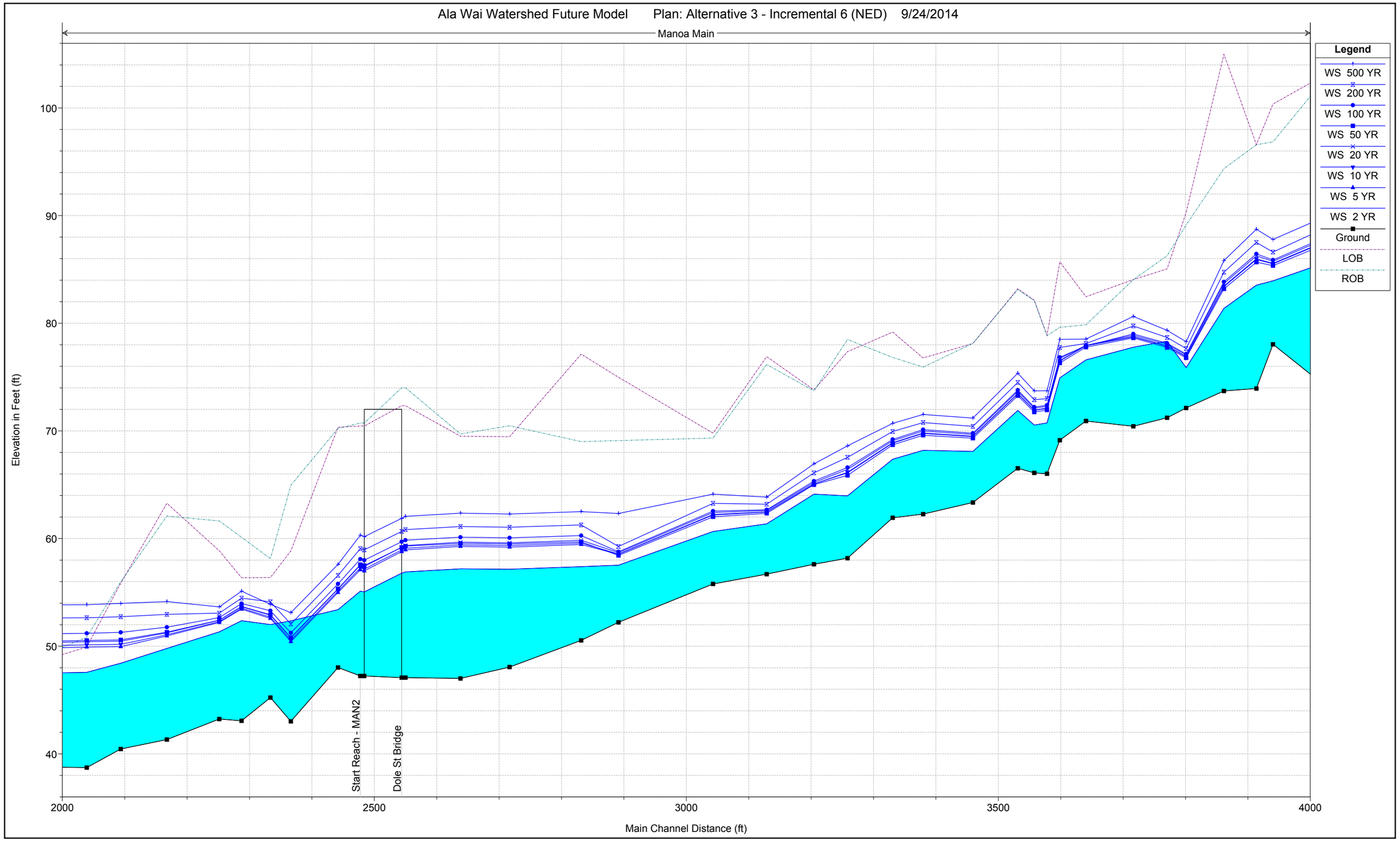

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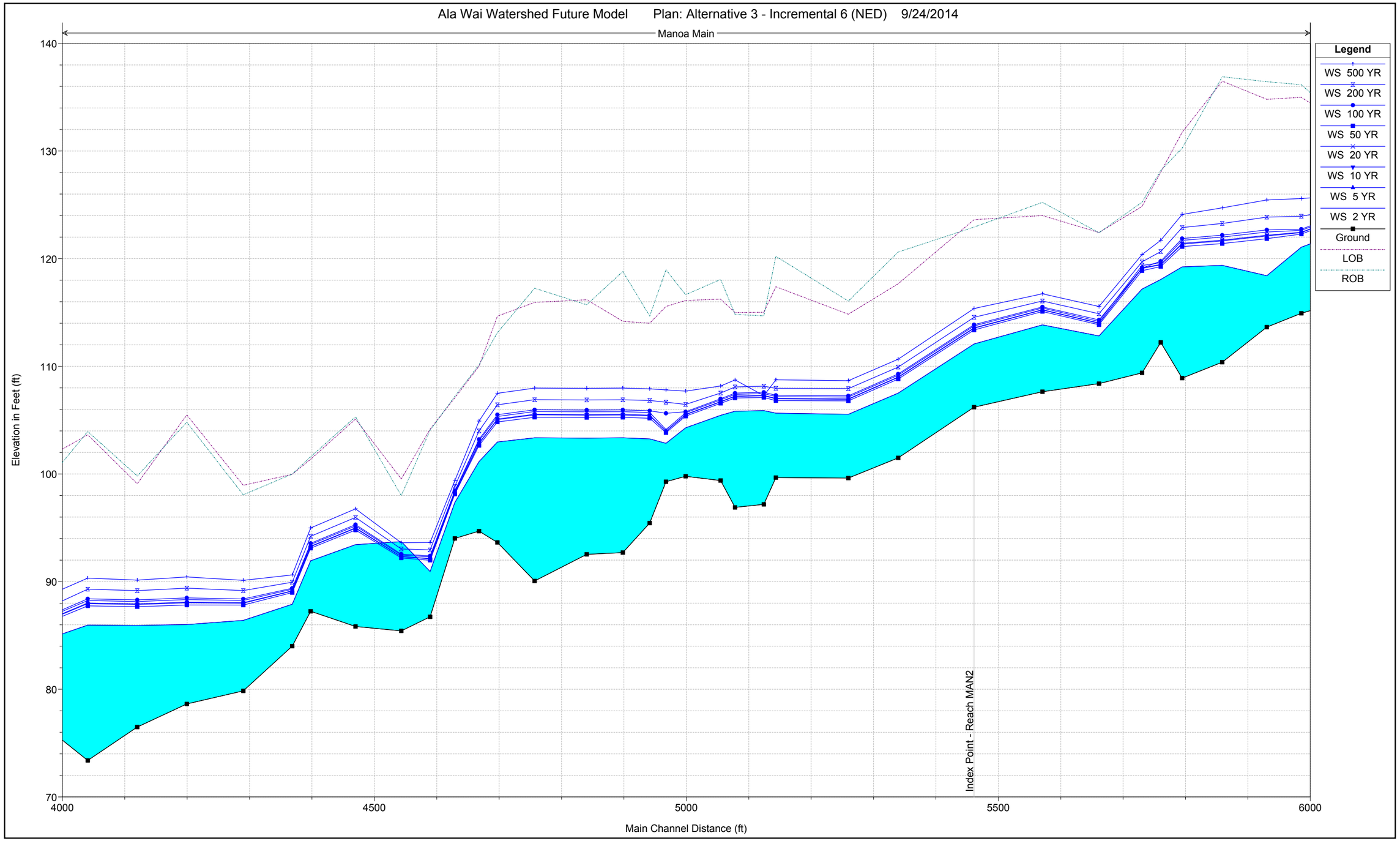

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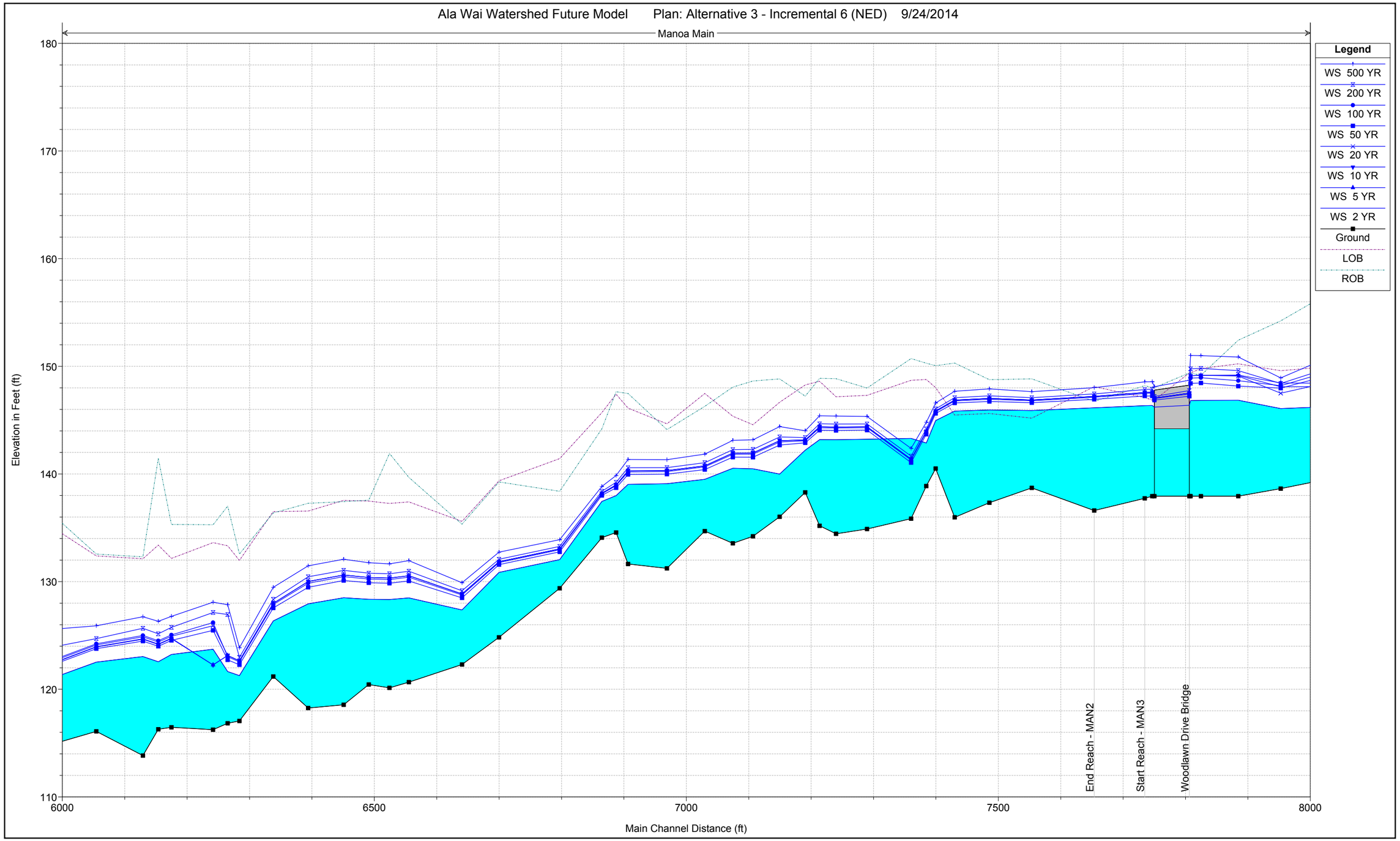

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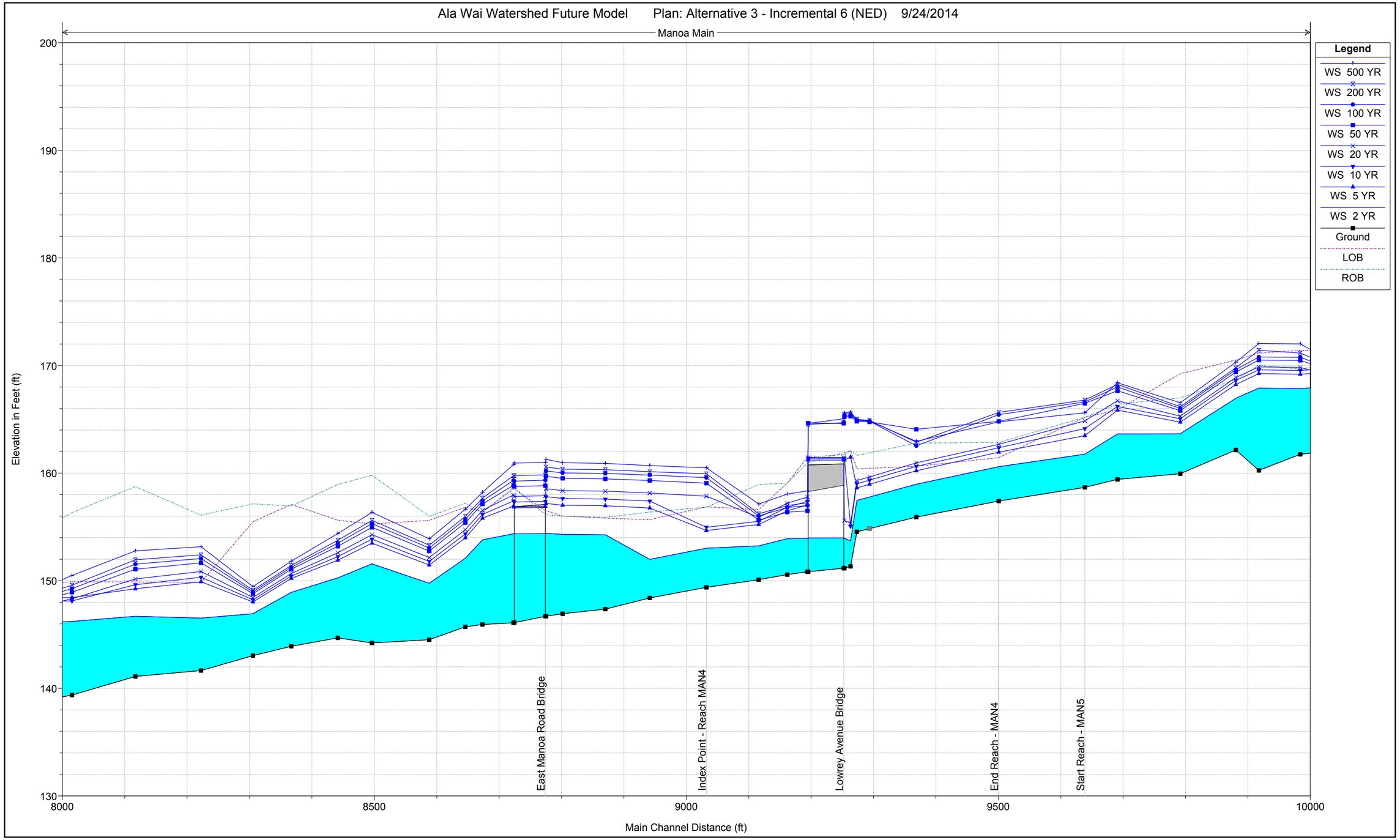

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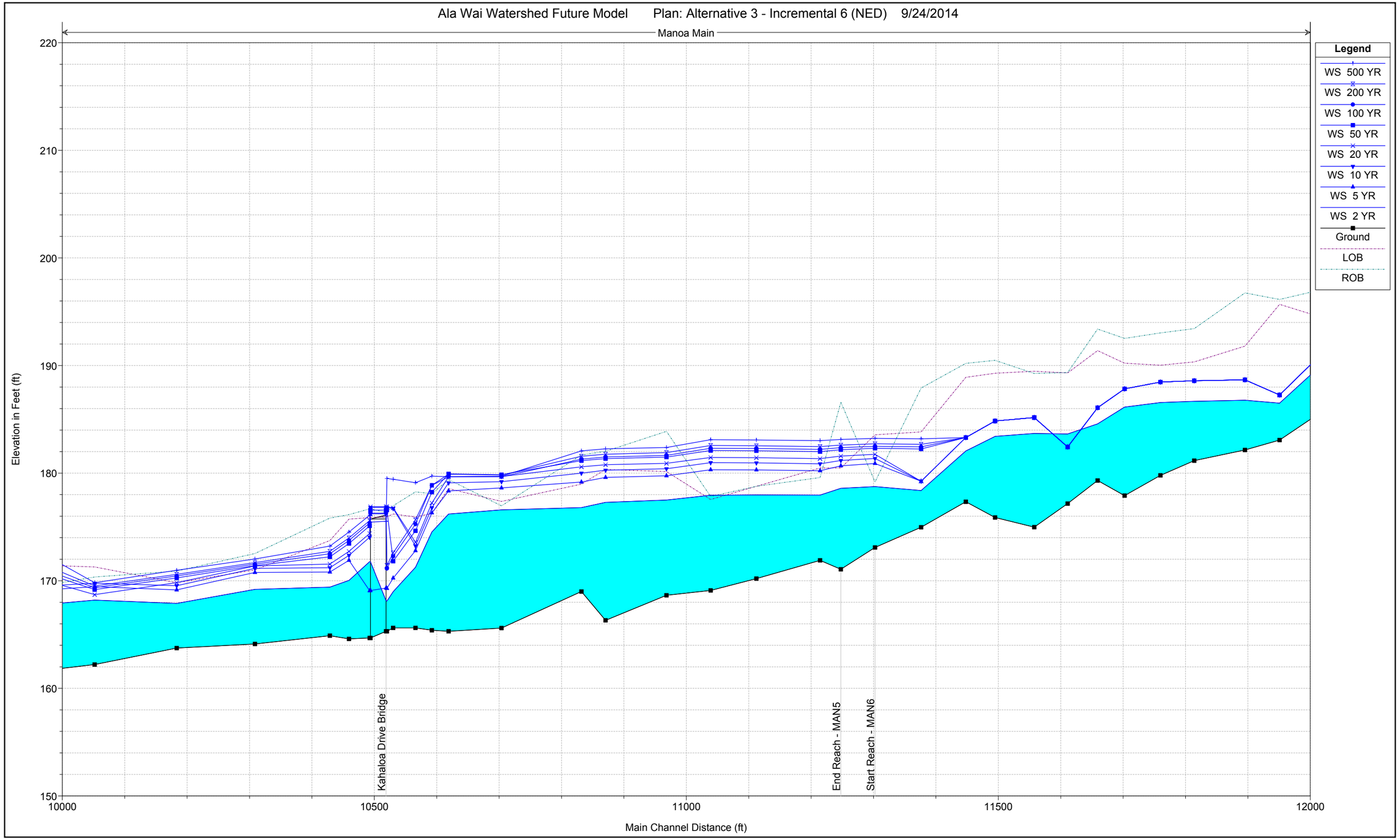

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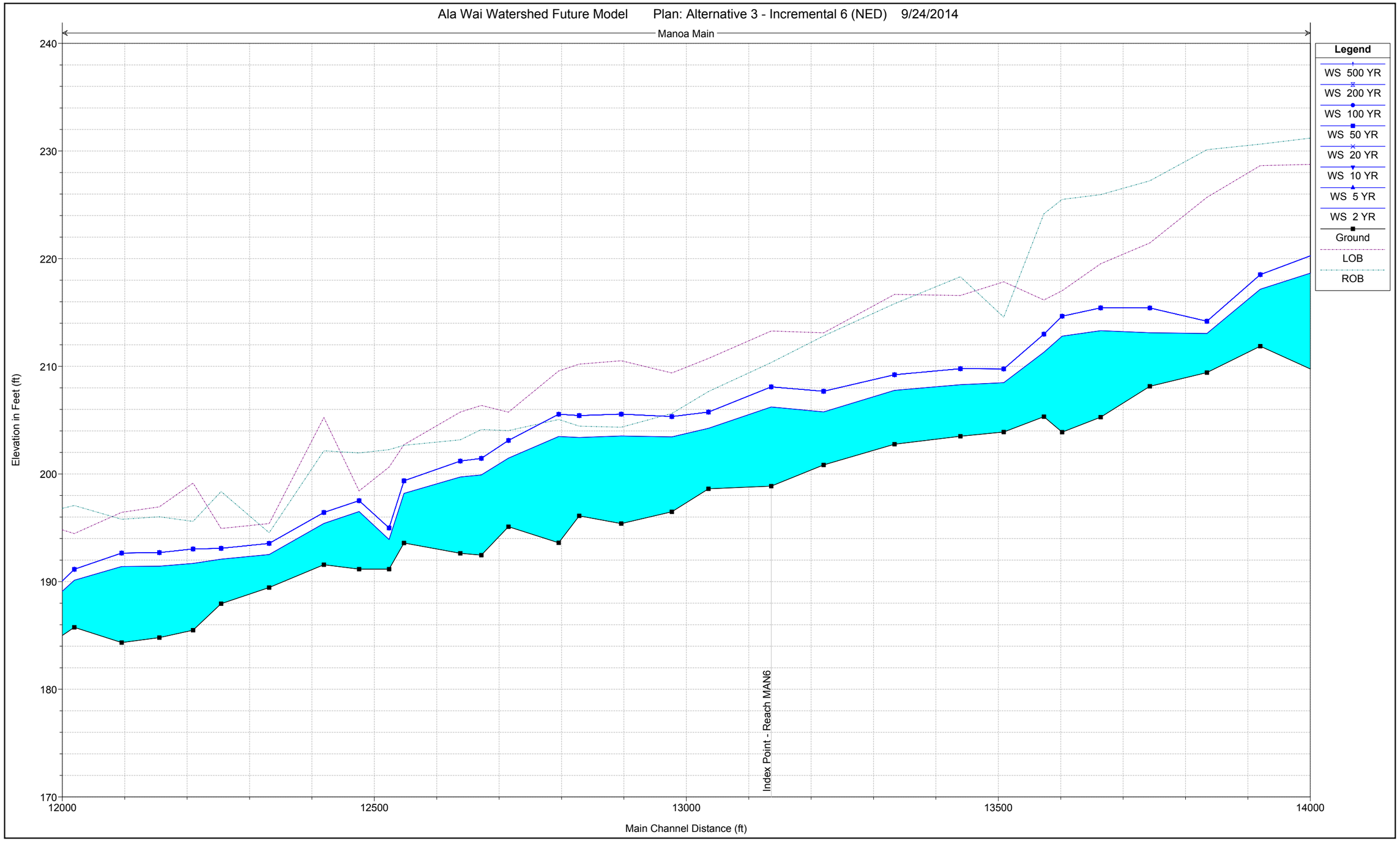
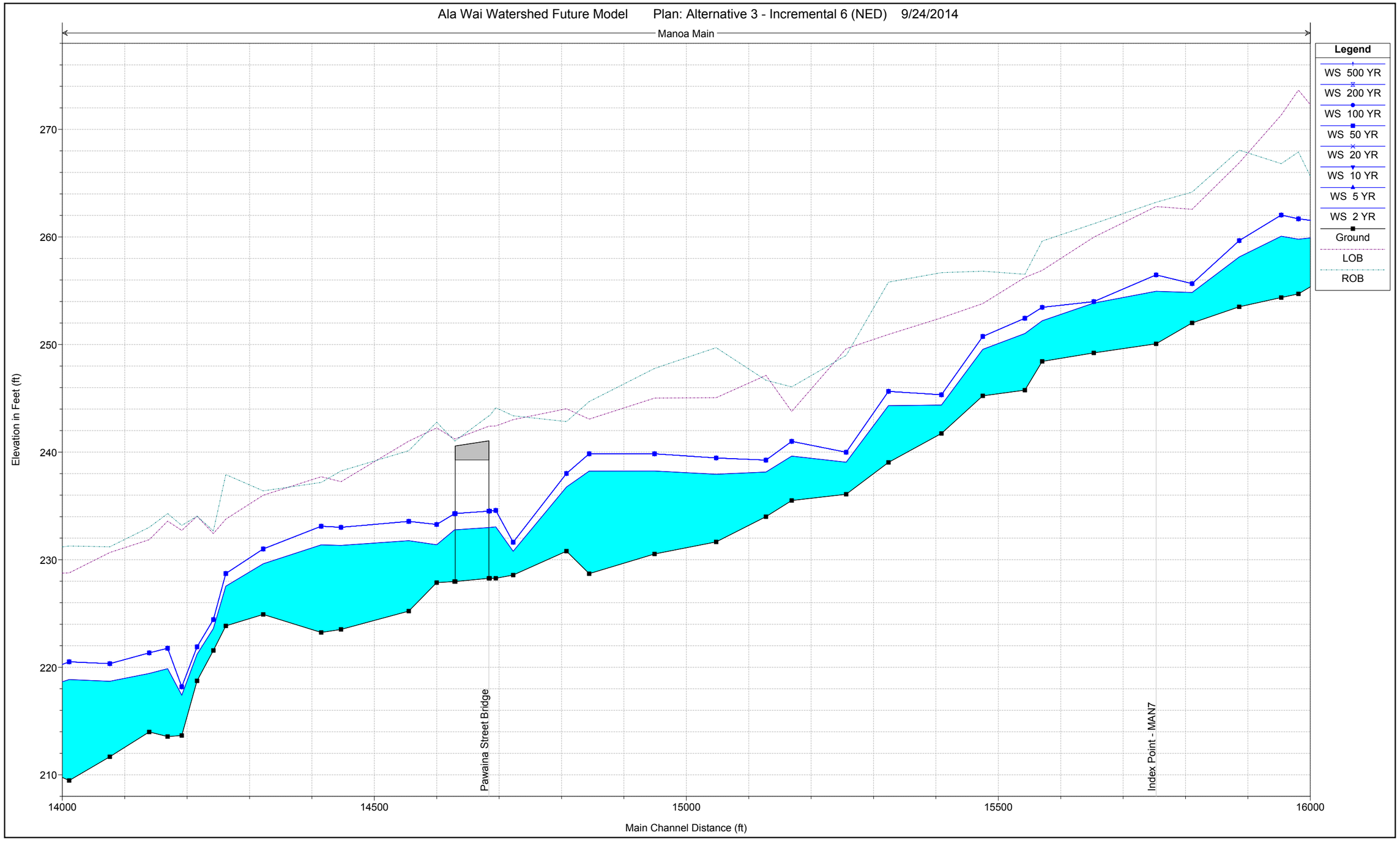


Plate 4 - Alternative 3 Hydraulic Profiles



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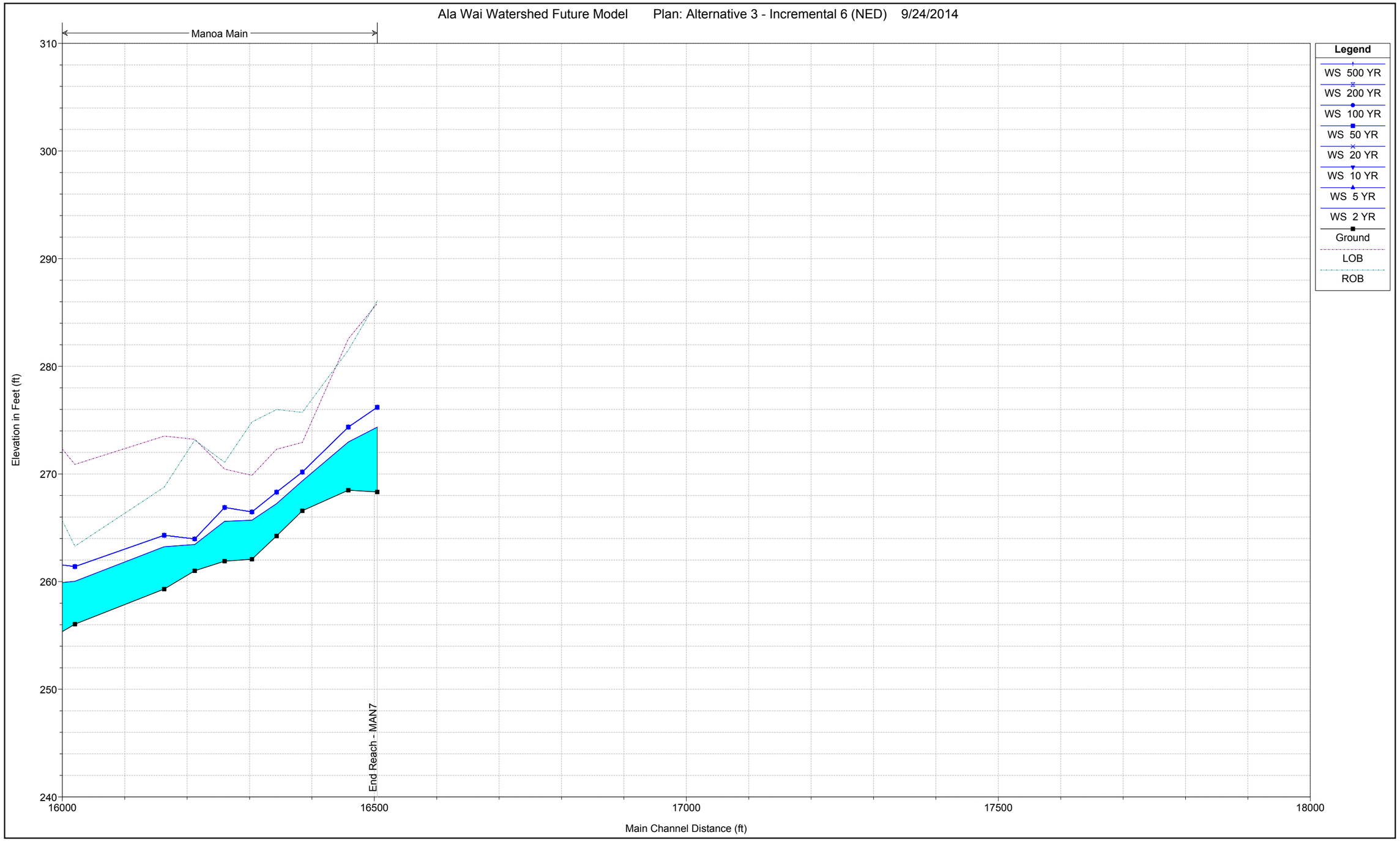

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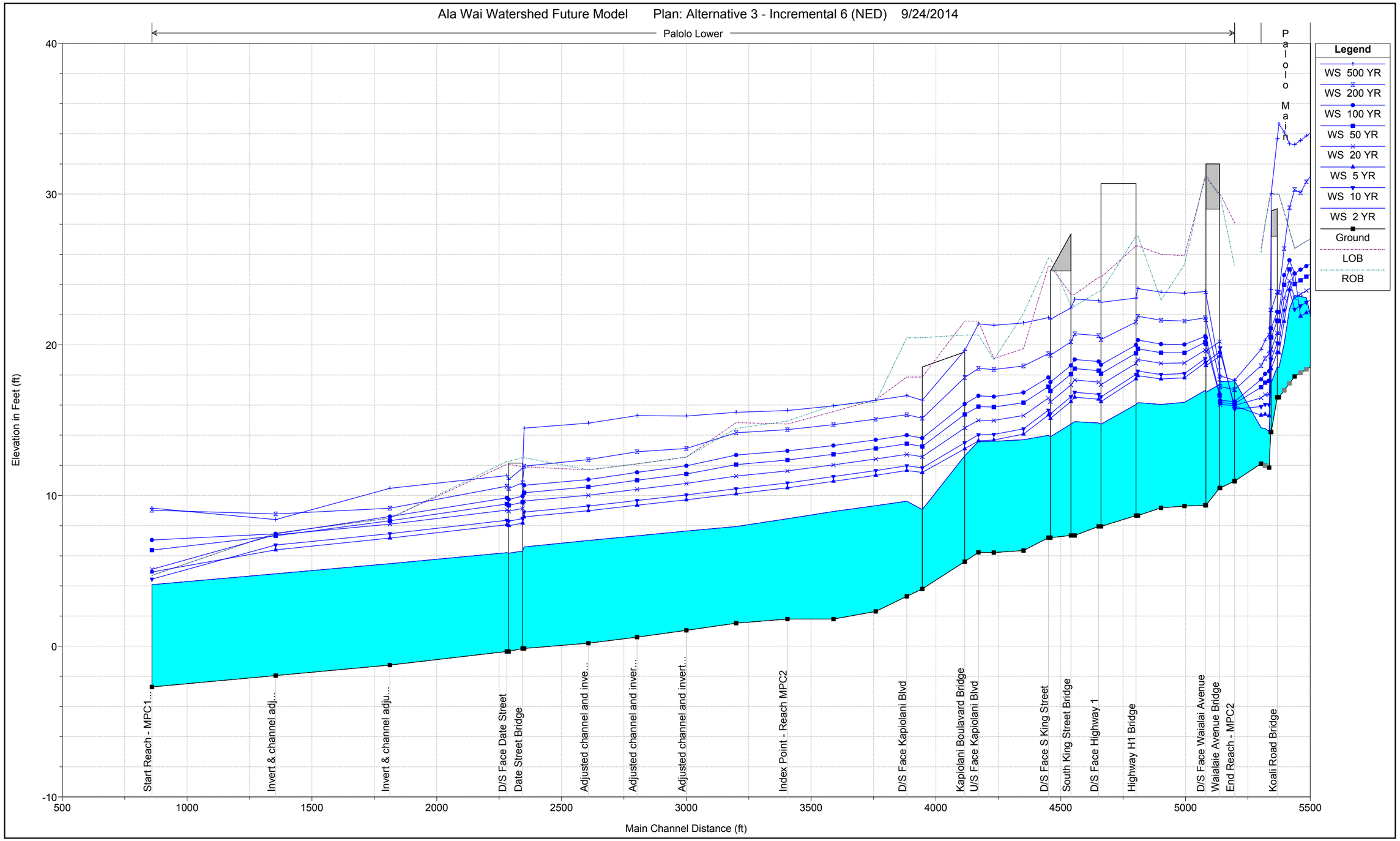

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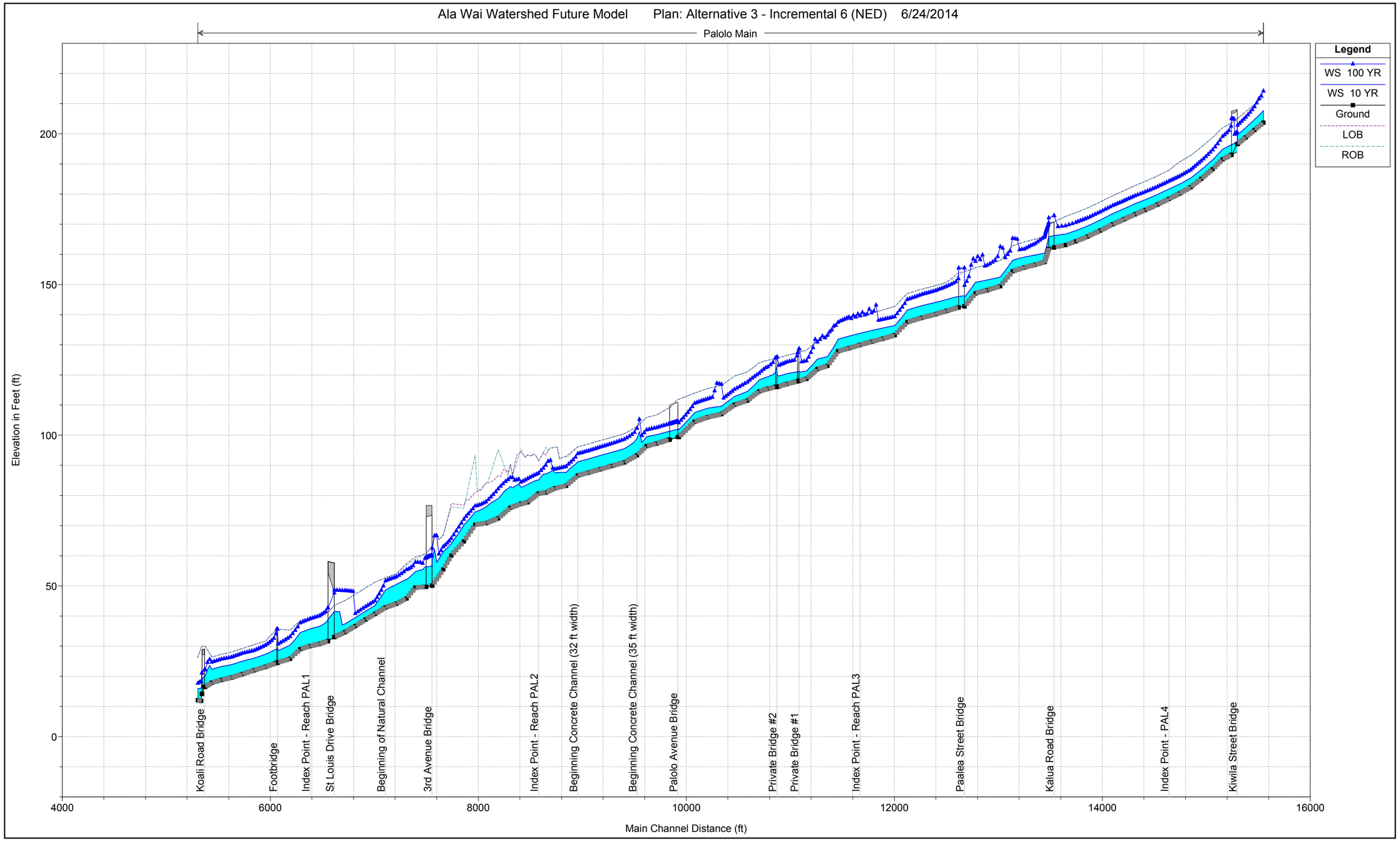

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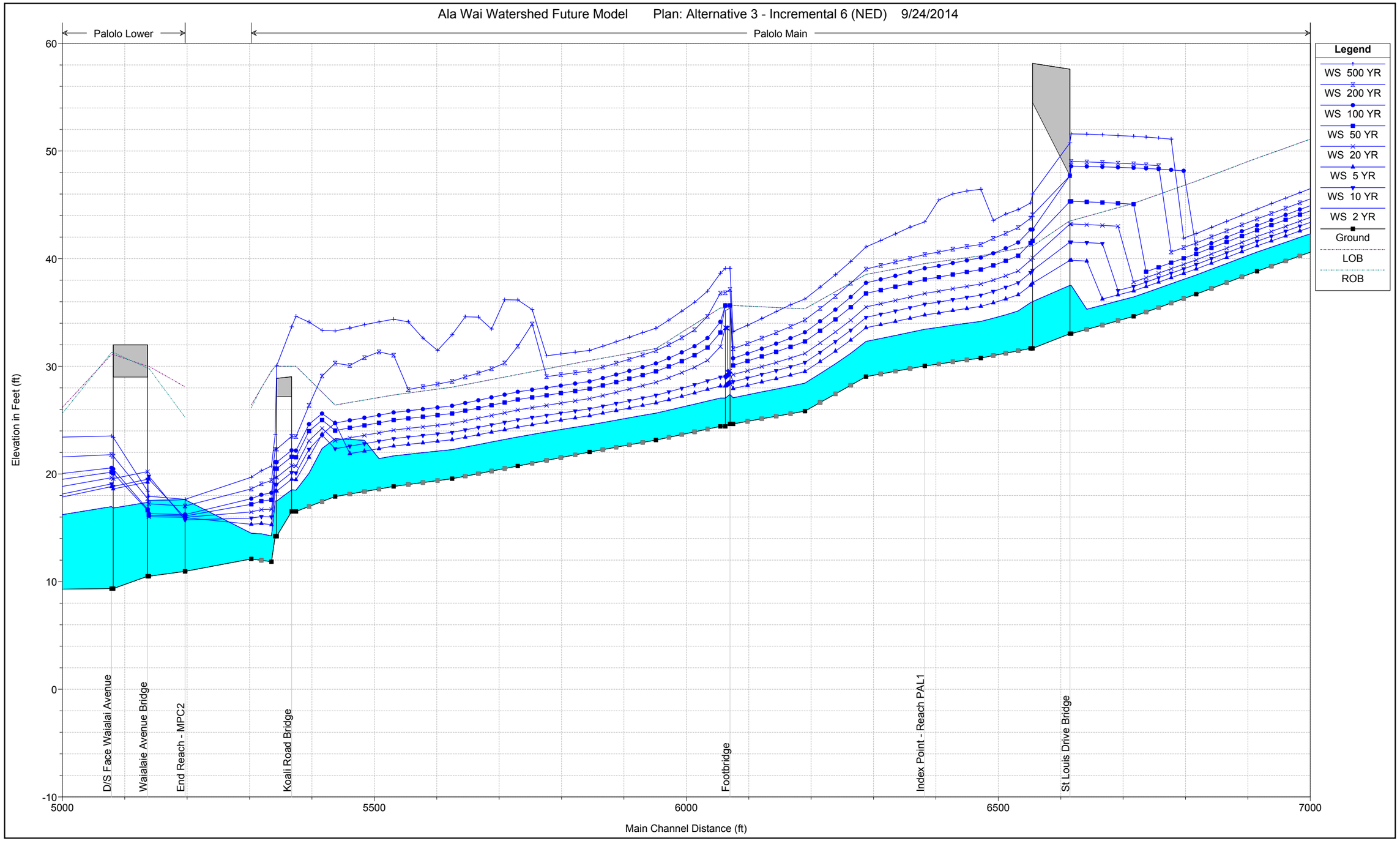

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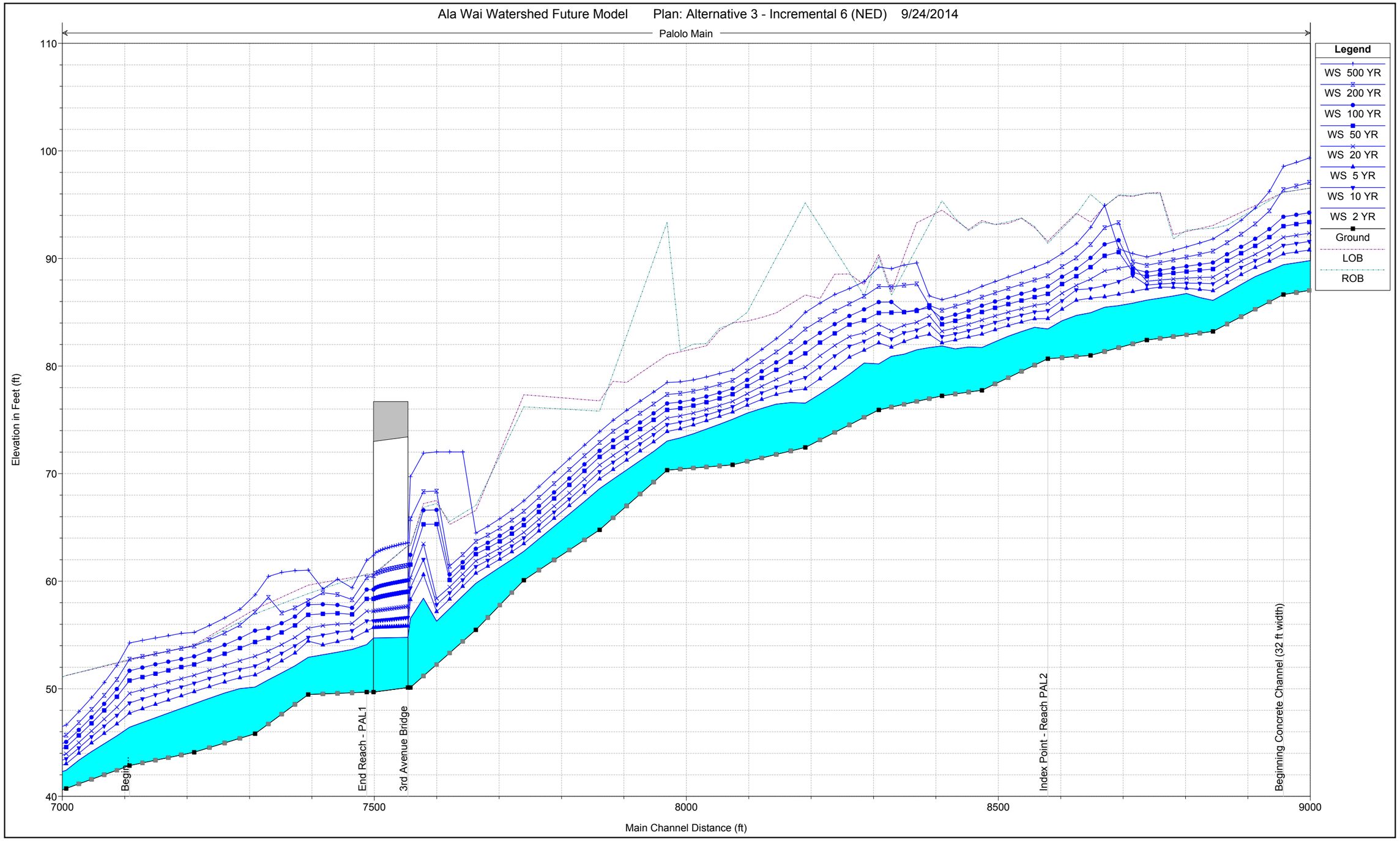

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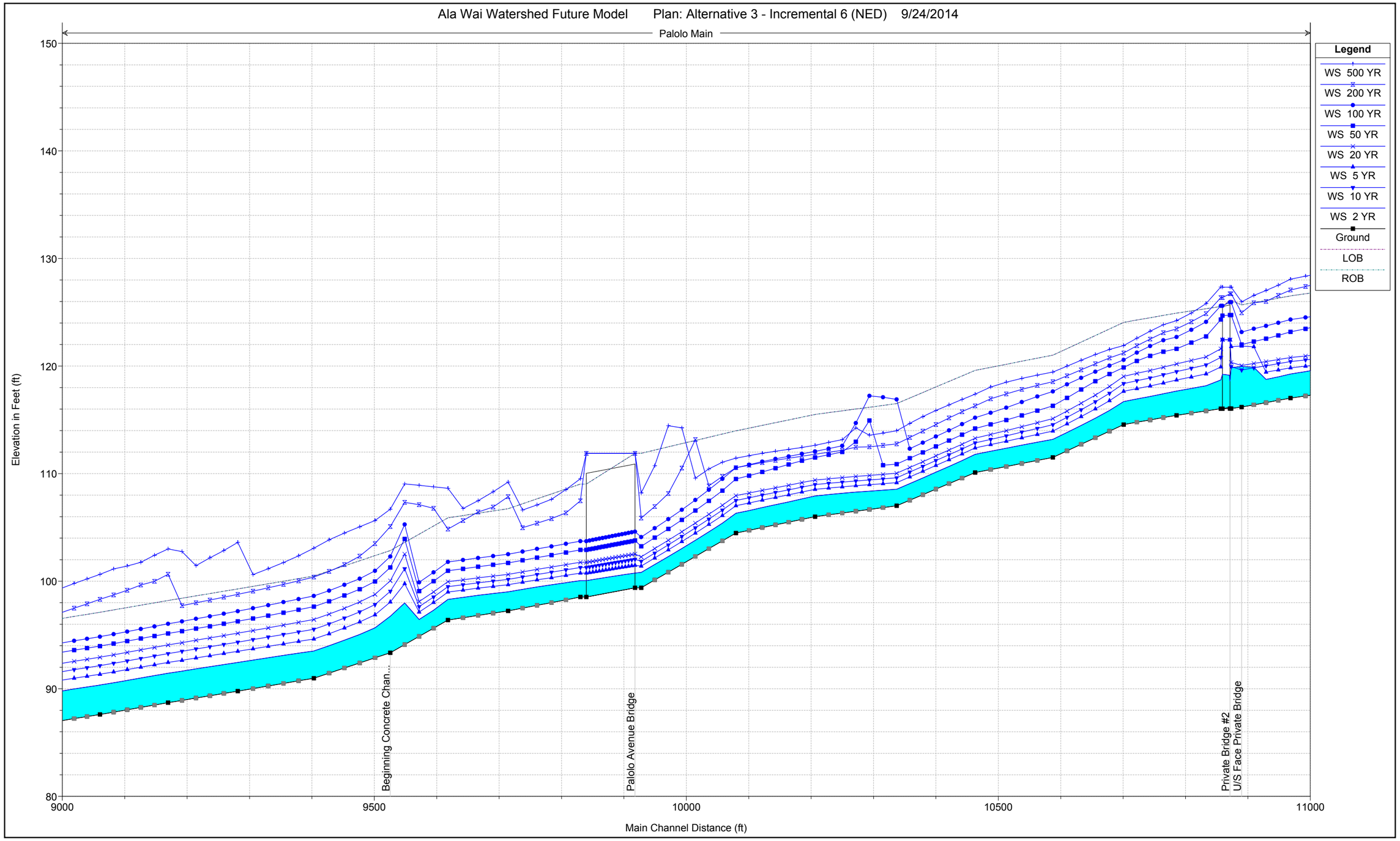

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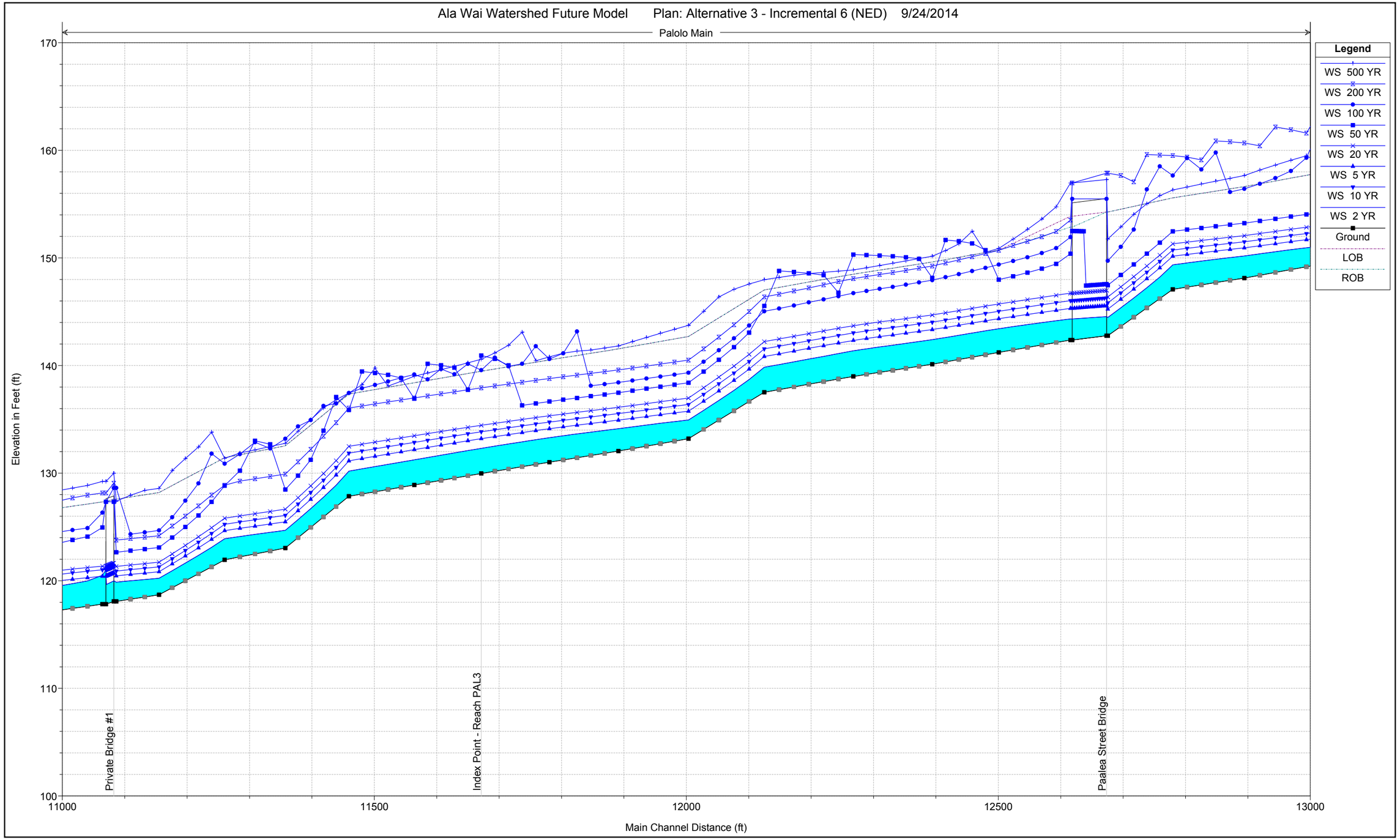

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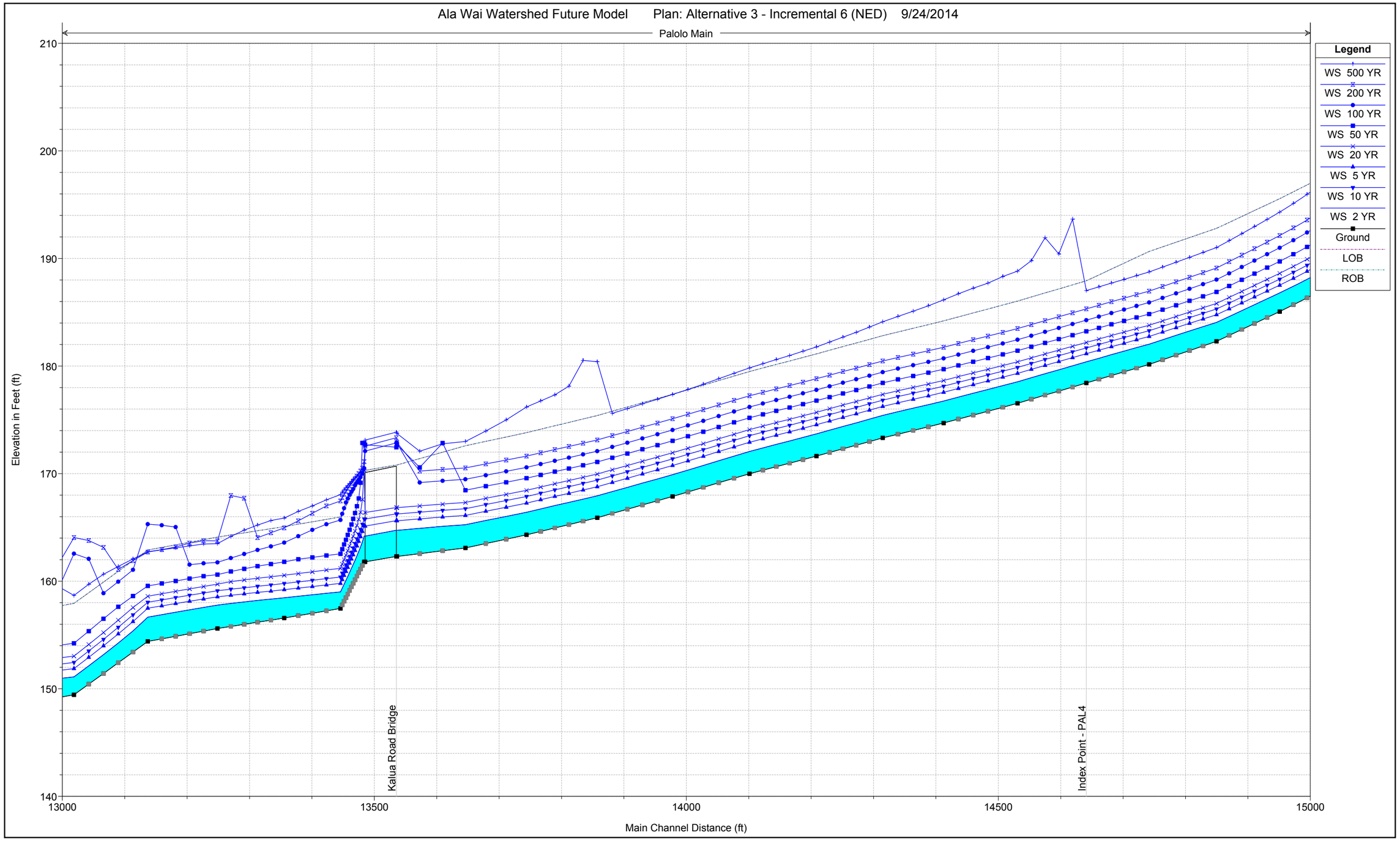

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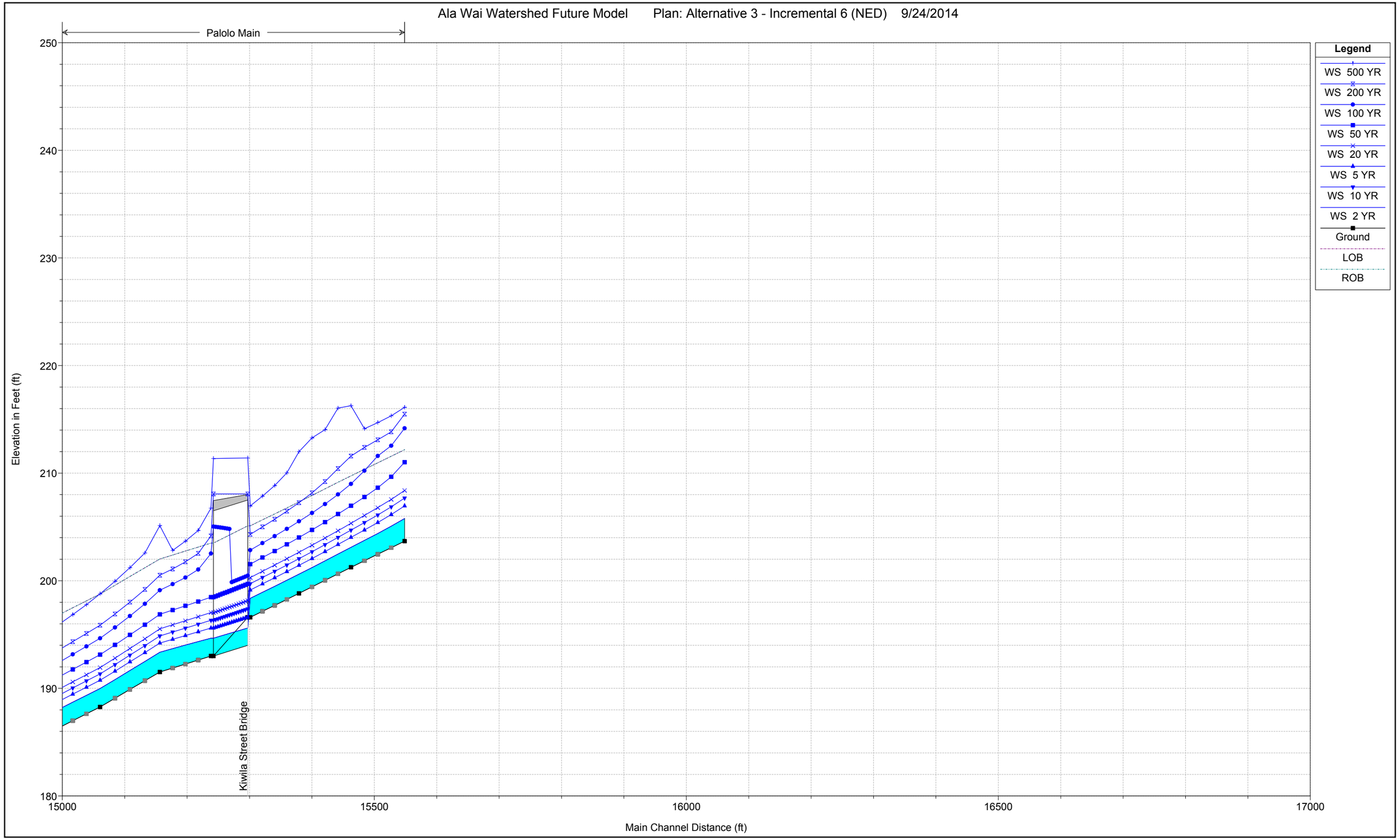

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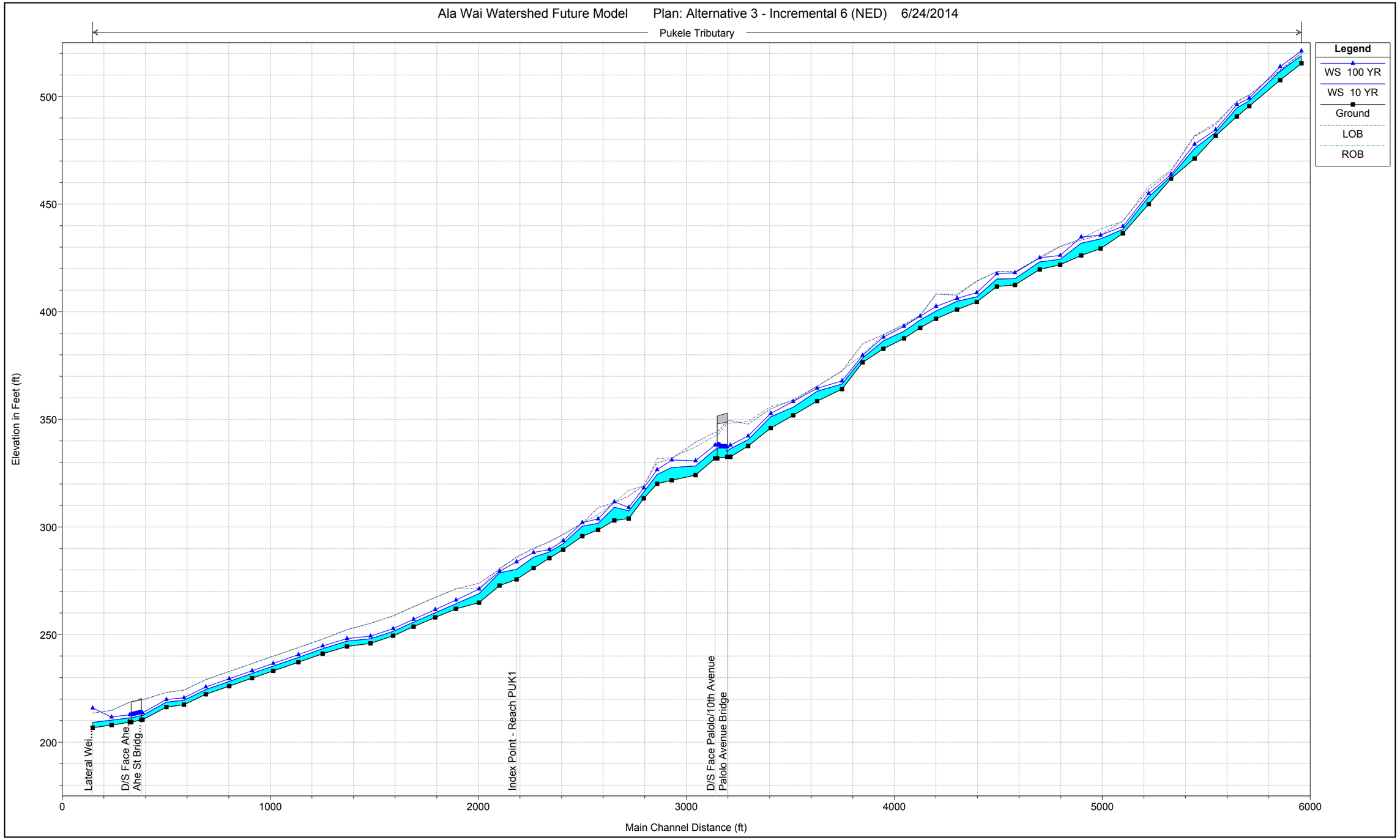

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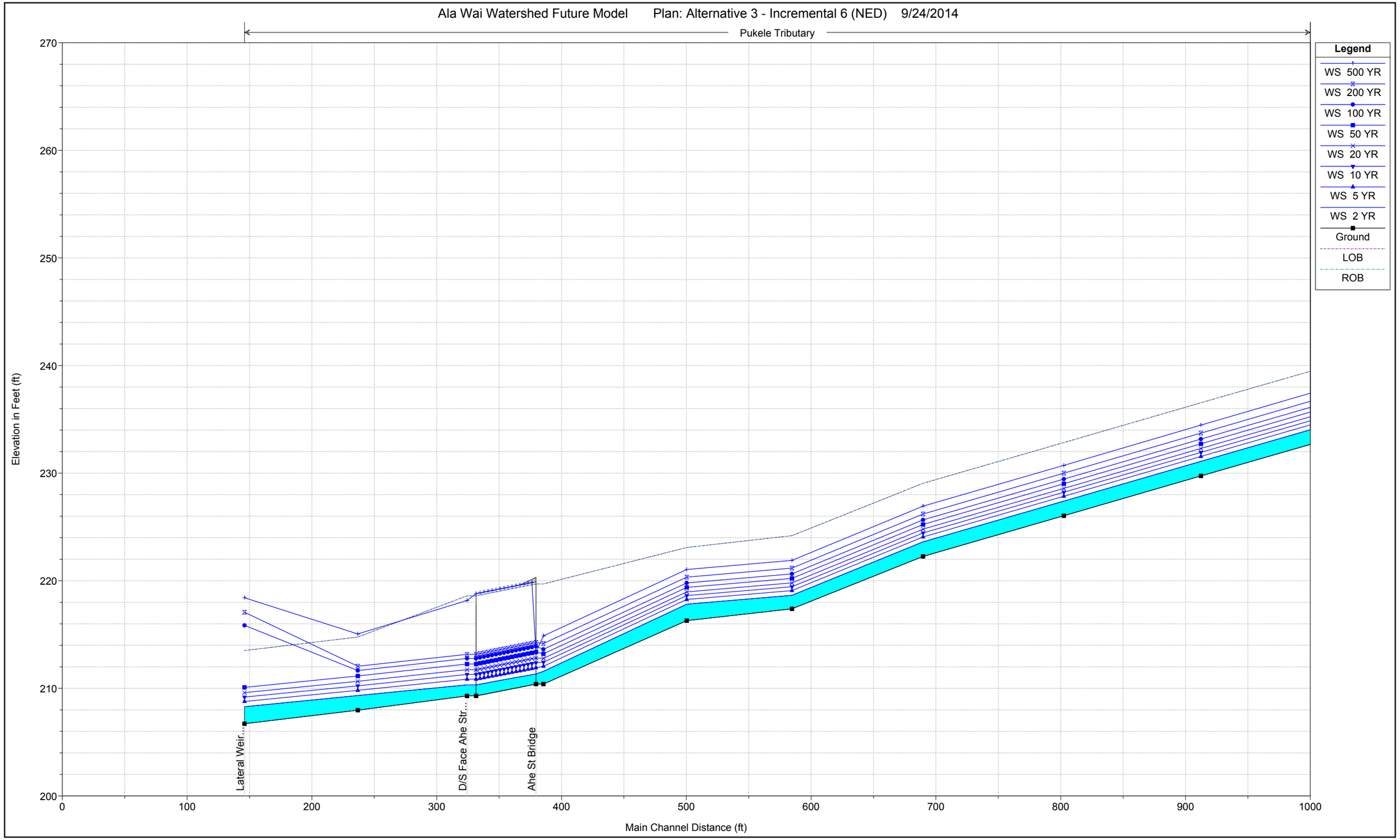

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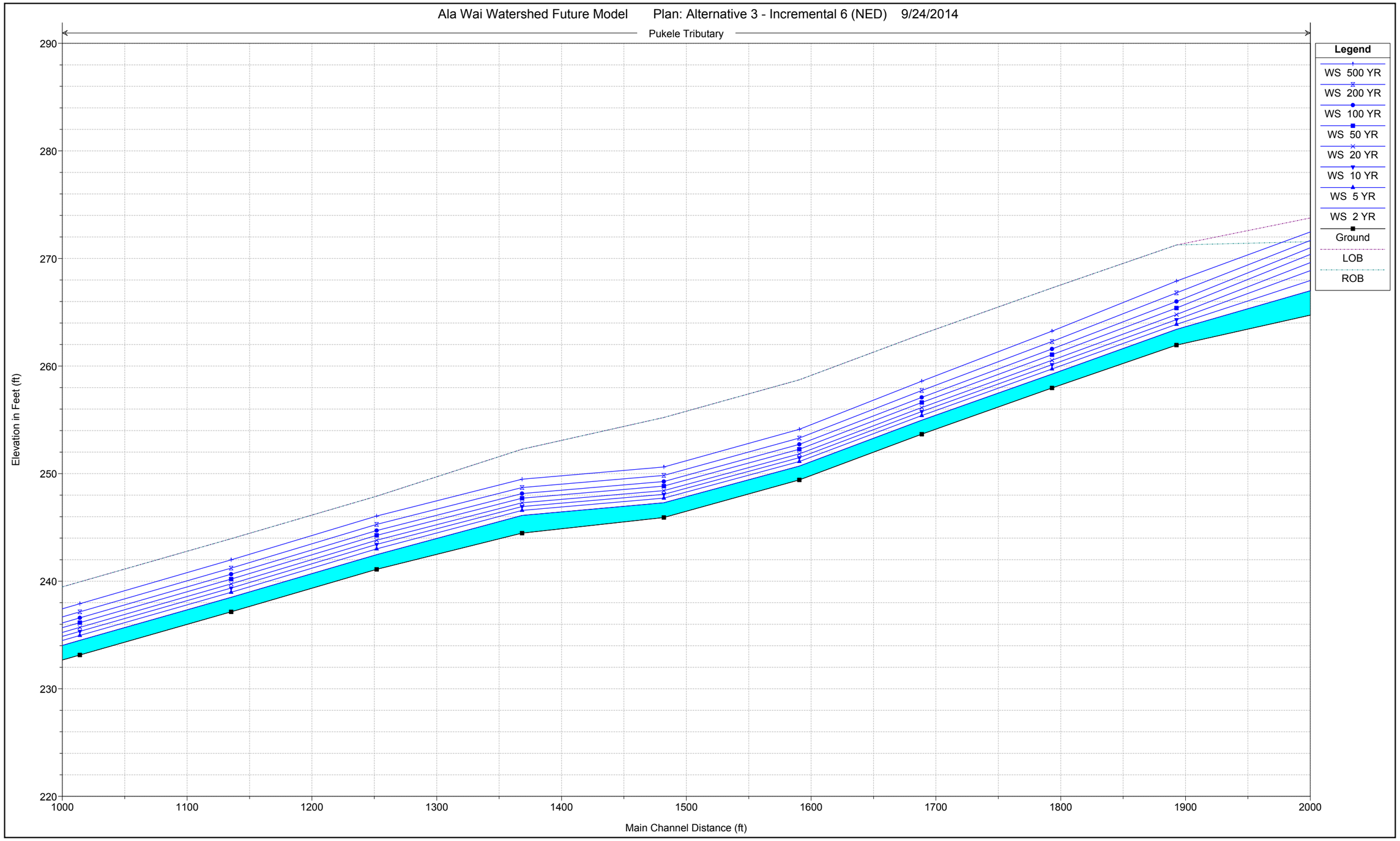

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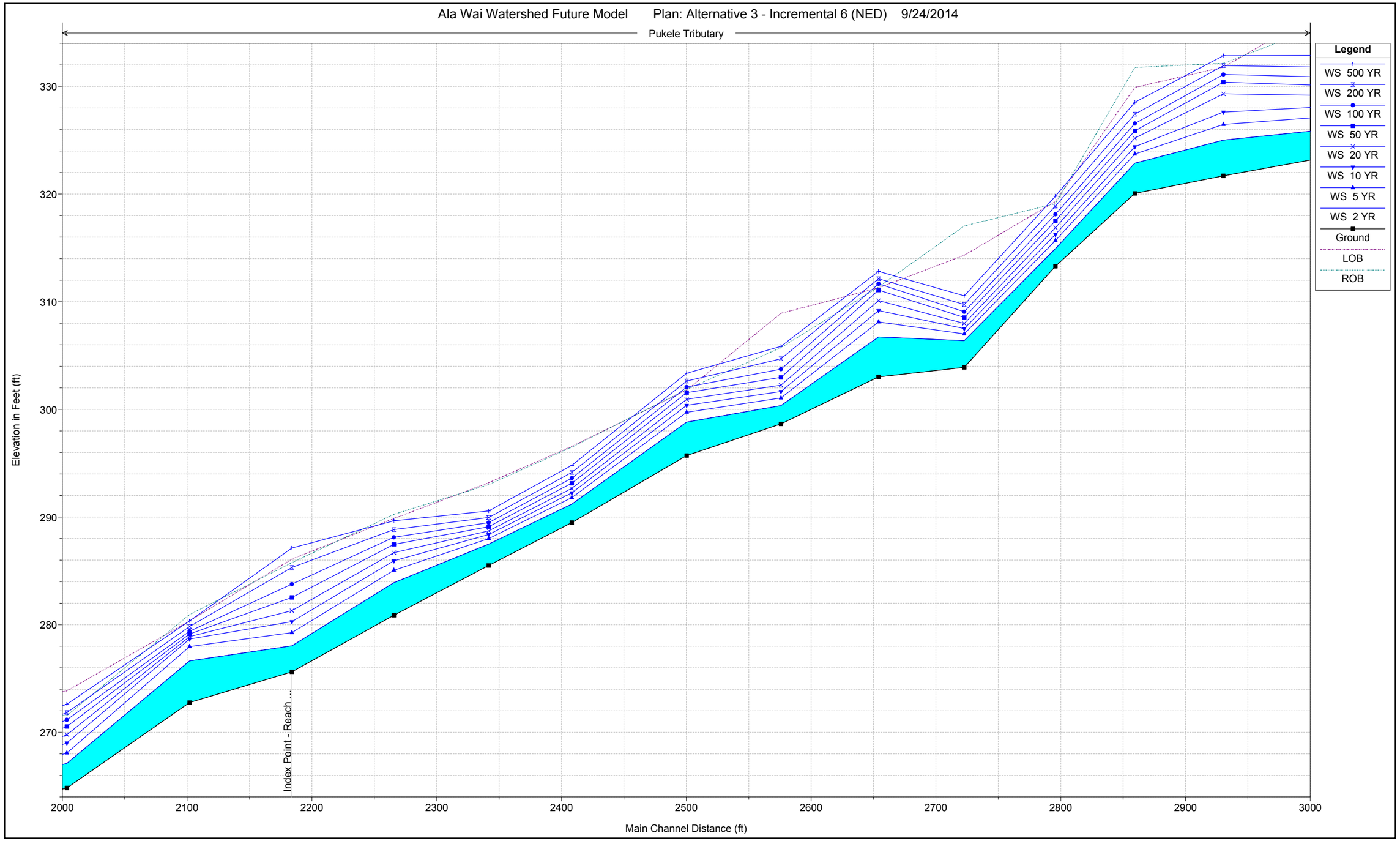

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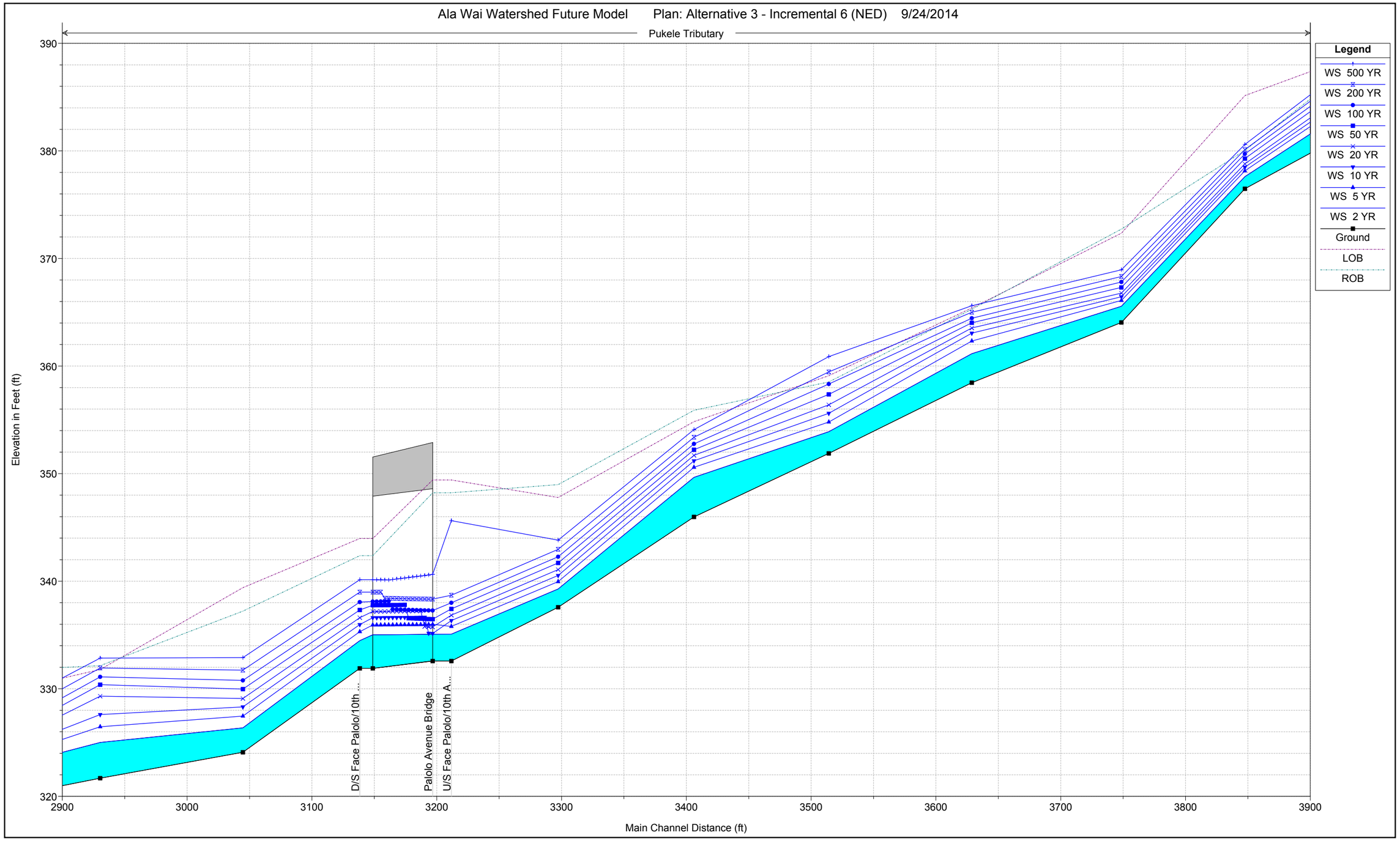

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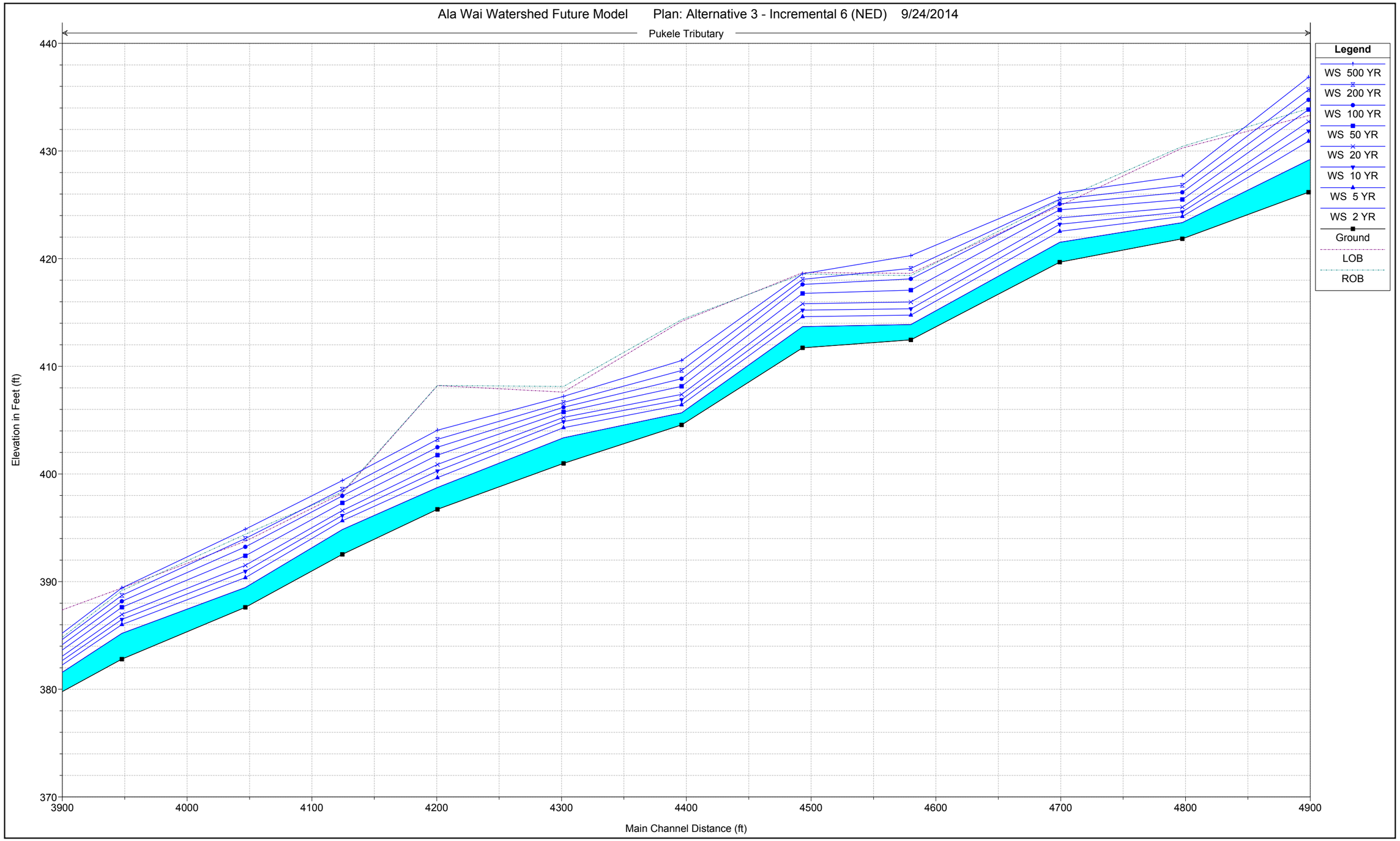

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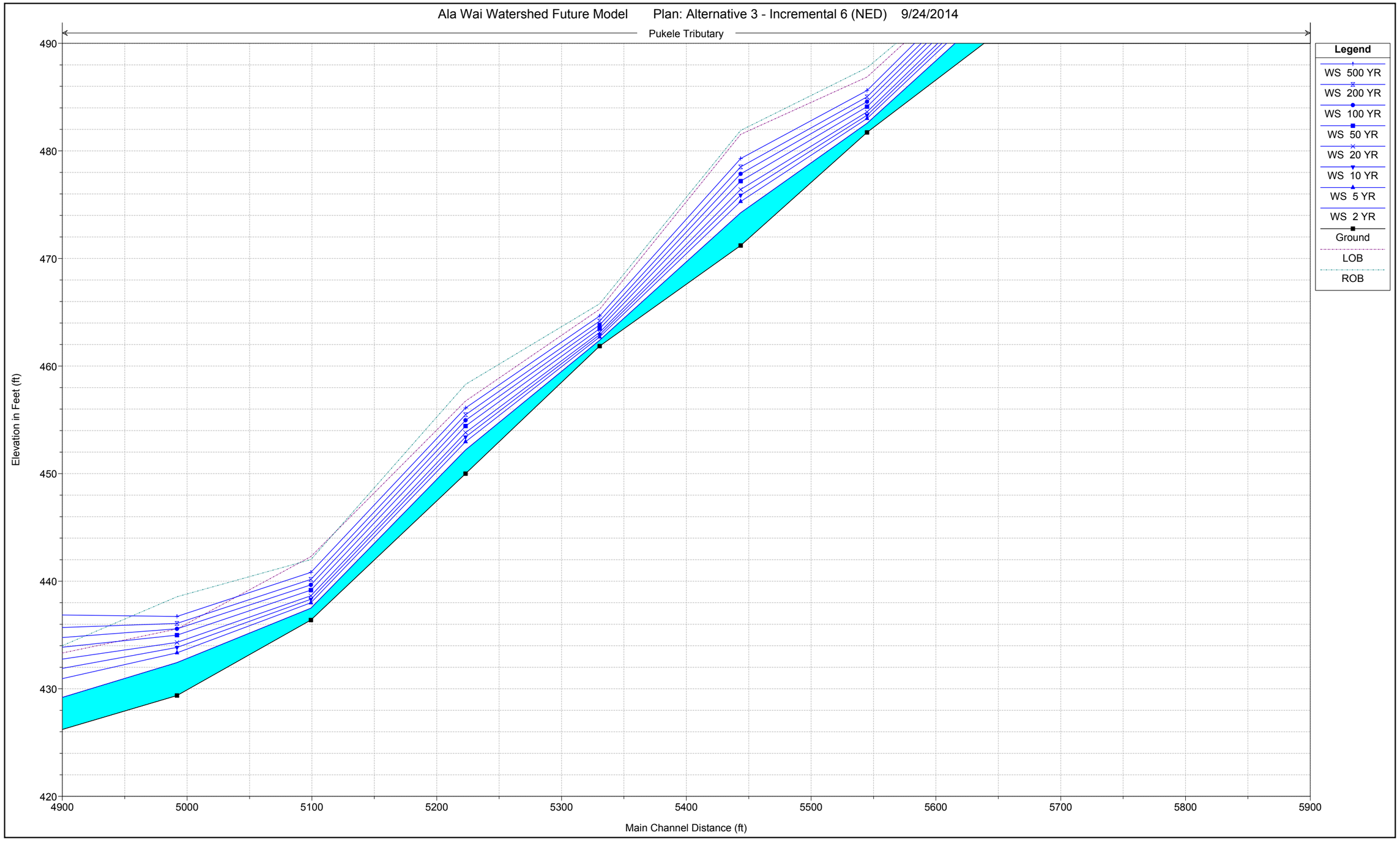

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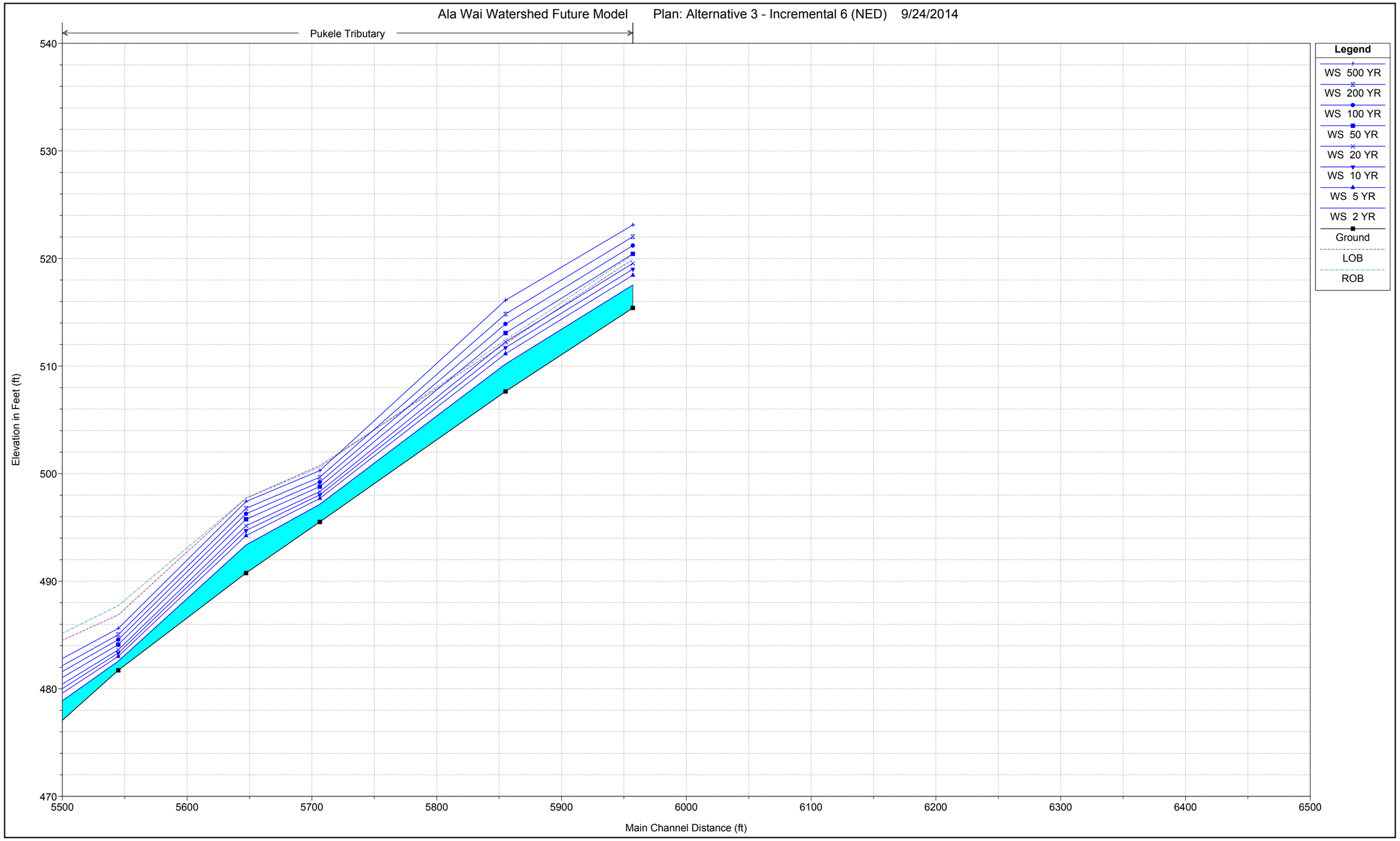

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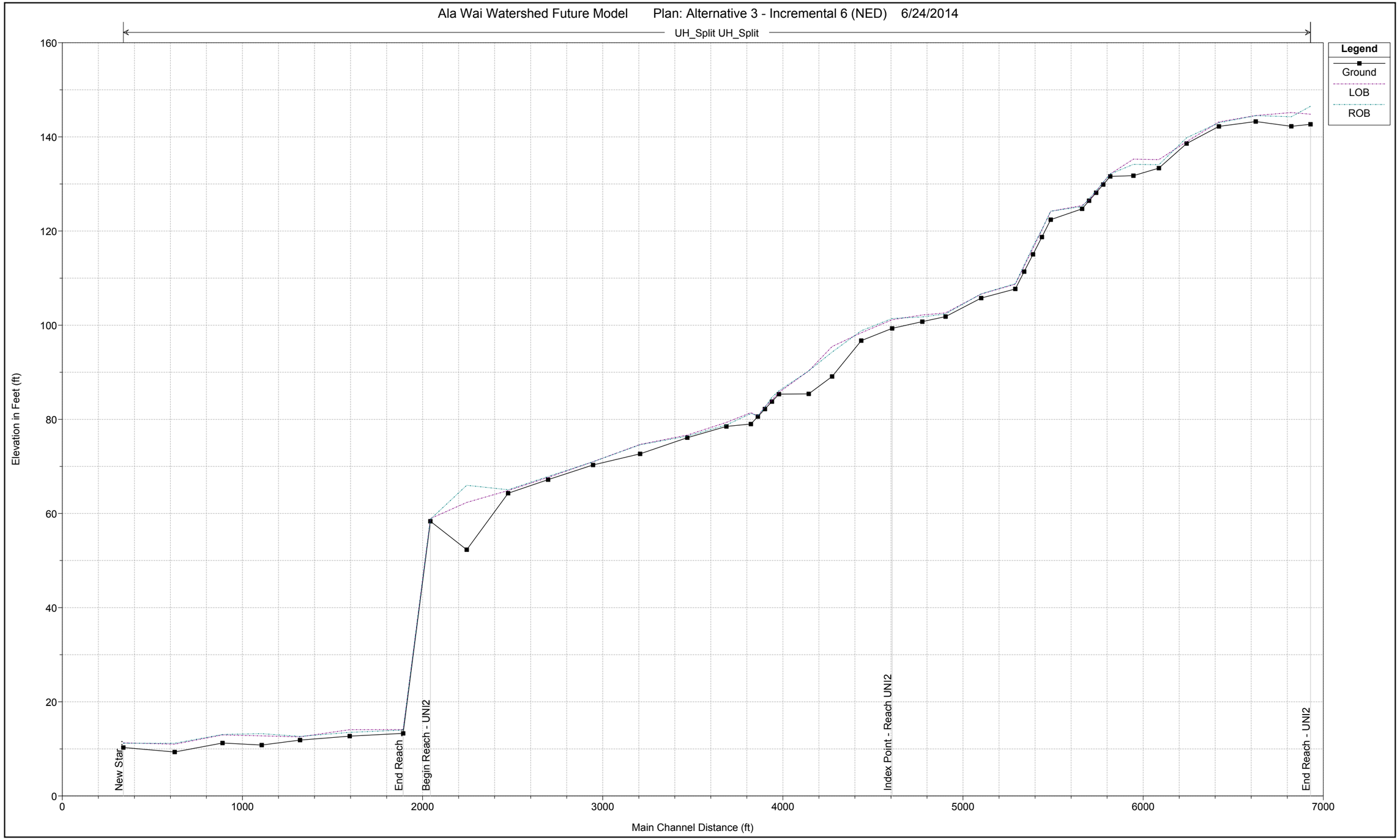

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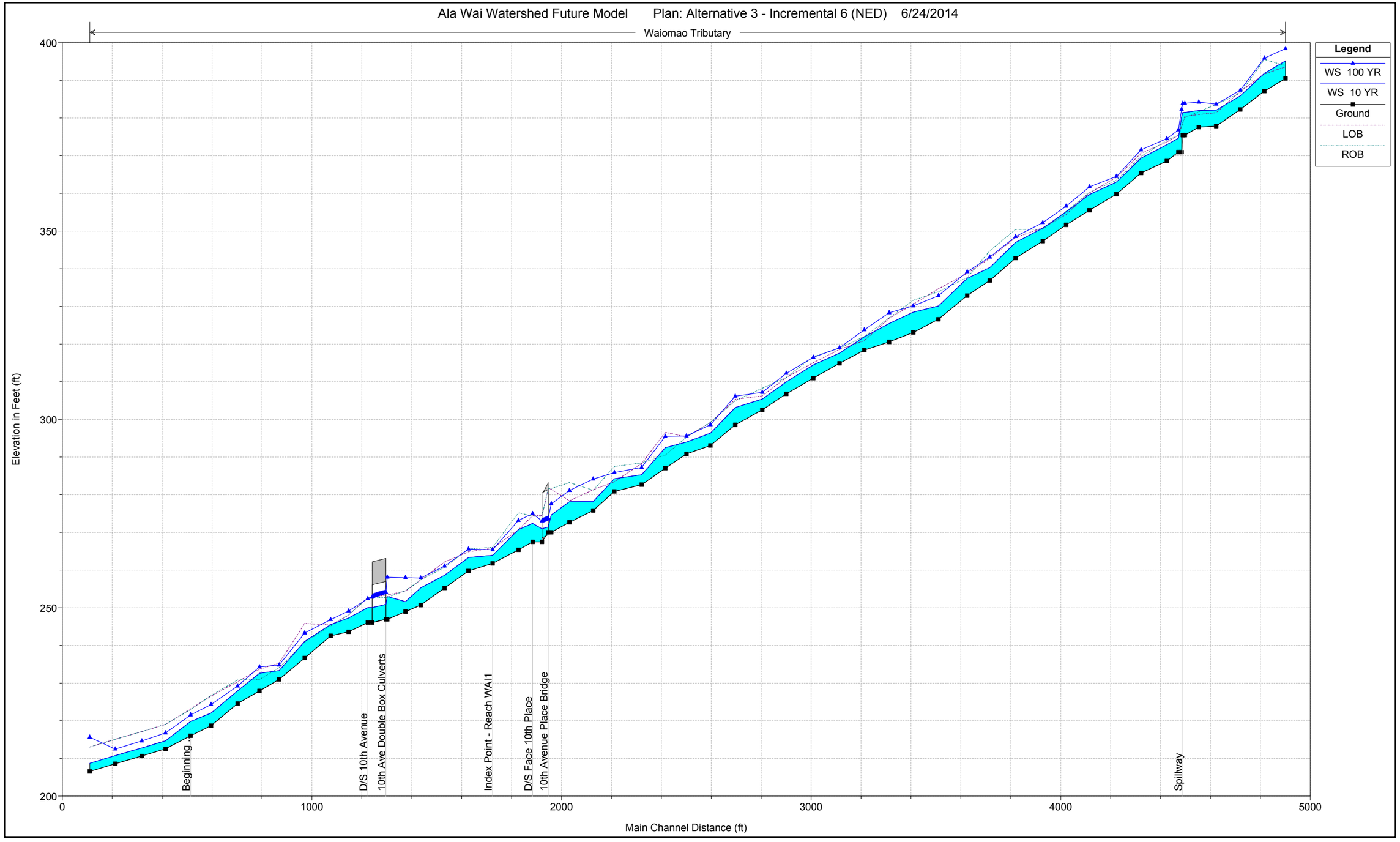

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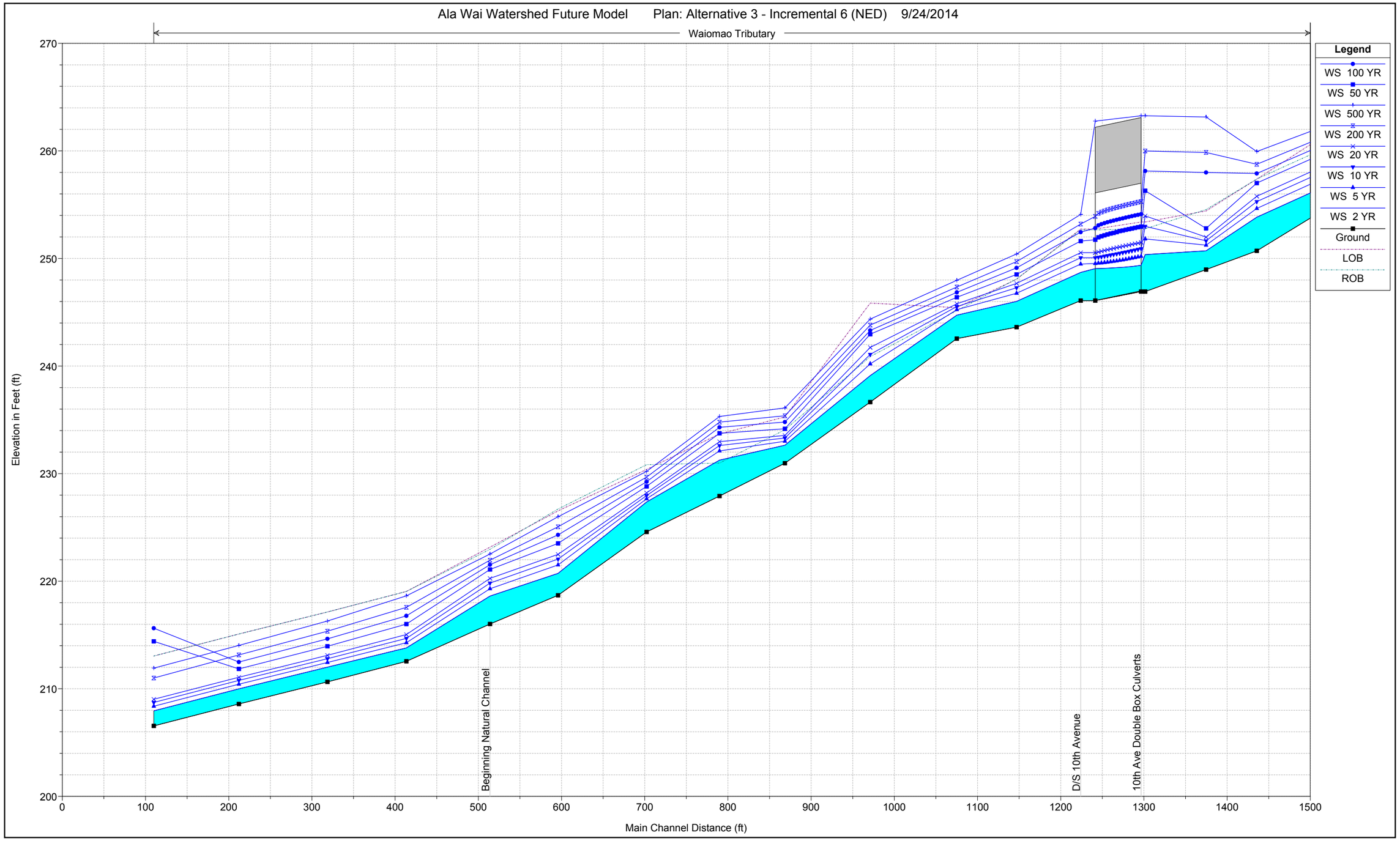

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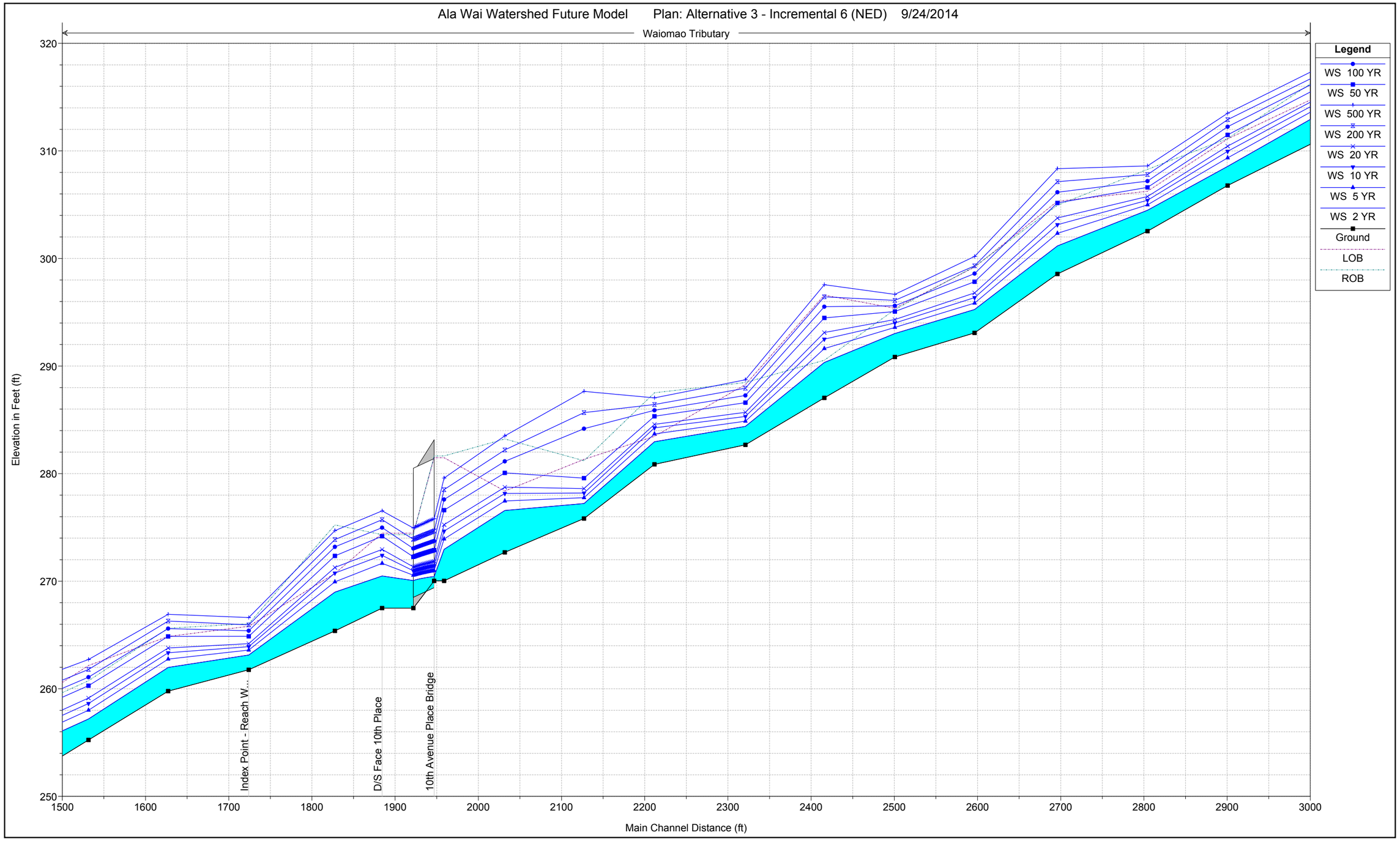

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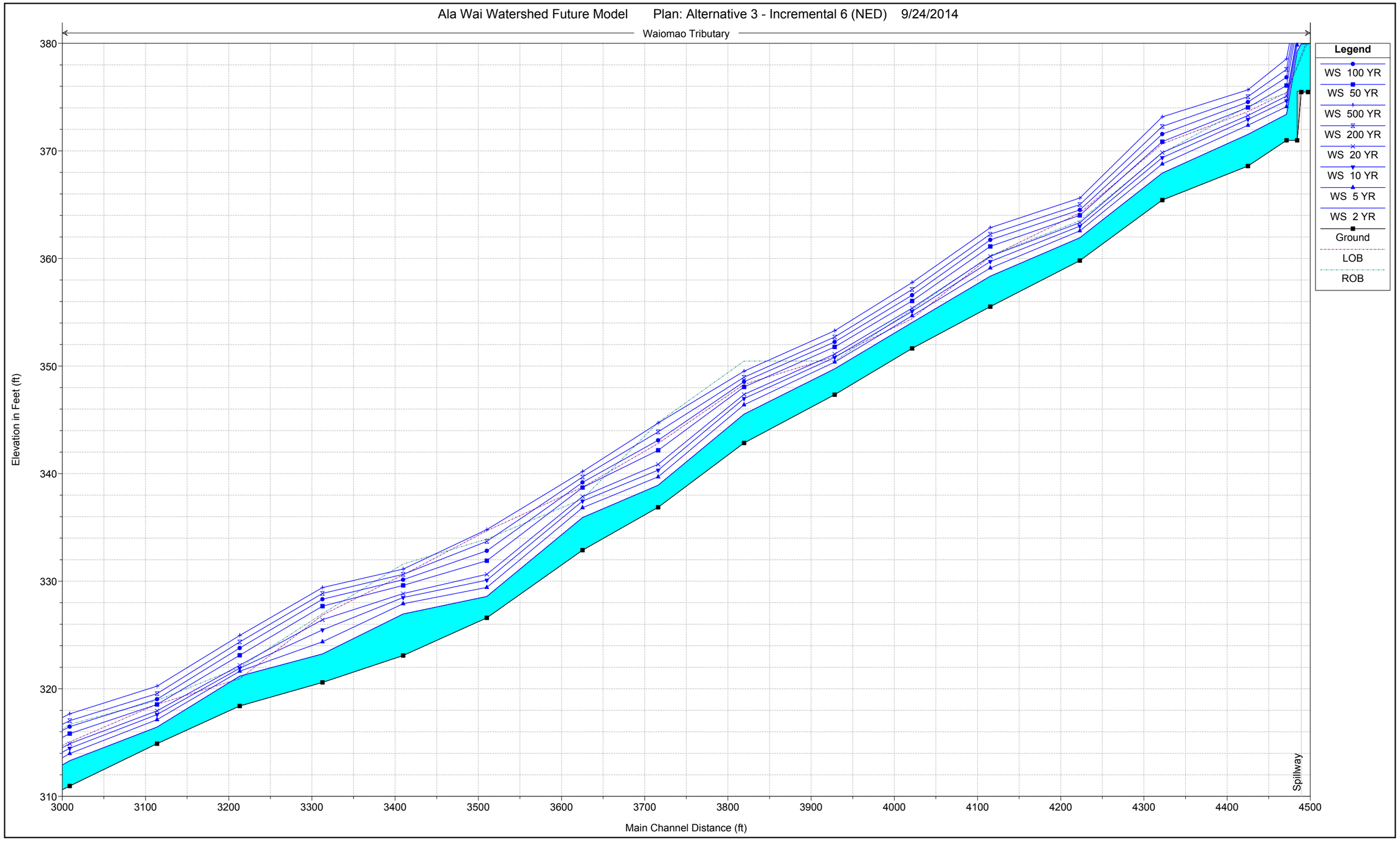

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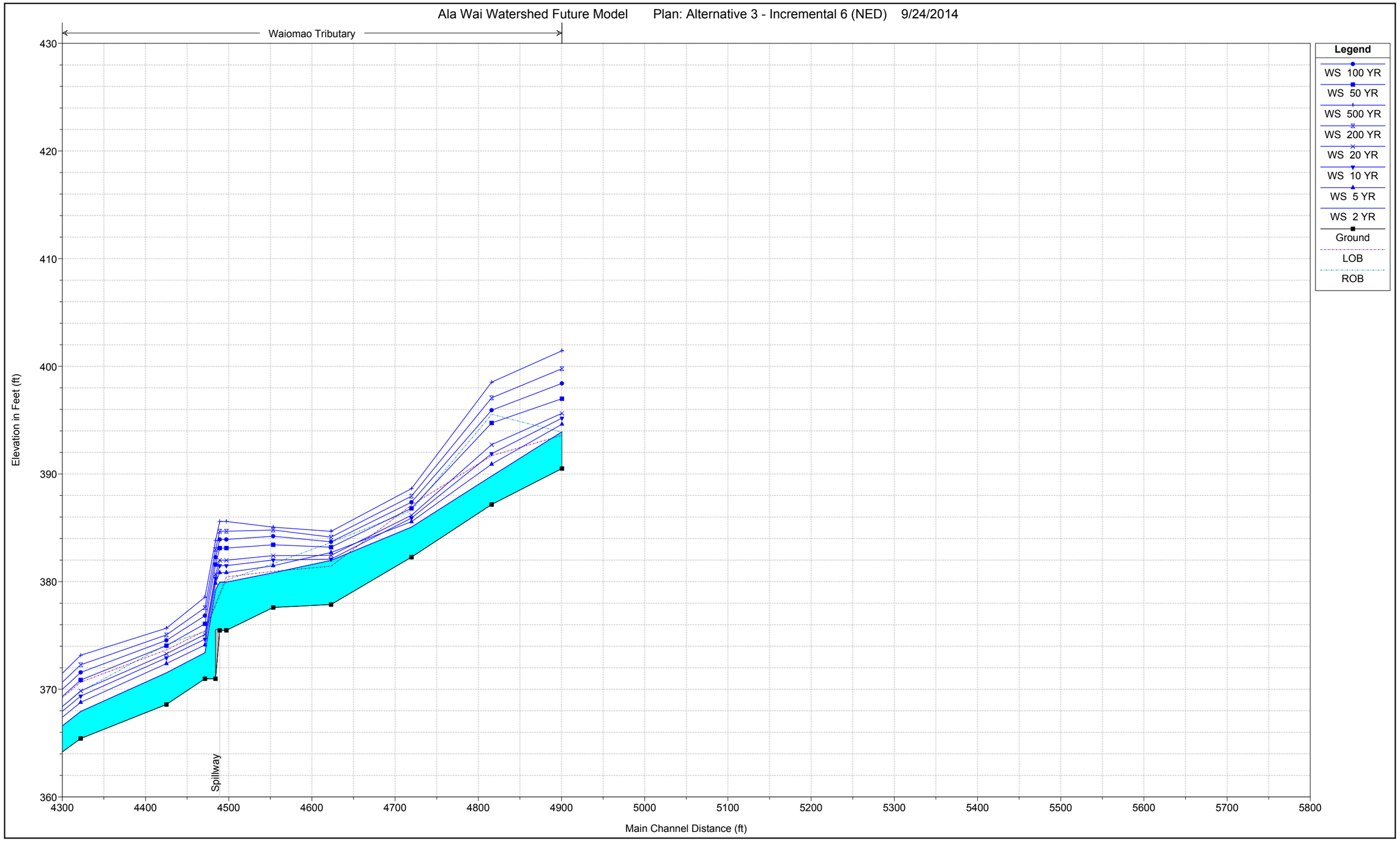
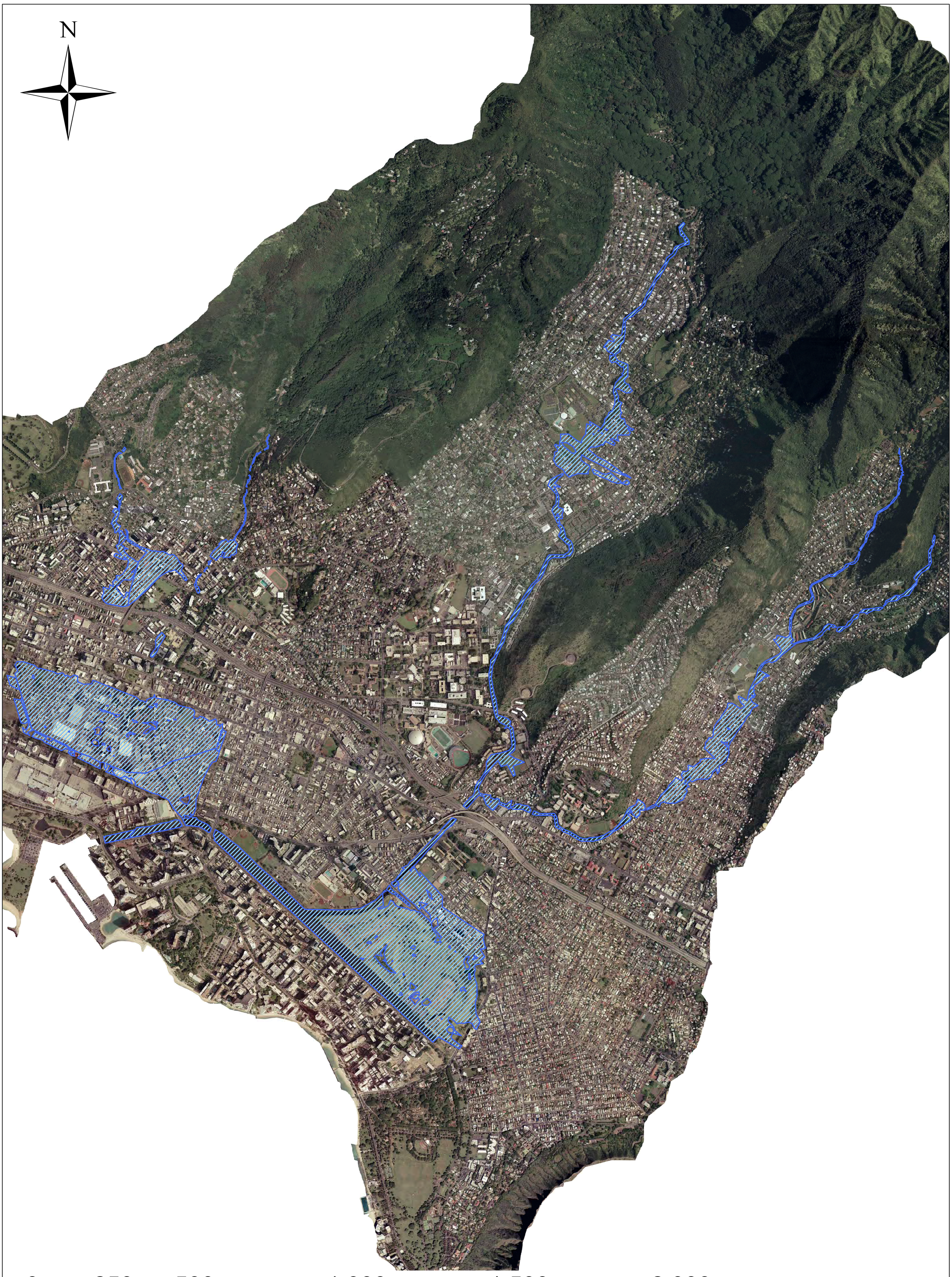


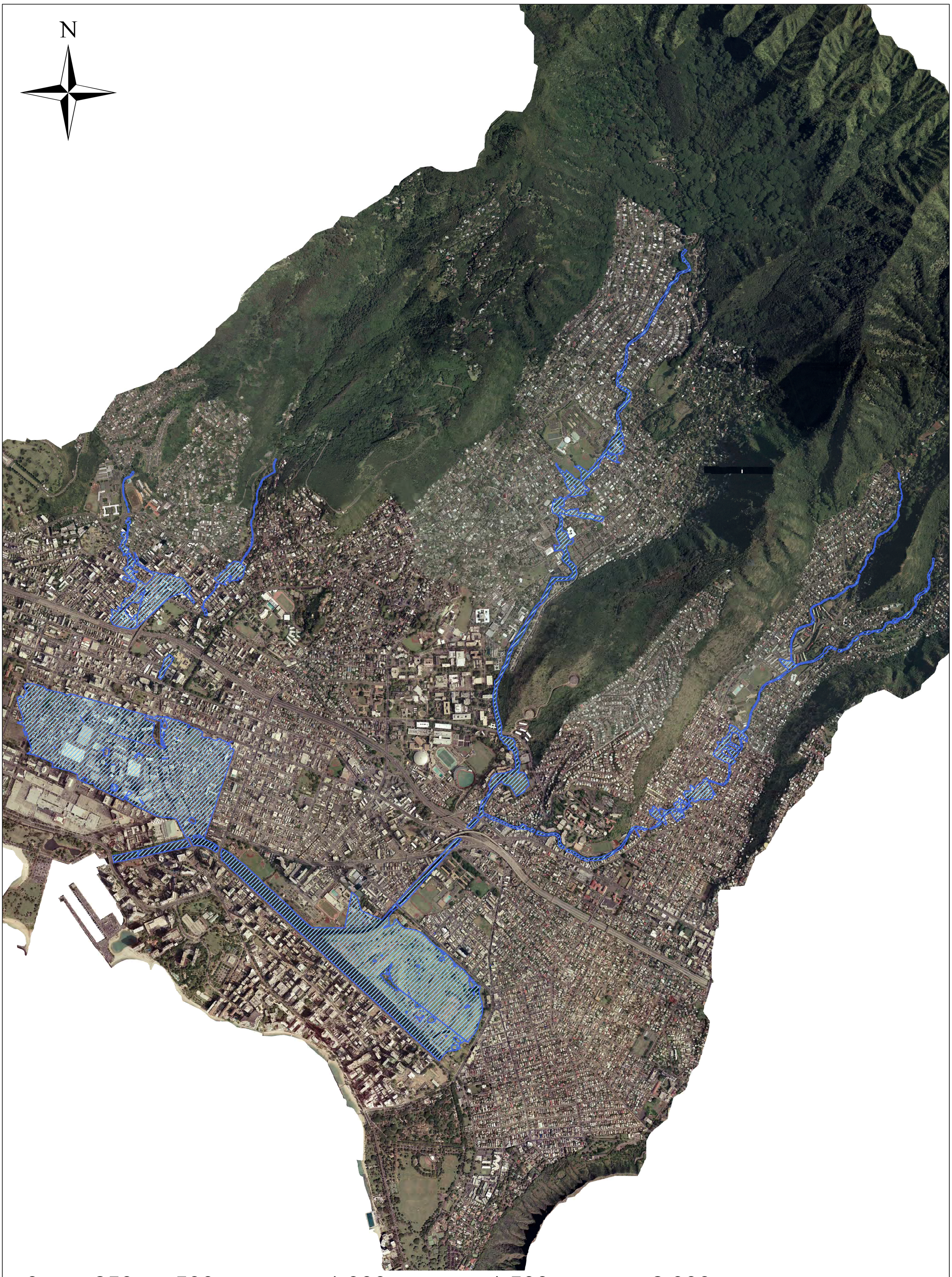


Ala Wai Canal Project - Alternative 2A

1-Percent ACE (100-Year) Floodplain

Note:
This flood boundary is subject to change.

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

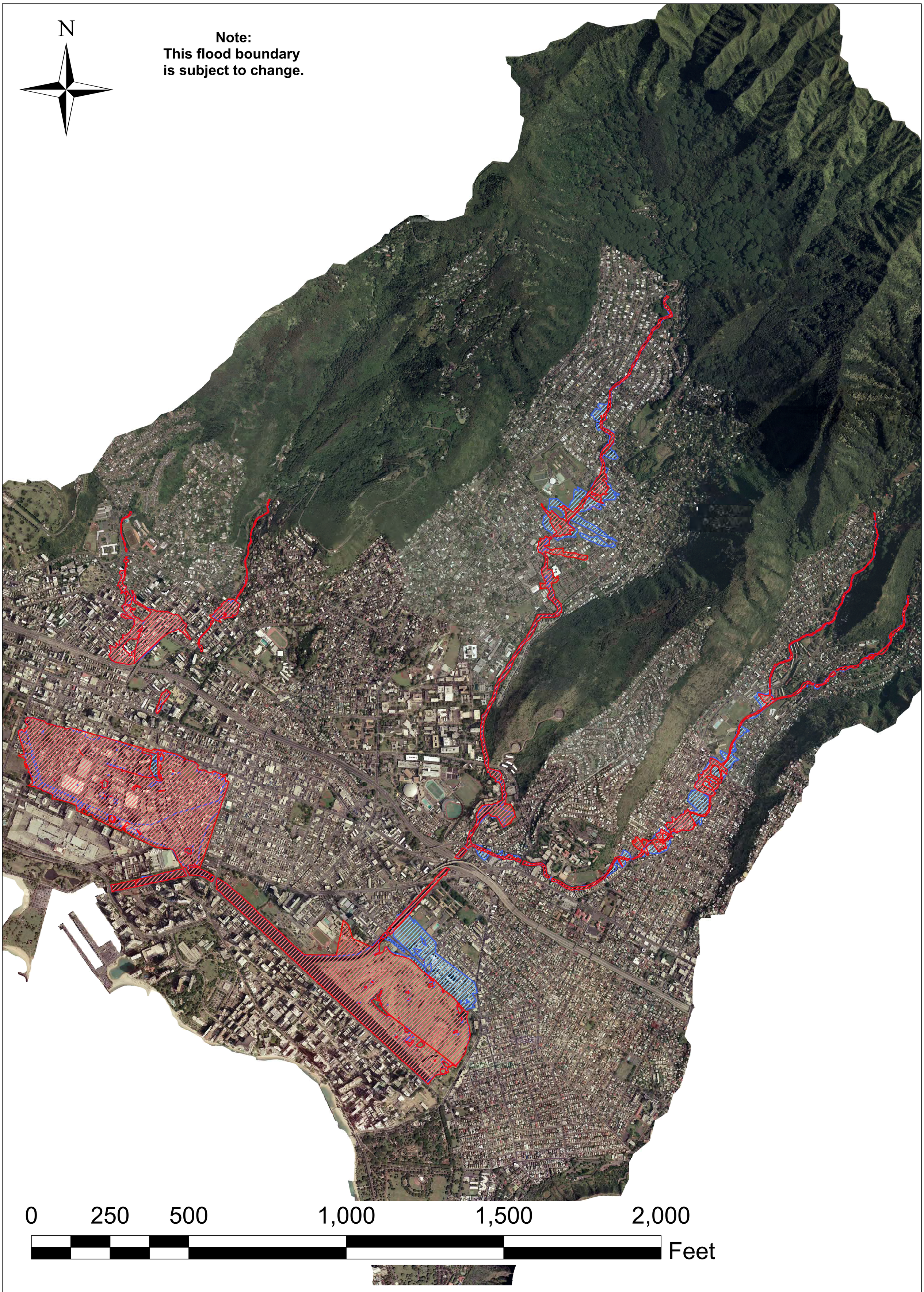


Ala Wai Canal Project - Alternative 3A

1-Percent ACE (100-Year) Floodplain

Note:
This flood boundary is subject to change.

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.



ALA WAI CANAL PROJECT - ALTERNATIVES 2A &3A

Alternative 3A 1-Percent ACE (100-Year) Floodplain

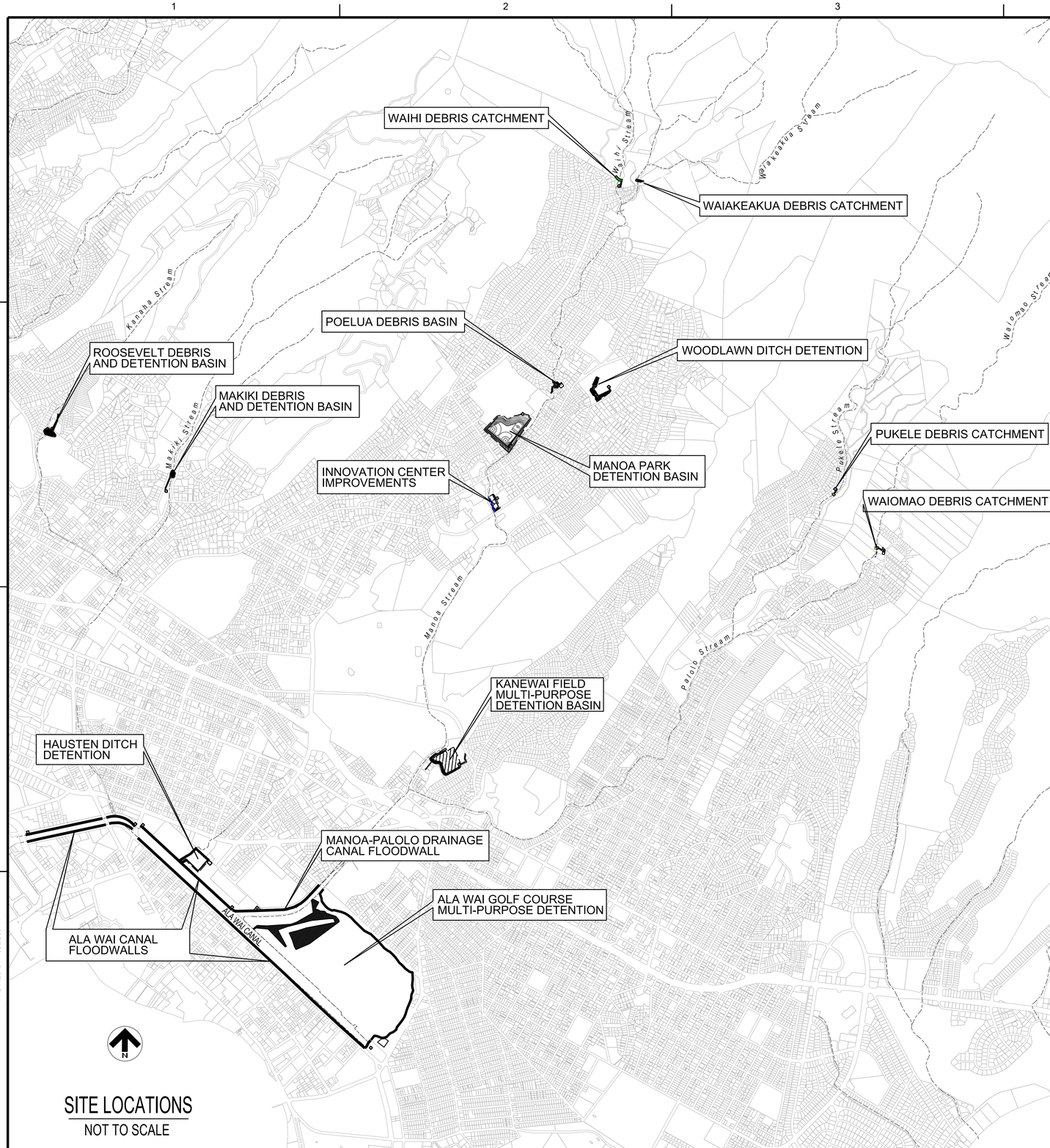
Alternative 2A 1-Percent ACE (100-Year) Floodplain

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

Plate 8 - Existing Without Project, Alternative 2A, and Alternative 3A 1-Percent ACE Water Surface Elevations at HEC-FDA Index Points

HEC-RAS		HEC-FDA	HEC-RAS	HEC-RAS Water Surface Elevations (ft)		
River	**Reach**	**Reach**	**River Station**	**Existing Without-Project**	**Alternative 2A**	**Alternative 3A**
Ala Wai	Lower	ALA1	1477	3.56	3.44	3.27
Ala Wai	Middle	ALA2	4847	7.48	6.94	6.82
Ala Wai	Upper	ALA3	8015	8.26	7.65	7.58
Palolo	Lower	MPC1	1813	10.96	9.55	8.61
Palolo	Lower	MPC2	3406	16.91	13.64	12.96
Makiki	Lower	MAK1	1719	10.61	9.50	9.01
Makiki	Lower	MAK2	4325	33.31	32.80	27.88
Makiki	Upper	MAK3	6606	71.59	70.17	70.17
Makiki	Upper	MAK4	9666	178.40	177.94	177.94
Kanaha	Split	KAO1	1393	42.90	42.24	42.96
Kanaha	Ditch	KAH1	1874	73.12	72.05	70.37
Kanaha	Ditch	KAH2	3005	78.15	76.96	78.15
Manoa	Main	MAN1	948	40.75	37.61	38.06
Manoa	Main	MAN2	5461	116.78	113.11	113.87
Manoa	Main	MAN3	8367	153.06	150.71	151.25
Manoa	Main	MAN4	9032	164.16	157.98	159.58
Manoa	Main	MAN5	10309	173.33	173.51	171.54
Manoa	Main	MAN6	13136	212.02	212.02	208.09
Manoa	Main	MAN7	15753	260.74	260.74	256.48
UH_Split	UH_Split	UNI1	1107	13.70	11.45	11.45
UH_Split	UH_Split	UNI2	4606	102.20	99.72	99.72
Palolo	Main	PAL1	6376	41.77	41.79	39.10
Palolo	Main	PAL2	8574	89.06	89.06	87.40
Palolo	Main	PAL3	11649	140.63	140.63	139.57
Palolo	Main	PAL4	14619	187.18	187.18	184.59
Pukele	Tributary	PUK1	2184	287.58	287.58	283.77
Waiomao	Tributary	WAI1	1724	266.67	266.66	265.39

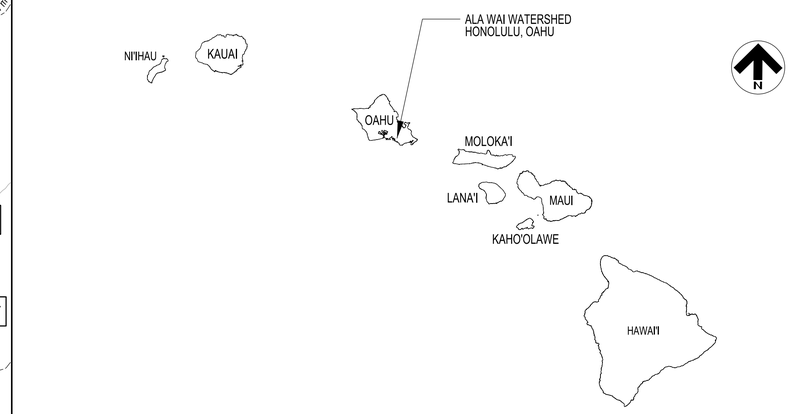
ALA WAI CANAL PROJECT
ALTERNATIVE 2A
HONOLULU, OAHU, HI



SITE LOCATIONS

NOT TO SCALE

PROJECT TITLE



VICINITY MAP

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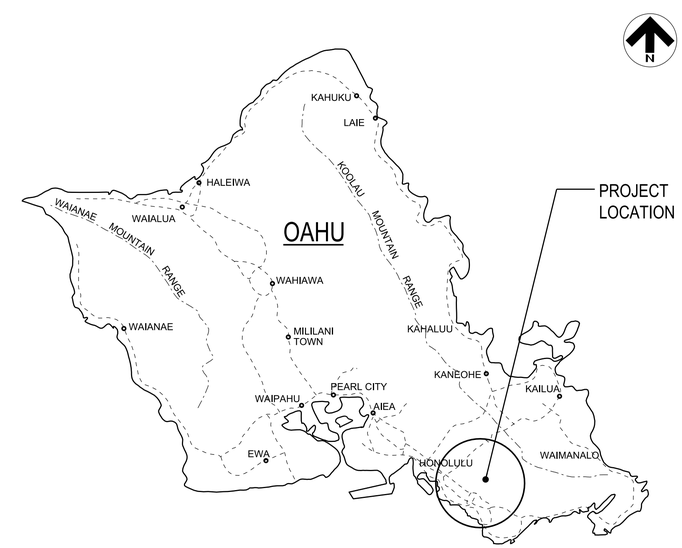

PROJECT LOCATION

NOT TO SCALE

US Army Corps of Engineers®
HONOLULU DISTRICT

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10% DESIGN

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DRAWN BY:
SUBMITTED BY:
PLOT SCALE: 1:1
PLOT DATE: 12/18/2014
SIZE: ANSI D
FILE NAME: Cover Sheet - Site Locations, Vicinity Map, Project Location
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

SITE LOCATIONS
PROJECT LOCATION & VICINITY MAP
ALTERNATIVE 2A

SHEET IDENTIFICATION
G-001
SHEET 1 OF 25

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ALA WAI CANAL PROJECT - ALTERNATIVE 2A
INDEX OF DRAWINGS

SHT. NO	SHT. REF. NO.	DESCRIPTION
1	G-001	COVER SHEET
2	G-002	INDEX TO DRAWINGS
3	C-101	ALA WAI CANAL FLOODWALLS, SITE PLAN
4	C-102	HAUSTEN DITCH DETENTION, PLAN
5	C-103	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, SITE PLAN
6	C-104	MANOA PARK DETENTION BASIN, PLAN
7	C-105	BY-PASS CULVERT TO MANOA PARK DETENSION BASIN, SITE PLAN
8	C-303	POELUA PLACE DEBRIS BASIN, PLAN AND PROFILE
9	C-304	INNOVATION CENTER IMPROVEMENTS, PLAN AND SECTIONS
10	C-305	WOODLAWN DITCH DETENTION BASIN, PLAN AND SECTIONS
11	C-306	KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN, PLAN AND SECTIONS
12	C-307	MANOA-PALOLO DRAINAGE CANAL FLOODWALL; PLAN, PROFILE AND SECTION
13	C-309	ALA WAI CANAL MIDDLE AND LOWER RIGHT BANK, PROFILE AND SECTION
14	C-310	ALA WAI CANAL MIDDLE AND LOWER LEFT BANK, PROFILE
15	C-311	ALA WAI CANAL UPPER LEFT BANK, PROFILE AND SECTION
16	C-312	MANOA PARK DETENTION BASIN, PLAN AND SECTIONS
17	C-314	ROOSEVELT DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
18	C-315	MAKIKI DEBRIS AND DETENTION BASIN, PLAN AND PROFILE
19	C-316	HAUSTEN DITCH, PROFILE AND SECTION
20	C-317	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE
21	C-319	WAIHI DEBRIS CATCHMENT, PLAN AND PROFILE
22	C-320	WAIAKEAKUA DEBRIS CATCHMENT, PLAN AND PROFILE
23	C-321	WAIOMAO DEBRIS CATCHMENT, PLAN AND SECTIONS
24	C-322	PUKELE DEBRIS CATCHMENT, PLAN AND SECTIONS
25	C-401	HAUSTEN BRIDGE; PLAN, SECTION AND PROFILE

GENERAL NOTES:

1. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. COORDINATE SYSTEM: NAD 1983 (HARN), HAWAII ZONE 3 (US FEET)
3. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
4. UNLESS SHOWN OTHERWISE, ALL DISTURBED AREAS NOT RECEIVING A HARD SURFACE SHALL BE COVERED WITH GRASS.
5. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
6. EXISTING UNDERGROUND UTILITIES OBTAINED FROM AS-BUILTS AND FROM FIELD SURVEYS. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION AND PROTECT ALL EXISTING UTILITIES DURING CONSTRUCTION.
7. THERE WILL BE A FLOODWARNING SYSTEM INSTALLED FOR THIS PROJECT.

GENERAL ABBREVIATIONS

A.C.	ASHPALT CONCRETE
AVE	AVENUE
BLVD	BOULEVARD
CONC	CONCRETE
DIA	DIAMETER
EL	ELEVATION
EXIST	EXISTING
FT	FOOT, FEET
IN	INCH, INCHES
INV	INVERT
LB	LEFT BANK
MAX	MAXIMUM
MSL	MEAN SEA LEVEL
NTS	NOT TO SCALE
o.c.	ON CENTER
O&M	OPERATIONS AND MAINTENANCE
PL	PLACE
RB	RIGHT BANK
RCP	REINFORCED CONCRETE PIPE
RD	ROAD
ST	STREET
STA	STATION
THK	THICK
TMK	TAX MAP KEY
TYP	TYPICAL
W.S.	WATER SURFACE
YR	YEAR

SYMBOLS

&	AND
@	AT
℄	CENTER LINE
'	FOOT, FEET
"	INCH, INCHES

US Army Corps of Engineers
HONOLULU DISTRICT

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE:
PLOT DATE:
SIZE: ANSI D
FILE NAME: Index To Drawings, General Notes & Abbreviations - Alternative 2A.dgn
DATE:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
REVISION:

ALA WAI CANAL PROJECT

INDEX OF DRAWINGS, GENERAL NOTES
ABBREVIATIONS & SYMBOLS
ALTERNATIVE 2A

SHEET IDENTIFICATION
G-002
SHEET 2 OF 25

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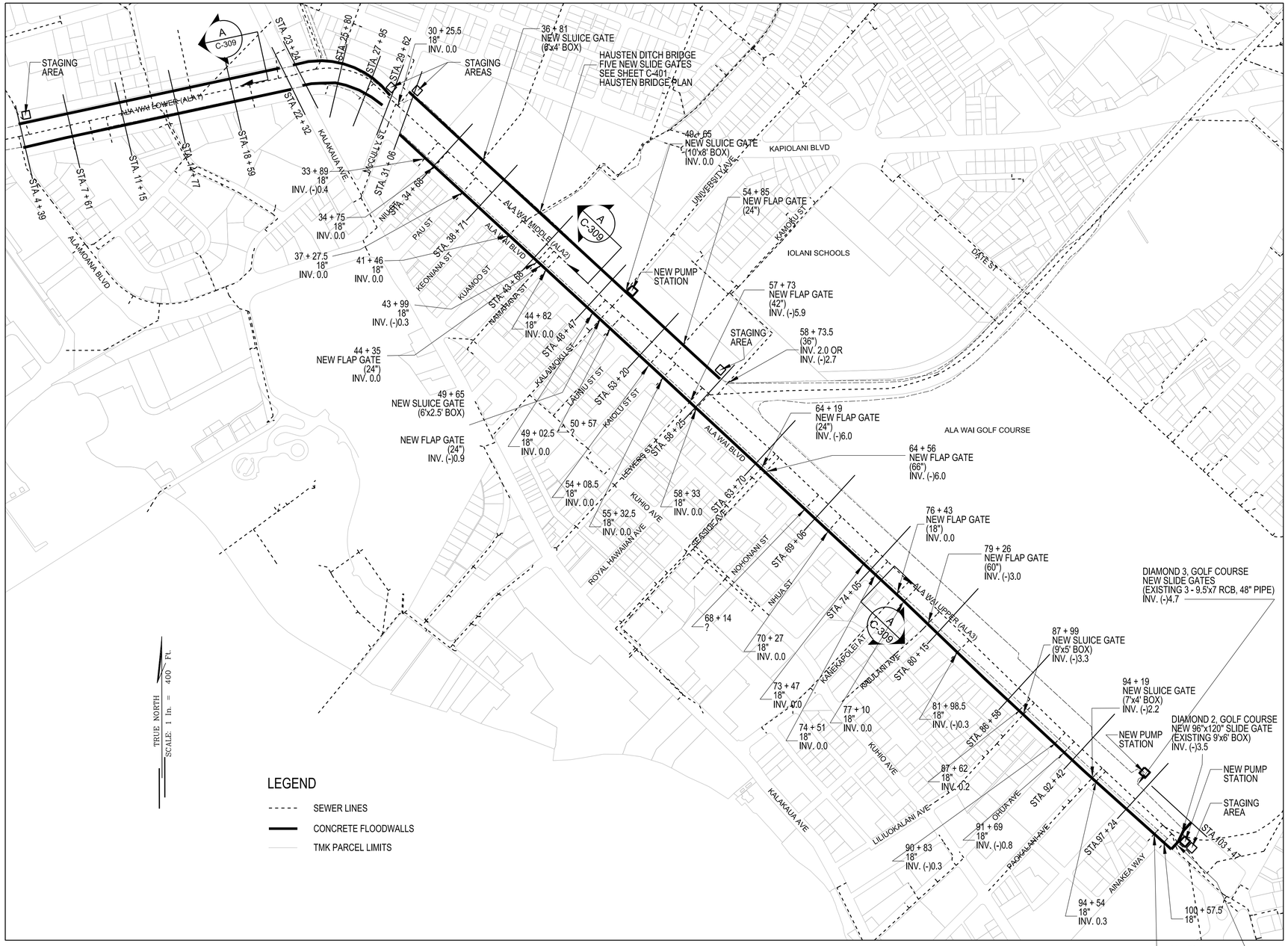

PLAN
ALA WAI CANAL FLOODWALLS

SCALE 1"=400'

ALA WAI CANAL INTERIOR DRAINAGE TABLE

CULVERT NAME	STATION	SIZE & TYPE	NOTES
DIAMOND 2, GOLF COURSE	102+45.5	96"x120" SLIDE GATE	PUMP STATION
DIAMOND 1, ALA WAI BLVD	101+75	2 - 60"x120" SLIDE GATES	
DIAMOND 3, GOLF COURSE	96+67	SLIDE GATES	PUMP STATION
100+57.5	100+57.5	18" FLAP GATE	
99+72.5	99+72.5	18" FLAP GATE	
94+54	94+54	18" FLAP GATE	INV. 0.3
94+19	94+19	SLUICE GATE	INV. (-)2.2
91+69	91+69	18" FLAP GATE	INV. (-)0.8
90+83	90+83	18" FLAP GATE	INV. (-)0.3
87+99	87+99	SLUICE GATE	INV. (-)3.3
87+62	87+62	18" FLAP GATE	INV. 0.2
81+98.5	81+98.5	18" FLAP GATE	INV. (-)0.3
79+26	79+26	60" FLAP GATE	INV. (-)3.0
77+10	77+10	18" FLAP GATE	
76+43	76+43	18" FLAP GATE	INV. 0.0
74+51	74+51	18" FLAP GATE	
73+47	73+47	18" FLAP GATE	
70+27	70+27	18" FLAP GATE	
68+14	68+14	?	
64+56	64+56	66" FLAP GATE	INV. (-)6.0
64+19	64+19	24" FLAP GATE	INV. (-)6.0
58+73.5	58+73.5	36" FLAP GATE	INV. 2.0 OR (-)2.7
58+33	58+33	18" FLAP GATE	
57+73	57+73	42" FLAP GATE	INV. (-)5.9
55+32.5	55+32.5	18" FLAP GATE	
54+08.5	54+08.5	18" FLAP GATE	
54+85	54+85	24" FLAP GATE	
50+57	50+57	?	
49+65, RB	49+65	SLUICE GATE	INV. 0.0, PUMP STATION
49+65	49+65	SLUICE GATE & 24" FLAP GATE	INV. ? & (-)0.9
49+02.5	49+02.5	18" FLAP GATE	
44+82	44+82	18" FLAP GATE	
44+35	44+35	24" FLAP GATE	
43+99	43+99	18" FLAP GATE	INV. (-)0.3
HAUSTEN DITCH BRIDGE	42+10	5 - SLIDE GATES	SEE SHEET C-401
41+46	41+46	18" FLAP GATE	
37+27.5	37+27.5	18" FLAP GATE	
36+81	36+81	SLUICE GATE	
34+75	34+75	18" FLAP GATE	
33+89	33+89	18" FLAP GATE	INV. (-)0.4
30+25.5	30+25.5	18" FLAP GATE	

NOTES:

1. SEE SHEET C-309 FOR THE RIGHT BANK (MOUNTAIN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
2. SEE SHEET C-310 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
3. SEE SHEET C-311 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI UPPER (ALA3).
4. PUMP STATIONS WILL BE 50'x50'.

US Army Corps of Engineers
HONOLULU DISTRICT

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DESIGNED BY: JHH | DATE: | REVISION:
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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: AS SHOWN | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: ALA WAI CANAL FLOODWALLS, PLAN

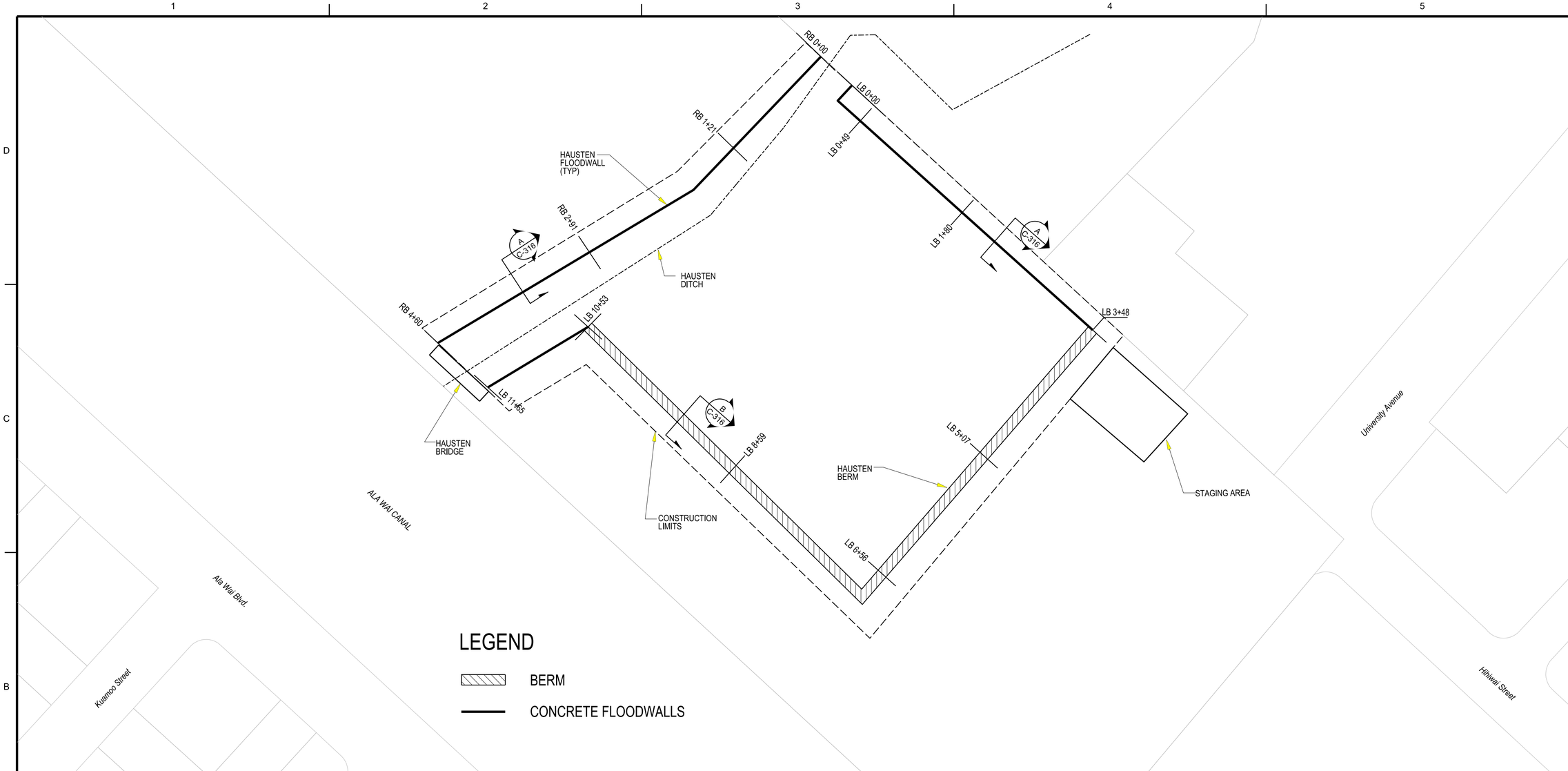
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI LOWER, MIDDLE & UPPER FLOODWALLS
SITE PLAN
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-101
SHEET 3 OF 25

FILE: c:\pwwork\poh-h1\3ec9jhhd\0139948\Ala_Wai_C-101xxx.dgn
MODEL NAME: C-101
DATE & TIME: 12/15/2014 1:03:21 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



LEGEND

BERM

CONCRETE FLOODWALLS

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-316 FOR THE PLAN AND PROFILE OF THE FLOODWALLS AND BERM.
3. SEE SHEET C-401 FOR THE HAUSTEN DITCH BRIDGE NEW CONRETE WALL PLAN.

HAUSTEN DITCH DETENTION PLAN

SCALE: 1"=50'

TRUE NORTH

SCALE: 1 In. = 50 FT.

50' 25' 0 50' 100'

SCALE: 1" = 50'

US Army Corps of Engineers® Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 12/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN DITCH DETENTION PLAN

ALA WAI CANAL PROJECT

HAUSTEN DITCH DETENTION PLAN ALTERNATIVE 2A

SHEET IDENTIFICATION
C-102
SHEET 4 OF 25

FILE: c:\pw-work\jpoh-1\j3ec9jhh\d0139948\Ala_Wai_C-102xxx.dgn
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DATE & TIME: 12/15/2014 1:07:39 PM
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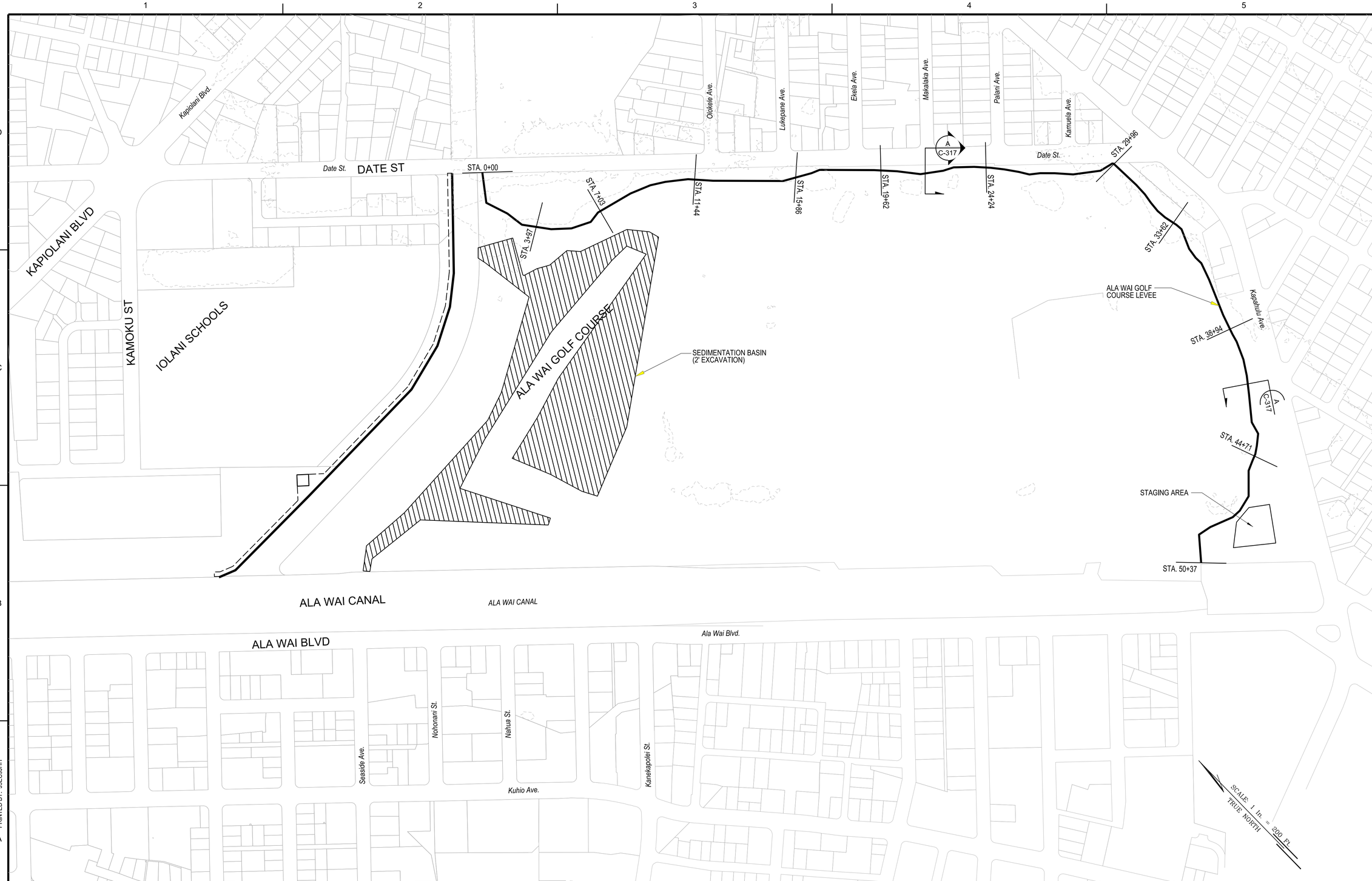
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



NOTES:

1. THE STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN

SCALE: 1"=200'

SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

200' 100' 0 200' 300'

SCALE: 1" = 200'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JRH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE: 12/23/2014
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION_A.dwg
DATE:
REVISION:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

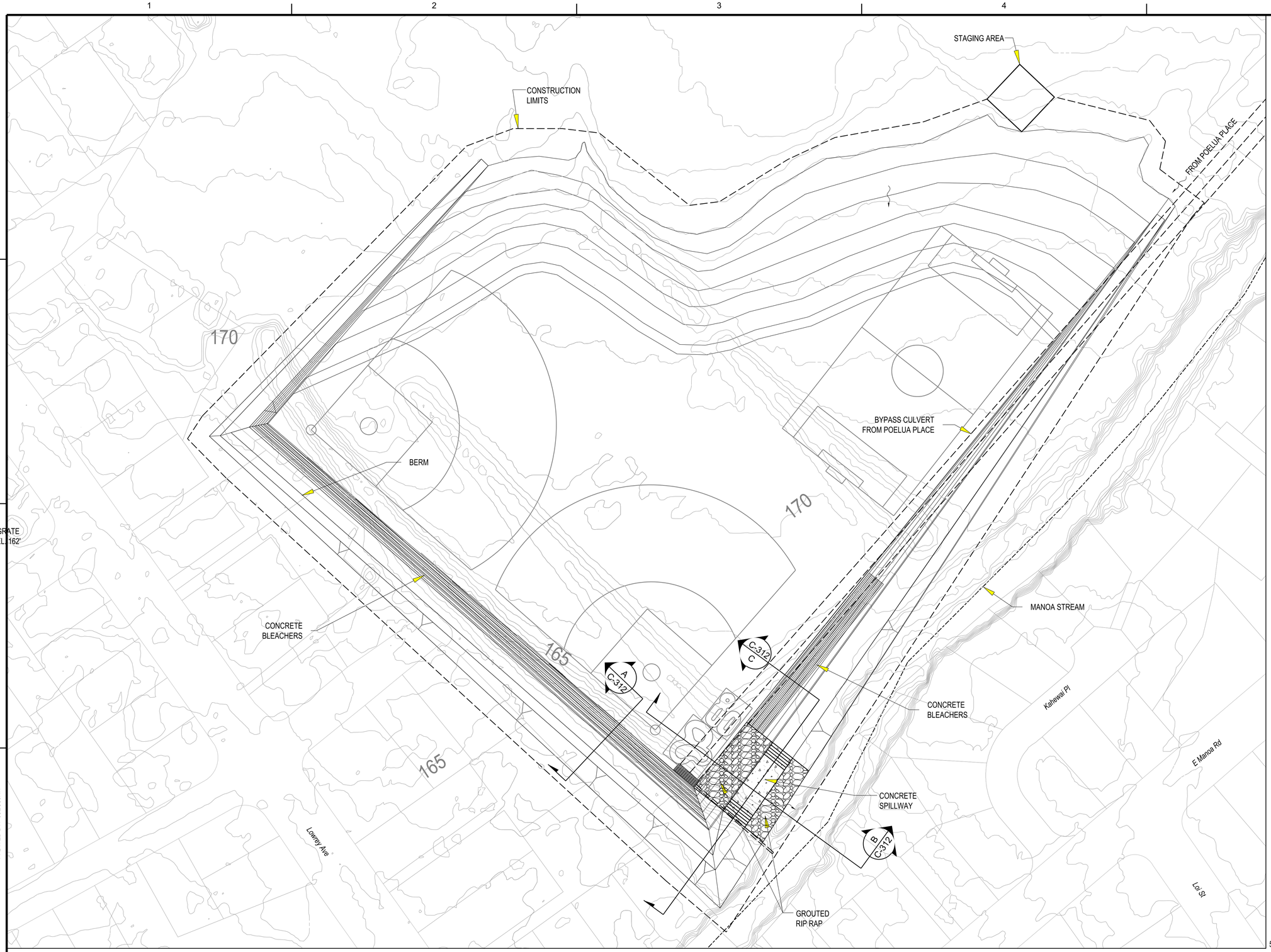
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION
PLAN
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-103
SHEET 5 OF 25

FILE: c:\pwwork\poh-ntj3ec9jhhd\0139948\Ala_Wai_C-103xxx.dgn
MODEL NAME: C-103
DATE & TIME: 12/23/2014 10:38:34 AM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



NOTES:

1. SEE SHEET C-312 FOR THE PLAN AND SECTIONS.

TRUE NORTH
SCALE: 1 in. = 50 ft.

50' 25' 0 50' 100'
SCALE: 1" = 50'

SOLID LINE = 5' CONTOURS
DOTTED LINE = 1' CONTOURS

MANOA PARK DETENTION BASIN
PLAN

US Army Corps of Engineers®
HONOLULU DISTRICT

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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: AS SHOWN
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: MANOA_PARK_DETENTION_BASIN_PLAN

ALA WAI CANAL PROJECT

MANOA PARK DETENTION BASIN
PLAN
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-104
SHEET 6 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-104xxx.dgn
MODEL NAME: C-104
DATE & TIME: 12/15/2014 1:11:45 PM
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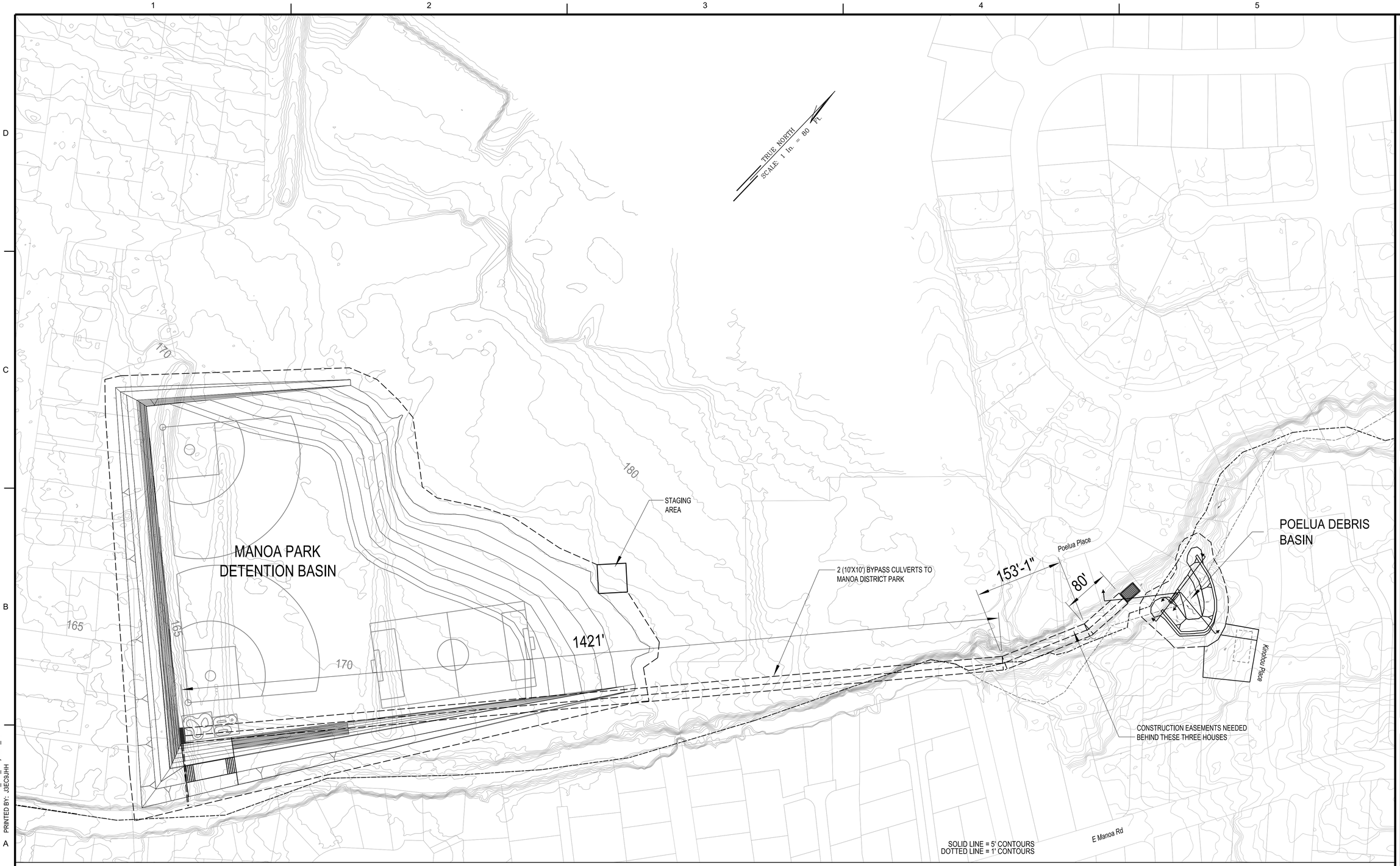
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECT series)\WorkSpace\system\plotcfg\printer.plotcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



BYPASS CULVERT TO MANOA PARK DETENTION BASIN
SITE PLAN

SCALE: 1"=80'

NOTES:

1. SEE SHEET C-104 FOR THE MANOA PARK DETENTION BASIN PLAN.
2. SEE SHEET C-303 FOR THE POELUA DEBRIS BASIN PLAN.

80' 0' 80' 160'

SCALE: 1" = 80'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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DESIGNED BY: JHH
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SUBMITTED BY:
PLOT SCALE:
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE: 12/15/2014
FILE NAME: BY-PASS CULVERT TO MANOA PARK DETENTION BASIN
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

POELUA PLACE DEBRIS BASIN
PLAN
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-105
SHEET 7 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-105xxx.dgn
MODEL NAME: C-105
DATE & TIME: 12/15/2014 1:14:37 PM
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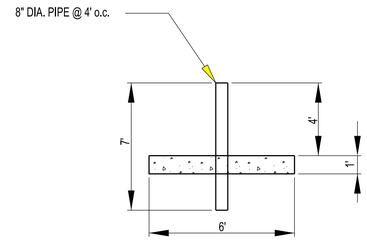
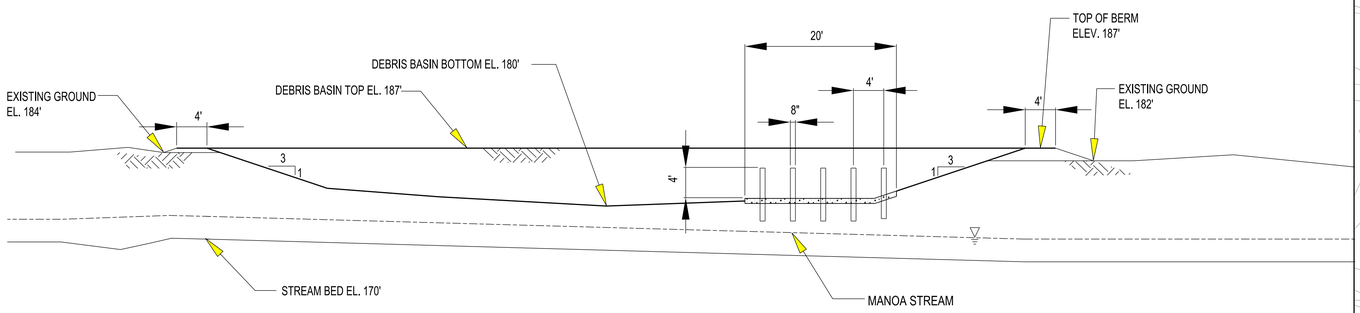
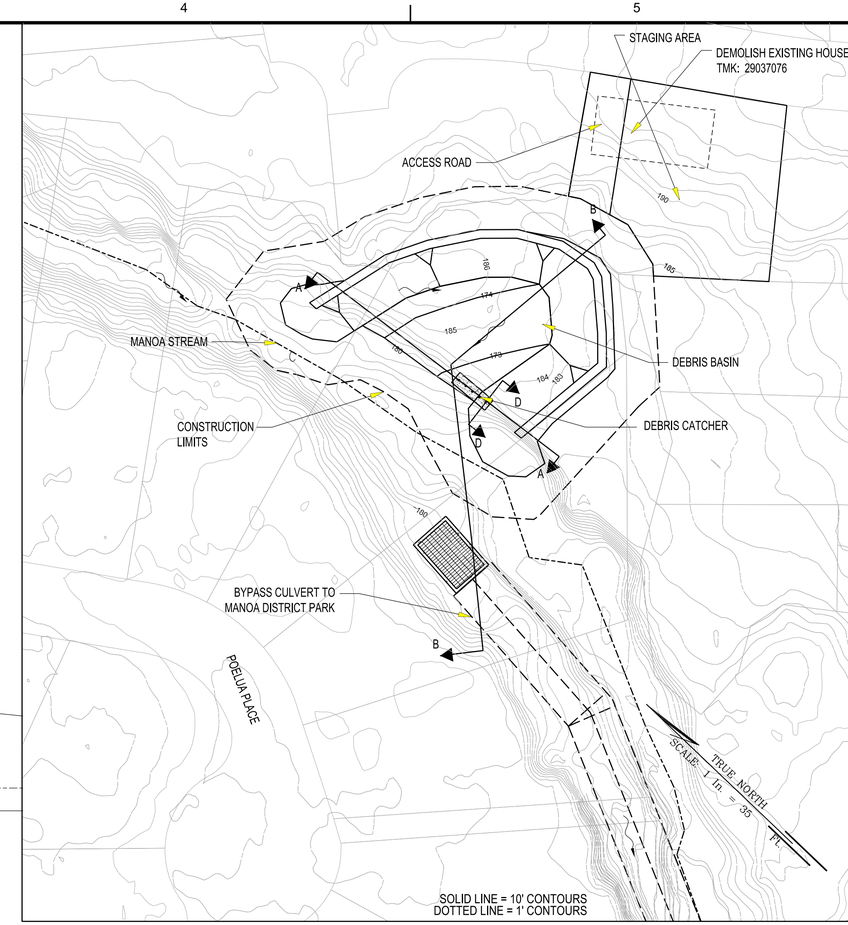
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: JJECSJHH



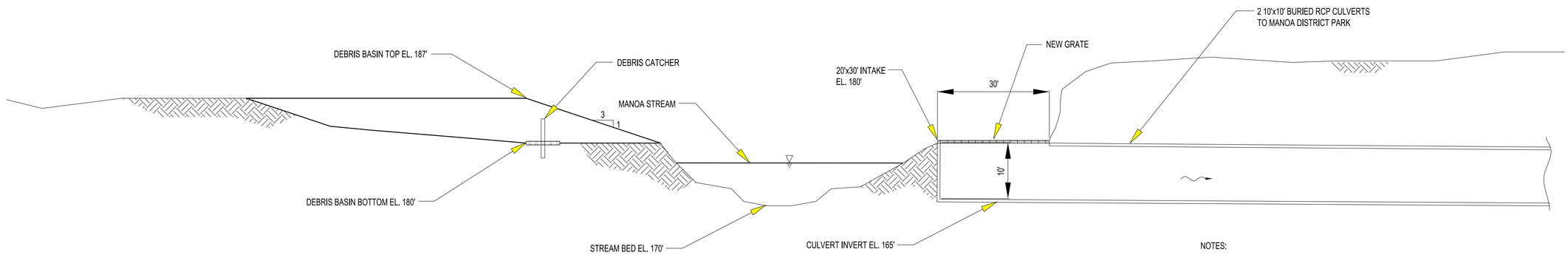
SECTION D-D
SCALE: NTS



POELUA PLACE DEBRIS BASIN
SECTION A-A
SCALE: 1"=10'



PLAN
SCALE: 1"=35'



10' 0' 10' 20'
SCALE: 1" = 10'

Note: All elevations are feet MSL

POELUA PLACE DEBRIS BASIN
SECTION B-B
SCALE: 1"=10'

NOTES:

1. 6 FOOT HIGH CHAIN LINK FENCE AROUND ACCESS ROAD AND STAGING AREA.
2. 6 FOOT HIGH AND 24 FOOT WIDE CHAIN LINK FENCE GATE TO BE INSTALLED IN FRONT OF THE ACCESS ROAD.

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SOLICIT. / CONTRACT NO.:
LOCATION CODE
PLOT DATE:
DRAWING NUMBER:
FILE NAME: POELUA PLACE_DEBRIS_BASIN_PLAN & SECTIONS

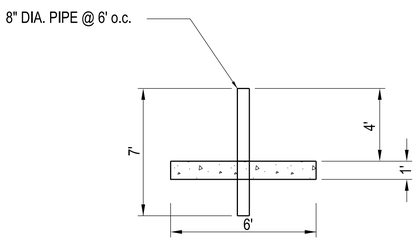
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

POELUA PLACE DEBRIS BASIN
PLAN AND SECTIONS
ALTERNATIVE 2A

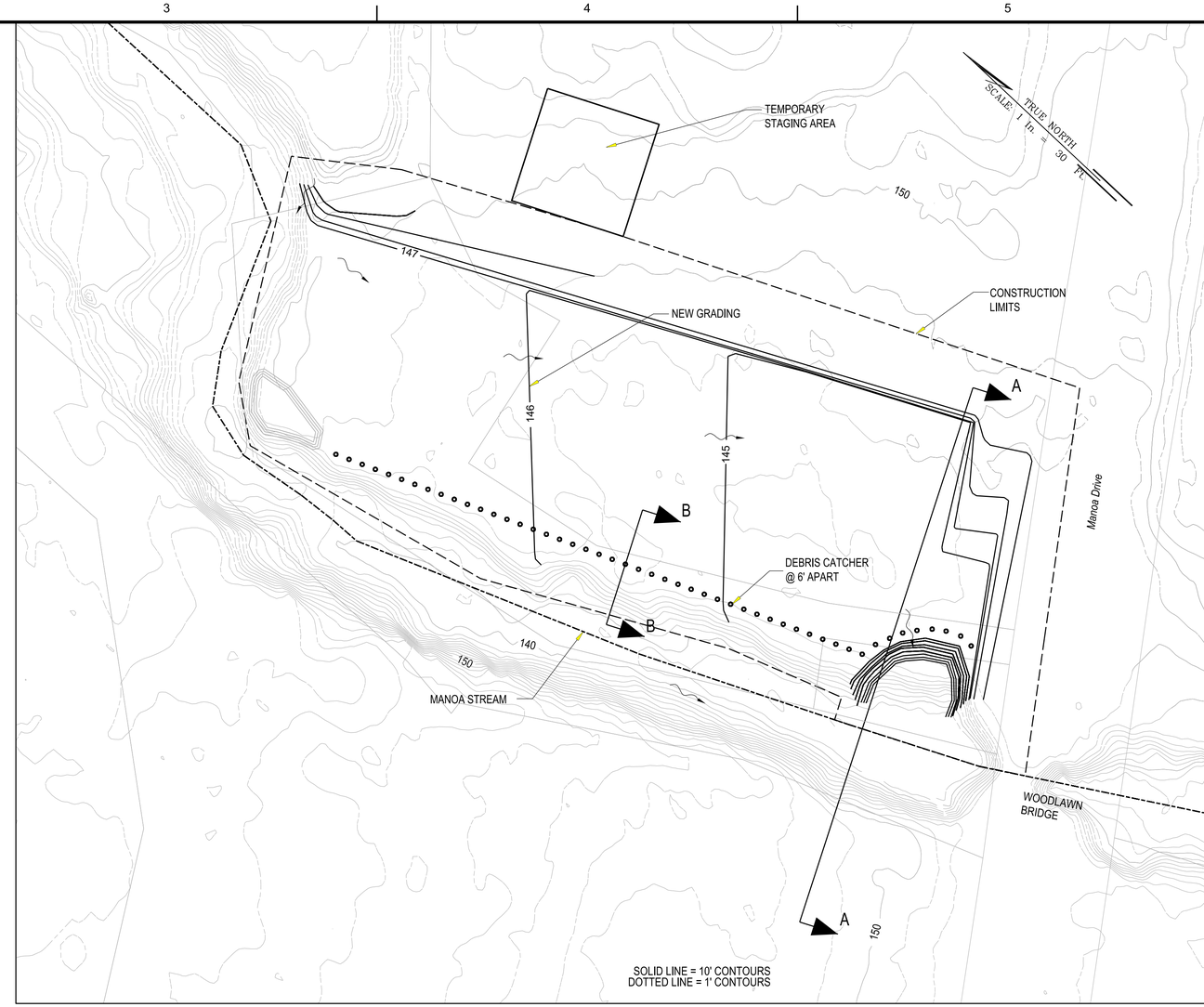
SHEET IDENTIFICATION
C-303
SHEET 8 OF 25

FILE: c:\pw-work\pch-1\j3ec9jhh\d0139948\Ala_Wai_C-303xxx.dgn
MODEL NAME: C-303
DATE & TIME: 12/15/2014 1:17:57 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



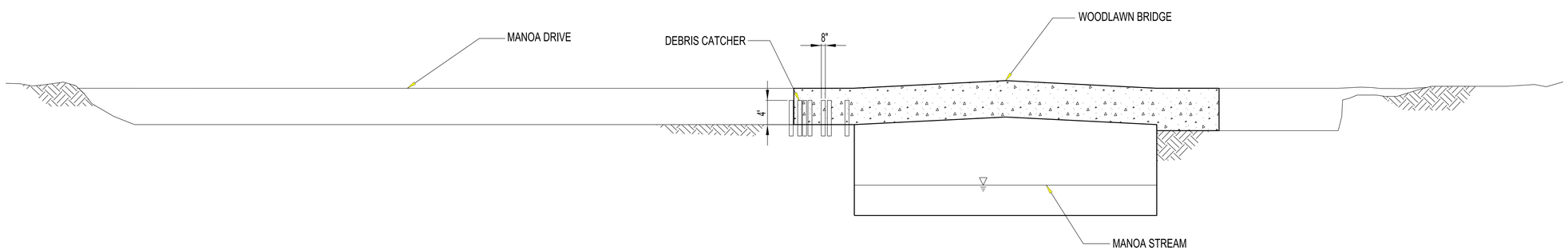
INNOVATION CENTER IMPROVEMENTS
SECTION B-B

SCALE: NTS



PLAN

SCALE: 1"=30'



10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

INNOVATION CENTER IMPROVEMENTS
SECTION A-A

SCALE: 1"=10'

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SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1 / 1:0.5 / 1:0.25
PLOT DATE:
DRAWING NUMBER:
FILE NAME: INNOVATION CENTER IMPROVEMENTS, PLAN & SECTIONS
SIZE: ANSI D

ALA WAI CANAL PROJECT

INNOVATION CENTER IMPROVEMENTS
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-304
SHEET 9 OF 25

FILE: c:\pw_work\poh-1\jec9jhh\d0139948\Ala_Wai_C-304xxx.dgn
MODEL NAME: C-304
DATE & TIME: 12/15/2014 1:20:22 PM
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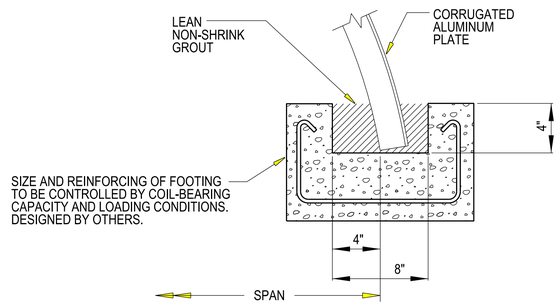
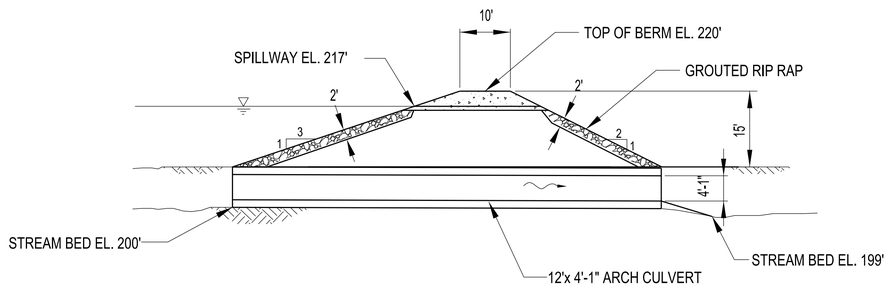
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY:. J3EC9JHH



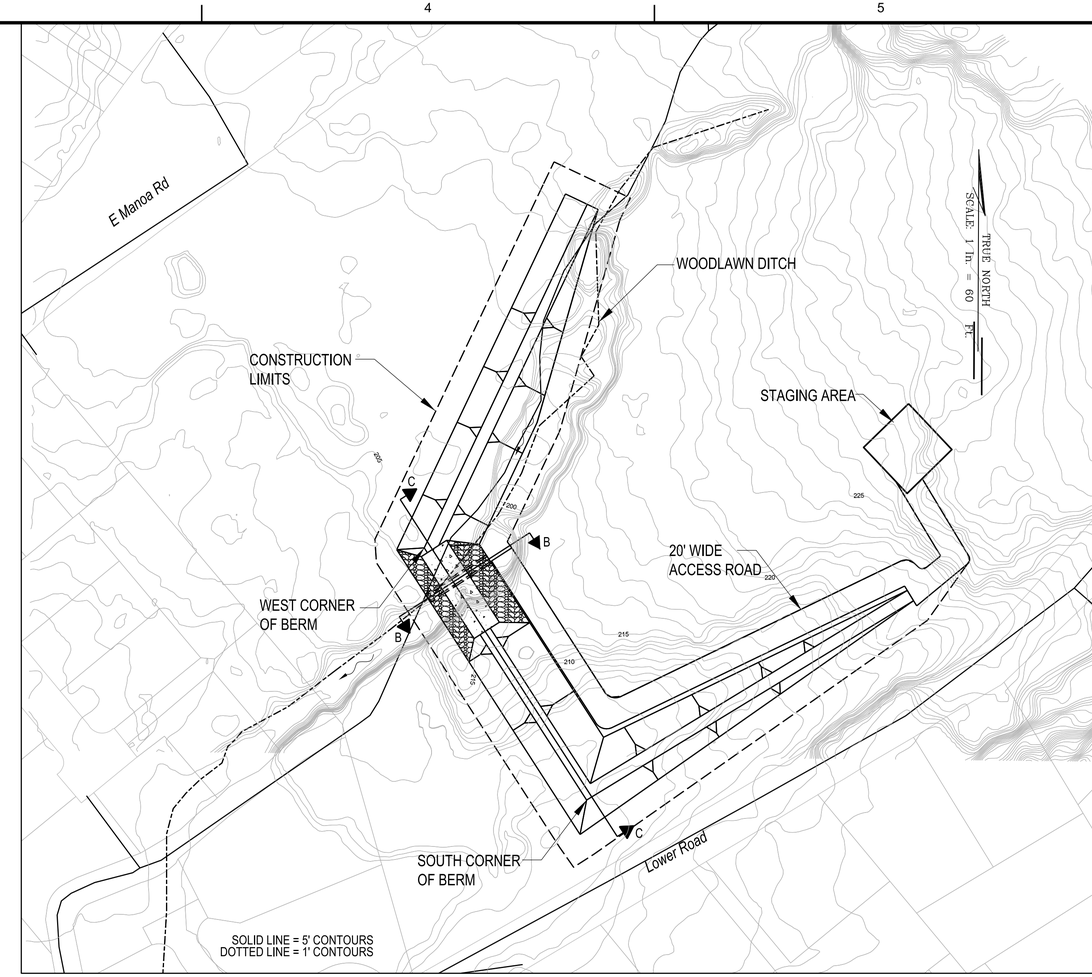
SLOTTED CONCRETE FOOTING
WOODLAWN DITCH DETENTION BASIN
SECTION D-D

SCALE: NTS



WOODLAWN DITCH DETENTION BASIN
SECTION B-B

SCALE: 1"=15'



PLAN

SCALE: 1"=60'

WOODLAWN DITCH DETENTION BASIN
SECTION C-C

SCALE: 1"=15'

15' 7.5' 0 15' 30'

SCALE: 1" = 15'

Note: All elevations are feet MSL

FILE: c:\pwworkl\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-305xx.dgn
MODEL NAME: C-305
DATE & TIME: 12/15/2014 1:48:51 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
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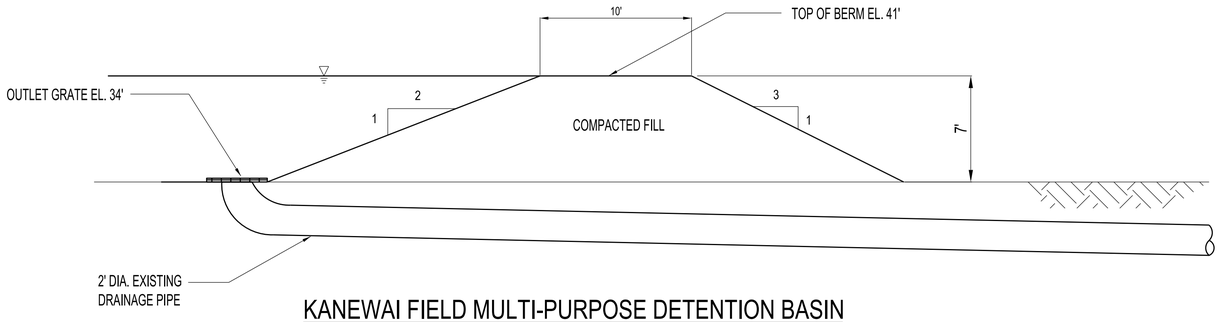
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/2014
SIZE: ANSI D
FILE NAME: WOODLAWN DITCH DETENTION BASIN, PLAN & SECTIONS.dgn
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

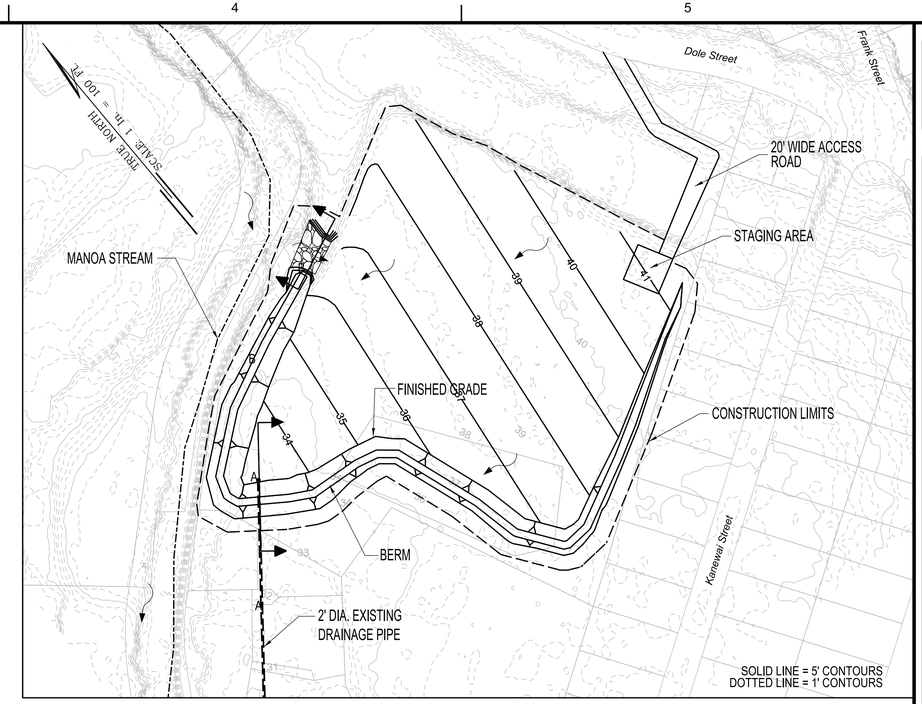
ALA WAI CANAL PROJECT

WOODLAWN DITCH DETENTION
PLAN AND SECTIONS
ALTERNATIVE 2A

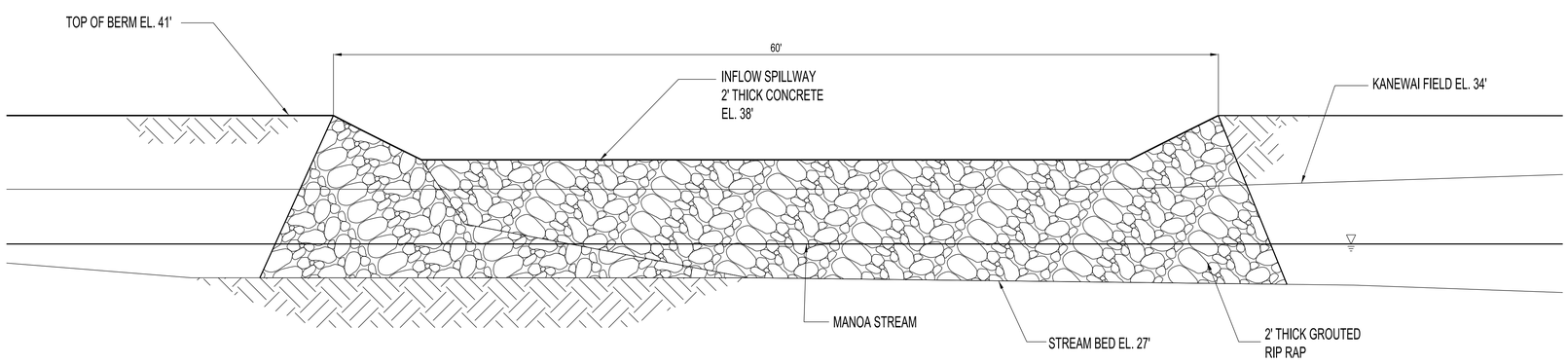
SHEET IDENTIFICATION
C-305
SHEET 10 OF 25



KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION A-A
SCALE: 1" = 5'



PLAN
SCALE: 1" = 100'



KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION B-B
SCALE: 1" = 5'

5' 2.5' 0 5' 10'
SCALE: 1" = 5'
Note: All elevations are feet MSL

US Army Corps of Engineers
Honolulu District

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY:
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
LOCATION CODE
PLOT DATE: 10/30/14
FILE NAME: KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN, PLAN AND SECTIONS
REVISION:
SOLICIT. / CONTRACT NO.:
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-306
SHEET 11 OF 25

FILE: c:\pw-work\pcb-1\j3ec9jhh\d0139948\Ala_Wai_C-306xxx.dgn
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DATE & TIME: 12/15/2014 1:52:44 PM
LAST SAVED BY: J3ECGJHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
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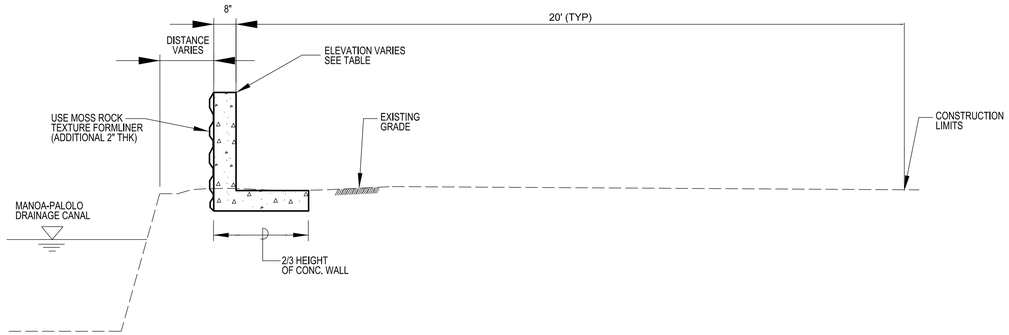
PRINTED BY: J3ECGJHH

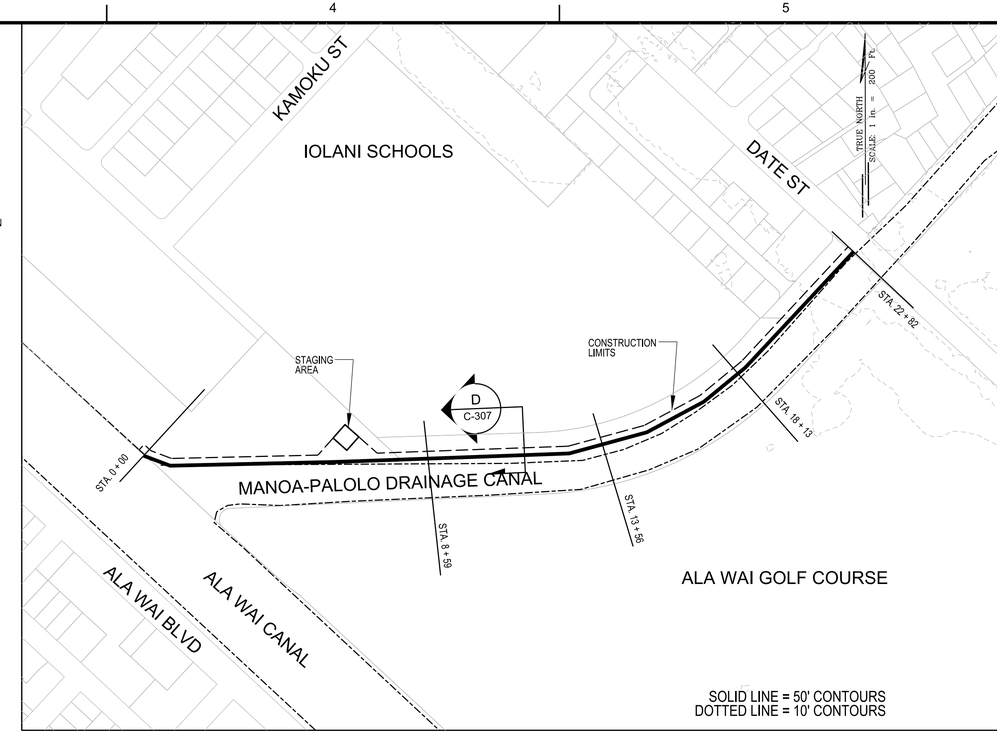


D TYPICAL CONCRETE FLOODWALL SECTION

NOT TO SCALE

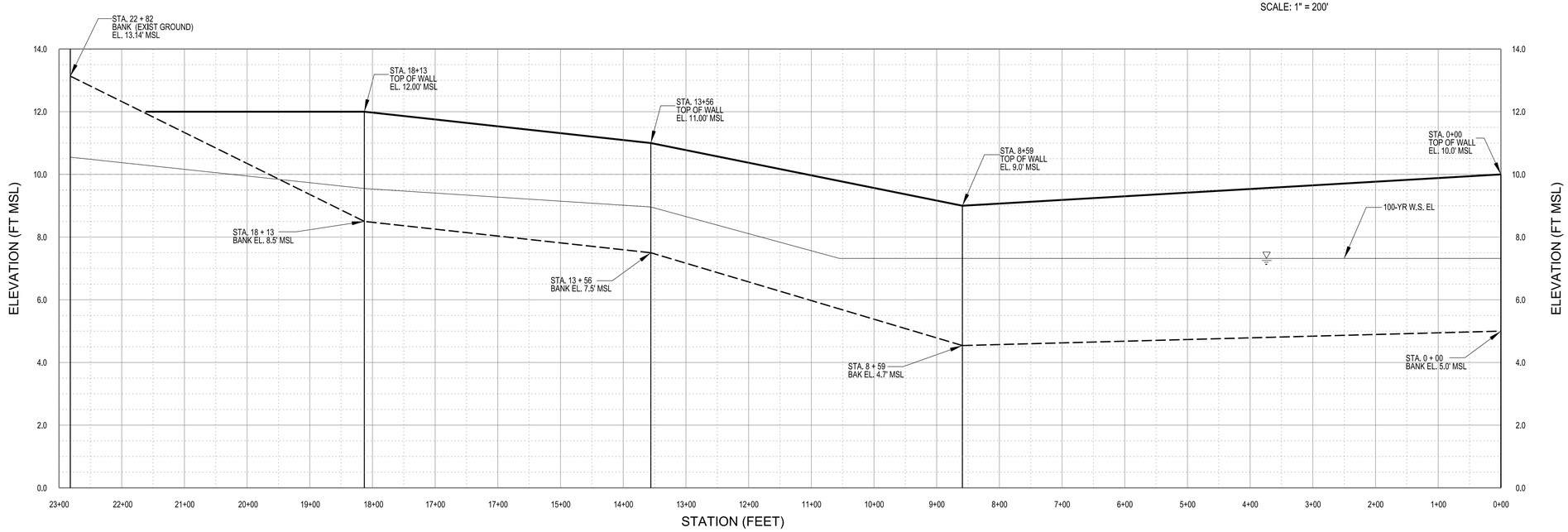
MANOA-PALOLO DRAINAGE CANAL
RIGHT BANK STA 22 + 82 TO 0 + 00

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
22 + 82	-	-
18 + 13	3.50	12.00
13 + 56	3.50	11.00
8 + 59	4.30	9.00
0 + 00	5.00	10.00



PLAN

SCALE: 1" = 200'



PROFILE
MANOA-PALOLO DRAINAGE CANAL FLOODWALL

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

US Army Corps of Engineers®
HONOLULU DISTRICT

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
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SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE: 01/30/14
FILE NAME: MANOA-PALOLO DRAINAGE CANAL FLOODWALL PLAN
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

MANOA-PALOLO DRAINAGE CANAL FLOODWALL
PLAN, PROFILE AND SECTION
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-307
SHEET 12 OF 25

FILE: c:\pw-work\pch-1\j3ec9jhh\d0139948\Ala_Wai_C-307xxx.dgn
MODEL NAME: C-301
DATE & TIME: 12/15/2014 1:55:16 PM
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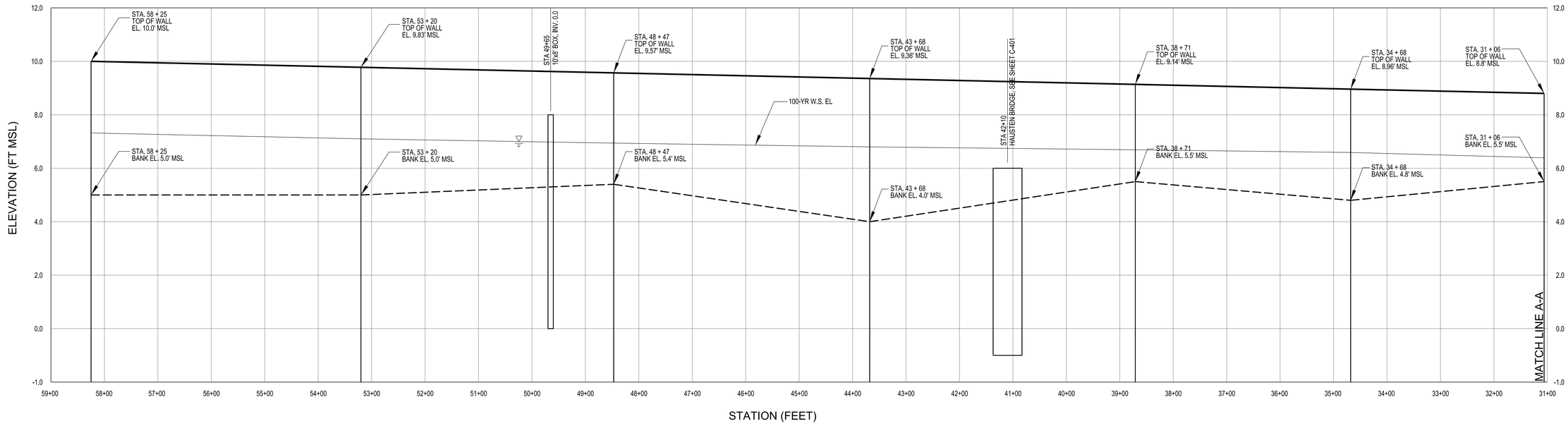
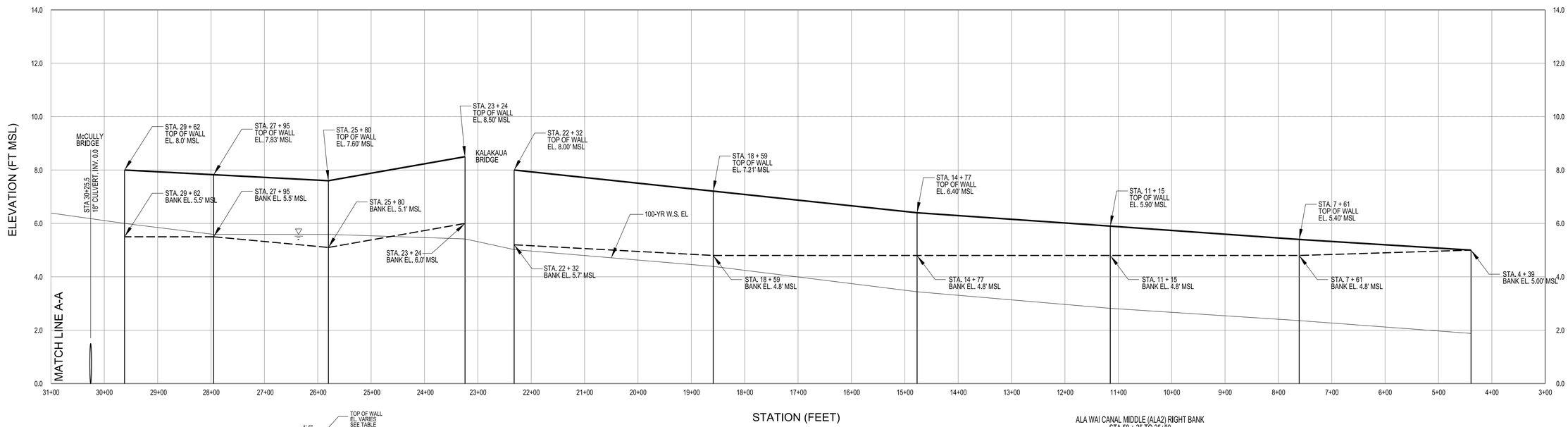
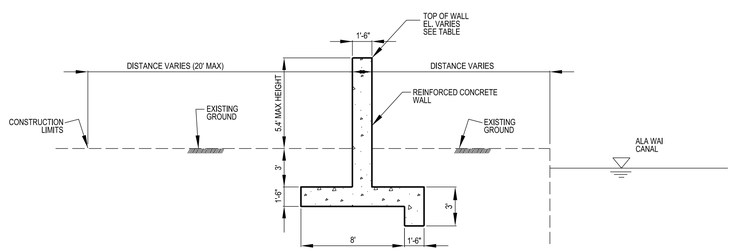
PEN TABLE: BW_and_Greyscale_Pen.tbl
PRINTED BY: J3EC9JHH







A TYPICAL RIGHT BANK REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE

PROFILE

ALA WAI MIDDLE (ALA2) AND LOWER (ALA1) RIGHT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

ALA WAI CANAL MIDDLE (ALA2) RIGHT BANK
STA 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	5.00	10.00
53 + 20	4.78	9.83
48 + 47	4.17	9.57
43 + 68	5.36	9.36
38 + 71	3.64	9.14
34 + 68	4.16	8.96
31 + 06	3.39	8.80
MCCLULLY BRIDGE		
29 + 62	2.50	8.00
27 + 95	2.33	7.83
25 + 80	2.50	7.60

ALA WAI CANAL LOWER (ALA1) RIGHT BANK
STA 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.50	8.50
KALAKAUA AVE BRIDGE		
22 + 32	2.80	8.00
18 + 59	2.41	7.21
14 + 77	1.60	6.40
11 + 15	1.10	5.90
7 + 61	0.60	5.40
4 + 39	0	5.00

US Army Corps of Engineers
HONOLULU DISTRICT

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
PLOT DATE:
FILE NAME: ALA WAI CANAL MIDDLE & LOWER RIGHT BANK PROFILE
DATE:
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

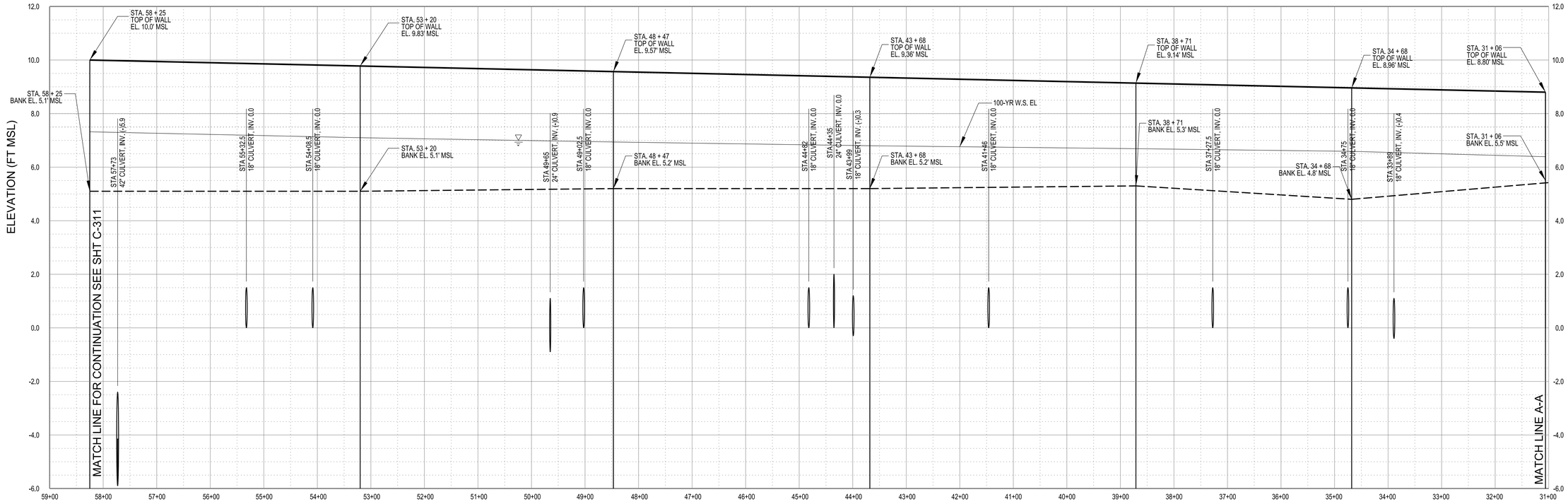
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

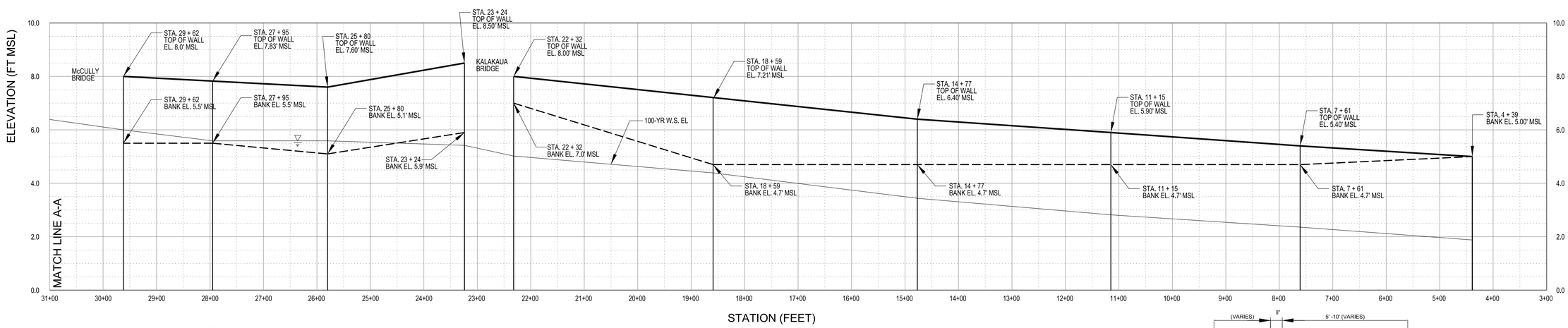
ALA WAI CANAL PROJECT

ALA WAI MIDDLE & LOWER RIGHT BANK FLOODWALLS
PROFILE AND SECTION
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-309
SHEET 13 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-309xxx.dgn
MODEL NAME: C-309
DATE & TIME: 12/15/2014 1:57:35 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH





ALA WAI CANAL MIDDLE (ALA2) LEFT BANK
STA TO 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	4.90	10.00
53 + 20	4.68	9.83
48 + 47	4.30	9.57
43 + 68	4.16	9.36
38 + 71	3.84	9.14
34 + 68	4.16	8.96
31 + 06	3.39	8.80
MCCLULLY BRIDGE		
29 + 62	2.50	8.00
27 + 95	2.33	7.83
25 + 80	2.50	7.60

ALA WAI CANAL LOWER (ALA1)LEFT BANK
STA TO 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.6	8.5
KALAKAUA BRIDGE		
22 + 32	1.00	8.00
18 + 59	2.51	7.21
14 + 77	1.70	6.40
11 + 15	1.20	5.90
7 + 61	0.70	5.40
4 + 39	0	5

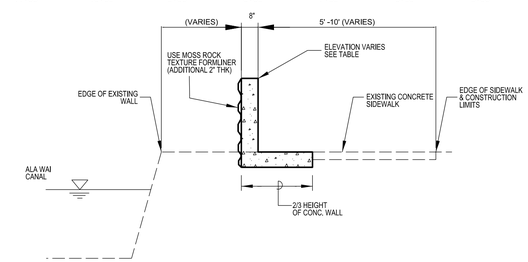
PROFILE

ALA WAI CANAL MIDDLE (ALA2) AND LOWER (ALA1) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

NOTES:

1. SEE DETAIL "C" ON SHEET C-311 FOR ALA WAI CANAL MIDDLE (ALA2) TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION.
2. ALA WAI CANAL LOWER (ALA 1) IS FROM STATION 23+24 TO STATION 4+39.



B TYPICAL ALA WAI LOWER (ALA1) LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

US Army Corps of Engineers
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
FILE NAME: ALA WAI CANAL MIDDLE & LOWER LEFT BANK PROFILE

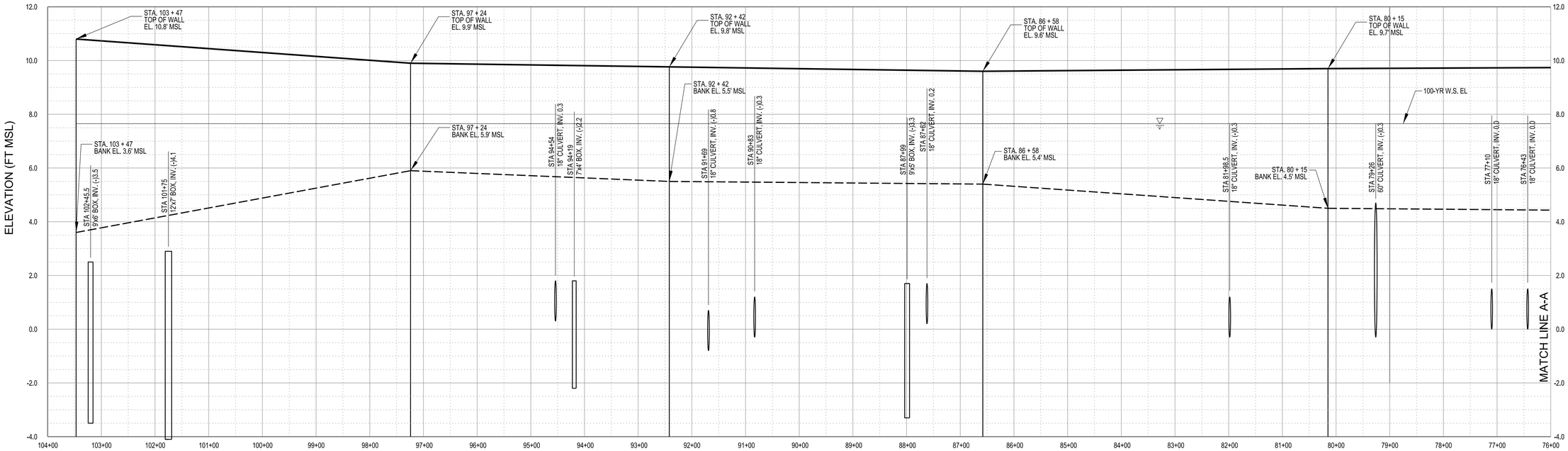
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

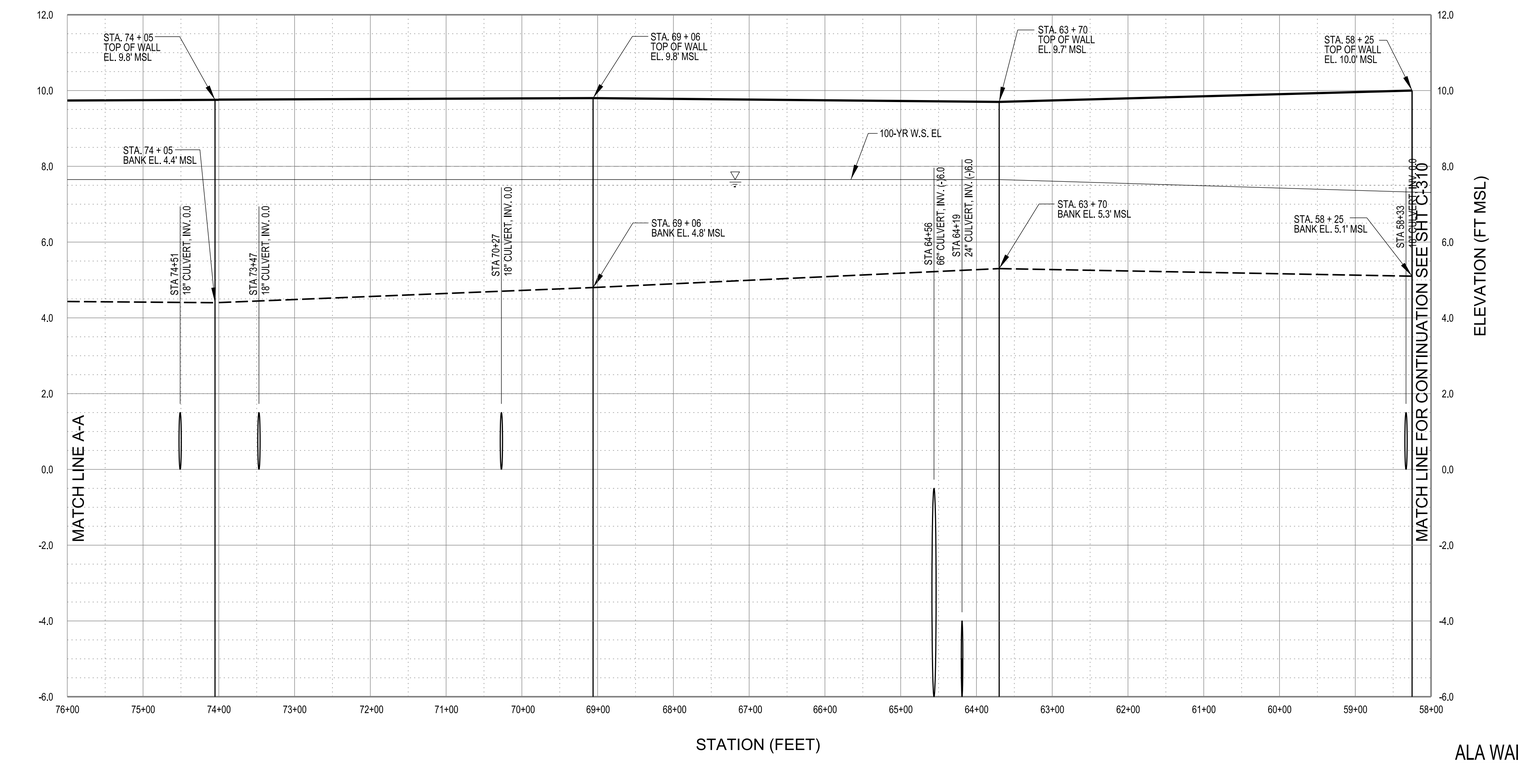
ALA WAI CANAL PROJECT

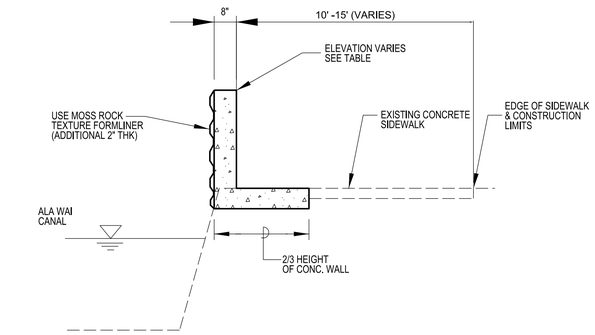
ALA WAI MIDDLE & LOWER LEFT BANK FLOODWALLS
PROFILE
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-310
SHEET 14 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d1399848\Ala_Wai_C-310xxx.dgn
MODEL NAME: C-310
DATE & TIME: 12/15/2014 2:06:11 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH







C

TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

ALA WAI CANAL UPPER (ALA3) LEFT BANK
STA 101 + 24 TO 58 + 25

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
101 + 24	7.20	10.80
97 +24	4.00	9.90
92 + 42	4.30	9.80
86 + 58	4.20	9.60
80 + 15	5.20	9.70
74 + 05	5.40	9.80
69 + 06	5.00	9.80
63 + 70	4.40	9.70
58 + 25	4.90	10.00

PROFILE

ALA WAI CANAL UPPER (ALA3) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

US Army Corps of Engineers®
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: 1:1 TO FITWIDTH
SIZE: ANSI D
DATE:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: ALA WAI CANAL UPPER LEFT BANK, PROFILE & SECTIONS
REVISION:

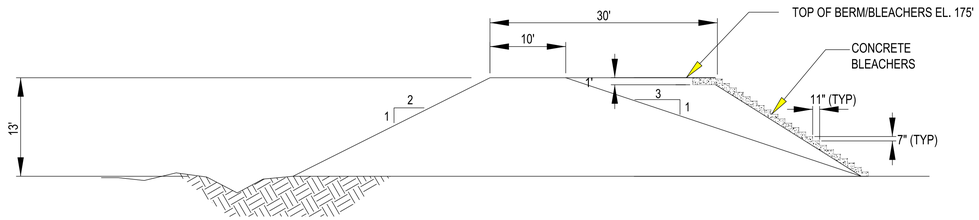
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

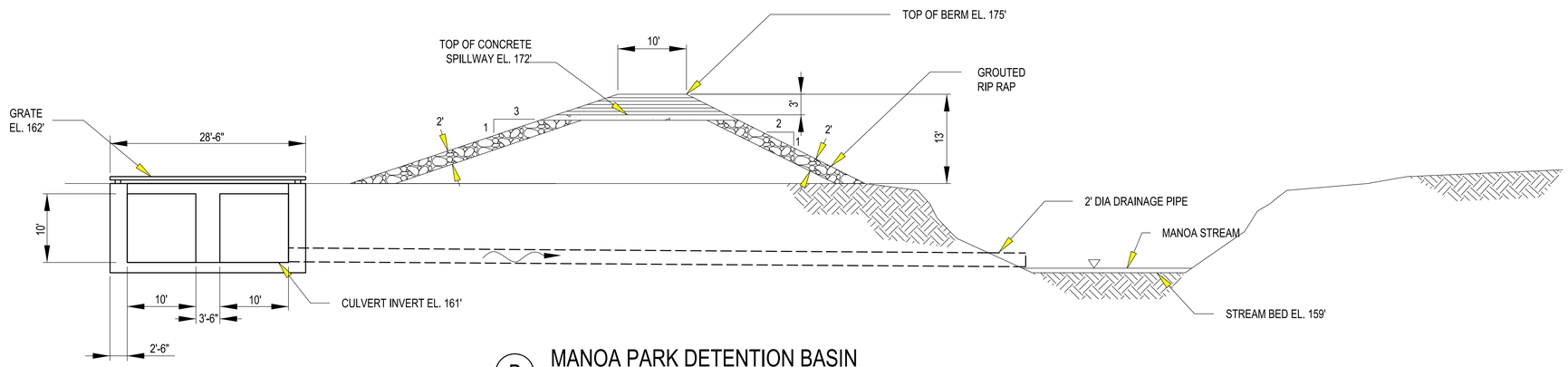
ALA WAI UPPER LEFT BANK FLOODWALLS
PROFILE
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-311
SHEET 15 OF 25

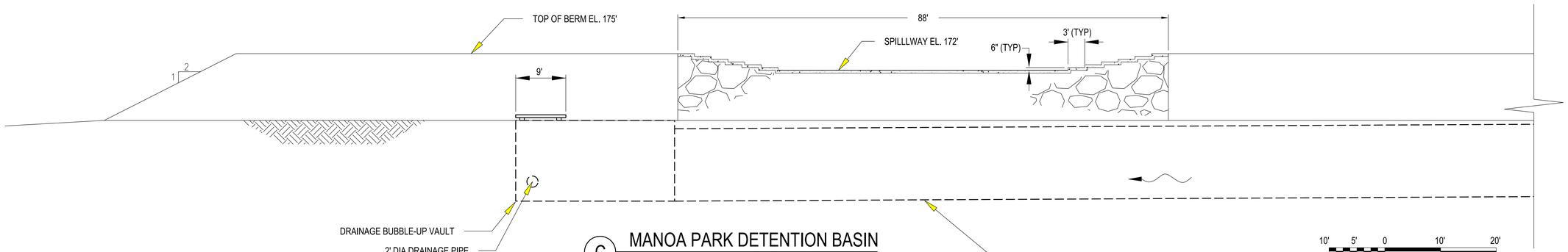
FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-311xxx.dgn
MODEL NAME: C-311
DATE & TIME: 12/15/2014 2:08:09 PM
LAST SAVED BY: j3ec9cp9
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: JJECSJHH



(A) MANOA PARK DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



(B) MANOA PARK DETENTION BASIN
SECTION B-B
SCALE: 1"=10'



(C) MANOA PARK DETENTION BASIN
SECTION C-C
SCALE: 1"=10'

10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

US Army Corps of Engineers®
Honolulu District

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/2014
SIZE: ANSI D
FILE NAME: MANOA PARK DETENTION BASIN, SECTIONS
DATE:
REVISION:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

MANOA PARK DETENTION BASIN
SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-312
SHEET16 OF25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-312xxx.dgn
MODEL NAME: C-312
DATE & TIME: 12/15/2014 2:10:44 PM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
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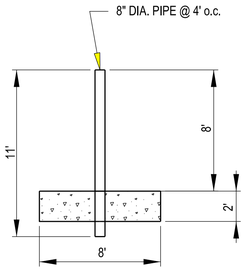
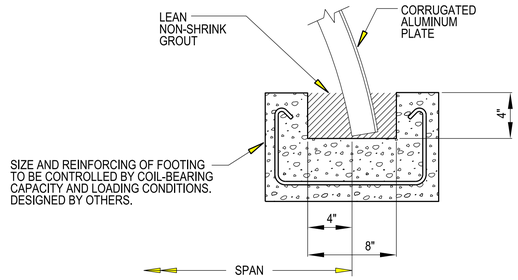


ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION A-A

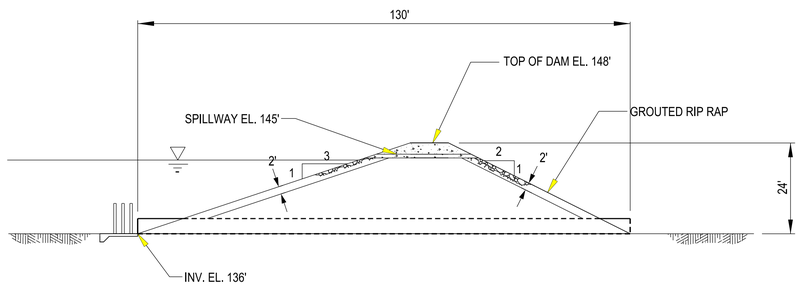
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION D-D

SCALE: NTS



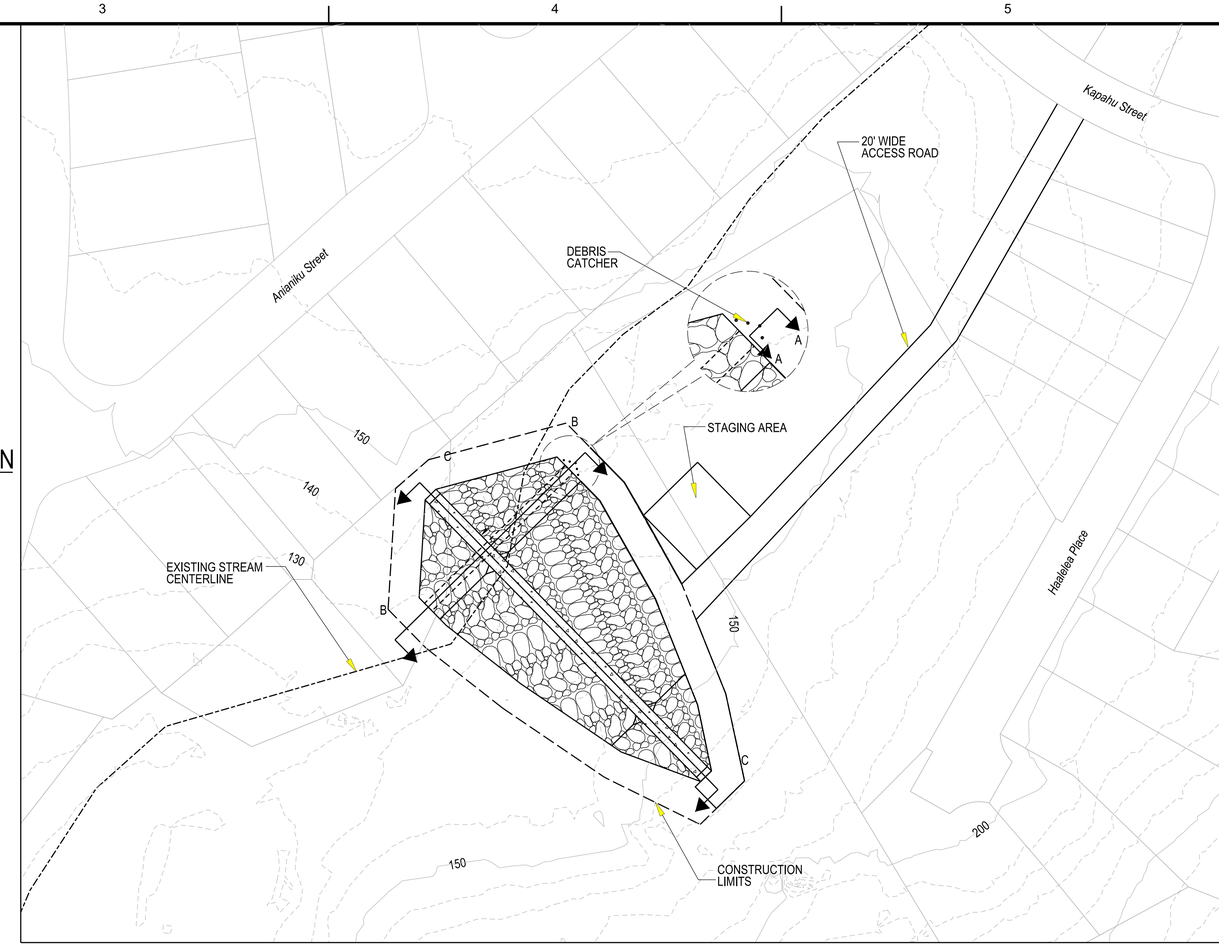
20' 10' 0 20' 40'

SCALE: 1" = 20'

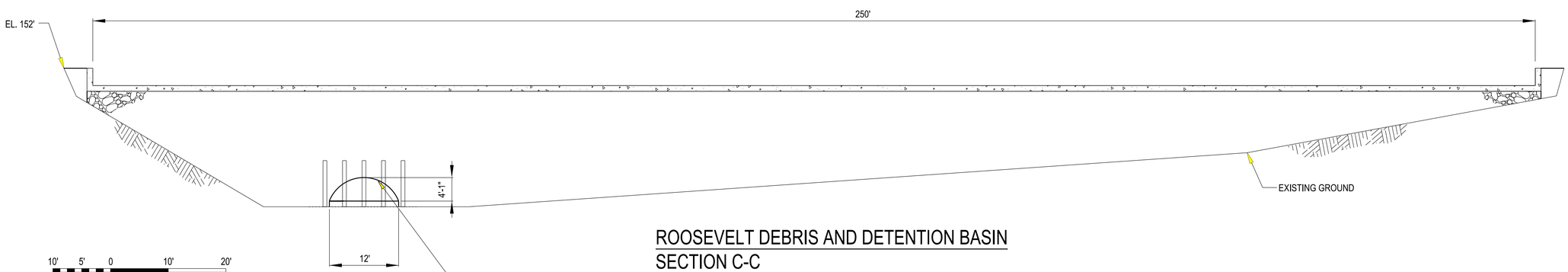
Note: All elevations are feet MSL

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION B-B

SCALE: 1"=20'



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS



10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION C-C

SCALE: 1"=20'

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JPH
DRAWN BY:
SUBMITTED BY:
DATE:
REVISION:
CHECKED BY: SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: ROOSEVELT DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ROOSEVELT DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-314
SHEET 17 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-314xxx.dgn
MODEL NAME: C-314
DATE & TIME: 12/15/2014 2:14:03 PM
LAST SAVED BY: J3EC9JHH
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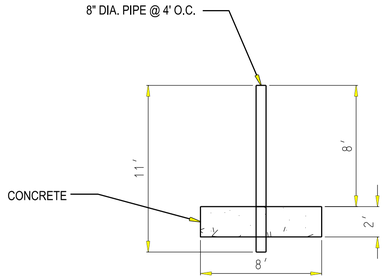
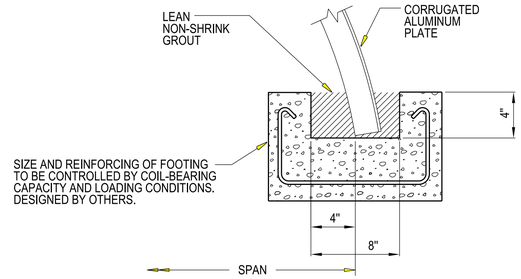
PRINTED BY: J3EC9JHH



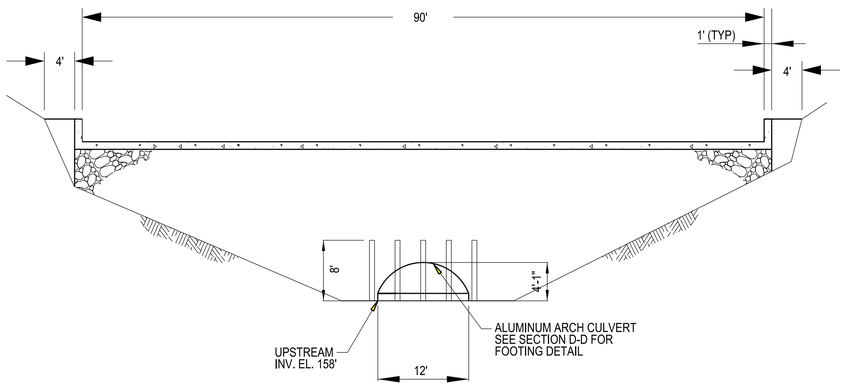
MAKIKI DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



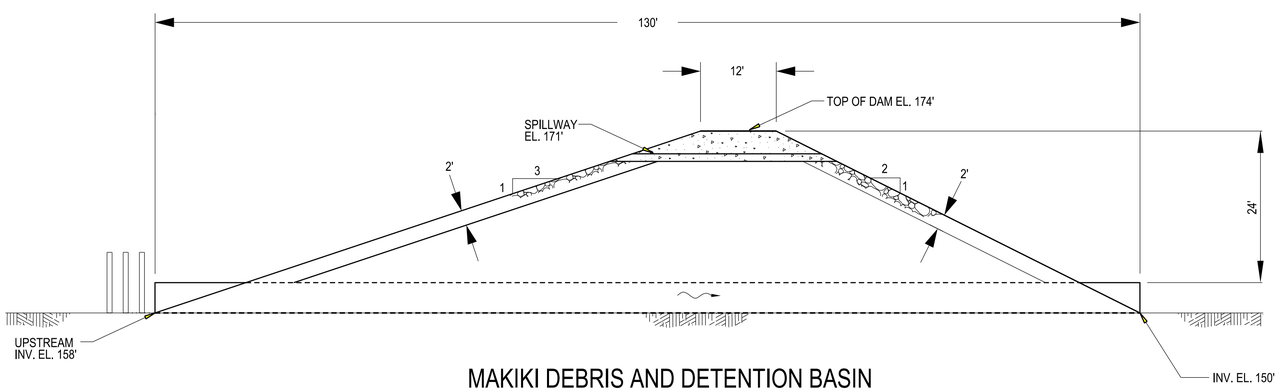
SLOTTED CONCRETE FOOTING MAKIKI DEBRIS AND DETENTION SECTION D-D

SCALE: NTS



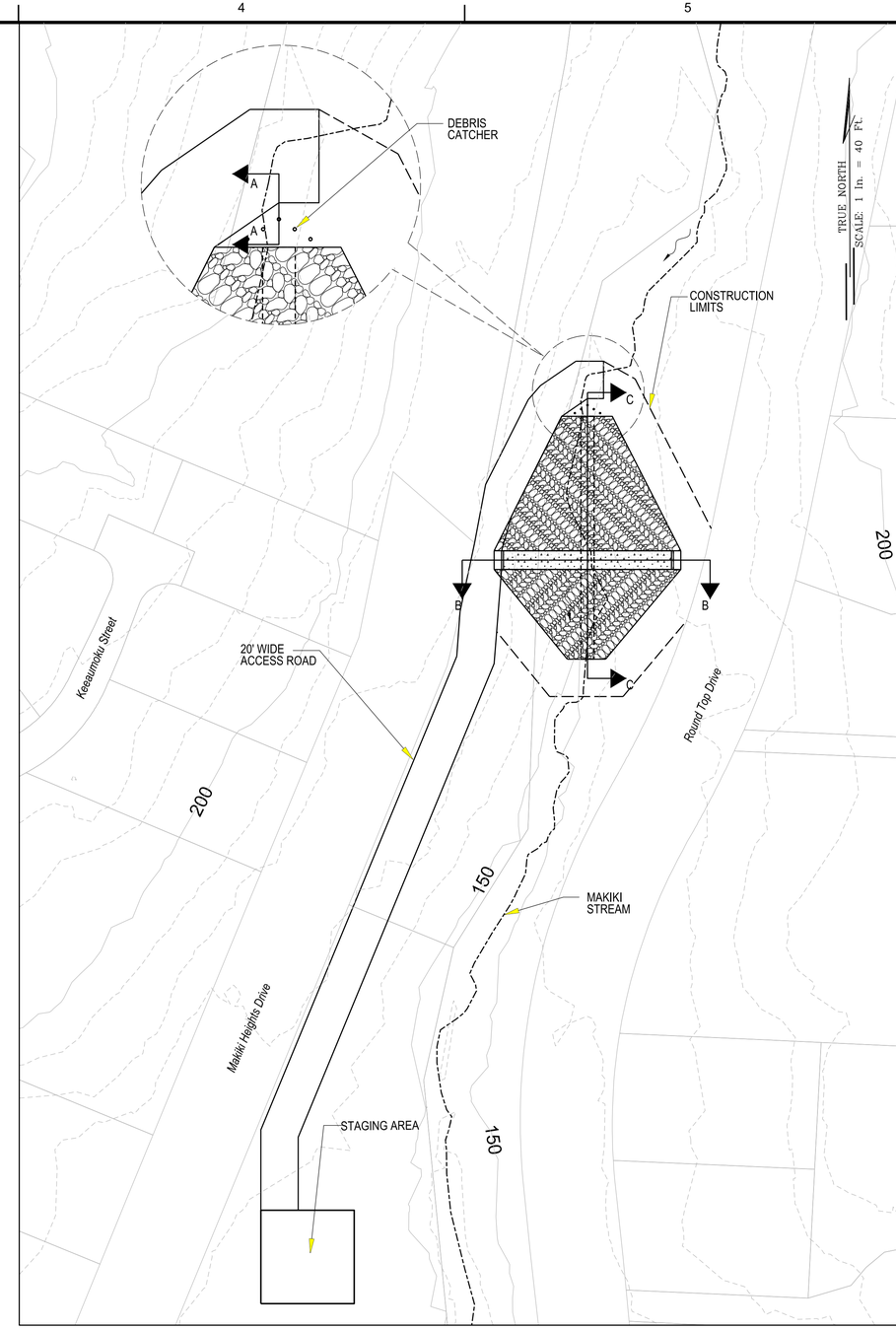
MAKIKI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'



MAKIKI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=10'



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

US Army Corps of Engineers®
Honolulu District

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: MAKIKI DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

MAKIKI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-315
SHEET 18 OF 25

FILE: c:\pwworking\honl\d0139948\Ala_Wai_C-315xxx.dgn
MODEL NAME: C-315
DATE & TIME: 12/15/2014 2:27:43 PM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\plotcfg\printer.pltcfg
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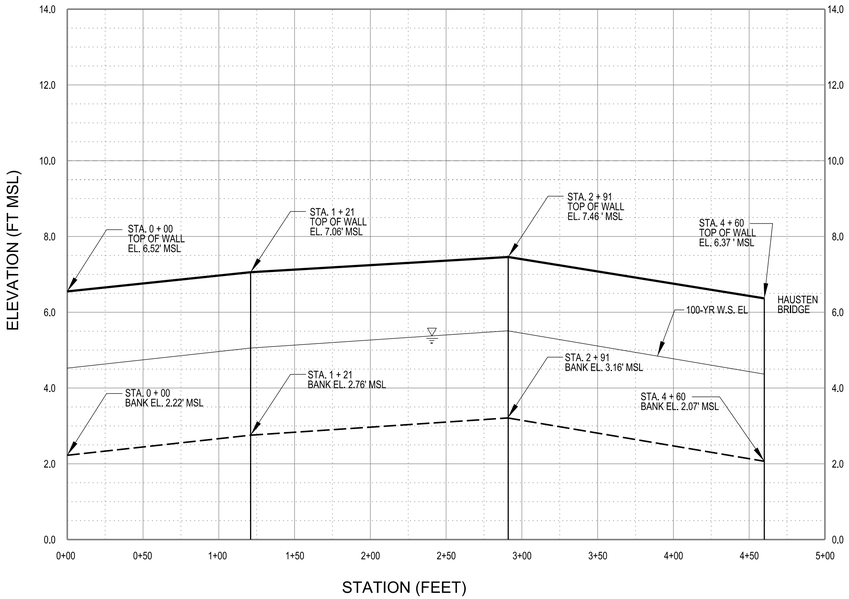
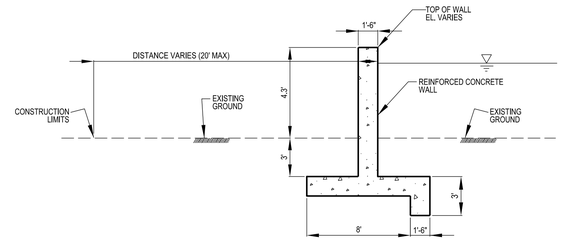


PROFILE

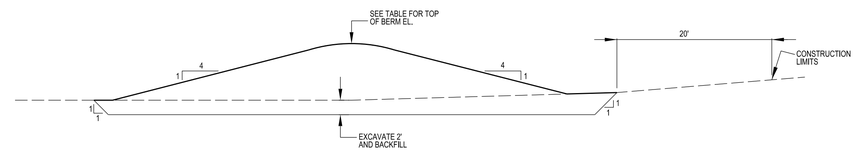
HAUSTEN DITCH RIGHT BANK FLOODWALL

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'



A TYPICAL REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE



B HAUSTEN TYPICAL EARTHEN BERM SECTION

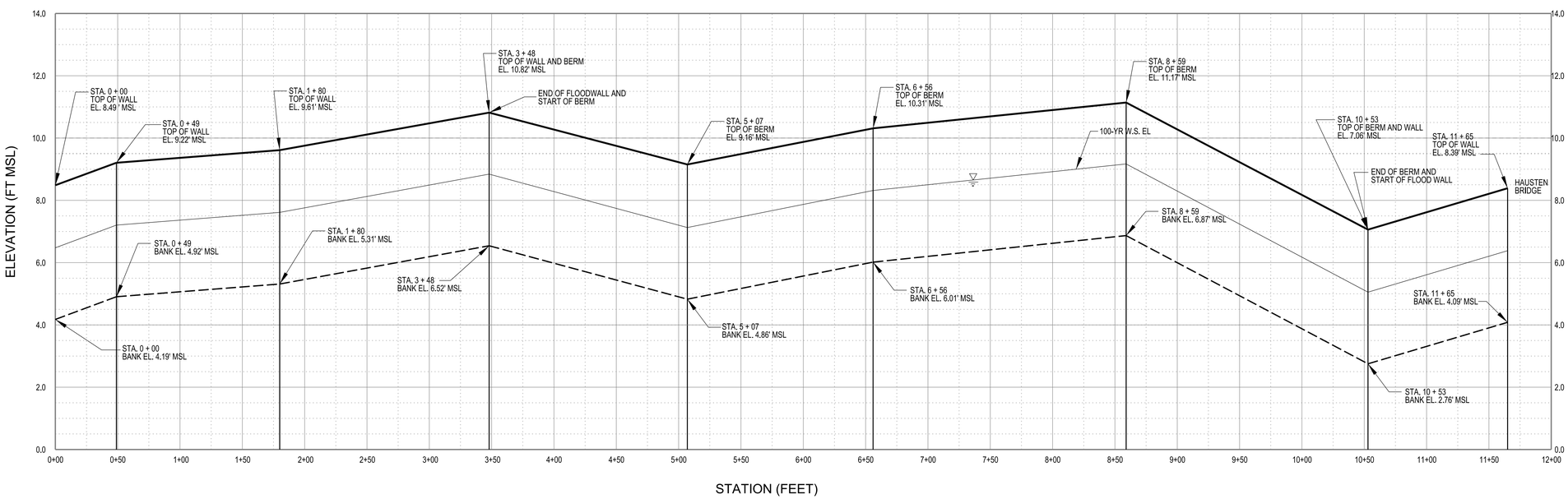
NOT TO SCALE

HAUSTEN DITCH RIGHT BANK FLOODWALL
STA TO 0 + 00 TO 4 + 60

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	6.52
1 + 21	4.30	7.06
2 + 91	4.30	7.46
4 + 60	4.30	6.37
HAUSTEN BRIDGE		

HAUSTEN DITCH LEFT BANK
FLOODWALL AND BERM
STA TO 0 + 00 TO 11 + 65

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	8.49
0 + 49	4.30	9.22
1 + 80	4.30	9.61
3 + 48	4.30	10.82
END OF FLOODWALL AND START OF BERM		
3 + 48	4.30	10.82
5 + 07	4.30	9.16
6 + 56	4.30	10.31
8 +59	4.30	11.17
10 + 53	4.30	7.06
END OF BERM AND START OF FLOODWALL		
10 + 53	4.30	7.06
11 + 65	4.30	8.39
HAUSTEN BRIDGE		



PROFILE

HAUSTEN DITCH LEFT BANK FLOODWALL AND BERM

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'

US Army Corps of Engineers
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JHH
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SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1 HORIZONTAL
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN DITCH, PROFILE & SECTIONS

ALA WAI CANAL PROJECT

HAUSTEN DITCH FLOODWALL AND BERM
PROFILE AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-316
SHEET 19 OF 25

FILE: c:\pw-work\poh-1\j3ec9jhh\d0139948\Ala_Wai_C-316xxx.dgn
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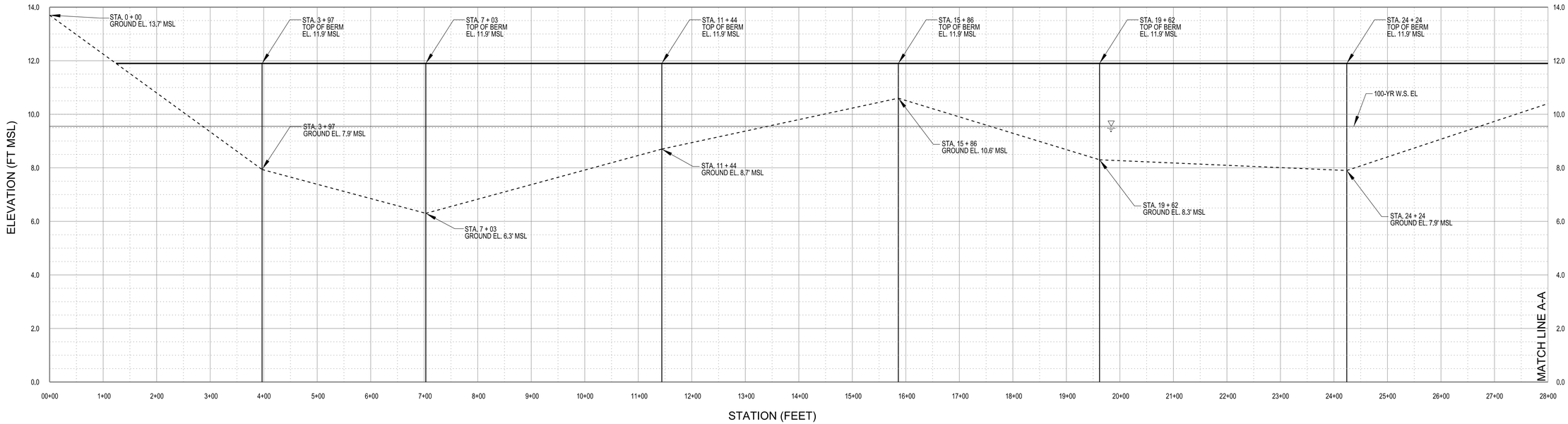
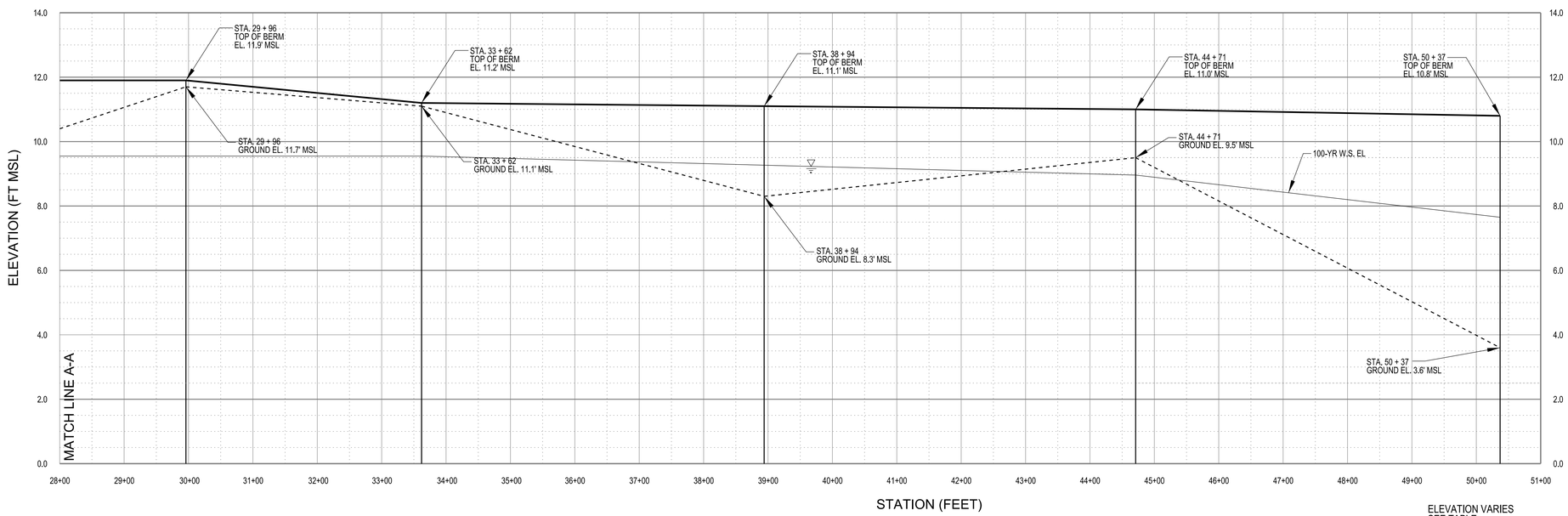




ALA WAI GOLF COURSE BERM PROFILE

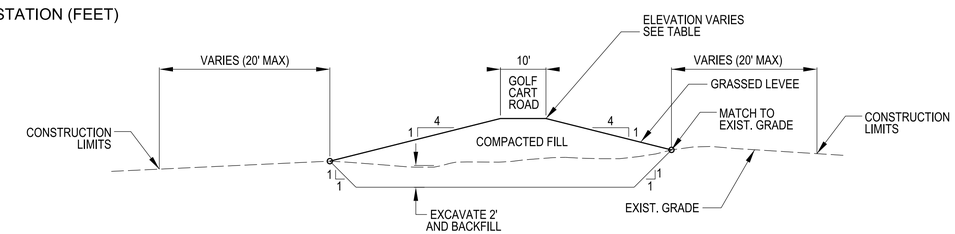
SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

ALA WAI GOLF COURSE BERM
STA 0 + 00 TO 50 + 37

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	-	-
3 + 97	4.0	11.9
7 + 03	5.6	11.9
11 + 44	3.2	11.9
15 + 86	1.3	11.9
19 + 62	3.6	11.9
24 + 24	4.0	11.9
29 + 96	0.2	11.9
33 + 62	0.1	11.2
38 + 94	2.8	11.1
44 + 71	1.5	11.0
50 + 37	7.2	10.8

NOTES:

1. NEW GOLF CART ROAD IS 2' THICK AC PAVEMENT.



A TYPICAL LEVEE SECTION
NOT TO SCALE

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LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: ALA WAI GOLF COURSE, PROFILE & SECTION

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE BERMING
PROFILE AND SECTION
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-317
SHEET 20 OF 25

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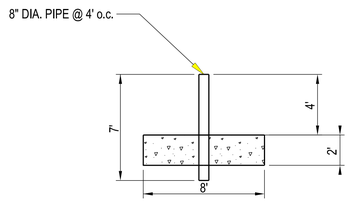
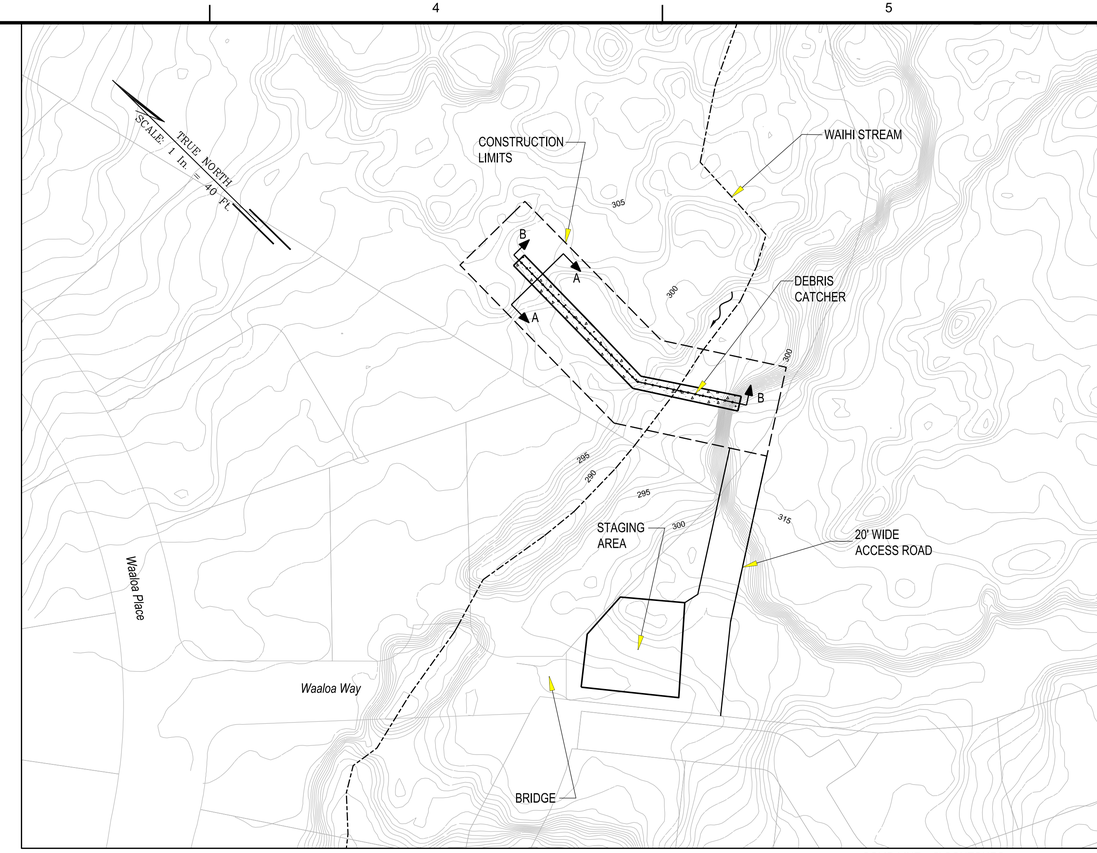
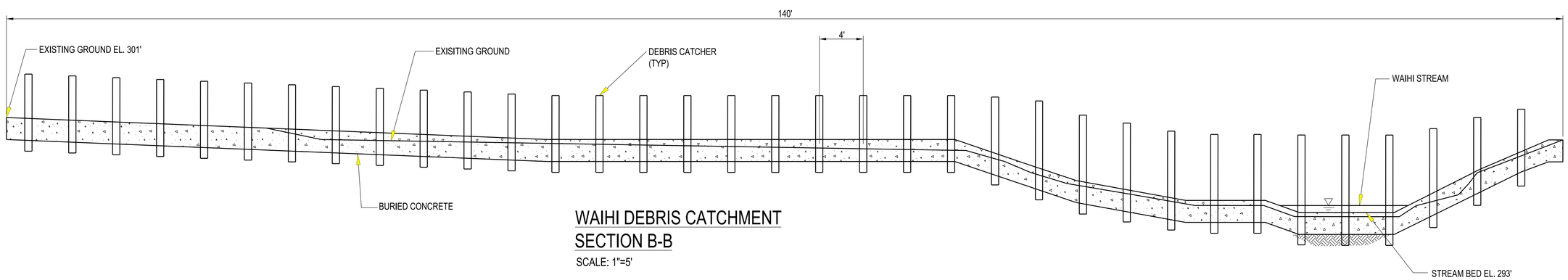


WAIHI DEBRIS CATCHMENT
SECTION A-A
SCALE: 1"=5'



PLAN
SCALE: 1"=40'

SOLID LINE = 5' CONTOURS
DOTTED LINE = 1' CONTOURS



WAIHI DEBRIS CATCHMENT
SECTION B-B
SCALE: 1"=5'

5' 2.5' 0' 5' 10'
SCALE: 1" = 5'

Note: All elevations are feet MSL

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PLOT SEED FILE: ANSI D | FILE NAME: WAIHI DEBRIS CATCHMEN_PLAN & SECTIONS
DRAWING NUMBER:

ALA WAI CANAL PROJECT

WAIHI DEBRIS CATCHMENT
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-319
SHEET 21 OF 25

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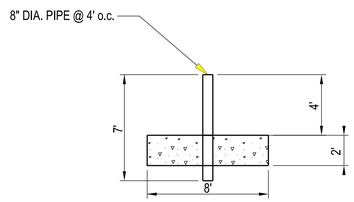
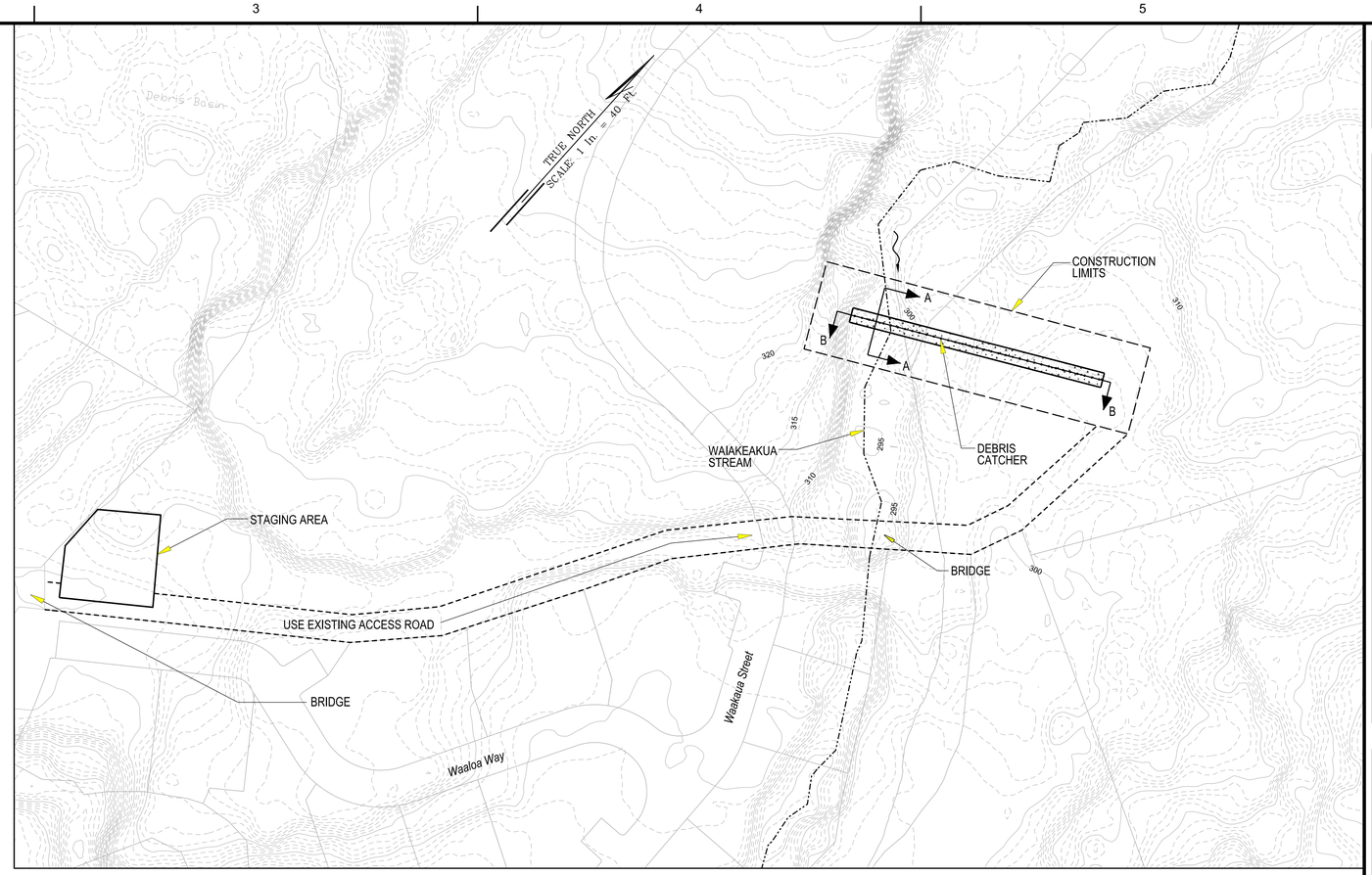


WAIAKEAKUA DEBRIS CATCHMENT SECTION A-A

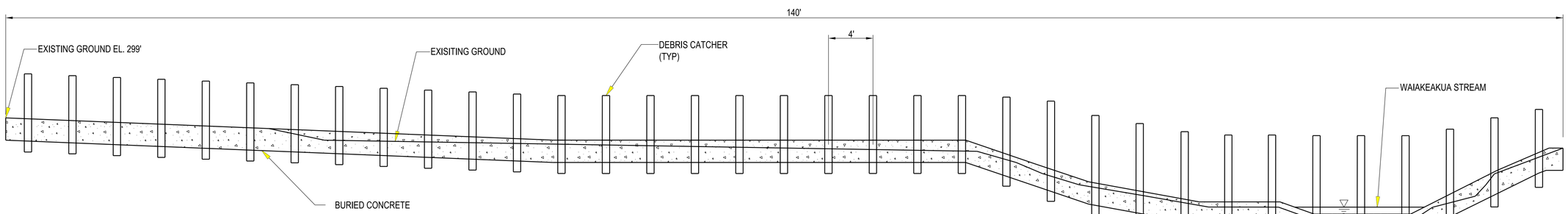
SCALE: 1"=5'



PLAN

SCALE: 1"=40'

SOLID LINE = 5' CONTOURS
DOTTED LINE = 1' CONTOURS



WAIKEAKUA DEBRIS CATCHMENT SECTION B-B

SCALE: 1"=5'

5 2.5' 0 5 10

SCALE: 1" = 5'
Note: All elevations are feet MSL

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PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: WAIAKEAKUA DEBRIS CATCHMENT_PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WAIAKEAKUA DEBRIS CATCHMENT
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-320
SHEET 22 OF 25

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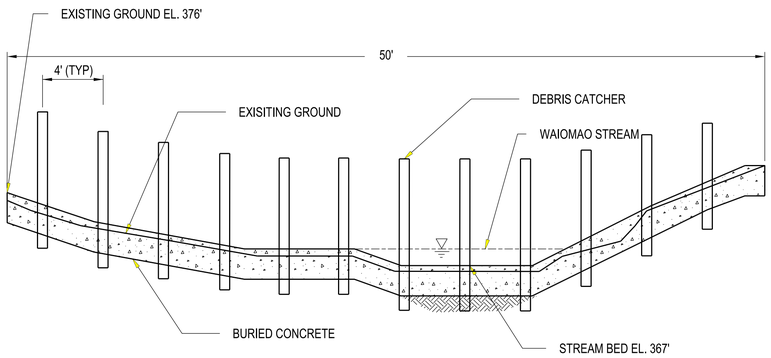
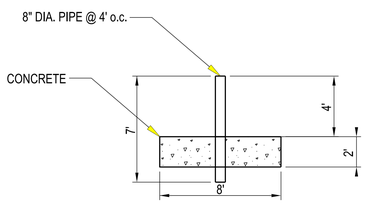
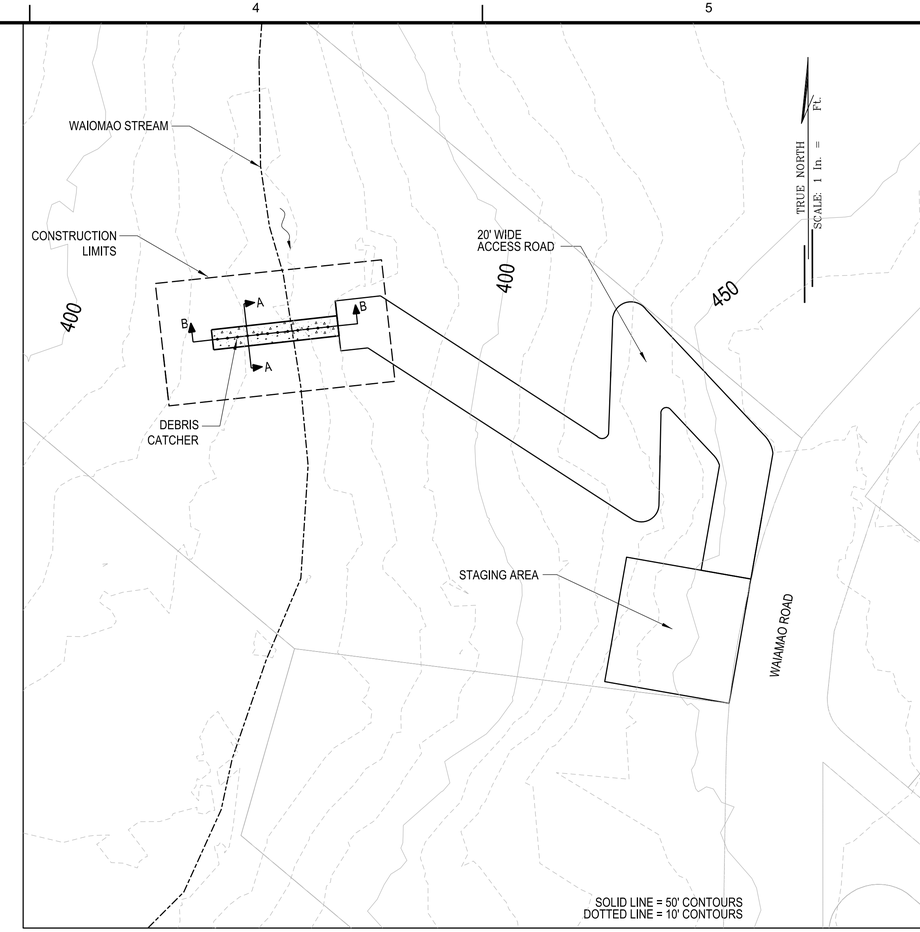


WAIOMAO DEBRIS CATCHMENT
SECTION B-B
SCALE: 1"=5'



WAIOMAO DEBRIS CATCHMENT
SECTION A-A
SCALE: 1"=5'



PLAN
SCALE: 1"=35'

10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL

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LOCATION CODE
DRAWING NUMBER:
PLOT DATE: 1/15/2014
FILE NAME: WAIOMAO DEBRIS CATCHMENT PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
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HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WAIOMAO DEBRIS CATCHMENT
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-321
SHEET 23 OF 25

JHH

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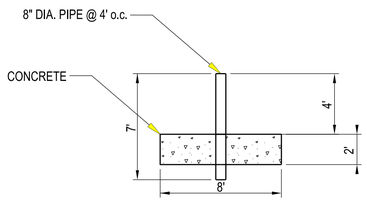
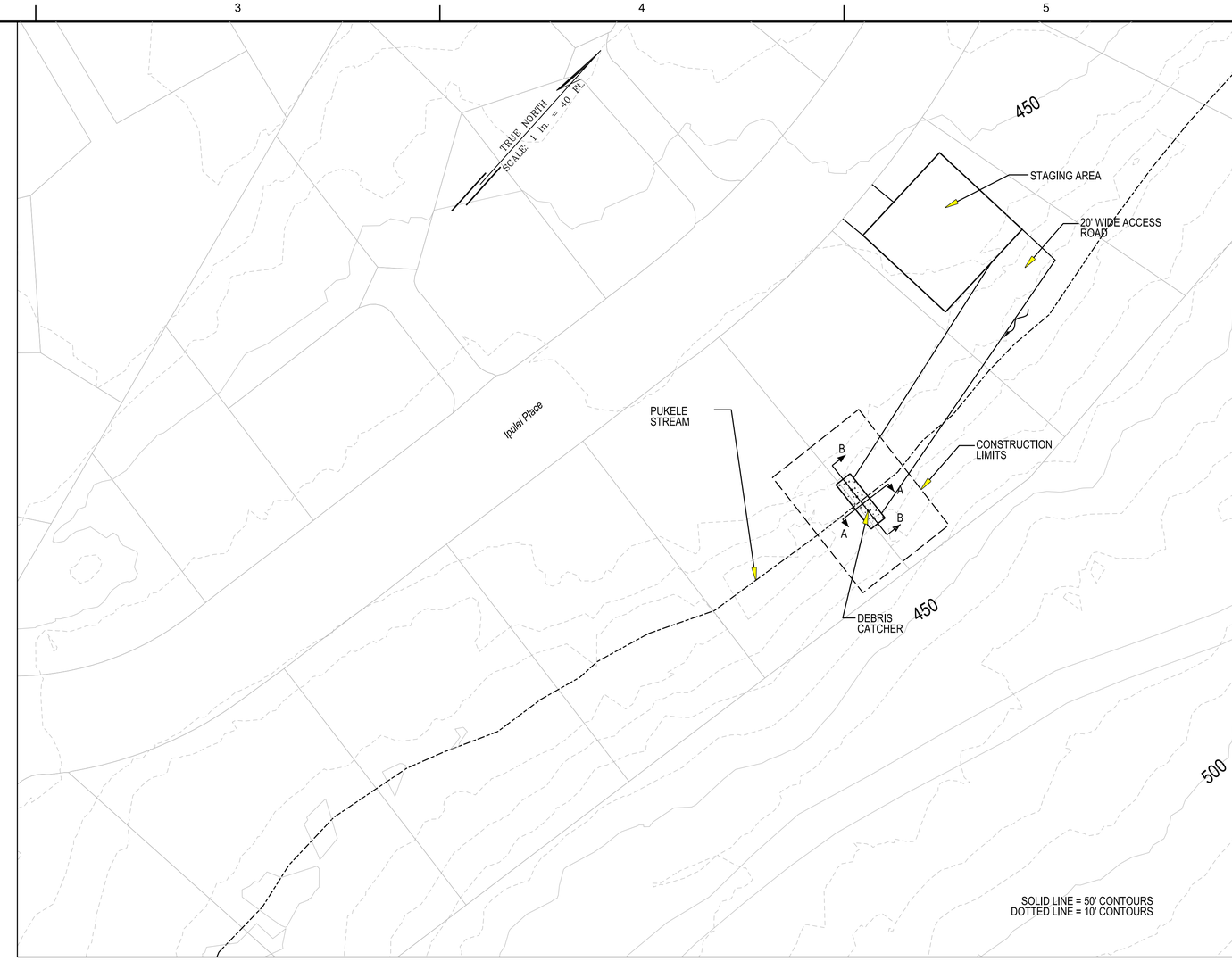


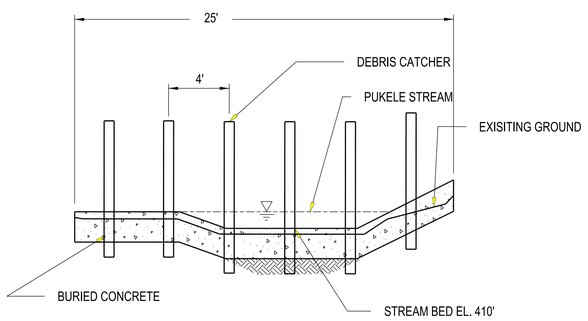
PUKELE DEBRIS CATCHMENT BASIN SECTION A-A

SCALE: 1"=5'



PLAN

SCALE: 1"=40'



PUKELE DEBRIS CATCHMENT SECTION B-B

SCALE: 1"=5'

5 2.5' 0 5 10

SCALE: 1" = 5'

Note: All elevations are feet MSL

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LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
VERIFY SCALE
FILE NAME: PUKELE DEBRIS CATCHMENT PLAN & SECTIONS

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HONOLULU, HAWAII

ALA WAI CANAL PROJECT

PUKELE DEBRIS CATCHMENT
PLAN AND SECTIONS
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-322
SHEET 24 OF 25

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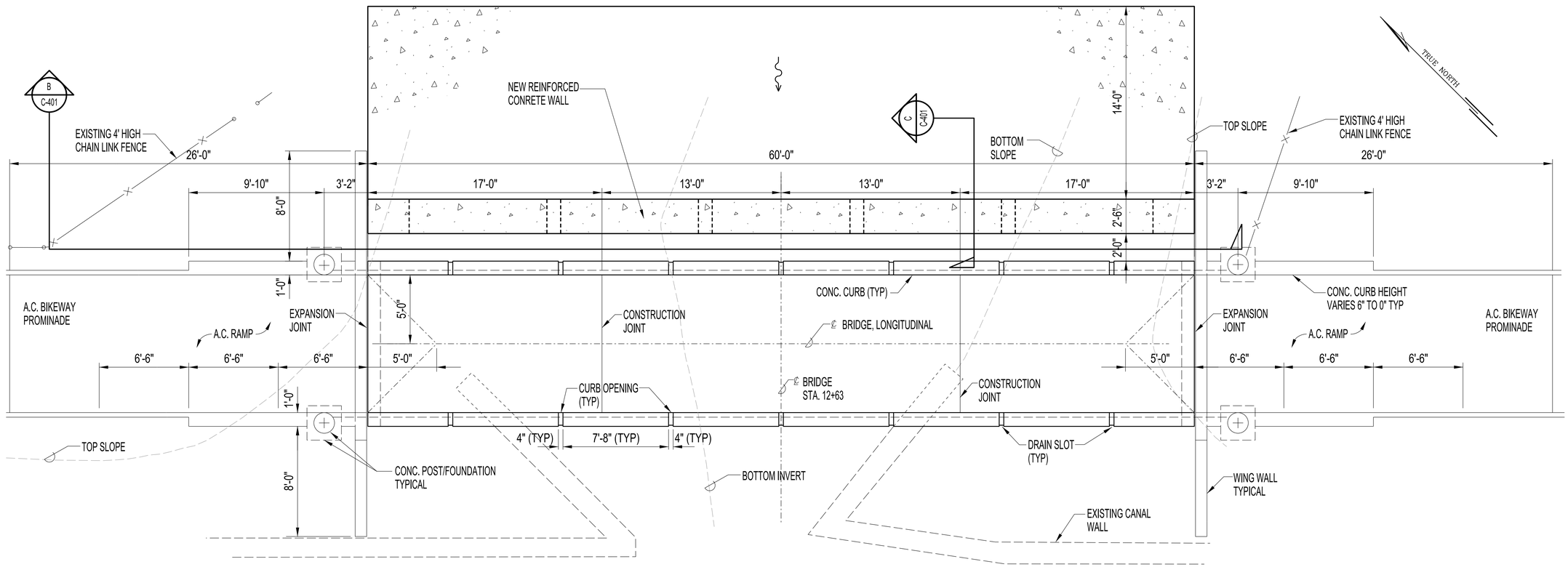
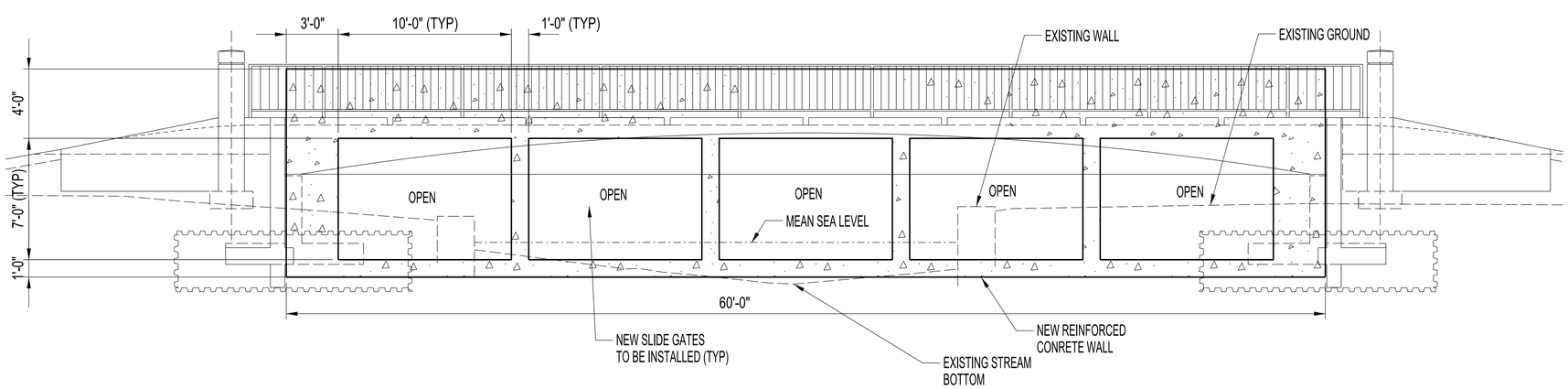


ALA WAI CANAL

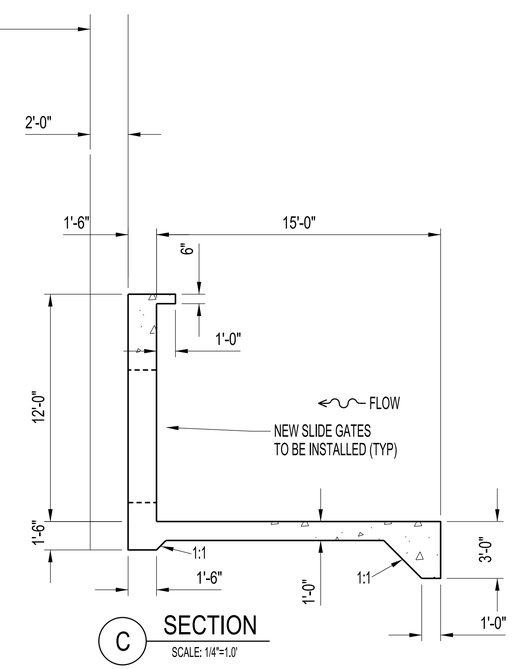
A PLAN

SCALE: 1/4"=1.0'



B ELEVATION

SCALE: 1/4"=1.0'



C SECTION

SCALE: 1/4"=1.0'

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PLOT DATE: 1/15/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN BRIDGE PLAN & SECTIONS

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HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

HAUSTEN BRIDGE CONCRETE WALL
PLAN, SECTION AND ELEVATION
ALTERNATIVE 2A

SHEET IDENTIFICATION
C-401
SHEET 25 OF 25

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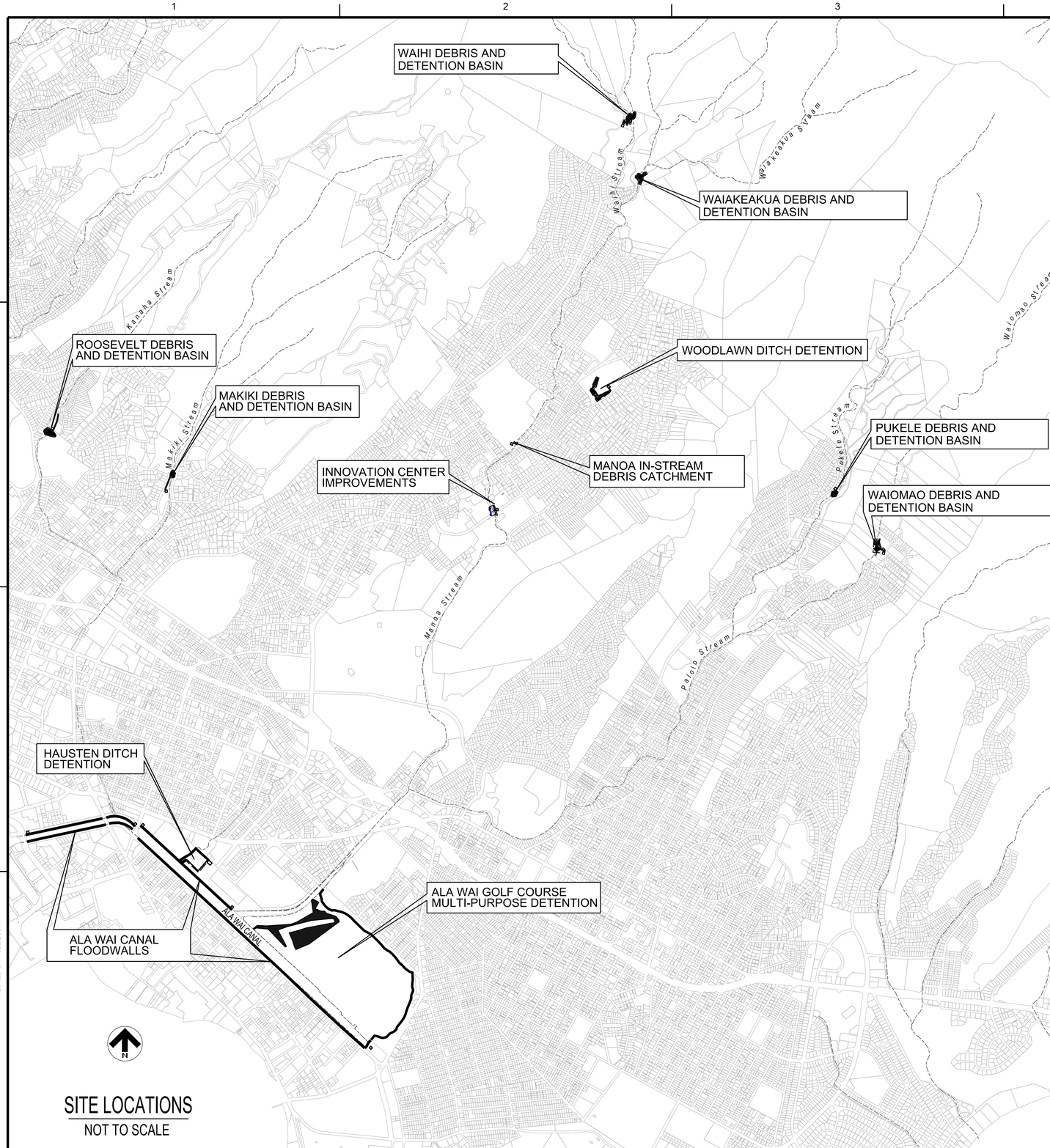
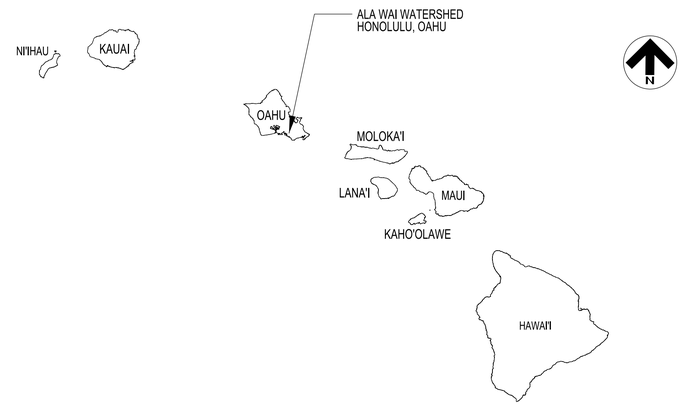
ALA WAI CANAL PROJECT
ALTERNATIVE 3A
HONOLULU, OAHU, HI

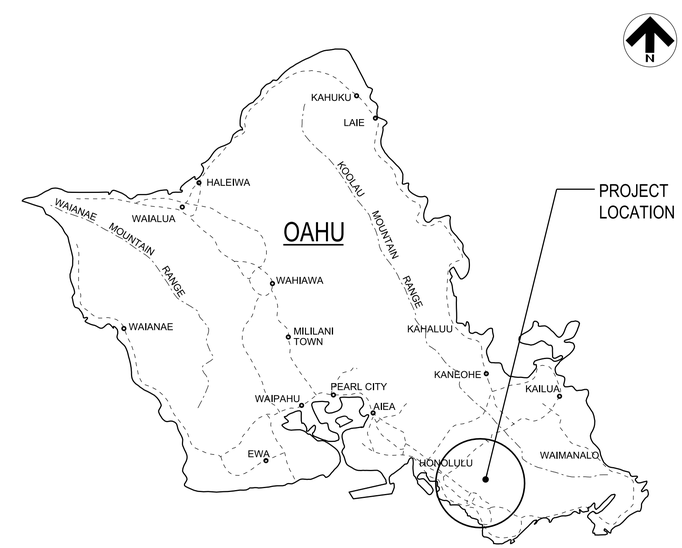


SITE LOCATIONS
NOT TO SCALE

PROJECT TITLE



VICINITY MAP
NOT TO SCALE



PROJECT LOCATION
NOT TO SCALE

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PLOT SCALE:
PLOT DATE:
DRAWING NUMBER:
SCALE:
SIZE: ANSI D
FILE NAME: Cover Sheet - Site Locations, Vicinity Map, Project Location

ALA WAI CANAL PROJECT

SITE LOCATIONS
PROJECT LOCATION & VICINITY MAP
ALTERNATIVE 3A

SHEET IDENTIFICATION
G-001A
SHEET 1 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhhd\0145830\Ala_Wai_G-001Axx.dgn
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PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH

ALA WAI CANAL PROJECT - ALTERNATIVE 3A
INDEX TO DRAWINGS

SHT. NO	SHT. REF. NO.	DESCRIPTION
1	G-001A	SITE LOCATIONS, PROJECT LOCATION AND VICINITY MAP
2	G-002A	INDEX TO DRAWINGS
3	C-101A	ALA WAI CANAL FLOODWALLS, SITE PLAN
4	C-102A	HAUSTEN DITCH DETENTION, SITE PLAN
5	C-103A	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PLAN
6	C-301	WAIHI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
7	C-302	WAIAKEAKUA DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
8	C-304A	INNOVATION CENTER IMPROVEMENTS, PLAN AND SECTIONS
9	C-305A	WOODLAWN DITCH DETENTION BASIN, PLAN AND SECTIONS
10	C-308	WAIOMAO DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
11	C-309A	ALA WAI CANAL MIDDLE AND LOWER RIGHT BANK, PROFILE AND SECTION
12	C-310A	ALA WAI CANAL MIDDLE AND LOWER RIGHT BANK, PROFILE
13	C-311A	ALA WAI CANAL UPPER LEFT BANK, PROFILE
14	C-313	PUKELE DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
15	C-314A	ROOSEVELT DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
16	C-315A	MAKIKI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
17	C-316A	HAUSTEN DITCH DETENTION FLOODWALLS AND BERM, PROFILE AND SECTIONS
18	C-317A	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE AND SECTION
19	C-318	MANOA IN-STREAM DEBRIS CATCHMENT, PLAN AND SECTIONS
20	C-401A	HAUSTEN BRIDGE CONCRETE WALL, PLAN, SECTION AND ELEVATION

GENERAL NOTES:

1. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. COORDINATE SYSTEM: NAD 1983 (HARN), HAWAII ZONE 3 (US FEET)
3. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
4. UNLESS SHOWN OTHERWISE, ALL DISTURBED AREAS NOT RECEIVING A HARD SURFACE SHALL BE COVERED WITH GRASS.
5. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
6. EXISTING UNDERGROUND UTILITIES OBTAINED FROM AS-BUILTS AND FROM FIELD SURVEYS. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION AND PROTECT ALL EXISTING UTILITIES DURING CONSTRUCTION.
7. THERE WILL BE A FLOODWARNING SYSTEM INSTALLED FOR THIS PROJECT.

GENERAL ABBREVIATIONS

A.C.	ASHPALT CONCRETE
AVE	AVENUE
BLVD	BOULEVARD
CONC	CONCRETE
DIA	DIAMETER
EL	ELEVATION
EXIST	EXISTING
FT	FOOT, FEET
IN	INCH, INCHES
INV	INVERT
LB	LEFT BANK
MAX	MAXIMUM
MSL	MEAN SEA LEVEL
NTS	NOT TO SCALE
o.c.	ON CENTER
O&M	OPERATIONS AND MAINTENANCE
PL	PLACE
RB	RIGHT BANK
RCP	REINFORCED CONCRETE PIPE
RD	ROAD
ST	STREET
STA	STATION
THK	THICK
TMK	TAX MAP KEY
TYP	TYPICAL
W.S.	WATER SURFACE
YR	YEAR

SYMBOLS

&	AND
@	AT
℄	CENTER LINE
'	FOOT, FEET
"	INCH, INCHES

US Army Corps of Engineers
Honolulu District

10% DESIGN

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US ARMY CORPS OF ENGINEERS
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HONOLULU, HAWAII

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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: 1:1 | PLOT DATE:
SCALE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: Index Of Drawings, General Notes & Abbreviations - Alternative 3A.dgn

ALA WAI CANAL PROJECT

INDEX OF DRAWINGS, GENERAL NOTES
ABBREVIATIONS & SYMBOLS
ALTERNATIVE 3A

SHEET IDENTIFICATION
G-002A
SHEET 2 OF 20

FILE: c:\pw-work\poh-1\j3esj9hh\d0145830\Ala_Wai_G-002Axx.dgn
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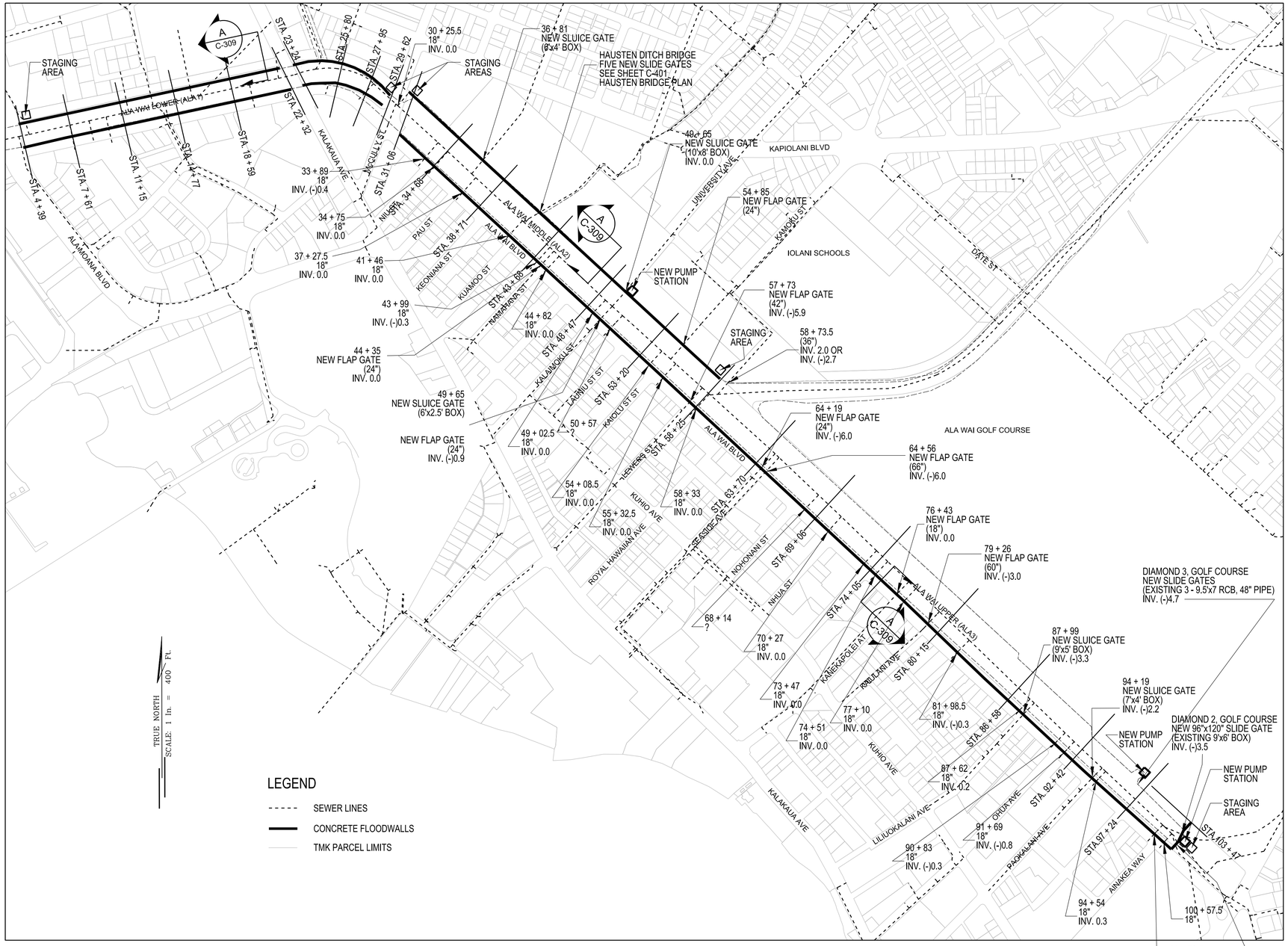
PRINTED BY: JJEC0JHH



PLAN
ALA WAI CANAL FLOODWALLS

SCALE 1"=400'

ALA WAI CANAL INTERIOR DRAINAGE TABLE

CULVERT NAME	STATION	SIZE & TYPE	NOTES
DIAMOND 2, GOLF COURSE	102+45.5	96"x120" SLIDE GATE	PUMP STATION
DIAMOND 1, ALA WAI BLVD	101+75	2 - 60"x120" SLIDE GATES	
DIAMOND 3, GOLF COURSE	96+67	SLIDE GATES	PUMP STATION
100+57.5	100+57.5	18" FLAP GATE	
99+72.5	99+72.5	18" FLAP GATE	
94+54	94+54	18" FLAP GATE	INV. 0.3
94+19	94+19	SLUICE GATE	INV. (-)2.2
91+69	91+69	18" FLAP GATE	INV. (-)0.8
90+83	90+83	18" FLAP GATE	INV. (-)0.3
87+99	87+99	SLUICE GATE	INV. (-)3.3
87+62	87+62	18" FLAP GATE	INV. 0.2
81+98.5	81+98.5	18" FLAP GATE	INV. (-)0.3
79+26	79+26	60" FLAP GATE	INV. (-)3.0
77+10	77+10	18" FLAP GATE	
76+43	76+43	18" FLAP GATE	INV. 0.0
74+51	74+51	18" FLAP GATE	
73+47	73+47	18" FLAP GATE	
70+27	70+27	18" FLAP GATE	
68+14	68+14	?	
64+56	64+56	66" FLAP GATE	INV. (-)6.0
64+19	64+19	24" FLAP GATE	INV. (-)6.0
58+73.5	58+73.5	36" FLAP GATE	INV. 2.0 OR (-)2.7
58+33	58+33	18" FLAP GATE	
57+73	57+73	42" FLAP GATE	INV. (-)5.9
55+32.5	55+32.5	18" FLAP GATE	
54+08.5	54+08.5	18" FLAP GATE	
54+85	54+85	24" FLAP GATE	
50+57	50+57	?	
49+65, RB	49+65	SLUICE GATE	INV. 0.0, PUMP STATION
49+65	49+65	SLUICE GATE & 24" FLAP GATE	INV. ? & (-)0.9
49+02.5	49+02.5	18" FLAP GATE	
44+82	44+82	18" FLAP GATE	
44+35	44+35	24" FLAP GATE	
43+99	43+99	18" FLAP GATE	INV. (-)0.3
HAUSTEN DITCH BRIDGE	42+10	5 - SLIDE GATES	SEE SHEET C-401
41+46	41+46	18" FLAP GATE	
37+27.5	37+27.5	18" FLAP GATE	
36+81	36+81	SLUICE GATE	
34+75	34+75	18" FLAP GATE	
33+89	33+89	18" FLAP GATE	INV. (-)0.4
30+25.5	30+25.5	18" FLAP GATE	

NOTES:

1. SEE SHEET C-309A FOR THE RIGHT BANK (MOUNTAIN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
2. SEE SHEET C-310A FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
3. SEE SHEET C-311A FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI UPPER (ALA3).
4. PUMP STATIONS WILL BE 50'x50'.

US Army Corps of Engineers
HONOLULU DISTRICT

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DESIGNED BY: JHH | DATE: | REVISION:
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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: AS SHOWN | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: ALA WAI CANAL FLOODWALLS, PLAN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI LOWER, MIDDLE & UPPER FLOODWALLS
SITE PLAN
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-101A
SHEET 3 OF 20

FILE: c:\pwworking\poh-h1\3ec9jhhd\01333590\Ala_Wai_C-101Axx.dgn
MODEL NAME: C-101
DATE & TIME: 12/15/2014 3:30:51 PM
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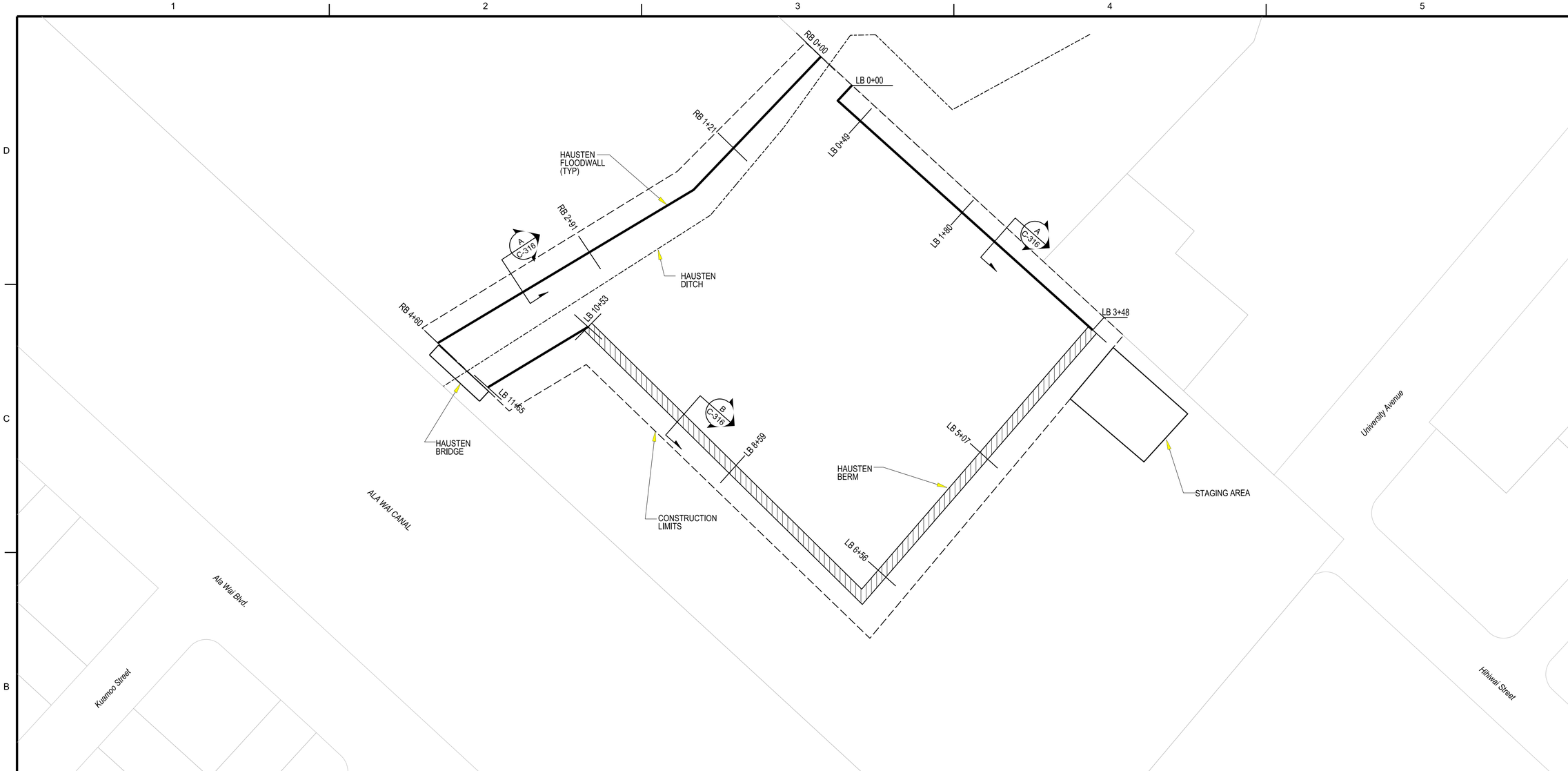
PRINTED BY: J3EC9JHH



NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-401A FOR THE HAUSTEN DITCH BRIDGE NEW CONRETE WALL PLAN.

HAUSTEN DITCH DETENTION PLAN

SCALE: 1"=50'

TRUE NORTH

SCALE: 1 In. = 50 FT.

50' 25' 0 50' 100'

SCALE: 1" = 50'

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 12/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN DITCH DETENTION PLAN

ALA WAI CANAL PROJECT

HAUSTEN DITCH DETENTION
SITE PLAN
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-102A
SHEET 4 OF 20

FILE: c:\pw-work\jhh-1\j3ec9jhh\d0133359\Ala_Wai_C-102Axx.dgn
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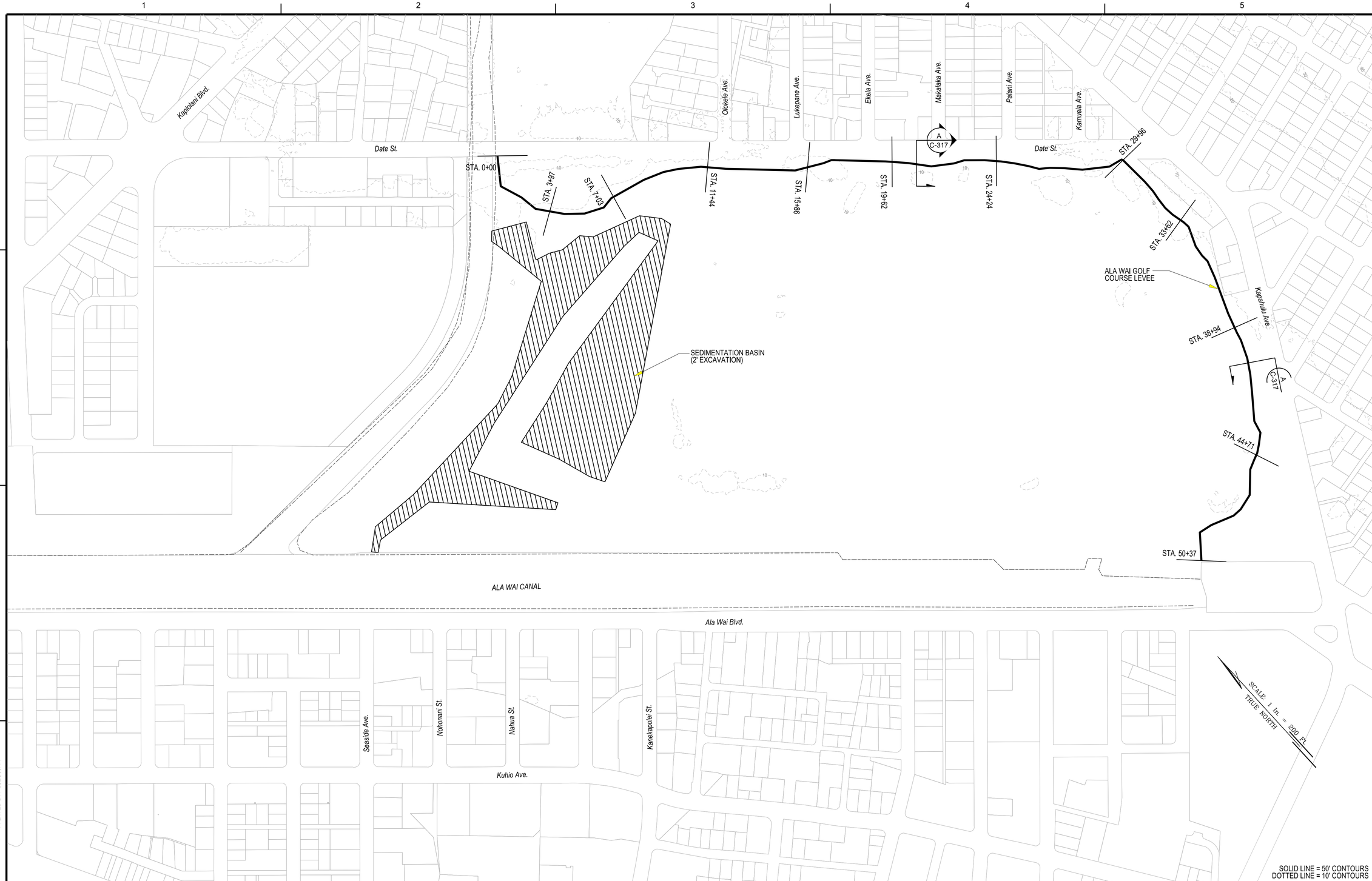
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdrv\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION
PLAN
SCALE: 1"=200'

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DRAWN BY:
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PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY: SOLICIT. / CONTRACT NO.:
LOCATION CODE
PLOT DATE:
DRAWING NUMBER:
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION
REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION
PLAN
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-103A
SHEET 5 OF 20

FILE: c:\pwwork\poh-1\j3ec9jhhd01333559\Ala_Wai_C-103Axx.dgn
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DATE & TIME: 12/15/2014 3:52:39 PM
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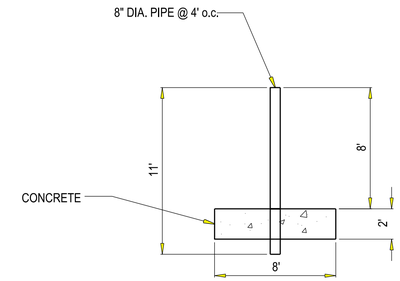
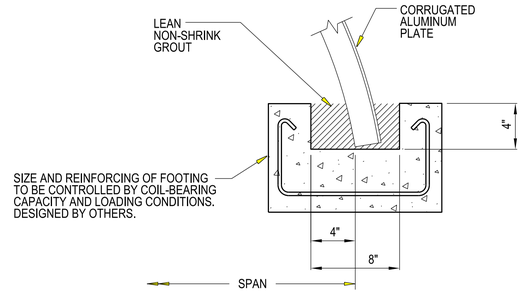
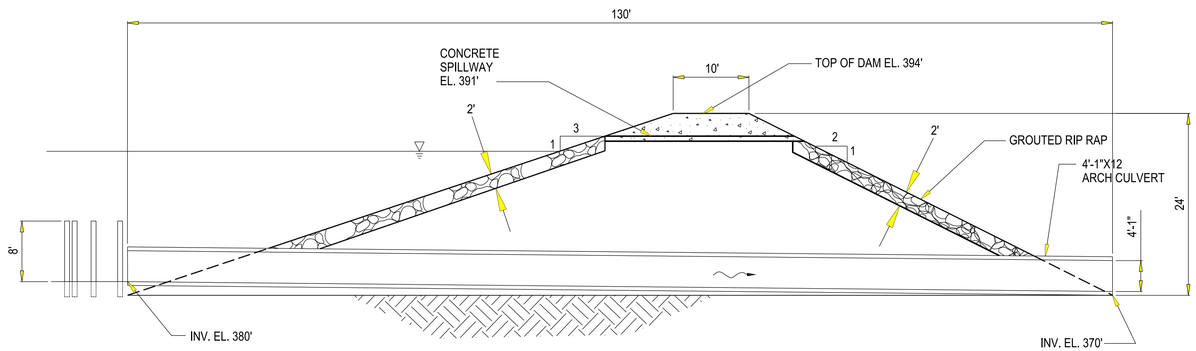


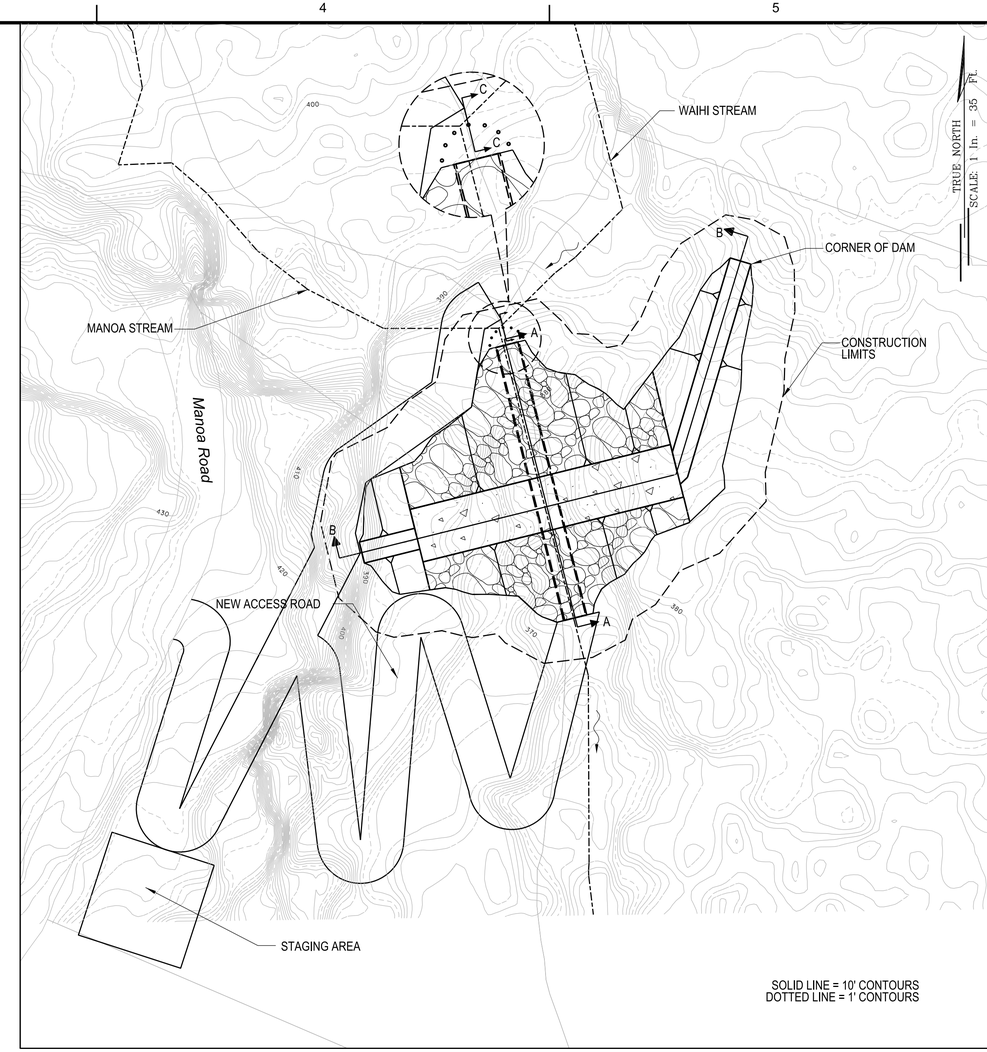
WAIHI DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



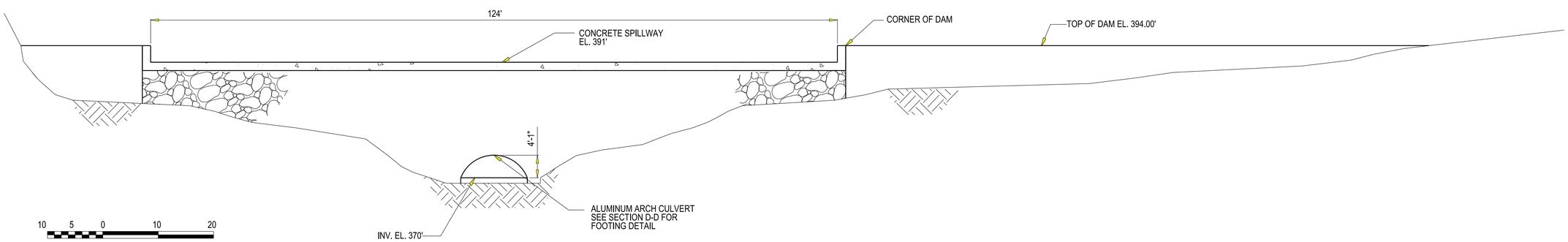
SLOTTED CONCRETE FOOTING
WAIHI DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



WAIHI DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



PLAN
SCALE: 1"=35'



10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL

WAIHI DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

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PLOT DATE:
SIZE: ANSI D
FILE NAME: WAIHI DEBRIS & DETENTION BASIN, PLAN & SECTIONS
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WAIHI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-301
SHEET 6 OF 20

FILE: c:\pwworkjpoh-f1j3ec9jhhd0f133359\Ala_Wai_C-301xxx.dgn
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DATE & TIME: 12/15/2014 3:54:42 PM
LAST SAVED BY: j3ec9cp9
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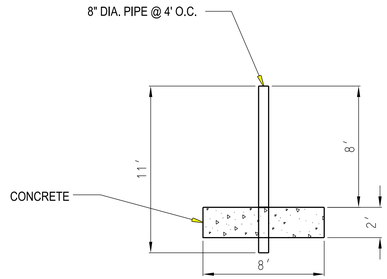
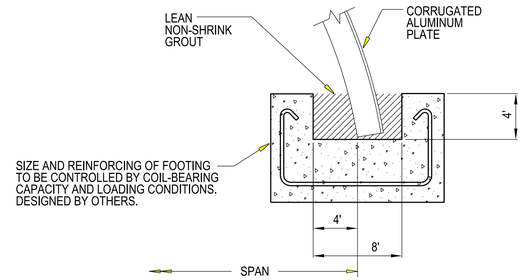
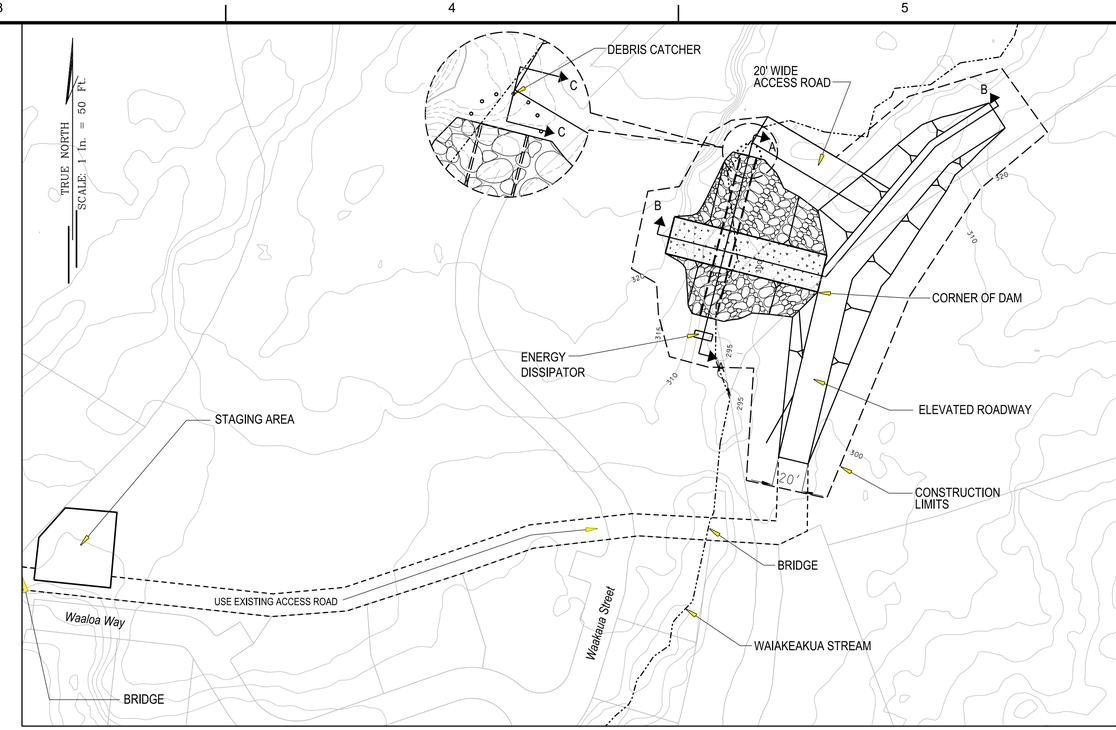


WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'

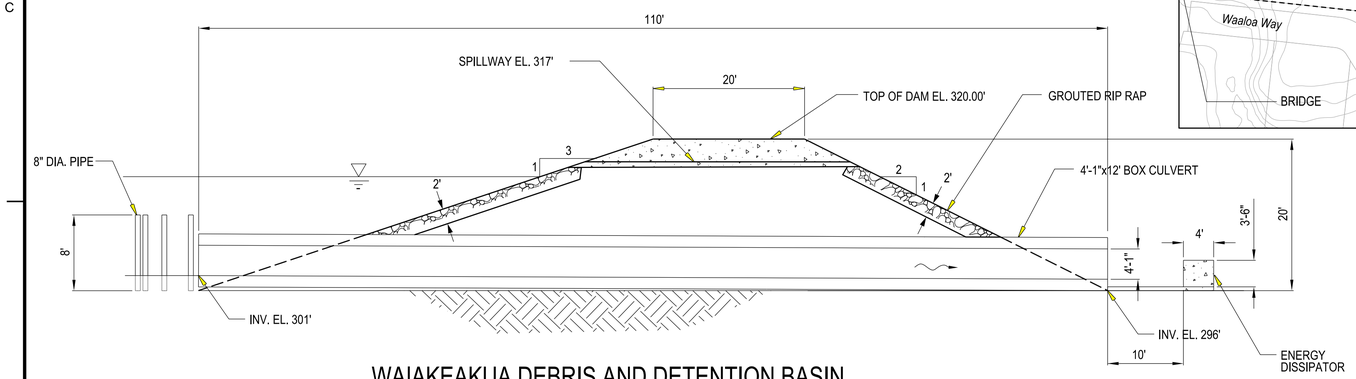


SLOTTED CONCRETE FOOTING
WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS

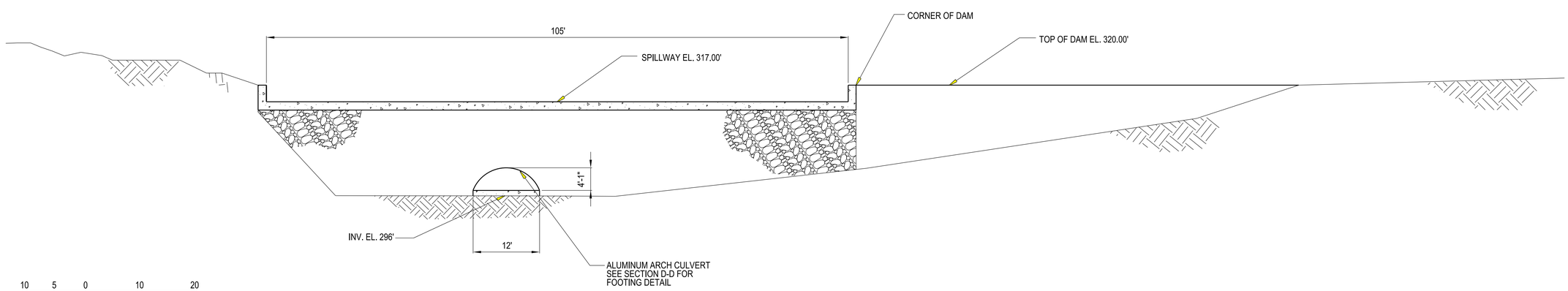


SOLID LINE = 5' CONTOURS

PLAN
SCALE: 1"=50'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL

US Army Corps of Engineers
Pacific Ocean Division
HONOLULU DISTRICT

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JPH
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PLOT SCALE: AS SHOWN
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DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE: 10/20/14
FILE NAME: WAIAKEAKUA DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WAIAKEAKUA DEBRIS AND DETENTION
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-302
SHEET 77 OF 200

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-302xxx.dgn
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DATE & TIME: 12/15/2014 4:10:45 PM
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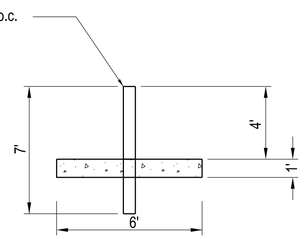
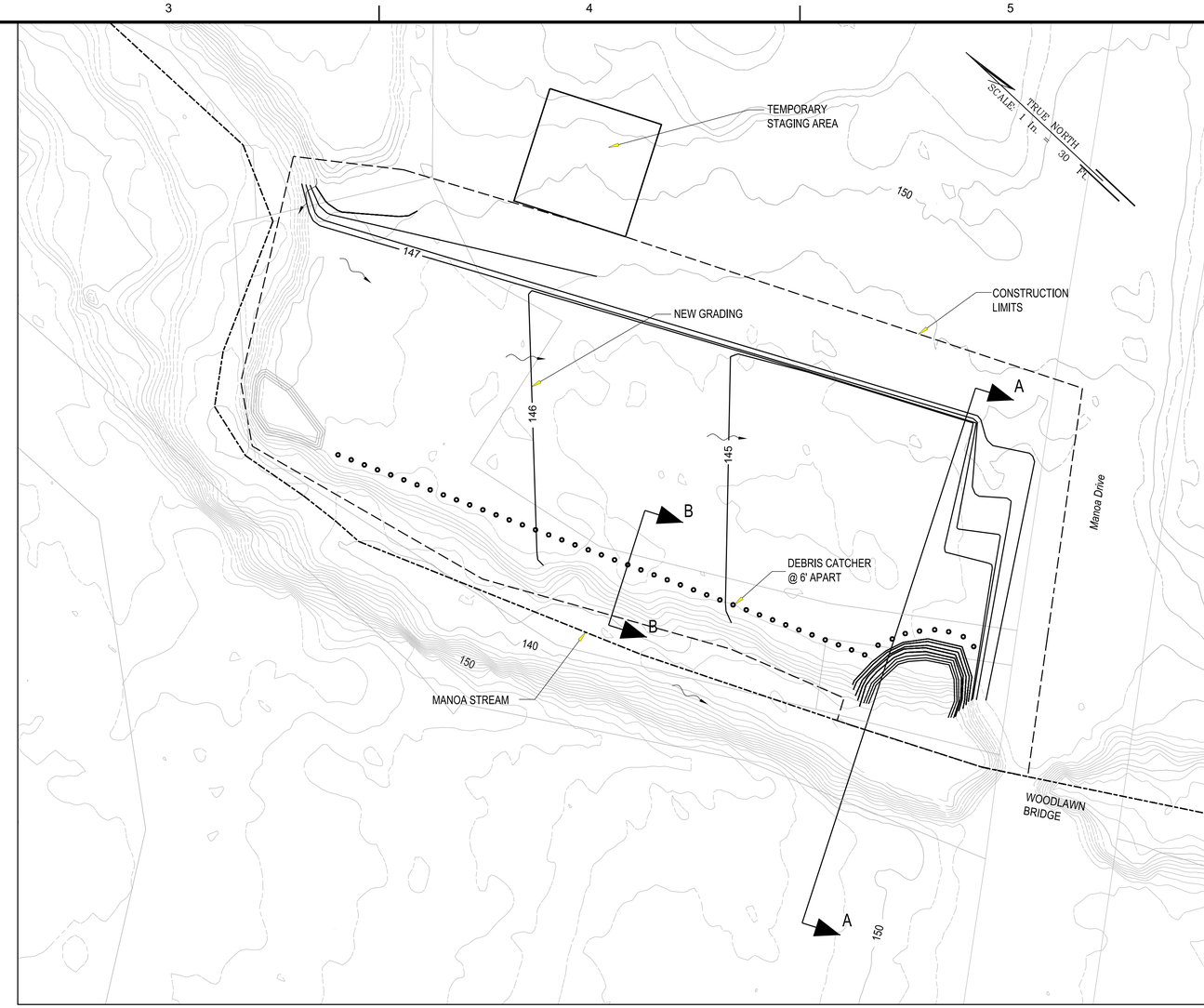
PRINTED BY: J3EC9JHH



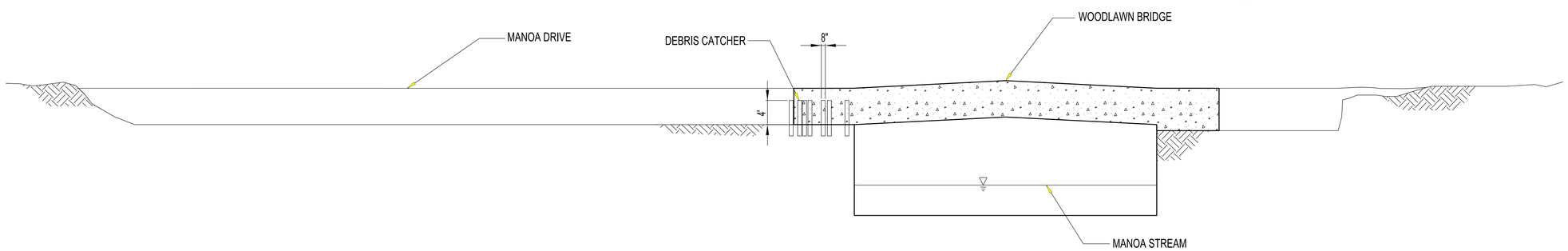
INNOVATION CENTER IMPROVEMENTS
SECTION B-B

SCALE: NTS



SOLID LINE = 10' CONTOURS
DOTTED LINE = 1' CONTOURS

PLAN
SCALE: 1"=30'



10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

INNOVATION CENTER IMPROVEMENTS
SECTION A-A

SCALE: 1"=10'

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Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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PLOT SCALE: 1:1000 | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: INNOVATION CENTER IMPROVEMENTS, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

INNOVATION CENTER IMPROVEMENTS
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-304A
SHEET 8 OF 20

FILE: c:\pw_work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-304Axx.dgn
MODEL NAME: C-304
DATE & TIME: 12/15/2014 4:23:28 PM
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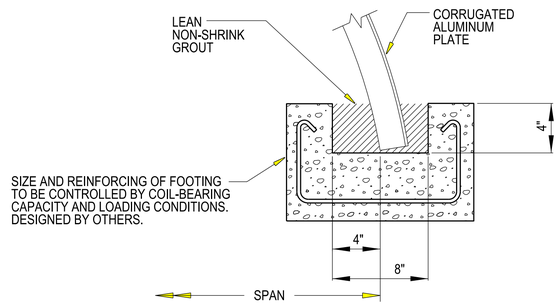
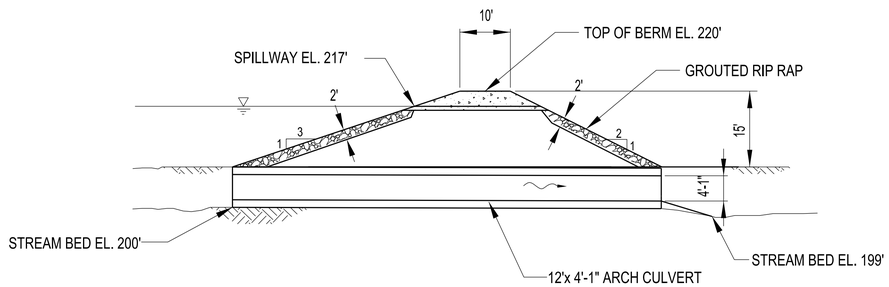
PRINTED BY: J3EC9JHH



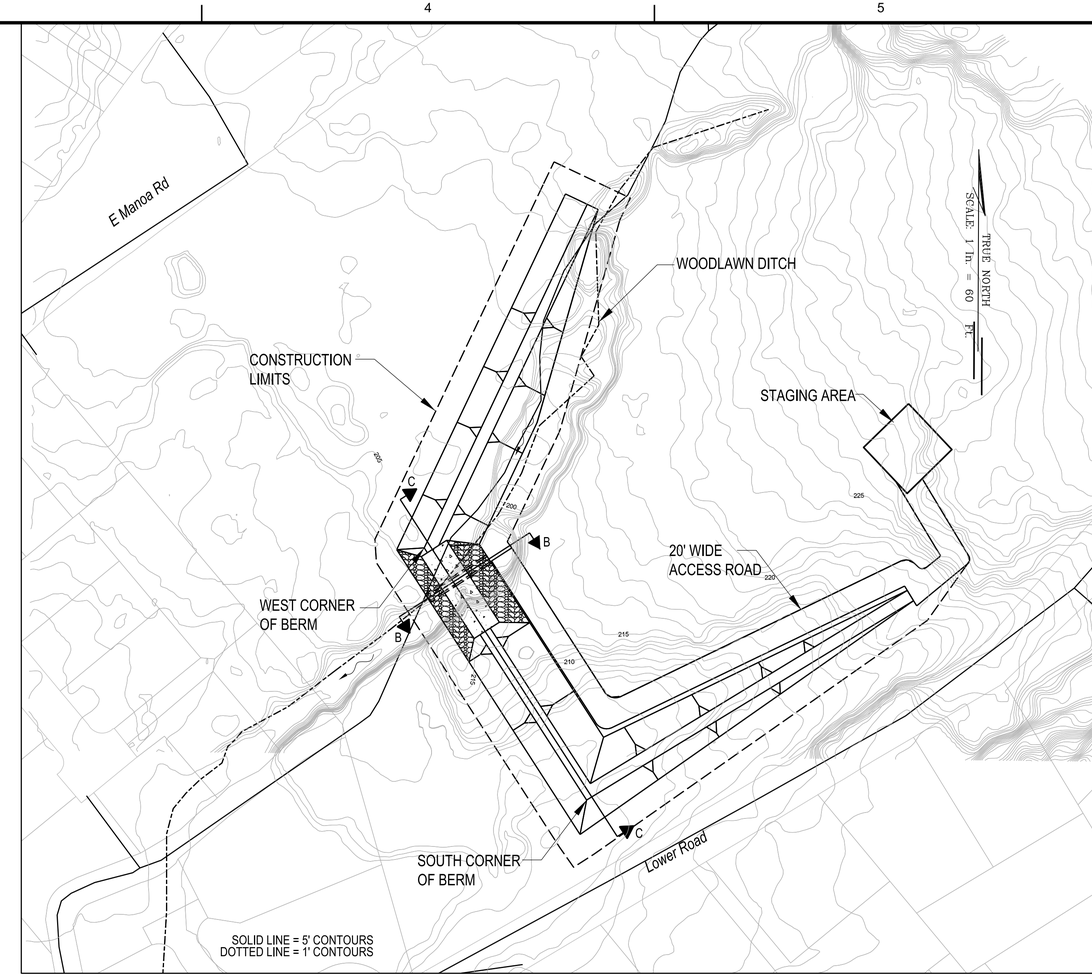
SLOTTED CONCRETE FOOTING
WOODLAWN DITCH DETENTION BASIN
SECTION D-D

SCALE: NTS



WOODLAWN DITCH DETENTION BASIN
SECTION B-B

SCALE: 1"=15'



PLAN

SCALE: 1"=60'

WOODLAWN DITCH DETENTION BASIN
SECTION C-C

SCALE: 1"=15'

15' 7.5' 0 15' 30'

SCALE: 1" = 15'

Note: All elevations are feet MSL

US Army Corps of Engineers®
HONOLULU DISTRICT

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DESIGNED BY: JHH
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SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/2014
SIZE: ANSI D
FILE NAME: WOODLAWN DITCH DETENTION BASIN, PLAN & SECTIONS.dgn

DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WOODLAWN DITCH DETENTION
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-305A
SHEET 9 OF 20

FILE: c:\pwworking\poh-1\j3ec9j\hid\01333559\Ala_Wai_C-305Axx.dgn
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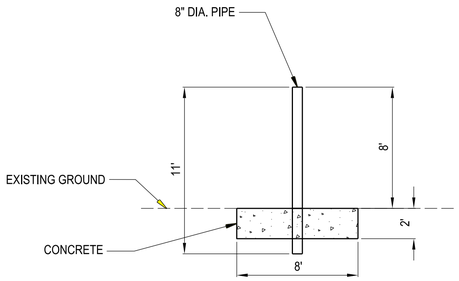
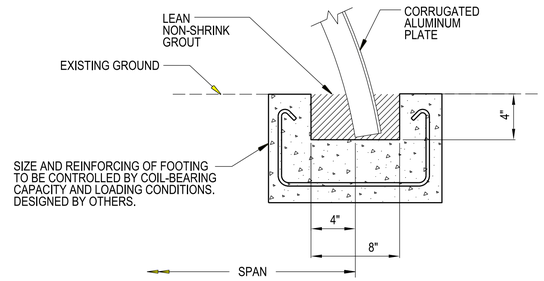
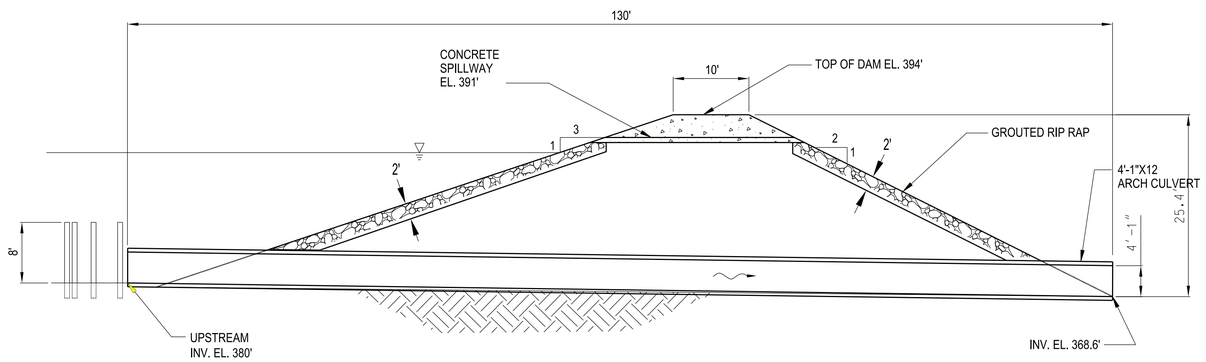


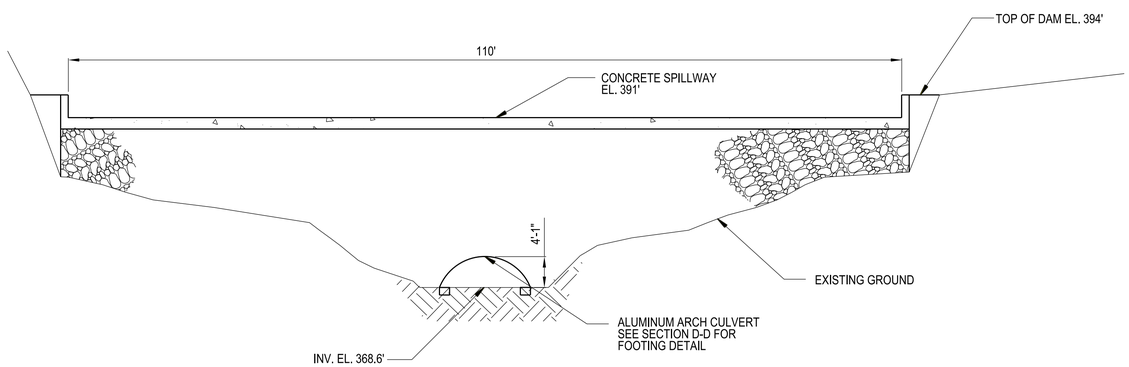
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



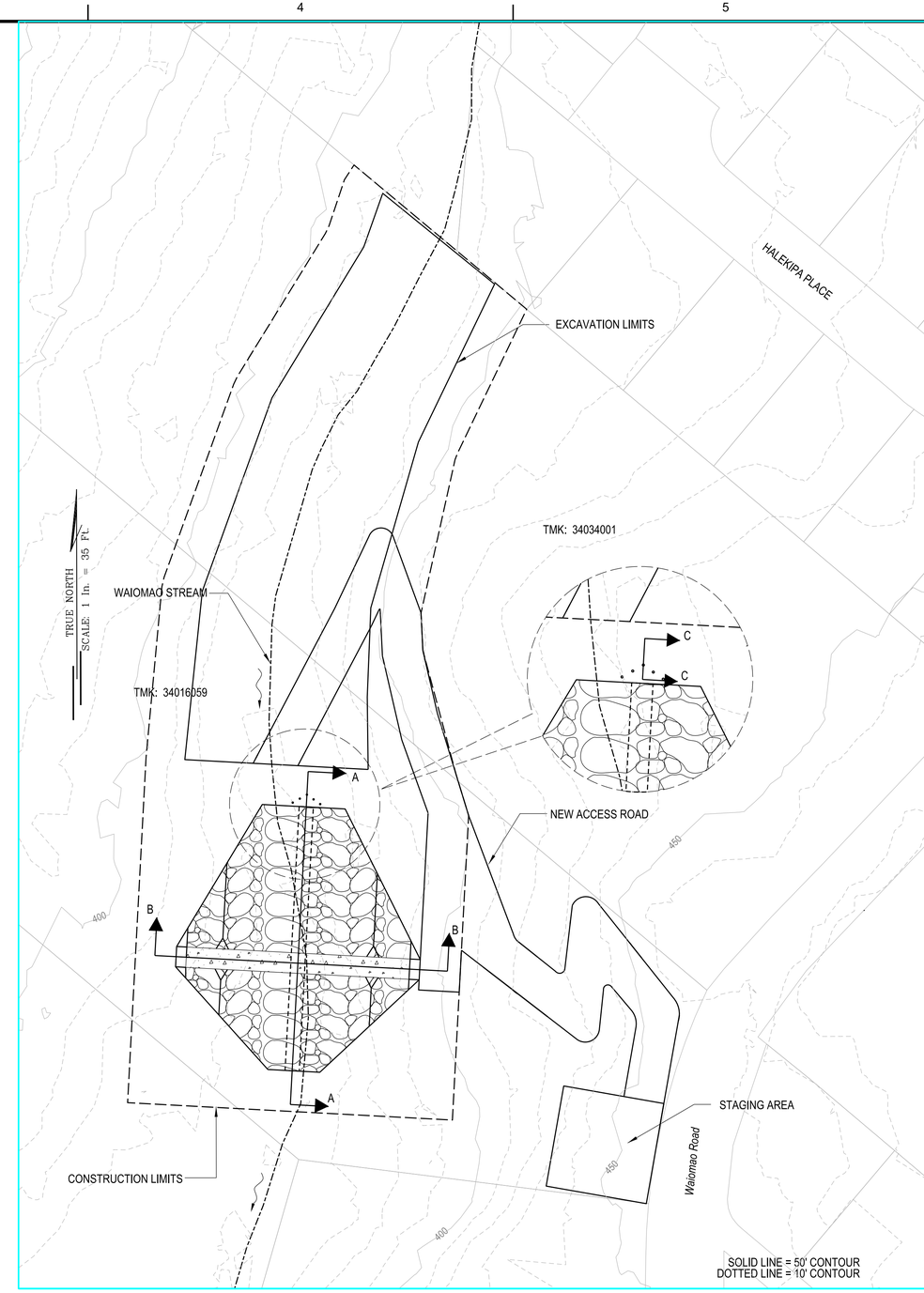
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



WAIOMAO DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL



PLAN
SCALE: 1"=35'

35 17.5 0 35 70
SCALE: 1" = 35'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JHH
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CHECKED BY:
SUBMITTED BY:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: WAIOMAO DEBRIS & DETENTION BASIN, PLAN & SECTIONS
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

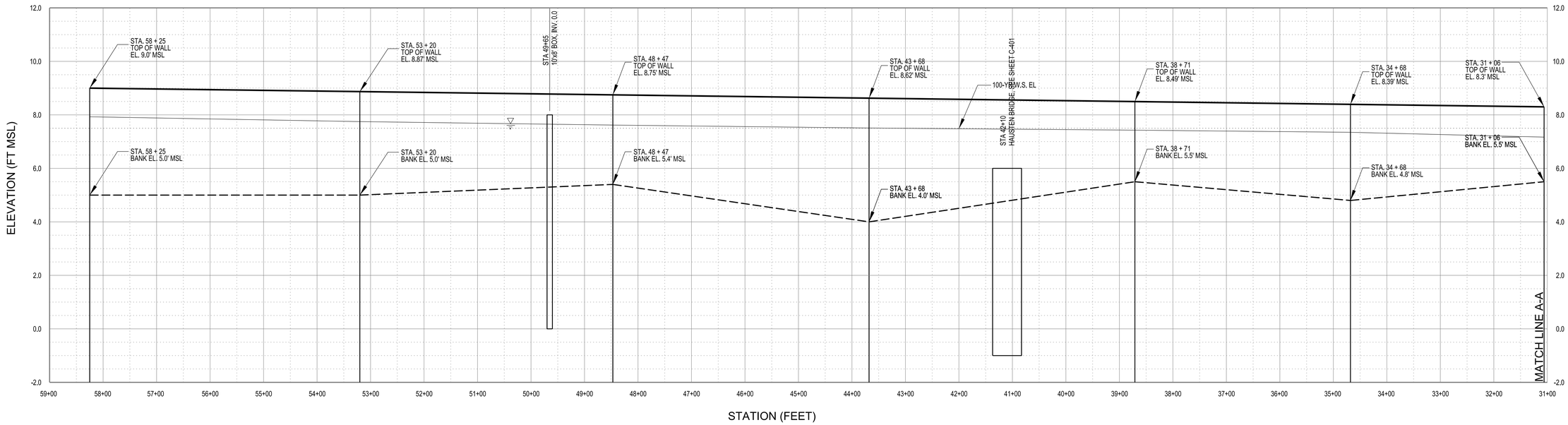
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

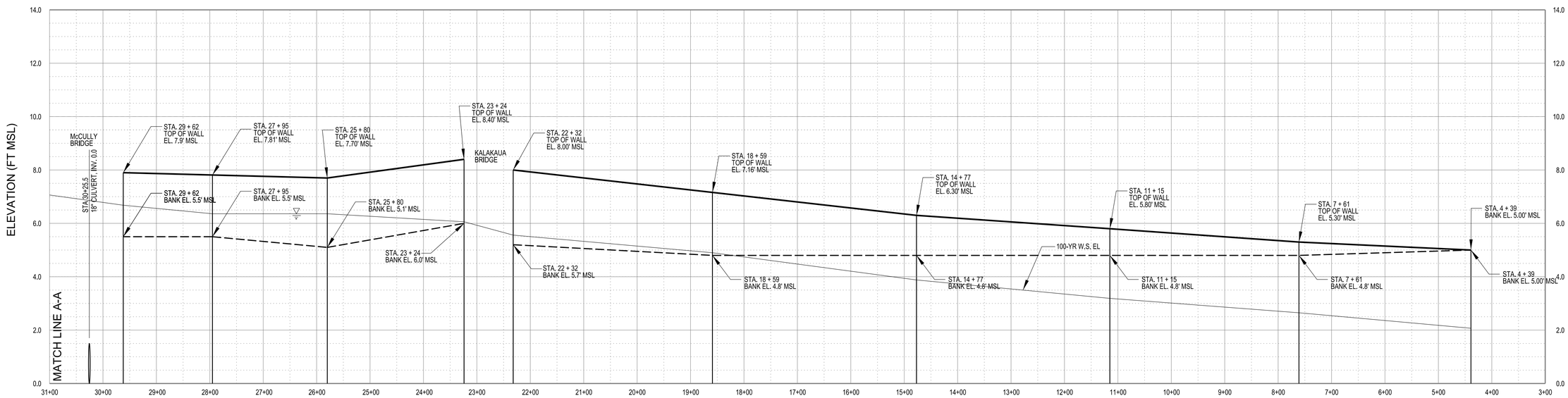
ALA WAI CANAL PROJECT

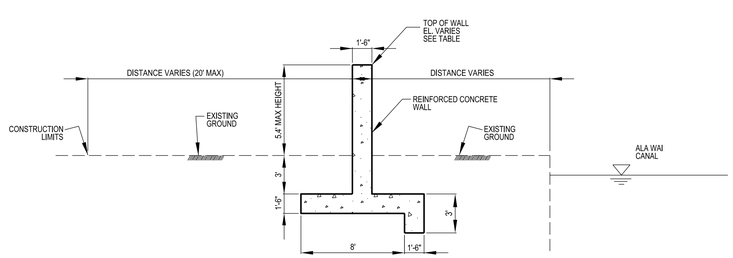
WAIOMAO DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-308
SHEET 10 OF

FILE: c:\pw-work\pph-1\jec9jhhi\d0133359\Ala_Wai_C-308xxx.dgn
MODEL NAME: C-308
DATE & TIME: 12/15/2014 4:33:49 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.plotdg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH







A TYPICAL RIGHT BANK REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE

PROFILE

ALA WAI MIDDLE (ALA2) AND LOWER (ALA1) RIGHT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

ALA WAI CANAL RIGHT BANK
STA 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	4.00	9.00
53 + 20	3.87	8.87
48 + 47	3.35	8.75
43 + 68	4.62	8.62
38 + 71	2.99	8.49
34 + 68	3.59	8.39
31 + 06	2.80	8.30
MCCLULLY BRIDGE		
29 + 62	2.40	7.90
27 + 95	2.31	7.81
25 + 80	2.60	7.70

ALA WAI CANAL RIGHT BANK
STA 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.40	8.40
22 + 32	2.80	8.00
18 + 59	2.36	7.16
14 + 77	1.50	6.30
11 + 15	1.00	5.80
7 + 61	0.50	5.30
4 + 39	0	5.00

US Army Corps of Engineers®
HONOLULU DISTRICT

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY: JHH
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: ALA WAI CANAL MIDDLE & LOWER RIGHT BANK PROFILE

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI MIDDLE & LOWER RIGHT BANK FLOODWALLS
PROFILE AND SECTION
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-309A
SHEET 11 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-309Axx.dgn
MODEL NAME: C-309A
DATE & TIME: 12/15/2014 4:35:51 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\plotd\plotter.pltcfg
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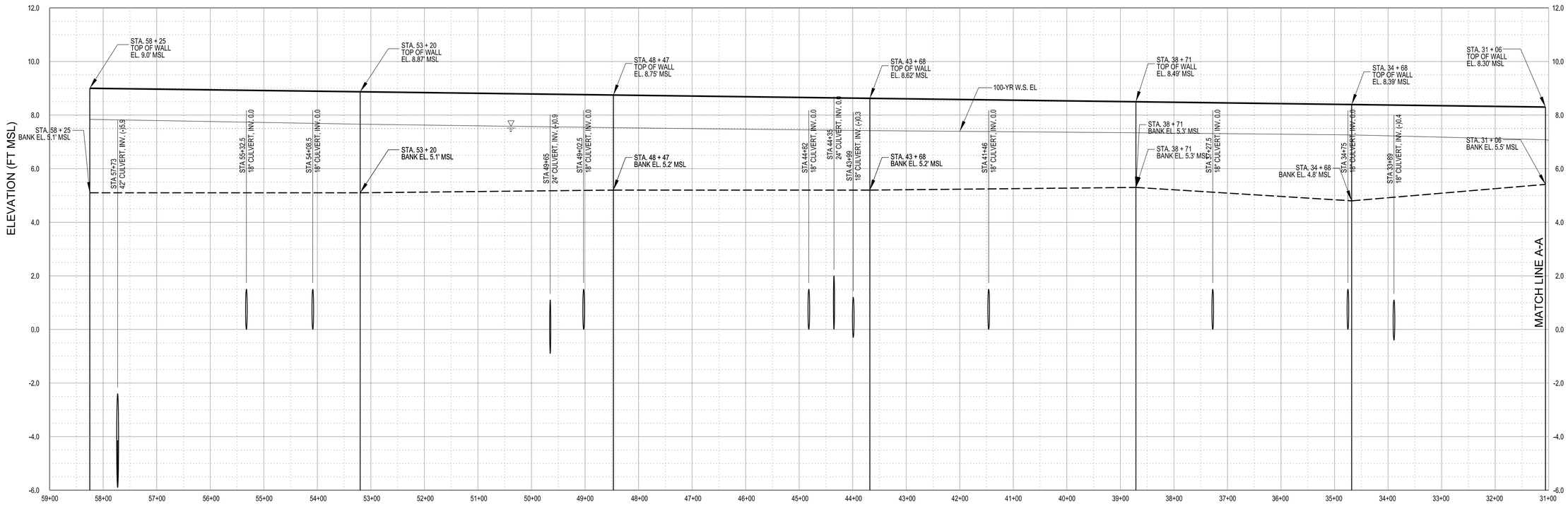
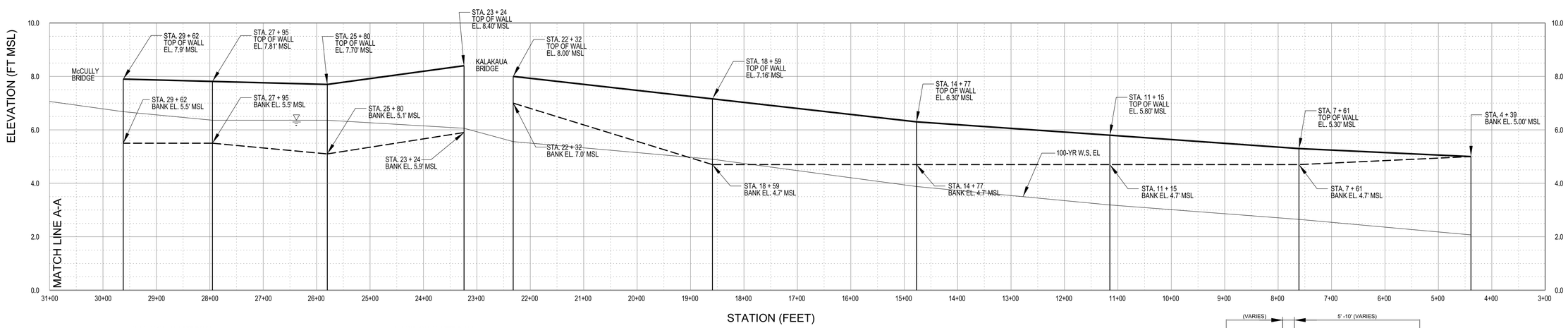
PRINTED BY: J3EC9JHH





ALA WAI CANAL LEFT BANK
STA TO 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	3.90	9.00
53 + 20	3.77	8.87
48 + 47	3.55	8.75
43 + 68	3.42	8.62
38 + 71	3.19	8.49
34 + 68	3.59	8.39
31 + 06	2.80	8.30
MCCLULLY BRIDGE		
29 + 62	2.40	7.90
27 + 95	2.31	7.81
25 + 80	2.60	7.70

ALA WAI CANAL LEFT BANK
STA TO 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.50	8.40
KALAKAUA BRIDGE		
22 + 32	1.00	8.00
18 + 59	2.46	7.16
14 + 77	1.60	6.30
11 + 15	1.10	5.80
7 + 61	0.60	5.30
4 + 39	0	5.00

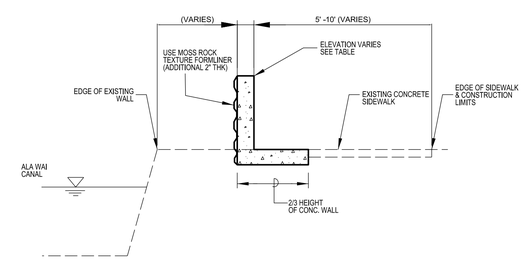
PROFILE

ALA WAI CANAL MIDDLE (ALA2) AND LOWER (ALA1) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

NOTES:

1. SEE DETAIL "C" ON SHEET C-311A FOR ALA WAI CANAL MIDDLE (ALA2) TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION.
2. ALA WAI CANAL LOWER (ALA1) IS FROM STATION 23+24 TO STATION 4+39.



B TYPICAL ALA WAI LOWER (ALA1) LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

US Army Corps of Engineers®
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

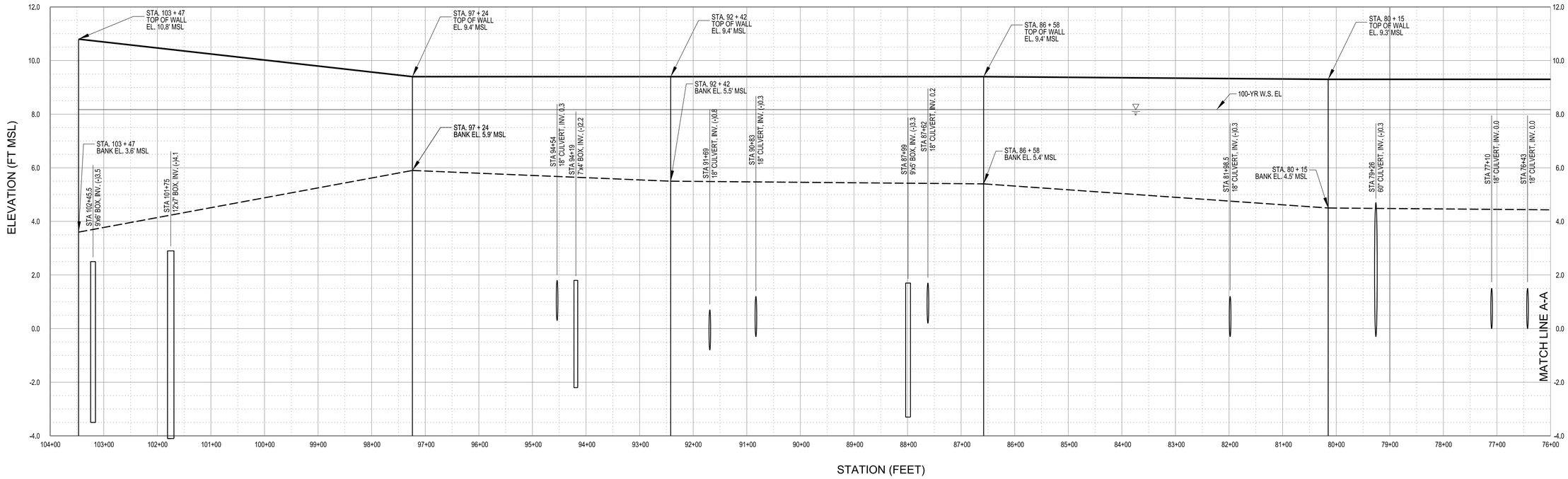
DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
FILE NAME: ALA WAI CANAL MIDDLE & LOWER LEFT BANK PROFILE
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

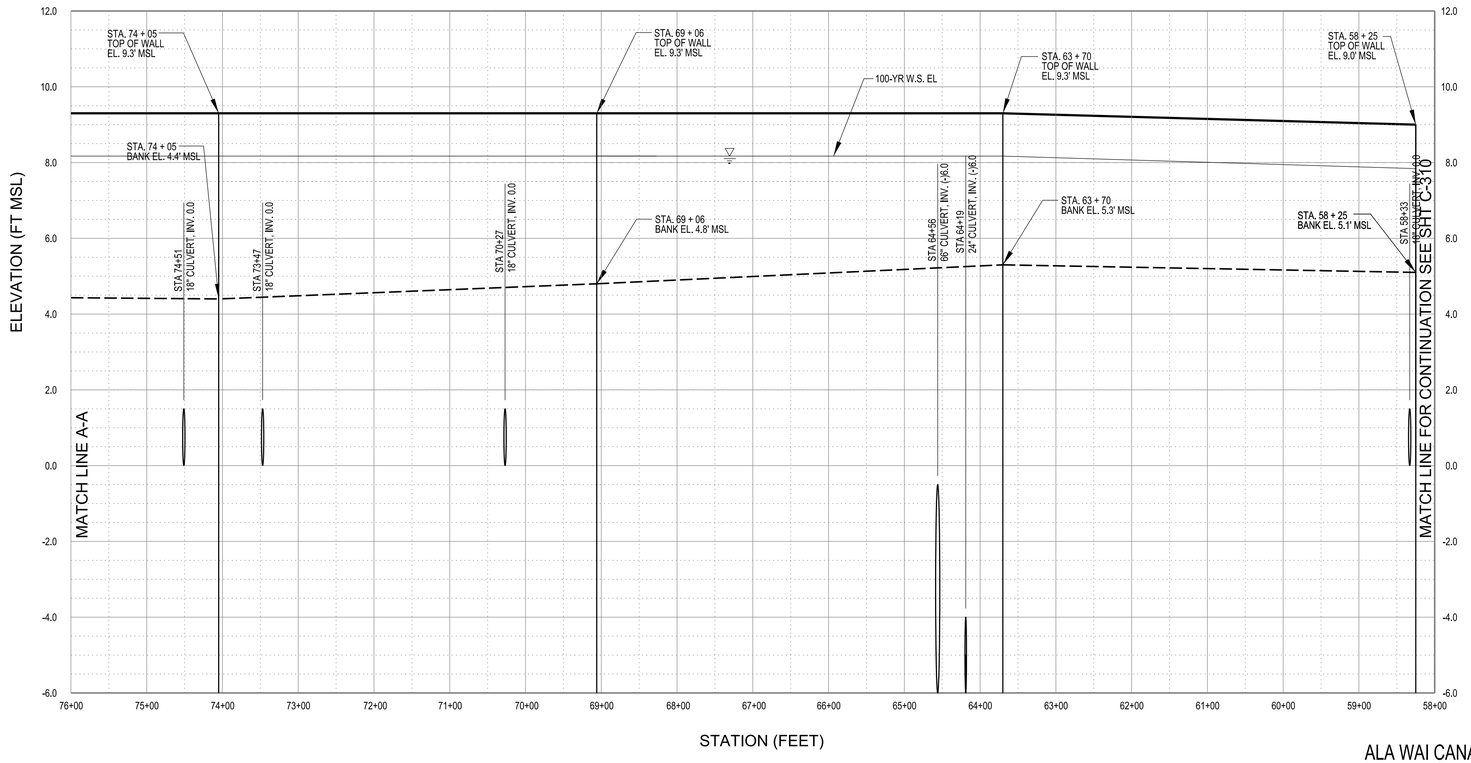
ALA WAI CANAL PROJECT

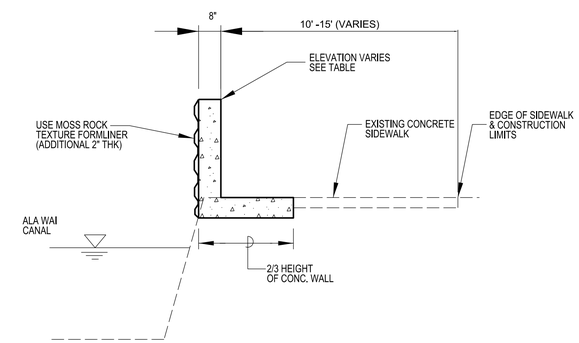
ALA WAI MIDDLE & LOWER LEFT BANK FLOODWALLS
PROFILE
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-310A
SHEET 12 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-310Axx.dgn
MODEL NAME: C-310A
DATE & TIME: 12/15/2014 4:37:32 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH







C TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

ALA WAI CANAL LEFT BANK
STA 101 + 24 TO 58 + 25

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
101 + 24	7.20	10.80
97 +24	3.50	9.40
92 + 42	3.90	9.40
86 + 58	4.00	9.40
80 + 15	4.70	9.30
74 + 05	4.80	9.30
69 + 06	4.50	9.30
63 + 70	4.00	9.30
58 + 25	3.90	9.00

PROFILE
ALA WAI CANAL UPPER (ALA3) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

US Army Corps of Engineers®
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
FILE NAME: ALA WAI CANAL UPPER LEFT BANK, PROFILE & SECTIO
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI UPPER LEFT BANK FLOODWALLS
PROFILE AND SECTION
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-311A
SHEET 13 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-311Axx.dgn
MODEL NAME: C-311A
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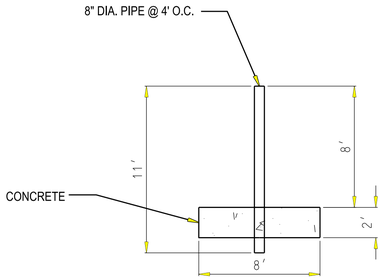
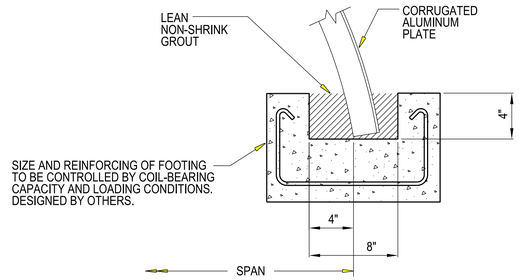
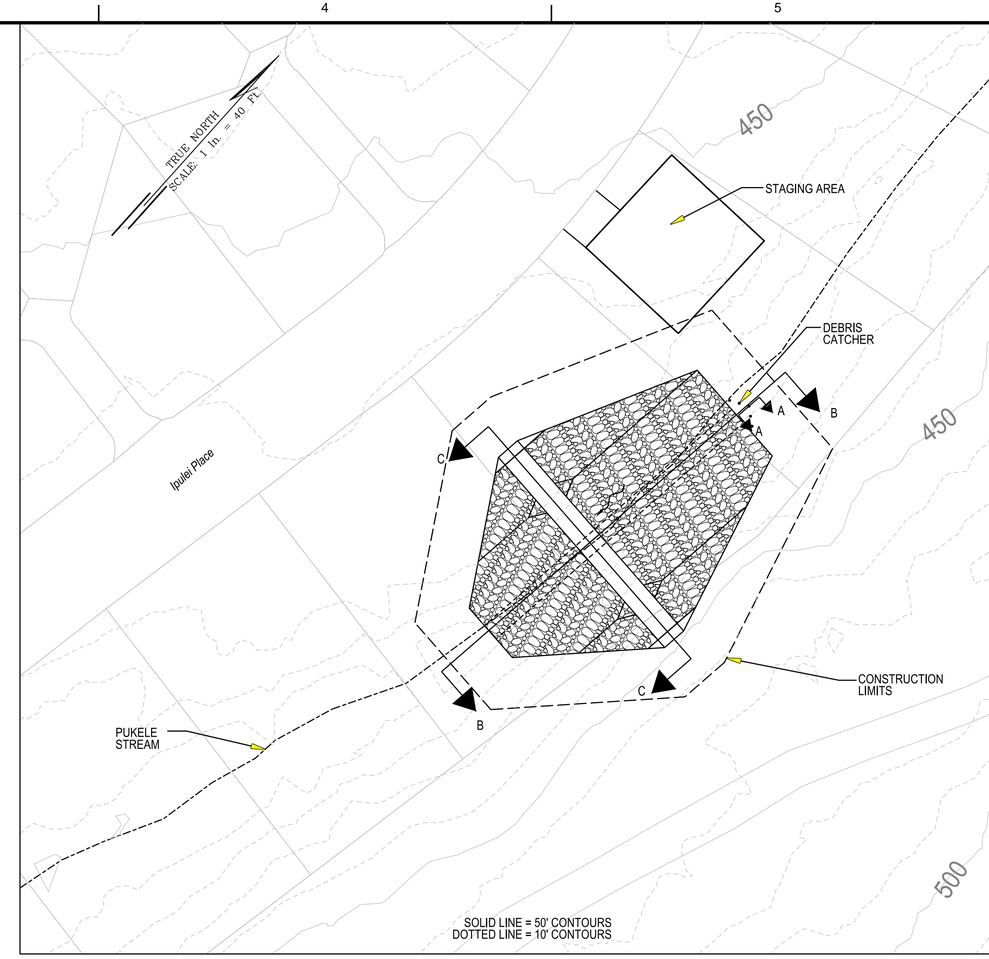
PRINTED BY: J3EC9JHH



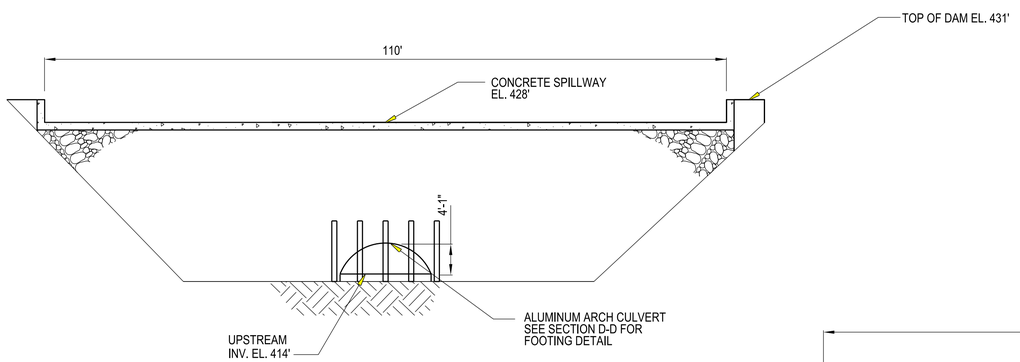
PUKELE DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=5'



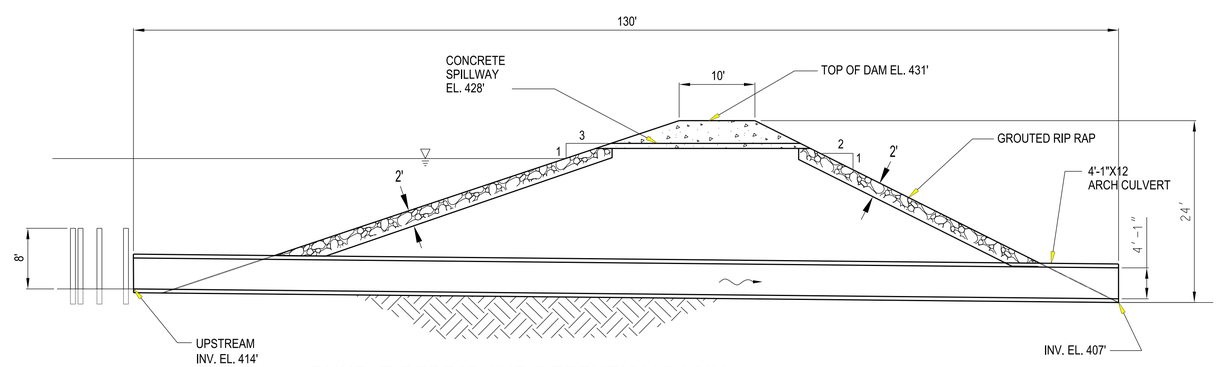
SLOTTED CONCRETE FOOTING
SECTION D-D
SCALE: NTS



PLAN
SCALE: 1"=40'



PUKELE DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



PUKELE DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=5'

5 2.5' 0 5 10
SCALE: 1" = 5'
Note: All elevations are feet MSL

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JJH
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1/2"=1'-0"
PLOT DATE: 12/15/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: PUKELE DEBRIS & DETENTION BASIN, PLAN & SECTION

ALA WAI CANAL PROJECT

PUKELE DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-313
SHEET 14 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-313xxx.dgn
MODEL NAME: C-313
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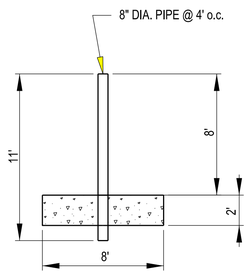
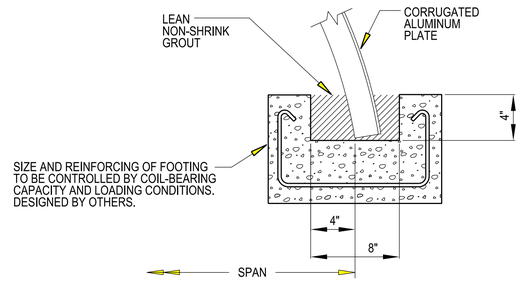
PRINTED BY: J3EC9JHH



ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION A-A

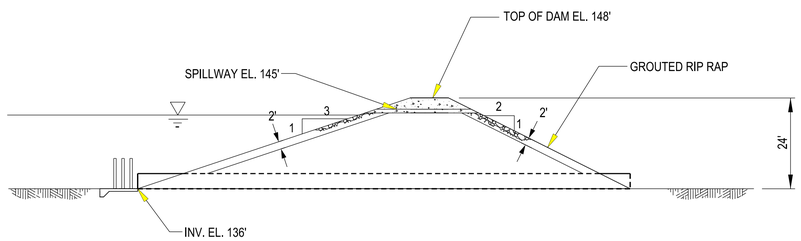
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION D-D

SCALE: NTS



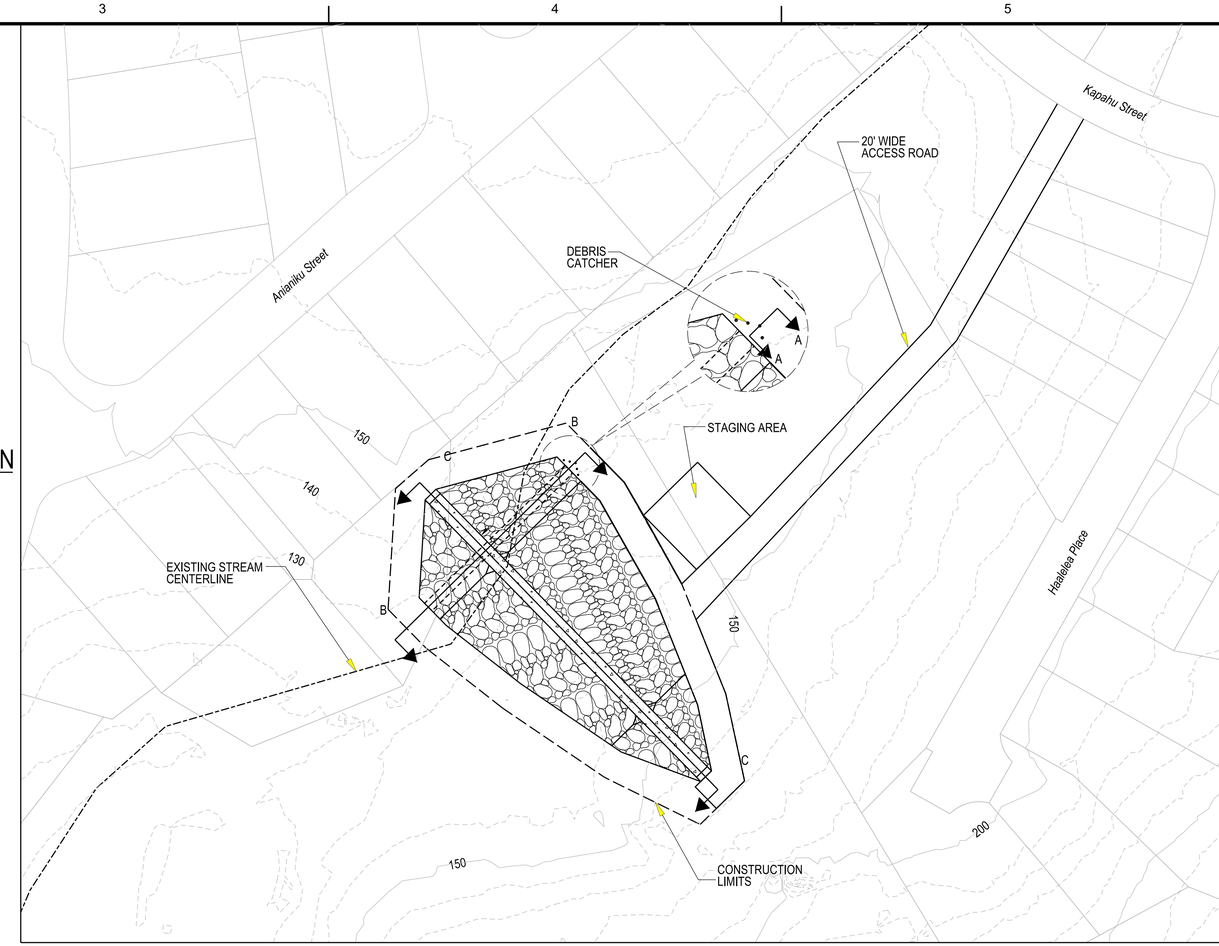
20' 10' 0 20' 40'

SCALE: 1" = 20'

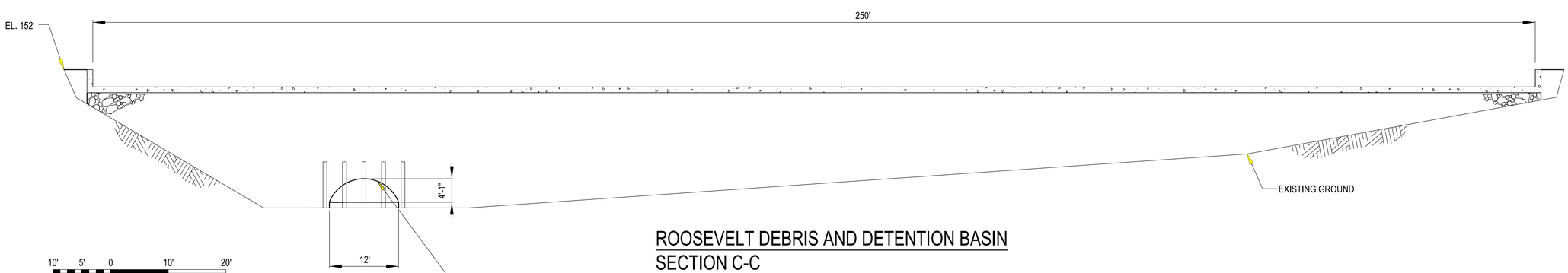
Note: All elevations are feet MSL

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION B-B

SCALE: 1"=20'



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS



10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

ROOSEVELT DEBRIS AND DETENTION BASIN
SECTION C-C

SCALE: 1"=20'

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JPH
DRAWN BY:
SUBMITTED BY:
DATE:
REVISION:
CHECKED BY: SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: ROOSEVELT DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ROOSEVELT DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-314A
SHEET 15 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-314Axx.dgn
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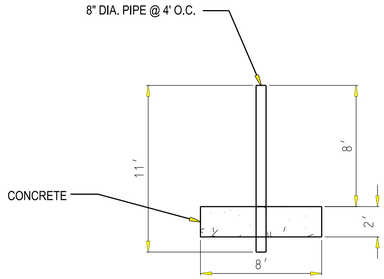
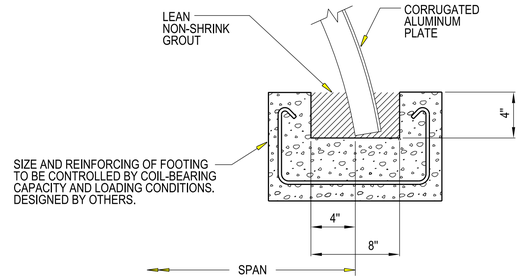
PRINTED BY: J3EC9JHH



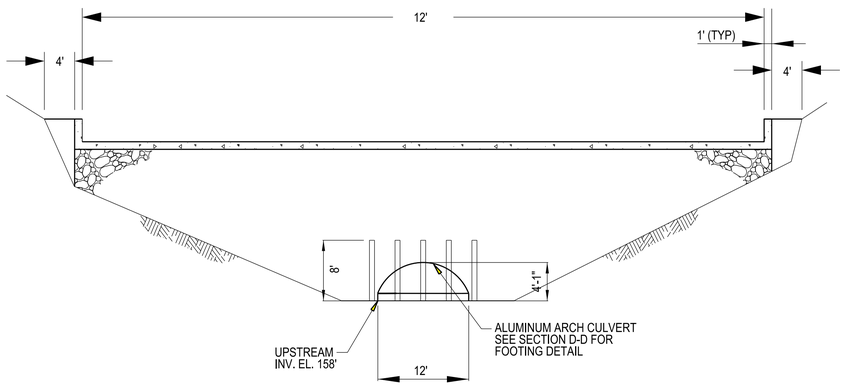
MAKIKI DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



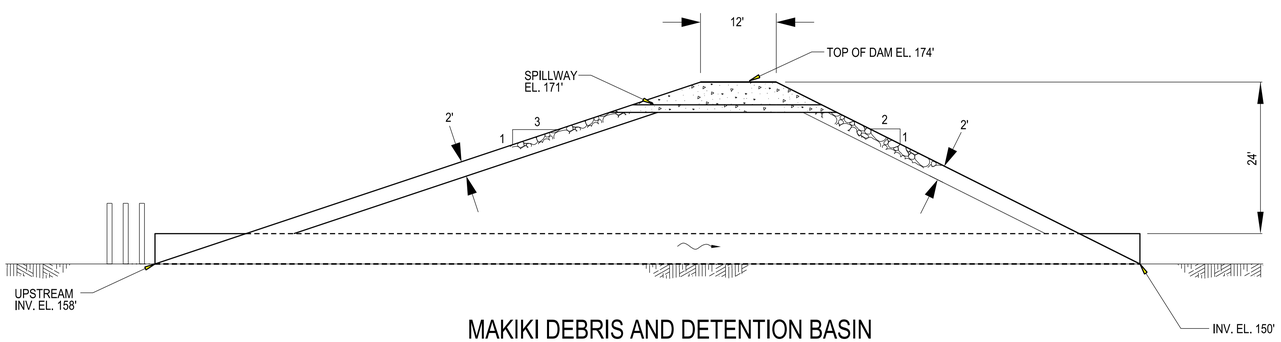
SLOTTED CONCRETE FOOTING MAKIKI DEBRIS AND DETENTION SECTION D-D

SCALE: NTS



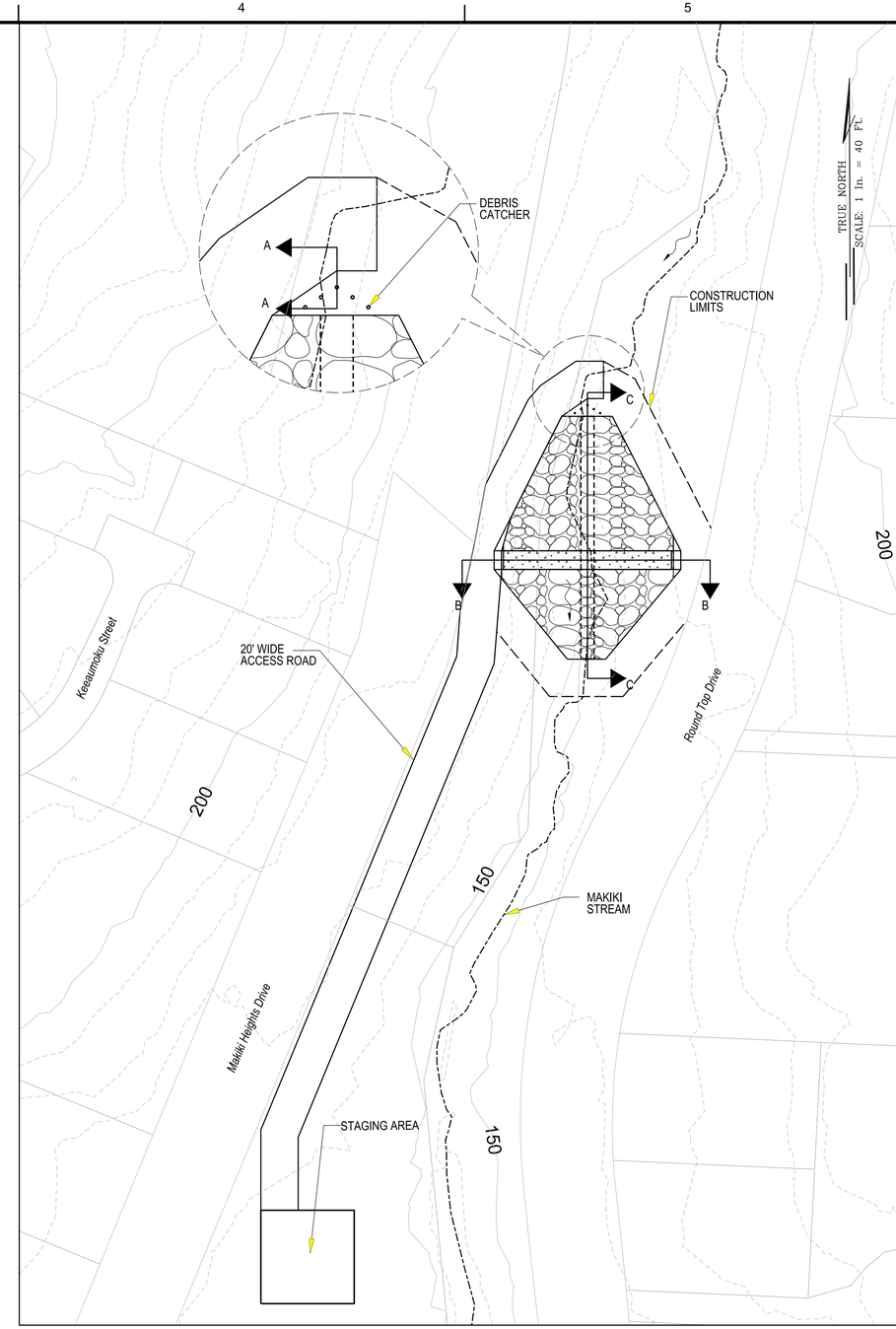
MAKIKI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'



MAKIKI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=10'



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL

US Army Corps of Engineers®
Honolulu District

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT SIZE: ANSI D
DATE:
CHECKED BY: SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE: 1/13/2014
FILE NAME: MAKIKI DEBRIS & DETENTION BASIN, PLAN & SECTIONS
REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

MAKIKI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-315A
SHEET 16 OF 20

FILE: c:\pwworking\honhd01\33359\Ala_Wai_C-315Axx.dgn
MODEL NAME: C-315
DATE & TIME: 12/15/2014 5:10:53 PM
LAST SAVED BY: j3ec9cp9
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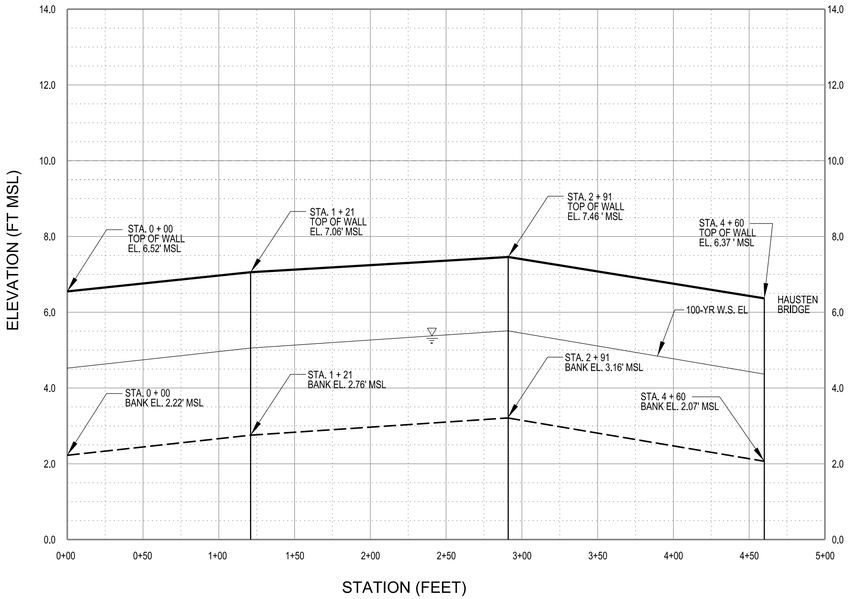
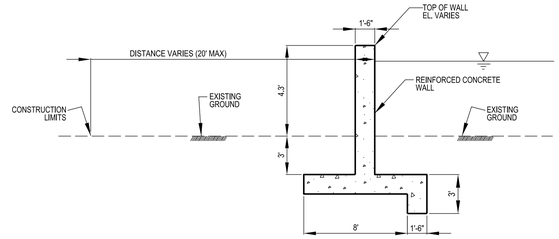


PROFILE

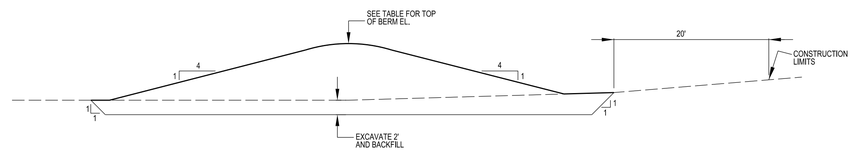
HAUSTEN DITCH RIGHT BANK FLOODWALL

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'



A HAUSTEN DITCH TYPICAL REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE



B HAUSTEN DITCH TYPICAL BERM

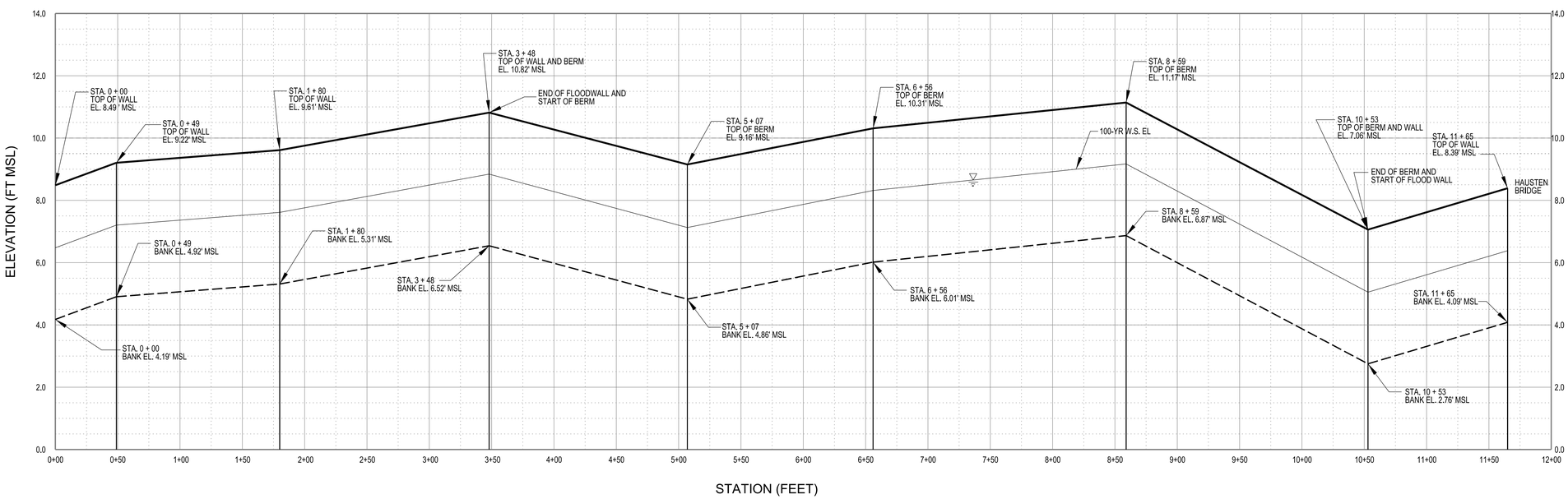
NOT TO SCALE

HAUSTEN DITCH RIGHT BANK FLOODWALL
STA TO 0 + 00 TO 4 + 60

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	6.52
1 + 21	4.30	7.06
2 + 91	4.30	7.46
4 + 60	4.30	6.37
HAUSTEN BRIDGE		

HAUSTEN DITCH LEFT BANK
FLOODWALL AND BERM
STA TO 0 + 00 TO 11 + 65

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	8.49
0 + 49	4.30	9.22
1 + 80	4.30	9.61
3 + 48	4.30	10.82
END OF FLOODWALL AND START OF BERM		
3 + 48	4.30	10.82
5 + 07	4.30	9.16
6 + 56	4.30	10.31
8 +59	4.30	11.17
10 + 53	4.30	7.06
END OF BERM AND START OF FLOODWALL		
10 + 53	4.30	7.06
11 + 65	4.30	8.39
HAUSTEN BRIDGE		



PROFILE

HAUSTEN DITCH LEFT BANK FLOODWALL AND BERM

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'

US Army Corps of Engineers
HONOLULU DISTRICT

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LOCATION CODE
PLOT SCALE: 1:1 HORIZONTAL
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN DITCH DETENTION, PROFILE & SECTIONS

ALA WAI CANAL PROJECT

HAUSTEN DITCH DETENTION FLOODWALLS AND BERM
PROFILE AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-316A
SHEET 17 OF 20

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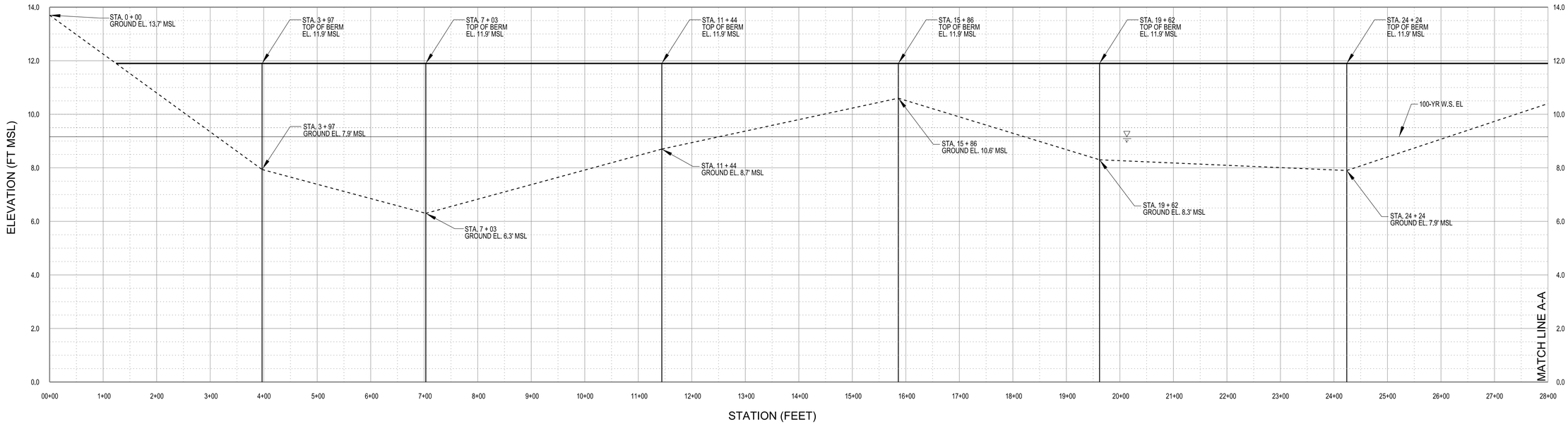
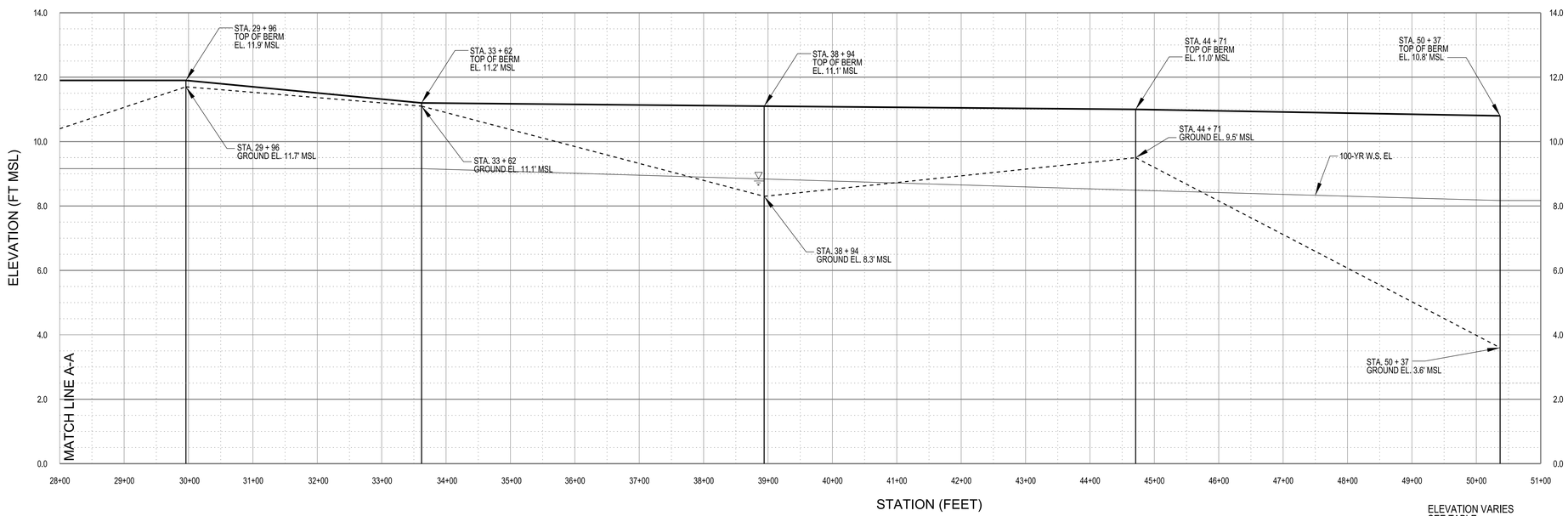


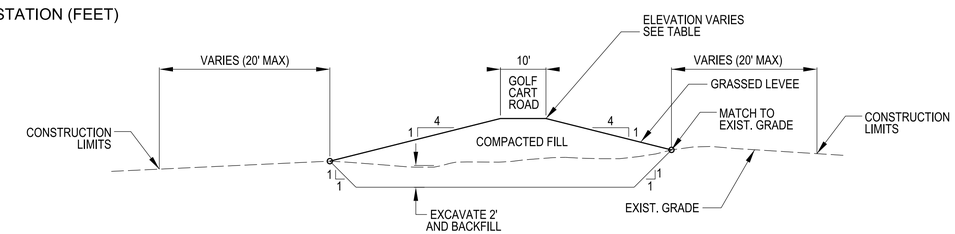


ALA WAI GOLF COURSE LEVEE
STA 0 + 00 TO 50 + 37

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	-	-
3 + 97	4.0	11.9
7 + 03	5.6	11.9
11 + 44	3.2	11.9
15 + 86	1.3	11.9
19 + 62	3.6	11.9
24 + 24	4.0	11.9
29 + 96	0.2	11.9
33 + 62	0.1	11.2
38 + 94	2.8	11.1
44 + 71	1.5	11.0
50 + 37	7.2	10.8

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE PROFILE

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'



A TYPICAL LEVEE SECTION
NOT TO SCALE

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PLOT SCALE: AS SHOWN
PLOT DATE: 12/15/14
SIZE: ANSI D
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE
DATE:
REVISION:
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LOCATION CODE
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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE LEVEE
PROFILE AND SECTION
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-317A
SHEET 18 OF 20

FILE: c:\pw_work\poh_1\j3ec9jhh\d0133359\Ala_Wai_C-317Axx.dgn
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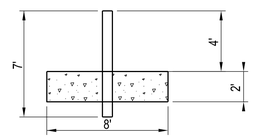
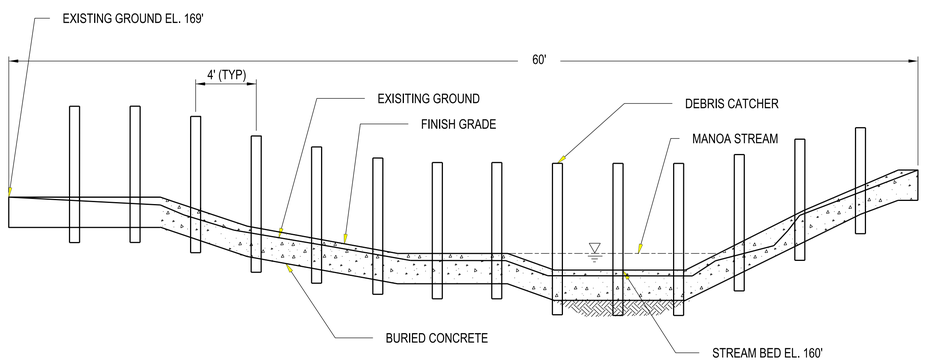


MANOA IN-STREAM DEBRIS CATHMENT
SECTION A-A

SCALE: 1"=5'



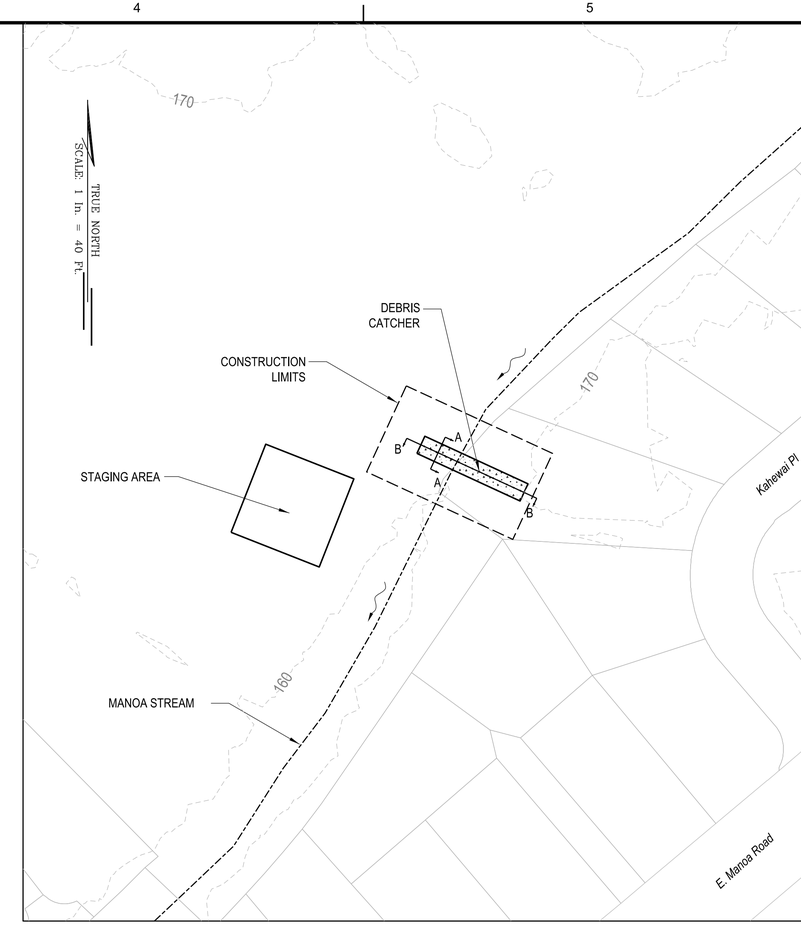
MANOA IN-STREAM DEBRIS CATCHMENT
SECTION B-B

SCALE: 1"=5'

5' 2.5' 0 5' 10'

SCALE: 1" = 5'

Note: All elevations are feet MSL



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

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HONOLULU, HAWAII

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SOLICIT./ CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: MANOA IN-STREAM DEBRIS CATCHMENT, PLAN & SECTIONS

ALA WAI CANAL PROJECT

MANOA IN-STREAM DEBRIS CATCHMENT
PLAN AND SECTIONS
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-318
SHEET 19 OF 20

FILE: c:\pw-work\poh-1\j3ec9jhh\d0133359\Ala_Wai_C-318xxx.dgn
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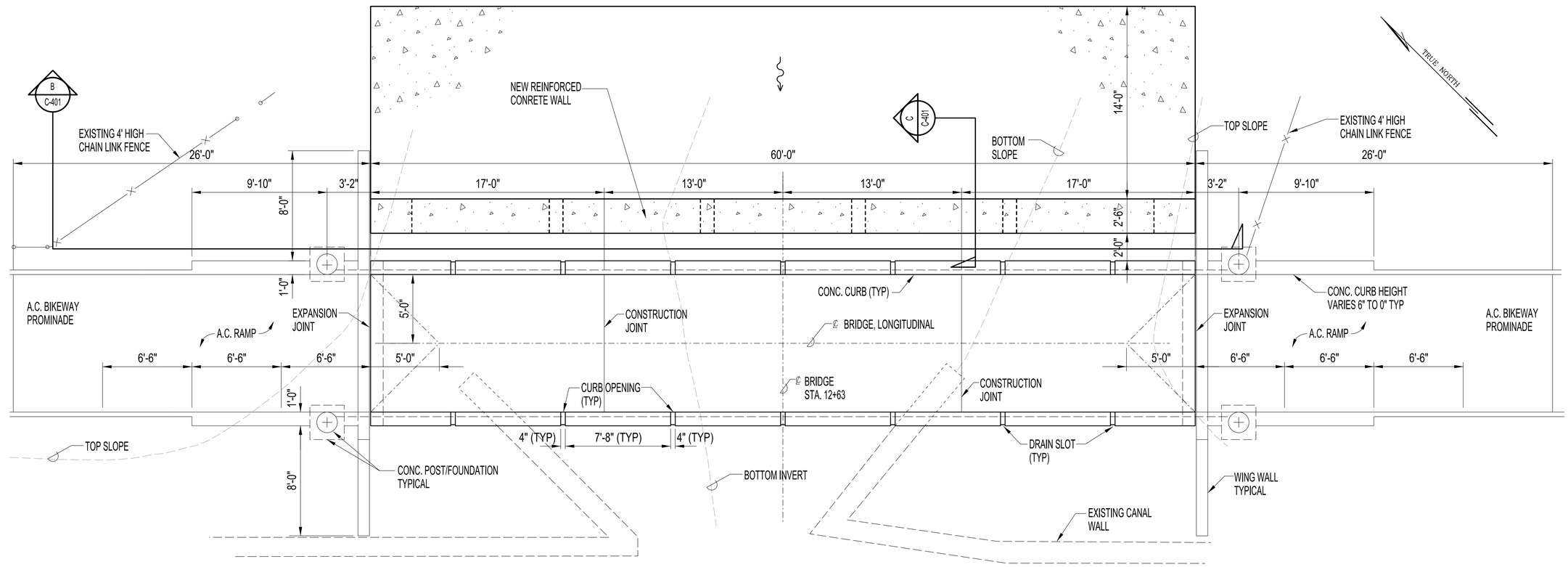
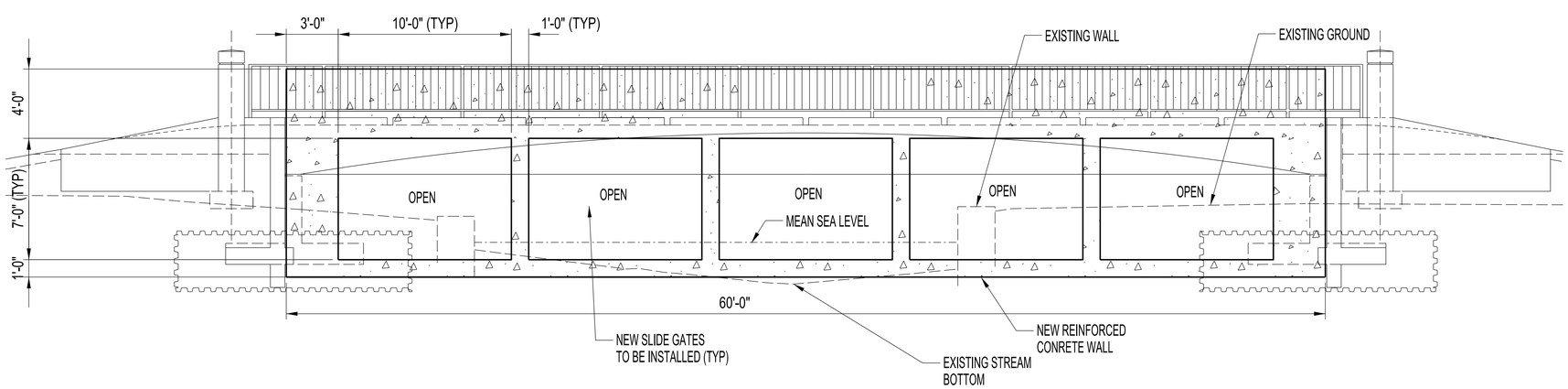


ALA WAI CANAL

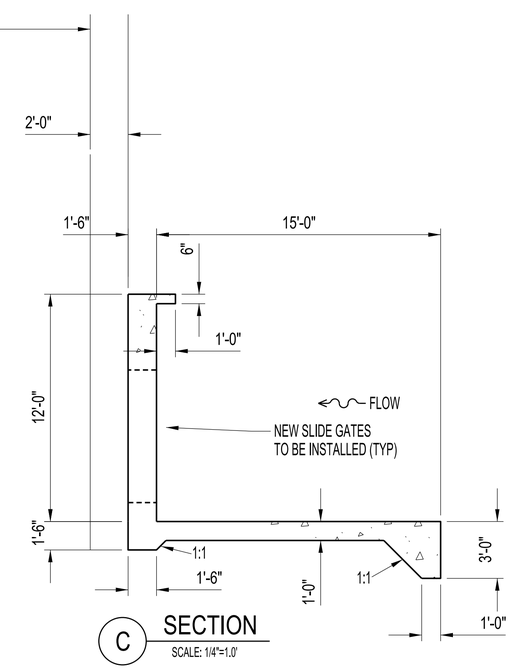
A PLAN

SCALE: 1/4"=1.0'



B ELEVATION

SCALE: 1/4"=1.0'



C SECTION

SCALE: 1/4"=1.0'

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LOCATION CODE
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
ASSIGNED:
SIZE: ANSI D
FILE NAME: HAUSTEN BRIDGE PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

HAUSTEN BRIDGE CONCRETE WALL
PLAN, SECTION AND ELEVATION
ALTERNATIVE 3A

SHEET IDENTIFICATION
C-401A
SHEET 20 OF 20

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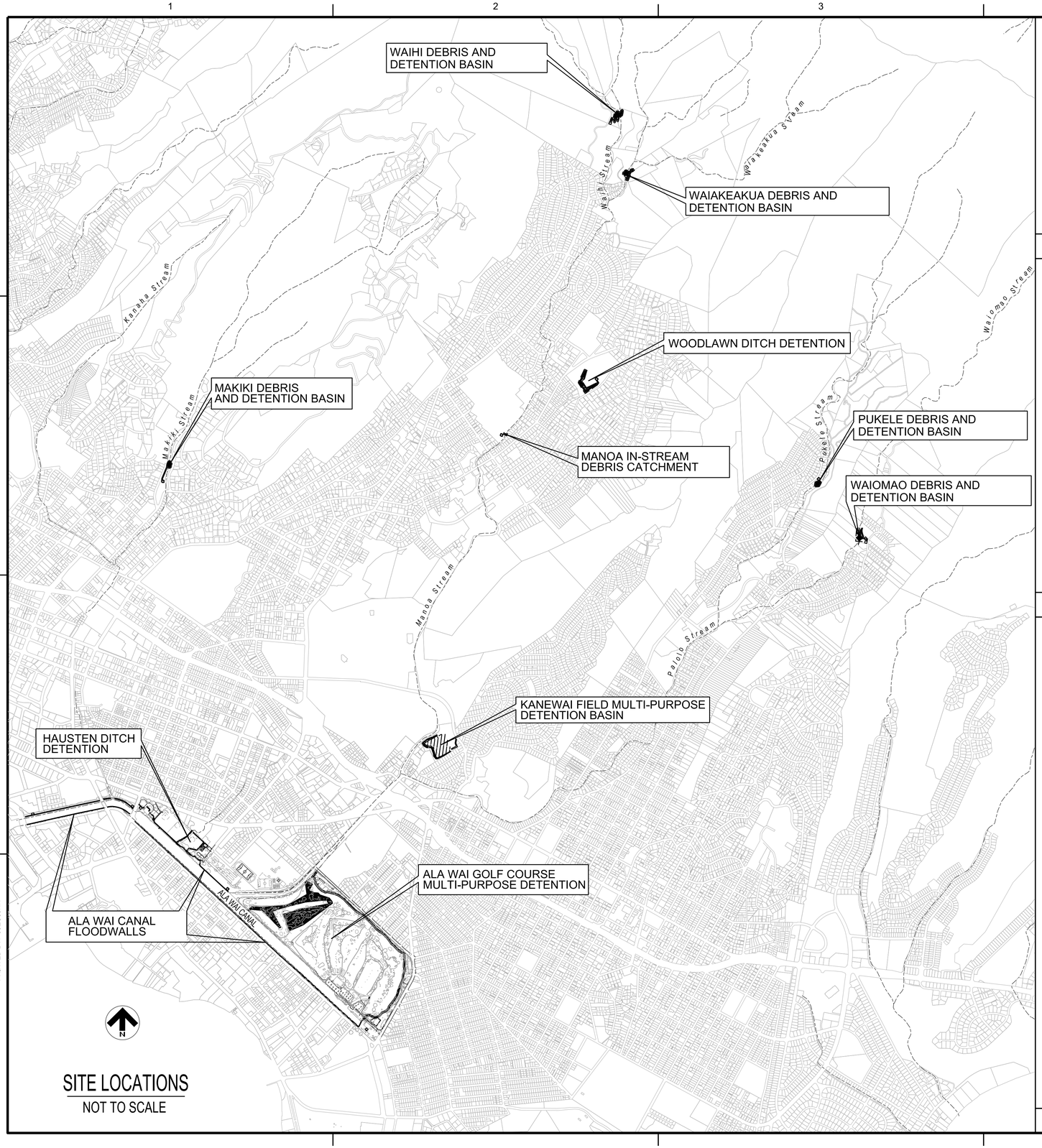


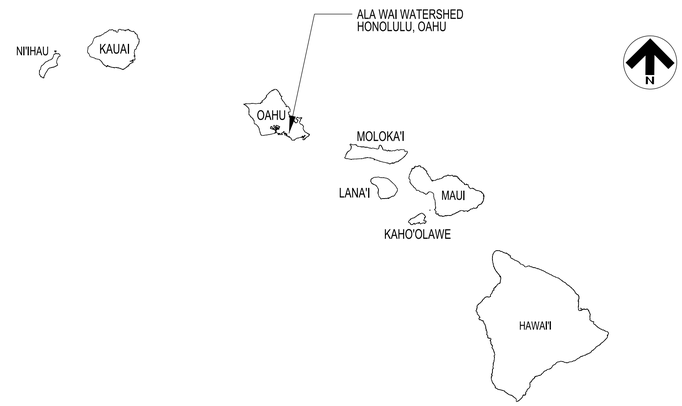
SITE LOCATIONS

NOT TO SCALE

ALA WAI CANAL PROJECT

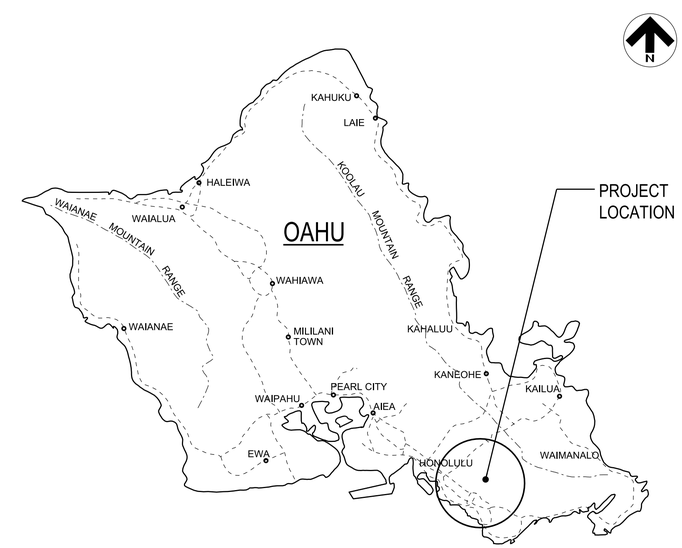
HONOLULU, OAHU, HI

PROJECT TITLE



VICINITY MAP

NOT TO SCALE



PROJECT LOCATION

NOT TO SCALE

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SIZE: ANSI D | FILE NAME: Cover Sheet - Site Locations, Vicinity Map, Project Location

ALA WAI CANAL PROJECT

SITE LOCATIONS
PROJECT LOCATION & VICINITY MAP

SHEET IDENTIFICATION
G-001
SHEET 1 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0145356\Ala_Wai_G-001xxx.dgn
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ALA WAI CANAL PROJECT
INDEX TO DRAWINGS

SHT. NO	SHT. REF. NO.	DESCRIPTION
1	G-001	SITE LOCATIONS, PROJECT LOCATION AND VICINITY MAP
2	G-002	INDEX TO DRAWINGS
3	C-101	ALA WAI CANAL FLOODWALLS, SITE PLAN
4	C-102	HAUSTEN DITCH DETENTION, SITE PLAN
5	C-103	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PLAN
6	C-104	ALA WAI UPPER LEFT BANK PLAN
7	C-105	ALA WAI UPPER END PLAN
8	C-106	KALAKAUA AVE AND ALA WAI BLVD PLAN
9	C-107	ALA WAI CANAL AND MCCULLY ST PLAN
10	C-301	WAIHI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
11	C-302	WAIAKEAKUA DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
12	C-305	WOODLAWN DITCH DETENTION BASIN, PLAN AND SECTIONS
13	C-306	KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN, PLAN AND SECTIONS
14	C-308	WAIOMAO DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
15	C-309	ALA WAI CANAL MIDDLE AND LOWER RIGHT BANK, PROFILE AND SECTION
16	C-310	ALA WAI CANAL MIDDLE AND LOWER LEFT BANK, PROFILE AND SECTION
17	C-311	ALA WAI CANAL UPPER LEFT BANK, PROFILE
18	C-313	PUKELE DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
19	C-315	MAKIKI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
20	C-316	HAUSTEN DITCH DETENTION FLOODWALLS AND BERM, PROFILE AND SECTIONS
21	C-317	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE AND SECTION
22	C-318	MANOA IN-STREAM DEBRIS CATCHMENT, PLAN AND SECTIONS
23	C-401	HAUSTEN BRIDGE CONCRETE WALL, PLAN, SECTION AND ELEVATION
24	C-501	STRUCTURAL NOTES AND MISCELLANEOUS DETAILS
25	C-601	SCHEDULE OF SLIDE GATES
26	A-101	PUMP STATION 1 - FLOOR PLAN
27	A-102	PUMP STATION 2 - FLOOR PLAN
28	A-103	PUMP STATION 3 - FLOOR PLAN
29	A-301	PUMP STATION 1 - SECTIONS
30	A-302	PUMP STATION 2 - SECTIONS
31	A-303	PUMP STATION 3 - SECTIONS

GENERAL NOTES:

1. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. COORDINATE SYSTEM: NAD 1983 (HARN), HAWAII ZONE 3 (US FEET)
3. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
4. UNLESS SHOWN OTHERWISE, ALL DISTURBED AREAS NOT RECEIVING A HARD SURFACE SHALL BE COVERED WITH GRASS.
5. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
6. EXISTING UNDERGROUND UTILITIES OBTAINED FROM AS-BUILTS AND FROM FIELD SURVEYS. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION AND PROTECT ALL EXISTING UTILITIES DURING CONSTRUCTION.
7. THE CONTRACTOR SHALL VERIFY AND CHECK ALL DIMENSIONS AND DETAILS SHOWN ON THE DRAWINGS PRIOR TO THE START OF CONSTRUCTION. ANY DISCREPANCY SHALL BE IMMEDIATELY BROUGHT TO THE ATTENTION OF THE CONTRACTING OFFICER FOR CLARIFICATION BEFORE PROCEEDING WITH CONSTRUCTION.
8. THERE WILL BE A FLOODWARNING SYSTEM INSTALLED FOR THIS PROJECT.
9. ANY ITEMS OF HISTORICAL OR ARCHEOLOGICAL VALUE OBSERVED DURING CONSTRUCTION ACTIVITIES SHALL BE REPORTED IMMEDIATELY TO THE CONTRACTING OFFICER, AND THE CONTRACTOR SHALL CEASE ALL ACTIVITIES THAT MAY RESULT IN THE DESTRUCTION OF SUCH RESOURCES IN ACCORDANCE WITH THE SPECIAL CONTRACT REQUIREMENTS.

GENERAL ABBREVIATIONS

A.C.	ASHPALT CONCRETE
AVE	AVENUE
BLVD	BOULEVARD
CONC	CONCRETE
DIA	DIAMETER
EL	ELEVATION
EXIST	EXISTING
FT	FOOT, FEET
IN	INCH, INCHES
INV	INVERT
LB	LEFT BANK
MAX	MAXIMUM
MSL	MEAN SEA LEVEL
NTS	NOT TO SCALE
o.c.	ON CENTER
O&M	OPERATIONS AND MAINTENANCE
PL	PLACE
RB	RIGHT BANK
RCP	REINFORCED CONCRETE PIPE
RD	ROAD
SQ	SQUARE
ST	STREET
STA	STATION
THK	THICK
TMK	TAX MAP KEY
TYP	TYPICAL
W.S.	WATER SURFACE
YR	YEAR

SYMBOLS

&	AND
@	AT
℄	CENTER LINE
'	FOOT, FEET
"	INCH, INCHES

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PLOT DATE:
FILE NAME: Index Of Drawings, General Notes & Abbreviations

US ARMY CORPS OF ENGINEERS
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HONOLULU, HAWAII

ALA WAI CANAL PROJECT

INDEX OF DRAWINGS, GENERAL NOTES
ABBREVIATIONS & SYMBOLS

SHEET IDENTIFICATION
G-002
SHEET 2 OF 31

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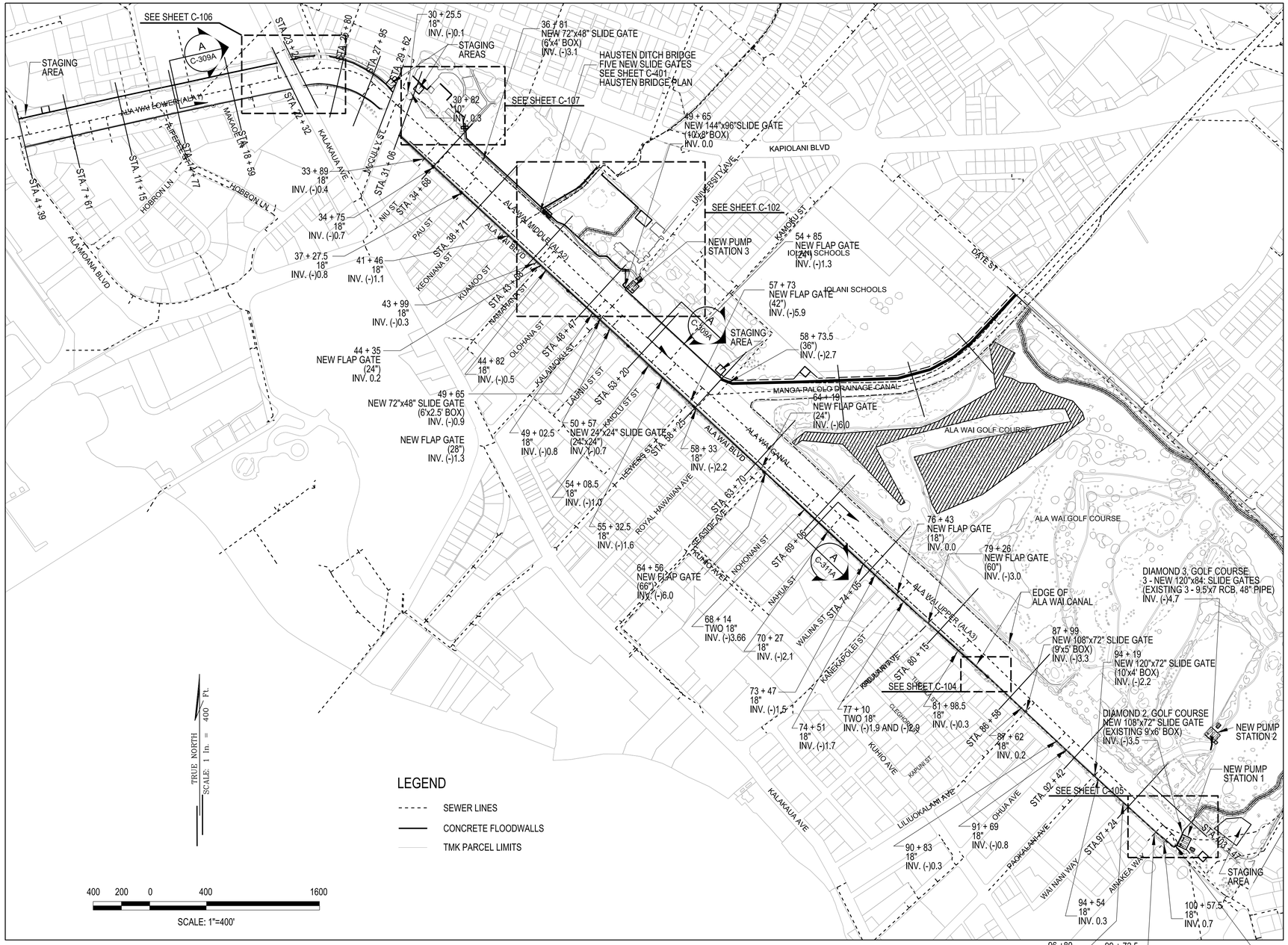

SITE PLAN
ALA WAI CANAL FLOODWALLS

ALA WAI CANAL INTERIOR DRAINAGE TABLE

CULVERT NAME	STATION	SIZE & TYPE	NOTES
DIAMOND 2, GOLF COURSE	102+45.5	108"x72" SLIDE GATE	PUMP STATION 1
DIAMOND 1, ALA WAI BLVD	101+75	144"x96" SLIDE GATES	
DIAMOND 3, GOLF COURSE	96+67	3 - 120"x84" SLIDE GATES	PUMP STATION 2
100+57.5	100+57.5	18" FLAP GATE	INV. 0.7
99+72.5	99+72.5	18" FLAP GATE	INV. 0.6
96+80	96+80	18" FLAP GATE	INV. (-)0.3
94+54	94+54	18" FLAP GATE	INV. 0.3
94+19	94+19	120"x72" SLIDE GATE	INV. (-)2.2
91+69	91+69	18" FLAP GATE	INV. (-)0.8
90+83	90+83	18" FLAP GATE	INV. (-)0.3
87+99	87+99	108"x72" SLIDE GATE	INV. (-)3.3
87+62	87+62	18" FLAP GATE	INV. 0.2
81+98.5	81+98.5	18" FLAP GATE	INV. (-)0.3
79+26	79+26	60" FLAP GATE	INV. (-)3.0
77+10	77+10	TWO 18" FLAP GATES	INV. (-)1.9 AND (-)2.9
76+43	76+43	18" FLAP GATE	INV. 0.0
74+51	74+51	18" FLAP GATE	INV. (-)1.7
73+47	73+47	18" FLAP GATE	INV. (-)1.5
70+27	70+27	18" FLAP GATE	INV. (-)2.1
68+14	68+14	TWO 18" FLAP GATES	INV. (-)3.7
64+56	64+56	66" FLAP GATE	INV. (-)6.0
64+19	64+19	24" FLAP GATE	INV. (-)6.0
58+73.5, RB	58+73.5	36" FLAP GATE	INV. (-)2.7
58+33	58+33	18" FLAP GATE	INV. (-)2.2
57+73	57+73	42" FLAP GATE	INV. (-)5.9
55+32.5	55+32.5	18" FLAP GATE	INV. (-)5.6
54+08.5	54+08.5	18" FLAP GATE	INV. (-)1.0
54+85, RB	54+85	24" FLAP GATE	INV. (-)1.3
50+57	50+57	24"x24" SLIDE GATE	INV. (-)0.7
49+65, RB	49+65	144"x96" SLIDE GATE	INV. 0.0, PUMP STATION 3
49+65	49+65	72"x48" SLIDE GATE & 28" FLAP GATE	INV. (-)1.3 & (-)0.9
49+02.5	49+02.5	18" FLAP GATE	INV. (-)0.8
44+82	44+82	18" FLAP GATE	INV. (-)0.5
44+35	44+35	24" FLAP GATE	INV. 0.2
43+99	43+99	18" FLAP GATE	INV. (-)0.3
HAUSTEN DITCH BRIDGE	42+10	4 - SLIDE GATES	SEE SHEET C-401
41+46	41+46	18" FLAP GATE	INV. (-)1.1
37+27.5	37+27.5	18" FLAP GATE	INV. (-)0.8
36+81, RB	36+81	72"x48" SLIDE GATE	INV. (-)3.1
34+75	34+75	18" FLAP GATE	INV. (-)0.7
33+89	33+89	18" FLAP GATE	INV. (-)0.4
30+82, RB	30+82	10" FLAP GATE	INV. 0.3
30+25.5, RB	30+25.5	18" FLAP GATE	INV. (-)0.1

NOTES:

1. SEE SHEET C-309 FOR THE RIGHT BANK (MOUNTAIN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
2. SEE SHEET C-310 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
3. SEE SHEET C-311 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI UPPER (ALA3).
3. SEE SHEET C-103 FOR ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN.

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SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: ALA WAI CANAL FLOODWALLS, PLAN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI LOWER, MIDDLE & UPPER FLOODWALLS
SITE PLAN

SHEET IDENTIFICATION
C-101
SHEET 3 OF 31

FILE: c:\pwworkl\poh-h1\jsc9jhh\d0143718\Ala_Wai_C-101xxx.dgn
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DATE & TIME: 12/16/2014 5:51:42 PM
LAST SAVED BY: J3EC9JHH
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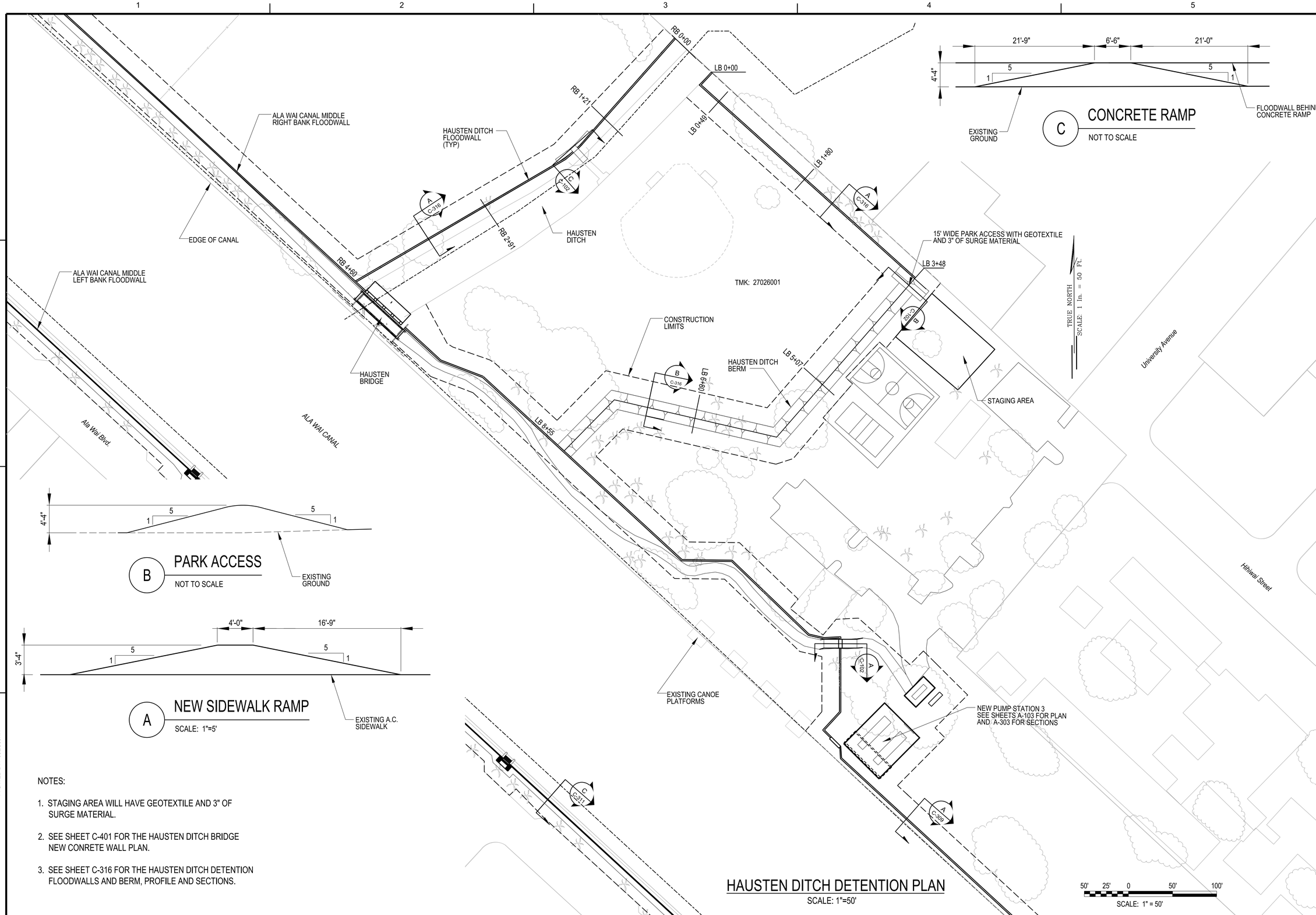
PEN TABLE: BW_and_Greyscale_Pen.tbl
PRINTED BY: J3EC9JHH



NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-401 FOR THE HAUSTEN DITCH BRIDGE NEW CONRETE WALL PLAN.
3. SEE SHEET C-316 FOR THE HAUSTEN DITCH DETENTION FLOODWALLS AND BERM, PROFILE AND SECTIONS.

FILE: c:\pwworkl\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-102xxx.dgn
MODEL NAME: C-102
DATE & TIME: 12/17/2014 8:50:34 AM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Greyscale_Pen.tbl
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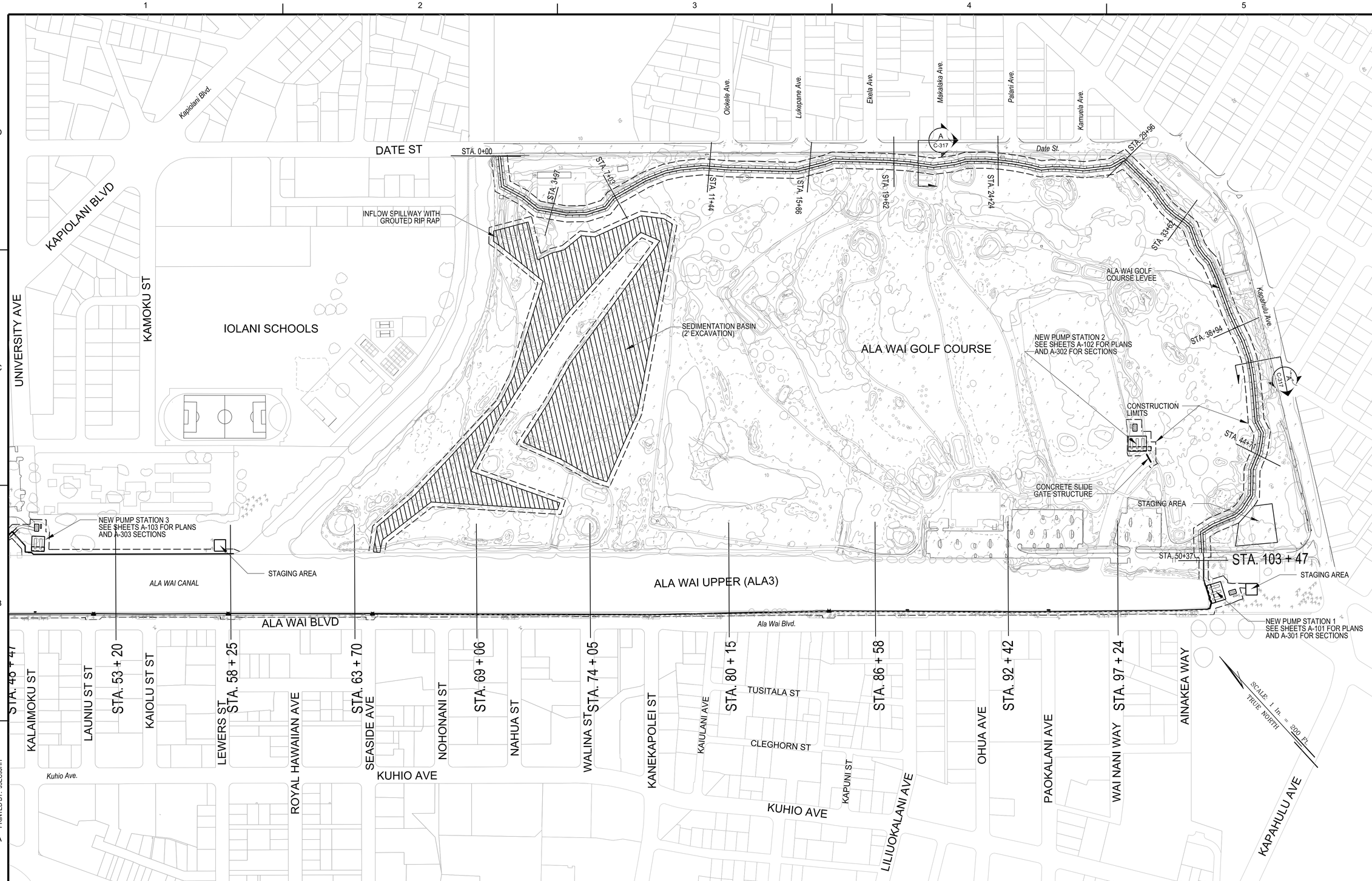
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT SIZE: ANSI D
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: HAUSTEN DITCH DETENTION PLAN

ALA WAI CANAL PROJECT

HAUSTEN DITCH DETENTION PLAN

SHEET IDENTIFICATION
C-102
SHEET 4 OF 31



NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-317 FOR THE ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE AND SECTION.

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN

SCALE: 1"=200'

200' 100' 0 200' 300'

SCALE: 1" = 200'

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SIZE: ANSI D
DATE:
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PLOT DATE:
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

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HONOLULU DISTRICT
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ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN

SHEET IDENTIFICATION
C-103
SHEET 5 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-103xx.dgn
MODEL NAME: C-103
DATE & TIME: 12/23/2014 10:19:16 AM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotd\printer.plotd
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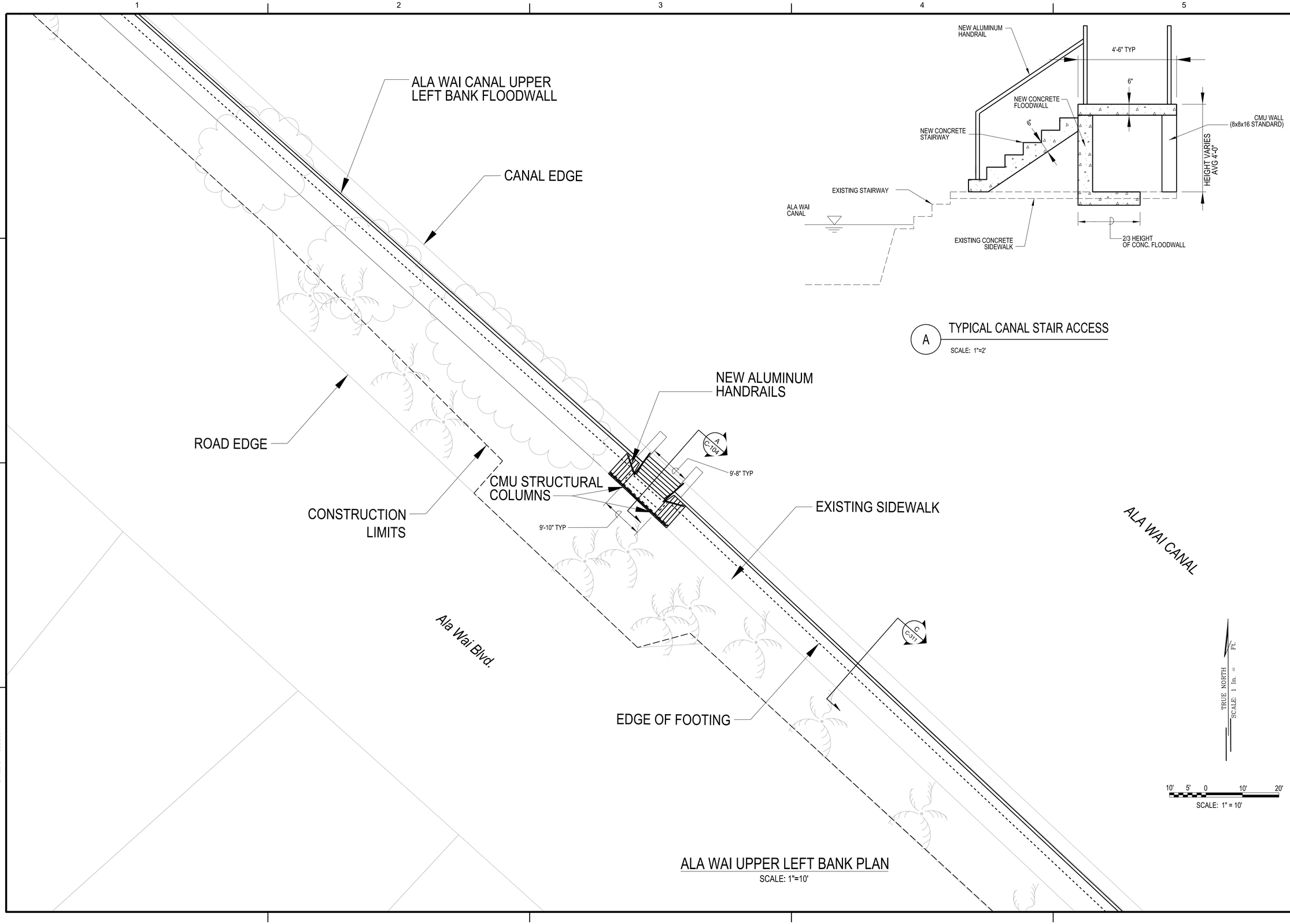
PRINTED BY: J3EC9JHH



ALA WAI UPPER LEFT BANK PLAN

SCALE: 1"=10'

A TYPICAL CANAL STAIR ACCESS

SCALE: 1"=2'

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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: 1:1 | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: ALA WAI UPPER LEFT BANK PLAN

ALA WAI CANAL PROJECT

ALA WAI UPPER LEFT BANK PLAN

SHEET IDENTIFICATION
C-104
SHEET 6 OF 31

FILE: c:\pw-work\pcb-1\j3ec3jhh\d0143718\Ala_Wai_C-104xxx.dgn
MODEL NAME: C-104
DATE & TIME: 12/17/2014 9:19:10 AM
LAST SAVED BY:
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
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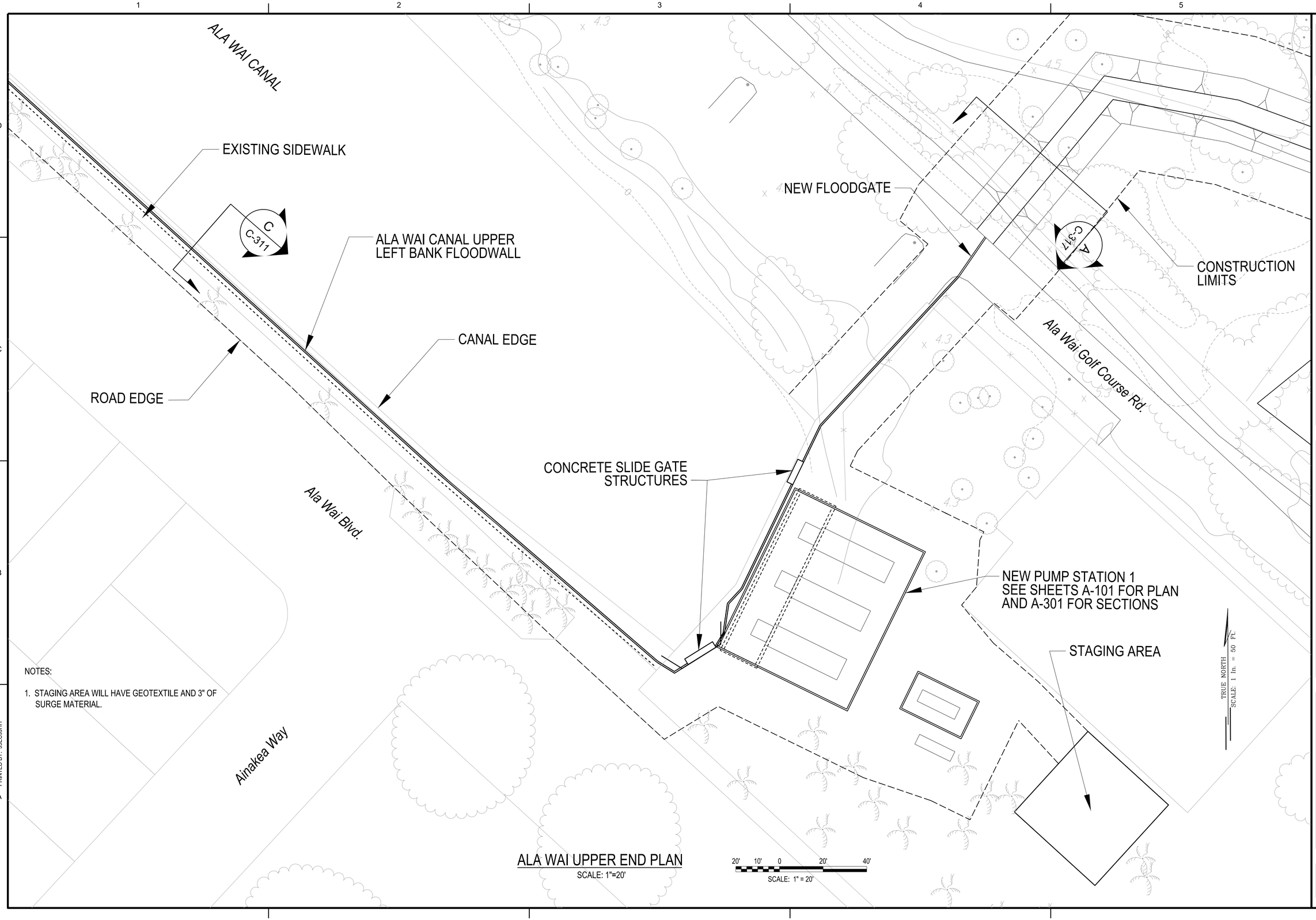

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.

ALA WAI UPPER END PLAN

SCALE: 1"=20'

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SUBMITTED BY:
PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: ALA WAI UPPER END PLAN
DATE:
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI UPPER END PLAN

SHEET IDENTIFICATION
C-105
SHEET 7 OF 31

FILE: c:\pw-work\pch-1\j3ec9jhh\d0143718\Ala_Wai_C-105xxx.dgn
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DATE & TIME: 12/17/2014 9:22:54 AM
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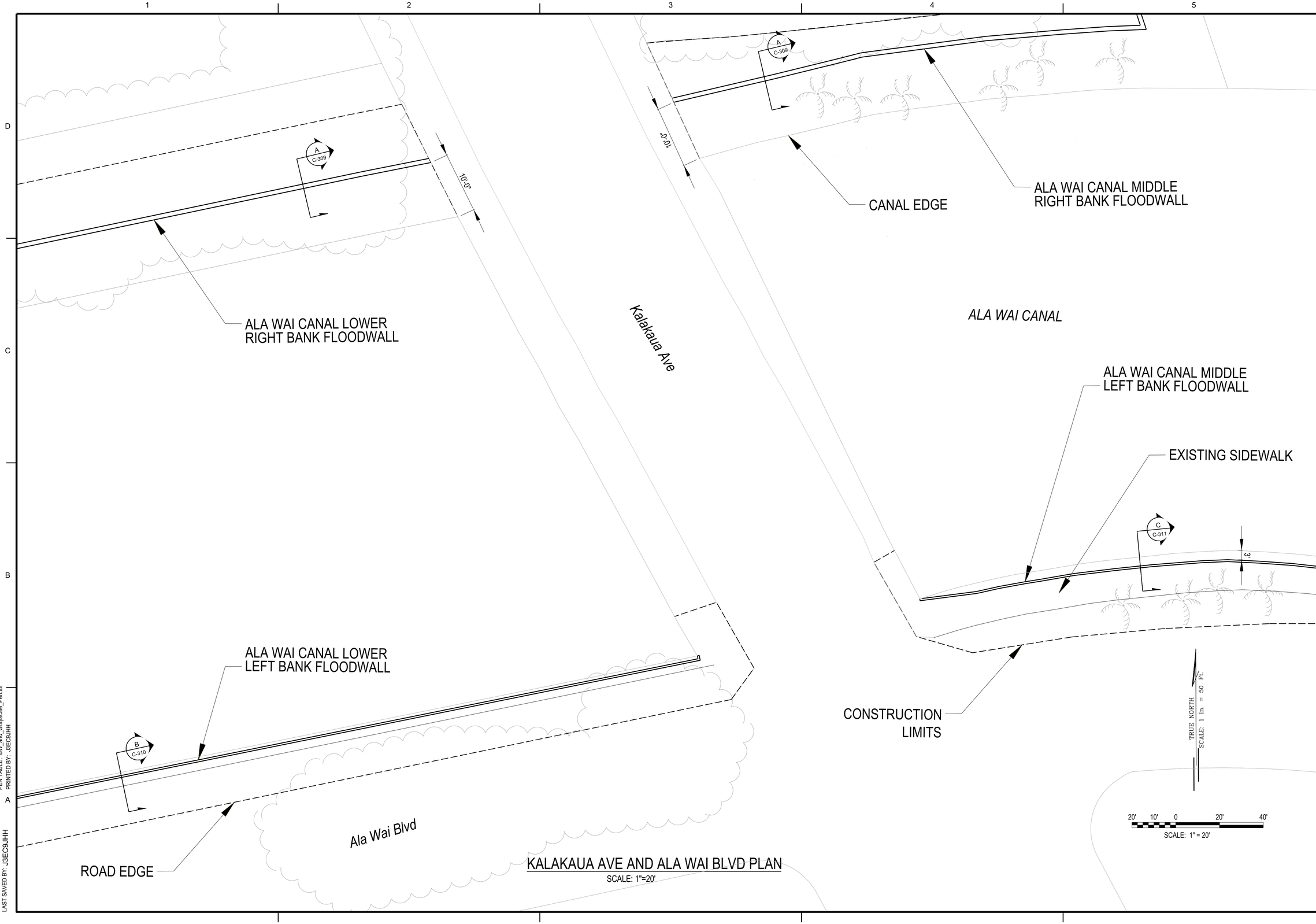
PRINTED BY: J3EC9JHH



KALAKAUA AVE AND ALA WAI BLVD PLAN

SCALE: 1"=20'

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SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
VERTICAL DATUM:
DRAWING NUMBER:
FILE NAME: KALAKAUA AVE AND ALA WAI BLVD PLAN

ALA WAI CANAL PROJECT

KALAKAUA AVE AND ALA WAI BLVD PLAN

SHEET IDENTIFICATION
C-106
SHEET 8 OF 31

FILE: c:\pw-work\poh-ntj3ec9jhhd\d0143718\Ala_Wai_C-106xxx.dgn
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LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
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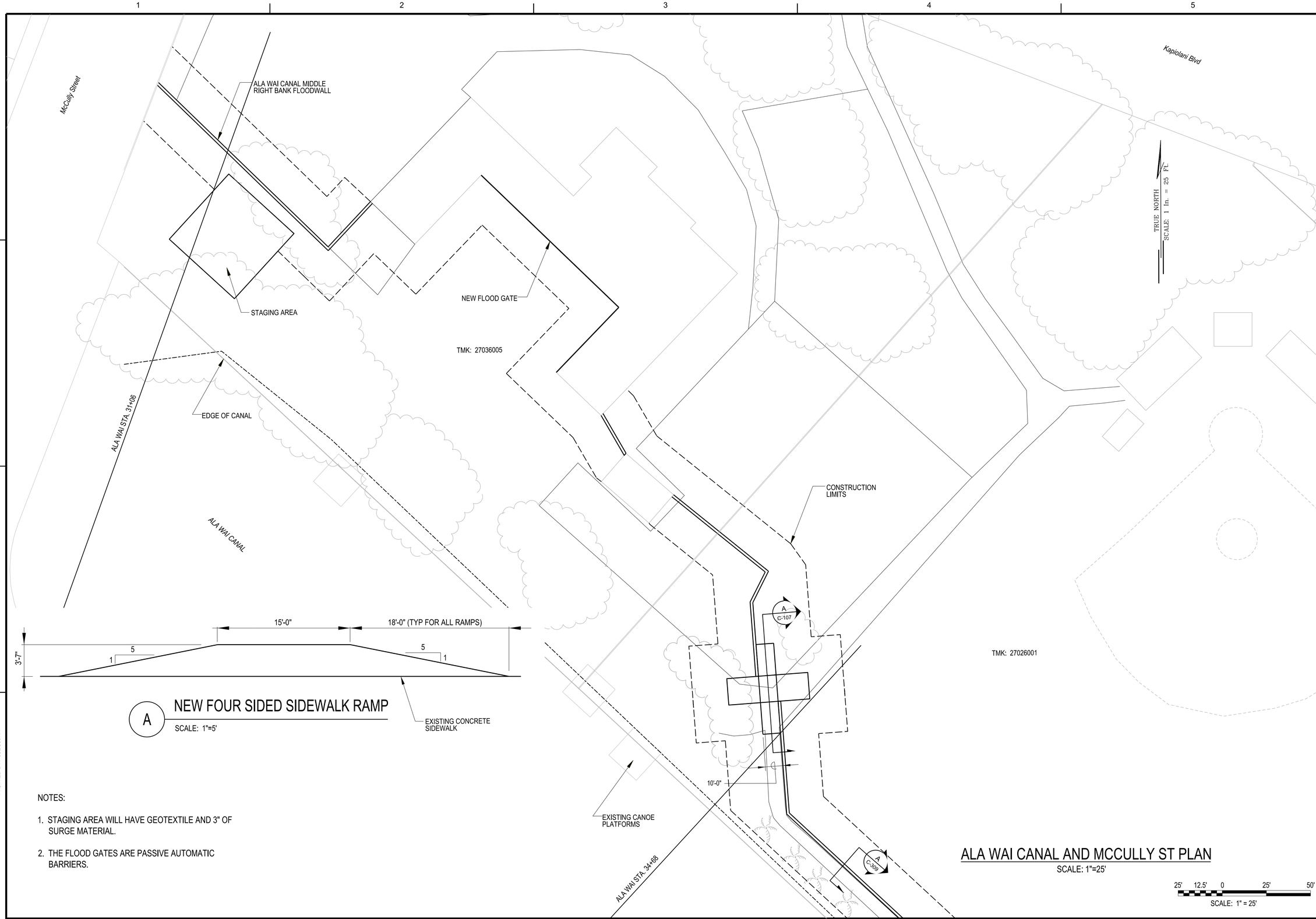

A NEW FOUR SIDED SIDEWALK RAMP

SCALE: 1"=5'

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. THE FLOOD GATES ARE PASSIVE AUTOMATIC BARRIERS.

ALA WAI CANAL AND MCCULLY ST PLAN

SCALE: 1"=25'

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PLOT SCALE:
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
FILE NAME: ALA WAI CANAL AND MCCULLY ST PLAN
REVISION:
SOLICIT./ CONTRACT NO.:
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DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI CANAL AND MCCULLY ST PLAN

SHEET IDENTIFICATION
C-107
SHEET 9 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-107xxx.dgn
MODEL NAME: C-102
DATE & TIME: 12/17/2014 9:57:05 AM
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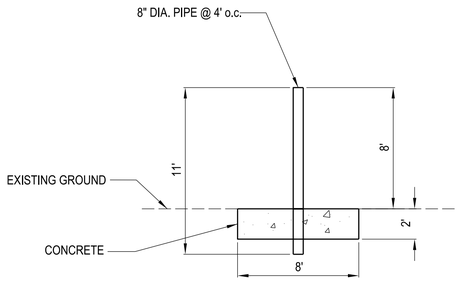
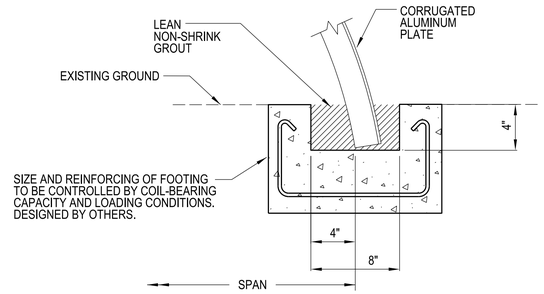
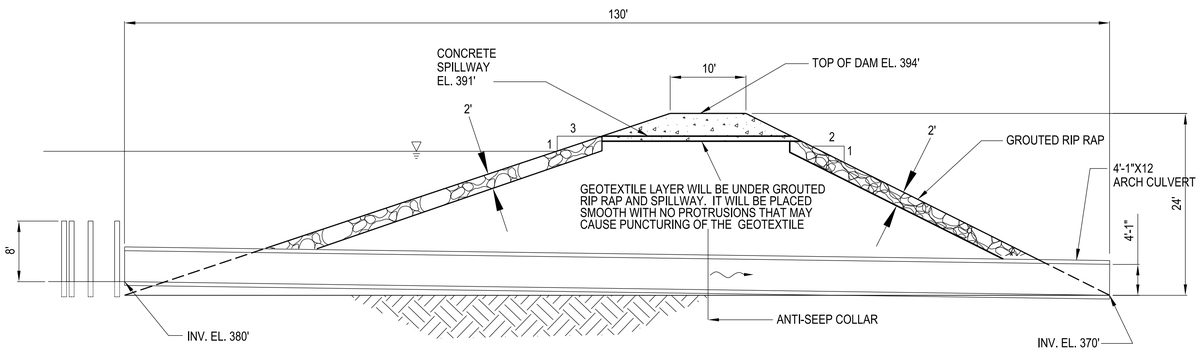


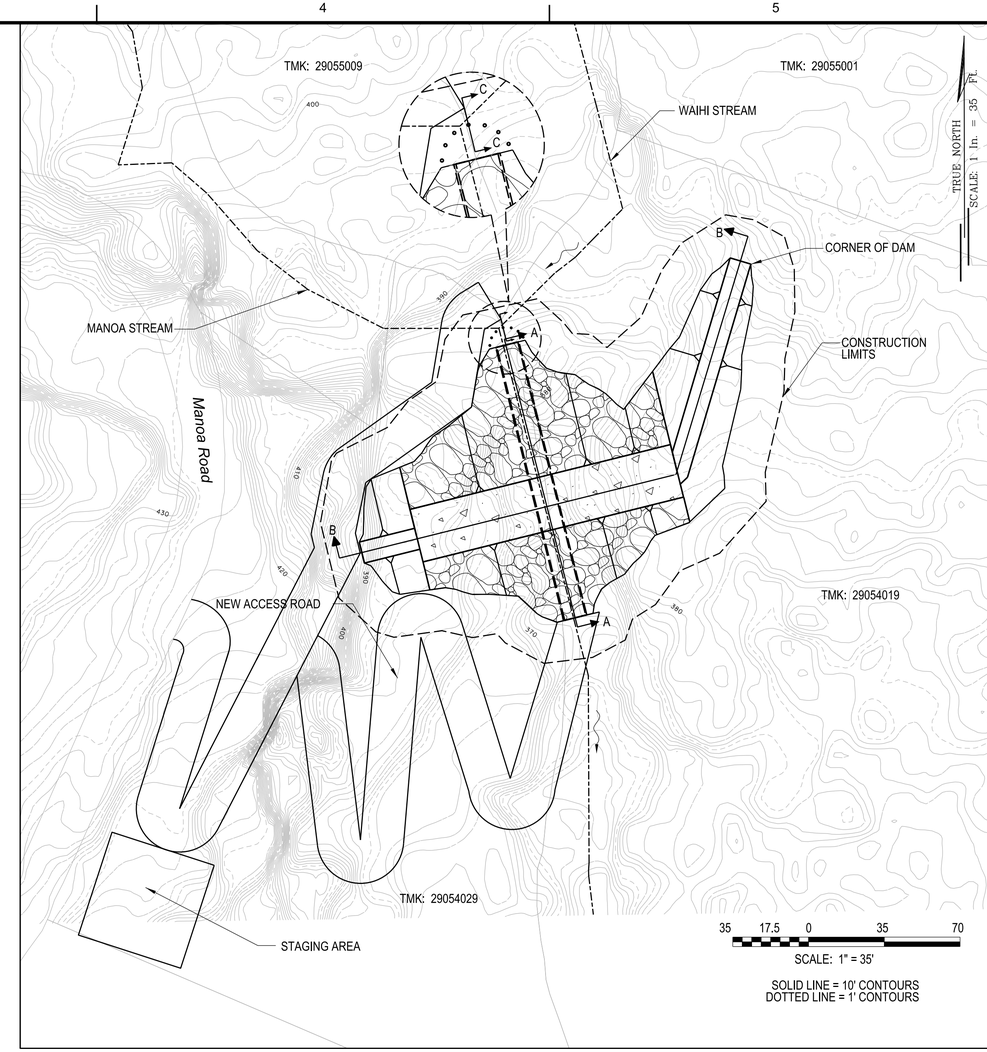
WAIHI DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



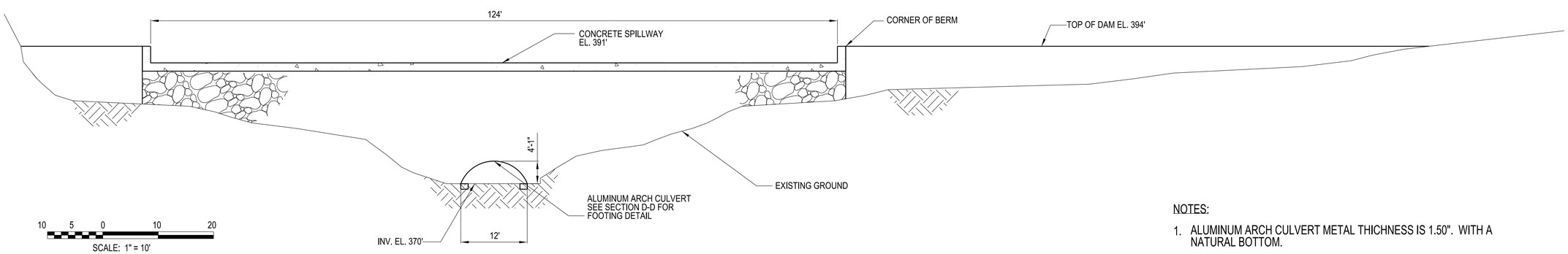
SLOTTED CONCRETE FOOTING
WAIHI DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



WAIHI DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



PLAN
SCALE: 1"=35'



Note: All elevations are feet MSL

WAIHI DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

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PLOT SCALE: 1:1 | PLOT DATE: 7/28/2015 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: SFILE$

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ALA WAI CANAL PROJECT

WAIHI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-301
SHEET 10 OF 31

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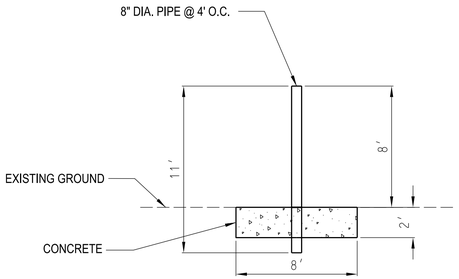
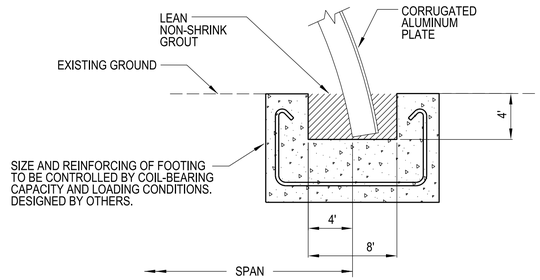
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

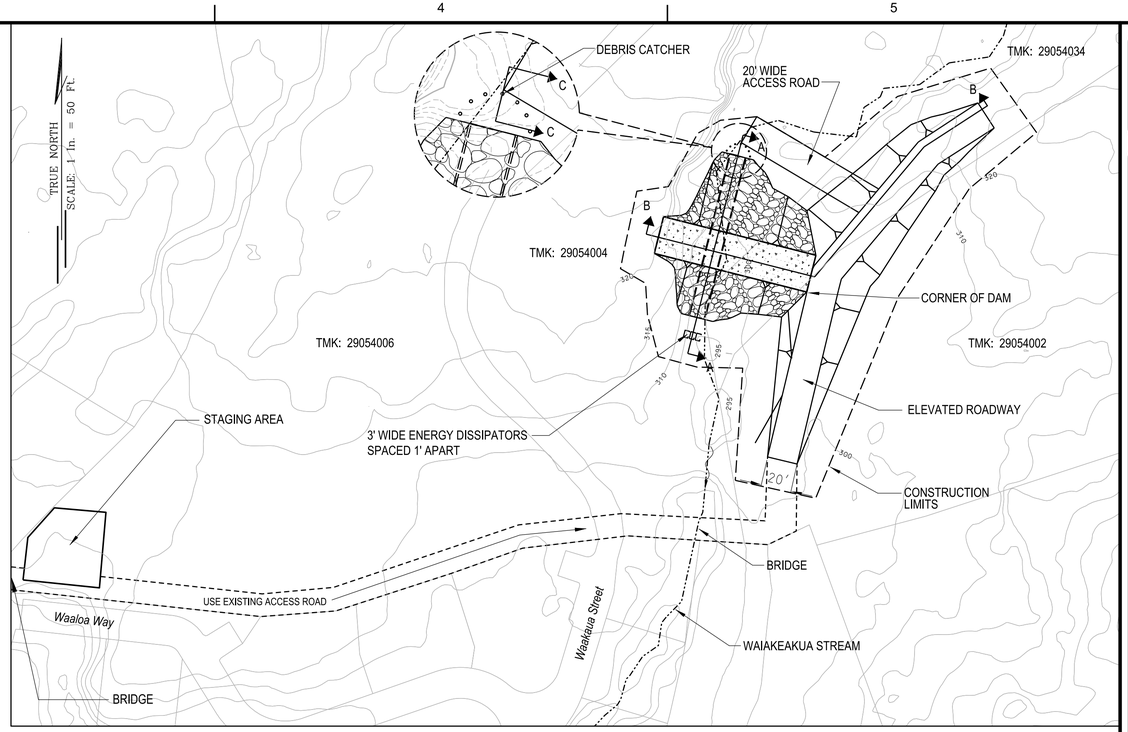
FILE: $FILE$$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:02:42 PM
LAST SAVED BY: J3EC9JHH



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING
WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS

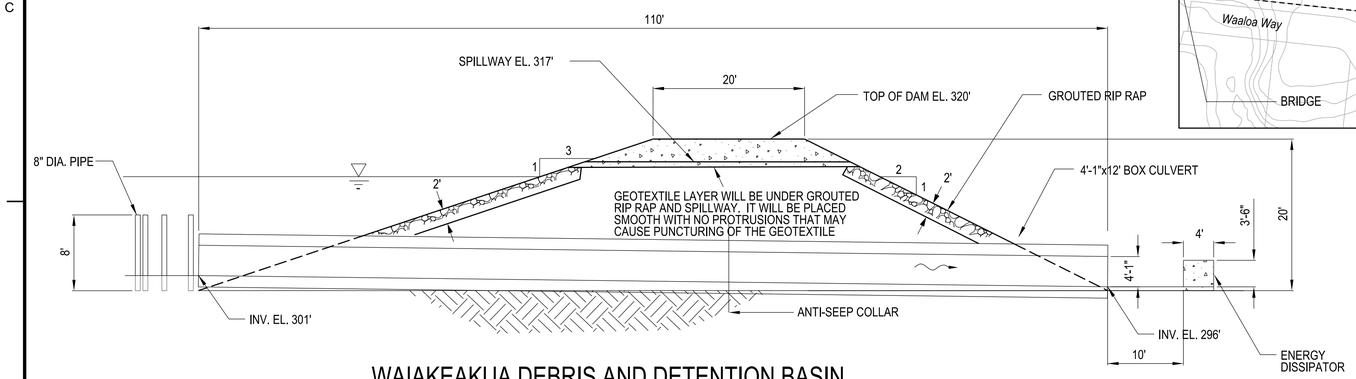


PLAN
SCALE: 1"=50'

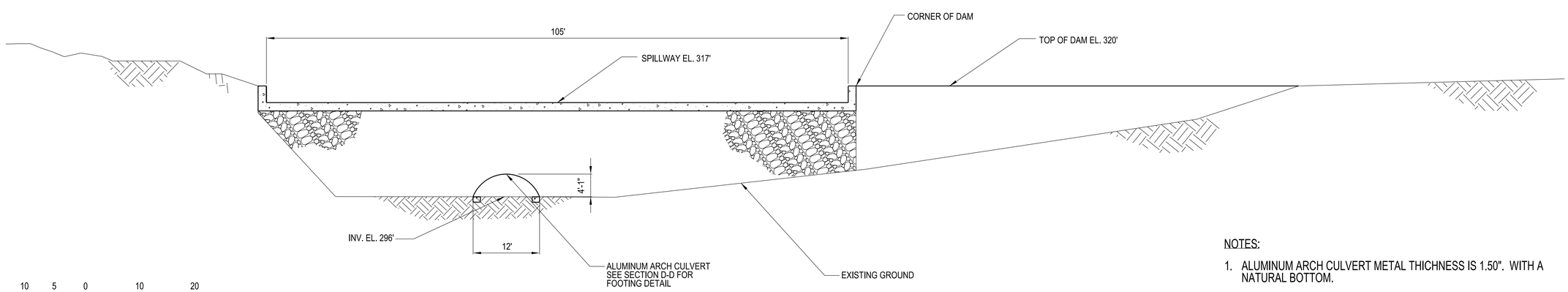
SOLID LINE = 5' CONTOURS

50 25 0 50 100

SCALE: 1" = 50'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

10 5 0 10 20

SCALE: 1" = 10'

Note: All elevations are feet MSL

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
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FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:03:44 PM
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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: | PLOT DATE: 7/28/2015 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: $FILE$

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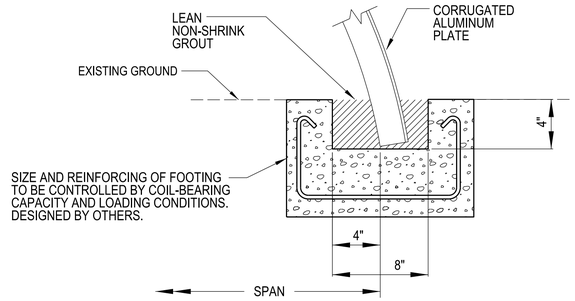
ALA WAI CANAL PROJECT

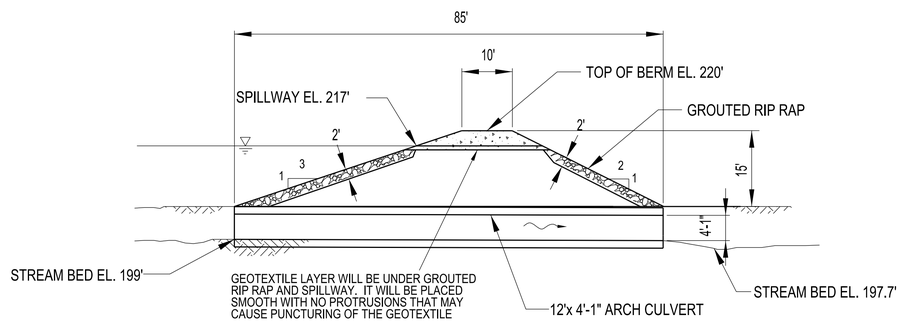
WAIAKEAKUA DEBRIS AND DETENTION
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-302
SHEET 11 OF 31



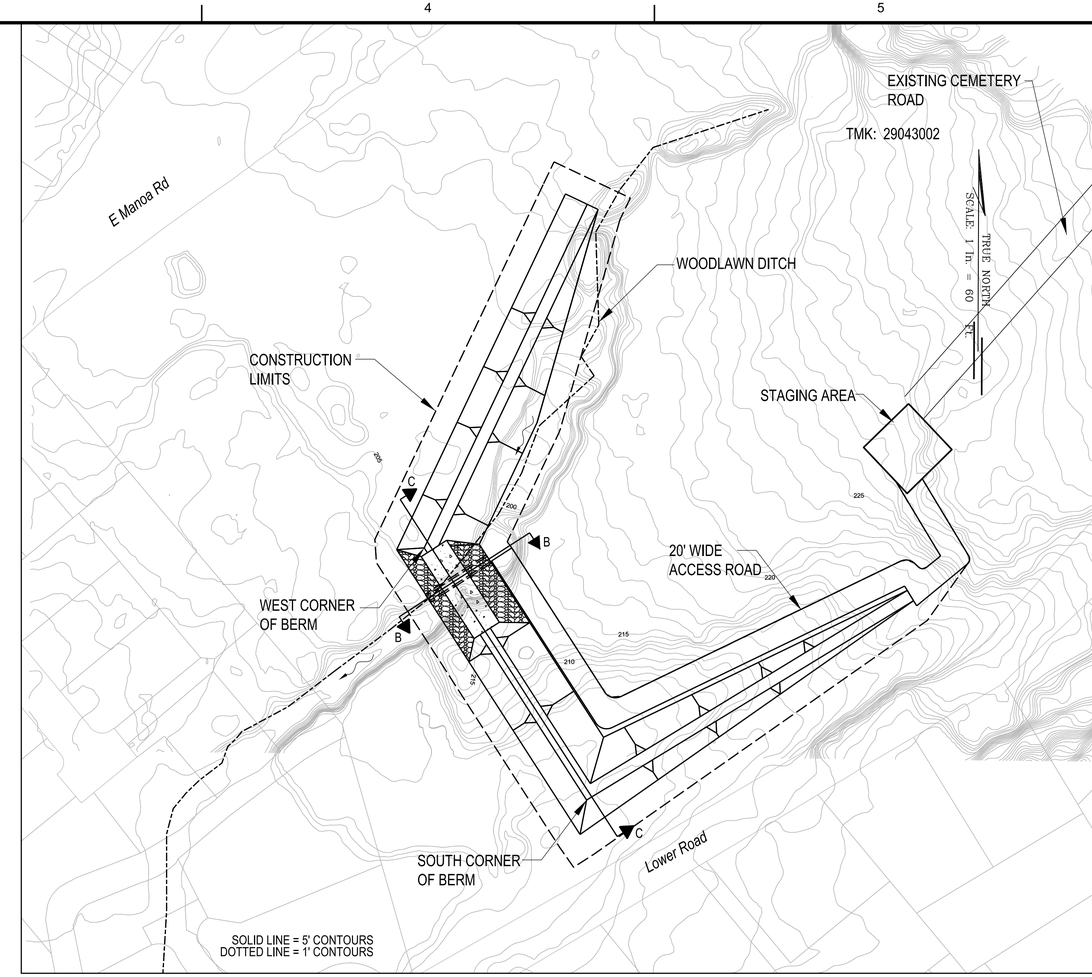
SLOTTED CONCRETE FOOTING
WOODLAWN DITCH DETENTION BASIN
SECTION D-D

SCALE: NTS



WOODLAWN DITCH DETENTION BASIN
SECTION B-B

SCALE: 1"=15'



PLAN

SCALE: 1"=60'

WOODLAWN DITCH DETENTION BASIN
SECTION C-C

SCALE: 1"=15'

15 7.5 0 15 30
SCALE: 1" = 15'

Note: All elevations are feet MSL

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

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PLOT SCALE: 1:1
PLOT DATE:
SIZE: ANSI D
FILE NAME: SFLE55
DATE:
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REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WOODLAWN DITCH DETENTION
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-305
SHEET 12 OF 31

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:04:18 PM
LAST SAVED BY: J3EC9JHH

PLOTDRIVER: $PLTDRV$$
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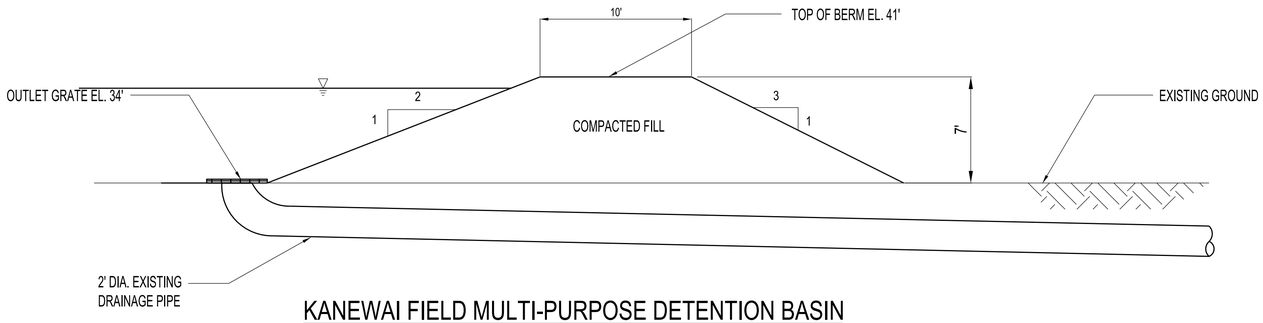
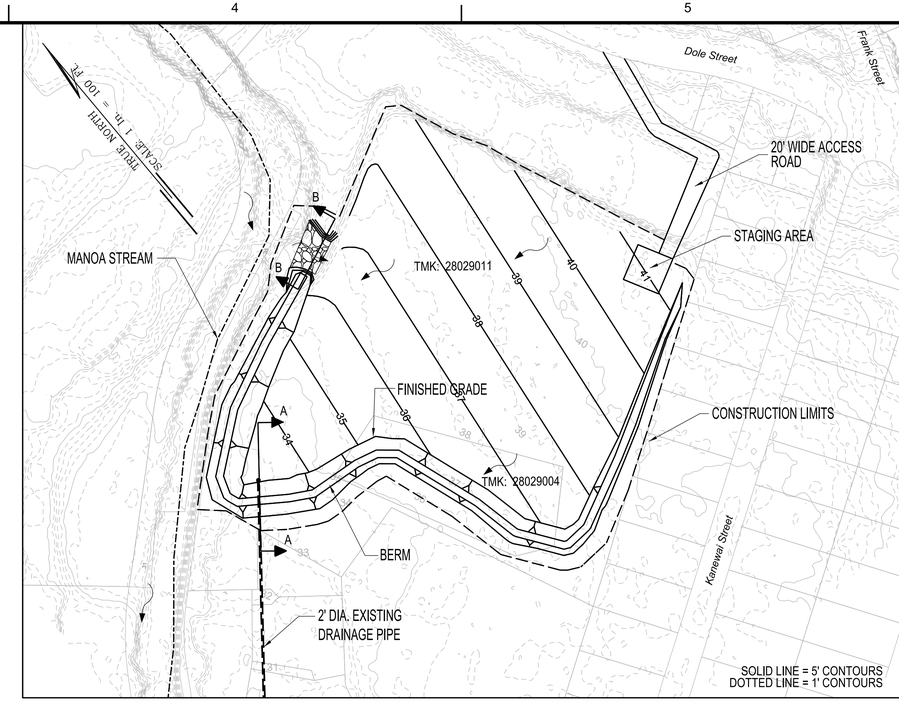


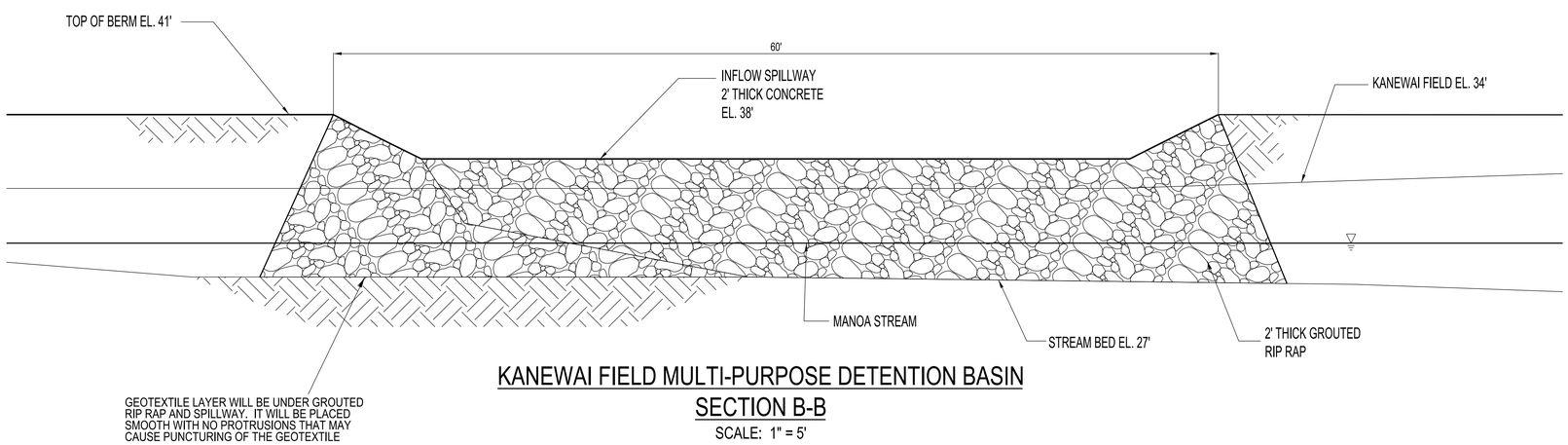
KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION A-A

SCALE: 1" = 5'



PLAN

SCALE: 1" = 100'



KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION B-B

SCALE: 1" = 5'

5' 2.5' 0 5' 10'

SCALE: 1" = 5'

Note: All elevations are feet MSL

NOTES:

1. THE ACESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:04:49 PM
LAST SAVED BY: J3ECQJHH

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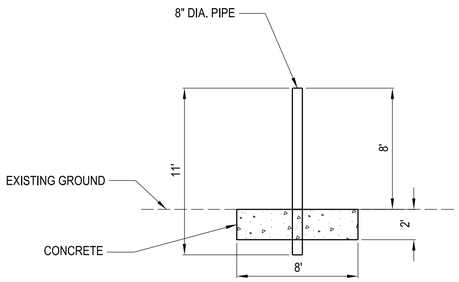
SUBMITTED BY: | LOCATION CODE
PLOT SCALE: 1:1 | PLOT DATE: 7/28/15 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: $FILE$

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

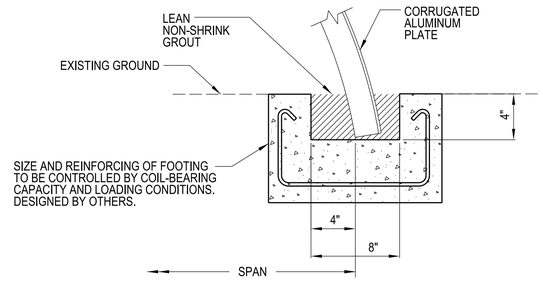
ALA WAI CANAL PROJECT

KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
PLAN AND SECTIONS

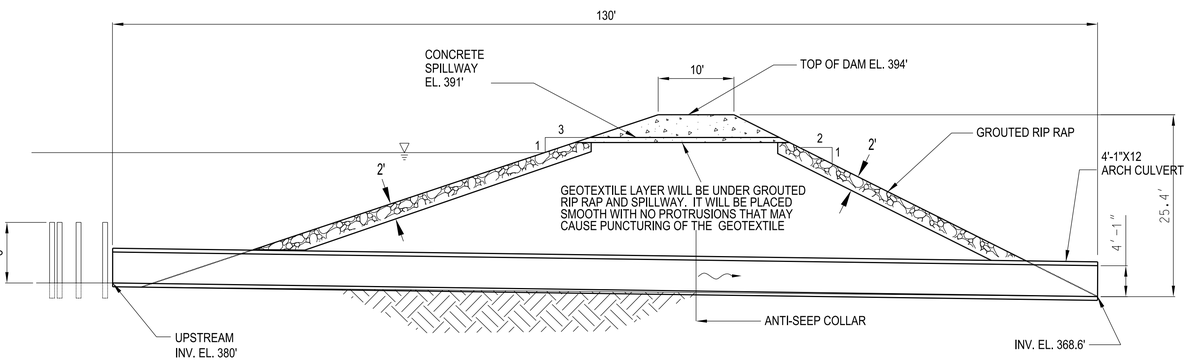
SHEET IDENTIFICATION
C-306
SHEET 13 OF 31



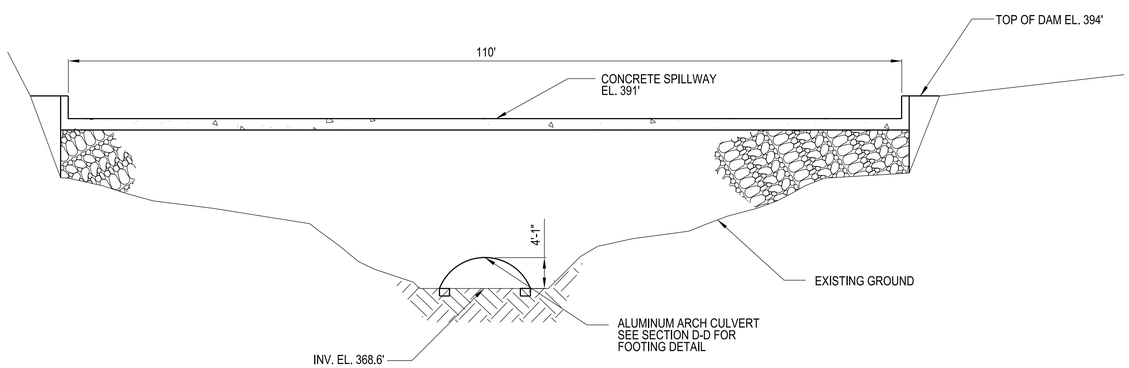
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



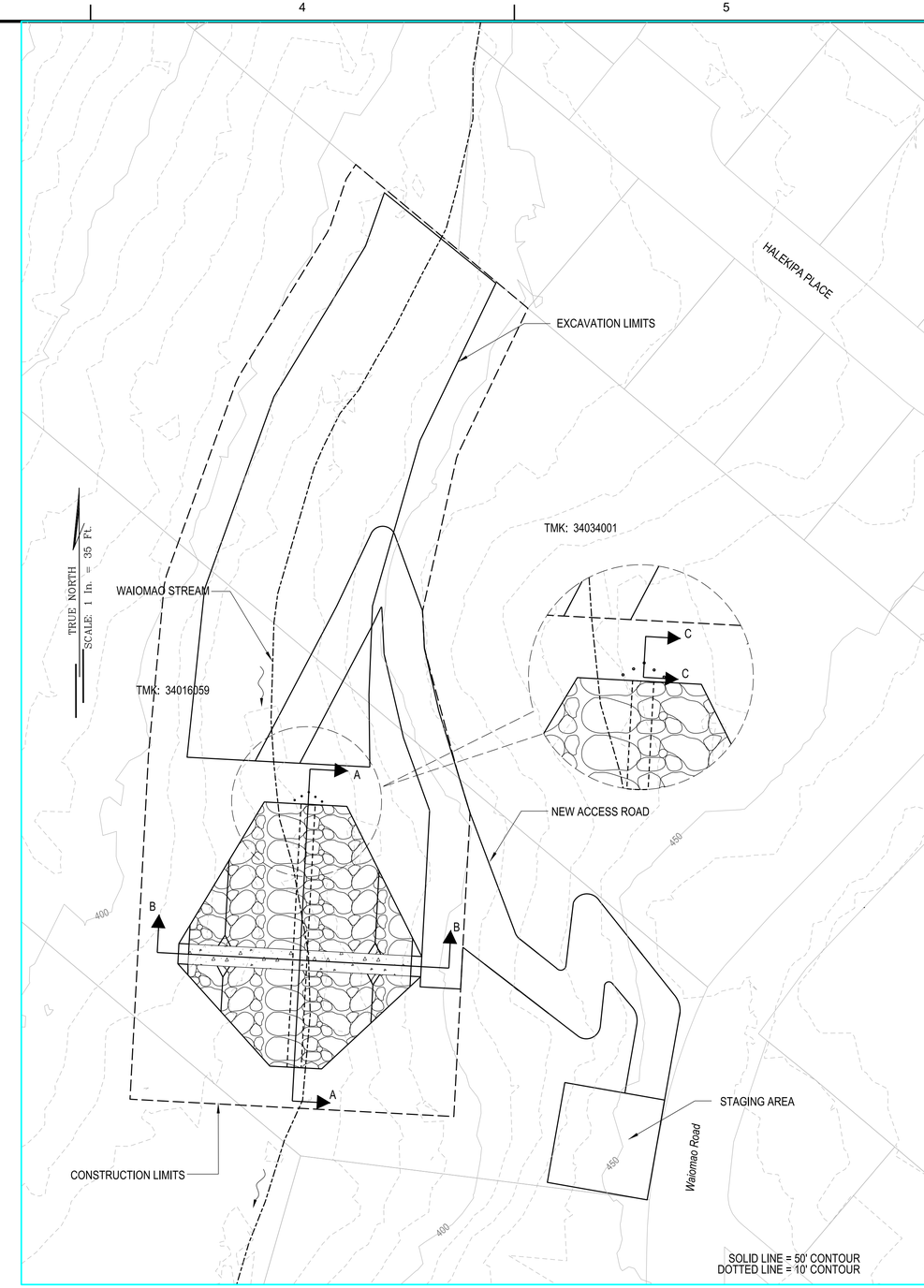
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



WAIOMAO DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL



PLAN
SCALE: 1"=35'

35 17.5 0 35 70
SCALE: 1" = 35'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

35% DESIGN

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: 1:1 PLOTTED
SIZE: ANSI D
FILE NAME: $FILE$
CHECKED BY: SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE: 7/28/2015
DATE:
REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

WAIOMAO DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-308
SHEET 14 OF 31

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:05:41 PM
LAST SAVED BY: J3EC9JHH
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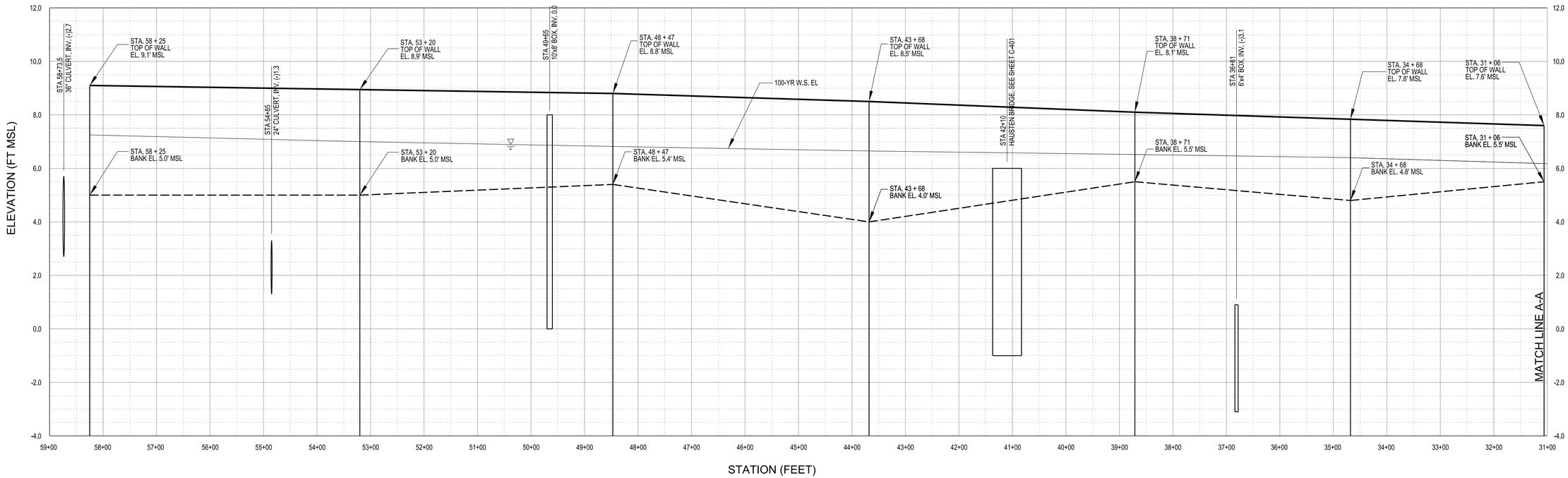

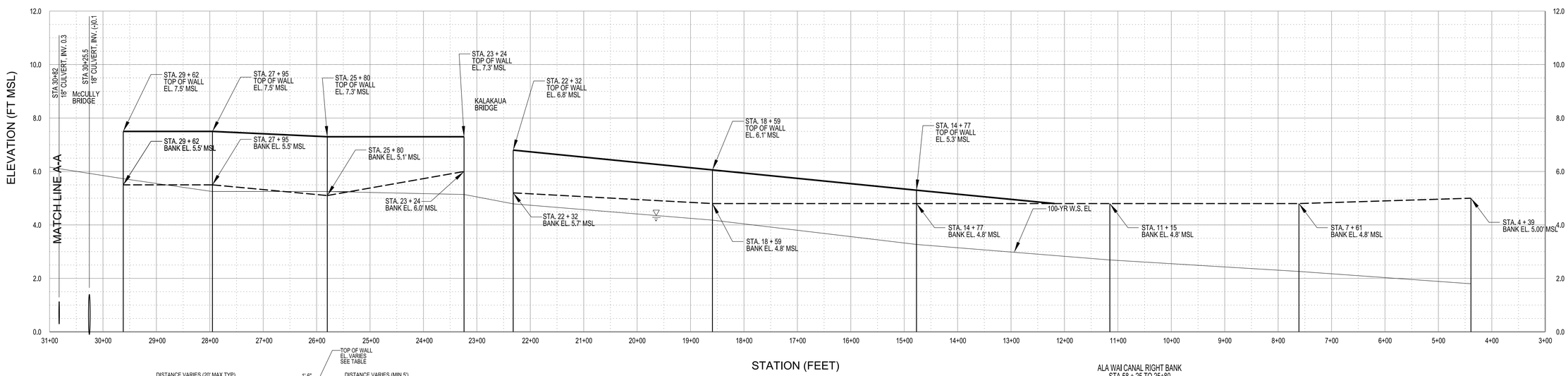

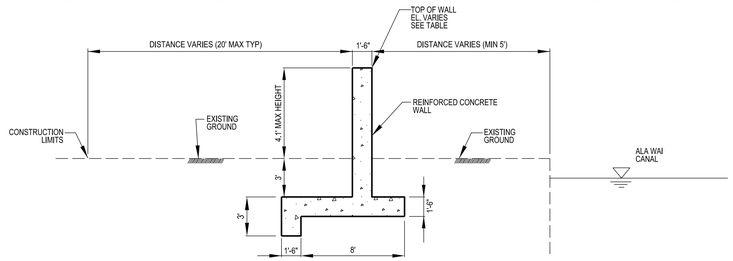

A TYPICAL RIGHT BANK REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE

PROFILE

ALA WAI MIDDLE (ALA2) AND LOWER (ALA1) RIGHT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

ALA WAI CANAL RIGHT BANK
STA 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	4.1	9.1
53 + 20	3.9	8.9
48 + 47	3.4	8.8
43 + 68	4.5	8.5
38 + 71	2.6	8.1
34 + 68	3.0	7.8
31 + 06	2.1	7.6
MCCLULLY BRIDGE		
29 + 62	2.0	7.5
27 + 95	2.0	7.5
25 + 80	2.2	7.3

ALA WAI CANAL RIGHT BANK
STA 23 + 24 TO 11 + 15

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	1.3	7.3
KALAKAUA BRIDGE		
22 + 32	1.1	6.8
18 + 59	1.3	6.1
14 + 77	0.5	5.3

PLOTDRIVER: $PLTDRV$S
PEN TABLE: $PENTBL$S
PRINTED BY: $USERS

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:06:07 PM
LAST SAVED BY: J3EC9JHH

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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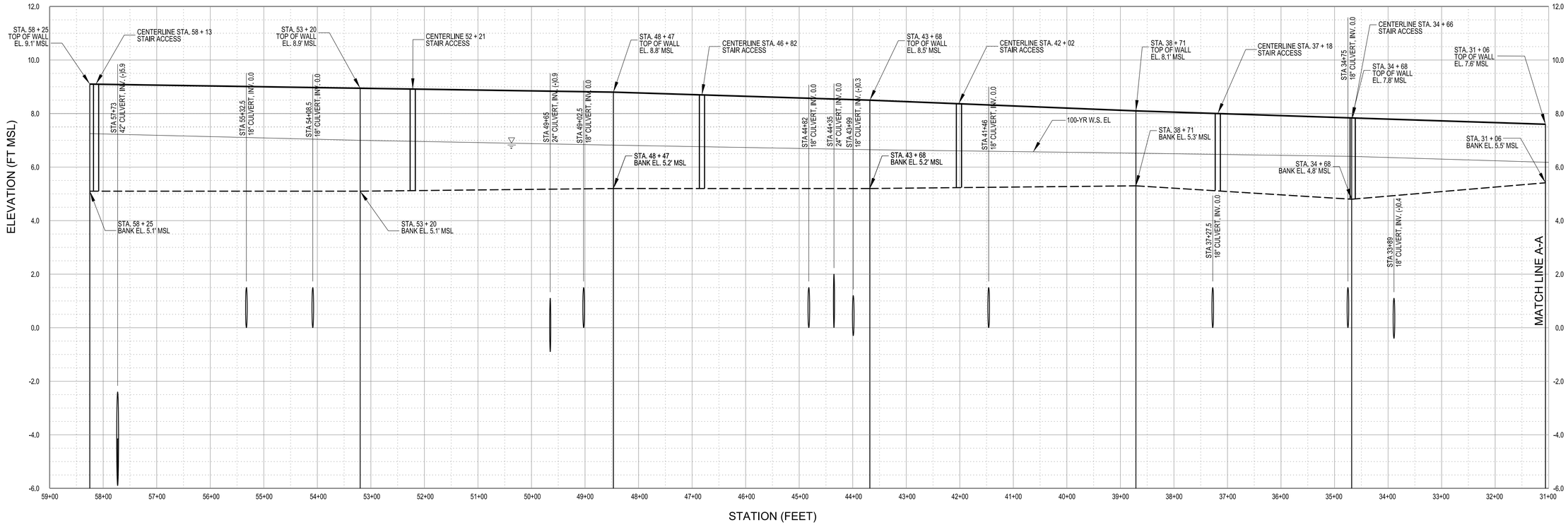
DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: 1:1000000
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
FILE NAME: $FILE$
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

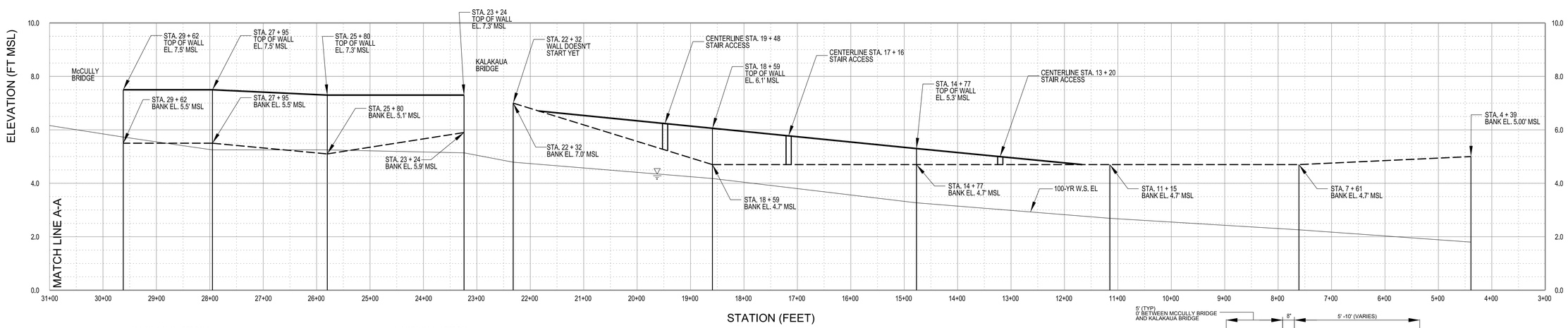
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI MIDDLE & LOWER RIGHT BANK FLOODWALLS
PROFILE AND SECTION

SHEET IDENTIFICATION
C-309
SHEET 15 OF 31





ALA WAI CANAL LEFT BANK
STA TO 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	4.0	9.1
53 + 20	3.8	8.9
48 + 47	3.6	8.8
43 + 68	3.3	8.5
38 + 71	2.8	8.1
34 + 68	3.0	7.8
31 + 06	2.1	7.6
MCCLULLY BRIDGE		
29 + 62	2.0	7.5
27 + 95	2.0	7.5
25 + 80	2.2	7.3

ALA WAI CANAL LEFT BANK
STA TO 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	1.4	7.3
KALAKAUA BRIDGE		
22 + 32	-	-
18 + 59	1.4	6.1
14 + 77	0.6	5.3

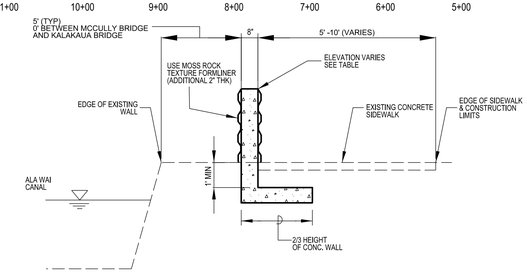
PROFILE

ALA WAI CANAL MIDDLE (ALA2) AND LOWER (ALA1) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

NOTES:

1. SEE DETAIL "C" ON SHEET C-311 FOR ALA WAI CANAL MIDDLE (ALA2) TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION.
2. ALA WAI CANAL LOWER (ALA1) IS FROM STATION 23+24 TO STATION 4+39.



B TYPICAL ALA WAI LOWER (ALA1) LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE:
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE: 7/28/2015
FILE NAME: $FILE$
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

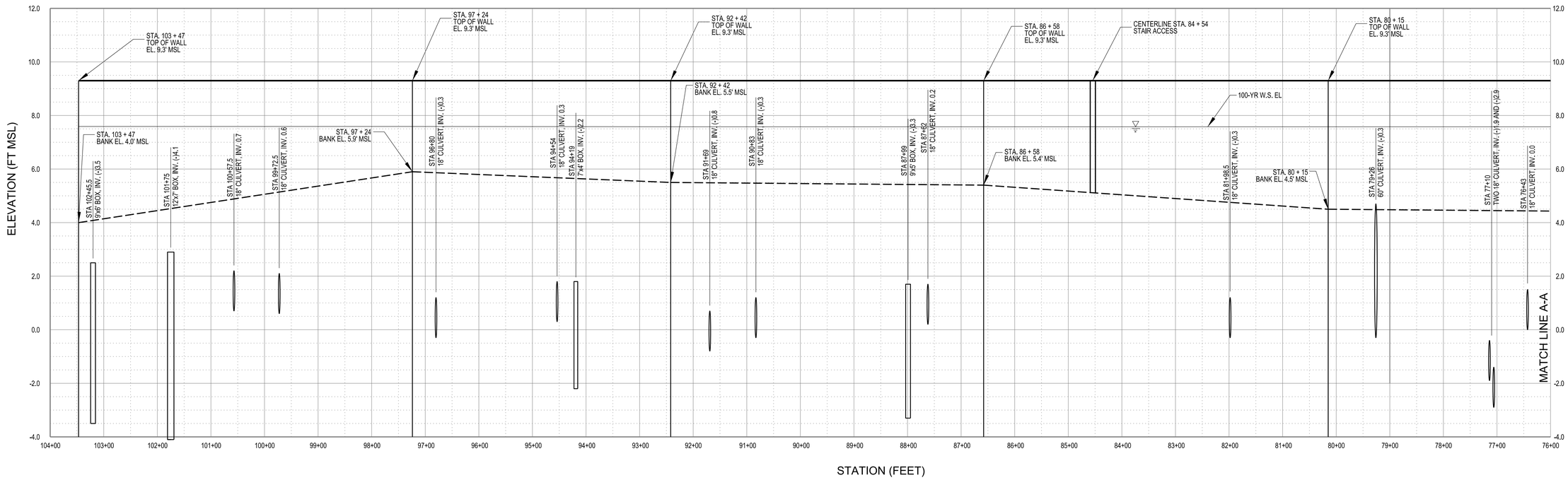
ALA WAI CANAL PROJECT

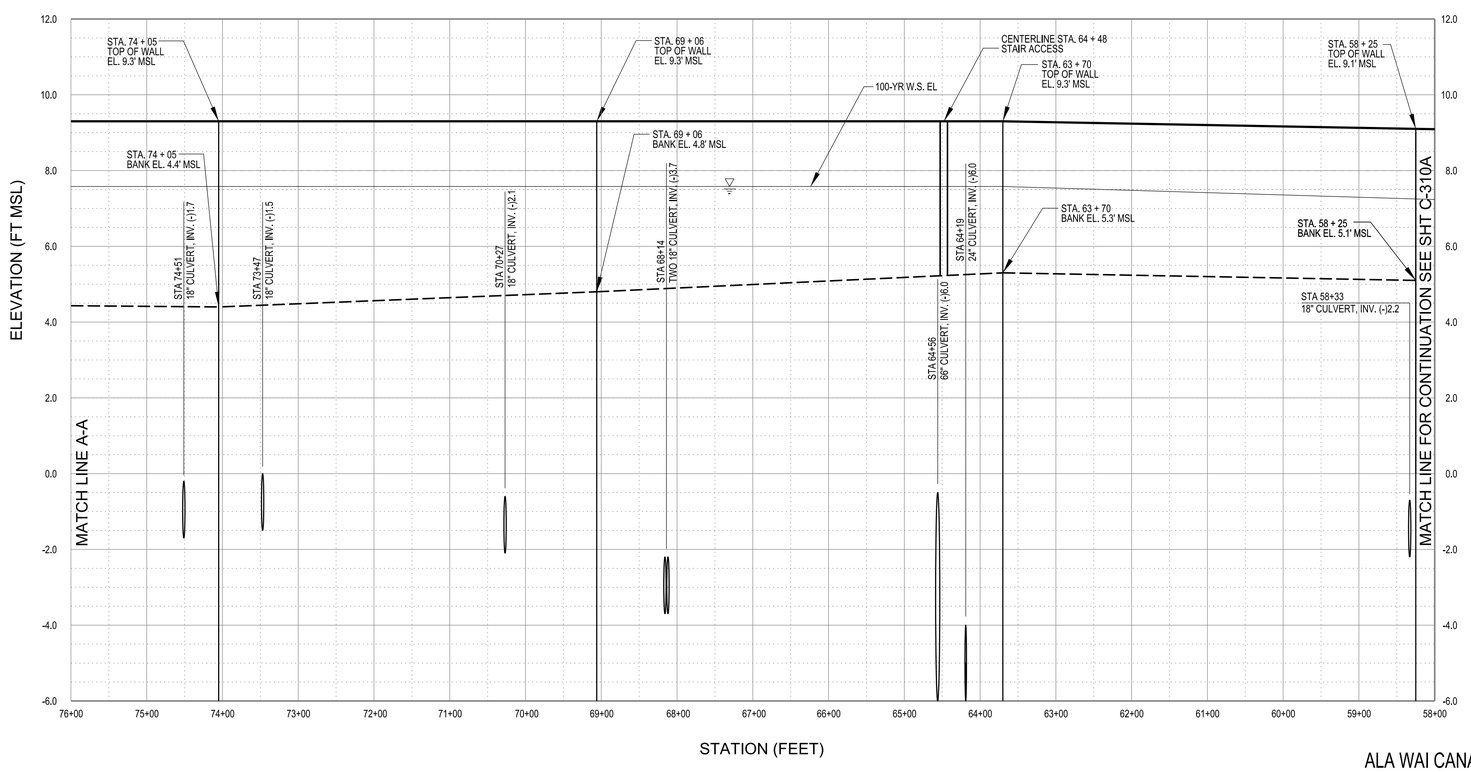
ALA WAI MIDDLE & LOWER LEFT BANK FLOODWALLS
PROFILE AND SECTION

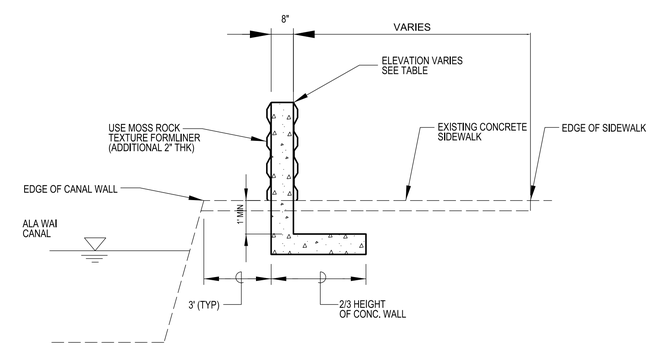
SHEET IDENTIFICATION
C-310
SHEET 16 OF 31

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:06:27 PM
LAST SAVED BY: J3EC9JHH

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$







C TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

ALA WAI CANAL LEFT BANK
STA 101 + 24 TO 58 + 25

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
103 + 47	5.3	9.3
97 +24	3.4	9.3
92 + 42	3.8	9.3
86 + 58	3.9	9.3
80 + 15	4.8	9.3
74 + 05	4.9	9.3
69 + 06	4.5	9.3
63 + 70	4.0	9.3
58 + 25	4.0	9.1

PROFILE
ALA WAI CANAL UPPER (ALA3) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

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Honolulu District

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1
PLOT DATE: 7/28/2015
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: $FILE$

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI UPPER LEFT BANK FLOODWALLS
PROFILE AND SECTION

SHEET IDENTIFICATION
C-311
SHEET 17 OF 31

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:07:03 PM
LAST SAVED BY: J3EC9JHH
PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
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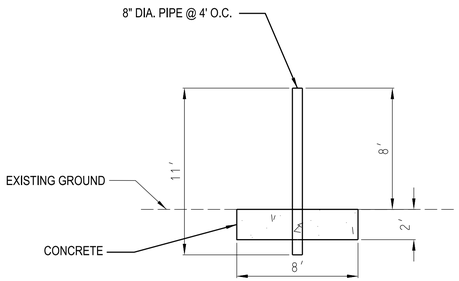
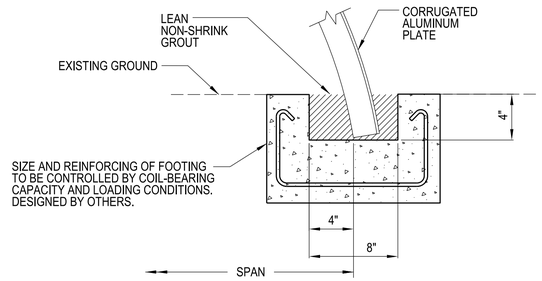


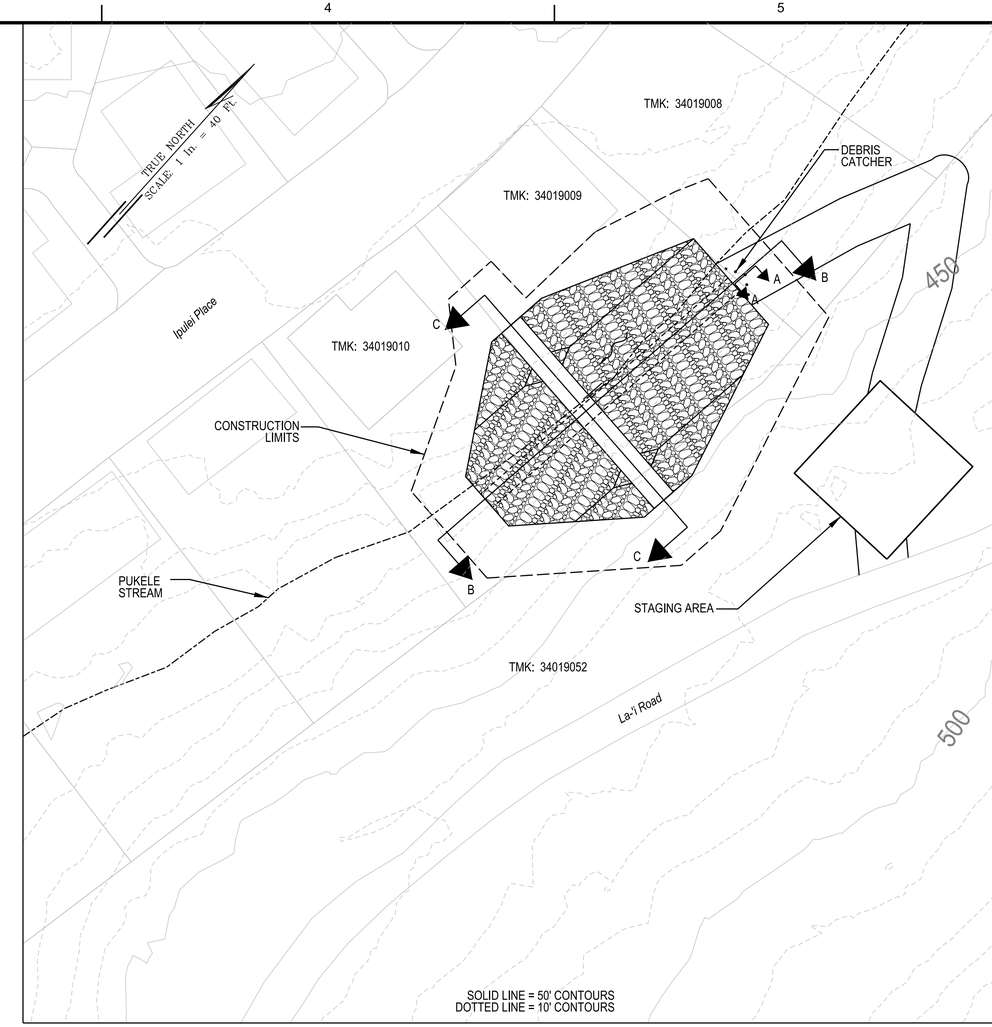
PUKELE DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



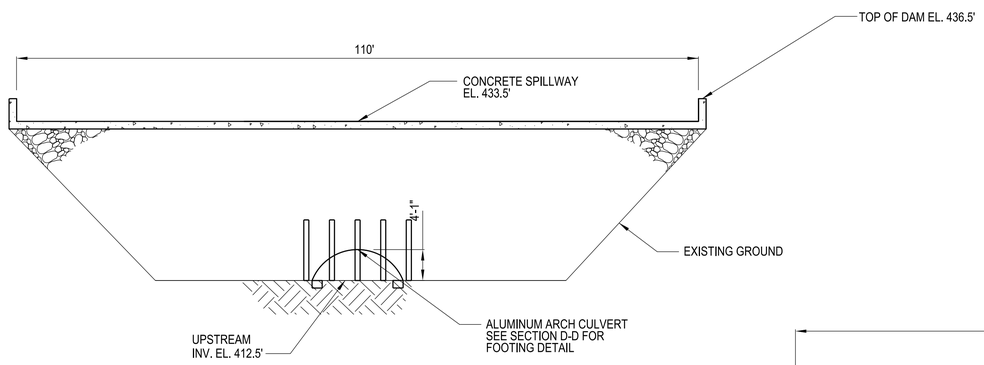
SLOTTED CONCRETE FOOTING SECTION D-D

SCALE: NTS



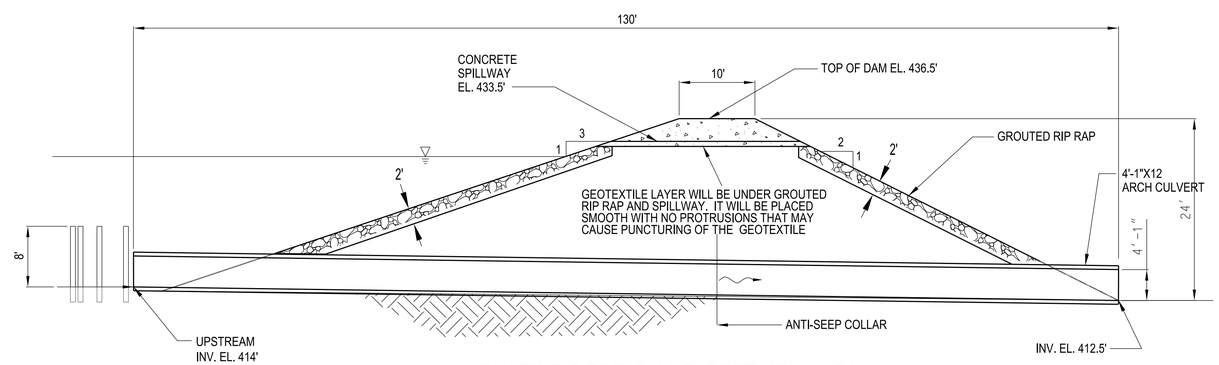
PLAN

SCALE: 1"=40'



PUKELE DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=5'



PUKELE DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=5'

5 2.5' 0 5 10

SCALE: 1" = 5'

Note: All elevations are feet MSL

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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DRAWN BY: | CHECKED BY: | SOLICIT./ CONTRACT NO.:
SUBMITTED BY: | LOCATION CODE
PLOT SCALE: 1:1 PLOTTED | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: $FILE$

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

PUKELE DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-313
SHEET 18 OF 31

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:08:16 PM
LAST SAVED BY: J3EC9JHH

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
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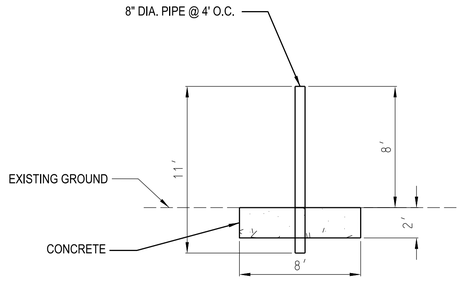
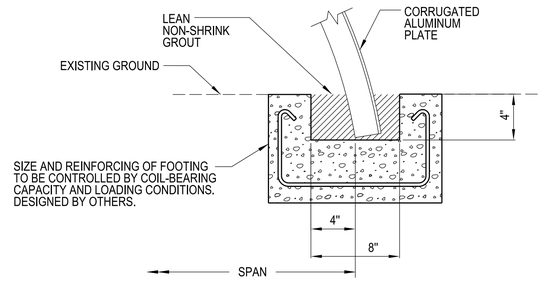


MAKIKI DEBRIS AND DETENTION BASIN SECTION A-A

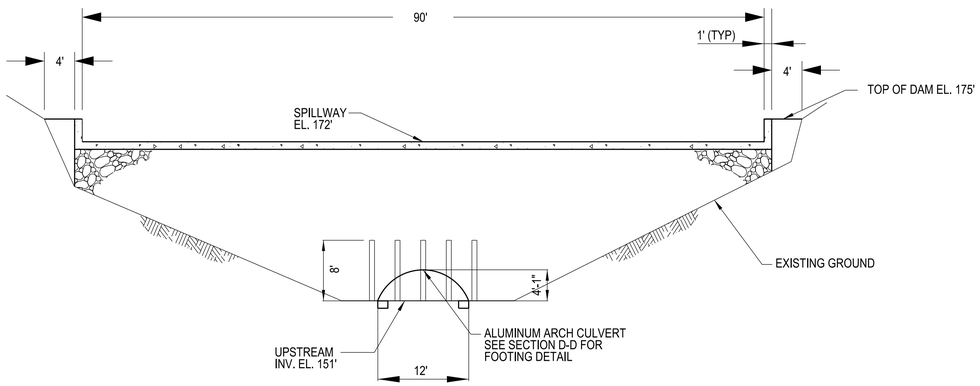
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING

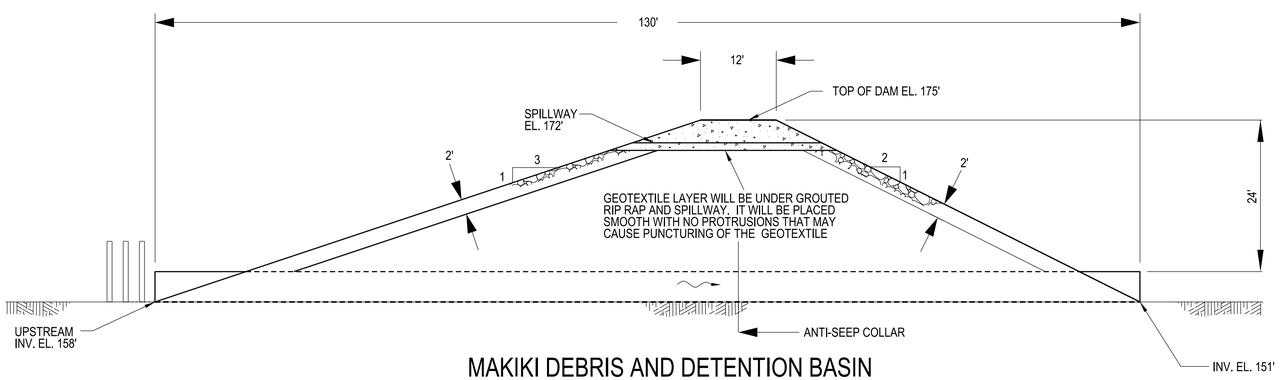
MAKIKI DEBRIS AND DETENTION SECTION D-D

SCALE: NTS



MAKIKI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'



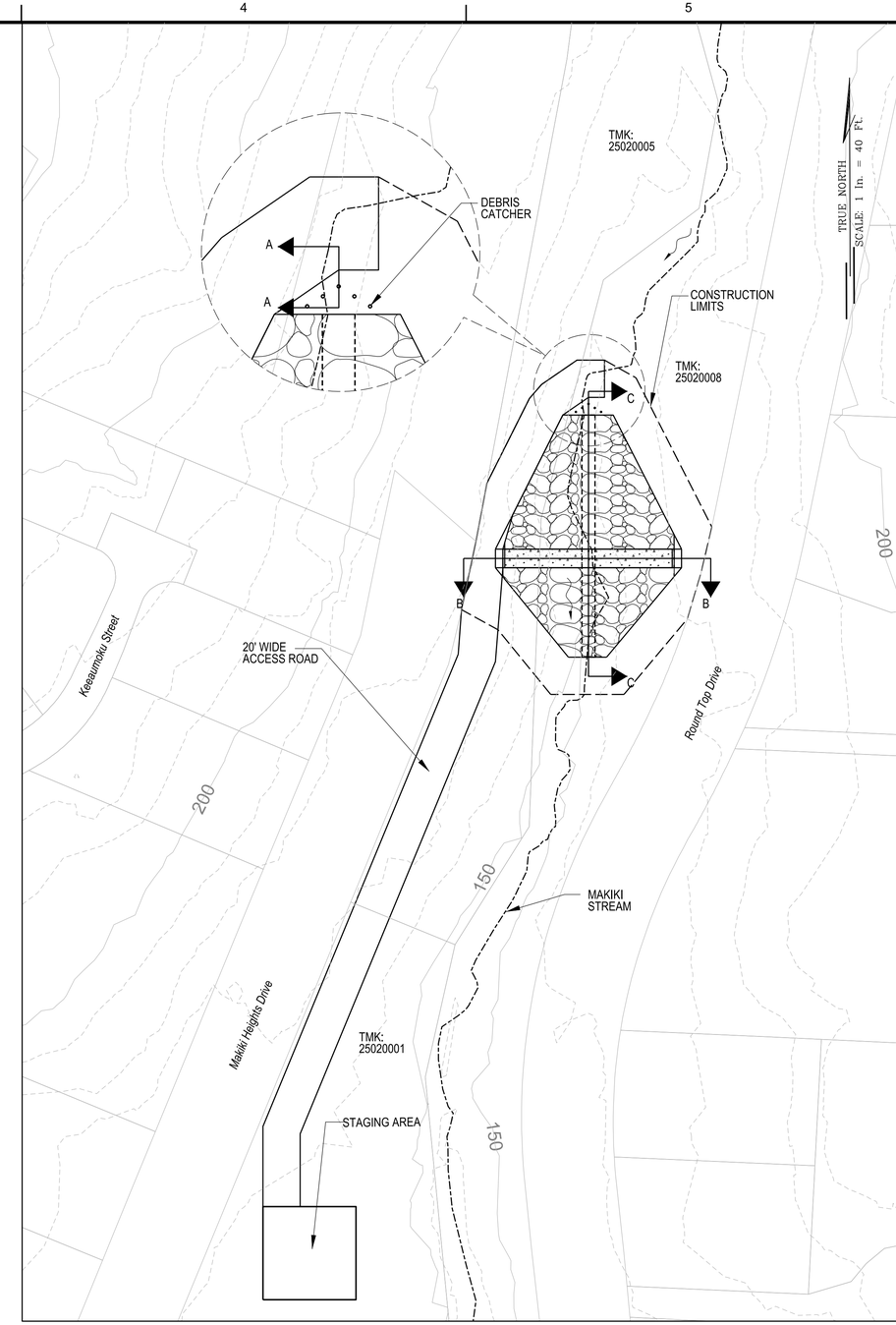
MAKIKI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=10'

10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.
3. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

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				35% DESIGN			

DESIGNED BY: JHH | DATE: | REVISION:
DRAWN BY: | CHECKED BY: | SOLICIT. / CONTRACT NO.:
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PLOT SCALE: | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: $FILES

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

MAKIKI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-315
SHEET 19 OF 31

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:13:11 PM
LAST SAVED BY: J3EC9JHH

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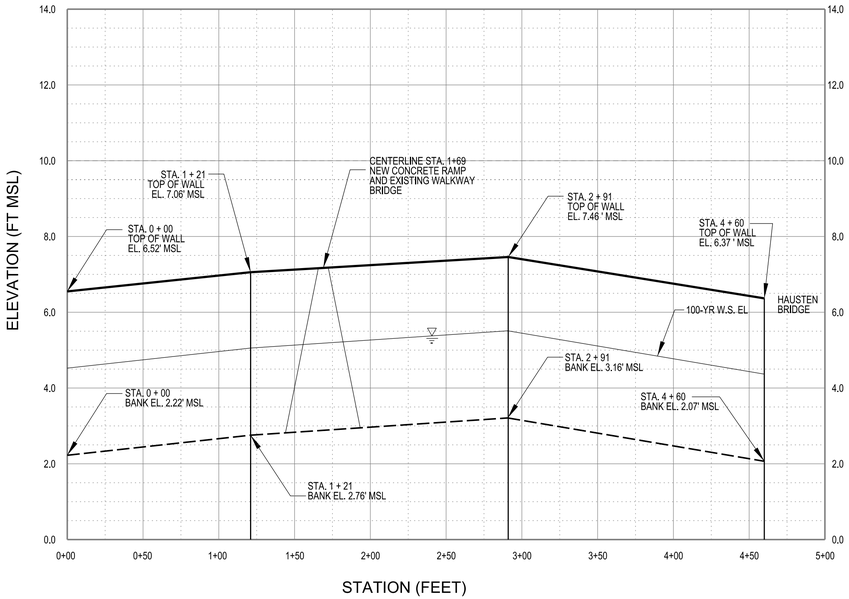
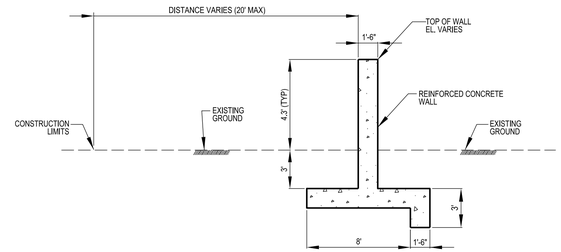


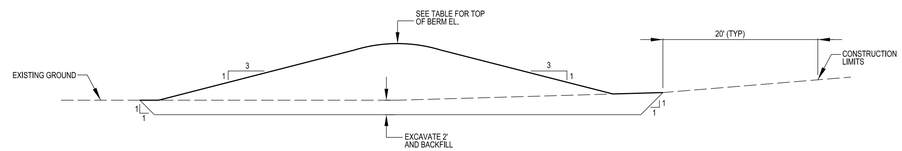
PROFILE
HAUSTEN DITCH RIGHT BANK FLOODWALL

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'



A HAUSTEN DITCH TYPICAL REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE



B HAUSTEN DITCH TYPICAL BERM

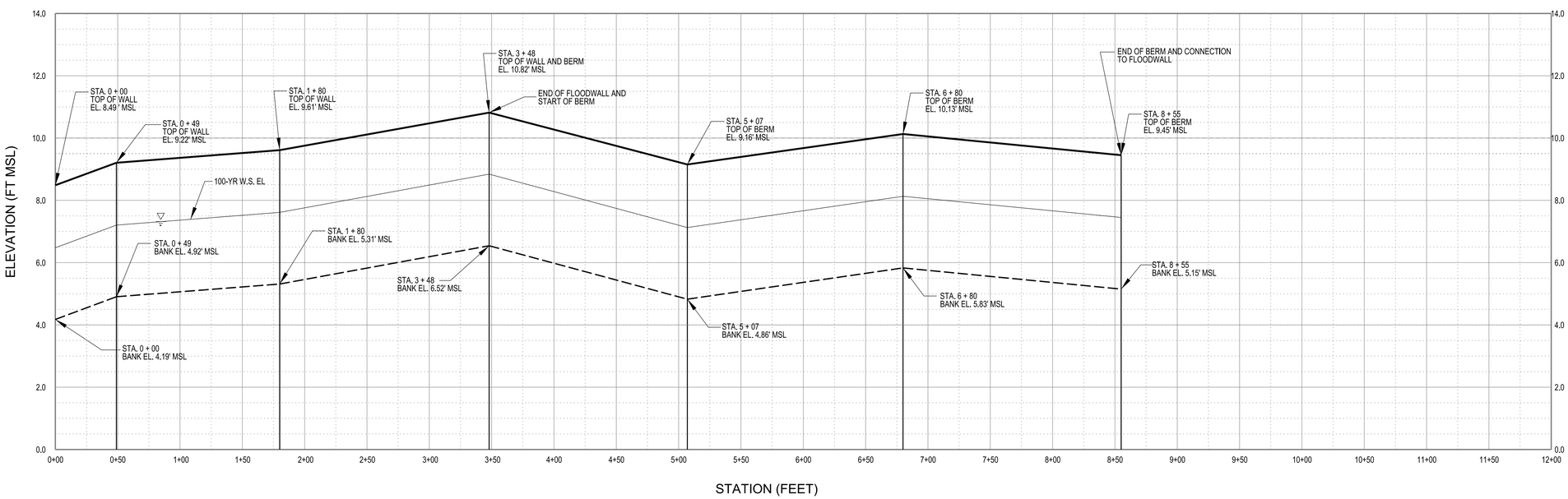
NOT TO SCALE

HAUSTEN DITCH RIGHT BANK FLOODWALL
STA TO 0 + 00 TO 4 + 60

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	6.52
1 + 21	4.30	7.06
2 + 91	4.30	7.46
4 + 60	4.30	6.37
HAUSTEN BRIDGE		

HAUSTEN DITCH LEFT BANK
FLOODWALL AND BERM
STA TO 0 + 00 TO 11 + 65

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	8.49
0 + 49	4.30	9.22
1 + 80	4.30	9.61
3 + 48	4.30	10.82
END OF FLOODWALL AND START OF BERM		
3 + 48	4.30	10.82
5 + 07	4.30	9.16
6 + 80	4.30	10.13
8 +55	4.30	9.45



PROFILE
HAUSTEN DITCH LEFT BANK FLOODWALL AND BERM

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'

US Army Corps of Engineers®
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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

35% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JHH
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1 PLOT DATE: 12/17/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: HAUSTEN DITCH DETENTION, PROFILE & SECTIONS

ALA WAI CANAL PROJECT

HAUSTEN DITCH DETENTION FLOODWALLS AND BERM
PROFILE AND SECTIONS

SHEET IDENTIFICATION
C-316
SHEET 20 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-316xxx.dgn
MODEL NAME: C-316
DATE & TIME: 12/17/2014 10:39:20 AM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
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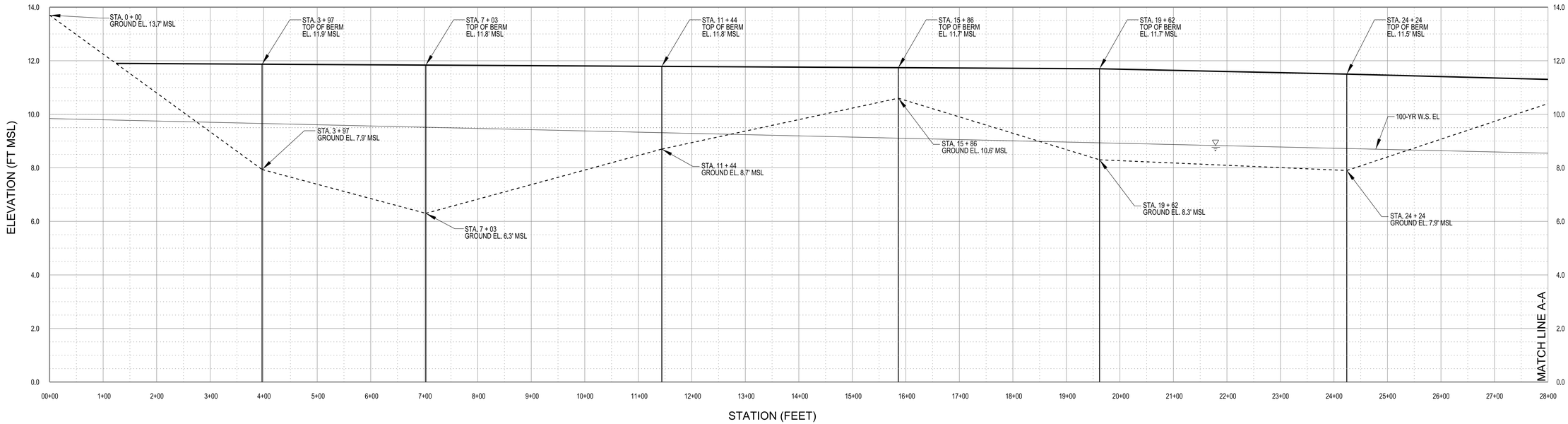
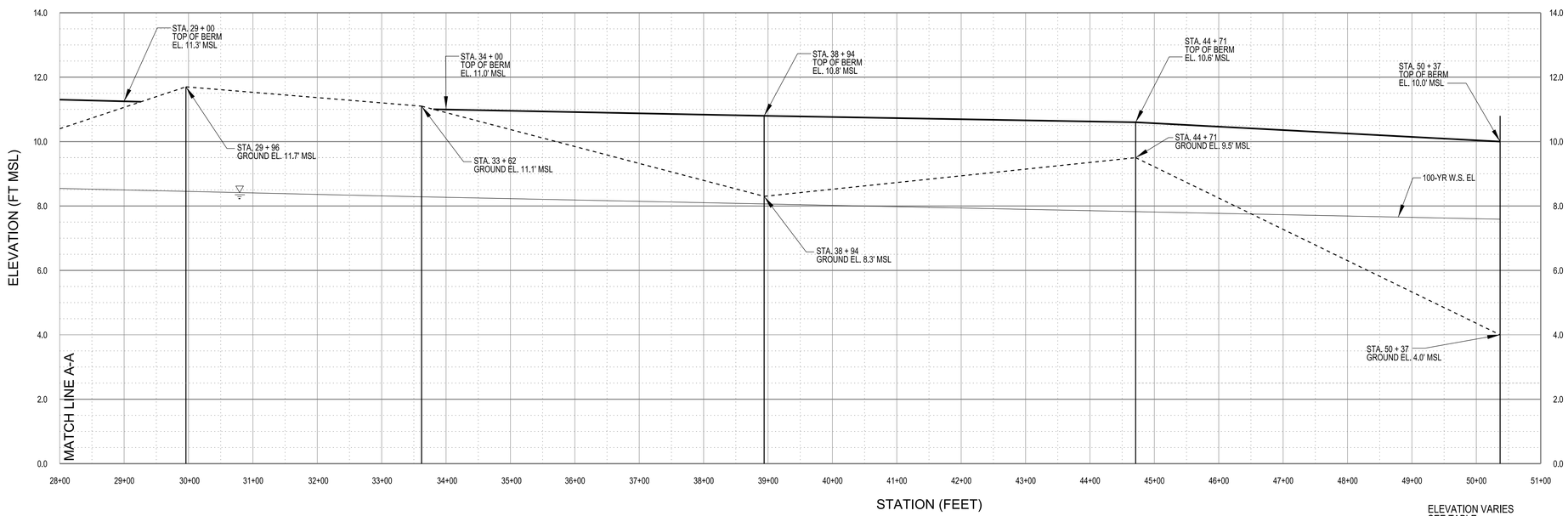


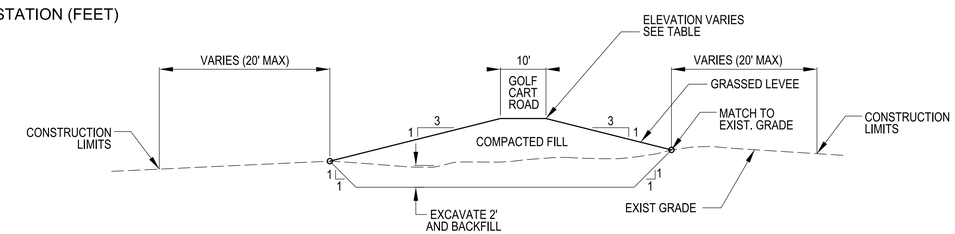


ALA WAI GOLF COURSE LEVEE
STA 0 + 00 TO 50 + 37

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	-	-
3 + 97	4.0	11.9
7 + 03	5.5	11.8
11 + 44	3.1	11.8
15 + 86	1.1	11.7
19 + 62	3.4	11.7
24 + 24	3.6	11.5
29 + 96	-	-
33 + 62	-	-
38 + 94	2.5	10.8
44 + 71	1.1	10.6
50 + 37	6.0	10.0

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE PROFILE

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'



A TYPICAL LEVEE SECTION
NOT TO SCALE

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Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

35% DESIGN

DESIGNED BY: JHH | DATE: | REVISION:
DRAWN BY: | CHECKED BY: | SOLICIT / CONTRACT NO.:
SUBMITTED BY: | LOCATION CODE
PLOT SCALE: 1:1 | PLOT DATE: | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE.dgn

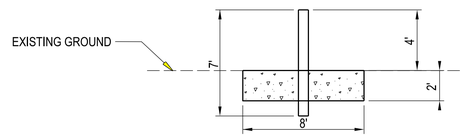
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

ALA WAI GOLF COURSE LEVEE
PROFILE AND SECTION

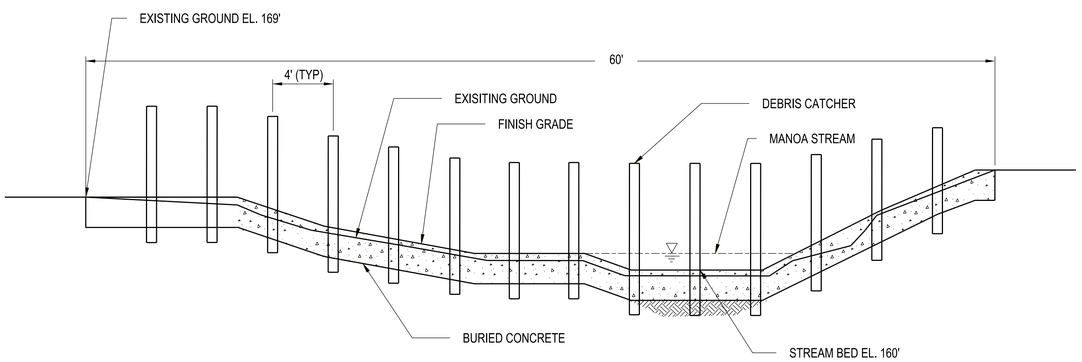
SHEET IDENTIFICATION
C-317
SHEET 21 OF 31

FILE: c:\pw_work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-317xxx.dgn
MODEL NAME: C-309
DATE & TIME: 12/17/2014 10:40:09 AM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotd\printer.plotcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



MANOA IN-STREAM DEBRIS CATHMENT
SECTION A-A

SCALE: 1"=5'



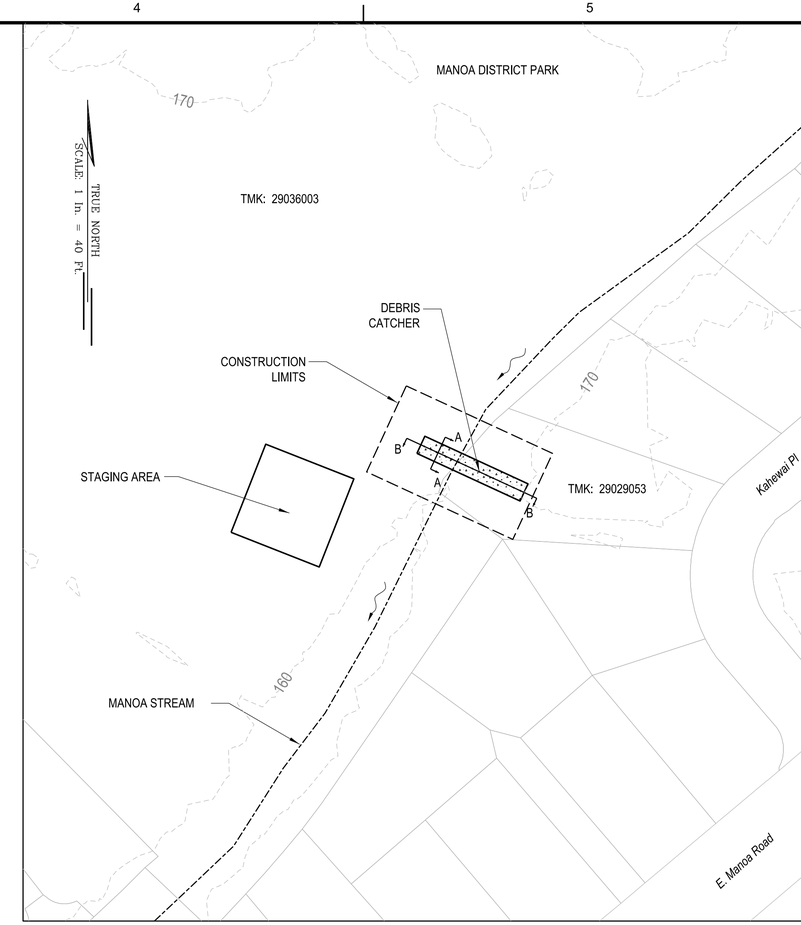
MANOA IN-STREAM DEBRIS CATCHMENT
SECTION B-B

SCALE: 1"=5'

5' 2.5' 0 5' 10'

SCALE: 1" = 5'

Note: All elevations are feet MSL



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

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HONOLULU DISTRICT
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DATE:
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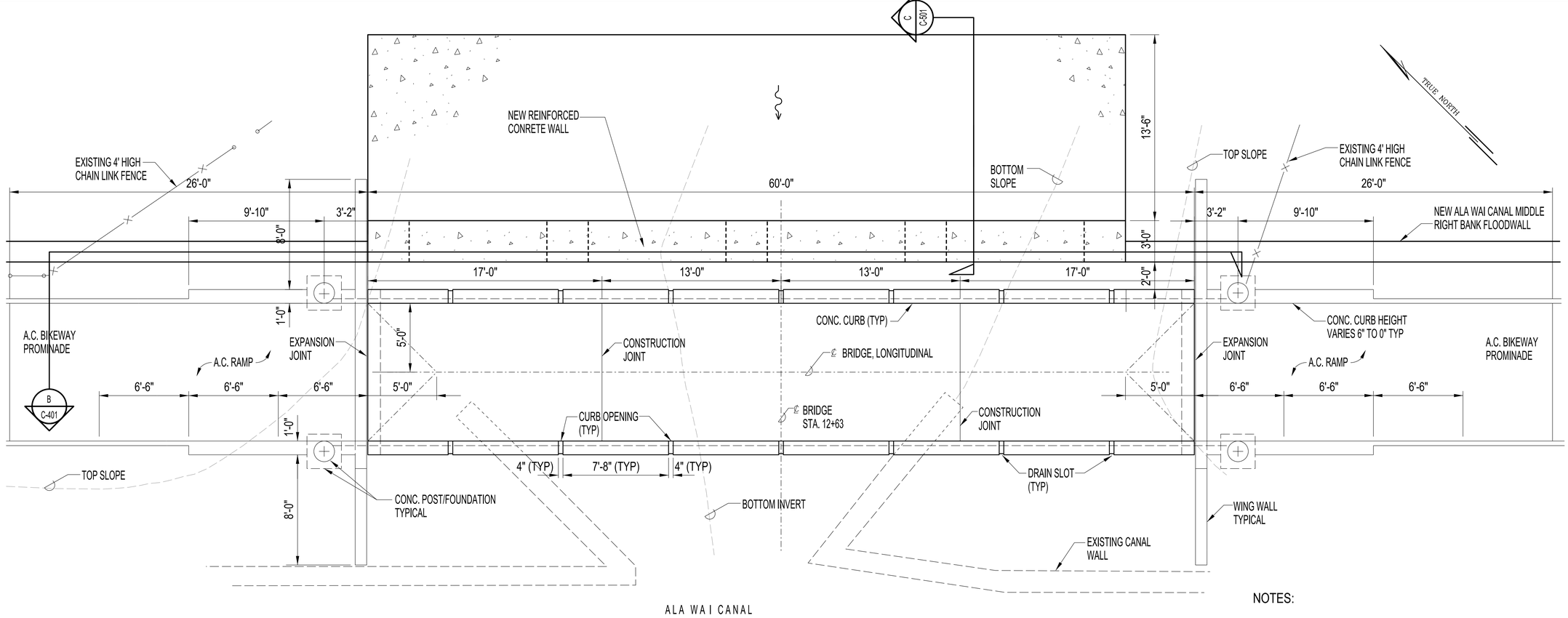
CHECKED BY:
SOLICIT./ CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE:
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: MANOA IN-STREAM DEBRIS CATCHMENT, PLAN & SECTIONS

ALA WAI CANAL PROJECT

MANOA IN-STREAM DEBRIS CATCHMENT
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-318
SHEET 22 OF 31

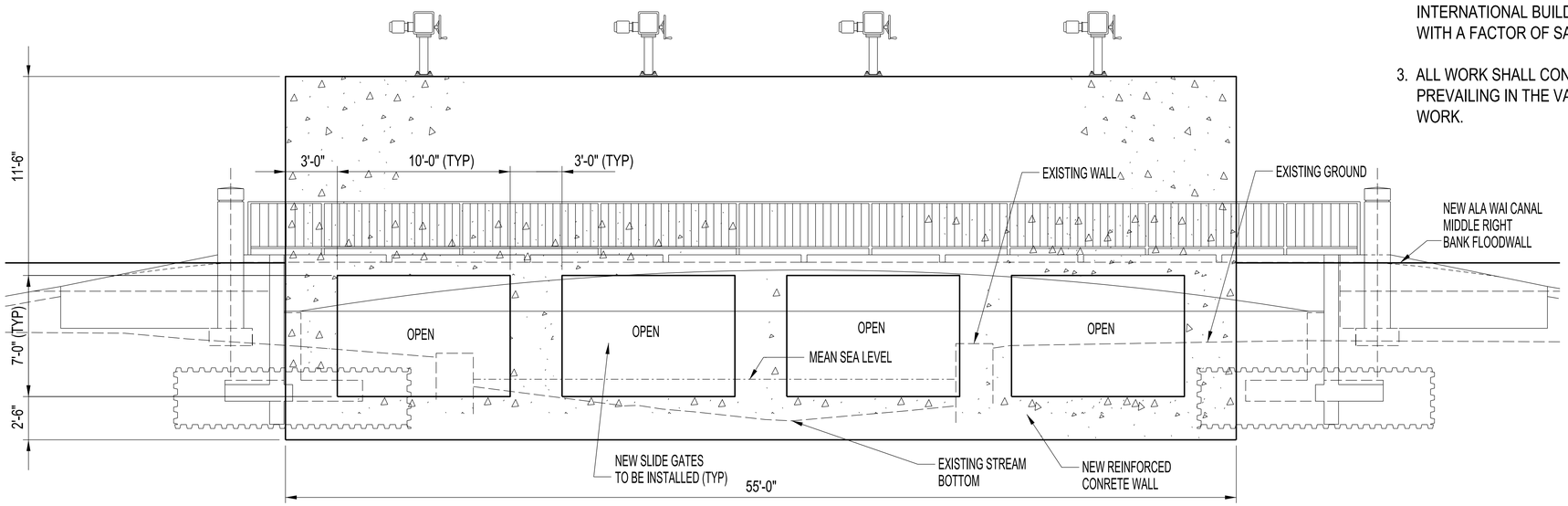
FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-318xxx.dgn
MODEL NAME: C-318
DATE & TIME: 12/17/2014 10:41:04 AM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotcfg\printer.plotcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH



A PLAN
SCALE: 1/4"=1'

NOTES:

1. SEE SHEET C-501 FOR THE SLIDE GATE DETAIL.
2. THE NEW CONCRETE WALL SHALL CONFORM TO THE 2012 INTERNATIONAL BUILDING CODE (IBC) AND EM 1110-2-2502 WITH A FACTOR OF SAFETY OF AT LEAST 1.5.
3. ALL WORK SHALL CONFORM TO THE BEST PRACTICE PREVAILING IN THE VARIOUS TRADES COMPRISING THE WORK.



B ELEVATION
SCALE: 1/4"=1'

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DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE:
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE: 7/28/2015
FILE NAME: $FILE$
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

HAUSTEN BRIDGE CONCRETE WALL
PLAN, SECTION AND ELEVATION

SHEET IDENTIFICATION
C-401
SHEET 23 OF 31

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:15:32 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

STRUCTURAL NOTES:

1. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND CONDITIONS AND REPORT ANY DISCREPANCIES IN WRITING TO THE CONTRACTING OFFICER BEFORE COMMENCING WORK.

2. DETAILS SHOWN ON THE DRAWINGS SHALL BE TYPICAL FOR ALL SIMILAR CONDITIONS.

CONSTRUCTION NOTES:

1. THE CONTRACTOR SHALL BE FULLY RESPONSIBLE FOR METHODS OF CONSTRUCTION, WORKMANSHIP, AND JOB SAFETY INCLUDING FALSEWORK, BRACING, AND OTHER TEMPORARY ITEMS USED FOR THE CONSTRUCTION OF THIS PROJECT.

2. THE CONTRACTOR SHALL NOTIFY THE CONTRACTING OFFICER AT LEAST 48 HOURS IN ADVANCE FOR INSPECTION OF EXCAVATIONS AND ALL CONCRETE POURS.

3. CHAMFER ALL EXPOSED EDGES 1/2" UNLESS OTHERWISE NOTED.

4. THE LOCATION OF EMBEDDED ITEMS SHALL BE COORDINATED WITH OTHER TRADES BEFORE CONCRETE POURS.

CONCRETE NOTES:

1. UNLESS OTHERWISE SHOWN, CONSTRUCTION JOINTS SHALL BE LOCATED BY THE CONTRACTOR SUBJECT TO APPROVAL BY THE CONTRACTING OFFICER. THEY SHALL BE SO LOCATED AS TO LEAST IMPAIR THE STRENGTH OF THE STRUCTURE AND TO MINIMIZE SHRINKAGE STRESSES. PROVIDE DOWELS AS DIRECTED AND THOROUGHLY CLEAN AND ROUGHEN SURFACES BEFORE PROCEEDING WITH THE NEXT POUR.

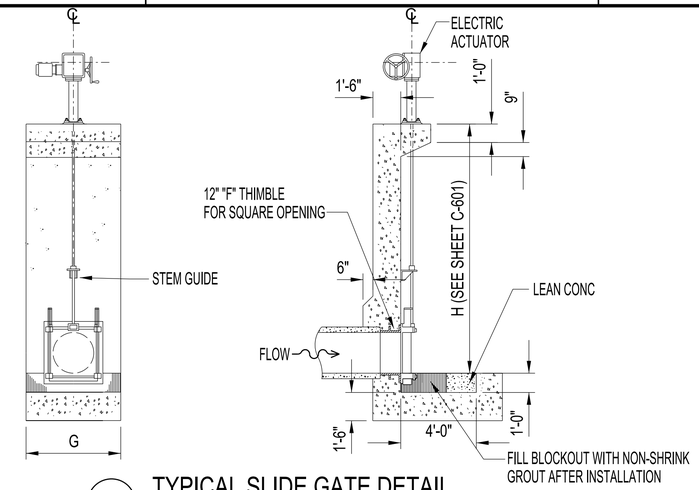
REINFORCING STEEL NOTES:

1. DOWELS SHALL BE THE SAME SIZE AND SPACING AND SHALL BE IN THE SAME PLANE AS THE BARS TO WHICH THEY ARE SPLICED UNLESS OTHERWISE SHOWN.

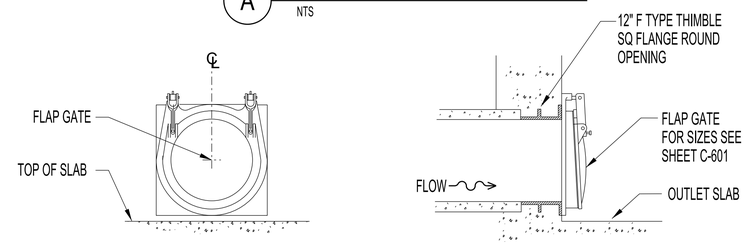
2. MINIMUM CONCRETE COVER:

CONCRETE DEPOSITED ON OR AGAINST EARTH.....3"

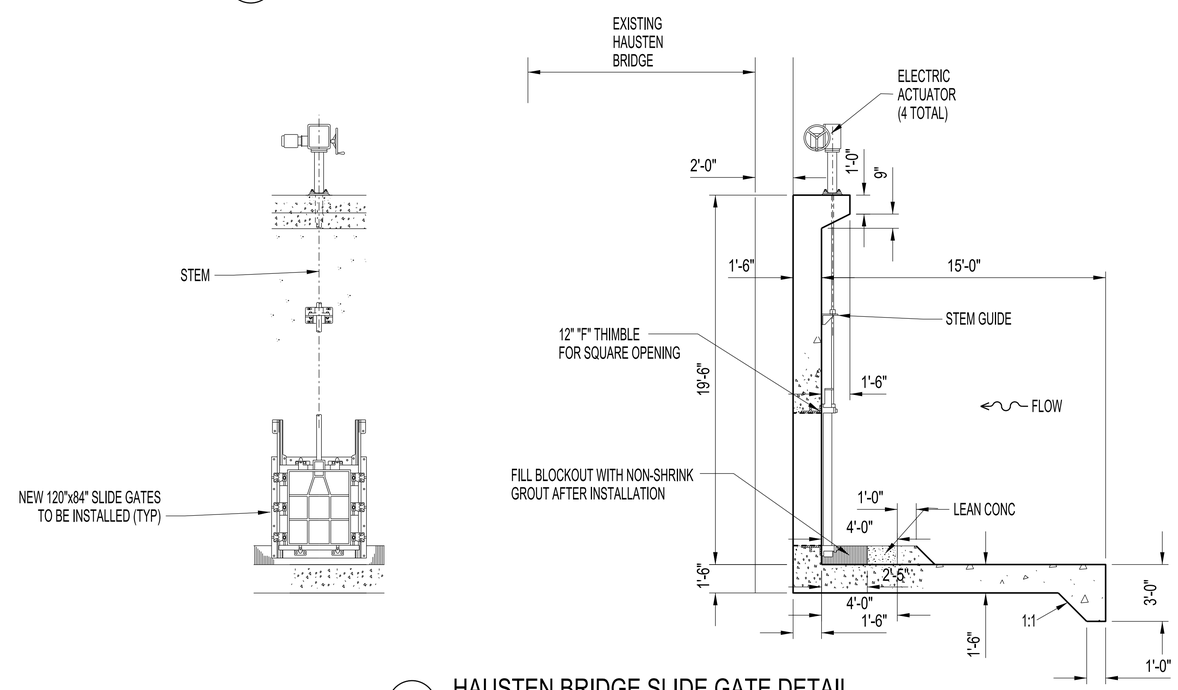
ALL OTHERS.....2"



A TYPICAL SLIDE GATE DETAIL
NTS



B TYPICAL FLAP GATE DETAIL
NTS



C HAUSTEN BRIDGE SLIDE GATE DETAIL
SCALE: 1/4"=1'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1(FOR FULL SIZE)
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: STRUCTURAL NOTES AND MISCELLANEOUS DETAILS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

STRUCTURAL NOTES AND MISCELLANEOUS DETAILS

SHEET IDENTIFICATION
C-501
SHEET 24 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-501xxx.dgn
MODEL NAME: C-501
DATE & TIME: 12/17/2014 10:42:33 AM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\plcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH

SCHEDULE OF SLIDE GATES ALONG THE ALA WAI CANAL

CULVERT NAME	STATION	SIZE (WIDTHxHEIGHT) AND TYPE	H	G
DIAMOND 2, GOLF COURSE	102+45.5	108"x72" RECTANGULAR OPENING SLIDE GATE	15'-0"	11'-6"
DIAMOND 1, ALA WAI BLVD	101+75	144"x96" RECTANGULAR OPENING SLIDE GATE	19'-0"	15'-0"
DIAMOND 3, GOLF COURSE	96+67	3 - 120"x84" RECTANGULAR OPENING SLIDE GATE	17'-6"	26'-0"
94+19	94+19	120"x72" RECTANGULAR OPENING SLIDE GATE	15'-6"	12'-6"
87+99	87+99	108"x72" RECTANGULAR OPENING SLIDE GATE	15'-0"	11'-6"
50+57	50+57	24"x24" SQUARE OPENING SLIDE GATE	6'-6"	4'-0"
49+65, RB	49+65	144"x96" RECTANGULAR OPENING SLIDE GATE	19'-0"	15'-0"
49+65	49+65	72"x48" RECTANGULAR OPENING SLIDE GATE	11'-0"	7'-6"
36+81, RB	36+81	72"x48" RECTANGULAR OPENING SLIDE GATE	11'-0"	7'-6"

GENERAL NOTES:

1. SEE SHEET C-501 FOR THE SLIDE GATE DETAIL.

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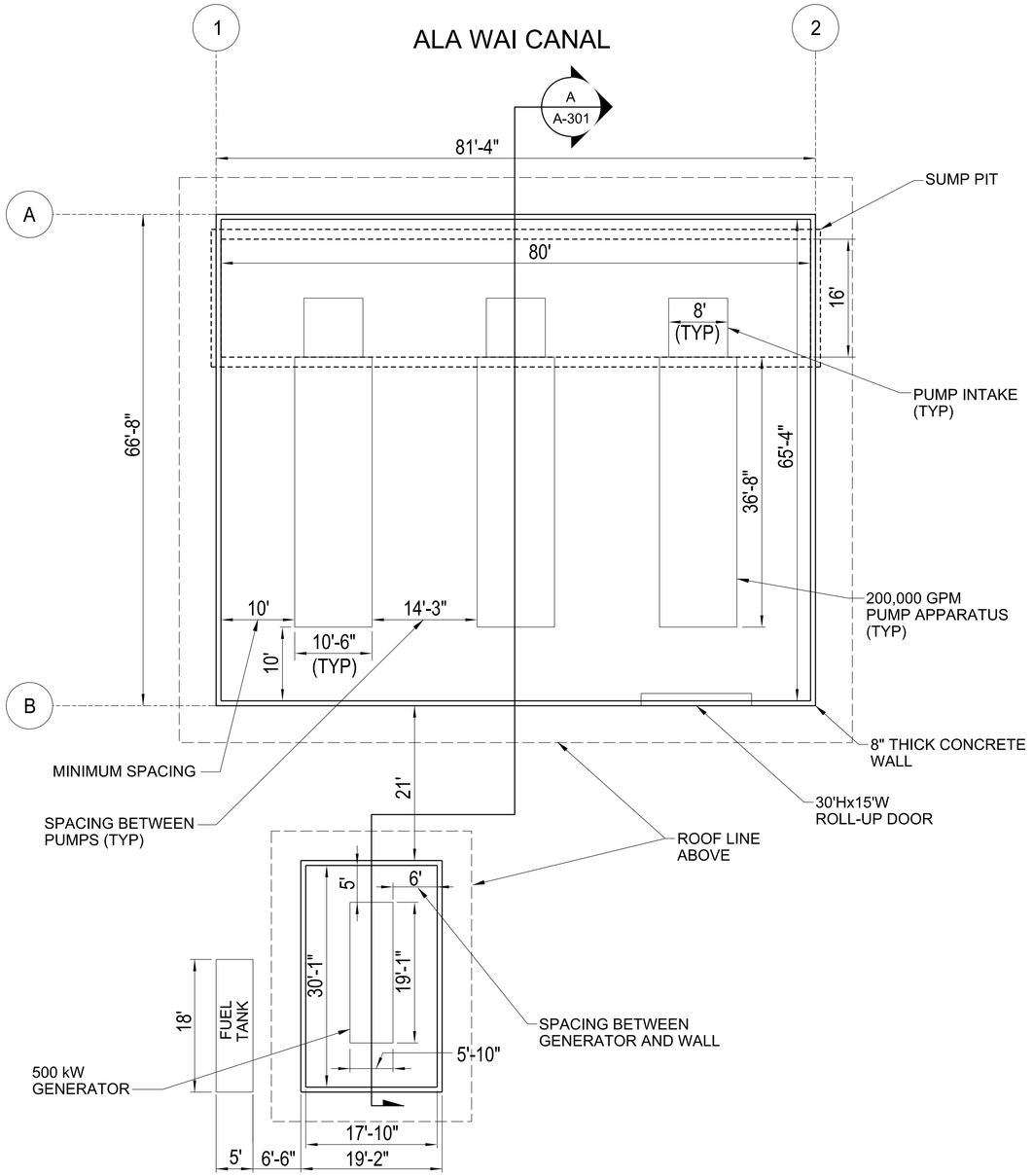
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1 TOTAL
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: SCHEDULE OF SLIDE GATES

ALA WAI CANAL PROJECT

SCHEDULE OF SLIDE GATES

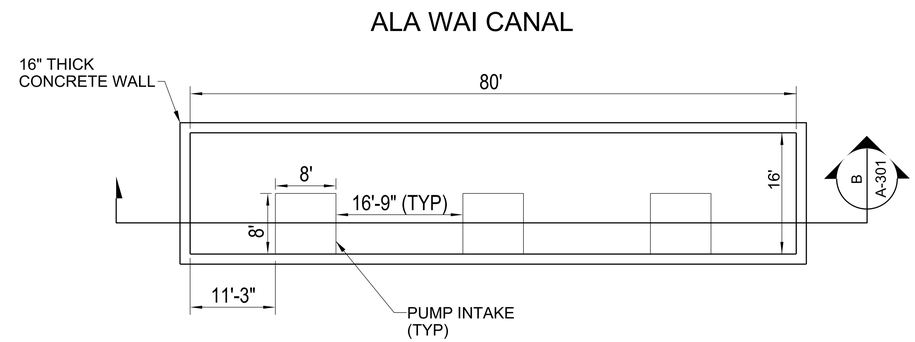
SHEET IDENTIFICATION
C-601
SHEET 25 OF 31

FILE: c:\pw-work\poh-1\j3ec3jhh\d0143718Ala_Wai_C-601xxx.dgn
MODEL NAME: Default
DATE & TIME: 12/17/2014 10:43:11 AM
LAST SAVED BY:
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECT series)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC3JHH



PUMP STATION 1 - FLOOR PLAN

SCALE: 1"=10'



SUMP PIT - FLOOR PLAN

SCALE: 1"=10'

TYPICAL NOTES FOR ALL PUMP STATIONS:

1. THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE CODES AND BUILDING REGULATIONS HAVING JURISDICTION OVER THIS PROJECT.
2. THE NEW CONCRETE WALL SHALL CONFORM TO THE 2012 INTERNATIONAL BUILDING CODE (IBC) AND EM 1110-2-3104.
3. ALL WORK SHALL CONFORM TO THE BEST PRACTICE PREVAILING IN THE VARIOUS TRADES COMPRISING THE WORK.

10 5 0 10 30

SCALE: 1"=10'

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:16:29 PM
LAST SAVED BY:

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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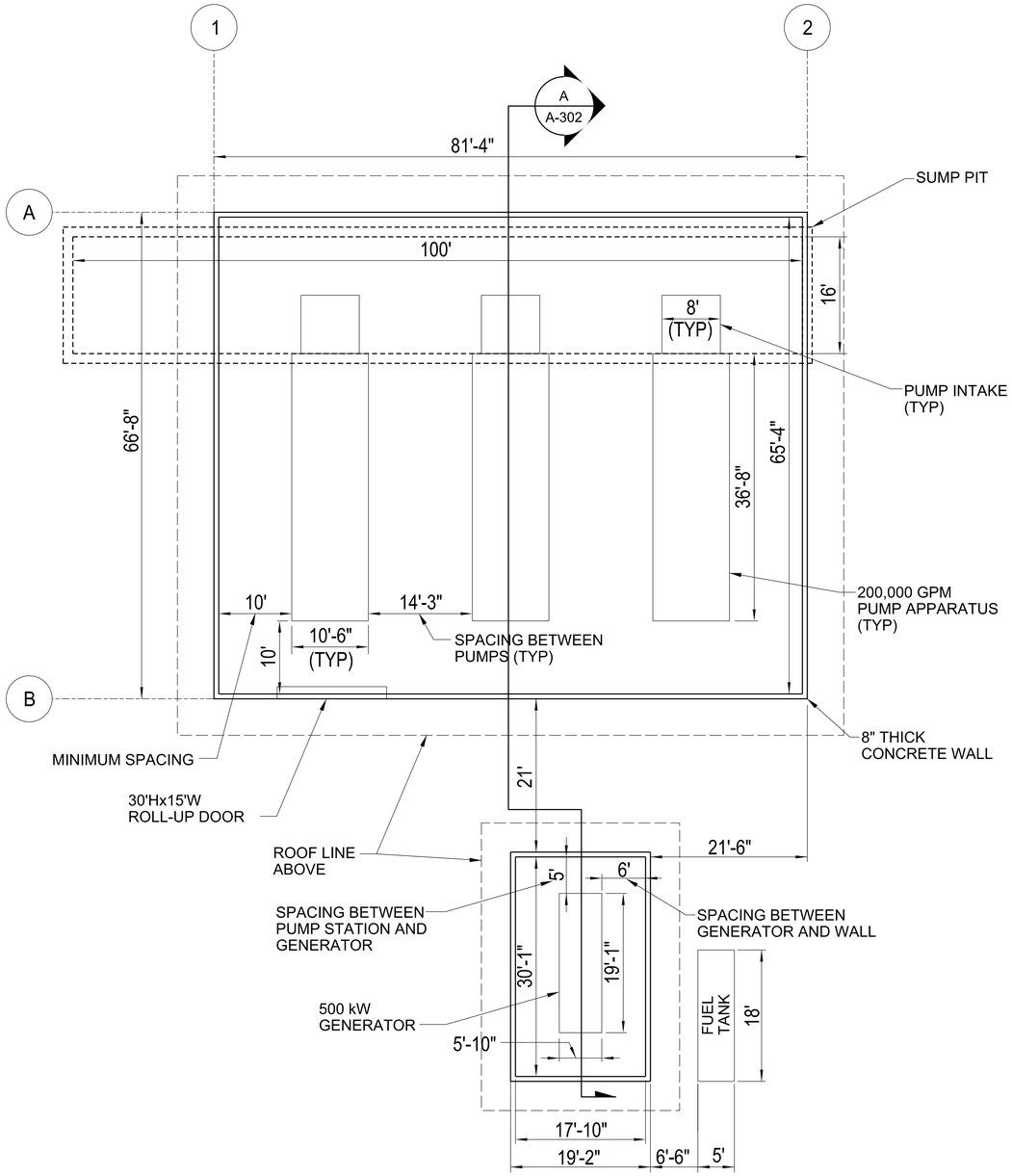
DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE:
SIZE: ANSI D
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE: 7/28/2015
FILE NAME: $FILE$$

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

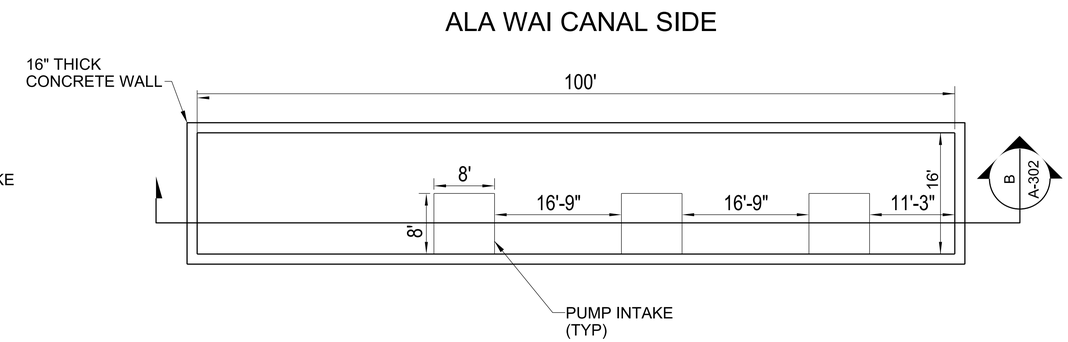
PUMP STATION 1 - FLOOR PLAN

SHEET IDENTIFICATION
A-101
SHEET 26 OF 31



PUMP STATION 2 - FLOOR PLAN

SCALE: 1"=10'



SUMP PIT - FLOOR PLAN

SCALE: 1"=10'

NOTES:

1. SEE TYPICAL PUMP STATION NOTES ON SHEET A-101.

SCALE: 1"=10'

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: 7/28/2015 3:16:58 PM
LAST SAVED BY:

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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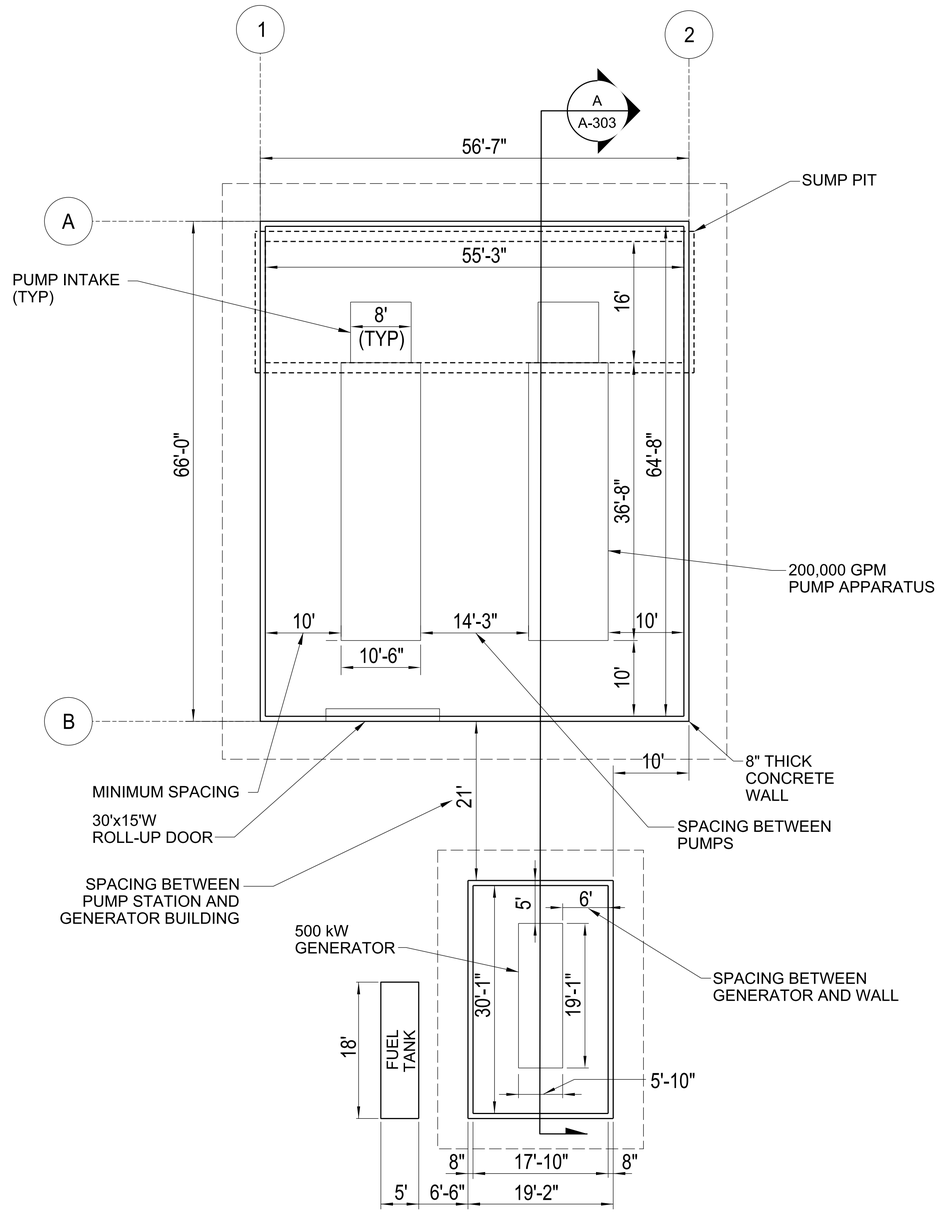
DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: 1:1
PLOT DATE: 7/28/2015
SIZE: ANSI D
FILE NAME: $FILE$
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

PUMP STATION 2 - FLOOR PLAN

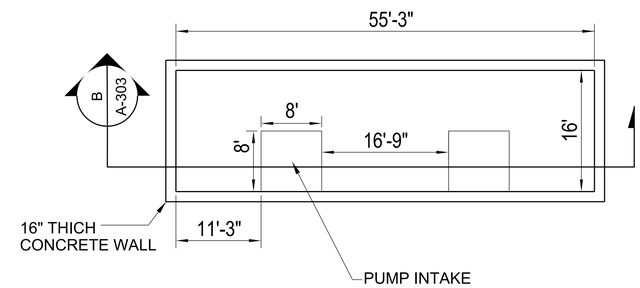
SHEET IDENTIFICATION
A-102
SHEET 27 OF 31



PUMP STATION 3 - FLOOR PLAN

SCALE: 1"=10'

ALA WAI CANAL SIDE



SUMP PIT - FLOOR PLAN

SCALE: 1"=10'

NOTES:

1. SEE TYPICAL PUMP STATION NOTES ON SHEET A-101.

SCALE: 1"=10'

FILE: $FILE$
MODEL NAME: $MODELNAMES
DATE & TIME: 7/28/2015 3:17:26 PM
LAST SAVED BY:
PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

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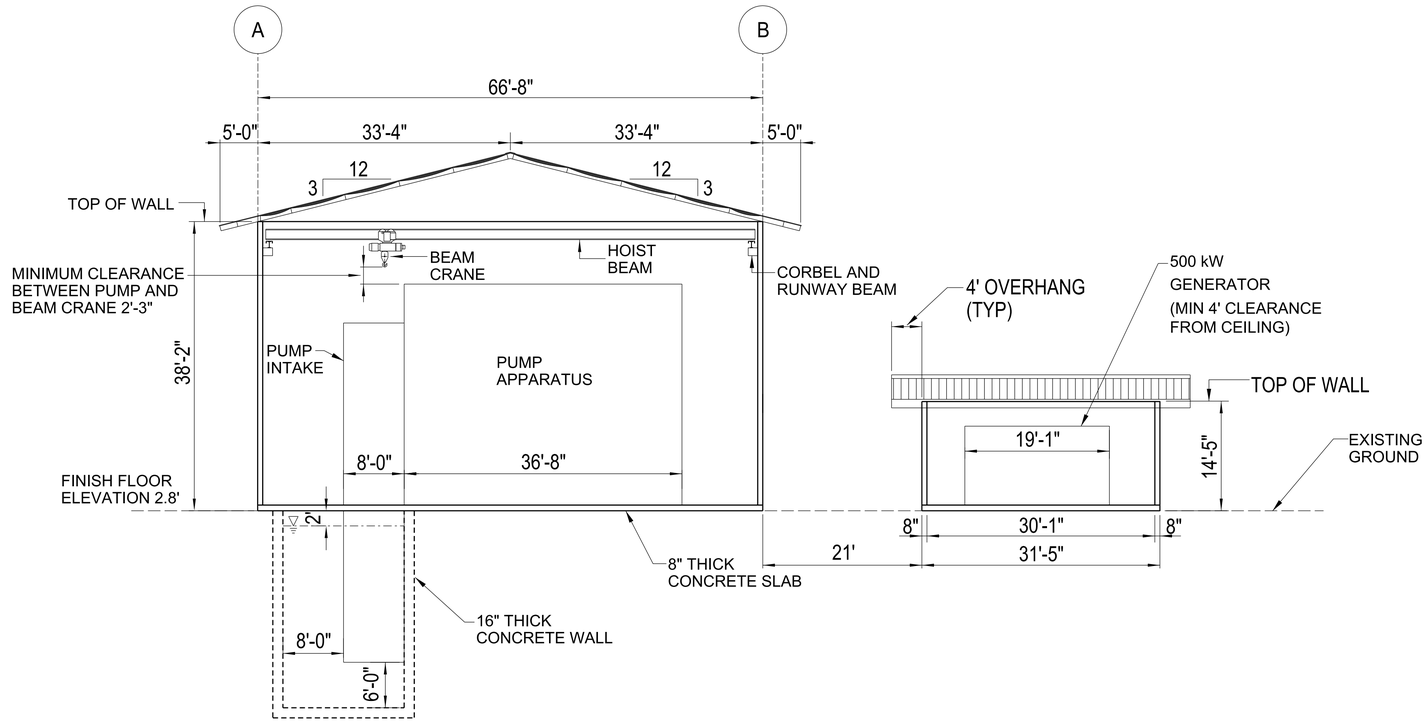
DESIGNED BY: JHH
DRAWN BY:
SUBMITTED BY:
PLOT SCALE: 1:1
PLOT DATE: 7/27/2015
SIZE: ANSI D
FILE NAME: $FILE$
CHECKED BY:
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

ALA WAI CANAL PROJECT

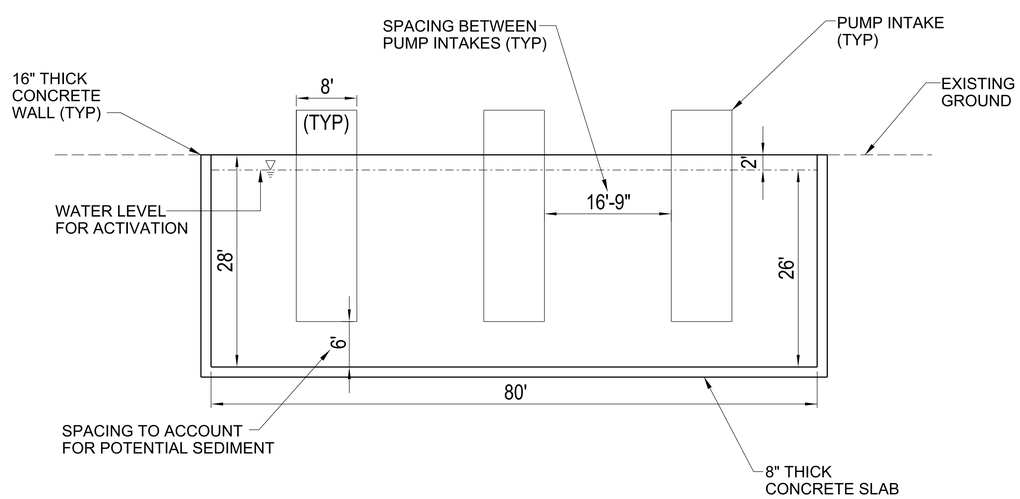
PUMP STATION 3 - FLOOR PLAN

SHEET IDENTIFICATION
A-103
SHEET 28 OF 31



A PUMP STATION 1 - SECTION

SCALE: 1"=10'



B PUMP SUMP PIT SECTION

SCALE: 1"=10'

SCALE: 1"=10'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

35% DESIGN

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE:
SIZE: ANSI D
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
VERTICAL DATUM:
FILE NAME: PUMP STATION 1, SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT

PUMP STATION 1 - SECTIONS

SHEET IDENTIFICATION
A-301
SHEET 29 OF 31

FILE: c:\pw-work\poh-1\j3ec9jhh\d0154243\Ala_Wai_A-301xxx.dgn
MODEL NAME: A-301
DATE & TIME: 12/17/2014 10:47:30 AM
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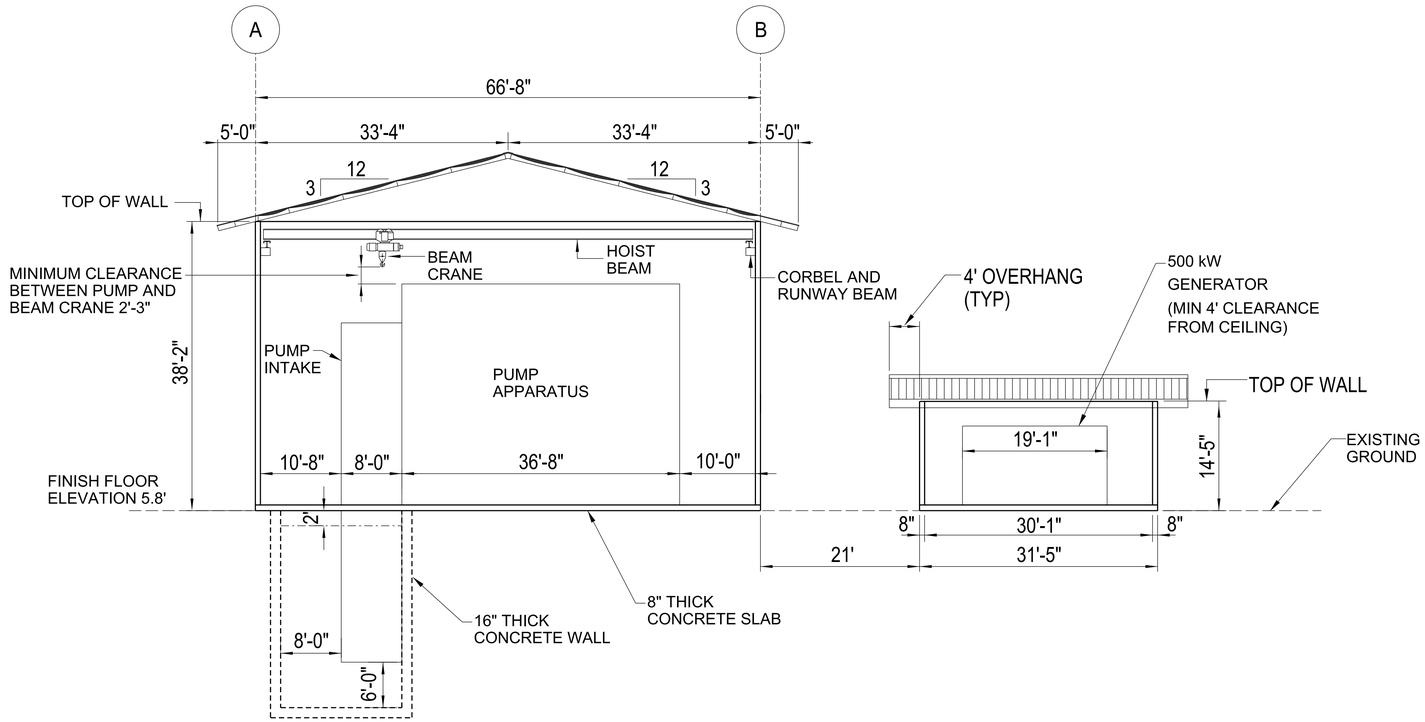
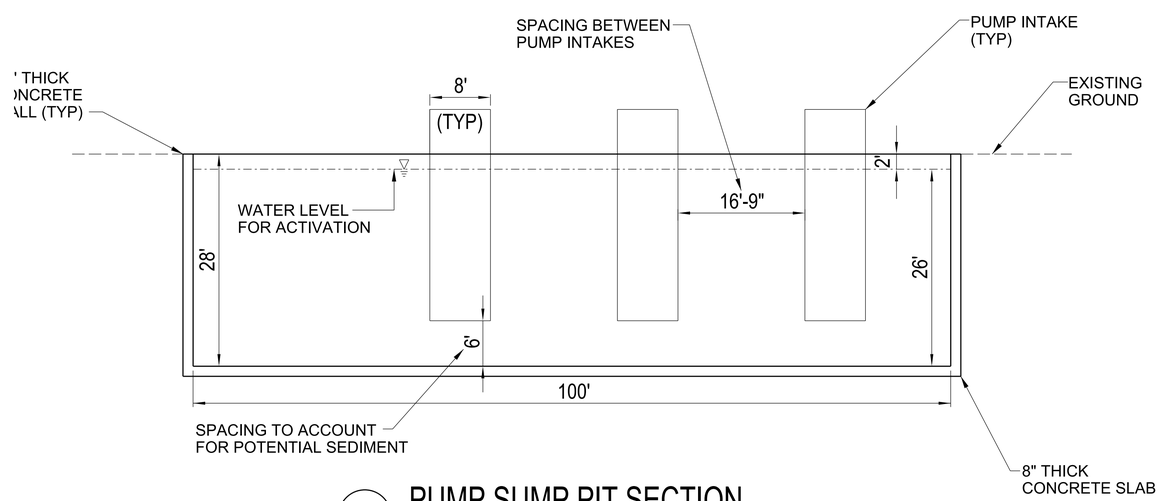
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: JJECSJHH



A PUMP STATION 2 - SECTION

SCALE: 1"=10'



B PUMP SUMP PIT SECTION

SCALE: 1"=10'

10 5 0 10 30

SCALE: 1"=10'

FILE: c:\pw-work\poh-1\j3ec9jhh\d0154243\Ala_Wai_A-302xxx.dgn
MODEL NAME: A-302
DATE & TIME: 12/17/2014 10:48:18 AM
LAST SAVED BY:
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Greyscale_Pen.tbl
PRINTED BY: J3EC9JHH

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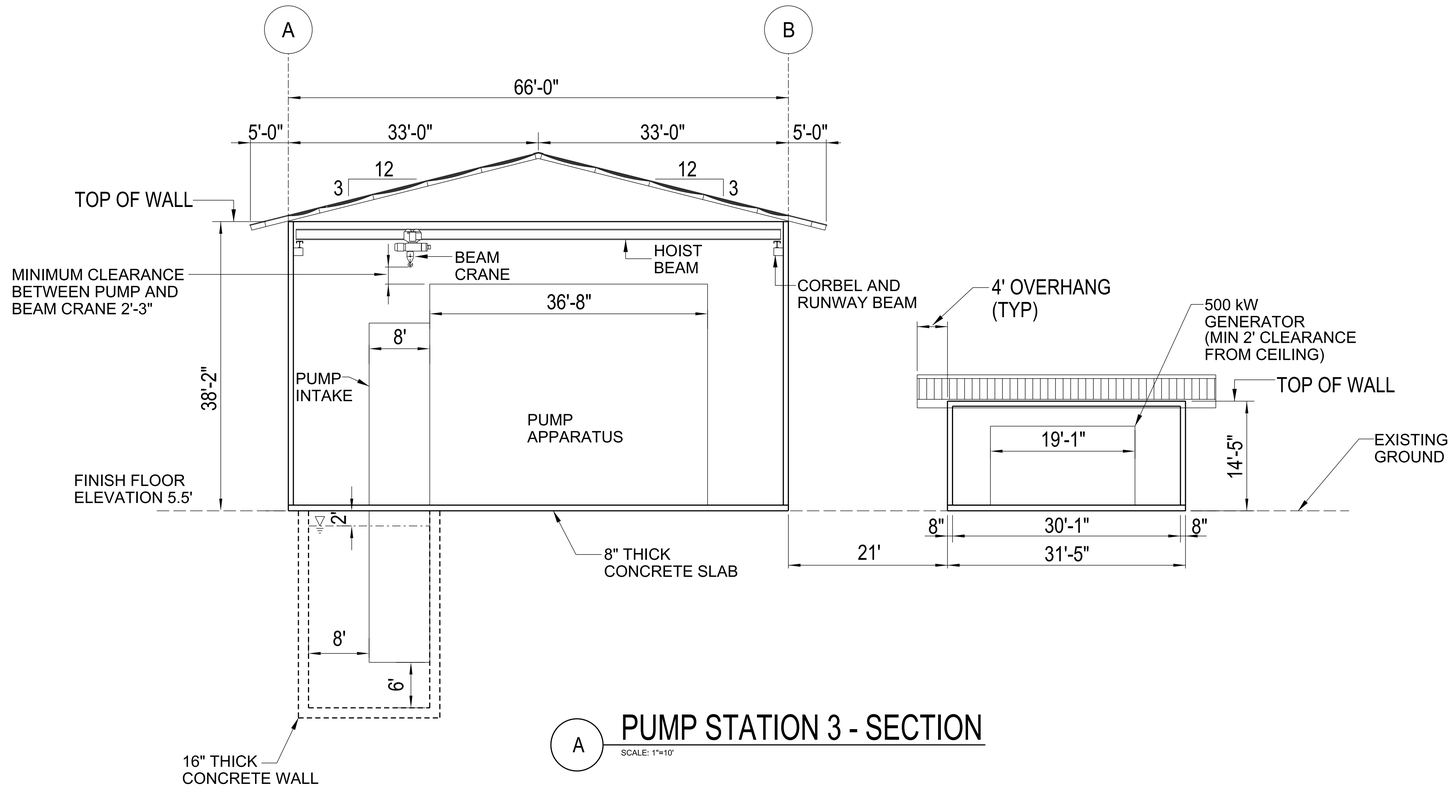
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JJH
DATE:
REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: 1:1 (FULL)
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: PUMP STATION 2, SECTIONS

ALA WAI CANAL PROJECT

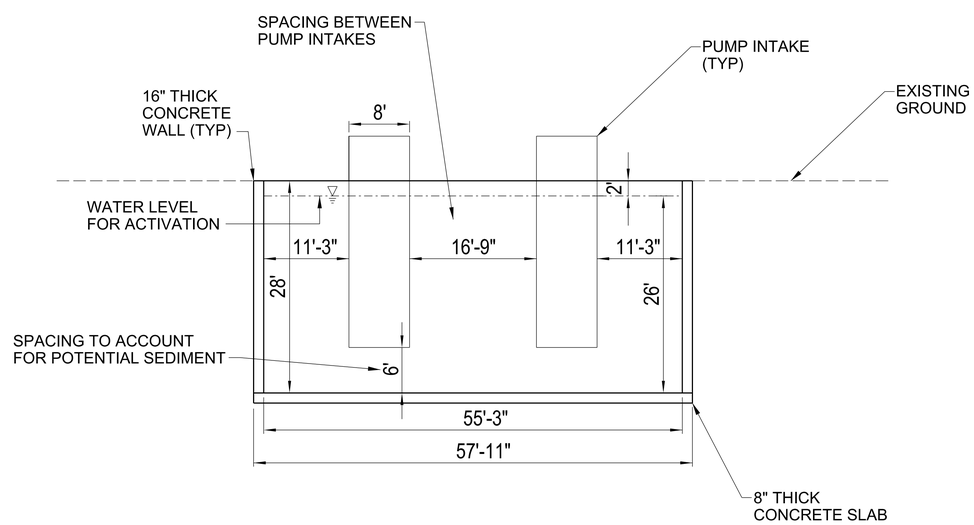
PUMP STATION 2 - SECTIONS

SHEET IDENTIFICATION
A-302
SHEET 30 OF 31



A PUMP STATION 3 - SECTION

SCALE: 1"=10'



B PUMP SUMP PIT SECTION

SCALE: 1"=10'

10 5 0 10 30

SCALE: 1"=10'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

DESIGNED BY: JJH
DATE:
REVISION:
DRAWN BY:
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SOLICIT./ CONTRACT NO.:
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ALA WAI CANAL PROJECT

PUMP STATION 3 - SECTIONS

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

SECTION 209 OF FLOOD CONTROL ACT OF 1962
(PUBLIC LAW 87-874)

APPENDIX A3

EXISTING WITHOUT-PROJECT HYDRAULIC AND WITH-PROJECT HYDROLOGIC AND HYDRAULIC

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Hillslope Runoff and Hazard Appendix

Ala Wai Watershed Study
Hillslope Runoff and Hazard Appendix

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Hillslope Runoff and Hazard Appendix
Ala Wai Watershed Study

1.0. Introduction

This Appendix describes the hydrologic assumptions, techniques, and methodologies used to evaluate the peak flow runoff percentages from hillslope areas in the Manoa and Palolo Valleys and discuss some of the hillslope hazards in the Ala Wai Watershed. This model builds upon the previous hydrological studies done for the Ala Wai Watershed (Oceanit 2008a and 2008d). It does not provide background information on the Ala Wai Watershed and assumes the reader is familiar with hydrologic modeling. Background information on the Ala Wai Watershed study area can be found in Townscape and Dashiell (2003).

1.1. Purpose. The purpose of this report is to characterize the hillslope hazards along the Manoa-Palolo Valley sides by determining the amount and contribution of runoff from the hillslope areas and summarizing previous work on shallow landslides and debris flow hazards in the study area. The runoff or peak flow discharges for various storm frequencies from hillslope areas was determined by a kinematic wave rainfall-runoff model of the Manoa-Palolo Watershed portion of the Ala Wai Watershed. The rainfall-runoff model was conducted using the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) computer model and Geographic Information Systems (GIS) software.

1.2. Scope. The hydrologic model extends from the upper Watershed in Manoa and Palolo Valleys to the junction of Manoa and Palolo Steams near Kaimuki High School. It is a sub-model of the larger Watershed model presented in Oceanit (2008b). The model was used to determine the peak flow discharges for the 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent chance floods (2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year recurrence intervals) for the purposes of determining the relative contribution from the upper Watershed areas, hillslope areas, and urban areas. Peak discharge data from this analysis does not supersede the peak flows determined previously (Oceanit 2008b) and that used in the hydraulic modeling effort.

1.3. Previous Hydrologic Models. Previous hydrologic rainfall-runoff model studies of the Ala Wai Watershed started in 2001 with a HEC-1 model which used the initial/constant loss method and the Snyder's Unit Hydrograph transformation method with kinematic wave transform method used in the urban areas [U.S. Army Corps of Engineers, 2001 (USACE)]. This model did attempt to break out the non-urban from the urban areas in terms of peak discharge contribution. The HEC-1 program is a predecessor to the HEC-HMS program. Part of this modeling effort was highlighting the data gaps in model calibration so additional data collection in the Watershed was funded by the (USACE), and this new data was first used in a HEC-HMS model analyzing the October 30, 2004 flood in Manoa Valley (USACE, 2006). Work by Oceanit (2008a; 2008b) refined and expanded the modeling efforts using new topographic data along with the newer hydrologic data for both Manoa Stream and then the entire Ala Wai Watershed. The final HEC-HMS model for the Ala Wai Watershed (Oceanit 2008b) uses the Soil Conservation Service, now Natural Resource Conservation

Service, curve number (CN) method for losses, the Clark Unit Hydrograph transform method with the kinematic wave transform method used in the urban areas.

2.0. Hydrologic Model Development

The HEC-HMS version 3.4 (USACE, 2009) model developed for this analysis is based upon the final Oceanit (2008b) model but only looks at the Manoa-Palolo Streams. Additional sub-basins were created from the previously derived sub-basins to separate the hillslope areas from the urban areas. The hillslope areas are those areas along the valley walls that drain into the developed areas before entering the stream channels (Figure 1). As part of the problems and opportunities development for the Ala Wai Watershed project ii was determined that the hillslope areas have a contribution to the hazards in the study area and this model is an attempt to quantify that contribution.

A summary of the sub-basins and areas that contribute to the total peak flows are presented in Table 1. The upper Watershed areas represent 46 percent of the total 10.4 mi^2 Manoa-Palolo Watershed, hillslope areas 18 percent, and urban areas 36 percent. The kinematic wave transform method was used throughout for all sub-basins. This method allows the separation of previous and impervious areas and thus is used for urban areas but can also be used for natural basins. The main required components of this method are the flow planes and the main channel but additional sub-collectors and collector channels can be incorporated in each sub-basin. The method is well documented in DeVries and MacArthur (1979) from which Figures 2 and 3 come from. These figures illustrate how the kinematic wave method models sub-basin Watershed areas. The kinematic wave method is much more physically based than the Clark or Snyder's Unit Hydrograph methods, and most of the input parameters needed are measured from available maps or GIS data.

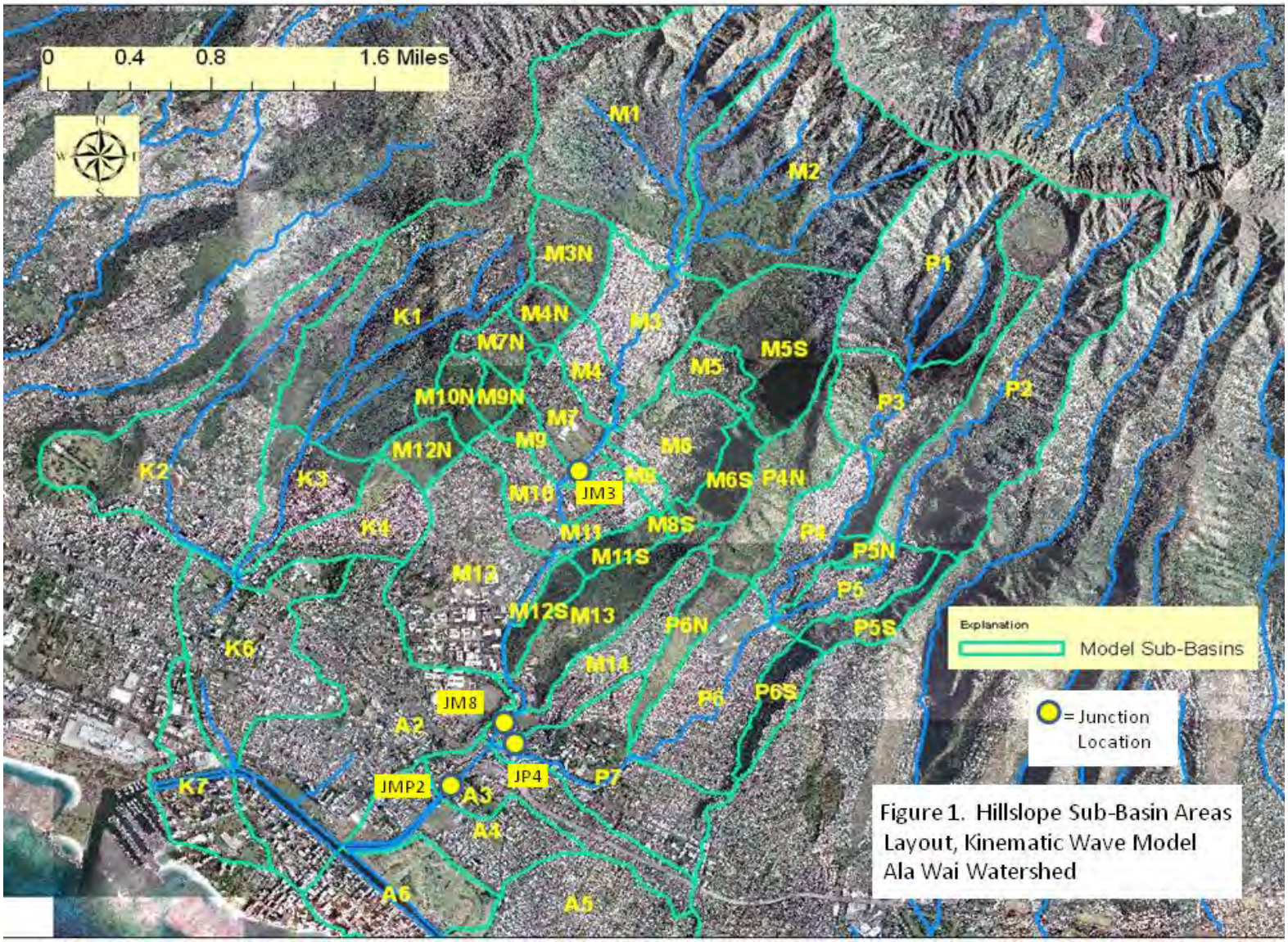

Figure 1. Hillslope Sub-Basin Areas Layout, Kinematic Wave Model Ala Wai Watershed

Table 1. Sub-Basins in Kinematic Wave HEC-HMS Model, Ala Wai Watershed, Oahu, Hawaii

Upper Watershed Areas		Hillslope Areas		Urban Areas	
Sub-Basin	**Area (mi^2)**	**Sub-Basin**	**Area (mi^2)**	**Sub-Basin**	**Area (mi^2)**
M1	1.20	M3N	0.18	M3	0.33
M2	1.07	M4N	0.08	M4	0.10
M5S	0.40	M6S	0.12	M5	0.10
P1	0.67	M7N	0.09	M6	0.23
P2	1.05	M8S	0.01	M7	0.15
P3	0.42	M9N	0.05	M8	0.04
Sum = 4.81		M10N	0.10	M9	0.07
Percentage = 46		M11S	0.07	M10	0.16
		M12N	0.09	M11	0.12
		M12S	0.08	M12	0.58
		M13	0.30	M14	0.25
		P4N	0.29	P4	0.22
		P5S	0.11	P5	0.17
		P5N	0.03	P6	0.43
		P6N	0.14	P7	0.45
		P6S	0.12	A3	0.30
		Sum = 1.84		**Sum = 3.71**	
		Percentage = 18		**Percentage = 36**	

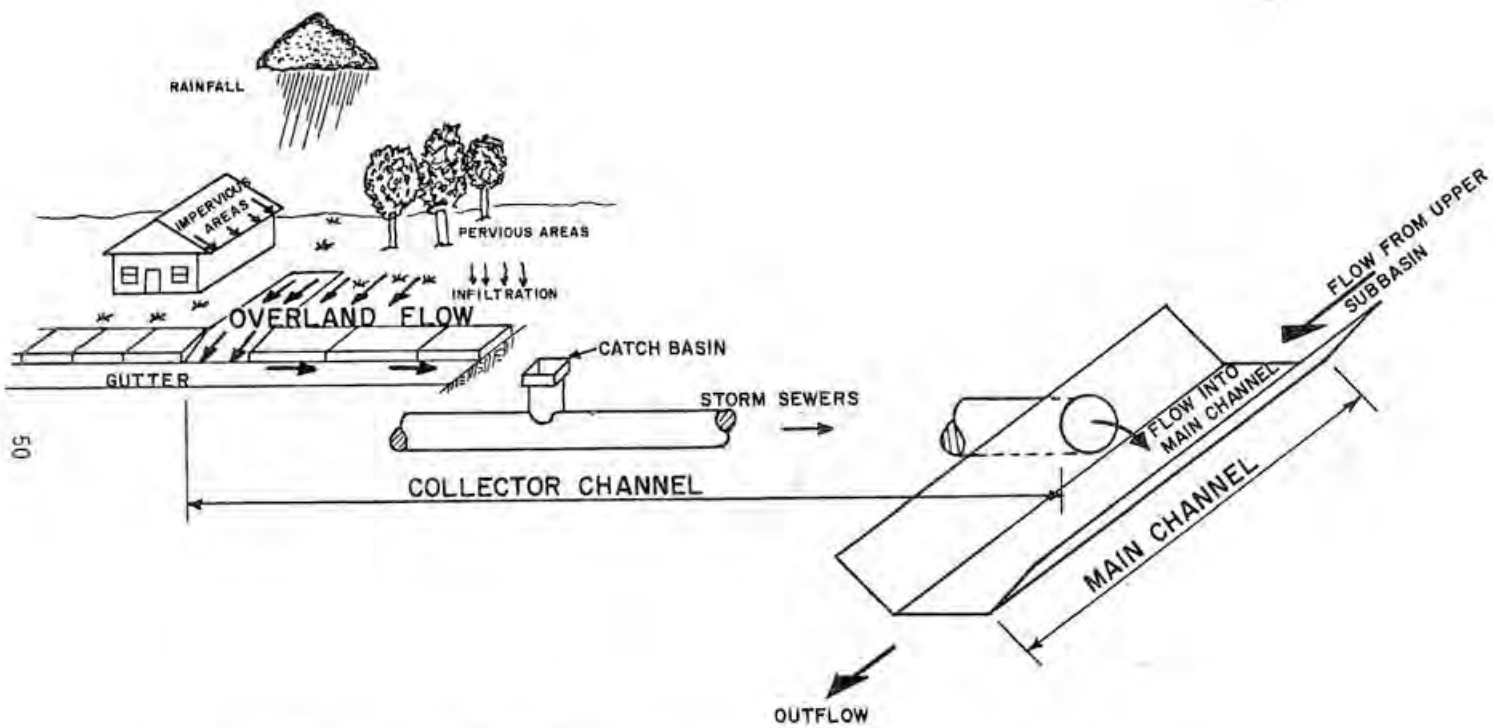

Figure 2. Typical Urban Drainage Pattern for Kinematic Wave Model
(from DeVries and MacArthur, 1979)

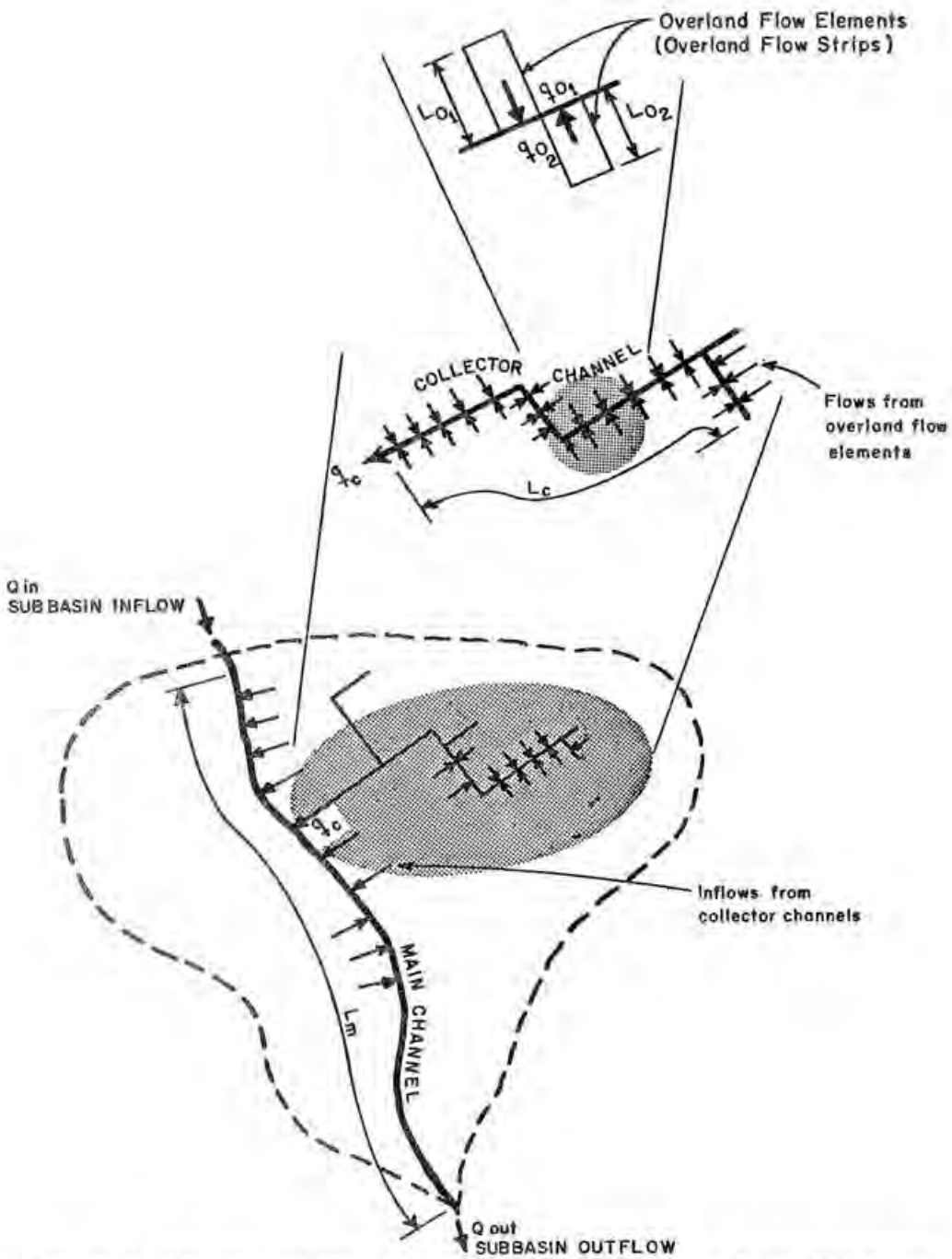

Figure 3. Relationships Between Kinematic Wave Flow Elements
(from DeVries and MacArthur, 1979)

The CN loss method used previously was also used with this model but adjusted due to the separation of the non-urban from the urban areas in the modified sub-basins. The initial values were determined using the same soils and land cover data presented in Oceanit (2008b). Initial abstraction data was not changed. Additional information for the kinematic wave method was determined using GIS tools with the topographic data and information on the storm sewer pipe sizes in the study area. The same channel routing data and method (Muskinghan-Cunge) was used for the channel reaches as in the Oceanit (2008b) model. A schematic of the HEC-HMS model is shown in Figure 4.

2.1. Model Calibration. After the determination of the CN and kinematic wave parameters for each sub-basin in the Manoa-Palolo Watershed, the storm data from the October 30, 2004 flood was used for model calibration. This is the same data used for calibration by Oceanit (2008b). The same rain gage weights (Oceanit, 2008b, Table 4-4) were also used with the new hillslope sub-basins using the same weights used as the main sub-basin used by Oceanit (2008b). Calibration parameters were the CN value, the flow plane length, and the flow plane roughness values.

Calibration results at the stream gage locations are show in Figures 5 to 9 and Table 2. Most of the peak flows in the upper basin areas are overestimated (Figures 5 and 6 and Table 2) but fit better to the observed data in the lower Watershed (Figure 9). Observed data is based upon U.S. Geological Survey (USGS) stream gaging stations in the study area. Calibration determined that the CN values needed to be lowered by 10 to 20 CN values from those used by Oceanit (2008b). One reason for that is in using the Clark Unit Hydrograph transform method, the Clark storage and lag parameters can account for storage in the sub-basin so the CN values do not have to be adjusted for that reason. The kinematic wave method does not account for Watershed storage, so the CN values were used for that reason. Final calibrated sub-basin model parameters are listed in Tables 3 to 5. Only those sub-basins which had defined sub-collectors and collector channels are listed in Table 3.

2.2. Peak Flow Frequency Analysis. The final calibrated parameters were then used with the frequency rainfall data to compute the peak flow discharges for the various storms. This method assumes that the resulting peak flow discharges have the same percent chance exceedance probabilities as the rainfall data and that the frequency storm data occurs uniformly throughout the Watershed model. Thus, the rainfall frequency data was determined at a point representing the centroid of the Ala Wai Watershed.

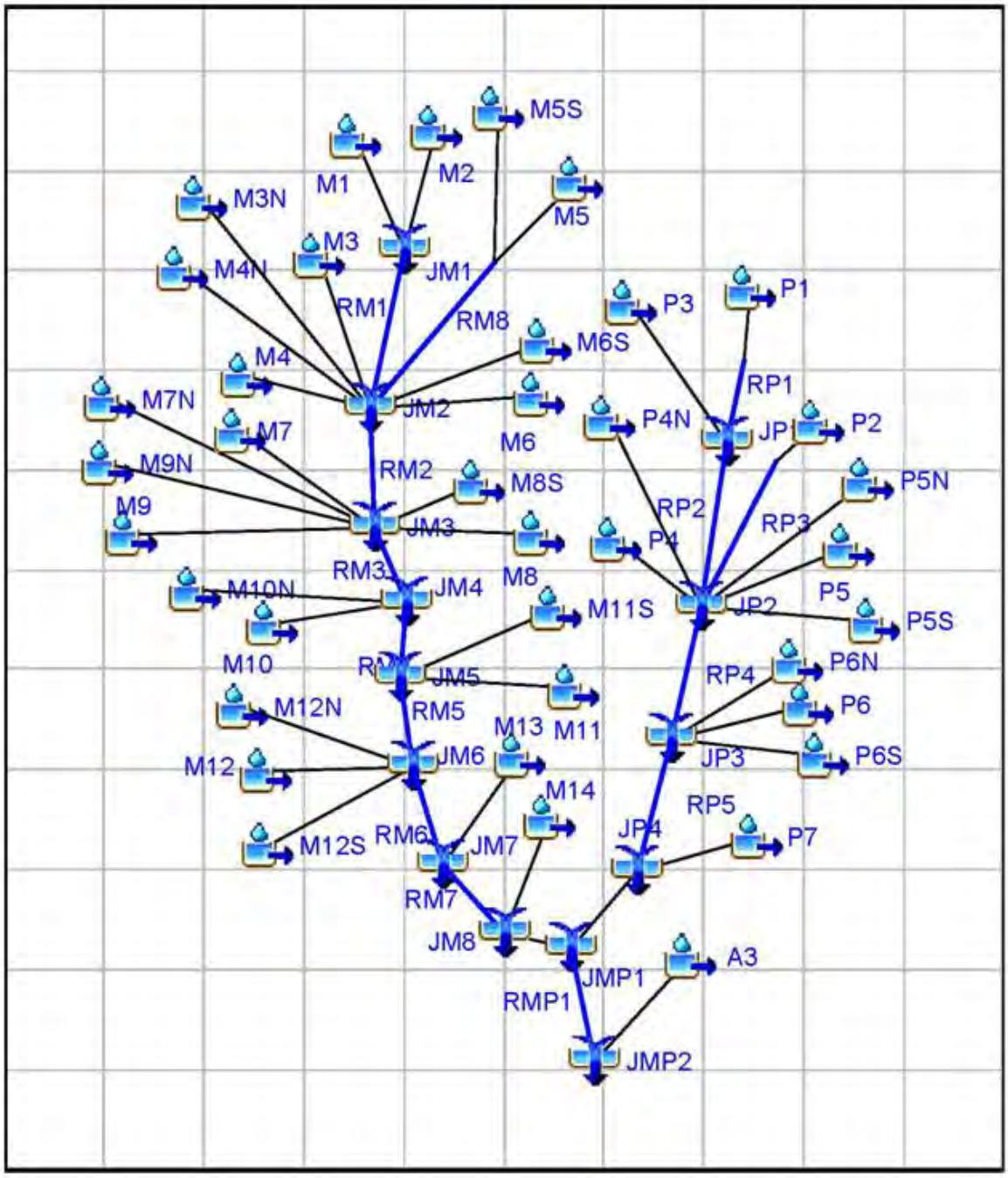

Figure 4. HEC-HMS Model Layout for the Manoa-Palolo Watershed, Ala Wai Watershed, Oahu, Hawaii

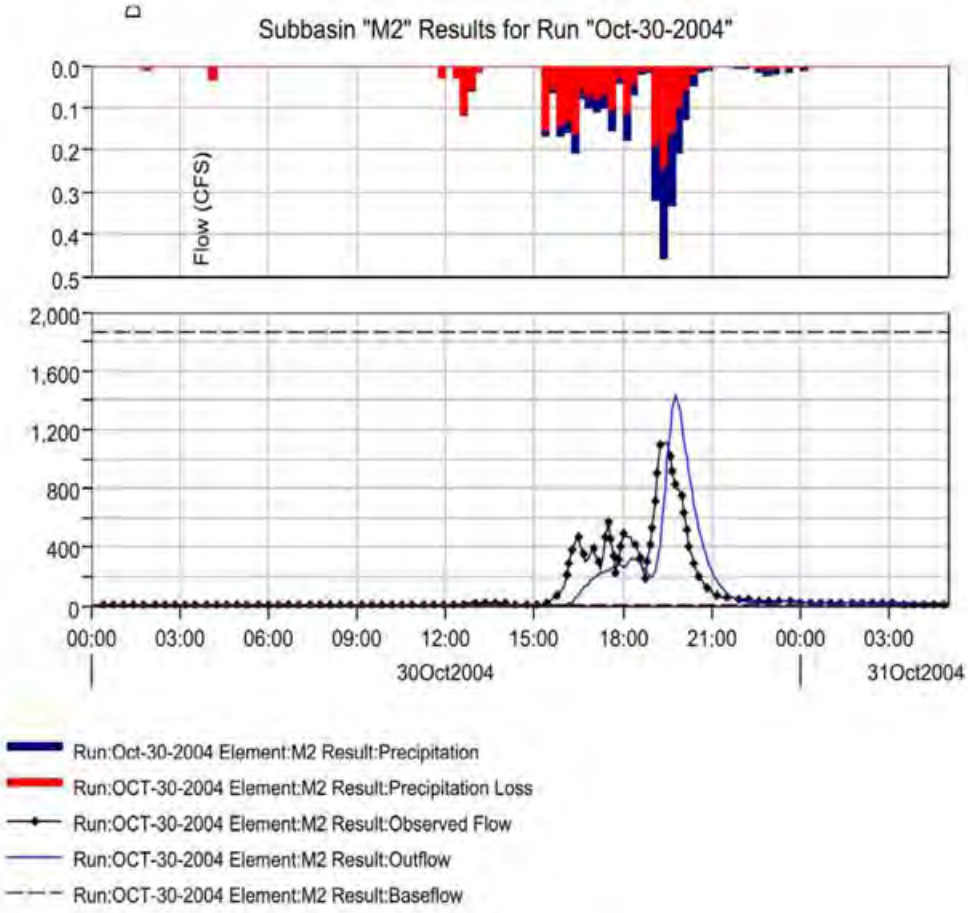

Figure 5. Model Calibration Results for Sub-Basin M2, USGS Gage 16240500 For the October 30, 2004 Storm, Manoa Stream, Ala Wai Watershed

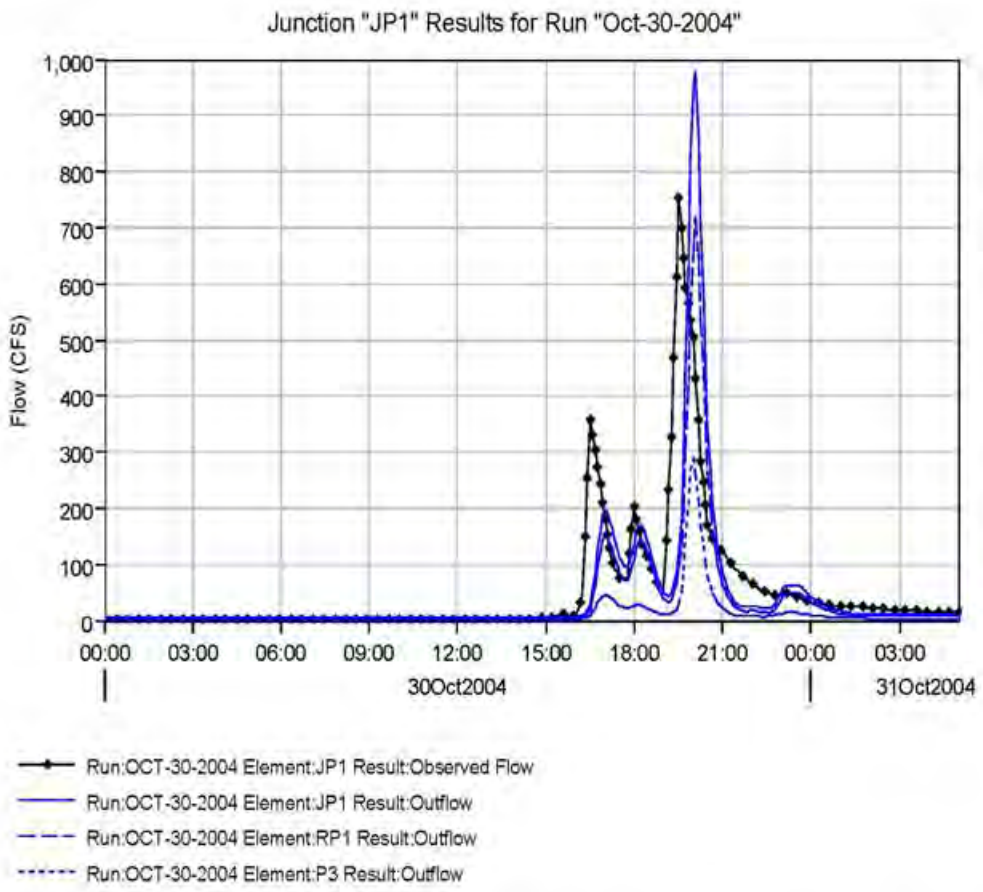

Figure 6. Model Calibration Results for Junction JP1, USGS Gage 16244000 For the October 30, 2004 Storm, Pukele Stream, Ala Wai Watershed

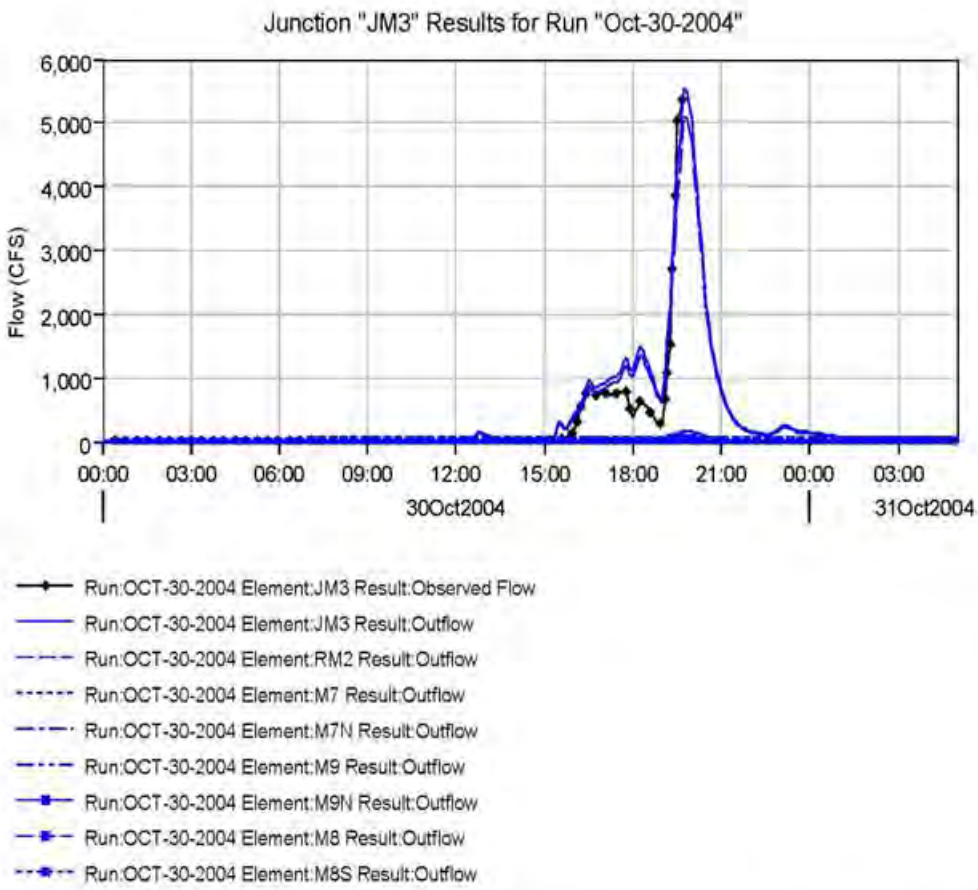

Figure 7. Model Calibration Results for Junction JM3, USGS Gage 16241500 For the October 30, 2004 Storm, Manoa Stream, Ala Wai Watershed

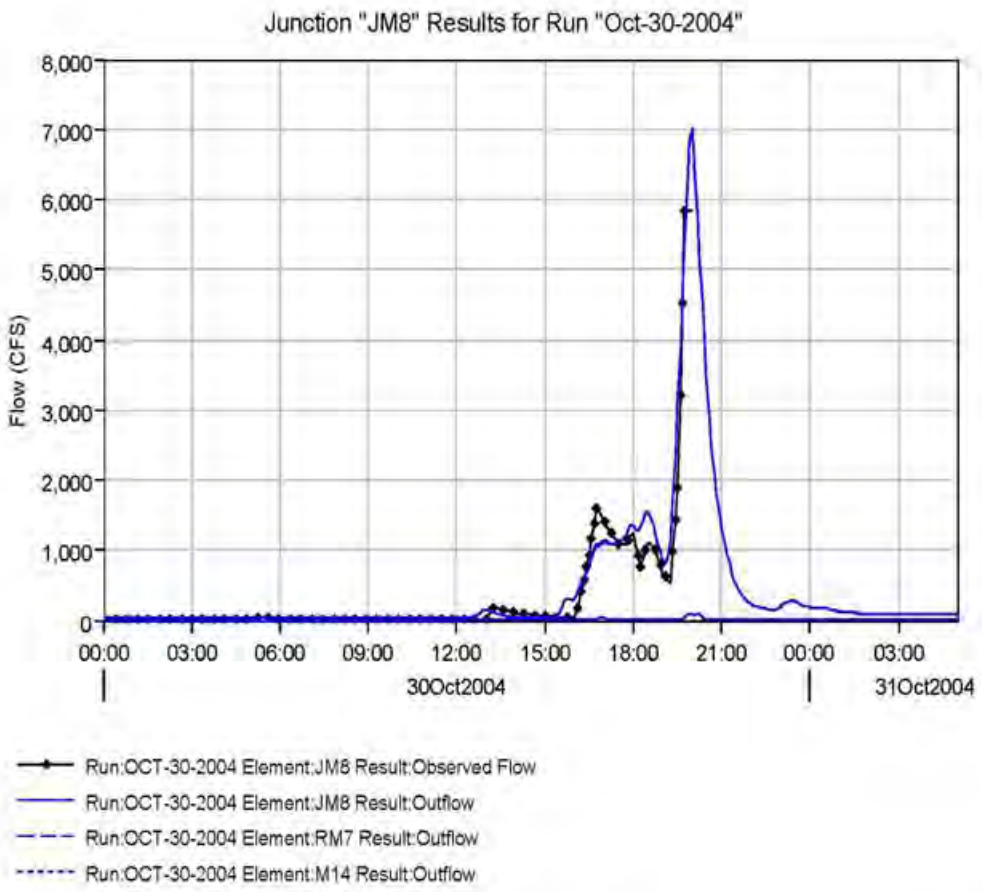

Figure 8. Model Calibration Results for Junction JM8, USGS Gage 16242500 For the October 30, 2004 Storm, Manoa Stream, Ala Wai Watershed

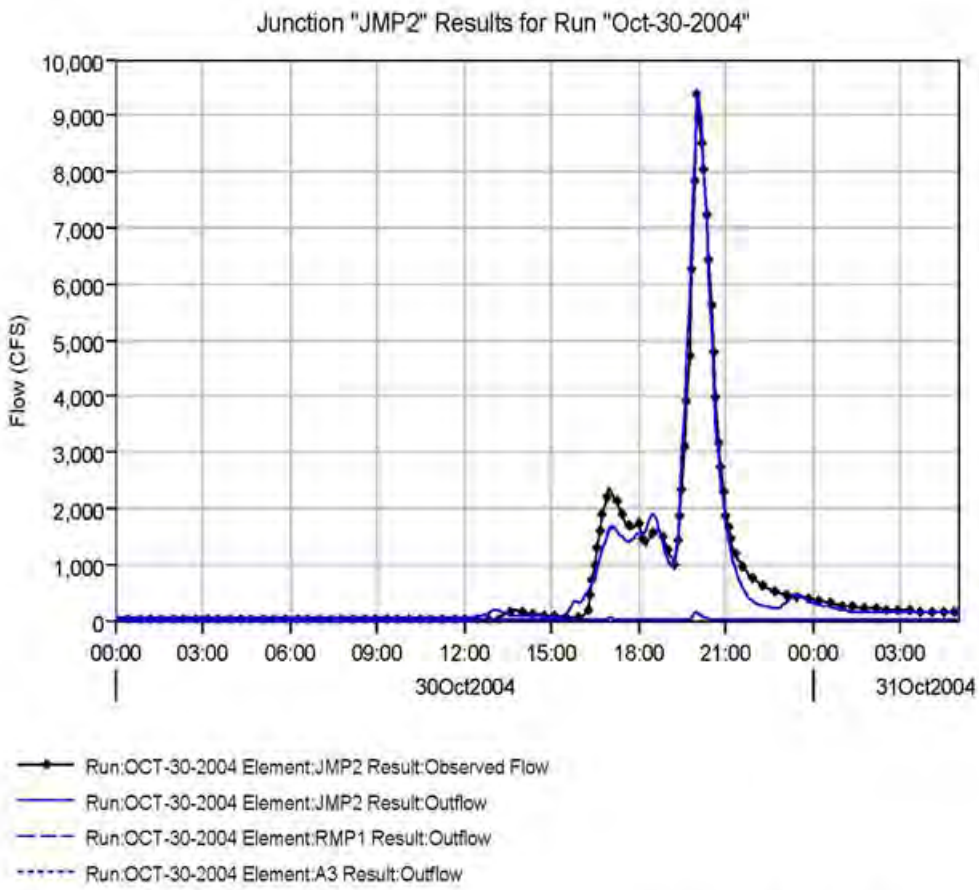

Figure 9. Model Calibration Results for Junction JMP2, USGS Gage 16247100
For the October 30, 2004 Storm, Manoa–Palolo Drainage Canal, Ala Wai Watershed

Table 2. Calibration Peak Flow Discharge Frequency Results (cubic feet per second) and Percent Contribution by Areas, October 30, 2004 Storm, Ala Wai Watershed, Oahu, Hawaii

Sub-Basin or Junction Location	Oct 30, 2004 Calibration		Percentage Contribution		
	Observed Peak	Modeled Peak	Upper	Hillslope	Urban
M2 Waiakeakua St.	1,100	1,430	100	0	0
JM3 Manoa St. at Lowrey Ave	5,050	5,550	58	9	34
JM8 Manoa St. near Kanewai Field	5,870*	7,030*	45	10	46
JP1 Pukele St.	753	978	100	0	0
JMP2 Manoa-Palolo Drainage Canal	9,380	9,330	48	9	42

* Modeled result assumes peak flow remained in stream rather than leaving channel and flooding University of Hawaii Campus as what actually happened (see USACE, 2006).

Table 3. Flow Plane Loss and Kinematic Wave Data for Ala Wai Watershed HEC-HMS Model Sub-Basins, Oahu, Hawaii

Sub-basin	IA (in)	CN	Length (ft)	Slope (ft/ft)	Surface Roughness	Area %
M1 (Plane 1)	0.5	37	650	0.6	1	100
M1 (Plane 2)						
M2 (Plane 1)	0.4	35	650	0.4	1	100
M2 (Plane 2)						
M5S (Plane 1)	0.6	41	200	0.4	1	100
M5S (Plane 2)						
M5 (Plane 1)	0.4	60	100	0.2	0.4	90
M5 (Plane 2)	0.1	95	60	0.02	0.1	10
M3 (Plane 1)	0.4	51	100	0.1	0.2	60
M3 (Plane 2)	0.1	95	60	0.03	0.1	40
M6 (Plane 1)	0.4	53	110	0.3	0.4	80
M6 (Plane 2)	0.1	95	60	0.03	0.1	20
M3N (Plane 1)	0.6	40	200	0.7	1	100
M3N (Plane 2)						
M6S (Plane 1)	0.5	39	150	0.5	0.8	100
M6S (Plane 2)						
M4 (Plane 1)	0.4	56	100	0.1	0.2	60
M4 (Plane 2)	0.1	95	60	0.02	0.1	40
M4N (Plane 1)	0.6	39	250	0.8	0.8	100
M4N (Plane 2)						
M7 (Plane 1)	0.5	51	900	0.07	0.4	90
M7 (Plane 2)	0.1	95	60	0.02	0.1	10
M7N (Plane 1)	0.5	40	150	0.8	0.8	100
M7N (Plane 2)						
M9 (Plane 1)	0.4	53	100	0.02	0.4	70
M9 (Plane 2)	0.1	95	60	0.02	0.1	30
M9N (Plane 1)	0.6	38	150	0.8	0.8	100
M9N (Plane 2)						
M8 (Plane 1)	0.4	66	100	0.2	0.4	60
M8 (Plane 2)	0.1	95	60	0.02	0.1	40
M8S (Plane 1)	0.6	43	161	0.25	0.8	100
M8S (Plane 2)						
M10 (Plane 1)	0.5	53	100	0.02	0.4	70
M10 (Plane 2)	0.1	95	60	0.02	0.1	30
M10N (Plane 1)	0.6	40	160	0.5	0.8	100
M10N (Plane 2)						
M11 (Plane 1)	0.4	65	100	0.01	0.4	80
M11 (Plane 2)	0.1	95	60	0.01	0.1	20
M11S (Plane 1)	0.6	45	130	0.3	0.8	100
M11S (Plane 2)						
M12 (Plane 1)	0.3	58	100	0.15	0.2	70
M12 (Plane 2)	0.1	95	60	0.02	0.15	30
M12N (Plane 1)	0.5	47	250	0.09	0.8	100

IA = Initial Abstraction
CN = Curve Number
Area % = Percentage of pervious and impervious areas (Plane 2 represents the impervious areas)

M12N (Plane 2)	

Table 3. Flow Plane Loss and Kinematic Wave Data for Ala Wai Watershed HEC-HMS Model Sub-Basins, Oahu, Hawaii

Sub-basin	IA (in)	CN	Length (ft)	Slope (ft/ft)	Surface Roughness	Area %
M12S (Plane 1)	0.5	47	150	0.3	0.8	100
M12S (Plane 2)						
M13 (Plane 1)	0.6	48	250	0.17	0.8	100
M13 (Plane 2)						
M14 (Plane 1)	1.1	64	100	0.2	0.2	70
M14 (Plane 2)	0.1	95	50	0.2	0.1	30
P1 (Plane 1)	0.7	44	350	0.5	1	100
P1 (Plane 2)						
P3 (Plane 1)	0.7	42	250	0.4	1	100
P3 (Plane 2)						
P2 (Plane 1)	0.8	40	200	0.8	1	100
P2 (Plane 2)						
P4N (Plane 1)	0.9	44	200	0.4	0.8	100
P4N (Plane 2)						
P4 (Plane 1)	0.7	63	100	0.06	0.2	80
P4 (Plane 2)	0.1	95	60	0.01	0.1	20
P5 (Plane 1)	0.6	61	90	0.05	0.4	80
P5 (Plane 2)	0.1	95	60	0.01	0.1	20
P5S (Plane 1)	0.8	43	140	0.5	0.8	100
P5S (Plane 2)						
P5N (Plane 1)	0.8	43	150	0.26	0.8	100
P5N (Plane 2)						
P6 (Plane 1)	0.7	79	100	0.1	0.2	70
P6 (Plane 2)	0.1	95	60	0.03	0.1	30
P6N (Plane 1)	0.9	48	157	0.13	0.8	100
P6N (Plane 2)						
P6S (Plane 1)	0.9	48	250	0.16	0.8	100
P6S (Plane 2)						
P7 (Plane 1)	1.2	78	150	0.01	0.3	60
P7 (Plane 2)	0.1	95	50	0.015	0.15	40
A3 (Plane 1)	0.9	73	150	0.01	0.3	60

IA = Initial Abstraction
CN = Curve Number
Area % = Percentage of pervious and impervious areas (Plane 2 represents the impervious areas)

Table 4. Sub-Collector and Collector Data for Ala Wai Watershed HEC-HMS Model Sub-Basins, Oahu, Hawaii

Sub-Basin	Length (ft)	Slope (ft/ft)	Manning's n	Area (mi^2)	Shape	Dia. (ft)	Width (ft)	Side-slope
M1(Sub-Collector)	4,100	0.3	0.05	0.27	Trapezoid	----	10	1
M1(Collector)	4,400	0.1	0.04	0.92	Trapezoid	----	18	1
M2(Sub-Collector)	3,900	0.3	0.06	0.16	Trapezoid	----	10	0.5
M2(Collector)	2,800	0.1	0.05	0.33	Trapezoid	----	18	0.5
M5S(Collector)	1,270	0.5	0.04	0.05	Trapezoid	----	2.5	0.5
M5(Sub-Collector)	400	0.1	0.02	0.019	Triangle	----	----	1
M5(Collector)	960	0.14	0.018	0.024	Circle	2	----	----
M3(Sub-Collector)	670	0.09	0.018	0.033	Circle	2	----	----
M3(Collector)	1,640	0.07	0.018	0.066	Circle	4	----	----
M6(Sub-Collector)	680	0.12	0.018	0.039	Circle	1.5	----	----
M6(Collector)	1,120	0.12	0.018	0.039	Circle	2	----	----
M4(Sub-Collector)	250	0.02	0.02	0.01	Triangle	----	----	1
M4(Collector)	810	0.08	0.018	0.017	Circle	2	----	----
M7(Sub-Collector)	200	0.02	0.02	0.051	Triangle	----	----	1
M7(Collector)	760	0.13	0.018	0.077	Circle	1.5	----	----
M9(Sub-Collector)	200	0.02	0.02	0.013	Triangle	----	----	1
M9(Collector)	220	0.01	0.018	0.04	Circle	2	----	----
M10(Sub-Collector)	250	0.18	0.02	0.023	Triangle	----	----	1
M10(Collector)	1,090	0.003	0.018	0.082	Circle	1.5	----	----
M10N(Collector)	760	0.18	0.04	0.033	Trapezoid		3	0.5
M11(Collector)	570	0.07	0.018	0.023	Circle	2	----	----
M12(Sub-Collector)	450	0.04	0.02	0.024	Triangle	----	----	1
M12(Collector)	1,320	0.05	0.018	0.168	Circle	2	----	----
M12N(Collector)	700	0.45	0.04	0.022	Trapezoid	----	1.5	1
M12S(Collector)	550	0.66	0.03	0.013	Trapezoid	----	1.5	1
M13(Collector)	1,160	0.28	0.04	0.074	Trapezoid	----	3	1
M14(Collector)	1,550	0.15	0.018	0.085	Circle	2	----	----
P1(Collector)	3,640	0.26	0.04	0.133	Trapezoid	----	5	0.5
P3(Collector)	2,220	0.33	0.04	0.059	Trapezoid	----	5	0.5
P2(Collector)	1,640	0.52	0.04	0.052	Trapezoid	----	3	0.5
P4(Sub-Collector)	360	0.11	0.02	0.032	Triangle	----	----	1
P4(Collector)	970	0.11	0.018	0.044	Circle	2	----	----
P5(Sub-Collector)	290	0.21	0.02	0.028	Triangle	----	----	1
P5(Collector)	760	0.14	0.018	0.033	Circle	1.5	----	----
P6(Sub-Collector)	350	0.1	0.02	0.01	Triangle	----	----	1
P6(Collector)	1,230	0.11	0.018	0.028	Circle	2	----	----
P7(Collector)	2,400	0.02	0.018	0.025	Circle	2	----	----
A3(Collector)	2,800	0.06	0.018	0.03	Circle	3	----	----

Area = Area drained by sub-collector and collectors
Dia. = diameter
---- = not applicable

Table 5. Sub-Collector and Collector Data for Ala Wai Watershed HEC-HMS Model Sub-Basins, Oahu, Hawaii

Sub-Basin	Length (ft)	Slope (ft/ft)	Shape	Manning's n	Diameter (ft)	Width (ft)	Side-slope
M1	2,300	0.1	Trapezoid	0.04	----	25	1
M2	800	0.1	Trapezoid	0.05	----	25	0.5
M5S	2,290	0.31	Trapezoid	0.04	----	5	0.5
M5	1,300	0.09	Rectangle	0.03	----	6	
M3	970	0.011	Trapezoid	0.03	----	20	0.5
M6	2,180	0.12	Circle	0.018	2.5	----	----
M3N	1,850	0.52	Trapezoid	0.04	----	3	0.5
M6S	650	0.8	Trapezoid	0.04	----	2.5	0.5
M4	1,090	0.11	Circle	0.018	2	----	----
M4N	1,400	0.6	Trapezoid	0.04	----	2	0.5
M7	1,500	0.1	Trapezoid	0.03	----	5	0.5
M7N	870	0.8	Trapezoid	0.04	----	4	0.5
M9	1,570	0.019	Rectangle	0.018	----	5	
M9N	650	0.8	Trapezoid	0.04		3	0.5
M8	2,720	0.088	Circle	0.018	1.5	----	----
M8S	610	0.8	Trapezoid	0.04	----	2	1
M10	1,300	0.005	Rectangle	0.018	----	4	
M10N	2,200	0.4	Trapezoid	0.04	----	4	0.5
M11	650	0.019	Circle	0.018	4.5	----	----
M11S	600	0.8	Trapezoid	0.04	----	2	0.5
M12	6,200	0.04	Circle	0.013	4	----	----
M12N	948	0.06	Trapezoid	0.03	----	2.5	0.5
M12S	2,200	0.04	Trapezoid	0.02	----	3	0.5
M13	5,830	0.295	Trapezoid	0.04	----	5	0.5
M14	3,330	0.156	Circle	0.018	4	----	----
P1	2,670	0.179	Trapezoid	0.04	----	10	0.5
P3	3,600	0.088	Trapezoid	0.04	----	15	0.5
P2	9,630	0.08	Trapezoid	0.04	----	15	0.5
P4N	1,310	0.56	Trapezoid	0.04	----	2.5	0.5
P4	6,000	0.05	Rectangle	0.025	----	25	----
P5	4,900	0.036	Rectangle	0.025	----	25	----
P5S	500	0.8	Trapezoid	0.04	----	2.5	0.5
P5N	550	0.8	Trapezoid	0.04	----	2	0.5
P6	5,050	0.0793	Rectangle	0.015	----	35	----
P6N	620	0.675	Trapezoid	0.04	----	2.5	0.5
P6S	760	0.5	Trapezoid	0.04	----	2.5	0.5
P7	4,300	0.0186	Rectangle	0.02	----	30	----
A3	800	0.0075	Trapezoid	0.03	----	5	0.5

---- = not applicable

When the hydrologic studies for Manoa and Ala Wai Watersheds were conducted (Oceanit 2008a and 2008b), the 1984 rainfall frequency data for Oahu was used in the rainfall-runoff modeling (Giambelluca et.al., 1984). In March 2009, the updated rainfall frequency data for the State of Hawaii was released as the Precipitation Frequency Data Server which is part of National Oceanic and Atmospheric Administration (NOAA) Atlas 14, Volume 4, Version 2.0, Hawaiian Islands, released March 30, 2009. Atlas 14 is official documentation of precipitation frequency estimates for the United States. Documentation can be found at: http://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume4.pdf, last accessed September 28, 2009 while the actual server is located at: http://hdsc.nws.noaa.gov/hdsc/pfds/hi/hi_pfds.html. This tool computes the rainfall frequency and intensity with 90 percent confidence limits for the 1- to 100-year storms for durations from 5 minutes to 60 days. A comparison between the previous and newer rainfall frequency duration values, indicated that the newer values were higher than the older data by an average of 4 to 13 percent depending on the rainfall recurrence interval and duration. In general, the shorter time periods had a larger change then the longer rainfall time periods. The newer rainfall frequency data was used in this analysis and is listed in Table 6.

Table 6. Rainfall Intensity Frequency Data for Existing Without-Project Conditions, Ala Wai Watershed, Oahu, Hawaii

% Chance Exceedance	Return Period (yrs)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.38	0.66	0.97	1.40	1.87	2.12	2.74	3.35	3.92
50	2	0.47	0.80	1.19	1.72	2.33	2.71	3.49	4.29	5.18
20	5	0.61	1.04	1.54	2.22	3.04	3.54	4.58	5.68	6.96
10	10	0.72	1.24	1.83	2.64	3.61	4.21	5.46	6.80	8.39
5	20	0.81	1.49	2.11	3.05	4.15	4.94	6.28	8.00	9.95
4	25	0.89	1.52	2.25	3.24	4.42	5.16	6.69	8.36	10.42
2	50	1.02	1.75	2.59	3.74	5.09	5.94	7.69	9.61	12.05
1	100	1.16	1.99	2.95	4.25	5.78	6.74	8.74	10.92	13.77
0.5	200	1.31	2.25	3.34	4.82	6.53	7.61	9.86	12.30	15.60
0.2	500	1.53	2.62	3.88	5.61	7.57	8.82	11.42	14.23	18.18

Rainfall Intensity Frequency data determined from NOAA Atlas 14 Precipitation Frequency Data Server using Watershed centroid of 21.3092 N, 157.8071 W. Values for the 5-percent chance storm are interpolated.

3.0. Model Results

Results are presented at model junctions in Table 7. Comparing the peak discharges at the junctions (Table 6) with those at the same junctions (Oceanit, 2008b) indicates that values are comparable. The Table 6 values are lower in magnitude for the 50- to 10-perecent chance floods and higher or the 1- to 0.2-percent chance floods then the previous values. Peak discharge data at just the hillslope sub-basins are presented in Table 8. Unit discharge ranges are roughly comparable among the hillslope sub-basins; for the 10-percent chance flood, they range from 820 to 1160 $ft^3/s/mi^2$ with an average of 980 $ft^3/s/mi^2$. For the 1-percent chance flood, the unit discharges range from 2,220 to 3,270 $ft^3/s/mi^2$ with an average of 2,810 $ft^3/s/mi^2$.

Table 7. Peak Flow Discharge Frequency Values (cubic feet per second) Determined by HEC-HMS Model, Ala Wai Watershed, Oahu, Hawaii

Flow Concentration Junction Location	% Chance Exceedance							
	50	20	10	5	2	1	0.5	0.2
JM1	275	686	1,120	1,640	2,530	3,320	4,300	5,740
JM2	985	1,940	2,920	4,020	5,770	7,460	9,210	11,900
JM3	1,010	2,010	3,040	4,240	6,140	7,770	9,540	12,200
JM4	1,130	2,260	3,370	4,590	6,580	8,420	9,910	13,200
JM5	1,180	2,340	3,500	4,800	6,770	8,560	10,300	13,400
JM6	1,460	2,870	4,250	5,660	7,760	9,670	11,500	15,100
JM7	1,520	2,990	4,460	5,970	8,170	10,200	12,200	15,600
JM8	1,610	3,150	4,680	6,240	8,540	10,600	12,600	16,400
JP1	198	503	821	1,200	1,770	2,250	2,860	3,830
JP2	587	1,490	2,390	3,510	5,290	6,670	8,340	10,300
JP3	977	2,070	3,310	4,640	6,650	8,300	10,400	13,300
JP4	1,390	2,880	4,310	5,990	8,290	10,200	12,600	15,500
JMP1	2,830	5,820	8,680	11,900	16,360	20,200	24,400	30,900
JMP2	2,990	6,180	9,180	12,500	17,100	21,000	25,300	32,000

Table 8. Peak Flow Discharge Frequency Values (cubic feet per second) Determined by HEC-HMS Model for Hillslope Sub-Basins, Ala Wai Watershed, Oahu, Hawaii

		% Chance Exceedance							
Hillslope Sub-Basin	Area (mi^2)	50	10	20	5	2	1	0.5	0.2
M3N	0.18	38.8	95.7	156	231	349	455	593	783
M4N	0.08	16.3	40.3	65.9	96.4	146	201	247	332
M6S	0.12	30.5	72.4	117	178	262	348	458	600
M7N	0.09	25.6	63.1	106	149	231	294	372	512
M8S	0.01	2.7	6.6	10.6	15.4	23.3	30.1	38.5	52.1
M9N	0.05	10.9	26.7	47.0	67.1	102	136	172	232
M10N	0.10	23.9	58.7	95.4	143	211	281	360	465
M11S	0.07	21.6	51.5	84.8	122	186	239	299	398
M12N	0.09	19.2	46.3	74.2	108	156	200	252	329
M12S	0.08	25.0	58.0	89.3	131	188	252	317	410
M13	0.30	70.1	170	274	392	572	726	912	1,240
P4N	0.29	60.5	163	269	399	601	788	1,060	1,380
P5S	0.11	26.6	67.6	115	173	258	335	433	574
P5N	0.03	6.9	17.5	29.0	42.8	65.0	86.8	113	148
P6N	0.14	30.1	81.0	131	196	286	374	484	634
P6S	0.12	22.2	60.0	99.6	147	216	278	349	483

A break-out of peak flow discharge contributions by upper Watershed, hillslope, and urban sub-basins was done and percentages are presented in Table 9 at selected model junctions. These percentages were determined by summing all the sub-basin peak flow discharges by contribution category (Table 1) and dividing by the total peak value of all sub-basins which is a higher value then the peak discharge data presented in Table 9. Since this summation ignored channel routing and peak flow attenuation, the percent contribution values in Table 9

are not exact but they are close to what the percent contributions would be if all routing and attenuation factors had been taken into account.

Table 9. Peak Flow Discharge Frequency Values (cubic feet per second) and Percent Contribution by Areas, Ala Wai Watershed, Oahu, Hawaii

	50% Chance Flood				20% Chance Flood			
Junction Location	**Peak Flow**	**Upper**	**Hillslope**	**Urban**	**Peak Flow**	**Upper**	**Hillslope**	**Urban**
JM3	1,010	23	8	69	2,010	29	10	61
JM8	1,610	12	10	78	3,150	16	12	72
JP4	1,390	20	7	73	2,880	25	10	65
JMP2	2,990	14	8	78	6,180	19	11	71

	10% Chance Flood				5% Chance Flood			
Junction Location	**Peak Flow**	**Upper**	**Hillslope**	**Urban**	**Peak Flow**	**Upper**	**Hillslope**	**Urban**
JM3	3,040	35	12	53	4,240	35	12	53
JM8	4,690	19	15	67	6,240	20	15	65
JP4	4,310	30	11	60	5,990	32	12	57
JMP2	9,180	22	12	66	12,500	24	13	63

	2% Chance Flood				1% Chance Flood			
Junction Location	**Peak Flow**	**Upper**	**Hillslope**	**Urban**	**Peak Flow**	**Upper**	**Hillslope**	**Urban**
JM3	6,140	37	13	50	7,770	38	13	48
JM8	8,540	21	16	62	10,600	23	17	60
JP4	8,290	34	13	53	10,200	36	14	50
JMP2	17,100	25	14	61	21,000	27	15	58

	0.5% Chance Flood				0.2% Chance Flood			
Junction Location	**Peak Flow**	**Upper**	**Hillslope**	**Urban**	**Peak Flow**	**Upper**	**Hillslope**	**Urban**
JM3	9,540	41	14	46	12,200	45	15	40
JM8	12,600	24	18	58	16,400	27	19	54
JP4	12,600	37	15	48	15,500	37	16	47
JMP2	25,300	28	16	56	32,000	30	17	53

The results in Table 9 indicate that the contribution by each category remains roughly the same regardless of the percent chance flood event. At JMP2, the downstream junction, the upper Watershed contribution to peak discharges varies from 14 to 30 percent, increasing from the 50-percent chance flood to the 0.2-percent chance flood. Hillslope areas contribution also increases from low to high magnitude flood events varying from 8 to 17 percent. Urban percentage contributions varied from 78 to 53 percent of the total peak discharges, decreasing from low to high magnitude flood events. This is the opposite of the how the upper Watershed and hillslope contributions changed.

From this model analysis, it seems that mitigation measures which reduce the lower magnitudes floods for the urban areas would be beneficial while for higher storm magnitudes, mitigation measures should focus on the urban and upper Watershed areas. It does not appear

that hillslope peak flow mitigation measures would be beneficial to reducing the peak flow discharges downstream.

4.0. Debris Flow and Landslide Hazard

The debris flow hazard from hillslopes in the Ala Wai Watershed has been defined in Ellen et.al. (1993). This study presented a debris flow hazard map for the Honolulu area of Southern Oahu from Moanalua Stream to Makapuu Point which includes the Ala Wai Watershed. Debris flows defined by Ellen et.al. (1993) include slope movements that have been called soil avalanches, mud flows, or mudslides. Debris flows begin when intense rainfall causes shallow landslides or soil slips on steep hillslopes. Shallow landslides are typically less than 3 feet thick and of volumes in the few hundred cubic yards. The sliding soil mass with the underlying weather bedrock and overtopping vegetation becomes a rapidly moving debris flow which may damage homes and other structures located in the pathway.

The debris flow hazard map is designed to provide a large scale overview and is limited in showing hazards only from areas underlain by Koolau Basalt, based on average long-term debris flow properties, and the resolution of 1:24,000 scale USGS topographical maps and corresponding 10-meter grid digital elevation model. This map is not designed to predict debris flow locations. The map defined the debris flow hazard into high moderate, and low. A high hazard corresponds to a return period of 500 years or less, a moderate hazard to return periods of 501 to 2,000 years, and a low hazard to return periods of 2,001 to 10,000 years (Ellen et.al., 1993). An extract showing the Ala Wai Watershed area is shown in Figure 10. The results of this study show that the potential landslide hazard is highest in highly weathered soil on steep slopes in areas of high annual rainfall.

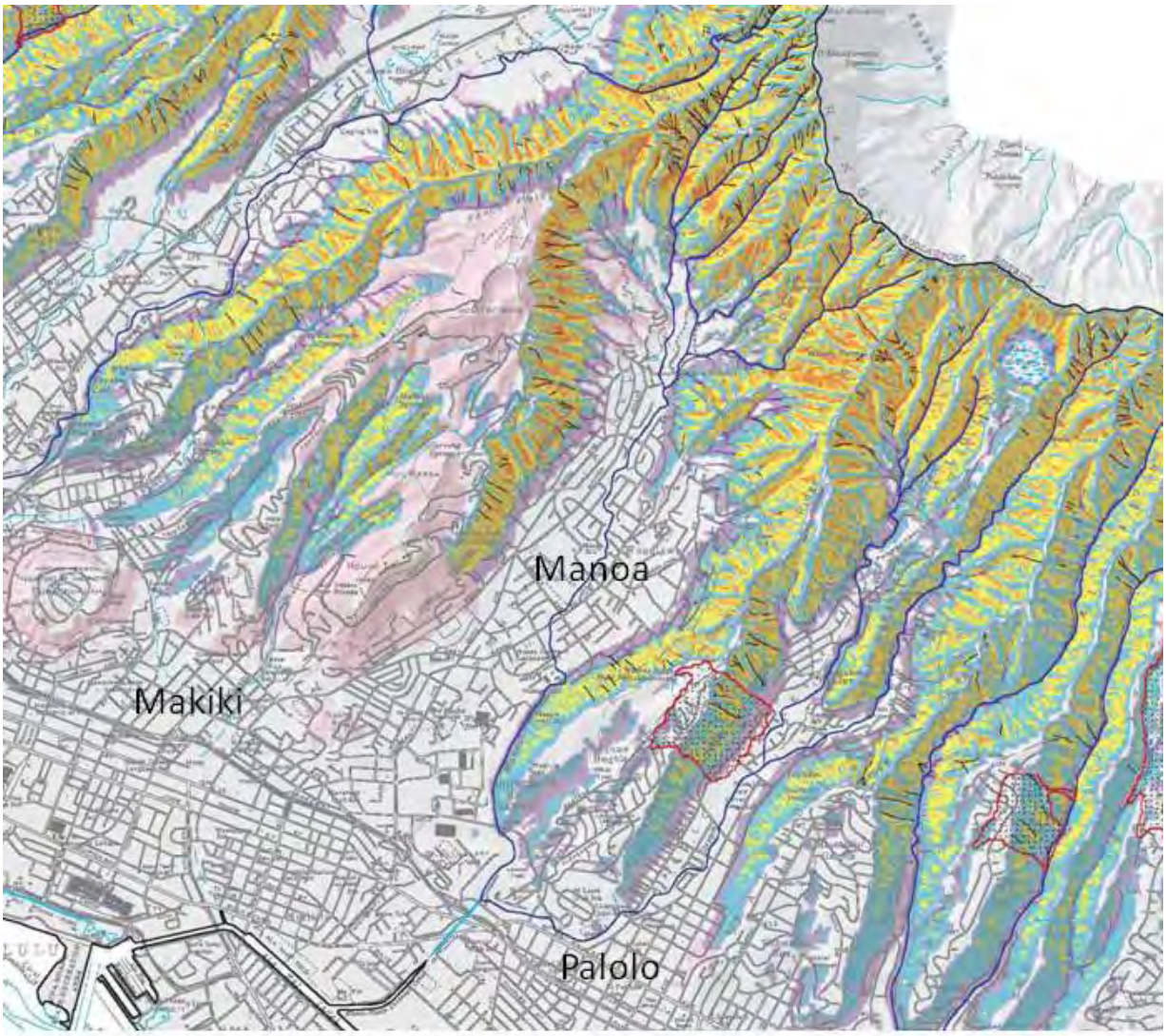

Figure 10. Section of Landslide Hazard Map from Ellen and Others, 1993 (USGS Open-File Report 93-213) covering the Ala Wai Watershed Area.

Areas colored orange represent high hazard areas, those in yellow are moderate, and blue is low hazard areas. Purple areas are possible under extreme conditions and pink areas were not evaluated. The red outlined dotted area represents an increased hazard due to windblown soil deposits.

As a companion to the debris flow hazard map, the USGS also studied rainfall thresholds that can trigger debris flows (Wilson et.al., 1992). This study was based on rainfall and soil pore pressure data from Pauoa Ridge in Nuuanu Valley to the west of the Ala Wai Watershed and Kaluanui Ridge in Hahaione Valley to the east of the Ala Wai Watershed. In general based on the Nuuanu data, 1-, 3-, and 6-hour cumulative rainfalls greater the 1.6, 3.7, and 5.5 inches, respectively, may cause many debris flows. These rainfall amounts roughly correspond to the 1-hour 50-percent chance storm, 3-hour 20-percent chance storm, and 6-hour, 10-percent storm based on rainfall frequency intensity duration data in Table 6.

Another study, Deb and El-Kadi (2009) used a deterministic model called SINMAP to assess shallow landslide hazards in Southern Oahu. This study covers a larger area of Southern Oahu than Ellen et.al., (1993) by including the windward side of Southern Oahu from Kaneohe to Makapuu Point. Their model is based on slope-stability parameters and geotechnical data to create a soil cohesion index and hydrologic data to create a wetness index. The rainfall frequency intensity data used to calculate the wetness index was based on the 50-year (2-percent chance), 24-hour storm. These data are then used in a GIS framework with topographic data based on a 10-meter grid digital elevation model and land cover data to compute a stability index. This index classifies areas as either safe or by various degrees of susceptibility from low to very high. In general, the areas of high to very high susceptibility are similar to the moderate and high debris-flow hazard areas indentified in Ellen et.al. (1993).

5.0. Summary

This report characterized the hillslope hazards along the Manoa-Palolo Valley sides by determining the amount and contribution of runoff from the hillslope areas and summarizing previous work on shallow landslides and debris flow hazards in the study area. A HEC-HMS kinematic wave rainfall-runoff model of the Manoa-Palolo Watershed portion of the Ala Wai Watershed was created and calibrated to the October 30, 2004 Storm. The calibrated model was used with frequency storm data to compute relative percentages of runoff from hillslope areas for the 50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent chance floods (2-, 5-, 10-, 20-, 50-, 100-, 200-, and 500-year recurrence intervals). These percentages were compared with those from the upper Watershed and urban areas.

The upper Watershed areas which represent 46 percent of the total 10.4 mi^2 Manoa-Palolo Watershed contributes to 14 to 30 percent of the peak flow runoff, with increasing contributions from low to high magnitude flood events. The hillslope areas which represent 18 percent of the total area contributes to 8 to 17 percent of the peak flow runoff, also increasing from low to high magnitude flood events. Finally the urban areas which represent 36 percent of the total Watershed area contributes to 78 to 53 percent of the total peak flows, decreasing from low to high magnitude flood events. These results and this model should be used in conjunction with previous hydrological models of the Ala Wai Watershed to determine mitigation measures for flood damage reduction.

The debris flow and shallow landslide hazards have been sufficiently studied in the past and only briefly summarized in this report. Because such hazards are highly variable, these studies can only provide a overview of the debris flow and landslide hazards, but serve to identify areas where such debris flows and landslides can cause potential damage. Using such hazard maps can aid in determining debris basin sizing and best management practices to control sediment from hillsides.

6.0. References

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

SECTION 209 OF FLOOD CONTROL ACT OF 1962
(PUBLIC LAW 87-874)

APPENDIX A4

EXISTING WITHOUT-PROJECT HYDRAULIC AND WITH-PROJECT HYDROLOGIC AND HYDRAULIC

Climate Change Scenarios for the
50-year (2070) and 10-year (2030)
Future Without Project Conditions
Ala Wai Watershed Project, Oahu, Hawaii
19 May 2010

Climate Change Scenarios for the 50-year (2070) and 10-year (2030)
Future without Project Conditions
Ala Wai Watershed Project, Oahu, Hawaii
19 May 2010

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23 Existing and Future Peak Discharge Values for the 0.5% Chance Flood at Selected Cross Sections for the 50-Year Future Without-Project Scenarios for the Ali Wai Watershed, Oahu, Hawaii CC-30

24 Existing and Future Peak Discharge Values for the 0.2% Chance Flood at Selected Cross Sections for the 50-Year Future Without-Project Scenarios for the Ali Wai Watershed, Oahu, Hawaii CC-31

25 Future 10-year Without-Project (2030) Scenarios and Components for the Ala Wai Watershed Project, Oahu, Hawaii CC-32

Climate Change Scenarios for the 50-year (2070) and 10-year (2030)
Future without Project Conditions
Ala Wai Watershed Project, Oahu, Hawaii
19 May 2010

1.0. Introduction

The U. S. Army Corps of Engineers' (USACE) planning guidance for civil works projects requires that the planning process incorporate a future without project scenario. The guidance also states that the planning process accounts for such future conditions such as climate variability, sea-level rise, subsidence, seismic influences, geomorphological changes, and changes from development which can place demands on the project systems during their life-cycle. Therefore, this document provides three future without-project scenarios for two future conditions 2030 and 2070, for the Ala Wai Watershed which will be used in the modeling, selection, and design of project alternatives.

The future without project condition attempts to describe the Ala Wai Watershed's future if there is no Federal action taken to solve the flood risk problem. The future condition is fundamentally uncertain and represents a best guess of conditions in the Watershed.

2.0. Purpose and Scope

The purpose of this study is to create a future without project scenario for use in the hydrologic and hydraulic analysis for the Ala Wai Watershed Project. This report addresses the components of the planning process with emphasis on sea-level rise and how these components impact the hydrologic and hydraulic model results. The resultant future without project floodplains will be incorporated in the economic analysis.

Climate change impacts for Hawaii have been summarized by Fletcher (2010). These changes are rising surface air temperature, decreasing rainfall and streamflow, increasing rainfall intensity, increasing sea level and sea surface temperature, and ocean acidification. For the purposes of hydrologic and hydraulic modeling, the future without-project scenarios will concentrate on the impacts of sea-level rise, increased rainfall frequency, debris generation and transport, and increased impervious area in the Ala Wai Watershed.

3.0. Study Area

The Ala Wai Watershed on the Island of Oahu includes the Makiki, Manoa, and Palolo Stream drainage areas as well as the urban Waikiki area which surrounds the Ala Wai Canal (Figure 1). Total drainage area is about 16 square miles. Mean annual rainfall varies from 20 to 150 inches from the coast to the Koolau Crest. Much of the Watershed along the canal is relatively flat and subject to flooding from high intensity rainfall storms while the flooding in the Manoa and Palolo Valleys is limited to those areas along the stream. More background information as well as a discussion of the problems and opportunities in the Watershed has

been documented in previous studies on the Ala Wai Watershed (Townscape and Dashiell, 2003).

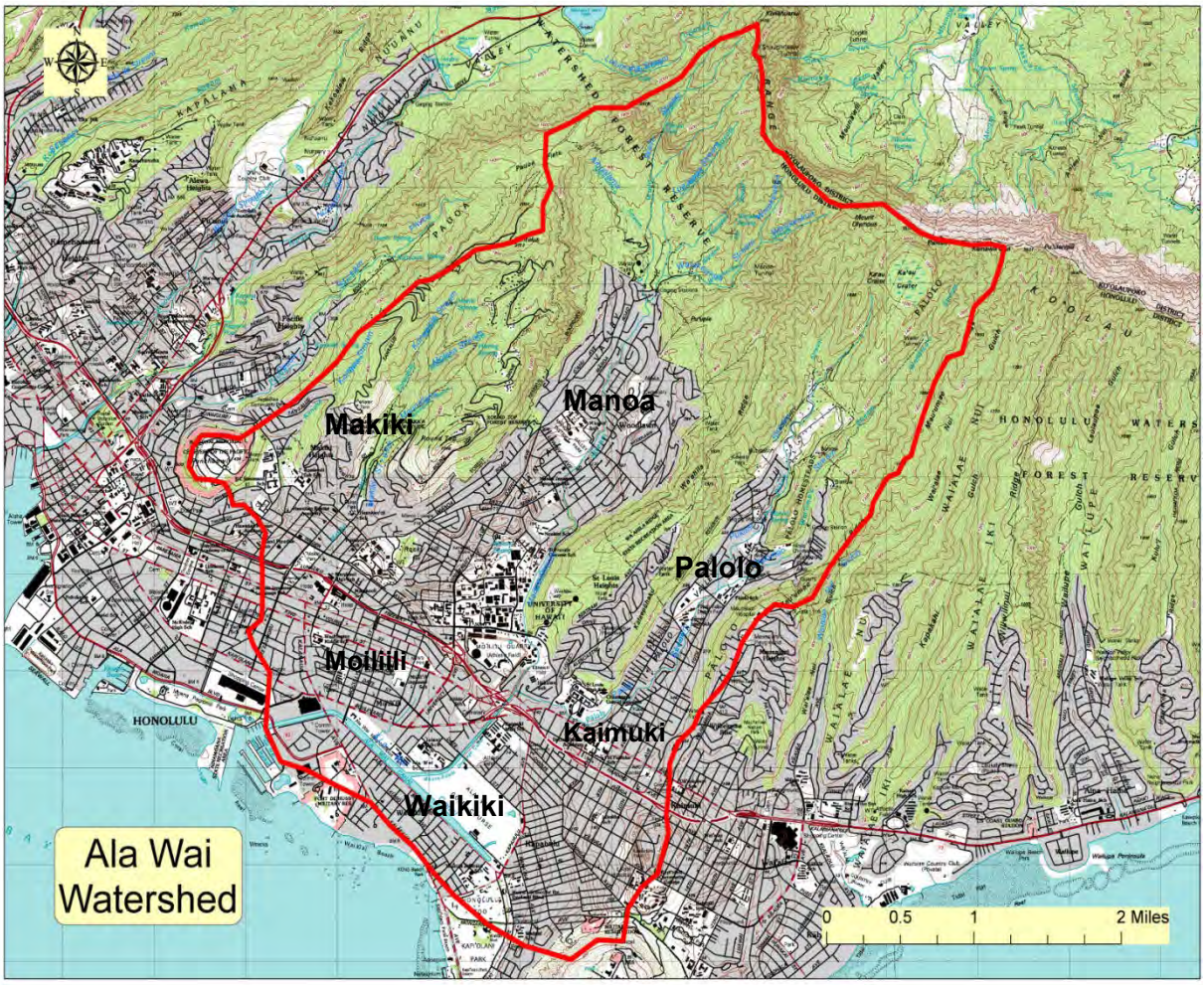

Figure 1. Ala Wai Watershed Area

4.0. Methodology and Guidance

Engineering Regulation 1105-2-100, *Planning Guidance Notebook*, Chapter 3-3, Flood Damage Reduction (Department of the Army, 2000), projects requires a forecast of the future without project condition. This forecast should not exceed beyond 50 years and becomes the basis for evaluation of project alternatives. One of the forecast requirements is to account for future hydrologic changes in the project evaluations. How and what factors to use in the forecast are not discussed in the guidance but left up to the project team to determine.

Recent guidance, Engineering Circular (EC), *Water Resource Policies and Authorities*, has been released in regards to handling sea-level rise in the planning process (Department of the Army, 2009). This document provides specific guidance to follow in determining sea-level rise for projects on the coast or impacted by tidal influences. The discussions on sea-level rise

in this report are presented in the same order as the recommended steps in EC 1165-2-211, Appendix C.

For planning purpose, a period of economic analysis also called the period of analysis is chosen. The period of analysis is the time period chosen used to evaluate plan impacts. The period of analysis must be the same for all plans considered in a study as well as the same for all the components of the plan (Yoe and Orth, 1996). Since economic analysis uses a base year for when project benefits start accruing, the forecast period must also start at the same base year. For the Ala Wai Watershed project, the base year is 2020. This date is based on a realistic construction start date of 2015 with a 5-year construction time period. Thus, the 50-year forecast period starts at 2020 and ends in 2070.

5.0. Climate Change Impacts and Scenarios

5.1 Sea-Level Rise. Following EC 1165-2-211, Appendix C (Department of the Army, 2009), the following steps were taken to compute the future sea-level rise scenarios for the Ala Wai Project. The first steps are to find and determine the applicability of tide station data for the project site. Such data has to be from tide station records longer than 40 years in length. The Honolulu Harbor tide gage, number 1612340, has a long record going back to 1905 and the harbor is located within 2 miles along the coastline to the west of the Ala Wai Canal. There is no dissimilar shoreline, bathymetry or hydrodynamic conditions between the tide station and the canal to disqualify the use of the Honolulu Harbor tide data. Previous tidal data collected in the Ala Wai Canal have shown that the tidal amplitude and phase between the harbor and the canal are nearly identical (Edward K. Noda and Associates, 1992). Thus, this data does adequately represent the local sea-level conditions at the project site.

The guidance recommends the National Oceanic and Atmospheric Administration (NOAA) CO-OPS values for the sea-level trend analysis if such values have been computed for that tide gage. For the Honolulu Harbor tide station, these values have been computed and are available at web site http://www.co-ops.nos.noaa.gov/sltrends. The value for Honolulu Harbor is 1.50 +/- 0.25 mm/year and is based on 100 years of data from 1905-2006. This value is the low or baseline trend rate for the low rise future without-project scenario.

The next step is to calculate a regional mean sea level trend for an identified vertically stable geologic platform in the region to determine if the regional mean sea-level trend is different from the eustatic or global mean sea-level trend of 1.7 +/- 0.5 mm/yr. For the main Hawaiian Island chain, Kauai and Oahu, have been considered relatively stable and this is shown by the very similar tide station trends (Table 1) compared to Maui and Hawaii. Geologic evidence points a slow uplift of Oahu over the last several thousand years resulting from flexural uplift from hotspot loading (Fletcher and Jones, 1996). Rates of uplift have been less than 0.1 mm/yr since the last interglacial period with an estimated mean of 0.06 mm/yr over the last 200,000 years (Fletcher and Jones, 1996; Caccamise, 2003). Given such a low rate of vertical uplift, less than the +/- 0.25 mm/yr uncertainty in the sea-level trend at Honolulu Harbor, the local sea-level trend of 1.50 mm/yr was considered to also be the regional mean sea-level trend for Oahu and no vertical land movement was taken into account for determining the future sea-level change.

Table 1. Mean Sea Level Rise Trends in Hawaii

Station Number	Station Location and Island	Period of Record	Years of Record	Computed Trend (mm/yr)
1611400	Nawiliwili, Kauai	1955-2006	52	1.53 +/- 0.59
1612340	Honolulu, Oahu	1905-2006	102	1.50 +/- 0.25
1612480	Mokuoloe, Oahu	1956-2006	51	1.31 +/- 0.72
1615680	Kahului. Maui	1947-2006	60	2.32 +/- 0.53
1617760	Hilo, Hawaii	1927-2006	80	3.27 +/- 0.35

Data from NOAA Tides and Currents website at http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml (last accessed 4 Feb 2010

The guidance then recommends the use of the modified National Research Council (NRC) Curve I (EC 1165-2-211, Appendix B) to calculate the intermediate rate of sea-level rise and modified NRC Curve III for the high rate of sea-level rise. It also recommends that these calculations be done in 5-year increments. The results of the low, intermediate and high sea-level rise rates for the Ala Wai Watershed study are presented in Table 2. The modified NRC curves are based on NRC scenarios for global sea-level rise adjusted to include the historic sea-level change rate of 1.7 mm/yr presented by the Intergovernmental Panel on Climate Change (IPCC) in 2007 (IPCC, 2007).

Results for the three sea-level rise scenarios (Table 2 and Figure 2) show a range of 0.08 to 0.68 meters in 2070. The intermediate and high sea-level rise rates for 2100 are 0.42 and 1.33 meters, which falls within the global sea-level rise rates of 0.5 to 1.4 m by 2100 in the updated studies which account for accelerated glacial ice melting (Fletcher, 2009). Fletcher (2009) makes a case for a 1 meter mean global sea-level rise by 2100 which would eliminate the low rate scenario from consideration in the Ala Wai Watershed planning process as being really too low and not a realistic forecast.

Table 2. Estimated Rates of Sea-Level Rise for the Ala Wai Watershed Project, Oahu, Hawaii

Low Rate (1.50 mm/yr)			Intermediate Rate (NRC Curve I)			High Rate (NRC Curve III)		
Year	Meters	Feet	Year	Meters	Feet	Year	Meters	Feet
2025	0.01	0.02	2025	0.02	0.06	2025	0.05	0.15
2030	0.02	0.05	2030	0.04	0.12	2030	0.10	0.31
2035	0.02	0.07	2035	0.05	0.18	2035	0.15	0.49
2040	0.03	0.10	2040	0.08	0.25	2040	0.21	0.69
2045	0.04	0.12	2045	0.10	0.32	2045	0.28	0.91
2050	0.05	0.15	2050	0.12	0.39	2050	0.35	1.14
2055	0.05	0.17	2055	0.14	0.47	2055	0.42	1.38
2060	0.06	0.20	2060	0.17	0.56	2060	0.50	1.65
2065	0.07	0.22	2065	0.20	0.64	2065	0.59	1.93
2070	0.08	0.25	2070	0.22	0.74	2070	0.68	2.22
2100	0.12	0.39	2100	0.42	1.36	2100	1.33	4.35

The sea-level rise impacts will be incorporated into the starting backwater conditions of the Ala Wai Canal HEC-RAS model which currently assumes a high tide of 1.08 feet (Mean High

High Water from Honolulu Harbor tide gage record, Station 1612340, current epoch) for the current or existing without-project condition for all storm frequencies. The various sea-level rise scenarios will be added to the high tide value. Therefore starting water surface elevations for the low, intermediate, and high scenarios will be 1.33, 1.82, and 3.30 feet, respectively.

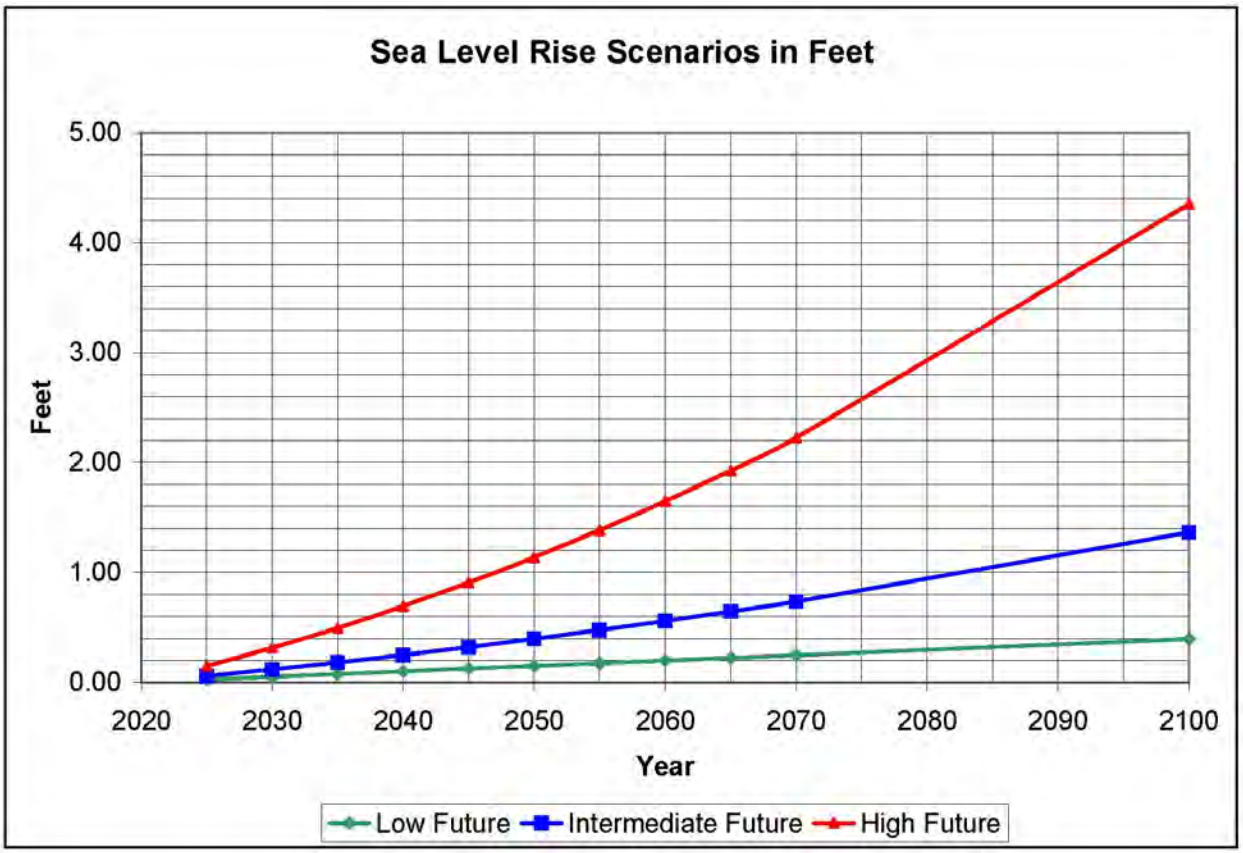

Figure 2. Plot of Sea Level Rise Data in Feet for All Three Scenarios

5.2. Hurricanes. Climate change studies currently indicate that hurricanes would not increase in frequency or movement, but that the intensity of hurricanes that occur could be greater (Christensen et. al., 2007; Meehl et. al., 2007)). Hurricane strikes to Hawaii and especially Oahu have been rare (Haraguchi, 1984). Because hurricanes are rare in Hawaii, the current hydrological and hydraulic studies for the Ala Wai Watershed project assume no coincidence between hurricanes and the high rainfall intensity flood producing storm systems which are more common. This assumption will also be part of the future without-project condition.

Past hurricane impacts to the Ala Wai Watershed from Hurricanes Iwa in 1982 and Iniki in 1992, have been limited to oceanfront hotel garages below ground being flooded by wave action and road closures of roads fronting these hotels (USACE, 1994). Post-hurricane studies have not documented if wave action has had surge impacts to the Ala Wai Canal. Since the mouth of the canal is protected from surge by the Ala Wai Yacht Harbor breakwaters and revetments, surge impacts are assumed minimal. Hurricanes have increased

the high tides recorded at tide gages so with sea-level rise, the potential exists that the canal can overtop and cause flooding from hurricanes near Oahu.

Alternatives providing protection from hurricane coastal flooding will not be addressed as part of the Ala Wai Watershed project. However, other planning efforts may continue to use the worst-case hurricane condition for southern Oahu until newer studies are conducted (Bretschneider et. al., 1985). The worst-case hurricane scenario has inundation limits in Moiliili up to Date Street and in Waikiki into the Ala Wai Golf Course (Bretschneider et. al., 1985).

5.3. Rainfall and Runoff

5.3.1. Amount of Rainfall. Regional IPCC results for the North Pacific region (Christensen et. al., 2007; page 915) show an estimated decrease of 0 to -5 percent in annual rainfall for Oahu due to estimated temperature increase in the Northern Pacific by 2080-2099. The estimated decrease is -5 to -10 percent for the winter months of December, January, and February (Christensen et. al., 2007; page 915). The decadal scale regional climatic feature of El-Nino Southern Oscillation (ENSO) already create drier than normal winter months so the impact on water supply, which is dependent on the tradewind rainfall patterns, will be aggravated when ENSO events occur with the estimated decrease in rainfall. A decrease in rainfall will have an impact to water supply on Oahu, which is highly dependent on ground water wells for drinking water, as rainfall is an important component of ground-water recharge. Sea-level rise will also impact groundwater resources by decreasing the freshwater lens or available amount of freshwater which can be pumped without causing saltwater intrusion. Therefore, water supply planning may look into large and small scale rain catchment or some means to catch storm runoff and store for later non-potable use.

5.3.2. Rainfall Frequency and Intensity. According to the report *Global Climate Change Impacts in the United States* (2009, p. 32), from 1958-2007, very heavy precipitation, defined as the heaviest 1 percent of all daily rain events, has increased by 12 percent for the State of Hawaii. The average number of days with heavy precipitation has increased by 8 percent for the State of Hawaii. It is expected that the frequency of heavy rainfall events will increase while the lightest precipitation is projected to decrease. The 5 percent chance (20-year) storm is expected to be between 10 to 25 percent heavier by the end of the 21st century (Global Climate Change Impacts in the United States, 2009, p. 32). It is unknown if decadal events such as ENSO variations can temper the expected increase in heavy precipitation.

The two hydrological studies for the Ala Wai Watershed (Oceanit, 2008a, 2008b) both used rainfall intensity frequency data from Report R-73 (Giambelluca et. al., 1984). Rainfall intensity frequency data for the State of Hawaii was recently updated by the NOAA National Weather Service as NOAA Atlas 14, Volume 4 (Perica et. al., 2009) and is available at the Precipitation Frequency Data Server (PFDS) website at http://hdsc.nws.noaa.gov/hdsc/pfds/. The PFDS was used to compute rainfall intensity frequency values at the centroid of the Ala Wai and Manoa watersheds. These values were then compared to those computed from the maps and methods in Giambelluca et. al. (1984).

Comparison of rainfall frequency intensity values between the values computed by Report R-73 and the newer NOAA Atlas 14 values showed that the NOAA values were consistently higher especially for the higher recurrence intervals. Only the lower rainfall intensity durations at the 50- and 10-percent chance storms showed the Report R-73 values to be consistently higher. In general the 10- and 1-percent (10- and 100-year) rainfall intensities, all durations (5 minutes to 24-hours) were on average higher by 0.04 inches and 0.44 inches. The NOAA values also tended to be higher in general compared to the Report R-73 for the Manoa watershed as well. Manoa watershed values were higher on average by 0.10 inches and 0.62 inches for the 10- and 1-percent chance storms.

The NOAA Atlas 14 rainfall frequency intensities will become the base values because they incorporate the latest data and methodology and the previous Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) models, representing the existing without-project conditions, will be updated using those values. It is not expected that the final peak flow discharges will change at all due to the fact the these discharges were also based on regional peak flow information and were generally higher than the HEC-HMS model results (Oceanit 2008a, 2008b). Because the Manoa Watershed was modeled separately from the rest of the Ala Wai Watershed, a combined model was used for modeling the future without-project scenarios. For the combined model, only the Ala Wai Watershed centroidal rainfall values were adjusted and used. For future scenario modeling, the rainfall changes will be applied in the HEC-HMS model and relative percent differences in the model output were applied to the final determined peak flow discharges. These values will then be applied in the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model.

The rainfall frequency intensity scenarios will use a 8-, 12-, and 16-percent increases to the NOAA Atlas 14 values for the low, intermediate, and high future conditions based on the values and range presented in the Climate Change Impacts in the United States (2009). Based on discussions with University of Hawaii climate researchers, this source represents the best available estimate of future rainfall intensity trends in Hawaii until more research on trends and downscaling of global climate models is completed in the coming years. The percent increases will be applied to all recurrence intervals and durations. These values are presented in Tables 3, 4, 5, and 6 and the 24-hour duration values plotted in Figure 3.

Table 3. Rainfall Intensity Frequency Data for Existing Without-Project Conditions, Ala Wai Watershed, Oahu, Hawaii

% Chance Exceedance	Return Period (yrs)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.38	0.66	0.97	1.40	1.87	2.12	2.74	3.35	3.92
50	2	0.47	0.80	1.19	1.72	2.33	2.71	3.49	4.29	5.18
20	5	0.61	1.04	1.54	2.22	3.04	3.54	4.58	5.68	6.96
10	10	0.72	1.24	1.83	2.64	3.61	4.21	5.46	6.80	8.39
5	20	0.81	1.49	2.11	3.05	4.15	4.94	6.28	8.00	9.95
4	25	0.89	1.52	2.25	3.24	4.42	5.16	6.69	8.36	10.42
2	50	1.02	1.75	2.59	3.74	5.09	5.94	7.69	9.61	12.05
1	100	1.16	1.99	2.95	4.25	5.78	6.74	8.74	10.92	13.77
0.5	200	1.31	2.25	3.34	4.82	6.53	7.61	9.86	12.30	15.60
0.2	500	1.53	2.62	3.88	5.61	7.57	8.82	11.42	14.23	18.18

Rainfall Intensity Frequency data determined from NOAA Atlas 14 Precipitation Frequency Data Server using watershed centroid of 21.3092 N, 157.8071 W. Values for the 5-percent chance storm are interpolated.

Table 4. Rainfall Intensity Frequency Data for Future Without-Project Conditions, Low Increase Scenario, Ala Wai Watershed, Oahu, Hawaii

% Chance Exceedance	Return Period (yrs)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.41	0.71	1.05	1.51	2.02	2.29	2.96	3.62	4.23
50	2	0.51	0.86	1.29	1.86	2.52	2.93	3.77	4.63	5.59
20	5	0.66	1.12	1.66	2.40	3.28	3.82	4.95	6.13	7.52
10	10	0.78	1.34	1.98	2.85	3.90	4.55	5.90	7.34	9.06
5	20	0.87	1.61	2.28	3.29	4.48	5.34	6.78	8.64	10.75
4	25	0.96	1.64	2.43	3.50	4.77	5.57	7.23	9.03	11.25
2	50	1.10	1.89	2.80	4.04	5.50	6.42	8.31	10.38	13.01
1	100	1.25	2.15	3.19	4.59	6.24	7.28	9.44	11.79	14.87
0.5	200	1.41	2.43	3.61	5.21	7.05	8.22	10.65	13.28	16.85
0.2	500	1.65	2.83	4.19	6.06	8.18	9.53	12.33	15.37	19.63

Rainfall Intensity Frequency data determined from Existing without-Project Conditions with a 8-percent increase in Rainfall Depths

Table 5. Rainfall Intensity Frequency Data for Future Without-Project Conditions, Intermediate Increase Scenario, Ala Wai Watershed, Oahu, Hawaii

% Chance Exceedance	Return Period (yrs)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.43	0.74	1.09	1.57	2.09	2.37	3.07	3.75	4.39
50	2	0.53	0.90	1.33	1.93	2.61	3.04	3.91	4.80	5.80
20	5	0.68	1.16	1.72	2.49	3.40	3.96	5.13	6.36	7.80
10	10	0.81	1.39	2.05	2.96	4.04	4.72	6.12	7.62	9.40
5	20	0.91	1.67	2.36	3.42	4.65	5.53	7.03	8.96	11.14
4	25	1.00	1.70	2.52	3.63	4.95	5.78	7.49	9.36	11.67
2	50	1.14	1.96	2.90	4.19	5.70	6.65	8.61	10.76	13.50
1	100	1.30	2.23	3.30	4.76	6.47	7.55	9.79	12.23	15.42
0.5	200	1.47	2.52	3.74	5.40	7.31	8.52	11.04	13.78	17.47
0.2	500	1.71	2.93	4.35	6.28	8.48	9.88	12.79	15.94	20.36

Rainfall Intensity Frequency data determined from Existing without-Project Conditions with a 12-percent increase in Rainfall Depths.

Table 6. Rainfall Intensity Frequency Data for Future Without-Project Conditions, High Increase Scenario, Ala Wai Watershed, Oahu, Hawaii

% Chance Exceedance	Return Period (yrs)	Depth (inches) for Specified Duration								
		5-min	15-min	30-min	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours
99	1	0.48	0.83	1.22	1.75	2.34	2.66	3.43	4.20	4.91
50	2	0.59	1.00	1.49	2.15	2.92	3.40	4.37	5.37	6.49
20	5	0.76	1.30	1.93	2.78	3.81	4.43	5.74	7.12	8.72
10	10	0.90	1.55	2.29	3.31	4.52	5.27	6.84	8.52	10.51
5	20	1.01	1.87	2.64	3.82	5.20	6.19	7.87	10.02	12.47
4	25	1.11	1.90	2.82	4.06	5.54	6.46	8.38	10.47	13.05
2	50	1.28	2.19	3.24	4.69	6.38	7.44	9.63	12.04	15.10
1	100	1.45	2.49	3.70	5.32	7.24	8.44	10.95	13.68	17.25
0.5	200	1.64	2.82	4.18	6.04	8.18	9.53	12.35	15.41	19.54
0.2	500	1.92	3.28	4.86	7.03	9.48	11.05	14.31	17.83	22.78

Rainfall Intensity Frequency data determined from Existing without-Project Conditions with a 16-percent increase in Rainfall Depths.

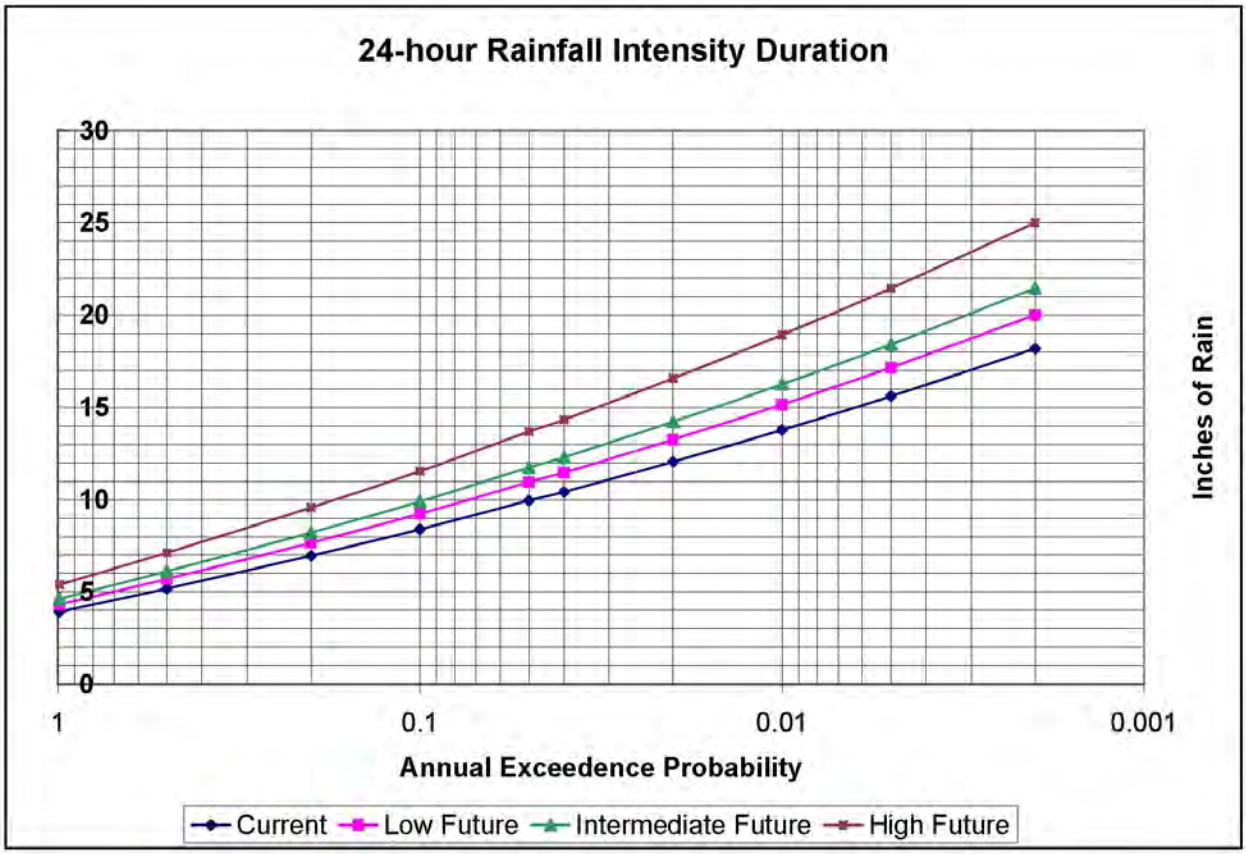

Figure 3. Plot of 24-hour Rainfall Intensity Data for Current and Future Scenarios

5.4. Debris Generation. One impact of large intense rainfall storms in Hawaii has been debris generation, both from vegetation and hill slope and channel erosion sources, which can impact the ability of stream channels and stream crossing structures to function as designed. In general, narrow streams rarely transport large floating debris that can block bridges. Large floating debris usually gets trapped or lodged across the channel and rarely moves without being broken into smaller pieces. Small and intermediate size floating debris becomes an issue where bridge piers or other obstructions occur, due to the potential of significant debris pile-ups on piers. Streams in the Ala Wai Watershed have steep channel slopes and exhibit rapid responses to rainfall, "flash floods", which tend to have a large amount of energy which can move large boulders or rapidly erode sections of stream bank or channel. This type of debris also has the potential to create blockages in the stream channels or reduce the ability of bridges to pass flood flows. One method of account for debris or sediment in runoff is the use of a bulking factor. The bulking factor is just an increase in the Manning's n-value, which is used to represent channel roughness in the hydraulic model. Normally, the higher the n-value used, the higher the resulting water-surface elevation, thus, the term bulking. Normally a percentage increase, like 10- or 20-percent is used to account for debris in the flood flows.

The ability to predict the amount of debris generated by any future storm event is pure speculation. Although debris volume estimates are made to assist in debris basin sizing, such volume estimates did not account for the sediment or floating debris that passes through the basin or are generated downstream of the basin, so are not as useful as the bulking factor to

account for suspended sediment and floating debris. For the future without project scenarios, it is difficult at best to make any guesses that debris amount will be larger or smaller in the future. Assuming the same land-use in 2070 as today, the amount of generated debris should not significantly change from those estimates used in the current without-project conditions models. Assuming such efforts as invasive species removal, feral pig control, stream clean-ups, and restoration of riparian vegetation are to be done in the future as smaller locally based projects, then the amount of debris generated will potentially decrease. Therefore, the future without-project scenarios will look at no increase debris generation for the low scenario, a plus 5-percent increase for the intermediate scenario, and an increase of an additional 10-percent to the bulking factor for the high impact scenario.

5.5. Increased Impervious Area. The Ala Wai Watershed is already a densely developed urban area. Residential land use dominates in the Makiki, Manoa, and Palolo areas with smaller areas of commercial activities. Waikiki is highly developed with high rise hotels and apartment buildings. Population in the Watershed is not expected to increase significantly in the future. In fact a future with a decreasing quality of life may lead to population decrease in Hawaii. Future construction is assumed to continue the current trend which consists of rebuilding on existing lots, possibly with higher density residential units which may add a minimal contribution to runoff. Current observation in the Kaimuki and Palolo areas, show a slow replacement of smaller single family homes with modern double wall construction 2-story homes having larger footprints. At a specific house lot then, there would be less open space for infiltration and potentially move direct connections from roof to street. The overall impact to runoff is small but potentially cumulative over time. Such redevelopment impacts can be mitigated through low-impact development ideas to be used in new construction or as a requirement for the Watershed.

For the future without-project scenarios, the potential increase in runoff from the urban areas will be modeled by increasing the Curve Number (CN) values for those sub-basins with urban development to account for less infiltration in the hydrologic model. The curve number method (Natural Resources Conservation Service, 2004) is used in the current without-project models to account for infiltration and impervious areas and is based on land cover and hydrologic soil group classification of the soil (Oceanit, 2008b). For the low scenario, the composite CN values for the urban sub-basins will remained unchanged from the existing conditions model, for the intermediate scenario, values will be increase by 2 curve number values, and for the high scenario, values will be increase by 5 to a maximum value of 95. Model CN values are summarized in Table 7.

Table 7. Curve Numbers used in HEC-HMS Hydrologic Model for the Ala Wai Watershed, Oahu, Hawaii

Area Where Sub-Basin Is Located (Fig. 1)	Sub-Basin in HEC-HMS Model	Existing and Low Scenario Curve Number	Intermediate Scenario Curve Number	High Scenario Curve Number
Moiliili	A1*	84	86	89
Moiliili	A2*	86	88	91
Kaimuki	A3*	83	85	88
Kaimuki	A4*	76	78	81
Kaimuki	A5*	81	83	86
Kaimuki	A7*	76	78	81
Makiki	K2	62	64	67
Makiki	K3	68	70	73
Makiki	K4	68	70	73
Makiki	K5*	85	87	90
Makiki	K6*	80	82	85
Makiki	A8*	86	88	91
Manoa	M3	74	76	79
Manoa	M4	77	79	82
Manoa	M5	65	67	70
Manoa	M6	69	71	74
Manoa	M7	73	75	78
Manoa	M8	82	84	87
Manoa	M9	78	80	83
Manoa	M10	79	81	84
Manoa	M11	78	80	83
Manoa	M12	77	79	82
Manoa	M14	85	87	90
Palolo	P4	72	74	77
Palolo	P5	73	75	78
Palolo	P6	85	87	90
Palolo	P7	88	90	93
Waikiki	W1*	83	85	88
Waikiki	W2*	86	88	91
Waikiki	W3*	82	84	87

* = Sub-basin uses kinematic wave transform method which uses separate flow planes to account for previous and impervious land surfaces. CN change applies only to the previous land flow plane

6.0. Future Without-Project Scenarios

For the future without-project conditions, three scenarios were created and modeled to create potential future floodplains for the Ala Wai Watershed. These scenarios also form the basis of project alternatives. The three scenarios were low, intermediate, and high. The low and high scenarios are the bounds to the potential future case and the intermediate scenario is the most probable future scenario. Except were determined by the sea-level rise guidance, the intermediate condition was selected as the most probable future condition and the low and high conditions as the bounds or confidence limits to that estimated condition. Thus, the most probable future is the intermediate scenario. The components of each scenario are listed in Table 8. The low scenario would represent a best case or actual continuation of current trends for sea level rise and rainfall intensity while the high scenario would represent a worst case scenario.

Table 8. Future 50-year Without-Project Scenarios and Components for the Ala Wai Watershed Project, Oahu, Hawaii

Component	Low	Most Probable	High
Sea Level Rise	Low	Intermediate	High
Rainfall Intensity	Low	Intermediate	High
Debris Generation	Low	Intermediate	High
Impervious Area	Low	Intermediate	High

7.0. Modeling Results of Future 50-year Without-Project Scenarios

7.1. Hydrologic Modeling Results. Hydrologic (HEC-HMS) modeling results to account for the higher rainfall intensity and increased impervious areas are presented by HEC-HMS model junction in Tables 9 to 16 by annual flood exceedance probabilities (50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent chance floods). Results are presented by Manoa and the rest of Ala Wai Watershed to correspond to the two hydrology reports. Junctions for the combined model are presented in Figure 4.

For the Manoa Watershed, the future low scenario increases peak flow discharges from 10 to 14-percent with an average of 11-percent. Peak flow values for the 50- and 20-percent chance floods had the greater increases. This was constant for the intermediate and high scenarios as well. The intermediate future scenario increase discharges from 15 to 24-percent with an average of 19 percent increase. The future high scenario increased peak flow values by 32 to 52 percent with an average increase of 40 percent (Tables 9 to 16).

The rest of the Ala Wai Watershed junctions had similar increases as the Manoa watershed junctions with the lower exceedance floods, 50- and 20-percent chance, having the higher percentage increases. The low scenario had increases of 9 to 17 percent with an average of 12 percent. The intermediate scenario had increase of 15 to 30 percent with an average of 20 percent. The high future scenario had increases of 31 to 66 percent with an average increase of 43 percent (Tables 9 to 16).

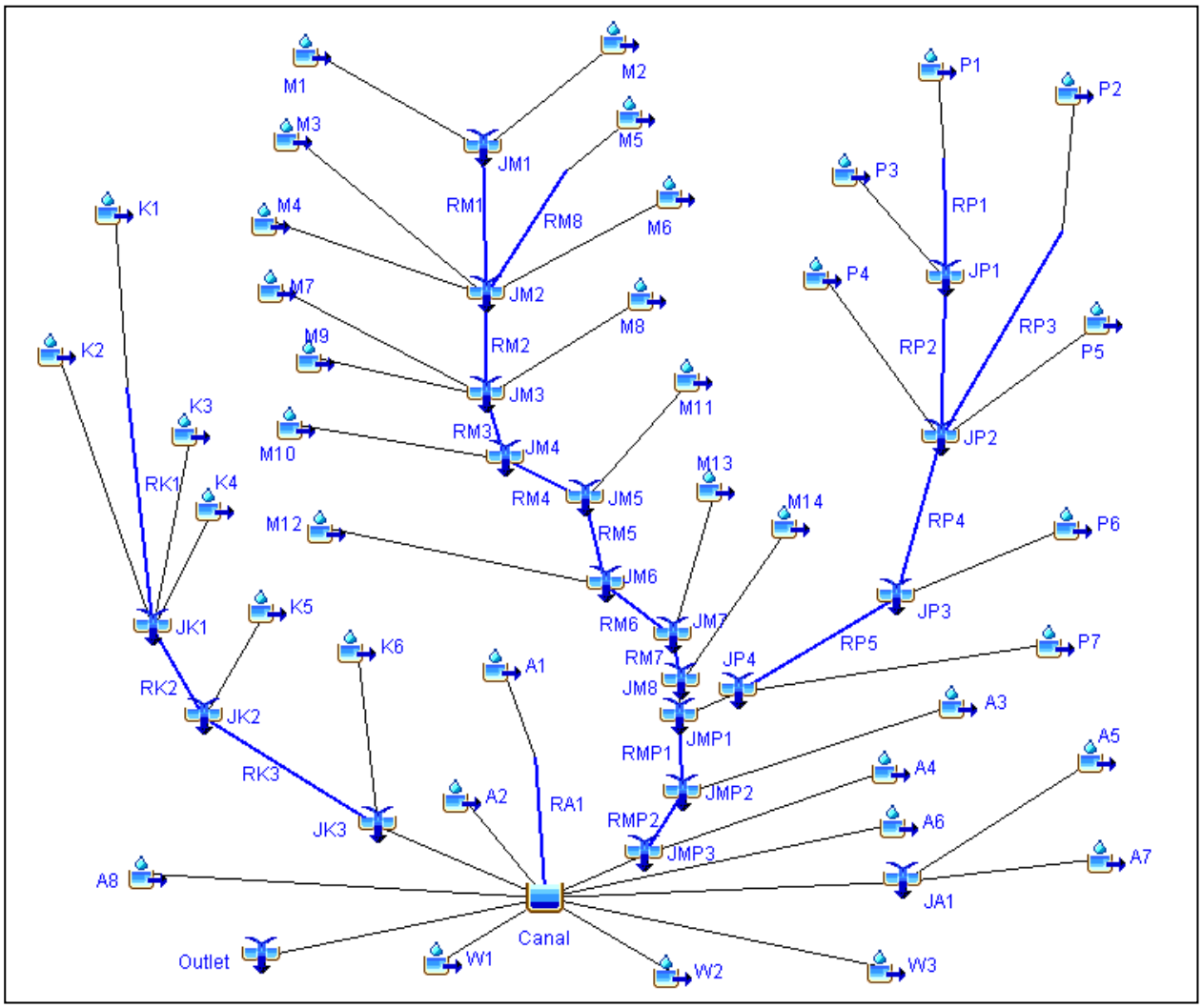

Figure 4. Ala Wai Watershed HEC-HMS Model Layout (from Oceanit 2008b)

Table 9. Existing and Future Peak Discharge Values for the 50-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		50-percent chance (2-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	1,120	1,270	1,450	1,540	1,850	*14*	*21*	*46*
	JM2	1,870	2,140	2,430	2,650	3,250	*14*	*24*	*52*
	JM3	2,110	2,310	2,640	2,880	3,550	*14*	*25*	*54*
	JM4	2,270	2,500	2,840	3,100	3,800	*14*	*24*	*52*
	JM5	2,370	2,620	2,980	3,260	3,980	*14*	*24*	*52*
	JM6	2,780	3,070	3,490	3,820	4,680	*14*	*24*	*52*
	JM7	2,929	3,220	3,670	4,010	4,900	*14*	*25*	*52*
	JM8	2,560	3,360	3,830	4,190	5,140	*14*	*25*	*53*
Ala Wai Watershed Model	**JK1**	570	799	945	1,070	1,420	18	34	78
	JK2	660	926	1,080	1,220	1,610	17	32	74
	JK3	890	1,220	1,450	1,640	2,120	19	34	74
	JP1	320	379	468	516	680	23	36	79
	JP2	940	1,300	1,550	1,710	2,190	19	32	68
	JP3	1,330	1,860	2,190	2,420	3,080	18	30	66
	JP4	1,550	2,170	2,540	2,830	3,600	17	30	66
	JMP1	4,020	5,400	6,220	6,850	8,500	15	27	57
	JMP2	4,090	5,560	6,390	7,000	8,700	15	26	56
	JMP3	4,220	5,760	6,640	7,290	9,020	15	27	57
	Ala Wai	6,000	8,080	9,150	9,920	11,900	13	23	47
Average percent difference Manoa Watershed							14	24	52
Average percent difference Ala Wai Watershed							17	30	66

Table 10. Existing and Future Peak Discharge Values for the 20-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		20-percent chance (5-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	2,140	2,000	2,250	2,380	2,820	*13*	*19*	*41*
	JM2	3,590	3,350	3,770	4,050	4,880	*13*	*21*	*46*
	JM3	3,990	3,640	4,110	4,420	5,340	*13*	*21*	*47*
	JM4	4,270	3,880	4,370	4,710	5,680	*13*	*21*	*46*
	JM5	4,440	4,050	4,570	4,930	5,950	*13*	*22*	*47*
	JM6	5,140	4,710	5,310	5,730	6,920	*13*	*22*	*47*
	JM7	5,410	4,930	5,580	6,010	7,240	*13*	*22*	*47*
	JM8	4,450	5,170	5,830	6,270	7,580	*13*	*21*	*47*
Ala Wai Watershed Model	**JK1**	1,200	1,430	1,650	1,830	2,320	15	28	62
	JK2	1,360	1,610	1,850	2,040	2,580	15	27	60
	JK3	1,770	2,110	2,420	2,660	3,350	15	26	59
	JP1	730	774	914	985	1,230	18	27	59
	JP2	2,030	2,350	2,730	2,950	3,680	16	26	57
	JP3	2,710	3,200	3,660	3,970	4,890	14	24	53
	JP4	3,120	3,700	4,220	4,560	5,550	14	23	50
	JMP1	7,170	8,620	9,750	10,500	12,700	13	22	47
	JMP2	7,340	8,800	9,940	10,700	13,000	13	22	48
	JMP3	7,450	9,130	10,300	11,200	13,500	13	23	48
	Ala Wai	10,100	12,000	13,100	13,900	15,300	9	16	28
Average percent difference Manoa Watershed							13	21	46
Average percent difference Ala Wai Watershed							14	24	52

Table 11. Existing and Future Peak Discharge Values for the 10-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		10-percent chance (10-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	2,870	2,630	2,950	3,120	3,650	*12*	*19*	*39*
	JM2	4,800	4,400	4,920	5,260	6,240	*12*	*20*	*42*
	JM3	5,330	4,790	5,360	5,740	6,830	*12*	*20*	*43*
	JM4	5,700	5,090	5,690	6,090	7,250	*12*	*20*	*42*
	JM5	5,940	5,320	5,950	6,350	7,590	*12*	*19*	*43*
	JM6	6,860	6,160	6,880	7,360	8,750	*12*	*19*	*42*
	JM7	7,190	6,470	7,220	7,730	9,170	*12*	*19*	*42*
	JM8	6,210	6,760	7,540	8,070	9,580	*12*	*19*	*42*
Ala Wai Watershed Model	**JK1**	1,890	1,990	2,280	2,490	3,100	15	25	56
	JK2	2,110	2,220	2,530	2,760	3,400	14	24	53
	JK3	2,690	2,930	3,250	3,540	4,330	11	21	48
	JP1	1,150	1,130	1,300	1,390	1,680	15	23	49
	JP2	3,190	3,300	3,780	4,040	4,890	15	22	48
	JP3	4,170	4,360	4,950	5,320	6,400	14	22	47
	JP4	4,720	4,970	5,600	6,000	7,210	13	21	45
	JMP1	10,300	11,400	12,700	13,600	16,200	11	19	42
	JMP2	10,500	11,600	13,000	13,900	16,600	12	20	43
	JMP3	10,700	12,000	13,500	14,500	17,200	13	21	43
	Ala Wai	13,400	14,400	15,200	15,700	16,900	6	9	17
Average percent difference Manoa Watershed							12	19	42
Average percent difference Ala Wai Watershed							12	21	45

Table 12. Existing and Future Peak Discharge Values for the 5-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		5-percent chance (20-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	3,570	3,340	3,720	3,920	4,460	*11*	*17*	*34*
	JM2	5,960	5,540	6,160	6,560	7,720	*11*	*18*	*39*
	JM3	6,620	6,040	6,710	7,160	8,430	*11*	*19*	*40*
	JM4	7,020	6,380	7,060	7,620	8,860	*11*	*19*	*39*
	JM5	7,310	6,680	7,400	7,970	9,180	*11*	*19*	*37*
	JM6	8,390	7,660	8,530	9,190	10,600	*11*	*20*	*38*
	JM7	8,820	8,040	8,920	9,590	11,100	*11*	*19*	*38*
	JM8	7,860	8,400	9,310	9,980	11,600	*11*	*19*	*38*
Ala Wai Watershed Model	**JK1**	2,400	2,630	2,980	3,250	3,990	13	24	52
	JK2	2,650	2,900	3,270	3,560	4,340	13	23	50
	JK3	3,340	3,710	4,160	4,500	5,430	12	21	46
	JP1	1,460	1,520	1,740	1,850	2,200	14	22	45
	JP2	4,010	4,350	4,910	5,230	6,260	13	20	44
	JP3	5,180	5,660	6,350	6,780	8,060	12	20	42
	JP4	5,810	6,350	7,120	7,610	9,030	12	20	42
	JMP1	12,900	14,300	15,900	17,000	19,900	11	19	39
	JMP2	13,000	14,600	16,200	17,300	20,200	11	18	38
	JMP3	13,300	15,100	16,700	17,900	21,000	11	19	39
	Ala Wai	15,200	16,000	16,700	17,200	18,300	4	8	14
Average percent difference Manoa Watershed							11	19	38
Average percent difference Ala Wai Watershed							12	19	41

Table 13. Existing and Future Peak Discharge Values for the 2-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		2-percent chance (50-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	4,340	4,340	4,820	5,060	5,850	*11*	*17*	*35*
	JM2	7,210	7,200	7,970	8,430	9,840	*11*	*17*	*37*
	JM3	8,010	7,840	8,680	9,200	10,700	*11*	*17*	*36*
	JM4	8,410	8,320	9,140	9,690	11,300	*10*	*16*	*36*
	JM5	8,800	8,710	9,540	10,100	11,800	*10*	*16*	*35*
	JM6	10,200	10,000	11,000	11,700	13,700	*10*	*17*	*37*
	JM7	10,700	10,500	11,500	12,200	14,300	*10*	*16*	*36*
	JM8	9,810	10,900	12,000	12,700	14,800	*10*	*17*	*36*
Ala Wai Watershed Model	**JK1**	3,150	3,570	4,040	4,340	5,230	13	22	46
	JK2	3,440	3,900	4,390	4,700	5,650	13	21	45
	JK3	4,280	4,890	5,460	5,840	6,920	12	19	42
	JP1	1,900	2,080	2,340	2,480	2,920	13	19	40
	JP2	5,180	5,800	6,500	6,920	8,110	12	19	40
	JP3	6,620	7,460	8,320	8,840	10,300	12	18	38
	JP4	7,400	8,350	9,300	9,870	11,500	11	18	38
	JMP1	16,100	18,600	20,600	21,800	25,400	11	17	37
	JMP2	16,300	19,000	21,000	22,200	25,900	11	17	36
	JMP3	16,600	19,700	21,700	23,000	26,700	10	17	36
	Ala Wai	16,700	17,800	18,600	19,000	20,700	4	7	16
Average percent difference Manoa Watershed							10	17	36
Average percent difference Ala Wai Watershed							11	18	38

Table 14. Existing and Future Peak Discharge Values for the 1-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		1-percent chance (100-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	5,010	5,160	5,700	5,980	6,880	*10*	*16*	*33*
	JM2	8,320	8,530	9,410	9,940	11,700	*10*	*17*	*37*
	JM3	9,230	9,290	10,200	10,800	12,600	*10*	*16*	*36*
	JM4	9,790	9,780	10,800	11,400	13,300	*10*	*17*	*36*
	JM5	10,200	10,200	11,300	11,900	13,900	*11*	*17*	*36*
	JM6	11,700	11,800	13,000	13,700	16,000	*10*	*16*	*36*
	JM7	12,300	12,300	13,600	14,400	16,800	*11*	*17*	*37*
	JM8	11,100	12,800	14,100	14,900	17,400	*10*	*16*	*36*
Ala Wai Watershed Model	**JK1**	3,740	4,360	4,890	5,250	6,260	12	20	44
	JK2	4,060	4,730	5,290	5,670	6,730	12	20	42
	JK3	5,000	5,860	6,490	6,920	8,180	11	18	40
	JP1	2,220	2,530	2,840	3,010	3,530	12	19	40
	JP2	6,040	6,990	7,820	8,220	9,640	12	18	38
	JP3	7,670	8,940	9,930	10,500	12,200	11	17	36
	JP4	8,550	9,980	11,100	11,700	13,600	11	17	36
	JMP1	18,500	21,900	24,200	25,600	29,900	11	17	37
	JMP2	18,700	22,400	24,700	26,100	30,300	10	17	35
	JMP3	18,900	23,100	25,500	26,900	31,300	10	16	35
	Ala Wai	17,700	19,100	20,300	20,700	21,900	6	8	15
Average percent difference Manoa Watershed							10	16	36
Average percent difference Ala Wai Watershed							11	17	36

Table 15. Existing and Future Peak Discharge Values for the 0.5-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		0.5-percent chance (200-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	**Current Existing**	**2070 Low**	**2070 Inter**	**2070 High**	**2070 Low**	**2070 Inter**	**2070 High**
Manoa Watershed Model	**JM1**	5,610	6,060	6,680	6,990	8,020	*10*	*15*	*32*
	JM2	9,280	9,980	11,100	11,700	13,500	*11*	*17*	*35*
	JM3	10,300	10,900	12,000	12,600	14,600	*10*	*16*	*34*
	JM4	10,900	10,900	12,700	13,400	15,500	*17*	*23*	*42*
	JM5	11,300	12,000	13,200	13,900	16,000	*10*	*16*	*33*
	JM6	13,100	13,800	15,200	16,100	18,600	*10*	*17*	*35*
	JM7	13,700	14,400	15,900	16,900	19,500	*10*	*17*	*35*
	JM8	12,400	15,000	16,500	17,500	20,300	*10*	*17*	*35*
Ala Wai Watershed Model	**JK1**	4,380	5,240	5,840	6,230	7,390	11	19	41
	JK2	4,730	5,660	6,290	6,700	7,920	11	18	40
	JK3	5,790	6,910	7,660	8,130	9,550	11	18	38
	JP1	2,590	3,060	3,380	3,560	4,160	10	16	36
	JP2	6,980	8,330	9,220	9,680	11,200	11	16	34
	JP3	8,850	10,600	11,700	12,300	14,200	10	16	34
	JP4	9,860	11,800	13,000	13,700	15,800	10	16	34
	JMP1	20,900	25,700	28,400	30,000	34,800	11	17	35
	JMP2	21,100	26,200	28,900	30,500	35,200	10	16	34
	JMP3	21,400	27,100	29,800	31,500	36,300	10	16	34
	Ala Wai	18,700	20,700	21,500	21,900	23,200	4	6	12
Average percent difference Manoa Watershed							11	17	35
Average percent difference Ala Wai Watershed							10	16	34

Table 16. Existing and Future Peak Discharge Values for the 0.2-percent Chance Flood at HEC-HMS Model Junctions for the Manoa and Ala Wai Watersheds, Oahu, Hawaii

HEC-HMS Model Junction		0.2-percent chance (500-yr) Flood peak discharges (ft^3/s)					Percent differences with current exisiting peak discharges		
		Previous Existing	Current Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Manoa Watershed Model	JM1	6,600	7,330	8,050	8,400	9,610	*10*	*15*	*31*
	JM2	10,900	12,100	13,300	14,000	16,100	*10*	*16*	*33*
	JM3	12,100	13,100	14,400	15,100	17,300	*10*	*15*	*32*
	JM4	12,800	13,900	15,300	16,100	18,400	*10*	*16*	*32*
	JM5	13,400	14,500	15,800	16,600	19,000	*9*	*14*	*31*
	JM6	15,400	16,700	18,400	19,300	22,100	*10*	*16*	*32*
	JM7	16,200	17,500	19,200	20,300	23,200	*10*	*16*	*33*
	JM8	14,500	18,200	20,000	21,100	24,100	*10*	*16*	*32*
Ala Wai Watershed Model	JK1	15,400	16,700	18,400	19,300	22,100	10	16	32
	JK2	16,200	17,500	19,200	20,300	23,200	10	16	33
	JK3	14,500	18,200	20,000	21,100	24,100	10	16	32
	JP1	3,110	3,780	4,170	4,400	5,050	10	16	34
	JP2	8,320	10,100	11,200	11,800	13,500	11	17	34
	JP3	10,500	12,800	14,100	14,800	17,000	10	16	33
	JP4	11,600	14,200	15,600	16,400	18,800	10	15	32
	JMP1	24,400	31,200	34,300	36,300	41,800	10	16	34
	JMP2	24,700	31,700	34,800	36,700	42,200	10	16	33
	JMP3	24,900	32,700	35,900	37,800	43,300	10	16	32
	Ala Wai	20,500	22,200	23,000	23,500	25,000	4	6	13
Average percent difference Manoa Watershed							10	15	32
Average percent difference Ala Wai Watershed							9	15	31

7.2. Hydraulic Modeling Results. Hydrologic (HEC-RAS) modeling results to account for the higher peak flow discharges for the hydrologic modeling, sea-level rise, and debris modeling are presented by water surface elevation at selected cross-sections in Tables 17 to 24 by annual flood exceedance probabilities (50-, 20-, 10-, 5-, 2-, 1-, 0.5-, and 0.2-percent chance floods). The cross-sections selected represent index locations used in the Hydrologic Engineering Center - Flood Damage Reduction Analysis (FDA) model for economic analysis (see economic appendix). The water-surface elevation results represent the end result of the future without-project modeling which is to determine the future potential flood damages without a Federal project.

Results on the differences between the future scenario water surface elevations compared to the existing ones are fairly consistent in each future scenario. The low scenario average increase is in the range of 0.4 ft with the highest average increase of 0.57 ft occurring with the 0.2-percent chance flood discharges (Table 24). The intermediate scenario average increase is around 0.8 ft, the highest average increase of 1.09 ft occurs with the 2-percent chance flood event (Table 21). The future high scenario has an average increase of about 1.5 ft with the 0.2-percent chance flood having the highest average increase of 2.28 ft (Table 24).

The interconnection of the four future scenario factors, sea-level rise, increase rainfall intensity, increased debris transport, and increased impervious surfaces make it difficult to compare the resultant increase in water-surface elevations to any one specific factor. In comparison to the sea-level rise backwater conditions of 0.25. 0.74, and 2.22 ft for the low, intermediate, and high 2070 scenarios, respectively, the average water-surface elevation increases were roughly 0.4, 0.8, and 1.5 ft, respectively. So in all but the high scenario, the resultant water-surface elevation increases were higher than the sea-level rise. In all of the future scenarios, low to high, the amount of discharge leaving the Ala Wai Canal through Waikiki was consistently higher for all percent chance floods. This is one reason why the resultant water-surface elevation differences in the Ala Wai Canal were lower as the percent chance floods became smaller (Tables 17 to 24).

In general, water-surface elevations and elevation differences increased as the scenarios progressed from low to high. A few cases had negative changes. For Kanaha Ditch cross-section 1874 for the 10-percent chance flood (Table 19), Manoa Stream cross-section 948 for the 5-percent chance flood (Table 20), and Ala Wai Middle cross-section 4847 for the 1-percent chance flood (Table 22); these small negative differences occurring in areas of relatively flat slopes where the higher channel velocities or change in flood plain extents create a lower water-surface elevation for a higher discharge. For Palolo Lower, the Manoa-Palolo Drainage Canal, cross-section 3406 for the 0.5-percent flood event (Table 23), the negative differences are much greater due to the higher existing water-surface elevation at this flood discharge. This jump in water-surface elevation for this flood event compared to the 1- or 0.2-percent chance events(Tables 21 and 23) is due to the impacts of the Date Street and Kapiolani Blvd bridges, the transition of cross-section geometry at cross-section 3406, and the backwater impacts of the Ala Wai Canal that occur in this reach for discharges in the 20,500 to 22,000 ft3/s range. This discharge range occurs during the 2-percent chance flood high future scenario, the 1-percent chance flood low and intermediate scenarios, and the 0.5-percent chance flood exiting conditions (Tables 21 to 23).

Table 17. Water Surface Elevation Results for the 50-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	50-percent chance (2-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	2.55	3.10	3.67	4.74	0.55	1.12	2.19
Ala Wai Middle	4847	5.19	6.05	6.59	7.37	0.86	1.40	2.18
Ala Wai Upper	8015	5.71	6.54	7.05	7.81	0.83	1.34	2.10
Kanaha Ditch	1874	68.38	68.80	68.93	69.06	0.42	0.55	0.68
	3005	73.63	73.97	74.20	74.82	0.34	0.57	1.19
Kanaha Split	1393	40.58	40.93	41.21	41.74	0.35	0.63	1.16
Makiki Lower	1719	6.38	6.51	6.67	7.09	0.13	0.29	0.71
	4325	27.21	27.60	27.83	28.91	0.39	0.62	1.70
Makiki Upper	6606	67.04	67.45	67.73	68.48	0.41	0.69	1.44
	9666	177.72	177.89	178.00	178.29	0.17	0.28	0.57
Manoa Stream Main Reach	948	33.97	34.31	34.95	36.19	0.34	0.98	2.22
	5461	112.15	112.50	112.74	113.37	0.35	0.59	1.22
	8367	149.69	150.09	150.36	151.02	0.40	0.67	1.33
	9032	154.08	154.46	154.93	157.26	0.38	0.85	3.18
	10309	169.18	169.53	169.78	170.41	0.35	0.60	1.23
	13136	206.64	207.10	207.47	208.30	0.46	0.83	1.66
	15753	255.28	255.67	255.93	256.58	0.39	0.65	1.30
Palolo Lower	1813	6.35	7.00	7.51	8.30	0.65	1.16	1.95
	3406	8.96	9.62	10.28	11.64	0.66	1.32	2.68
Palolo Main	6376	34.72	35.21	35.57	36.49	0.49	0.85	1.77
	8574	84.93	85.35	85.64	86.38	0.42	0.71	1.45
	11649	135.40	135.89	136.28	137.35	0.49	0.88	1.95
	14619	183.78	184.35	184.74	185.81	0.57	0.96	2.03
Pukele Tributary	2184	280.73	281.24	281.57	282.41	0.51	0.84	1.68
UH_Split	1107	11.45	11.45	11.46	11.54	0.00	0.01	0.09
	4606	99.66	99.66	99.67	99.79	0.00	0.01	0.13
Waimao Ditch	1724	264.75	265.01	265.34	265.97	0.26	0.59	1.22
					Average Difference =	0.41	0.74	1.52

Table 18. Water Surface Elevation Results for the 20-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	20-percent Chance (5-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	3.28	3.60	4.04	4.94	0.32	0.76	1.66
Ala Wai Middle	4847	6.57	6.98	7.30	8.00	0.41	0.73	1.43
Ala Wai Upper	8015	7.06	7.47	7.78	8.44	0.41	0.72	1.38
Kanaha Ditch	1874	69.17	69.22	69.30	69.38	0.05	0.13	0.21
	3005	75.02	75.42	75.68	76.68	0.40	0.66	1.66
Kanaha Split	1393	41.72	41.88	42.06	42.40	0.16	0.34	0.68
Makiki Lower	1719	6.79	7.01	7.14	7.65	0.22	0.35	0.86
	4325	28.41	28.85	29.40	30.51	0.44	0.99	2.10
Makiki Upper	6606	68.51	68.98	69.28	70.11	0.47	0.77	1.60
	9666	178.32	178.50	178.62	178.95	0.18	0.30	0.63
Manoa Stream Main Reach	948	35.72	36.46	36.64	37.61	0.74	0.92	1.89
	5461	113.36	113.77	114.02	114.73	0.41	0.66	1.37
	8367	151.07	151.49	151.76	152.48	0.42	0.69	1.41
	9032	157.22	159.86	160.17	160.76	2.64	2.95	3.54
	10309	170.54	170.94	171.19	172.14	0.40	0.65	1.60
	13136	207.88	208.34	208.64	209.38	0.46	0.76	1.50
	15753	256.31	256.72	256.96	257.65	0.41	0.65	1.34
Palolo Lower	1813	7.59	7.96	8.35	9.05	0.37	0.76	1.46
	3406	10.81	11.48	12.16	13.63	0.67	1.35	2.82
Palolo Main	6376	36.15	36.70	37.07	38.06	0.55	0.92	1.91
	8574	86.11	86.54	86.82	87.60	0.43	0.71	1.49
	11649	137.04	137.56	140.36	140.14	0.52	3.32	3.10
	14619	185.39	186.02	186.43	187.55	0.63	1.04	2.16
Pukele Tributary	2184	282.43	282.98	283.31	284.17	0.55	0.88	1.74
UH_Split	1107	11.45	11.45	11.46	11.54	0.00	0.01	0.09
	4606	99.66	99.66	99.67	99.68	0.00	0.01	0.02
Waimao Ditch	1724	265.71	265.99	266.32	266.93	0.28	0.61	1.22
					Average Difference =	0.46	0.84	1.51

Table 19. Water Surface Elevation Results for the 10-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	10-percent chance (10-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	3.56	3.88	4.23	5.06	0.32	0.67	1.50
Ala Wai Middle	4847	7.06	7.40	7.67	8.28	0.34	0.61	1.22
Ala Wai Upper	8015	7.55	7.88	8.14	8.71	0.33	0.59	1.16
Kanaha Ditch	1874	69.42	69.38	69.39	69.49	-0.04	-0.03	0.07
	3005	76.68	76.68	76.68	76.69	0.00	0.00	0.01
Kanaha Split	1393	42.07	42.20	42.34	42.62	0.13	0.27	0.55
Makiki Lower	1719	6.91	7.12	7.32	7.87	0.21	0.41	0.96
	4325	28.58	28.99	29.56	30.59	0.41	0.98	2.01
Makiki Upper	6606	69.54	70.03	70.35	71.20	0.49	0.81	1.66
	9666	178.72	178.91	179.03	179.38	0.19	0.31	0.66
Manoa Stream Main Reach	948	36.96	37.58	37.98	38.38	0.62	1.02	1.42
	5461	114.38	114.82	115.09	115.82	0.44	0.71	1.44
	8367	152.14	152.59	152.84	153.59	0.45	0.70	1.45
	9032	160.50	161.06	161.41	162.43	0.56	0.91	1.93
	10309	171.94	172.45	172.84	174.00	0.51	0.90	2.06
	13136	209.02	209.43	209.73	210.53	0.41	0.71	1.51
	15753	257.39	257.82	258.08	258.82	0.43	0.69	1.43
Palolo Lower	1813	8.14	8.49	8.88	9.58	0.35	0.74	1.44
	3406	12.04	12.74	13.43	14.77	0.70	1.39	2.73
Palolo Main	6376	37.20	37.77	38.13	39.13	0.57	0.93	1.93
	8574	86.92	87.37	87.66	88.42	0.45	0.74	1.50
	11649	139.37	139.48	140.21	140.76	0.11	0.84	1.39
	14619	186.64	187.30	187.72	189.54	0.66	1.08	2.90
Pukele Tributary	2184	283.57	284.07	284.40	285.37	0.50	0.83	1.80
UH_Split	1107	11.45	11.45	11.59	13.16	0.00	0.14	1.71
	4606	99.66	99.66	99.85	101.55	0.00	0.19	1.89
Waimao Ditch	1724	266.31	266.57	266.84	267.46	0.26	0.53	1.15
					Average Difference =	0.35	0.65	1.46

Table 20. Water Surface Elevation Results for the 5-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	5-percent chance (20-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	3.93	4.21	4.43	5.38	0.28	0.50	1.45
Ala Wai Middle	4847	7.57	7.90	8.20	8.66	0.33	0.63	1.09
Ala Wai Upper	8015	8.21	8.39	8.65	9.10	0.18	0.44	0.89
Kanaha Ditch	1874	69.49	69.54	69.67	70.01	0.05	0.18	0.52
	3005	76.68	76.70	76.87	77.30	0.02	0.19	0.62
Kanaha Split	1393	42.44	42.61	42.71	42.87	0.17	0.27	0.43
Makiki Lower	1719	7.27	7.56	7.81	8.49	0.29	0.54	1.22
	4325	29.47	29.72	30.74	33.20	0.25	1.27	3.73
Makiki Upper	6606	71.25	71.81	72.18	73.19	0.56	0.93	1.94
	9666	179.41	179.63	179.78	180.18	0.22	0.37	0.77
Manoa Stream Main Reach	948	38.25	38.21	38.47	38.96	-0.04	0.22	0.71
	5461	115.48	115.94	116.23	116.92	0.46	0.75	1.44
	8367	153.09	153.56	153.87	154.60	0.47	0.78	1.51
	9032	161.86	162.28	162.77	163.71	0.42	0.91	1.85
	10309	173.14	173.91	174.21	174.77	0.77	1.07	1.63
	13136	210.01	210.50	210.89	211.20	0.49	0.88	1.19
	15753	258.44	258.90	259.21	259.95	0.46	0.77	1.51
Palolo Lower	1813	9.02	9.56	9.91	10.69	0.54	0.89	1.67
	3406	13.61	14.37	15.13	16.82	0.76	1.52	3.21
Palolo Main	6376	38.90	39.78	40.35	41.61	0.88	1.45	2.71
	8574	88.23	88.76	89.08	89.98	0.53	0.85	1.75
	11649	140.59	140.90	141.11	141.61	0.31	0.52	1.02
	14619	189.20	190.01	190.50	192.52	0.81	1.30	3.32
Pukele Tributary	2184	285.27	285.85	286.19	287.07	0.58	0.92	1.80
UH_Split	1107	12.01	12.85	13.31	13.81	0.84	1.30	1.80
	4606	100.46	101.26	101.78	102.25	0.80	1.32	1.79
Waimao Ditch	1724	267.09	267.41	267.62	268.18	0.32	0.53	1.09
					Average Difference =	0.44	0.79	1.58

Table 21. Water Surface Elevation Results for the 2-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	2-percent chance (50-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	4.12	4.25	4.80	5.88	0.13	0.68	1.76
Ala Wai Middle	4847	8.05	8.10	8.70	8.70	0.05	0.65	0.65
Ala Wai Upper	8015	8.61	8.67	9.26	9.36	0.06	0.65	0.75
Kanaha Ditch	1874	69.83	70.27	71.07	71.52	0.44	1.24	1.69
	3005	77.19	77.47	77.89	78.12	0.28	0.70	0.93
Kanaha Split	1393	42.76	42.84	42.98	43.07	0.08	0.22	0.31
Makiki Lower	1719	7.55	7.69	8.45	8.34	0.14	0.90	0.79
	4325	31.04	33.37	33.87	34.03	2.33	2.83	2.99
Makiki Upper	6606	72.84	73.48	74.43	74.97	0.64	1.59	2.13
	9666	180.02	180.28	180.68	180.90	0.26	0.66	0.88
Manoa Stream Main Reach	948	38.72	38.97	39.21	39.73	0.25	0.49	1.01
	5461	116.70	117.18	117.41	118.17	0.48	0.71	1.47
	8367	154.35	154.83	155.10	156.02	0.48	0.75	1.67
	9032	163.26	163.98	164.32	165.64	0.72	1.06	2.38
	10309	174.70	175.23	175.56	175.68	0.53	0.86	0.98
	13136	211.07	211.32	211.52	212.08	0.25	0.45	1.01
	15753	259.92	260.42	260.71	261.58	0.50	0.79	1.66
Palolo Lower	1813	10.35	10.81	11.41	11.70	0.46	1.06	1.35
	3406	15.55	16.86	18.75	22.10	1.31	3.20	6.55
Palolo Main	6376	41.59	42.35	43.43	43.74	0.76	1.84	2.15
	8574	89.97	90.53	91.36	91.82	0.56	1.39	1.85
	11649	141.65	141.98	142.39	142.77	0.33	0.74	1.12
	14619	192.53	193.18	194.58	194.92	0.65	2.05	2.39
Pukele Tributary	2184	287.05	287.64	288.51	289.03	0.59	1.46	1.98
UH_Split	1107	13.53	13.77	14.30	15.23	0.24	0.77	1.70
	4606	101.96	102.23	102.58	102.98	0.27	0.62	1.02
Waimao Ditch	1724	268.08	268.47	269.02	269.50	0.39	0.94	1.42
					Average Difference =	0.49	1.09	1.65

Table 22. Water Surface Elevation Results for the 1-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	1-percent chance (100-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	4.15	4.26	4.68	5.86	0.11	0.53	1.71
Ala Wai Middle	4847	8.30	8.28	8.63	8.81	-0.02	0.33	0.51
Ala Wai Upper	8015	8.84	8.94	9.27	9.57	0.10	0.43	0.73
Kanaha Ditch	1874	70.71	71.23	71.57	72.41	0.52	0.86	1.70
	3005	77.93	78.25	78.43	78.96	0.32	0.50	1.03
Kanaha Split	1393	42.95	43.03	43.10	43.26	0.08	0.15	0.31
Makiki Lower	1719	7.65	7.76	8.28	8.36	0.11	0.63	0.71
	4325	33.56	33.93	34.05	35.17	0.37	0.49	1.61
Makiki Upper	6606	74.31	75.04	75.46	76.65	0.73	1.15	2.34
	9666	180.63	180.92	181.08	181.57	0.29	0.45	0.94
Manoa Stream Main Reach	948	39.08	39.38	39.64	40.16	0.30	0.56	1.08
	5461	117.42	117.94	118.22	119.02	0.52	0.80	1.60
	8367	155.08	155.68	156.00	156.76	0.60	0.92	1.68
	9032	164.27	165.04	165.58	166.04	0.77	1.31	1.77
	10309	175.57	175.68	175.68	175.68	0.11	0.11	0.11
	13136	211.50	211.76	212.08	212.78	0.26	0.58	1.28
	15753	260.87	261.43	261.74	262.86	0.56	0.87	1.99
Palolo Lower	1813	11.04	11.48	11.70	12.33	0.44	0.66	1.29
	3406	17.69	20.42	22.06	18.16	2.73	4.37	0.47
Palolo Main	6376	43.26	43.74	43.92	47.37	0.48	0.66	4.11
	8574	91.21	91.82	92.18	93.21	0.61	0.97	2.00
	11649	142.28	142.68	142.87	143.48	0.40	0.59	1.20
	14619	194.32	194.82	195.08	196.08	0.50	0.76	1.76
Pukele Tributary	2184	288.29	289.00	289.38	290.37	0.71	1.09	2.08
UH_Split	1107	14.04	14.39	14.83	16.10	0.35	0.79	2.06
	4606	102.42	102.63	102.81	103.33	0.21	0.39	0.91
Waimao Ditch	1724	268.89	269.48	269.71	270.37	0.59	0.82	1.48
					Average Difference =	0.47	0.81	1.42

Table 23. Water Surface Elevation Results for the 0.5-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	0.5-percent chance (200-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	4.14	4.26	4.50	5.42	0.12	0.36	1.28
Ala Wai Middle	4847	8.37	8.75	8.79	9.06	0.38	0.42	0.69
Ala Wai Upper	8015	9.09	9.42	9.50	9.82	0.33	0.41	0.73
Kanaha Ditch	1874	71.53	72.02	72.47	73.47	0.49	0.94	1.94
	3005	78.54	78.87	79.07	79.61	0.33	0.53	1.07
Kanaha Split	1393	43.09	43.16	43.24	43.41	0.07	0.15	0.32
Makiki Lower	1719	7.71	8.00	8.08	8.68	0.29	0.37	0.97
	4325	34.03	34.24	35.13	35.48	0.21	1.10	1.45
Makiki Upper	6606	75.78	76.56	77.00	78.28	0.78	1.22	2.50
	9666	181.39	181.71	181.92	182.49	0.32	0.53	1.10
Manoa Stream Main Reach	948	39.57	39.89	40.11	40.58	0.32	0.54	1.01
	5461	118.28	118.86	119.13	119.77	0.58	0.85	1.49
	8367	155.98	156.51	156.78	159.14	0.53	0.80	3.16
	9032	165.55	165.88	166.04	166.46	0.33	0.49	0.91
	10309	175.68	175.68	175.68	175.68	0.00	0.00	0.00
	13136	212.01	212.42	212.76	213.48	0.41	0.75	1.47
	15753	261.81	262.55	262.99	263.96	0.74	1.18	2.15
Palolo Lower	1813	11.64	12.04	12.24	12.79	0.40	0.60	1.15
	3406	20.59	17.69	17.94	19.12	-2.90	-2.65	-1.47
Palolo Main	6376	43.97	46.62	47.40	48.59	2.65	3.43	4.62
	8574	92.22	92.84	93.24	94.43	0.62	1.02	2.21
	11649	142.89	143.32	143.52	144.07	0.43	0.63	1.18
	14619	195.09	195.69	196.69	197.49	0.60	1.60	2.40
Pukele Tributary	2184	289.57	290.16	290.57	292.35	0.59	1.00	2.78
UH_Split	1107	14.55	15.31	15.96	17.53	0.76	1.41	2.98
	4606	102.76	103.02	103.29	104.07	0.26	0.53	1.31
Waimao Ditch	1724	269.85	270.26	270.51	271.20	0.41	0.66	1.35
					Average Difference =	0.37	0.70	1.51

Table 24. Water Surface Elevation Results for the 0.2-Percent Chance Flood at Selected Cross-Sections for the 50-year Future Without-Project Scenarios, Ala Wai Watershed, Oahu, Hawaii

HEC-RAS Model Reach Name	Cross-Section ID	0.2-percent chance (500-yr) Flood Water Surface Elevation (ft)				Water Surface Elevation Differences from Existing Values (ft)		
		Existing	2070 Low	2070 Inter	2070 High	2070 Low	2070 Inter	2070 High
Ala Wai Lower	1477	4.04	4.16	4.41	5.68	0.12	0.37	1.64
Ala Wai Middle	4847	8.43	8.90	8.94	9.24	0.47	0.51	0.81
Ala Wai Upper	8015	9.29	9.66	9.76	10.28	0.37	0.47	0.99
Kanaha Ditch	1874	72.50	73.13	73.98	75.28	0.63	1.48	2.78
	3005	79.18	79.56	79.78	81.00	0.38	0.60	1.82
Kanaha Split	1393	43.22	43.30	43.40	43.70	0.08	0.18	0.48
Makiki Lower	1719	7.72	7.82	8.07	8.40	0.10	0.35	0.68
	4325	35.20	35.40	34.76	35.00	0.20	-0.44	-0.20
Makiki Upper	6606	77.60	78.52	78.98	81.67	0.92	1.38	4.07
	9666	182.21	182.61	182.81	184.11	0.40	0.60	1.90
Manoa Stream Main Reach	948	40.10	40.34	40.54	41.75	0.24	0.44	1.65
	5461	119.11	119.59	119.72	120.13	0.48	0.61	1.02
	8367	156.90	159.01	159.30	159.92	2.11	2.40	3.02
	9032	165.95	166.37	166.53	166.94	0.42	0.58	0.99
	10309	175.68	175.68	175.68	177.98	0.00	0.00	2.30
	13136	212.65	213.04	213.37	214.10	0.39	0.72	1.45
	15753	262.99	263.63	263.96	265.01	0.64	0.97	2.02
Palolo Lower	1813	12.25	12.65	12.82	15.23	0.40	0.57	2.98
	3406	17.77	18.84	19.11	23.95	1.07	1.34	6.18
Palolo Main	6376	47.50	48.31	48.77	50.34	0.81	1.27	2.84
	8574	93.33	94.05	94.51	98.57	0.72	1.18	5.24
	11649	143.55	143.93	144.13	145.24	0.38	0.58	1.69
	14619	195.96	197.26	197.56	199.14	1.30	1.60	3.18
Pukele Tributary	2184	290.8	292.14	292.56	294.44	1.34	1.76	3.64
UH_Split	1107	16.06	16.53	17.69	20.43	0.47	1.63	4.37
	4606	103.32	103.69	104.13	105.16	0.37	0.81	1.84
Waimao Ditch	1724	270.59	271.06	271.31	272.72	0.47	0.72	2.13
					Average Difference =	0.57	0.84	2.28

8.0. Modeling the 2030 or 10-year Without Project Future

At the request of the economic team, an additional set of future scenarios were created and modeled representing a 10-year future (2030) without project conditions for economic comparisons with the existing and 50-year (2070) future scenarios. For these future scenarios, the same conditions determined for the 50-year without project scenarios were used, but in a different combination to create a low, intermediate or most probable, and a high scenario for the year 2030.

The sea-level rise values for the low, intermediate, and high scenarios were taken from the 2030 year data in Table 2. Not as obvious as sea-level rise, the remaining conditions are presented in Table 25 below. It was assumed that rainfall intensity and impervious area increases would not be much different from the existing without-project condition and only the high 2030 future case was adjusted using the intermediate values for the 2070 future. Debris generation, again highly variable among storm events, was left the same as determined for the 2070 or 50-year without-project future.

Table 25. Future 10-year Without-Project (2030) Scenarios and Components for the Ala Wai Watershed Project, Oahu, Hawaii

Component	Low	Most Probable	High
Sea Level Rise	Low From Table 2	Intermediate From Table 2	High From Table 2
Rainfall Intensity	Existing From Table 3	Existing From Table 3	Intermediate From Table 5
Debris Generation	Low as per Year 2070 Future	Intermediate as per Year 2070 Future	High as per Year 20270 Future
Impervious Area	Existing	Existing	Intermediate From Table 7

Results of the 2030 future year modeling are not presented. The increase in water-surface elevations are not as great as that determined for the 2070 or 50-year future as the hydrologic and hydraulic increases were not as large. The resultant impact on damages for this future scenario is discussed in the economic appendix.

9.0. Summary

The future without project condition attempts to describe the Ala Wai Watershed's future if there is no Federal action taken to solve the flood risk problem. The future condition is fundamentally uncertain and represents a best guess of conditions in the Watershed. Planning guidance states that the planning process accounts for such future conditions such as climate variability, sea-level rise, subsidence, seismic influences, geomorphological changes, and changes from development which can place demands on the project systems during their life-cycle. Therefore this document provides three future without-project scenarios for two future conditions 2030 and 2070, for the Ala Wai Watershed which will be used in the economic analysis, modeling, selection, and design of project alternatives. This report emphasis the 50-year without-project or year 2070 future model assumptions and results. The future scenarios were labeled low, intermediate, and high, with the intermediate scenario representing the most

probable future. The year 2030 or 10-year future without-project was done using scenarios created for the year 2070 future as an additional comparison for economic analysis.

This report addressed the hydrologic and hydraulic modeling of the future without-project scenarios concentrating on the impacts of sea-level rise, increased rainfall frequency, debris generation and transport, and increased impervious area in the Ala Wai Watershed. The impacts of these four components were determined based on best available information on climate change impacts for Hawaii in the literature and on sea-level rise guidance published by the USACE.

Hydrologic results for the 50-year future (2070) without-project scenarios for the entire Ala Wai Watershed indicated that the increased rainfall intensity and impervious areas resulted in an average 12 percent increase in peak flow discharges for the low future scenario, 20 percent for the intermediate scenario, and 42 percent for the high future scenario. These increased discharges along with debris transport and sea-level rise resulted in an average increase in water surface elevation of 0.45, 0.81, and 1.62 ft for the low, intermediate, and high scenarios, respectively, for all flood exceedance probabilities. Results from both the 2030 and 2070 future conditions will be used in the HEC-FDA program used in the economic analysis. More discussion on the HEC-FDA program and results can be found in the economic appendix.

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX B
ECONOMICS

B1 Economic Analysis

ALA WAI CANAL PROJECT
OAHU, HAWAII

SECTION 209 OF FLOOD CONTROL ACT OF 1962
(PUBLIC LAW 87-874)

APPENDIX B1

ECONOMIC ANALYSIS

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July 2015

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ALA WAI CANAL PROJECT FEASIBILITY STUDY, OAHU, HAWAII DRAFT ECONOMIC ANALYSIS

EXECUTIVE SUMMARY

The purpose of this economic analysis is to describe the economic assumptions, methodologies and findings used to evaluate the Ala Wai Canal floodplain and lead to the selection of the Tentative Selected Plan (TSP). Most of the effort described herein was to assess, model and describe results of the with- and without-project flood damage conditions in the Ala Wai Canal watershed. This establishes the baseline condition against which all future alternatives will be compared.

Economics will not be the only decision point for selection of the preferred alternative as many other criteria exist. However, it is critical to success of any water resources project to ensure that recommended alternatives do not cause dramatic and possibly harmful changes to the national or regional economies or local social infrastructure. Recently released regulations and guidelines like Executive Order 11988 have instructed Federal agencies responsible for water resource development projects to give more weight to projects that potentially reduce the threat to human health and safety and/or valuable natural resources.

The Ala Wai Canal watershed is located in the heart of Honolulu, on the island of Oahu, Hawaii. The neighborhoods of Makiki, Manoa, Waikiki, McCully/Moiliili, Kaimuki/Palolo, and Ala Moana comprise the primary impact area for the proposed flood risk management alternatives described in this feasibility report. For the purposes of this study, the area designated as the Ala Wai Canal floodplain is generally defined by its 0.2 percent annual chance exceedance (ACE) floodplain. A total of about 200,000 people live in this inundation area. The 0.2 percent ACE floodplain, commonly referred to as the 500-year floodplain, includes about 4,000 residences 1,000 commercial buildings and 100 public buildings, or more than $5.5 billion worth of total structural and content value. The majority of this value is located in the Waikiki vicinity. With numerous hotels and hundreds of stores and restaurants, it is easily the most important economic driver in the State of Hawaii. The majority of public facilities are found in the Manoa Valley. Manoa houses the main campus of the University of Hawaii in addition to research buildings and other district public schools.

Given the current built-out status of the watershed, new development will be almost entirely restricted to replacing old structures with new ones. As this happens, the study area is expected to expand vertically with new high rises replacing single family homes and outdated apartment buildings, and multiple storied structures replacing older single floor development. Similarly, commercial development is expected to follow suit. Exactly which buildings will be replaced and by what is impossible to say. Therefore, this study assumes that no significant changes will occur to the structure inventories or other assets on which damage categories are based, and that future conditions will be the same as present conditions for the purposes of calculating damages or costs. However, the number of potentially placed in harm's way from a flood, whether they

be residents, workers, shoppers, tourists and motorists traveling through the floodplain, will clearly be increasing over the 50-year planning horizon.

The primary benefit associated with a flood risk management project is the reduction in inundation damages to structures and their contents. Reducing potential flood damages to structures and contents are the only categories of benefits analyzed in the economic justification for this project. They are unquestionably the most significant National Economic Development (NED) benefits in terms of monetary impacts and the economic justification of the recommended plan. For the most part, a thorough, quantitative analysis of the effects of flooding on the regional economy is beyond the scope of this study.

The economic evaluation of potential damages due to flooding and improving the net productivity of flood-prone land resources is accomplished through the use of two models developed by the USACE's Hydrologic Engineering Center: hydraulic, River Analysis System (HEC-RAS), which computes river stages and water depths associated with varying size flood events; and one economic, Flood Damage Reduction Analysis (HEC-FDA), which generates important economic metrics including expected annual damages, expected annual benefits and equivalent annual benefits. HEC-FDA uses Monte Carlo simulation techniques to account for uncertainty in key variables while evaluating the full range of possible flood events within the study area under base and future year conditions.

The plan formulation for this project follows the new USACE guidelines for implementing the SMART Planning paradigm. A complete account of how the Project Delivery Team screened through various project alternatives and arrived at the recommended TSP, along with the planning objectives and selection criteria followed can be found in Chapters 3 and 4of the main Feasibility Report. This economic appendix picks up the SMART planning process in the later stages of plan comparison and describes and displays the economic results behind such decisions as:

- How Alternative 5, the Stand-Alone Nonstructural Plan, was developed and why it was dropped from further consideration;
- Why Alternative 3A was selected as superior to Alternative 2A in the Final Array stage;
- How the multi-measures of Alternative 3A were incrementally justified;
- How Alternative 3A was optimized and emerged as the most cost effective plan, NED Plan;
- How the NED Plan also proved to be the TSP; and,
- How the TSP/NED Plan has greater than 95 percent confidence level of passing the 1 percent ACE event.

In summary, Alternative 3A is recommended as the TSP, and is also the NED Plan. It is a comprehensive, basin-wide plan consisting of floodwalls along the Ala Wai Canal along with an assortment of detention and debris basins and a flood warning system. The economic analysis of this TSP concluded the following regarding benefits, costs, net benefits and benefit-cost ratio:

Table ES-01. The Economics of the TSP ($000)
Oct. 2013 Price Levels; 3.5% Discount Rate

	TSP
Total First Cost	$166,592
Total Investment	$176,427
Expected Annual Cost (EAC)	$8,504
Expected Annual Benefits (EAB)	$20,256
Net Benefits	$11,752
Benefit/Cost Ratio	2.38

By implementing the TSP, expected annual damages (EAD) to structures and contents within the watershed are anticipated to decrease from about $21.3million to about $1million, a 95 percent reduction. Other losses associated with flooding beyond the scope of this investigation should follow suit. The reduction is even more impressive in the Ala Wai Canal reaches, ALA1, ALA2 and ALA3, where Waikiki flooding is of upmost concern; there residual damages to structures and contents would be reduced to less than 1 percent of their without project conditions. In addition, with the TSP or NED Plan floodwalls in place, there is greater than 95% assurance at the 1 percent ACE that the Ala Wai Canal floodwalls would not be overtopped, which is in compliance with Corps guidance.

The effects on life safety are not as easily measured. For the most part, the Ala Wai Canal Project is not a floodplain with a high risk for loss of life from flooding. That is not to say that lives would not be endangered in the event of a major flood; flooding can be flashy or come with little warning. However, these conditions exist primarily in the steeply sloped, less populated hillside communities with relatively narrow floodplains. In the lower floodplain, it is much flatter and floodwater would rise much more slowly. Plus, with the addition of a new, basin-wide flood warning system, people should have adequate warning and time to move to higher ground or upper floors and out of harm's way.

Much work remains to be done in the Pre-engineering and Design Phase (PED) as this proposed flood risk management project moves closer to possible authorization and appropriation. For instance another look may be warranted at including nonstructural components for individual structures that remain flood prone after the implementation of the TSP. More precise finished floor elevations and comprehensive structural engineering evaluations will be required for selective buildings where buying out, relocating, ring walling, elevating or flood proofing might be economically justified. Or, given the effectiveness of the TSP at reducing flood damages, there might not be sufficient remaining damages to justify and add nonstructural components to the structural measures.

Another job for PED could be based on the decision that a more sophisticated, unsteady flow model is required to further refine the hydraulics of the watershed. From the economic perspective, those model refinements could necessitate further economic modeling and evaluation of the TSP and NED Plan. As they were left at this level of Feasibility Phase analysis, the TSP and NED Plan are in all probability one in the same.

Ala Wai Canal Project Feasibility Study,
Oahu, Hawaii
Draft Economic Analysis

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ALA WAI CANAL PROJECT FEASIBILITY STUDY, OAHU, HAWAII DRAFT ECONOMIC ANALYSIS

1.0. INTRODUCTION

1.1. Purpose. The purpose of this economic analysis is to describe the economic assumptions, methodologies and findings used to evaluate the Ala Wai Canal floodplain and lead to the selection of the Tentative Selected Plan (TSP). The economic evaluation was conducted using Hydrologic Engineering Center's Flood Damage Reduction Analysis (HEC-FDA), version 1.2.5a computer model (USACE, 2008). Most of the effort described herein was to assess, model and describe results of the with- and without-project flood damage conditions in the Ala Wai Canal watershed. This establishes the baseline condition against which all future alternatives will be compared.

Economics will not be the only decision point for selection of the preferred alternative. The economics and social effects are used as criteria to ensure that recommended alternatives do not cause dramatic and possibly harmful changes to the local economy or social infrastructure. Recently released regulations and guidelines for Federal agencies responsible for water resource development projects have been instructed to give more weight to projects that potentially reduce the threat to human health and safety and/or valuable natural resources.

1.2. Location and Description. The Ala Wai Canal watershed is located in the heart of Honolulu, on the island of Oahu, Hawaii. Figure B-1 shows the watershed and highlights the areas that would be inundated by two floods—the 20 percent chance and the 0.2 percent chance events. The watershed is made up of the Palolo, Manoa, and Makiki drainage areas and covers over 16 square miles. The neighborhoods of Makiki, Manoa, Waikiki, McCully/Moiliili, Kaimuki/Palolo, and Ala Moana comprise the primary impact area for the proposed flood risk management alternatives described in Section 4.0, *Summary of Alternatives*, of the main report.

As shown in Table B-1, these six neighborhoods comprising the Ala Wai watershed had a total population of about 200,000 in the year 2010, and have been increasing at an annual rate of about 2.1 percent since. The total asset base as defined by depreciated replacement value of all the structures and contents in the watershed is more than $5.5 billion. This figure includes the value of structures and contents of the upper floors of multi-story buildings found in the watershed as well. These billions of dollars of property are spread across the central part of Honolulu in the form of businesses, residential properties and public facilities. The majority of this value is located in the Waikiki vicinity. With numerous hotels and hundreds of stores and restaurants, it is easily the economic driver for the State. Businesses in the district rely heavily on tourist dollars for sustenance and growth. Other districts with large commercial activities are Makiki and Kapahulu, which are located north and northwest of Waikiki, respectively. The majority of public facilities are found in the Manoa Valley. Manoa houses the main campus of the University of Hawaii in addition to research buildings and other district public schools. As for residential properties, some of the affluent residential properties are also located in Manoa.

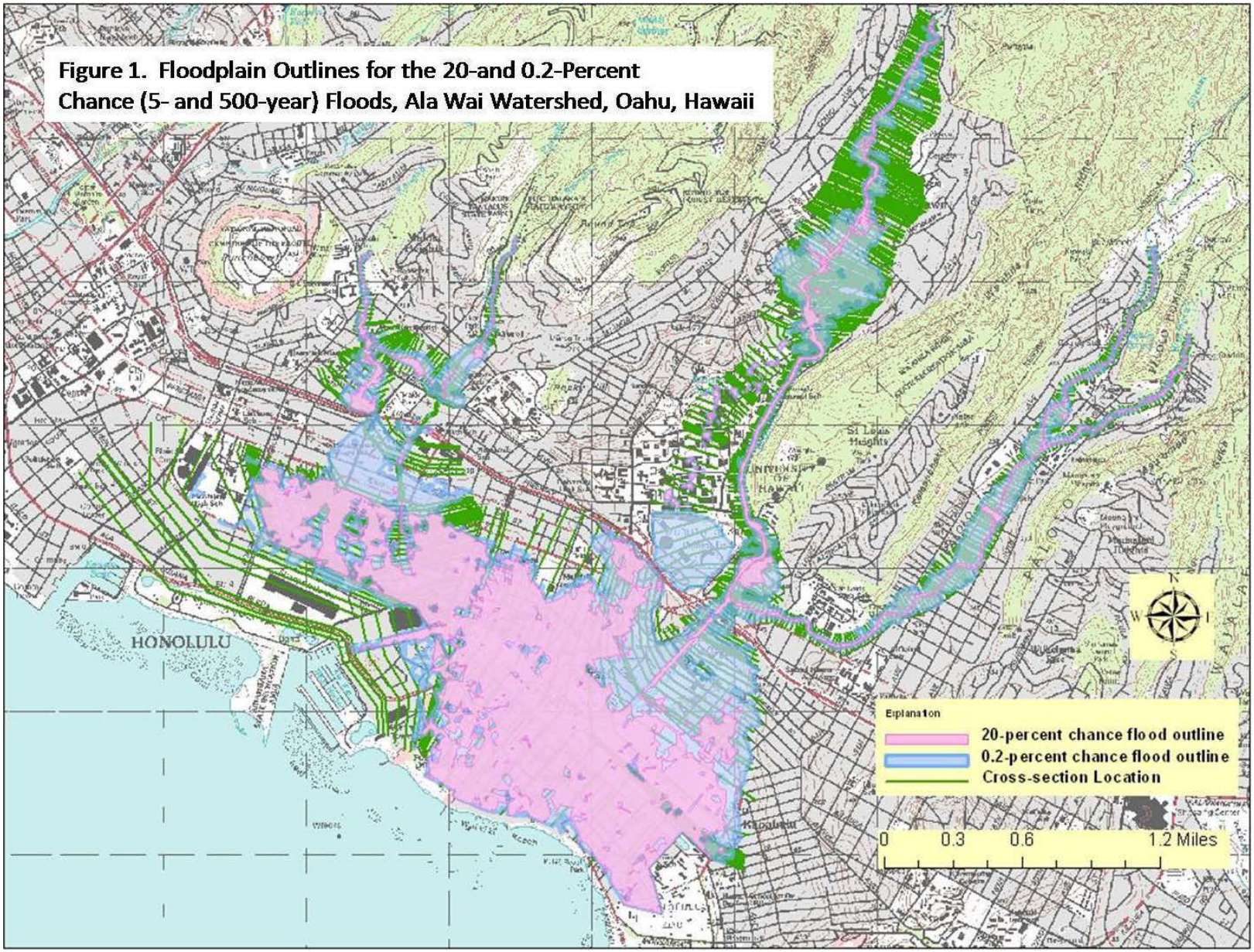


Figure 1. Floodplain Outlines for the 20-and 0.2-Percent Chance (5- and 500-year) Floods, Ala Wai Watershed, Oahu, Hawaii

Makiki also had a high residential value more due to its numerous amounts of small apartments. Rounding out the top residential areas were Waikiki, Kapahulu, and Palolo.

Table B-1. Total Population in the Ala Wai Watershed

Neighborhood	2000	2010	2014	% Change 2000-2014
Ala Moana	13,906	17,597	17,967	29.0%
Kaimuki/Palolo	48,839	49,987	51,037	4.5%
Makiki	21,435	22,358	22,850	6.6%
Manoa	43,921	45,812	46,820	6.6%
McCully/Moiliili	31,187	32,500	33,183	6.4%
Waikiki	27,507	31,413	32,073	17.0%
Total	**186,795**	**199,668**	**203,929**	**9.2%**

	2000	2010	2013	% Change 2000-2013
Honolulu County	876,156	953,207	983,429	12.2%
State of Hawaii	1,211,537	1,360,301	1,404,054	15.9%
United States	281,400,000	308,747,716	316,128,839	12.3%

Overall, population growth in the watershed has increased an estimated 9.2 percent since the 2000 census. This is less than the City of Honolulu's 12.2 percent over roughly the same time period, Hawaii's 15.9 percent and the United States' 12.3 percent. The Ala Moana neighborhood showed the largest percentage growth, 29 percent, among the Ala Wai watershed neighborhoods; it also has the smallest population of all of them. Waikiki had the next highest rate of growth with a 17 percent change. Kaimuki/Palolo had the largest population followed by Manoa. McCully/Moiliili has seen an outmigration of 13 percent since the turn of the century.

The population of Honolulu and the Ala Wai Canal watershed is expected to continue to grow at an annual rate of between 1 and 2 percent over the 50-year planning horizon, with the Waikiki and Ala Moana districts anticipated to grow the fastest. Both residential and commercial areas of the floodplain are fully built out, with little room available for construction of new structures without demolishing of existing structures. Given the current built-out status of the watershed, new development will be almost entirely restricted to replacing old structures with new ones. As this happens, the study area is expected to expand vertically with new high rises replacing single family homes and outdated apartment buildings, and multiple storied structures replacing older single floor development. Similarly, commercial development is expected to follow suit. Exactly which buildings will be replaced and by what is impossible to say. Therefore, this study assumes that no significant changes will occur to the structure inventories or other assets on which damage categories are based, and that future conditions will be the same as present conditions for the purposes of calculating damages or costs. The number of residents, workers, shoppers, tourists and motorists traveling through the floodplain who will potentially be placed in harm's way from a flood, those numbers will clearly be increasing over the 50-year planning horizon.

1.3. The Reaches. The Ala Wai Canal Project hydraulic and economic models extend from the mouth of the canal upstream to the extent of the developed areas along Makiki, Manoa, and Palolo Streams (Figure B-1). For the purpose of economic analysis, the watershed study consists of 27 reaches (note that the H&H analysis uses 13 reaches for its HEC-RAS model), and each reach has specific characteristics that make it unique. To locate reaches, see Figure B-2. The Ala Wai Canal itself is divided into three reaches: ALA1, ALA2, and ALA3. Other larger sections of the project area, such as Makiki, Manoa, and Palolo, have as many as seven reaches. Then, there are smaller stream sections that break into two or less reaches.

ALA1 is the last leg of the Ala Wai Canal before it arrives at the ocean. Therefore, this reach is the western part of Waikiki and includes a few landmarks such as the Ala Moana Shopping Center, Ilikai Hotel, and Hawaii Prince Hotel. The tourist population density is relatively heavy in this area. Most of the resident population live in apartments and large condominiums. There are a handful of single family residences, but space is extremely limited, so the housing lots are relatively small. Other than Ala Moana Mall, most businesses are small retail stores and restaurants. Overall, commercial properties have much more value and potential to be damaged by flooding than residential properties in this reach.

ALA2 is the middle section of Waikiki and it extends into McCully, up to King Street. Like ALA1, the tourist population density is heavy and is primarily located in the hotels next to the ocean. Most of the resident population live in apartments and condominiums. Northwest of the Ala Wai Canal is the community of McCully. McCully is made up of small to medium sized residential homes with several condominiums in the area. The residents are predominately an older generation and within the area there is a mixture of commercial activity. Most are restaurants and retail stores in the small to medium size range. Residential and commercial development in this reach are the highest of any reach in the study area, and stand to incur the most flood damage of them all. Some of the landmarks are the Hale Koa, Fort DeRussy, the Hilton Hawaiian Village, Trump International Hotel, and Waikiki Beachwalk.

ALA3 is the southeastern part of Waikiki. It starts at the beginning of the Ala Wai Canal and ends at Iolani School. This reach could have the second most damage of any reach in the watershed. Many of Waikiki's landmark hotels are found in this reach. Residents live in apartments and condominiums. Businesses range from small to large and depend greatly on tourism to survive. Commercial activity vastly outweighs any other type of damage-properties in this reach. Some of the landmarks are the Royal Hawaiian, Halekulani Hotel, the Royal Hawaiian Shopping Center, Moana Surfrider, the Hyatt, the Waikiki Beach Marriott, and the Sheraton Princess Kaiulani Hotel.

KAH1 is a part of the upper Makiki Valley. It is primarily residential with few condominiums and some small apartments. The majority of the residents live in single family houses that are less than 5000 square feet of lot space. There are no major commercial operations in this vicinity and the potential for flood losses is minimal compared to most.

KAH2 is adjacent to KAH1 and is located next to Roosevelt High School. The reach is relatively small compared to the other reaches and has minimal potential for flood damages. It is comprised of single family homes and there are no commercial operations.

KAO1 is another small reach located next to the Kanaha Ditch. It stretches from the upper Makiki Valley into Makiki. The reach has a mix of apartment, condominiums, and single family residential houses. Overall, apartments seem to dominate this section. Businesses also vary in which there are small and medium sized commercial properties in the area. Flood losses could be quite significant in KAO1.

MAK1 is the lower half of Makiki. There are a many single family homes and small apartments in this reach but, overall, it is one of the more prominent commercial areas in the watershed. The sizes of commercial properties vary from small to large with some of the largest being food and department stores. Property damages from flooding in this reach, especially to businesses, could amount to one of the highest totals in the watershed. Makiki District Park is another notable landmark in this reach.

MAK2 is in the center of Makiki. It is primarily residential with mix of apartments, condominiums, and single family homes. Overall, the majority of properties are single family homes; however, condominiums and the commercial businesses in the area could sustain heavy flood damage.

MAK3 is the upper portion of the Makiki Valley. It is a relatively small reach that consist of mainly apartments and single family homes. There are no substantial commercial activities in this reach; however, the high number of condominiums in the area contributes to the commercial damages.

MAK4 is the located above MAK3 and is the highest elevation region in the Makiki Stream. MAK4 consists of entirely single family residential development and flood damages are relatively low.

MAN1 has a mix of residential and public properties. The unique aspect of this reach is that some of the University of Hawaii buildings are a part of the commercial and residential makeup. The residential properties consist of mostly single family homes and the reach demonstrates a significant vulnerability to potential flooding.

MAN2 is mainly University of Hawaii facilities. It includes the faculty apartments, classrooms, lecture halls, and administration offices; these fall into the category of public. The university has made great strides in lowering their vulnerability to flooding over recent years. There are some single family houses in the area, as well.

MAN3 is the beginning of the residential section of the Manoa Valley. The majority of the area is single family homes with a handful of small commercial properties and one medium sized commercial shopping center, Manoa Market Place. Significant flood losses are possible in this reach.

MAN4 is the next section of the Manoa watershed and is made up of mainly single family residences. There are no apartments and condominiums. There are, however, a couple of small commercial properties in the area. Residential flood damages in this reach are could be substantial.

MAN5 is both residential and public. Half of the area is public due to the public school, Manoa Elementary School, and the surrounding Manoa District Park, which consist of four baseball fields, basketball courts, tennis courts, a pavilion, a gymnasium, and a swimming pool. The other half is residential due to the single family housing in the area. There are also a few apartments adjacent to the district park. Commercial properties are sparse. There is definitely a potential for damages from flooding in this reach.

MAN6 is further up the valley from MAN5. It is mostly residential properties, some of which are in the floodplain. There is a 34-acre cemetery, Manoa Chinese Cemetery, which is located in the middle of the reach. Although the cemetery is quite large, it is built into the mountain which makes it less susceptible to the flood waters. Furthermore, there are a couple of commercial properties in the area, mostly small family owned businesses or convenience stores.

MAN7 is the last reach in the Manoa Valley watershed. The district is residential with mainly single family homes. Although mainly single family homes, there are not many residences in the area. There are no commercial properties. Flood damages would be light.

MPC1 is located to the south and southeast of the University of Hawaii. This reach has a mix of residential, commercial, and public. The largest of the three damage types is residential; however, commercial is not far behind. The predominant residential properties are single family homes and small apartments. On the other hand, the commercial category has an array of properties, which consist of business buildings, convenience stores, restaurants, and a mini shopping center. On Kapahulu Avenue, which runs from the University to Waikiki, the street is lined with restaurants and businesses. Lastly, there is a large public feature, Kaimuki High School. This reach has the potential to be a high damage area.

MPC2 is a relatively large, L-shaped reach that encompasses some areas of McCully-Moiliili, runs through Iolani School, and ends at Ala Wai Golf Course. Like MPC1, this reach is located south of the University of Hawaii. Residential properties dominant the area and it one of the most populated and damageable reaches in the watershed. There is also an array of commercial businesses and a few public facilities in the reach. The landmarks in the reach are Iolani School and Ala Wai Golf Course.

PAL1 is southeast of the University of Hawaii and north of MCPC1. The only damage type in this reach is residential and it is fairly minimal. The residential properties consist of single family homes and small apartments.

PAL2 is west of PAL1 and consist of primarily of single family homes. Its damage potential from flooding is relatively minor.

PAL3 is northeast of PAL2 and consists entirely of residential properties. Most of the residential properties are single family homes. This reach contributes the highest damage figures of all the Palolo reaches.
PAL4 is northeast of PAL3. The reach consists mainly of residential properties, Jarrett Middle School, and Palolo Valley District Park. In addition, there are several public housing units in the

reach. Most of the residential properties are single family homes. Flood losses could be significant compared to many of the smaller reaches.

PUK1 is to the northeast of PAL4 and south of WAI1. There are not many damage types in the area; however, residential, commercial, and public facilities can be found. Commercial structures have the most value here, followed by residential and then public. Flood losses would be relatively light.

UNI1 is the lower part of the University of Hawaii campus. It contains the athletic fields, tennis courts, portable classrooms, parking structure, sports administration department, recreation center, and a few gymnasiums. One of the major landmarks in this reach is the Stan Sheriff Center. The University has made great strides in recent years protecting its properties from flooding, but the largest of floods could still get into many of their buildings.

UNI2 is the main campus of the University of Hawaii. The majority of the campus comprises of buildings, no taller than 10 stories, with several portable classrooms spread throughout the grounds. Some of the buildings are historical and have rare artifacts and documents. Other buildings are newer and have technological equipment and research data. The buildings are generally classrooms or designated study areas except for the administration buildings. Some of the notable landmarks in this reach are Hamilton Library, Campus Center, the Biomedical Building, and Kuykendall Hall. During the 2006 storm event, Hamilton Library particularly sustained heavy damage. Again, that is one of the buildings the University has recently flood proofed, but like many campus buildings, the threat of large floods still looms large.

WAI1 is the northern most reach of Palolo Valley. It consists of entirely residential properties. The properties are single family homes and small apartments. It has the smallest potential for flood damages of all the reaches in the watershed.

1.4. Historical Damages. For as long as flood records have been kept, there has not been an actual flood in the Ala Wai Canal watershed of the magnitude included in the basin model developed herein. Historical events such as the November 1965 and December 1967 storms and the passage of Hurricane Iniki in 1992 caused damages in the watershed, but these events were nowhere near what would be considered today's 1 percent annual chance exceedance (ACE) flood (formerly referred to as the 100-year event), and damage estimates are spotty.[1] Even the catastrophic rain event in the Manoa Valley, October 30, 2004, which caused between $80 and $100 million to the University of Hawaii campus, was probably only a 5 percent ACE event.

1.5. General. The comparison and evaluation of alternatives that will evolve from the planning process involves considering the effects that the plans would have on planning objectives and constraints. The economic analysis presented in this appendix begins by addressing the without-project condition and the future without-project condition and establishes a general description and baseline for the primary impact area.

[1] The1967 storm caused a reported $10,000 in damages (unadjusted for price levels) in the Ala Wai Canal area, according to USACE's Circular C47. No damage estimates for the Ala Wai watershed could be found for the 1965 event and Hurricane Iniki in 1992.

In this without-project condition economic analysis, benefits and costs are expressed at an estimated October 1, 2013 (FY2014) price level. However, this analysis sets the stage for converting costs and benefits occurring at different points in time to an expected annual equivalent basis over the 50-year period of analysis using the Federal discount rate prescribed for water resources projects. The discount rate used for economic calculations is the Fiscal Year 2014 rate of 3.5 percent. The project base year, or first year of project operation, is FY2026, with the earliest year of anticipated construction being 2021, thereby making the construction period 5 years from beginning to completion. It also follows that the 50-year period of analysis is from FY2026 through FY2076. However, since much of the work on future with and without-project conditions, including impacts from expected sea level rise, was accomplished several years ago, there is no accounting herein for the indiscernible difference between ending the planning horizon at 2070 and 2076.

As previously stated, reducing potential flood damages to structures and contents are the only categories of benefits analyzed in the economic justification for this project. They are unquestionably the most significant National Economic Development (NED) benefits in terms of monetary impacts and the economic justification of the recommended plan. However, these are not the only NED benefits that would be realized by implementing the recommended plan. Additional economic impacts would undoubtedly include other NED benefits, such as reductions in flood damages to utilities, roadways, automobiles, landscaping and emergency relief costs. In addition to these secondary benefits, a case can be made to evaluate benefits for reducing costs resulting from travel delays and maintaining the banks of the existing channel that would continue under without-project conditions but not if the recommended plan were implemented. These other categories of benefits are difficult to forecast to a reasonably degree of accuracy and create problems when added to structure and content damages which have been computed to a higher level of reliability and account for uncertainty within key variables. Further, these secondary benefits altogether would likely make up no more than an additional 20 percent of the total structural and content damages and the project already demonstrates a strong benefit-cost ratio (BCR) without them. Most importantly, inclusion of these secondary benefits would not impact the plan selection since they tend to be closely correlated with reductions in flood damages to structures and contents, and they would be roughly the same for all the structural alternatives considered; thus, they would not change the ranking order of structural solutions considered, and contribute far less to nonstructural plans. Therefore, this economic analysis did not attempt to quantify these secondary benefits. However, a great deal of attention was given to another kind of intangible, yet critically important, effect of flooding concerning the safety and wellbeing of residents who occupy these neighborhoods and may experience a flood event.

1.6. Methodology and Terminology

1.6.1. Annual Chance Exceedance (ACE). Before explaining how inundation damages and reduction benefits were computed, a basic hydrologic concept needs to be established. In past years, most USAE flood risk management studies referred to individual flood frequencies as occurring on an average of once every X number of years; e.g., the 100-year flood. This terminology often confuses citizens into thinking such a flood could only occur once every 100 years, when it actually means there is a 1 percent chance of any event occurring capable of producing the flow or stage in excess of a particular value. Therefore, this former terminology

has been replaced with the ACE of a given event; e.g., the 1 percent ACE event has replaced the former terminology of 100-year flood.

1.6.2. Methodology. The primary benefit associated with a flood risk management project is the reduction in inundation damages to structures and their contents. The economic evaluation of improving the net productivity of flood-prone land resources is accomplished through the use of two models developed by the USACE's Hydrologic Engineering Center: One hydraulic, River Analysis System (HEC-RAS), which computes river stages and water depths associated with varying size flood events; and one economic, HEC-FDA, which generates important economic metrics including expected annual damages, expected annual benefits and equivalent annual benefits.

HEC-FDA uses Monte Carlo simulation techniques to evaluate the full range of possible flood events within the study area under base and future year conditions. The algorithm the program follows begins with the selection of a base or future year river flow at an index point within the study area. The range of possible base and future year river flows and their associated probabilities of exceedance are provided by the project's hydrologist. The sampled river flow is then paired with a stage or water surface elevation from a distribution of possible values, provided by the hydraulic engineer. This water surface elevation is compared against the river's bank and levee height at the index point to determine if sampled event results in flooding. In the event that the river stage induces flooding the floodplain water surface elevations are computed and compared against topographic and first floor elevations to determine the depth of flooding, at each structure within that index point's reach. This depth of flooding is transformed into flood damages using depth-percent damage functions and depreciated structure values provided by the project economist. These reach-by-reach damage estimates are paired with the selected base or future year's river flow percent exceedance probability, to produce a probability-damage function. These probability damage functions are expressed in expected annual damages under without-project alternative and with-project alternatives. The difference in these expected annual damage estimates essentially constitutes the benefit for reducing the risk of inundation.

More specifically, the areas of flooding and the water surface depths associated with flood events with probabilities of 50, 20, 10, 4, 2, 1, 0.5 and 0.2 percent ACE are estimated using HEC-RAS computer software. Then, HED-FDA determines the economic effects of flooding on the thousands of structures in the Ala Wai Canal floodplain by comparing the water elevations for flood events between 50 and 0.2 percent ACE with the first floor elevations for each structure in the floodplain inventory. This determines the height of the flood waters at each structure for any given flood event. HEC-FDA analyzes the percent damages to each structure and its contents associated with each level of flooding. The percent damages are multiplied by the structure or content value to arrive at dollar damages. This procedure is performed for every structure in the floodplain, with results consolidated by reach and integrated over the range of probable flood events.

HEC-FDA also explicitly takes into consideration the uncertainty of the variables involved in calculating flood damages. The hydrologic, hydraulic, and economic data used in flood damage analysis are not known with certainty. To model these uncertainties, the probability distributions of the pertinent variables are input into HEC-FDA. The program then applies Monte Carlo

simulation techniques to the data using discharge-probability, stage-discharge, and stage-damage functions containing these distributions. By conducting a large number of iterations, the program computes the expected value of damages while specifically accounting for the uncertainties in the underlying data.

1.6.3. Expected Annual Damages (EAD). EAD represents the probability weighted average annual flood damages computed through integration of the probability-damage distributions generated by HEC-FDA. It describes the flood damages that one would expect to incur in any given year under base or future conditions, without a prior knowledge of if any flooding will occur. Since EAD represents an annualized weighted average, it simultaneously over estimates the actual flooding that occurs in most years (since no flooding occurs in most years), and under estimates flood damages following many flood events.

1.6.4. Expected Annual Benefits (EAB). EAB represent the difference between with and without project expected annual damages. Thus it measures the reduction in flood damages attributable to the implementation of a particular alternative.

1.6.5 Equivalent Annual Damages. Equivalent Annual Damages provide the expected annual damages during the period of analysis; given the transition between base and future year conditions. It provides a value against which annualized project costs, known as equivalent annual costs can be compared.

1.6.6. Expected Annual Cost (EAC). Expected annual cost (EAC) is used in economic analysis to compare costs and benefits on an annual basis from a consistent point in time. EAC begins with a detailed estimate of a project's total construction cost and annualizes it much the same as a typical home mortgage is converted to a monthly payment. The formula for the calculation of EAC involves applying the appropriate discount rate and time period to the total cost of an alternative, including costs for mitigation, real estate, further planning and design studies, management of the construction and operation, maintenance, repairs, rehabilitations, and replacements (OMRR&R). EAC also includes an economic cost, interest during construction, to account for the opportunity costs of the investment itself.

2.0. THE SYSTEM OF ACCOUNTS

2.1. General. In the 1970 Flood Control Act, Congress identified four national accounts for use in water resources development planning: National Economic Development, Regional Economic Development, Environmental Quality, and Other Social Effects (NED, RED, EQ, and OSE). Policy in the 1970s regarded making contributions to only two of these, NED and EQ, as national objectives. As ecosystem restoration has risen in importance as one of the U.S. Army Corps of Engineers (USACE) priority missions and its principal EQ objective, national ecosystem restoration (NER) outputs or benefits have become an important driver of plan formulation for these types of projects. Additionally, with each passing decade since the1970s, the USACE has been encouraged to give increasing weight to OSE in addition to its focus on NED and NER (USACE, 2009).

For the purpose of this FSM Report, the discussion of the four national accounts is limited to addressing the without-project condition and future without-project condition. All four accounts are expected to ultimately realize benefits and come more heavily into play further into the planning process with the development of alternative plans of improvement in the Ala Wai Canal watershed.

2.2. National Economic Development. The Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable Executive orders, and other Federal planning requirements. Typical USACE economic analysis quantifies the effects of alternatives and optimizes the output of goods and services from a national perspective (the NED account). NED benefits are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the impact region and the rest of the nation.

One of the primary outputs of the kind of water resource improvement alternatives that are expected to come out of the Ala Wai Canal Project will be NED benefits associated with lowering the risk of flood damages to structures and their contents in the watershed. Floodplain management, including flood control and prevention, contributes to the NED objective by improving the net productivity of flood-prone land resources. This occurs from an increase in the output of goods and services and/or by reducing the cost of using the land resources. These improvements in economic efficiency are estimated by comparing the most likely future conditions without the project (the "without-project" condition) with the most likely future conditions resulting from the implementation of flood damage reduction measures (the "with-project" condition). NED benefits are anticipated to be positive and extensive from reducing the risk of flooding in the Ala Wai Canal neighborhoods and possibly improving recreation opportunities.

If Federal funds are eventually spent of a flood risk management or ecosystem restoration project in the watershed, it would likely result in a temporary increase in jobs on the Island of Oahu or at the regional economic development (RED) level. At the same time, some positive effects of adding to the country's NED would be likely. Unemployed people might come off the unemployment ranks and underemployed people might land better jobs. Federal income taxes will be paid on earnings that might otherwise not have existed. Hotels and restaurants that were not shut down because of a flood that did not happened would pay more taxes as well. Recreation gear inventories might be manufactured and sold that otherwise might not have been ordered. In addition, NED benefits include increases in the net value of all goods and services, whether they are marketed or not. A project of this nature for the Ala Wai Canal area would likely realize an increase in tourism and recreational opportunities and more people might be willing to pay for these recreation opportunities.

2.3. Regional Economic Development (RED). The biggest difference in perspectives between a Federal water resource agency and the non-Federal partner is often in respect to the NED objective. The goal of the NED or Federal perspective is to identify "the alternative plan with the greatest net national economic benefit consistent with protecting the nation's environment (the NED Plan). Major infrastructure projects, such as water resource

developments, will often also result in economic impacts that are not NED impacts. These are called Regional Economic Development benefits and include benefits such as employment shifts from one region to another. RED benefits impact a region, not the nation as a whole. Consequently, RED benefits are usually not involved in determining the extent of Federal participation in the development of flood control projects. Rather, they are included to provide a measure of the overall impact of flooding from the study sponsor's perspective. The RED account is intended to illustrate the impacts of the proposed alternatives to the regional economy, especially employment and income. Any future proposed project would likely benefit these criteria as well as have the potential to increase tourism, recreation and related industry within the impact region.

For example, local governments seek to preserve the tax base and encourage the growth in overall property values to create stability and employment in their region. The steady growth of the local community and surrounding region is considered a creditable goal by the state and local governments. However, if these positive things happen in one region at the expense of another region, that is, they are transfers from one region to another, there is no net gain to the nation; this would be considered a regional benefit. While the prevention of flood-induced business losses is not normally considered a NED benefit, minimizing disruptions to businesses in the Ala Wai Canal Project floodplain can be a significant RED benefit of providing flood protection. Or, if hotel occupancy or revenue were to drop at a Waikiki hotel due to flooding conditions that could have been prevented by civil works projects like the ones studied in this report, would that be considered a NED or RED benefit? In most cases, the answer is the loss of income is considered a regional economic loss and not a loss to the NED account. It is assumed that rental income lost to the hotel ownership would be transferred to some other owner in an alternate location; this might be a loss to the region, but not the nation since those would-be customers would simply patronize another hotel safely removed from the flooding. In Section 3.1.6 of this Economic Appendix, the case is made that due the remoteness, uniqueness and lack of substitutes for Hawaii (and Waikiki Beach), as well as the large proportion of tourism dollars coming from international sources, much of these typically RED impacts could, in fact, be NED.

Whether these kinds of impacts are RED, NED or some combination of both, should not be interpreted to mean that loss of regional revenue is not an important factor in the decision to support this kind of flood risk management project. Reducing the duration and intensity of flooding can potentially prevent millions of dollars in lost sales for area businesses. A project that reduces the risk of flooding in a Waikiki hotel could have tremendous regional impact on tourism, jobs and income. These dollars can multiply several times over as they purchase goods and services through interconnected business sectors in the region's economy. Capturing and quantifying regional, indirect and induced economic impacts is beyond the scope of this study. This study concentrates on estimating the value of reducing the risk of flooding from the Federal perspective and identifying primarily NED impacts.

Job creation and the indirect and induced economic impacts attributable to new jobs is another important RED impact that typically stems from large civil works projects. Any large investment or injection of Federal money in the construction sector of a local economy is likely to produce some increase in the number of jobs, or at a minimum, sustain or support existing construction jobs. In addition, favorable indirect and induced impacts on employment would

result as that injection of dollars turns over within the local economy. These impacts on employment might be short lived, however, lasting only through the construction of the project. The USACE developed a methodology for the Office of Management and Budget for estimating jobs created by spending stimulus funds distributed in the American Recovery and reinvestment Act (ARRA) of 2009. Based on this methodology, for every $1 million of Federal investment, the number of jobs created in the impact region would be between 24 and 25. For example, with every $100 million in Federal investment associated with the Ala Wai Canal Project, the projected increase in jobs would be more than 2,400 (USACE, 2013). These jobs would result from both direct expenditures in the local region's construction sector, as well as the cumulative effects from increases in household spending as that injection of dollars turns over within the local economy.

Besides the construction jobs that would be created by building a water resource type project in the Ala Wai Canal watershed, there would be maintenance and operation jobs associated with the new project. In addition, there could be on-going needs for heavy equipment maintenance, periodic dredging, pump replacement, automobile rentals, electricity, water, sewer, telephone, internet access, landscaping and janitorial services.

This qualitative assessment of some of the RED impacts of a large flood risk management project for the Ala Wai Canal study area does not attempt to quantify any of these RED benefits. These analyses could be undertaken in the future but were judged to be beyond the scope of this feasibility study—to establish that there is a Federal interest in the project and demonstrate its basic economic justification in terms of NED benefits. The potential exists for developing a quantifiable amount of RED benefits and these could significantly add to the importance of constructing the project, especially from the perspective of the non-Federal sponsor. Yet it is doubtful that the addition of RED benefits would lead to the selection of a different plan of action than the one selected herein.

2.4. Environmental Quality. Over recent decades**,** the USACE has increased its focus on the EQ account and broadened its scope to include ecosystem restoration as one of its priority missions. The USACE objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). NER benefits, although normally not monetarily quantifiable, have become an important component of many Civil Works projects. Single-purpose ecosystem restoration projects should be formulated and evaluated in terms of net contributions to NER, while multipurpose projects that include ecosystem restoration should be formulated and evaluated in terms of both NED and NER. Initially begun as a combination ecosystem restoration and flood risk management study, ecosystem restoration has since been dropped as a project purpose of the Ala Wai Canal Project. For further information, see Section 1.6, *Study History and Background*, in the main report.

2.5. Other Social Effects (OSE). Another hard to quantify set of impacts from a water resource projects are lumped into the OSE Account. These include such impacts from a water resource projects as reducing the risk of loss of life by removing residents from flood prone areas, while not unjustly favoring or harming people of various races, age groups or economic status (USACE, 2009). The potential for flooding creates a life safety risk for people in or

passing through the watershed, including residents, visitors and workers, although no account was found of anyone losing their life in a local flood.

The affected population within the existing 1 percent chance floodplain is comprised of an estimated 54,000 residents, plus an additional estimated 79,000 visitors in Waikiki on any given day. The affected population is expected to be even larger during daytime hours, when there is an influx of students to 11 schools (approximately 28,500 students), as well as workers to the Waikiki District and other centers of employment (e.g., University of Hawaii), which collectively provide more than 65,000 jobs. As evidenced by past flooding events, there is a potential for life loss due to flooding in the watershed; in addition, health and safety threats include injuries associated with movement of debris and/or health concerns related to contaminated floodwaters. These threats are compounded by the fact that many people within the study area are unaware of the potential threats, so may not be adequately prepared or able to respond in the event of a flood.

Much of the watershed's critical infrastructure is located within the existing 1 percent chance floodplain, which elevates the life safety risks and decreases the community's ability to recover from potential flooding events. This infrastructure includes four fire stations, one police station, two hospitals, two nursing facilities and nine emergency shelters. In addition, the existing floodplain includes many of the major roadways and side streets, including the primary access in and out of Waikiki.

Although the study did not uncover a wealth of OSE "benefits" attributable to the recommended plan of action, positive OSE impacts in the socio-economic well-being of the impact region will follow with making any flood risk management improvements in the watershed. The opportunity now exists to accomplish one of the main objectives of the study; that is to take people out of harm's way with regard to flooding and ensure that this is accomplished by optimizing and balancing as many types of benefits and outputs from all four accounts as possible.

3.0. FLOOD DAMAGE ASSESSMENT MODEL

Addressing the without-project conditions and future without-project conditions set the baseline for measuring future reductions in costs associated with flooding—a NED benefit and the most important objective of this study and any potential project spawned by this study. Once the future without-project condition is established, the benefits and costs of the various alternative plans will be compared to the damage susceptibility of this baseline database of floodplain properties. Alternative plans will be screened out until one rises to the top as the alternative that will reasonably maximize net NED benefits. This will be accomplished by comparing the incremental expected annual benefits and the incremental expected annual costs of the alternatives being considered. The alternative with a BCR greater than one and the highest net incremental benefits will be designated as the NED Plan and, in many cases, the Tentatively Selected Plan (TSP) as well. This plan will consist of a group of measures, individually economically justified and each adding to the overall net benefits. When the last measure

introduced into the plan fails to yield net benefits, that measure will be dropped and the plan will be set to include every measure up to that one.

3.1. General Description of Development in the Floodplain. Establishing the future without-project condition begins with systematically inventorying the damageable properties in the floodplain and gathering the data required to run HEC-FDA. After all the damageable properties are accounted for, they are uploaded into the HEC-FDA program, along with the corresponding hydrology and hydrologic analysis. Specifically, HEC-FDA will analyze three data functions of the existing conditions: discharge-frequency, depth-discharge, and depth-damage. From these functions, the frequency-damage function can be derived. Once this occurs, the frequency-damage curve can be applied to the structure inventory, which leads to the Expected Annual Damage (EAD) value. EAD, as explained in Section 1.6, is the annualized present worth of damages, taking into account uncertainties in stage-damage, stage-flow, and flow-frequency relationships, amortized over the 50-year economic evaluation period. Flood damage calculations are in compliance with Section 308 of WRDA 1990; meaning that there are no damages claimed for structures built in the flood plain after June 1991, and used for project justification, that are not in compliance with the first-floor elevations requirement to be above the 1 percent AEP flood.

The Ala Wai Canal Project structure inventory includes a variety of building types from single-family homes and apartments to small commercial establishments, the State's largest shopping mall in Ala Moana, and many of its largest hotel and condominium properties in Waikiki. In the case of the Ala Wai Canal watershed, the primary impacted area is heavily developed and has been for many years. The watershed encompasses more than 16 square miles of some of the most densely developed land in Hawaii. All six neighborhoods are highly built-up and heavily urbanized in both their residential and commercial districts.

For the purposes of this study, the area designated as the Ala Wai Canal floodplain is generally defined by its 0.2 percent annual chance exceedance (ACE) floodplain. Approximately 200,000 people live in this inundation area. The 0.2 percent ACE floodplain, commonly referred to as the 500-year floodplain, includes about 4,000 residences 1,000 commercial buildings and 100 public buildings, or more than $5.5 billion worth of total structural and content value. The majority of this value is located in the Waikiki vicinity. With numerous hotels and hundreds of stores and restaurants, it is easily the most important economic driver in the State of Hawaii. The majority of public facilities are found in the Manoa Valley. Manoa houses the main campus of the University of Hawaii in addition to research buildings and other district public schools.

A larger floodplain area than the 0.2 percent ACE also exists; it is called the Probably Maximum Flood (PMF) floodplain. It could be considered the area that takes in all the land at risk of being flooded beyond the 0.2 percent ACE event. It is this area that makes up the structural inventory for the Ala Wai Canal watershed. If the structural inventory were to only include development within the 0.2 percent ACE floodplain, structures on the fringes of that delineation that have a risk of being flooded today or in the future could be excluded from the model. Table B-2 breaks down all the structure values within the PMF floodplain by reach and includes everything that went into the HEC-FDA inventory. At nearly 9,000 structures worth about $4.7 billion, these numbers greatly exceed those of the 0.2 percent ACE floodplain.

Table B-2. Ala Wai Structure Inventory Reach Breakdown, PMF Floodplain

Stream Name	Reach Name	Number of Structures	Total Value of Structures
Ala Wai	ALA1	472	$1,145,103,000
	ALA2	1,776	$586,048,000
	ALA3	657	$452,934,000
Kanaha Ditch	KAH1	105	$27,069,000
	KAH2	22	$6,946,000
Kanaha Split	KAO1	222	$73,096,000
Manoa-Palolo Canal	MPC1	471	$139,419,000
	MPC2	846	$167,419,000
Makiki	MAK1	1,237	$388,987,000
	MAK2	297	$190,069,000
	MAK3	94	$24,861,000
	MAK4	76	$15,433,000
Manoa	MAN1	123	$51,454,000
	MAN2	180	$42,900,000
	MAN3	106	$40,547,000
	MAN4	196	$33,726,000
	MAN5	270	$50,268,000
	MAN6	463	$88,639,000
	MAN7	211	$29,470,000
Palolo	PAL1	69	$16,162,000
	PAL2	88	$17,110,000
	PAL3	317	$43,488,000
	PAL4	237	$32,071,000
Pukele	PUK1	233	$29,780,000
University	UNI1	21	$226,814,000
	UNI2	54	$759,851,000
Waiomao	WAI1	125	$18,214,000
TOTAL		**8,968**	**$4,697,878,000**

3.1.1. Typical Residential Structures. Generally, residential lots in the primary impact area are around 5,000 square feet, while single family homes average about 1,600 square feet. Many have extra rooms, cottages, garage apartments or second houses on the same parcel that are rented to tenants or occupied by extended family members. In addition to the multiple living areas covering many of these lots, most have other out-buildings extended garages, workshops, tool sheds and paved driveways. Consequently, the tendency in these neighborhoods is to find nearly the entire lot to be roof-lined or impervious and relatively little left natural or in lawn. The homes are mostly wood or masonry, single story structures with no basement. Home values vary from neighborhood to neighborhood but single family houses across the watershed generally average about $175,000 in structural value according to the Tax Map Key (TMK) data. It is not unusual for the City and County of Honolulu's total TMK value to be as much as 90 percent land value, which is not subjected to inundation damages in USACE flood risk management studies. There are about 4,000 homes located within the 0.2 percent ACE (500-

year) floodplain of the Ala Wai Canal Project. Most of the homes were built in the 1970s and 1980s, with the average construction year for residences in the floodplain is about 1980.

3.1.2. Typical Commercial Structures. Similarly, commercial development in the Ala Wai Canal watershed is generally comprised of two and three story structures lining both sides of the neighborhood thoroughfares and business districts. Typically, the street level will be a continuous strip of shops, restaurants and offices. Second and third floors of these business districts are generally more dedicated to offices and apartments. Waikiki is exceptionally densely developed with 2 to 40-story luxury hotels, and upscale restaurants and boutiques. Ala Moana is similarly developed and, in addition, has one of the largest shopping malls in the U.S. with areas of multiple level parking. Many of the commercial structures in the Ala Wai Canal watershed inventory have been in existence for over 20 years and, for the most part, have been well maintained. There are about 1,000 commercial structures in the Ala Wai Canal Project).2 percent ACE floodplain, averaging about $650,000 in structural value. Their structural values vary greatly considering the large range in their sizes effectively making an average structural value fairly meaningless. As with residential properties, compared with the rest of the U.S., the portion of the total TMK value that is based on land value is disproportionately high.

3.1.3. Typical Public Structures. For reporting purposes, the public structures in the watershed are lumped together with the commercial structures and together make up what is called the "non-residential" category. These public buildings are typically large, multi-storied structures averaging between $5 and $6 million in value. There are about 100 of them located throughout the flood plain of the Ala Wai Canal watershed. There are about two dozen public and private school and college complexes in the watershed, most notably, the University of Hawaii's main campus at Manoa. About 90 acres of this 320-acre campus is within the 0.2 percent ACE floodplain. Over 20,000 college students attend classes at the Manoa campus. In addition to the University of Hawaii, there are at least another 20,000 students enrolled in the other schools and institutions in the primary impact area of the Ala Wai Canal Project in what would have to be the heaviest concentration of students in the entire State.

There are nearly 150 buildings spread throughout the University of Hawaii's campus totaling about $3 billion in structure and content assets. More than 100 of these buildings are greater than 10,000 square feet and about 20 exceed 100,000 square feet of floor space. About 40 of the campus buildings are susceptible to flooding by the 0.2 percent ACE event. Included in these is the 400,000 square foot Hamilton Library, which sustained $60 million in damages in the 2004 flood. The entire campus suffered between $80 and $100 million from that event, depending on source quoted. The athletic complexes and fields in the old quarry section of campus are also susceptible to flooding.

3.1.4. **Parks**. It is probably safe to say, if land in the watershed is developable, it has already been built on. The exception would be the land that has been dedicated to City and County parks and green space in these neighborhoods. There are about 400 acres of parklands in the watershed, including two regional parks, as documented in the Recreation Appendix.

3.1.5. The Economic Engine, Waikiki. Tourism is the heart of Hawaii's economy and Waikiki is the heart of its tourism. Through tourism, Waikiki has become the "economic

engine" of the State and one of the most famous beaches in the world. It also comprises the single most valuable neighborhood in the Ala Wai Canal Project area, and the one that would suffer the most flood damage and highest risk of loss of life from a catastrophic event.

About one-half of Hawaii's hotel rooms, about 30,000, are in Waikiki, and about one-half of visiting tourists to the State spend time there. That can add 70,000 to 80,000 visitors a day to the permanent population of about 28,000 (DBEDT, 2003). Added to that population is the estimated 37,500 workers employed there and on any given day, the beach community can see its population swell to over 130,000. That is more than 100,000 additional people than represented in the permanent population shown in Table B-1.

In addition to the 37,500 jobs within Waikiki, there are another 100,000 indirectly supported by the economic activity there. An estimated 45 percent of the State's total tourism expenditure of $14.4 billion was spent in Waikiki in 2013. That breaks down to about $40 million a day or about $1.67 million an hour in visitor expenditures. Based on these figures, any disruptions in the flow of commerce that takes place in Waikiki will have repercussions for the entire state economy, and reducing the duration and intensity of flooding has the potential to prevent millions of dollars in lost sales for Waikiki businesses.

Accounting for more than $14 billion visitor expenditures in 2013, the tourism industry is unquestionably the lifeline of the State of Hawaii's economy; just as Waikiki is unquestionably the most important concentration in the State of hotels, restaurants, and other businesses catering to tourists. As shown is Table B-3, Waikiki directly or indirectly contributes about 7.4 percent of the State's gross domestic product, 7.2 percent of its civilian work force and 8.7 percent of its tax revenues. Waikiki is also home to almost one-half of the hotel rooms in Hawaii, and over 85 percent of the hotel rooms on Oahu. Economic impacts from flood events, or flood events avoided, cannot be limited to physical property damages only. Flooding within this highly concentrated center of the State's visitor industry can quickly translate into millions of dollars of lost revenue, lost wages and a total disruption of tens of thousands of tourists lives whether it be for hours, days or weeks. Finding alternative emergency accommodations for 80,000 overnight guests staying in Waikiki hotel rooms if flooding forced a mass evacuation would be an impracticable task. Many of these visitors could move upward to higher floors within hotel and condominium towers to escape the dangers of floodwaters, but that alone would not solve the overnight accommodation problems.

Table B-3. Contribution to the State's Economy by Statewide Visitor Industry and by Waikiki: 2013

Measure of Tourism	Statewide Visitor Industry Contribution To Economy		Waikiki Contribution To State Economy	
	Number	Percent	Number	Percent
Direct impact 1/				
Gross domestic product 2/	(X)	(X)	(X)	(X)
Civilian jobs 3/	104,870	12.8	46,156	5.6
State taxes ($millions)	1,008	15.8	444	7.0
Direct and indirect impact 4/				
Gross domestic product ($millions) 4/	12,569	16.7	5,532	7.4
Civilian jobs 3/	134,233	16.4	59,080	7.2
State taxes ($millions)	1,260	19.8	555	8.7

X Not applicable.

1/ Measures the impact of visitor expenditures on only those firms that sell directly to visitors.

2/ In this Input-Output analysis, direct and indirect GDP are not readily separated.

3/ Civilian jobs include wage and salary jobs plus self-employed but exclude military jobs.

4/ Measures the impact of visitor expenditures through all firms that contributed to goods and services sold to visitors.

Source: Hawaii State Department of Business, Economic Development & Tourism, records.

3.1.6. Are the Economic Impacts of Flooding RED or NED? In most instances, many of the economic impacts of flooding that come to mind would be primarily Regional Economic Development (RED) in nature and thus not included in an NED analysis. This is typically the case when in most areas of the U.S., if flood conditions were to force an evacuation or interruption in one hotel's business, those dollars will be re-directed to another hotel or some other goods or services; that is, there is no revenue loss on the national level. Such transfers are excluded from traditional NED analyses but may be captured in the RED account, which is viewed as less important to the nation as a whole. In Waikiki's case, however, this argument is less valid, and a sizable portion of what would normally be considered RED benefits may actually be NED benefits. This is especially the case with Waikiki hotel rooms; there simply are relatively few alternative rooms available on Oahu. More often than not, visitors to Oahu stay within the floodplain of the Ala Wai Canal Project, and for this they spend an average of more than $14 million per day in Waikiki alone.

First, because of its isolation from the rest of the nation and its uniqueness compared to other states in the U.S., Hawaii is more of a predetermined destination than perhaps any state in the nation, with the possible exception of Alaska. Hawaii is uniquely different from all the other American states and travelers are generally not as indifferent with plans to visit Hawaii as they might be when choosing between other states. If they come to Hawaii, tourists are more than likely going to find their way to Waikiki and the Ala Wai Canal Project area.
Second, the contention is that money moving between state economies generated from Federal expenditures (e.g., a harbor improvement) is normally considered a regional transfer, thereby

excluded from NED benefit analysis. This argument is diluted in Hawaii because a disproportional amount of money spent and invested in Hawaii comes from outside the U.S., and what would normally appear to be purely a regional benefit in other states is partly an NED benefit in Hawaii.

It is the international tourist's expenditures forgone that could be classified as NED benefits. Most International econometric models analyze expenditures or monetary injections from foreign sources separately from domestic expenditures. Statistics show that international visitors spend about 30% of the tourist dollars spent in Waikiki (Hawaii Data Book, Section 7, 2013). Some of these expenditures would be made up elsewhere in Honolulu but the hotel accommodations present a unique problem. If a massive flood where to shut down Waikiki, there simply would be nowhere on Oahu (or the entire state of Hawaii for that matter) to accommodate this many overnight guests, and most would probably end up in temporary shelters at no personal cost. Potentially, millions of dollars of expenditures could be lost in a matter of hours. Further, this would likely have a devastating effect of these tourists ever coming back to Hawaii or spending money on U.S. soil.

These international tourists willing to spend the money to come to Hawaii have made the conscientious decision that this is the kind of tropical vacation they are seeking and are not likely to substitute any other location in the United States to meet their expectations. The majority of them book hotels at Waikiki. The limited number of accommodations elsewhere on Oahu, and even the other Hawaiian islands, usually are at near capacity so transferring to another hotel is simply not an option for these thousands of visitors. The same case could be made for the U.S, tourists, but their expenditures are more likely to be deferred and made up somewhere in the U.S. economy at a later date.

Over recent years, foreign tourists have made up about 25 percent of the visitors to Hawaii and spend between $5 and $6 billion each year in the State. The daily census of foreign visitors in the State averages more than 50,000, and yield almost 20 million visitor days. About 75 percent of these visitor days are spent on Oahu, and the vast majority of these people stay at Waikiki. The Japanese comprise, by far, most of these visitors; followed by Koreans, Australians, Canadians and Chinese foreign visitors. In addition, the Japanese, on average, spend anywhere from 60 percent in 2013 to 85 percent in 2012 more than American tourists (Hawaii Data Book, Section 7, 2013).

It would be difficult to pinpoint exactly how much revenue from foreign sources could be lost because of a major flood event affecting Waikiki, and the low probability of such an event would effectively lessen the magnitude of the dollars expressed in an average annual basis. It is also not a given that this monetary impact of lost foreign revenue due to flooding could, in fact, pass as a NED benefit provided it could be prevented under with-project conditions. Suffice to say that the NED benefits that are claimed, herein, for the purpose of economic justification are on the conservative side.

Severe flooding in Waikiki will also have long-term economic effects. Evidence from past disasters show that some businesses take much longer to rebound than others and that some businesses never recover. Jobs are lost and properties go unused. The positive image of Waikiki

which industry officials work diligently to maintain could also be damaged. Reports of clogged roads and soaked businesses may take away some of Waikiki's allure in the minds of potential visitors. Reducing the level of flooding that might occur will help minimize these long-term impacts.

3.1.7. Other Business Activity in the Study Area. The businesses in areas surrounding Waikiki also stand to lose during a major flood event. Several thousand businesses are found in the floodplain of the Ala Wai Canal Project along congested corridors on Ala Moana Boulevard; including the largest mall in the State; Kalakaua Avenue; McCully Street; Kapiolani Boulevard; Kapahulu Avenue; University Avenue; Wai'alae Avenue; East Manoa Road; and portions of South King Street. Another important entity in the Ala Wai Canal Project area is the City and County of Honolulu's Ala Wai Golf Course. Established in the early 1930s, this public course generates millions of dollars each year and is considered the busiest golf course in the world. Located across the Ala Wai Canal from Waikiki, its 146 acres provides valuable storage area for flood water under both with and without-project conditions.

These Honolulu business establishments within the Ala Wai Canal Project area provide tens of thousands of jobs and generate annual payrolls totaling over $1 billion. The data also shows that a majority of these establishments were small businesses with less than 10 employees. These are the types of businesses that tend to have the least amount of resources to recover from a natural disaster. Under with-project conditions, some of these small business owners will be spared the hardships related to recovering from a major flood.

3.2. Damages to Residential and Non-Residential Structures and Contents. To estimate flood damages to structures and their contents, it was necessary to identify the following information for each structure in the floodplain:

- The watershed, and reach associated with the structure;
- The location or river station of each structure along the length of the watershed;
- The first floor elevation of each structure;
- The depreciated replacement value of each structure;
- The depth-damage relationship for each type of structure that describes the effect of flooding at various depths on the structure and its contents.

Structures were identified and were assigned watersheds, reaches, river stations and ground elevations using a geographical information system (GIS) map with layers for county TMK parcels, centroids (points) identifying structure locations, the floodplain coinciding with the 0.2 percent ACE event, a 2-foot contour interval, LIDAR elevation layer within the GIS, and aerial photographs of the project area. The floodplain was divided into 27 reaches that stretch across eight districts in Honolulu. More specifically, it covers from Makiki to Kapahulu Avenue. Within this area, there are about 5,000 commercial structures, public facilities, and houses; about 3,000 of which are within the 1 percent ACE floodplain, and about 1,000 within the 10 percent ACE floodplain. There is a total replacement cost less depreciation value of about $3 billion in structure value and an estimated total content value of about $1.5 billion within the 0.2 percent ACE floodplain at October 2013 price levels.

Most of the data on the structures in the floodplain and their characteristics were obtained from on-site, field surveys performed by USACE economists, or through the City and County of Honolulu Real Property Assessment Office, or a combination of the two. After identifying the initial structure inventory a windshield survey of about 500 structures was performed by USACE economists in July and August, 2009, to estimate general condition and quality of the structures. Other characteristics including interior area, year of construction, foundation type, and various construction features were obtained from the county assessor's web site, www.hawaiipropertytax.com. These characteristics were entered into the Marshall & Swift Residential Estimator ™ software program to obtain depreciated replacement costs for each structure in the inventory.

When using the estimator software, it requires the user to enter essential data about the structure. Some of those characteristics are zip code, square footage, exterior wall type, foundation, roof type, number of stories, structure condition, and so forth. The data is then processed and the depreciated replacement cost is calculated. Overall, the majority of the houses in the watershed was one story and occupied less than 5,000 square feet. The houses were also mostly wooden-framed; however, there was a mixture of concrete and raised foundations.

Inundation damages were computed by combining the estimated structure and content values with the anticipated extent of the flooding from various storms. The areas of flooding and the depths associated with the different events were computed as described in the hydraulic section. The effects of flooding on the structures in these reaches were measured using depth-damage relationships. These depth-damage "curves" relate depth of flooding to percent damages to structures and contents.

3.3. Adjusting Structure Values. Each parcel of land and improvements to the land is identified by a TMK, which is administered by the City and County of Honolulu. The City and County periodically appraises the properties, and displays the assessments on their database website. Although all the properties in the watershed have been appraised for taxation purposes, not all values that were investigated first hand by the team of economists were acceptable as being representative of depreciated replacement value as required by USACE regulations (Department of the Army, 2000; ER 1105-2-100). In fairness to the City and County Tax Department, this is not the same value they are charged with estimating. USACE regulations warn against blindly following TMK values as not being an acceptable practice in the inventorying process. Therefore, USACE economists performing the inventory of structures use a variety of resources at their disposal to complete their own estimate of structure value. These include TMK square footages, age of structures, Marshall & Swift ™ software cost factors, and input from local experts in Honolulu's building costs and depreciation.

Over the past 5 to 6 years, the HEC-FDA structure file for the Ala Wai Canal Project has undergone several major updates. For the purposes of this report, it has been updated to October 2013 (FY 2014) price levels. The most recent update took into account the TMK values of the winter of 2013-2014. These values were updated by the City and County of Honolulu appraisers only months earlier and are in line with the FY 2014 price levels used for the cost estimates in this study. Since the appraisals attempt to focus on market value and USACE guidelines require

that depreciated replacement value be used, in many cases the TMK values were adjusted to reflect the difference. After performing a windshield survey of the entire inventory of floodplain structures and confirming the USACE stipulations for structure values were met, as well as independently cross-checking a sample of these appraised values using Marshall and Swift Appraisal software, USACE economists believe the structure values used in this analysis to be a reasonably accurate representation of depreciated replacement value.

The initial HEC-FDA structure file update took place a few years earlier and brought the price level up to FY 2010. Due to the vast amount of inventory in the defined area, it was determined at that time that it would be impractical to survey each structure. Therefore, a sampling technique was implemented to randomly re-evaluate 10 percent of the properties. Marshall & Swift Real Estate Estimator ™ software was heavily relied upon to reappraise the value of hundreds of properties in the Ala Wai Canal watershed. After collecting the sample data from each neighborhood, using regression analysis performed through the Microsoft Excel function, it became apparent that patterns in the data were measurable and predictable.

Overall, five regressions equations were calculated for the districts of McCully/Moiliili, Kapahulu, Manoa, Palolo, and Makiki. Districts, such as Kaimuki, were distributed into nearby districts due to the lack of sample size to produce standardized results. In each regression, the Build Value found in the City and County database was the dependent variable, and the Marshall & Swift value was the independent variable. The coefficient of determination, R square, varied from a high of 0.81 in Manoa to a low of 0.58 in Palolo; however, all regressions had a Multiple R of over 0.7. In other words, they all demonstrated a reasonably high degree of statistical fit. Therefore, the systematic bias that was corrected for using the regression coefficients accounts for a large amount of variation between the tax assessment and Marshall & Swift valuations. In this case, a typical equation for regression analysis would be:

Marshall & Swift value = Build Value coefficient * Build Value + Intercept Coefficient

After correcting the Build Values using the regression coefficients, these values were plugged into the database as the final structure values for the floodplain inventory. The end result was judged to be fair representations of the depreciated replacement cost for structures at that time.

3.4. Content Values. The content values for residential structures were estimated using the generic relationship defined in the depth-damage curves found in Economic Guidance Memorandum (EGM) 04-01, *Generic Depth-Damage Relationships for Residential Structures*. The generic content damage models are statistically significant and their use eliminates the need to establish survey generated content to structure ratios.

Content values for non-residential structures were estimated using content value to structure value ratios from past USACE New Orleans District flood studies (USACE, 2006). Every non-residential structure in the watershed was grouped into one of 12 business type classifications, each with an individual content multiplier and depth-damage relationship. These generalized commercial and public building structure and content, depth-damage curves were developed by conducting surveys of actual business losses due to flooding. These curves were derived from a large sample size and are the results of rigorous testing. The replacement cost less depreciation

value of each structure was multiplied by the applicable content value to structure value ratio to estimate the value of the damageable contents in each building.

3.5. Non-Residential Depth-Damage Curves. Twelve depth-damage curves for non-residential structures and contents were taken from USACE, New Orleans District flood studies (USACE, 2006) for use in this analysis. Like the residential depth-damage curves, they represent the effects of short duration and freshwater flooding. To demonstrate the variance in these functions, Tables 4A and 4B show examples of two commonly used non-residential curves; Table B-4A is used for basic commercial businesses such as automotive garages; Table B-4B is used for unconventional or architecturally designed commercial businesses such as retail stores.

Table B-4A. A Basic Non-Residential Depth-Damage Curve

Feet of Flooding Over First Floor	Structure Damage (%)	Content Damage (%) (Single Story)
0	3	0
1	7	11
2	12	17
3	17	2
4	20	23
5	24	25
6	28	29
7	32	35
8	37	42
9	41	51
10	46	63

Table B-4B. An Unconventional Non-Residential Depth-Damage Curve

Feet of Flooding Over First Floor	Structure Damage (%)	Content Damage (%) (Single Story)
0	0	0
1	55	35
2	69	48
3	77	54
4	86	54
5	94	55
6	94	55
7	94	55
8	94	55
9	97	55
10	97	99

The roughly 1,100 commercial and public buildings within the 0.2 percent ACE floodplain of the Ala Wai Canal Project range from small shops and businesses to 40-plus story hotels and large public institutional buildings like hospitals and college classroom buildings. The large number

of structures precluded developing depth-damage relationships for each individual structure, while the range of structure sizes precluded meaningful use of depth-damage curves without some adjustment for the number of floors. Even in an event with a 0.2 percent ACE, floodwaters would not reach the second story of any structures in the floodplain. Consequently, it is practical to limit the area evaluated for flood damage to the first story of each structure. A simplifying assumption was therefore made that the depreciated replacement costs of each building's first story equaled the total depreciated replacement costs for the building divided by the number of stories in the building.

Table B-5 breaks down the entire structural inventory of the Ala Wai Canal's PMF floodplain to illustrate the frequency of usage for the various depth-damage curves and the total number, value and square footage of each type structure.

Table B-5. Breakdown of Ala Wai Structure Inventory Occupancy Type, PMF Floodplain

Occupancy Type	Total Value of Structures	Total SquareFootage	Number of Structures
BANK	$9,476,000	57,083	13
CHURCH	$9,572,000	66,661	20
COMM-1	$11,292,000	103,004	10
COMM-2	$7,900,000	35,475	4
CONVSTR	$25,259,000	487,315	165
GARAGE	$6,173,000	61,377	11
HOSPITAL	$43,989,000	53,306	12
HOTEL	$583,135,000	3,845,553	181
MFR1	$99,227,000	459,208	244
MFR2	$970,799,000	6,788,936	2,354
OFFICE	$244,276,000	5,670,940	692
PUB-1	$464,474,000	N/A	83
PUB-2	$924,938,000	N/A	138
REST	$63,082,000	601,720	98
RETAIL	$547,134,000	10,462,068	657
SFR1	$312,494,000	2,765,450	2,911
SFR2	$286,917,000	2,458,064	1,291
WAREHOUSE	$87,741,000	1,412,628	84
Total	**$4,697,878,000**	**35,328,788**	**8,968**

3.6. Residential Depth-Damage Curves. The residential curves were derived from a large sample size and are the results of rigorous testing as explained in the IWR report, EGM 04-01, *Generic Depth-Damage Relationships for Residential Structures.* The depth-damage curve in Table B-6 represents flood damage to single family, one story residential structures and contents from short duration, freshwater flooding. These are the most common residential structures found in the watershed. Other residential depth-damage curves represented in the model are single family two-story structures and multi-family, multi-storied structures. All three of these curves are based on a comprehensive accounting of losses from the records of victims of major flooding that occurred in various parts of the United States in 1996, 1997, and 1998.

Table B-6. Typical Residential Depth-Damage Curve

Feet of Flooding over First Floor	Structure Percent Damage (%)	Content * Percent Damage (%)
0	13.4	8.1
1	23.3	13.3
2	32.1	17.9
3	40.1	22.0
4	47.1	25.7
5	53.2	28.8
6	58.6	31.5
7	63.2	33.8
8	67.2	35.7
9	70.5	37.2
10	73.2	38.4

* Content damage percentages are a function of structure (and not content) value.

3.7. Stream Reaches. The floodplain of Ala Wai Canal Project was divided into 27 reaches for the economic analysis, while HEC-RAS uses 13 reaches to model the watershed's hydraulics. An economic reach may be associated with at most one hydraulic reach, but a single hydraulic reach may be associated with multiple economic reaches. The economic reaches are broken up by stream names and similar hydraulic and economic characteristics. The beginning damage frequency for each reach is shown in Table B-7. A more aggregated reach designation is also used in Table B-7, where these 27 reaches are grouped by the streams and their tributaries. This table also shows the index points used by the HEC-FDA model to represent each reach.

3.8. Risk and Uncertainty Analysis. Risk and uncertainty is fundamental to all water resource planning and communication, and each aspect of a flood risk assessment must account for risk and uncertainty. USACE risk assessment procedures were followed in this study to account for uncertainty in the information to the extent practicable. However, there is some project performance uncertainty in all studies, even with the risk assessment procedures.

This study incorporated risk management framework principles and risk-informed planning into the plan formulation process. The analysis follows guidance described in ER 1105-2-101: Risk Analysis for Flood Damage Reduction Studies. As stated in the ER, "A variety of planning and design variables may be incorporated into risk analysis in a flood damage reduction study. Economic Variables in an urban situation may include, but are not limited to, depth-damage curves, structure values, content values, structure first-floor elevations, structure types, flood warning times, and flood evacuation effectiveness. The uncertainty of these variables may be due to sampling, measurement, estimation, and forecasting." Specific examples include the following:

- Risk analysis and communication was conducted, consistent with ER 1105-2-101, Risk Analysis for Flood Damage Reduction Studies, and EM 1110-2-1619, Risk-Based Analysis for Flood Risk Management Studies.
- The Project Delivery Team (PDT) incorporated risk-informed decision making into the planning process. An internal document (referred to as the risk register) was developed and used to document and carry forward those risk management concepts.

- Uncertainty was captured through cost engineering's mandatory risk assessment process to establish cost contingencies. The economic analysis developed ranges of economic outputs with mid and mean number ranges to best capture uncertainties and identify risks in the risk register.
- Risk and uncertainty ranges were iteratively refined for costs and economics with each subsequent level of design. This analysis confirmed the conceptual numbers were still within the established ranges of uncertainty, validating assumptions and risk decisions.

3.8.1. First Floor Elevations. First floor elevations were estimated using an aerial survey topographical map with five-foot contours. According to "Risk-based Analysis for Flood-damage-reduction Studies" (Department of the Army, 1996; EM 1110-2-1619), the standard deviation of the measurement error for such a map is 0.60 feet. However, 0.70 feet was used for a more conservative approach and was recommended by the hydraulic engineer.

3.8.2. Structure Value. According to "Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations (IWR 95-R-9, April 1995, page 43)," tax assessment data can be used as a proxy for depreciated replacement value when the assessment (1) has been performed recently, (2) gives consideration to effective age, remaining life, etc., (3) assesses land and improvements separately, and (4) when the economic depreciation is negligible. Most commercial, public, and residential property values used for this study were obtained from the City and County of Honolulu Tax Map Keys (TMKs) which can be accessed online. The According to Sec. 8-7.1, Revised Ordinances of Honolulu, it requires the fair market value of all real property to be determined and annually assessed by the market data and cost approaches to value. The properties are valued at 100 percent of market value, land values are tabulated separately from structure value and age of the structure is accounted for in determining its value. As explained in Section 3.3, the structure file currently being used in the HEC-FDA program has undergone two major updates while studying the Ala Wai Canal Project. USACE economists believe the structure values used in this analysis to be reasonably accurate representations of depreciated replacement values as of October 2013 price levels.

3.8.3. Content Value. Content values for non-residential and residential properties were based on a Content-to-Structure ratio as given in EGM 04-01.

3.8.4. Hydrology and Hydraulics (H&H) Exceedance Probability Functions. Functions were derived by using the HEC-FDA "Graphical from WSP" function with a 50 year equivalent record length for each reach. Refer to the H&H Appendix for more details on these and the following functions.

3.8.5. H&H Stage-Discharge Function. Functions were derived by using the "Retrieve from WSP" function using Normal Distribution and a standard deviation of 0.7 feet.

3.8.6. Residential Depth-Percent Damage Functions. This analysis uses generic IWR depth-damage functions and depth-damage functions with associated uncertainty parameters described in the U.S. Army Corps of Engineers Economic Guidance Memorandum (EGM) 04-01, "Generic Depth-Damage Relationships for Residential Structures with Basements." The EGM also list depth-damage relationships for structures without basements, which were used in this analysis.

The standard deviation of measure error is listed for each level of flooding in the damage schedules.

3.8.7. Commercial Depth-Percent Damage Functions. This analysis uses IWR depth-damage functions and depth-damage functions developed for the USACE New Orleans District to estimate the effects of flooding on commercial structures and contents (USACE, 2006). A panel of experts composed of one general contractor, one insurance adjuster, and one certified restorer was asked to estimate damages to three types of commercial structure construction at various flooding depths. Of the three types (metal frame walls, masonry walls, and wood or steel frame), the damage function for masonry walls under freshwater conditions were used in this study as best representing the commercial structures in the Ala Wai Canal watershed.

3.8.8. Probabilistic Values of Damages and Damages Reduced. The HEC-FDA program calculates both expected reduction in mean damages, and the amount of with-project damages that are likely to be exceeded at three specific levels of probability. This information is required by ER 1105-2-101. These numbers do not include reduction in the operating cost of the National Flood Insurance Program.

3.9. Structure Elevations. The estimated first floor elevations of residential and commercial structures were obtained by USACE personnel using 2008 LIDAR data obtained from GIS metadata developed especially for the Ala Wai Canal Project. Ground elevations were joined to the TMK data within the GIS for each structure. By conducting windshield surveys of 10 percent of the total structures in the Ala Wai floodplain, USACE personnel established that the average structure has a first finished floor elevation of 2.0 feet above its ground level. The ground elevation plus this 2-foot average height to the first floor, rounded to the nearest tenth of a foot, was entered into the structure file. To account for Risk and uncertainty of structure elevations, a standard deviation of first floor elevation error of 0.6 feet was used for all structures based on Table B-6-5 in EM 1110-2-1619 (Department of the Army, 1996).

3.10. Refining the Model. Where historical flood data were available, as was the case with the University of Hawaii, the model inputs were adjusted to bring results in line with these records. Unfortunately, there is little data available to use for making such adjustments. As stated in Section 1.4, there is no historic record of an event in the Ala Wai Canal watershed that would be considered extremely rare, such as a 2 percent ACE flood.

Adjustments in the model were also made to the HEC-FDA model to account for such things as flood proofed buildings and dry streams that only exist after flood waters jump from the main streams, a condition that cannot be modeled in the program. The software requires a nominal flow greater than zero and that a water surface elevation be specified, even for return periods where no flow is expected, and that both flow and elevation increase monotonically as frequency decreases. For instance, the floodway through the three University reaches contain water only when it is fed by overflow from Manoa Stream. In the without-project condition, the University reaches have no flow for events with a return period of 20-years or less. Ideally, a flow of zero would be entered into HEC-FDA for these conditions with no water surface elevation, since none would exist. Because this is not possible, false levees were created to truncate flooding where it could not logically occur.

3.11. Model Results. Specifically, HEC-FDA needs three data functions of the existing conditions: discharge-frequency, depth-discharge, and depth-damage. From these functions, the frequency-damage function can be derived. Once this occurs, a depth-damage curve, certified by the Institute of Water Resources (IWR) or the USACE Center of Expertise, can be applied to the structure inventory, which leads to the EAD value.

3.11.1. Where Damages Begin. Table B-7 shows a reach by reach account of the beginning damage point by percent ACE event.

Table B-7. Beginning Damage by Reach

Stream	Reach	Index Point	Beginning Damage % ACE
ALA WAI			
Ala Wai	ALA1	1477	20
Ala Wai	ALA2	4847	20
Ala Wai	ALA3	8015	20
Manoa-Palolo Canal	MPC1	1813	10
Manoa-Palolo Canal	MPC2	3406	5
MAKIKI			
Makiki	MAK1	1719	10
Makiki	MAK2	4325	10
Makiki	MAK3	6606	5
Makiki	MAK4	9666	5
Kanaha Split	KAO1	1393	50
Kanaha Ditch	KAH1	1874	10
Kanaha Ditch	KAH2	3005	10
MANOA			
Manoa	MAN1	948	20
Manoa	MAN2	5461	5
Manoa	MAN3	8367	5
Manoa	MAN4	9032	5
Manoa	MAN5	10309	10
Manoa	MAN6	13136	5
Manoa	MAN7	15753	2
University	UNI1	1107	2
University	UNI2	4606	2
PALOLO			
Palolo	PAL1	6376	10
Palolo	PAL2	8574	2
Palolo	PAL3	11649	10
Palolo	PAL4	14619	10
Pukele	PUK1	2184	1
Waiomao	WAI1	1724	0.2

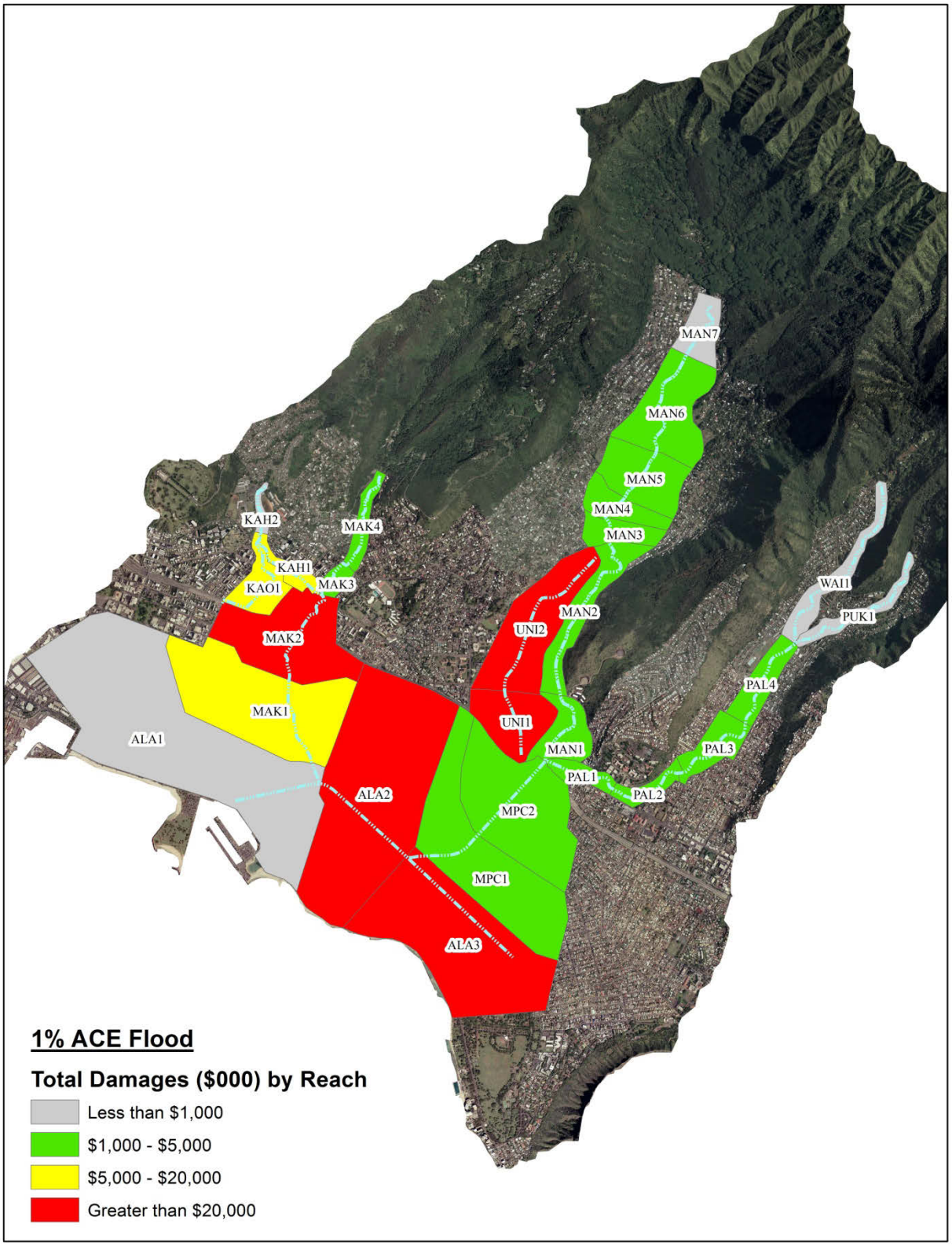
3.11.2. Total Damages. Table B-8 displays projected without-project total inundation damages for the entire array of event frequencies by damage category. As the table shows, the 1 percent ACE flood would cause an estimated $318million in property damage. Commercial and public property damage is, by far, the most significant damage category. The term "total damage" at this point in the economic modeling effort, refers to flood damages to structures and contents. Other less significant damages and other NED benefit categories, such as landscape damages and travel delay reductions, could add an additional 20 percent or more to the total damage figures. There is also the point made earlier in this appendix that total damages and NED benefits could be understated because of negative impacts from flooding to other than domestic spending sources.

Table B-8. Total Damages ($000) Without-Project - HEC-FDA Calculated with Uncertainty by Frequency and Stream (Oct 2013 Price Levels)

Exceedance Probability	Ala Wai	Makiki	Manoa	Palolo	Total
0.5	$1.7	$69.8	$0.0	$0.0	$71.6
0.2	$23,849.5	$1,000.4	$6.5	$0.0	$24,856.5
0.1	$46,140.5	$2,182.4	$236.9	$36.6	$48,596.5
0.05	$67,428.4	$5,895.5	$2,223.7	$1,457.5	$77,005.1
0.02	$98,753.4	$19,345.2	$39,256.9	$3,625.3	$160,980.9
0.01	$142,589.3	$90,408.7	$77,388.0	$7,457.3	$317,843.3
0.005	$184,867.7	$106,485.7	$118,603.5	$17,705.4	$427,662.3
0.002	$273,700.8	$135,213.9	$232,462.3	$29,929.5	$671,306.5

Figure B-2 shows by color-coded reaches the range of total damages under without-project conditions for the 1 percent ACE flood. Reaches ALA2 and ALA3, which consist of many of Waikiki's landmark hotels, are the largest contributors to total damages.

Figure B-2. Ala Wai Canal Project Without-Project 1% ACE Event Total Damage by Reach.



3.11.3. Without-Project Expected Annual Damages (EAD). Table B-9 presents total without-project EAD for each damage category and by reach. EAD by reach for the entire watershed totals $21,256,000. If the two Manoa-Palolo Drainage Canal reaches are included with the Ala Wai Canal reaches as shown in Table B-9, these lower reaches comprise about two-thirds of the without-project EAD. This area surrounding the Ala Wai Canal is clearly the where most of the greater watershed's flood problems exist. The remainder of the overall watershed's flood problems in descending order shows that Makiki Stream reaches would contribute the next highest damage totals, followed closely by the Manoa Stream reaches and, lastly, the Palolo Stream reaches.

About 48 percent of the total structure and content EAD for the entire watershed is residential including large condominiums, about 40 percent is commercial including large hotels, and about 12 percent is public or institutional including the University of Hawaii campus. The Ala Wai Canal reaches (includes Manoa-Palolo Canal) comprise about 68 percent of the total EAD for the entire watershed. It is important to understand that despite the commercial significance of Waikiki Beach, this flood risk management project is just as much, if not more, about protecting residential property.

With only a smattering of historical data from relatively small and localized past floods, it is not possible to substantiate this EAD of about $21 million. Based on the sheer value found in the floodplain and the vulnerability of properties to inundation damage, and similar densely developed urban flooding in other areas of the county, it is judged to be reasonable.

Figure B-3 shows expected annual damages (EAD) by color-coded reaches under without-project conditions.

Figure B-3. Ala Wai Canal Project Without-Project EAD by Reach

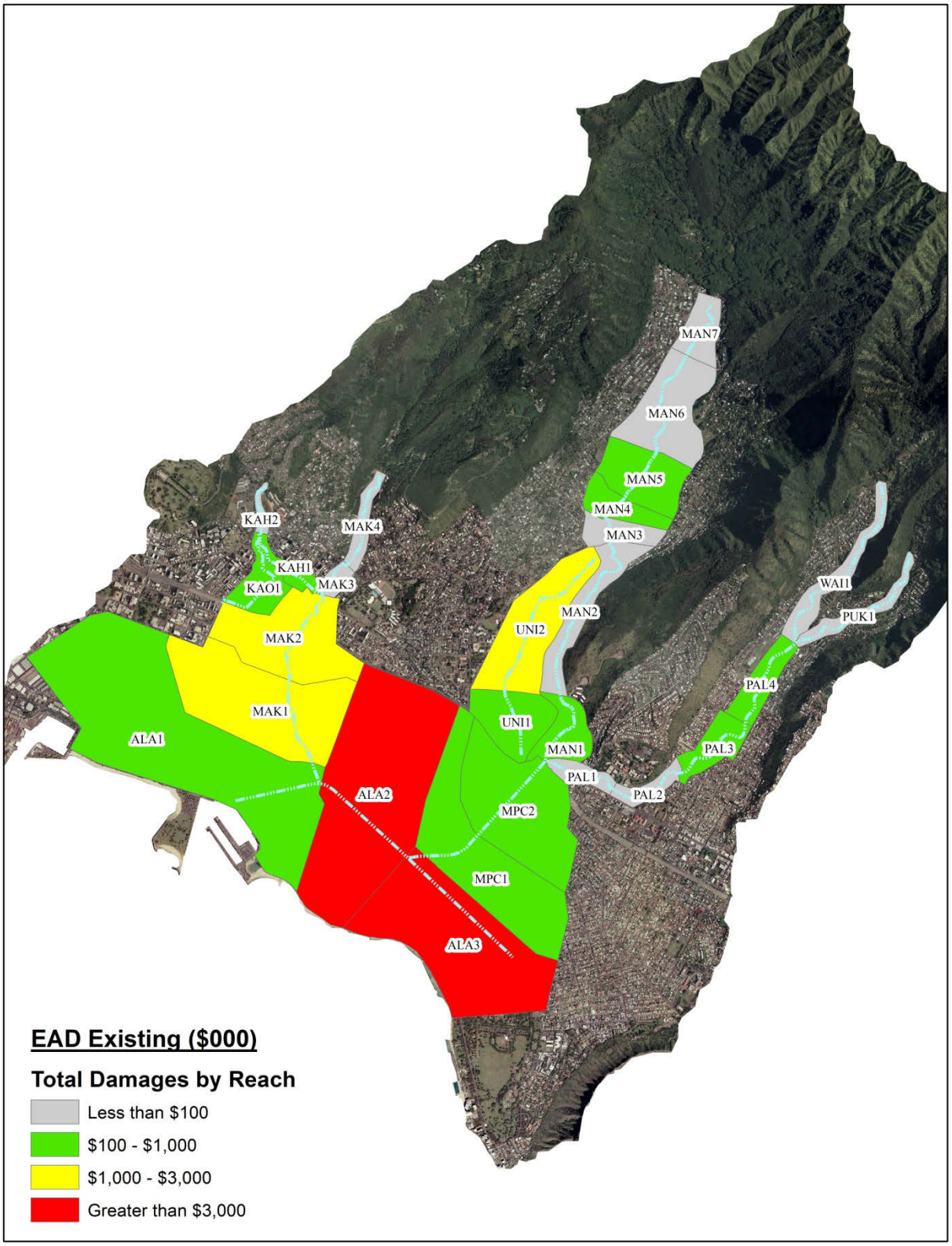


Table B-9. Without-Project EAD by Reach

Ala Wai Canal Project TSP Without-Project Expected Annual Damages by Reach ($000)				
Reach	Damage Categories			Residual Damages
	Commercial	Public	Residential	
ALA1	$646.9	$22.2	$70.1	$739.2
ALA2	$1,668.7	$203.3	$4,600.1	$6,472.1
ALA3	$4,650.8	$212.2	$1,921.6	$6,784.6
MPC1	$51.6	$0.0	$78.8	$130.4
MPC2	$128.0	$0.3	$221.5	$349.8
Ala Wai Subtotal	**$7,145.9**	**$438.0**	**$6,892.2**	**$14,476.1**
KAH1	$0.0	$0.0	$418.7	$418.7
KAH2	$0.0	$0.0	$9.4	$9.4
KAO1	$74.7	$0.0	$397.1	$471.8
MAK1	$439.9	$0.0	$674.9	$1,114.8
MAK2	$761.5	$7.5	$539.6	$1,308.5
MAK3	$0.2	$0.0	$38.5	$38.7
MAK4	$0.0	$0.0	$66.6	$66.6
Makiki Subtotal	**$1,276.2**	**$7.5**	**$2,144.8**	**$3,428.5**
MAN1	$0.0	$74.6	$192.5	$267.1
MAN2	$0.0	$62.6	$0.5	$63.1
MAN3	$23.1	$2.3	$49.9	$75.3
MAN4	$2.5	$0.0	$227.2	$229.7
MAN5	$3.9	$0.0	$165.6	$169.5
MAN6	$0.0	$0.0	$87.7	$87.7
MAN7	$0.0	$0.0	$10.4	$10.4
UNI1	$0.0	$688.2	$0.0	$688.2
UNI2	$0.0	$1,273.3	$0.0	$1,273.3
Manoa Subtotal	**$29.6**	**$2,101.0**	**$733.7**	**$2,864.3**
PAL1	$0.0	$0.0	$64.2	$64.2
PAL2	$0.8	$0.0	$89.6	$90.5
PAL3	$0.0	$0.0	$218.5	$218.5
PAL4	$0.0	$10.6	$100.7	$111.3
PUK1	$0.0	$0.7	$1.8	$2.5
WAI1	$0.0	$0.1	$0.0	$0.1
Palolo Subtotal	**$0.8**	**$11.4**	**$474.8**	**$487.0**
TOTAL	**$8,452.5**	**$2,557.9**	**$10,245.5**	**$21,255.9**

3.11.4. Other Flood Damage Categories. In addition to structural and content damages to residential and commercial structures, flooding also causes damages to motor vehicles, landscaping around homes and business, parking lots, streets and utilities. Flooding also causes traffic delays and necessitates emergency assistance costs. For example, there was about $1.5

million in emergency assistance expenditures associated with the Niu Valley relief effort in 1988. A flood risk management project for the Ala Wai Canal watershed could reduce the amount of flood related expenses for mitigating these other categories of inundation damages.

Individually, the contribution of each of these other flood damage categories to the total EAD in the watershed could be considered relatively minor in the overall consequence picture. However, collectively these other types of damages could increase total EAD (and expected annual benefits under with-project conditions) on the order of an additional 20 percent. Take streets and thoroughfares for example. There is an estimated 68 miles of neighborhood streets and thoroughfares within the floodplain of Ala Wai Canal Project. At $400,000 (Hawaii DOT) per mile, that is about $27 million worth of roads. Although roadways can come through flooding situations with little apparent damage, in many cases, rapidly moving flood waters can destroy sections of pavement and damage bridges necessitating expensive repairs. Damaged or debris blocked roadways also lead to traffic delays and traffic delays prevented could be another category of flood damages. An estimated 250,000 vehicles traverse the Ala Wai Canal watershed every day, about 60,000 of which travel through Waikiki. Road closures would be a major inconvenience to these motorists, and reducing or eliminating these delays would represent a benefit of a flood risk management project.

3.12. Future Without-Project Conditions. USACE planning guidance for civil works projects (Department of the Army, 2000; ER 1105-2-100) requires that the planning process incorporate a future without-project scenario. The future without-project condition attempts to describe the Ala Wai Canal watershed's future makeup if there is no Federal action taken to solve the flood risk problem. This forecast becomes the basis for evaluation of project alternatives. For the Ala Wai Canal Project, the base year is 2026. Thus, the 50-year forecast period starts at 2026 and ends in 2076.

Given the great degree of uncertainty, the future condition represents a best guess of conditions in the watershed over the 50-year planning horizon. The guidance states that the planning process accounts for such future conditions such as climate variability, sea-level rise, subsidence, seismic influences, geomorphological changes, and changes from development which can place demands on the project systems during their life-cycle. The most significant of these changes over the next 50 years will likely be changes in development patterns and sea-level rise (SLR). As for development changes, there is little room for new development without re-development in the Ala Wai Canal watershed. In other words, for something new to go in, something must come out. In spite of the recession of the last couple of years, growth has continued in some areas of the watershed, albeit much slower than the booming 1990s. In Waikiki, for instance, several high-profile condominiums and hotels have gone up over the last several years. More than 500 new units were added with the coming of the luxury condominium projects the Allure Waikiki and the Watermark Waikiki. In 2009, the five-star Trump Hotel and Tower added another 464 units. In 2010, the Hilton Grand Waikikian opened another 331 new units. Over the same period, several new commercial ventures opened including the $535 million redevelopment of Waikiki Beach Walk and the $85 million revamping of the Royal Hawaiian Shopping Center. In addition, accompanying these large projects were many new businesses and smaller residential projects, as well as a significant number of hotel room renovations. Ala Moana and Makiki have also seen several significant new condominium and other redevelopment projects over the last

few years. Other neighborhoods in the watershed have shown little growth or, as with McCully and Moiliili, had a net out migration of people in the last decade.

The most significant development trend for the foreseeable future according to the City and County of Honolulu's Department of Planning and Permitting (DPP), is that older residential single family development will give way to more high rise and denser residential structures; i.e., condominiums and multistory apartment buildings. This will effectively bring more people into the watershed, while increasing its asset base. There will also be the normal replacement of older with new homes, but no large single family housing projects are projected. There are dozens of sites, however, that are currently underutilized, or not developed to their highest possible potential, that could be put to a higher use if redeveloped. However, to reflect this city-wide trend with corresponding changes to the structure database used to define the future without-project condition would introduce a great deal more uncertainty into the model. With no definite plans or permits on the books, predicting which of these will be improved would be impossible. For that reason, the same structure base used to define the base year without-project damage conditions is used for the future without-project condition. That is not to say that there will not be changes in the business and residential makeup of the watershed between now and the year 2076. It has more to do with the uncertainty of what those changes will be.

One of the forecast requirements is to account for future hydrologic changes in the project evaluations. The other most significant factor likely to increase flood damages in the future is SLR. To account for the uncertainty of how much sea level is expected to rise between 2026 and 2076, three scenarios were created and modeled to create potential future floodplains for the Ala Wai Canal watershed in accordance with USACE guidance (Department of the Army, 2009; EC 1165-2-211). The intermediate condition was selected as the most probable future condition and the low and high conditions as the bounds or confidence limits to that estimated condition. Thus, the most probable future is the intermediate scenario. The low scenario would represent a best case or actual continuation of current trends for SLR and rainfall intensity while the high scenario would represent a worst case scenario.

3.13. Future Total Damage Results. Results for the three sea-level rise scenarios, as detailed in the Climate Change Scenarios Appendix, range from 0.26 to 2.23 feet in 2076. The sea-level rise impacts have been incorporated into the starting backwater conditions of the Ala Wai Canal Project HEC-RAS model which currently assumes a high tide of 1.08 feet. When added to the high tide value, the various sea-level rise scenarios add to the starting water surface elevations for the low, intermediate, and high scenarios between 1.3 and 3.30 feet. In all but the high scenario, the resultant water-surface elevation increases were higher than the sea-level rise. In all of the future scenarios, low to high, the amount of discharge leaving the Ala Wai Canal through Waikiki was consistently higher for all percent chance floods. Obviously, together these factors make for much worse flooding potential as time goes by.

As sea-level rises over the coming decades, tidal and backwater impacts during periods of riverine flooding will cause higher water surface elevations corresponding to various frequency storms. Therefore, development that was on the cusp of the existing floodplain will clearly be inside its boundaries in the future. Likewise, it is also true that development that was out of, for instance, the 20 or 50-percent ACE floodplains during the first few years of the period of

analysis, will be squarely in these floodplains toward the end of the next 50-years. Although it is not captured in the modeling, and despite enforcement of floodplain regulations deterring new growth within the 1 percent ACE floodplain, the combination of expanding the without-project future floodplain by adding more structures of higher density and applying across-the-board increases in water surface elevations of event frequencies due to SLR, if nothing is done to reduce the risk of flooding in the Ala Wai Canal watershed, flood damage will likely increase throughout the 50-year period of analysis.

When running most likely future condition scenarios, HEC-FDA first computes new EAD for the future year, in this case 2076. Then, the computed stream of EAD out to the year 2076 must be discounted at the prescribed interest rate and annualized to obtain the "equivalent" expected annual damage (EEAD) before it can be compared to the base year EAD. The EEAD will be computed for the low, intermediate and high SLR scenarios. Most of the higher potential for flood damage in the future is attributable to increases in the water surface elevations due to future SLR. This is particularly true for the more frequent storms.

The future condition HEC-RAS and HEC-FDA runs have not been updated since 2012. The plan is to address future H&H conditions and their impact on the economics in the Pre-engineering and Design Phase (PED) Phase when model refinements such as the use of an unsteady flow H&H model are expected to add to the accuracy of such calculations. Consequently, the structure file for HEC-FDA runs was not changed over the 50-year period of analysis. In the final analysis, the future H&H modeling with the intermediate sea level rise will unquestionably increase EAD, but when discounted back to base year's price levels, the final equivalent expected annual damage will likely be slightly higher than the existing without-project condition EAD; that is, the effect of discounting future results tends to minimize the variation between future without-project conditions and base year conditions.

4.0. THE WITH-PROJECT CONDITION

As described in Chapters 3 and 4of the main Feasibility Report, Alternative 3A was chosen as the Tentative Selected Plan (TSP) and the NED Plan. The following is a short description of this multi-faceted, basin-wide plan:

- Ala Wai Canal Floodwalls;
- Multi-purpose detention basins at Ala Wai Golf Course and Kanewai Field;
- Detention basins at Hausten and Woodlawn ditches;
- In-stream debris basin at Manoa District Park; and a
- Flood warning system.

4.1. The Plan Selection Process. The plan formulation for this project follows the new USACE guidelines for implementing the SMART Planning paradigm (Department of the Army, 2014). For a general description of SMART Planning, go to Section 1.8 of the main Feasibility Report. To reduce the size and repetitiveness of this document, please refer to Chapters 3 and 4 of the main Feasibility Report for a complete account of how the PDT screened through various project alternatives and arrived at the recommended TSP. Planning objectives and selection criteria are also covered in detail in these other sections of the report. This economic appendix picks up the

SMART planning process in the later stages of plan comparison and describes and displays the economics behind such decisions as:

- How Alternative 5, the Stand-Alone Nonstructural Plan, was developed and why it was dropped from further consideration;
- Why Alternative 3A was selected as superior to Alternative 2A in the Final Array stage;
- How the multi-measures of Alternative 3A were incrementally justified;
- How Alternative 3A was optimized and emerged as the most cost effective plan, NED Plan;
- How the NED Plan also proved to be the TSP; and,
- How the TSP/NED Plan has greater than 95 percent confidence level of passing the 1 percent ACE event.

4.2. The Nonstructural Alternative (Alternative 5). Early in the formulation stages of the Ala Wai Canal Project, the PDT settled on the Flood Risk Management Objective of the study to be to reduce riverine flood hazards to property and life safety in the Ala Wai Canal watershed. This section of the economic appendix describes how the PDT attempted to weave nonstructural solutions into the overall study objective of reducing the risk of flooding.

4.2.1. Background. First, however, some general background and description of nonstructural solutions should prove helpful. Flood risk in the United States continues to increase despite many efforts during the past decades to reduce and eliminate that risk. Flood risk is defined as the product of the frequency of flooding and the consequences of flooding. Early efforts to reduce flood risk were focused on controlling floods by reducing the frequency of flooding with the use of structural alternatives such as dams, levees, channels, and diversions. These structural alternatives modified the characteristics of floods. This concept began to fade in the 1960's as it became apparent that structural means alone could not reliably control nature and contain flooding.

The focus then evolved to flood damage reduction. The theory with the flood damage reduction focus was in order to reduce flood damage from an economic perspective the focus had to be not only on reducing the frequency of flooding but also the consequences of flooding. The flooding could be made less damaging through modifying the characteristics of floods (structural alternatives), and also modifying the characteristics of development in the floodplain and the behavior of people living within the floodplain (nonstructural alternatives). Flood damage reduction focused primarily on damages and their effects on the economy.

Many believe that the national sentiment over recent years has gradually shifted its thinking from merely reducing property damage due to flooding to overall flood risk reduction and flood risk management. The nation has recognized that the adverse affects of flooding were manifested comprehensively across many categories including loss of life, rather than simply economic damages. In the flood risk reduction/flood risk management environment, floodplain/flood risk

managers realize that to effectively reduce flood risk, as many "tools" in the flood risk reduction "toolbox" as practicable must be used. These "tools" include both structural and nonstructural measures. These nonstructural measures, when considered in the context of reducing flood risk, become alternatives that can be compared with structural alternatives. (USACE, 2011).
Even before Section 2033 of the Water Resources Development Act of 2007 stressed that Principles and Guidelines was to be revised to ensure both nonstructural and structural alternatives are to be evaluated equitably, it was USACE policy to present and analyze for economic feasibility a purely nonstructural plan as an alternative to traditional structural solutions. Nonstructural measures are proven methods and techniques for reducing flood risk and flood damages in floodplains. Today, nonstructural measures are required to have equal consideration to structural measures in USACE studies, and, in many cases, have been shown to provide justifiable benefits.

The overall purpose of a nonstructural alternative is to reduce flood risk. Nonstructural alternatives reduce flood risk by modifying the characteristics of the buildings and structures that are subject to floods or modifying the behavior of people living in or near floodplains. In general, nonstructural alternatives do not modify the characteristics of floods nor do they induce development in a floodplain that is inconsistent with reducing flood risk. In contrast, structural alternatives reduce flood risk by modifying the characteristics of the flood. Structural alternatives do not modify the characteristics of existing development in the floodplain. Because structural alternatives reduce the frequency of flooding within a particular floodplain, they can affect the behavior of people living in or near the floodplain by allowing them to think that the floodplain is no longer subject to flooding. Because of this, structural alternatives, while they decrease the frequency of flooding, can actually increase flood risk if the consequences of flooding are allowed to increase. This occurs when new development is placed in the floodplain that is inconsistent with reducing flood risk (USACE, 2011).

A particular advantage of nonstructural measures when compared to structural measures is the ability of nonstructural measures to be sustainable over the long term with minimal costs for operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). Nonstructural measures require different implementation as compared to structural measures. Since each structure is owned and occupied by people, agreements must be entered into with each owner. In order to achieve flood risk/flood damage reduction, structure owners need to participate in any project incorporating nonstructural measures. This can be either voluntary or mandatory depending upon the needs of the project and the desires of the community. Voluntary is always the preferred method of implementation, but could result in a patchwork effect due to some owners refusing to participate in the project. The ability of nonstructural measures to be implemented in very small increments, each increment producing flood risk reduction benefits, and the ability to initiate and close a nonstructural program with relatively minimal costs are important characteristics of this form of flood risk reduction (USACE, 2011).

There are some important limiting factors when it comes to nonstructural solutions. For instance, flood proofing does not result in a high level of protection (about 3 feet in most cases is the limit); therefore, the residual risk is high as the failure of the flood proofing measures may result in damages that equal or exceed the without-project condition. Further, solutions like

permanent relocation and acquisitions generally prove to be quite expensive and identifying sufficient benefits in flood risk reduction to justify these costs can be a daunting task.

Nonstructural flood risk management utilizes measures to prepare for and prevent flood damage in the floodplain without altering structural aspects of the waterway. These measures do not alter the characteristics of the flood path itself via hydraulic structures, e.g., levees, diversions, detention dams, etc., Effectively, NS measures remove the people from the flood in contrast to structural measures which remove the flood from the people (NFPC 2001). Nonstructural measures do not affect the stage-discharge relationship significantly and instead focus on modifying the stage-damage relationship within the floodplain and reducing the risks to people living or working in the floodplain (Adams, 2014).

Nonstructural measures are cost shared at 65 percent Federal /35 percent non-Federal just like structural measures. Nonstructural measures include raising, relocating and acquiring or buying-out structures, implementing flood warning and preparedness systems, floodplain restoration, flood proofing, and building individual ring walls or low elevation, earthen berms and floodwalls for a small cluster of buildings. Once again, nonstructural measures change the use of the floodplain or accommodate existing uses in the floodplain, without changing the extents and nature of the flood itself.

Flood warning systems are another form of nonstructural solutions and one was developed for the Ala Wai Canal Project area. There is no separate economic justification for the Ala Wai Canal watershed flood warning system; it contributes to improving life safety and community resilience for a relatively small cost. More on the cost and composition of this flood warning system can be found in the H&H appendix. Also, a good synopsis of flood warning systems and their benefits can be found in the Adams reference below.

4.2.2. A Purely Nonstructural Solution for the Ala Wai Canal Project Area. The task within this phase of study for the PDT was to develop a "stand alone" nonstructural alternative consisting of 100 percent nonstructural measures that could be used to provide specific flood risk reduction to specific structures. The Ala Wai Watershed Study nonstructural analysis began with the formulation of a purely nonstructural plan by screening for structures that sustain enough expected annual damage to economically justify some kind of nonstructural solution. This was a daunting task considering the time constraint, the readiness of data and the specificity of the data relative to each and every structure. In terms of specificity of data, data was not available that was needed in order to correctly and thoroughly analyze each structure and apply a nonstructural measure. Some examples of this lack of specific data are elevation of first floor, number of doors and windows in each building, elevation of the doors and windows, presence, condition and elevation of basements, size of structure relative to the size of lot, the building's construction materials, and more.

With this many unknowns, the PDT had to make many assumptions in order to accomplish the task of developing stand alone nonstructural alternatives with cost estimate and ultimate benefits. For example, the PDT assumed that there are few homes with basements and, therefore, no depth-damage curves calculating basement damages were used. Other assumptions included, if susceptible to 12 feet of flooding or greater, the structure had to be relocated or bought out.

Elevating a structure would work for depths up to 12 feet for residential. Non-residential was not considered for raising. Dry flood proofing, or waterproofing the building, was considered for structures that did not have basements and that did not have design flood depths greater than 3 feet above the first floor.

USACE economists took the lead for the PDT to screen the results of their economic flood damage reduction model, HEC-FDA, and identify structures that could potentially justify the expense of an individual nonstructural measure. The goal of this screening level evaluation was to estimate if a nonstructural measure or plan would a) be economically feasible and b) if it was economically feasible, the magnitude of net benefits would be comparable to those derived from a structural plan. A more refined nonstructural analysis would only be conducted if *a* and *b* were found to be true through the initial analysis. The results of the H&H and economic modeling, in conjunction with other layers provided in the data collection task, were used to identify nonstructural mitigation measures that would be technically adequate, cost effective and capable of implementation. Estimated costs associated with the nonstructural measures were determined, structures were classified by level of risk (i.e., low, medium, high) and HEC-FDA output files were perused for damages high enough to produce positive net benefits for individual nonstructural solutions for those buildings that demonstrated potential. Keeping in mind as the PDT proceeded, if USACE's benefit-cost ratio (BCR) methodology proved to be too restrictive, that other programs in collaboration with the other partners might further produce opportunities for implementing nonstructural solutions.

4.2.2.1. The 3-Step Process for Evaluation Nonstructural Measures. The following represents the basic 3-step screening process for inclusion of nonstructural alternatives used by the USACE economists:

Step	Action
1	Formulate a stand-alone nonstructural alternative;
1.a	Economist's initial screening of HEC-FDA results to identify those structures with sufficient damages to potentially justify implementing some kind of nonstructural solution by determining if EAD/building with contents are great enough to support an $80,000 expenditure for residential, and $100,000 for commercial and public . These figures were provided by a local contractor as average cost estimates for elevating structures in Hawaii;
1.b	Economist's initial cost estimate of purely nonstructural alternative consists of number of residential candidates times $80,000, plus number of commercial and public structures times $100,000. These costs are based on average Hawaii construction costs of elevating structures;
1.c	Economist's initial estimate of a purely nonstructural alternative BCR based on totals from the structure by structure analysis.
2.a	Economist's second level of screening involving closer inspection of structure elevation and determining most suitable type of nonstructural solution for each candidate;

2.b Economist's second level of cost estimates implement general cost schedule adopted by the National Nonstructural/Flood Proofing Committee and regionalized for Hawaii;

2.c Economist's second level BCR estimate of a purely nonstructural alternative.

3.a If refinement of a purely nonstructural alternative for the Final Array of Alternatives made it through the economist's first two levels of screening, precise floor level elevations of the potential properties affected would be determined and closer inspection by structural and cost engineers would be warranted;

3.b Only those properties making economic and engineering sense to implement a nonstructural solution would be selected after these refinements;

3.c A refined BCR, taking into account inputs from the economist and cost and structural engineer, would be calculated for a purely nonstructural alternative.

During the early stages of formulating various alternative plans, based on the PDT's screening methodology, limited flood proofing and other nonstructural opportunities for structures along Manoa, Palolo and Makiki Streams, as well as in Waikiki, began to show potential economic justification. These measures and dozens more were molded into what the PDT evaluated as Alternative 5—A Purely Nonstructural Alternative. In addition, selective opportunities to reduce flood risks for property owners through nonstructural measures were added to the other four structural alternatives to supplement the structural solutions being implemented to further reduce flood damages.

As for Alternative 5--the purely nonstructural alternative--the plan is comprised entirely of evaluating the application of some type of nonstructural solution for as many flood prone properties in the Ala Wai Canal watershed as economically feasible. For this study, these nonstructural measures generally included elevating and waterproofing residential structures and individual ring walls or earthen berms for commercial structures. In many instances, other nonstructural solutions can address the flooding problems of a significant portion of the study area, however, elevating structures was assumed to be the most widely acceptable method used in Hawaii.

To determine the risk of flooding was high, medium or low for nonstructural alternative formulation and identification of TSP, H&H and economic modeling was used. The focus was on the individual structures' Annual Chance Exceedance (ACE) scale; those structures with high risk of inundation from 10 percent to 50 percent ACE floods rose to the top in terms of sustaining significant flood risk and producing significant damages. Less likely to produce sufficient flooding consequence were those structures with 2 percent to 8 percent ACE; this medium-level of risk tends to yield potential flood reduction benefits that are hard to justify large expenditures for individual flood protection. For the most part, those structures that were not in harm's way even with a 1 percent ACE and resulting insufficient damages were eliminated from further consideration. With only very rare events contributing to their benefit base, the cost to retrofit them into the existing floodplain via some kind of nonstructural measure generally overwhelms the limited benefit of their removal or reduction in potential damages.

The alternative includes evaluating the economic feasibility of applying some type of flood proofing measure only to those homes, businesses and public buildings in the watershed where nonstructural measures could be justified. A building by building HEC-FDA output file for the without-project condition was used to determine which structures would be included in this stand-alone nonstructural plan. The intension was that by identifying and including only those structures that could potentially be economically justified by nonstructural means, a feasible nonstructural plan could emerge. Initially, this approach did produce a nonstructural plan that warranted investigating further.

4.2.2.2. The First Screening. The results of this initial nonstructural screening suggested that about 340 structures within the floodplain of the Ala Wai Canal Project could contribute positive net benefits to a purely nonstructural alternative and comprise an economically justifiable plan. Breaking down these total structures further, about 115 residential and 225 commercial and institutional buildings are potentially justifiable. The construction cost is estimated at $31.3 million, expected annual cost at $1.72 million and the BCR at 1.2. Following the initial screening, a stream by stream description of where these nonstructural solutions would be concentrated follows:

Manoa

- There are approximately 45 homes, businesses and public buildings along the Manoa reaches MAN1 through MAN6, and MPC1 and MPC2 that experience enough damages under existing conditions to economically justify some type of nonstructural measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding. Others must be elevated, protected with a ring wal or relocated or purchased.
- The main campus of the University of Hawaii could implement some kind of nonstructural flood proofing measure on 15 of its large classroom and multipurpose buildings.

Palolo

- There are approximately 10 homes, businesses and churches along the Palolo reaches PAL3 and PAL4 that experience enough damages under existing conditions to economically justify some kind of flood proofing measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding. Others must be protected by a ring wall, elevated, relocated or purchased.

Makiki

- There are approximately 90 homes, businesses, churches and public buildings along the Makiki reaches MAK1 through MAK4, KAH1 and KAO1 that experience enough damages under existing conditions to economically justify some type of nonstructural measure. About two-thirds of these are homes.

- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding. Others must be protected by a ring wall, elevated, relocated or purchased.

Ala Wai Canal

- There are approximately 180 structures along the Ala Wai Canal reaches ALA2 and ALA3 that experience enough damages under existing conditions to economically justify some type of nonstructural measure, typically individual ring walls. About 90 percent of these are businesses and condominiums.
- Many of these structures are potentially justifiable to be water proofed or protected by a ring walls to withstand up to 3 feet of flooding.

For the initial screening and the level of detail that went into the development of this nonstructural alternative, all homes were assumed to capable of being raised, water proofed or protected by an individual ring wall. Permanent relocation and acquisition (i.e., removing homes located in the floodplain), as nonstructural solutions were not part of this analysis. Relocation and acquisition require purchasing the entire property, land and structure, and in Hawaii, where land prices are some of the highest in the nation, these options are rarely justifiable. Waterproofing or elevating as a means of mitigating flood damages, on the other hand, are generally technically feasible for most single-family residences and were assumed to be implementable for an average of about $80,000 per structure.

In some instances, ring walls or low elevation, earthen berms can be implemented more economically or make more practical sense than elevating or waterproofing. Ring walls or low elevation berms generally consist of compact earthen soil material located around the exterior of a single structure or small group of structures. The difference in the two terms is basically a ring wall surrounds the property, while a ring wall or berm is a linear aligned barrier between the property and stream. Either of these nonstructural techniques is applicable on a small-scale basis and is not supported for protecting large parcels of land or numerous structures, where the natural characteristics of the floodplain or floodway could be changed. As nonstructural measure berms or ring walls, are intended to provide flood risk reduction benefits where other nonstructural or structural measures are infeasible to implement. Upon closer inspection of the criteria used and the results of the initial screening, the PDT realized it needed to strengthen the nonstructural analysis.

4.2.2.3. The Second Screening. A second screening followed the initial one after tightening some of the benefit and cost criteria. Many of the structures proved much larger and more expensive to protect than what was assumed in the initial screening, particularly in the Ala Wai Canal reaches. Again, the second screening leaned heavily on the without-project hydrologic and economic model results for the watershed, but with more appropriate cost data and more emphasis on the recurring frequency of damages and resulting larger potential flood damage totals. The result was that the 340 candidates for inclusion in a stand-alone nonstructural plan dropped to 100 - 125 structures with sufficient damage from 2 to 20 percent chance flood events. After the second screening, the breakdown of these potential candidates to comprise a purely nonstructural alternative stood as follows:

Manoa

- There are approximately 50 homes, businesses and public buildings along the Manoa reaches MAN1, MAN4, MAN 5 and MPC2 that experience enough damages under existing conditions to economically justify some type of nonstructural measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding.

Palolo

- There are approximately 20 homes, businesses and public buildings along the Palolo reaches PAL3 and PAL4 that experience enough damages under existing conditions to economically justify some kind of nonstructural flood proofing measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding.

Makiki

- There are approximately 40 homes, businesses and public buildings along the Makiki reaches MAK2, KAH1 and KAO1 that experience enough damages under existing conditions to economically justify some type of nonstructural flood proofing measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding.

Ala Wai Canal (including Waikiki)

- There are approximately 15 homes, businesses and public buildings along the Ala Wai Canal reaches ALA2 and ALA3 that experience enough damages under existing conditions to economically justify some type of nonstructural measure.
- Many of these structures are potentially justifiable to be water proofed to withstand up to 3 feet of flooding.

4.2.2.4. The Third Screening. These structures that passed this second screening process were then screened again on an individual basis to ensure they were indeed viable candidates for some form of cost-effective nonstructural alteration. During this third screening, the structures were individually evaluated for specific site conditions, practicality of most likely nonstructural solution and a rough cost estimate of that solution. Consideration was also given to the fact that, some structures, if examined on an individual basis, may not be economically feasible even though the entire group of structures of which these individually infeasible structures are located, could be feasible. The determination of economic feasibility was not based on individual structure feasibility; rather it was based on groups of structures. This approach tends to level the playing field between structural and nonstructural economic feasibility (USACE, 2011).

Despite this approach, even more of the nonstructural candidates dropped out with the third level of screening. Eventually, all but 17 structures (10 along Manoa Stream and 7 along Makiki Stream) were screened out as not economically feasible nonstructural solution could be found. Unfortunately, in most cases, the deeper the team dug into the specifics of a nonstructural solution for these properties, the more unlikely the economic feasibility of the solution became. With such few structures surviving this more rigorous screening, a pure nonstructural alternative was deemed infeasible and dropped from further evaluation.

It is important to note that nonstructural cost estimates used in these analyses, were not developed to the MCACES-level by USACE cost engineers, and subsequently reviewed by the Cost Center of Expertise within the USACE. This would have been the case if any of the nonstructural measures ever progressed to the point of being part of a recommended alternative.

Rather, these nonstructural cost estimates were basically screening-level estimates. For example, ring wall or berm costs were derived from the *Fargo-Moorhead Metropolitan Area Feasibility Report, July 2011*. Based on that document, ring walls or berms up to 6 feet high were determined to be constructible in Hawaii for about $400/linear foot. A typical Waikiki condominium might require about 600 linear feet to completely surround the ground floor footprint. Therefore, the assumption is that for the large high-rise condominiums, a construction first cost of $240,000, say $250,000, would offer a nonstructural solution to mitigate its 1 percent ACE flood damages.

Ring walls or earthen berms could be constructed throughout much of Waikiki where more than one structure would be protected from flooding by the same ring walls, thus decreasing the nonstructural solution cost per building. Similarly, generalized flood proofing costs were taken from National Nonstructural/Flood Proofing Committee literature and the recently developed nonstructural cost estimating software called nSERVO (USACE, 2014). Similarly, the nonstructural screening process did not evolve to the point of involving a structural engineer's analysis, or even establishing a precise floor level elevation of the structures that could be addressed nonstructurally.

4.2.2.5. The Outcome. One of the disadvantages of nonstructural plans often face is that to maintain a positive economic BCR, the relative number of people who can participate in such a plan is substantially less than the broad-brush protection offered by a structural plan, Therefore, nonstructural plans tend to positively impact fewer people and are not as comprehensive as structural plans. Whereas, a structural alternative can reduce flood damages by reducing water surface elevation throughout an entire floodplain, a nonstructural alternative is not as comprehensive and affects only selective individual properties. This was the conclusion the PDT reached.

The purely nonstructural alternative ended up being dismissed based on the economist's analysis that very few structures would pass economic justification, and the PDT's call that reducing flood risks to this few structures would not adequately address the project objectives. The purely nonstructural plan helped far fewer people, did not meet the project objectives and was not supported by the non-Federal sponsor.

The possibility of combining the best of the individual nonstructural opportunities with a structural solution remained open in the process followed, provided the nonstructural piece could be incrementally justified. The farthest any of the individual nonstructural solutions in combination with a structural solution was carried ended with the elimination of Alternative 2A. The cost estimate for Alternative 2A included a total of $788,000 for a ring wall of one structure and flood proofing another. The elimination of Alternative 2A from further consideration is described in the next section of this appendix; however, had it not been eliminated, it is not known whether these two nonstructural additions to the plan would have survived further economic scrutiny. Along this same line of thought, it was decided that the 17 structures still demonstrating potential for nonstructural measures would be re-examined later in the planning process in conjunction with the structural alternative emerging as the TSP. Consequently, no nonstructural costs have been carried into the latest cost estimate for Alternative 3A.

4.3. Choosing Alternative 3A over Alternative 2A in the Final Array Stage. Table B-10 shows some of the PDTs earlier screening work during the SMART Planning Process (Department of the Army, 2014) when the viable array of alternatives consisted of Alternatives 2, 3 and 5. Section 4.2 above explained how Alternative 5 was eliminated from further consideration. To further evaluate advantages and disadvantages between Alternatives 2 and 3, early cost and benefit estimates, such as those in Table B-10, were refined to risk-assessed cost and benefit estimates of Table B-11. During this process, as measures and locations of available sites along the streams changed over time, "A"s were added to the basic numbered alternatives to distinguish them from earlier versions of nearly the same alternative. Thus Alternatives 2A and 3A emerged and advanced through the team's planning process as the two plans with the highest potential to reduce flood risk and be economically feasible. Chapters 3 and 4 in the Main Feasibility Report deal with the planning process including a complete account of the evaluation and selection of the array of alternatives. For a complete description of Alternative 2A, see Section 4.2.3 of the Feasibility Report. Alternative 3A is detail both in the Feasibility Report and throughout the rest of the Economic Appendix.

Table B-10. Early Relative Order of Magnitude (ROM) Cost and Benefit Estimates (Screening Cost – November 2013)

Screening for a National Economic Development (NED) Plan ($000)				
		Alternative 2A	Alternative 3A	Alternative 5A
1	Project Cost (First Cost)*	$272,885	$223,917	$78,691
2	Estimated Average Annual Cost (50 years) (3.75%)	$14,045	$10,752	$3,508
3	Total Annual Benefit	$24,801	$32,727	$9,843
4	Annual Net Benefits	$10,756	$21,520	$6,335
5	Benefit-Cost Ratio (BCR)	1.77	3.04	2.81

* Project Cost includes Real Estate, PED, CM and 25% contingencies

Table B-11. 10% Design - Cost and Benefit Estimates, February 2014

Screening for a NED Plan ($000)			
		Alternative 2A	Alternative 3A
1	Project Cost (First Cost)	221,231	178,096
2	Estimated Average Annual Cost (50 years) (3. 5%)	11,097	8,923
3	Total Annual Benefit	24,814	32,272
4	Annual Net Benefits	13,717	23,349
5	Benefit-Cost Ratio (BCR)	2.24	3.62

* Project Cost includes Real Estate, PED, CM and 25% contingencies

From the beginning, and confirmed with the refinement later in the process, with almost $10 million more in net benefits than Alternative 2A, Alternative 3A proved to be the best choice.

Basically, Alternative 2A had too many less economically efficient flood risk management measures. Alternative 2A's floodwalls along the Manoa-Palolo Canal proved to be too costly, and several of its detention and debris catchment sites, such as the Manoa District Park multipurpose site and the Makiki debris and detention site, were less effective than first thought. The fact that Alternative 3A's floodwalls and detention measures do a much better job protecting Waikiki properties where the bulk of the benefits come from, leads to it being clearly a better plan than Alternative 2A.

4.4. Incremental Cost Analysis for Alternative 3A Measures. After screening out Alternatives 5A and 2A, the PDT focused on adding measures to the base of Alternative 3A to improve its economic efficiency. In order to add a measure, that measure had to be incrementally justified. In other words, the implemented measure needed to add net benefits to the overall project. If it failed to do this, the measure could not be used. However, this did not rule out the measure from being combined with another, in the same reach, in order to seek justification. In addition, if there were competing measures purposed for a single area, the one with the most net benefits was implemented in the project.

When conducting the incremental analysis for a project, there were three main contributors. One of the major contributors was the H&H engineer. The H&H engineer used his best professional judgment and the HEC-RAS model results to determine which areas would be more susceptible to inundation, and the measures that would potentially produce the largest benefit impact per cost. A further explanation about the H&H methodology can be found in the H&H appendix. Next, the cost engineer developed the cost for the specific measure. A further explanation about cost methodology can be found in the Cost appendix. Lastly, the economist brought the process together by modeling the Estimated Annual Damages (EAD) and seeing if the reduction in damages was worth the cost of the measure.

Once Alternative 3A was determined to be the most cost effective of the alternatives, further refinement was initiated. Various flood reduction measures were added one at a time to assemble the most cost efficient, comprehensive Alternative 3A possible. The focus of the incremental analysis was to confirm that each measure in Alternative 3A was economically justified and added to net benefits. Based on best professional judgment, the increments considered in the analysis were defined based on economic efficiency; the analysis started with the increment that was assumed to add the most net benefits, with each subsequent increment based on contribution of benefits. The increments or measures that were analyzed are listed in Table B-12. They were added sequentially to increment 0, testing whether they added to net benefits each step of the process as shown in Table B-13. Each subsequent incremental measure is evaluated under the assumption that all previous measures are in place to ensure there is no double counting of benefits.

Table B-12. Definition of Increments Used for Incremental Justification

Increment	Measure(s) Added
0	Flood warning system, Ala Wai Canal floodwalls, Ala Wai Golf Course multi-purpose detention basin, and Hausten Ditch detention basin
1	Waiakeakua Debris and Detention Basin Waihi Debris and Detention Basin, and Manoa In-stream Debris Catchment
2	Pukele Debris and Detention Basin and Waiomao Debris and Detention Basin
3	Roosevelt Debris and Detention Basin
3.5	Makiki Debris and Detention Basin (remove Roosevelt Debris and Detention Basin)
4	Roosevelt Debris and Detention Basin and Makiki Debris and Detention Basin
5	Woodlawn Ditch Detention Basin
6	Kanewai Field Multi-purpose Detention Basin
7	Manoa-Palolo Drainage Canal Floodwall

Table B-13 shows the detailed results of the incremental cost analysis, and Figure B-4 shows the net benefits curve as measures were added to the project. Due to the potential devastating effect in Waikiki, flood protection measures along the Ala Wai Canal, i.e., increment 0, provided the foundation for the overall plan. However, increment 0 by itself, as shown in Table B-13, is not economically justified (0.87 BCR). Basically, the Ala Wai Canal floodwalls would have to be built too high, with too many huge pumps. The floodwall economics improve dramatically as the other incremental measures are added and effectively reduce peak flows. The most potentially effective measures were added to increment 0 in the order of their effectiveness, based on best professional judgment, until the benefits could no longer support the costs. Overall, nine increments were tested through HEC-FDA modeling to determine the NED Plan.

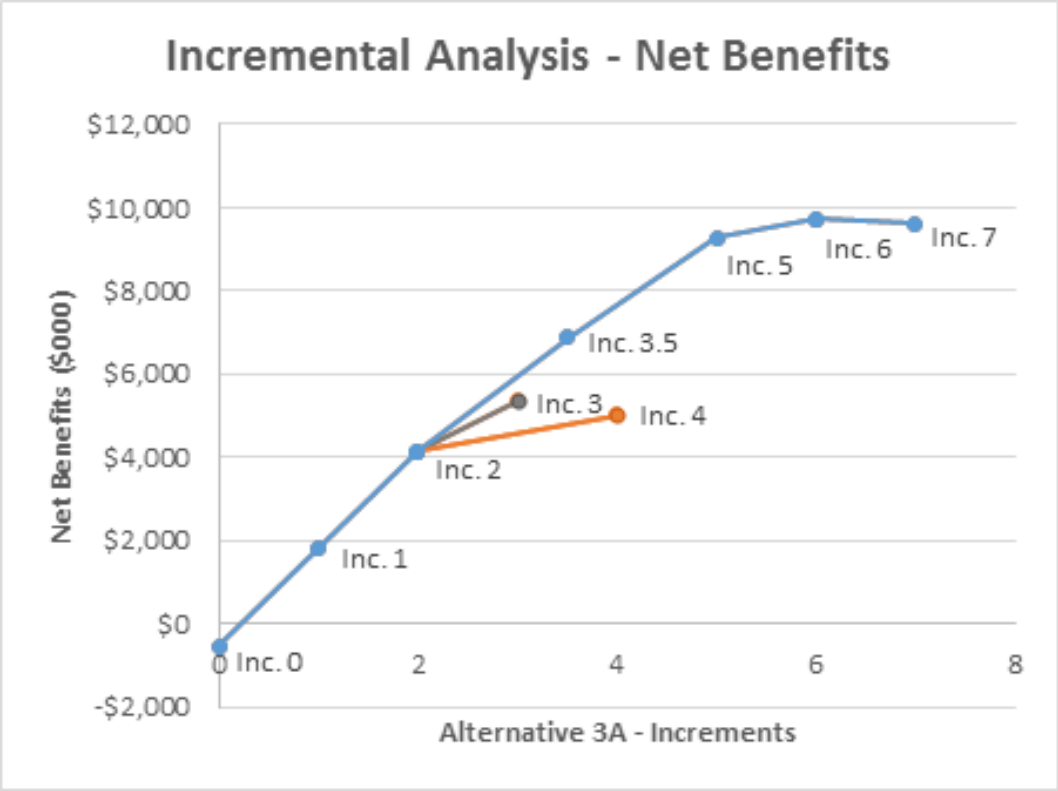
Table B-13. Using Incremental Cost Analysis, May 2014

Ala Wai Incremental Analysis - Expected Annual Costs ($000)									
Cost Description	**Incremental 0**	**Incremental 1**	**Incremental 2**	**Incremental 3**	**Incremental 3.5**	**Incremental 4**	**Incremental 5**	**Incremental 6**	**Incremental 7**
Plans & Specs	13,513	18,884	23,214	24,922	25,684	28,198	28,882	29,443	29,726
Construction Management	7,537	10,531	12,946	13,899	14,325	15,726	16,110	16,420	16,579
Lands	-	2,715	6,738	6,738	6,738	6,738	7,488	7,488	7,488
Construction Contract	51,980	72,633	89,290	95,855	98,805	108,463	111,108	113,240	114,342
Total First Cost	**$73,030**	**$104,763**	**$132,188**	**$141,414**	**$145,552**	**$159,125**	**$163,588**	**$166,591**	**$168,135**
Interest During Construction	1,861	2,600	3,333	4,463	4,753	6,403	5,690	6,685	6,750
Total Investment	**$74,891**	**$107,363**	**$135,521**	**$145,877**	**$150,305**	**$165,528**	**$169,278**	**$173,276**	**$174,885**
Equivalent Annual Cost (50YRS@3.5%)	**$3,193**	**$4,577**	**$5,778**	**$6,219**	**$6,408**	**$7,057**	**$7,217**	**$7,387**	**$7,456**
Annual O&M	761	834	875	916	903	944	942	982	982
Expected Annual Cost (EAC)	**$3,954**	**$5,411**	**$6,652**	**$7,135**	**$7,311**	**$8,001**	**$8,159**	**$8,369**	**$8,438**

Ala Wai Incremental Analysis - Expected Annual Benefits ($000)									
Benefit Description	**Incremental 0**	**Incremental 1**	**Incremental 2**	**Incremental 3**	**Incremental 3.5**	**Incremental 4**	**Incremental 5**	**Incremental 6**	**Incremental 7**
Residential	3,658	5,152	7,192	8,043	8,239	8,085	9,228	9,584	9,540
Commercial	(21)	1,255	2,618	3,464	4,882	3,937	5,847	6,116	6,096
Public	(210)	835	984	986	1,065	987	2,355	2,398	2,420
Expected Annual Benefits (EAB)	**$3,428**	**$7,242**	**$10,794**	**$12,493**	**$14,187**	**$13,010**	**$17,430**	**$18,098**	**$18,056**

Ala Wai Incremental Analysis - Net Benefits & BCR ($000)									
	Incremental 0	**Incremental 1**	**Incremental 2**	**Incremental 3**	**Incremental 3.5**	**Incremental 4**	**Incremental 5**	**Incremental 6**	**Incremental 7**
Net Benefits	**($526)**	**$1,830**	**$4,142**	**$5,358**	**$6,876**	**$5,009**	**$9,271**	**$9,728**	**$9,618**
Benefit/Cost Ratio	**0.87**	**1.34**	**1.62**	**1.75**	**1.94**	**1.63**	**2.14**	**2.16**	**2.14**

Figure B-4. Results of the Incremental Analysis



In the incremental optimization process of adding the next best measure to Alternative 3A, if there were multiple options for one area that accomplished basically the same results, each one was tested independent of the other to find the more cost effective one. This was the case with Increment 3, Increment 3.5, and Increment 4 in Makiki, and to include all of them would have been needlessly redundant and costly. Initially it was assumed that the Roosevelt Debris and Detention Basin would add more net benefits than the Makiki Debris and Detention Basin; these measures were analyzed individually (as Increments 3 and 3.5) to confirm this assumption. As shown in Figure B-4, the results of the analysis indicated that the Makiki Debris and Detention Basin added more net benefits than the Roosevelt Debris and Detention Basin. The two measures were analyzed together (as Increment 4), but were found to have fewer net benefits than the Makiki Debris and Detention Basin alone (Increment 3.5); thus, the most cost effective Alternative 3A includes Increment 3.5, and the Roosevelt Debris and Detention Basin was eliminated. As such, Increment 5 was based on adding Woodlawn Ditch Detention Basin to Increment 3.5

As part of the analysis, it was also determined that the Innovation Center Improvements did not provide any flood reduction benefit; instead, the Kanewai Field Multi-purpose Detention Basin was analyzed as Increment 6 and was found to be economically justified and add to net benefits.

With the addition of Increment 7, [2] there was a drop off in net benefits; thereby, identifying the inflection point. Increment 7 produced a decrease in net benefits of $110,000. Net benefits maximized with Increment 6 at $9,728,000, while the BCR is 2.16. Accordingly, the most cost effective Alternative 3A leading to establishing the NED Plan was determined to include the measures in Increments 0, 1, 2, 3.5, 5, and 6.

4.5. Possible Trade-Offs in Measures to Improve Alternative 3A. Nonstructural measures as a stand-alone plan, was not capable of meeting the overall planning objectives. However, nonstructural measures were considered for integration with structural measures to maximize effectiveness of the alternatives. In several cases, the PDT attempted to maximize the net benefits of structural alternatives by adding selective nonstructural components to improve the economic efficiency of the structural plans. This section demonstrates by example how these combination plans were formulated and what the PDT was attempting to accomplish. For instance, after the PDT projected that net benefits would be maximized with the addition of the Kanewai Field detention (i.e., sixth incremental measure), further analysis was conducted to determine whether equal or greater net benefits could not be attained if the height of the Ala Wai Canal floodwalls (AWCFW) were increased by approximately 0.5 feet in lieu of adding Kanewai Field detention to the optimal mix.

At the time of non-Federal sponsor's request to investigate this variation of Alternative 3A, the plan thought to maximize net benefits was Increment 6 with +2 or 6-foot average height of the AWCFW. However, the non-Federal sponsor was interested in finding if the same or more reduction in flood damages could be attained through means other than converting Kanewai Field to a temporary detention basin during periods of flooding, This analysis also included consideration of non-structural solutions to protect structures at Kanewai Field, as needed to allow for comparison of benefits. In other words, the PDT was tasked with identifying the trade-offs between Kanewai Field and an additional 0.5 feet of additional wall height to AWCFW.

Since the PDT did not have a risk-based cost estimate for this option, Increment 5 with 6-1/2 foot floodwalls, it set out to make the best assumptions it could make using the detailed cost estimates it did have, and deduced the following:

> Revised 7/22/2014 Increment 6 cost with +0 (i.e., 4-foot high) AWCFW
> Total Cost = $173,117,000;
> Original Increment 6 with +0 Total Cost = $168,135,000;
> Difference is refined cost for stairs at AWCFW and other miscellaneous details added to design drawings = $4,982,000.
>
> Increment 5 (+0) Total Cost = $163,588,000;
> Plus refined cost change above $4,982,000 = $168,570,000;
> This is new Increment 5 (+0) cost = $168,570,000.

[2] Risk-based cost estimates were developed for all incremental measures except Incremental 7. FDA modeling showed that total benefits for Incremental 7 were actually lower than those associated with Incremental 6, and the addition of this measure adversely impacted the overall flood reduction contributions of the other 6 measures. Construction costs were assumed to go up slightly, as were PED and construction management costs. The obvious net effect was a lower net benefit. Thus, the PDT saw little benefit of insisting on a risk-based cost estimate with such clear indications that net benefits would have to be less than Incremental 6.

Difference Increment 6 (+2) revised versus Increment 6 (+0) revised,
Total Cost is $180,675,000 - $173,117,000 = $7,558,000;
Added to Increment 5 (+0) refined cost fives cost for Increment 5 (+2) estimate:
$168,570,000 + $7,558,000 = $176,128,000.

This is total cost for Increment 5 (6-foot high floodwalls) without Kanewai Field.
Increment 5 would most likely have 6.5-foot of FW needed.
Based on Increment 6 (+1), revised, difference with Increment 6 (+2), revised, which is $2,668,000, and dividing by ½ = $1,334,000;
Adding $1,334,000 to $176,128,000 = $177,462,000 as total estimated cost of Increment 5 with 6.5-foot (+2.5), revised AWCFW.

This cost of $177,462,000 is obviously less than Increment 6 (+2) revised total cost of $180,675,000, and would make Increment 5 (lower by $3,213,000) the NED Plan, not Increment 6. This would also remain true after adding Interest during Construction, amortizing at 3.5 percent, and adding the appropriate Operations & Maintenance (O&M), thus converting these first construction costs into expected annual costs. The resulting Net Benefits for Increment 5 (+2-1/2) equals $11,923,000, and yields a BCR of 2.35. As shown in Table B-14, this compares to Net Benefits of $11,740,000 and a BCR of 2.31 for Increment 6 with 6 feet high AWCFW:

Table B-14. A Check On the Validity of the Last Increment Added

	Inc 5 at 6-1/2'	Inc 6 at 6'
Net Benefits	$11,923,000	$11,740,000
BCR	2.35	2.31

However, this assumes the expected annual benefits (EAB) for Increment 5 (+2-1/2) would be the same as increment 6 (+2), That is, both equal to $20,735,000. For that to be true, one would have to account for the additional nonstructural cost necessary to bring the total benefits of these two plans to equivalent values. As it turned out, the results of the analysis showed that the incremental cost of adding Kanewai Field detention was about $3 million, while replacing Kanewai with nonstructural protection was more than ten times that amount, confirmed that benefits were maximized with the addition of Kanewai Field Detention Basin Therefore, to attain equal EAB and comparable residual risk of flooding, the true cost of Increment 5 (+2-1/2) would be much higher than Increment 6 (+2), and could not have higher net benefits, nor could it be the NED Plan. In fact, in no instance, were USACE economists able to show that the addition of nonstructural features for the protection of individual structures was found to be economically feasible and a justifiable additional feature to be included in any of the alternative plans; they simply did not improve the economic efficiency of any structural alternative. The structural alternative normally claims the lion's share of the benefits and the residual damages proves to be insufficient to offset the incremental cost of additional nonstructural components. Based on this example and other attempts like it, the PDT'S economists were able to verify that Increment 6 with +2 or 6-foot average height of the AWCFW remained the most cost effective plan up to that point based on it maximizing net benefits. As the analysis progressed and the 4-foot high average floodwall was determined to be the NED Plan, the same conclusion held true.

4.6. Optimization and NED Plan Determination. With Increment 6 in place as the final justifiable measure, the next step was to determine the optimal size and height of each measure. Federal policy requires identification of the plan that reasonably maximizes net NED benefits (i.e., the NED plan); the NED plan must be recommended for implementation unless there are overriding reasons for recommending another plan. This optimization step was determined to be unnecessary for debris and detention basins. Based on an analysis of the 10-percent level of design documents, it was determined that optimization was not necessary for the debris and detention basins. Specifically, each of the detention basins was designed to maximize capacity, either up to the 0.2-percent ACE event or based on existing site constraints (e.g., topography). As a result, each of the debris and detention basins can accommodate at least the 1-percent ACE flood event. As debris and detention basins with a lower level of protection would still require nearly the same footprint and would not offer significant cost savings, it was determined that down-scaling would provide minimal (if any) benefit, and therefore was not considered as part of the optimization process.

Therefore, the optimization efforts focused on the height of the floodwalls along the Ala Wai Canal; that is the only project feature that varies within Alternative 3A, is the average height of the AWCFW. As costs and benefits were refined throughout fiscal year 2014, so was the optimal average height of the AWCFW and the determination of the NED Plan.

At the 10-percent level of design, an average height of 4 feet was assumed to be the baseline for the optimization effort for the AWCFW. For each HEC-FDA the floodwall average height was changed in one-foot increments until the height that maximized net benefits was found. Then, floodwalls performance was assessed to ensure it provided a 95 percent or greater assurance that it would not be overtopped by a 1 percent ACE flood. In addition, since the Ala Wai Canal itself is divided into three reaches, ALA1, ALA2, and ALA3, each reach needed to comply with the 95 percent assurance requirement.

The analysis accounted for design elements that would differ depending on the floodwall height. In particular, at an average height of 5 feet, the floodwalls include more robust footings and floodgates for access to the Canal; the 4-foot-high floodwalls include less robust footings and stair access.
As shown in Table B-15, lowering the floodwall heights by 1 foot (i.e., 3-foot average height) resulted in slightly lower net benefits. Similarly, raising the floodwalls in 1-foot increments also resulted in lower net benefits for both an average height of 5 feet and 6 feet. Although the difference in net benefits is small, the average floodwall height of 4 feet maximizes net benefits and appears to be the NED Plan.

Table15. Ala Wai NED Plan Optimization Analysis - EAC ($000)

Cost Description	Floodwall (3FT)	Floodwall (4FT)	Floodwall (5FT)	Floodwall (6FT)
Plans & Specs	29,429	29,443	31,552	32,049
Construction Management	16,415	16,420	17,598	17,875
Lands	7,488	7,488	7,488	7,488
Construction Contract	113,200	113,240	121,369	123,263
Total First Cost	**$166,532**	**$166,592**	**$178,007**	**$180,675**
Interest During Construction	9,831	9,835	10,508	11,096
Total Investment	**$176,363**	**$176,427**	**$188,515**	**$191,771**
Annualized Total Inv (50YR@3.5%)	**$7,519**	**$7,522**	**$8,037**	**$8,176**
Annual O&M	982	982	982	982
Expected Annual Cost (EAC)	**$8,501**	**$8,504**	**$9,019**	**$9,158**

Ala Wai NED Plan Optimization - EAB ($000)				
Benefit Description	**Floodwall (3FT)**	**Floodwall (4FT)**	**Floodwall (5FT)**	**Floodwall (6FT)**
Residential	9,280	9,445	9,455	9,455
Commercial	8,118	8,263	8,271	8,272
Public	2,504	2,548	2,551	2,551
Expected Annual Benefits (EAB)	**$19,902**	**$20,256**	**$20,277**	**$20,278**

Ala Wai NED Plan Optimization - Net Benefits & BCR ($000)				
	Floodwall (3FT)	**Floodwall (4FT)**	**Floodwall (5FT)**	**Floodwall (6FT)**
Net Benefits	**$11,401**	**$11,752**	**$11,258**	**$11,120**
Benefit/Cost Ratio	**2.34**	**2.38**	**2.25**	**2.21**

Because the difference in net benefits is small between the 3 and 4-foot average floodwall heights and, when the difference is judged to be indiscernible, USACE regulations suggest the smaller plan should be selective, a great deal of thought was given before declaring the 4-foot average floodwall height the NED Plan over the 3-foot high floodwall.

Advantages of the 4-foot average height (over the 3-foot) floodwalls include:

- It maximizes net benefits although the difference is minor;
- It meets the 95 percent assurance of passing the 1 percent ACE event, while the 3-foot floodwall does not;
- There is less risk of it being overtopped and it lowers residual damages;
- It provides an additional $354,000 in expected annual benefits, while costing about $60,000 more than the 3-foot floodwall;
- It provides a more resilient and robust project;

- It better accounts for inherent uncertainties in the modeling, including the concerns of sea level rise.

The only advantage of the floodwall with an average height of 3 feet over the 4-foot high floodwall is that, aesthetically, it could be considered less obtrusive and easier to see over. This has been expressed by the non-Federal sponsor as an important consideration.

Given that the net benefits associated with 3-foot average height floodwalls (Alternative 3A-2.1) are only marginally lower than those associated with 4-foot average height floodwalls (Alternative 3A-2.2), additional analysis may be conducted prior the Final Report to determine whether the floodwall heights can be further optimized (that is, whether net benefits are further maximized at an average height between 3 and 4 feet). However, for the purposes of this Draft Report, the NED plan is based on an average floodwall height of 4 feet, consistent with the results of the current level of analysis.

According to the results of the incremental justification and optimization process described above, Alternative 3A-2.2 was identified as the NED plan; the results summarized in Table B-15 (and shown in Figure B-5) illustrate how the costs and benefits were used to bracket Alternative 3A-2.2 as the NED Plan. As it turns out, it is also the TSP.

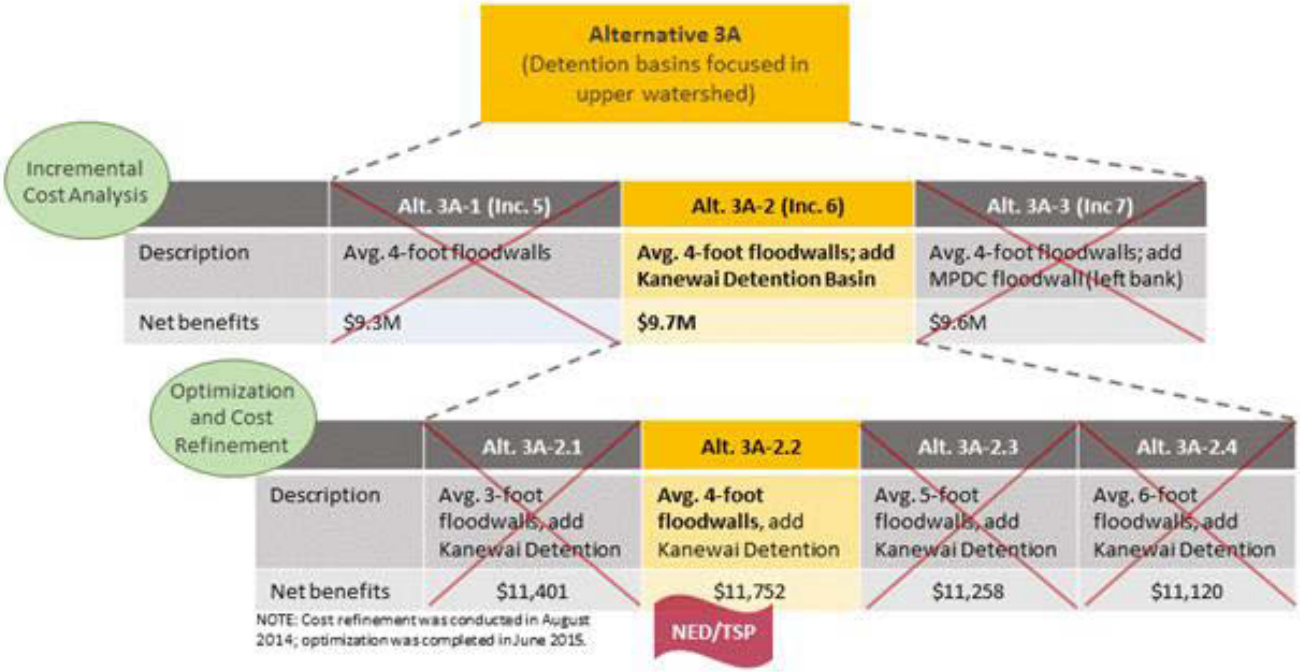


Figure B-5. Identification of the NED Plan and the Tentatively Selected Plan

4.7. Selection of the Tentatively Selected Plan. As described above, Alternative 3A-2.2 was identified as the TSP, as well as the NED Plan. Federal policy requires that the NED plan be recommended for implementation unless there are overriding reasons for recommending another plan. The PDT reviewed the attributes of the NED plan relative to the planning objectives, criteria and engineering standards and determined that there were no overriding reasons that warranted recommendation of another plan, and as such identified the NED Plan as the tentatively selected plan.

As part of this process, the PDT weighed the attributes of Alternative 3A-2.1 relative to those of the NED plan, as this alternative incorporates lower flood walls (average height of 3 feet) with only a slight reduction in net benefits. Based on this evaluation, the PDT identified several important distinctions which underscore the designation of the NED plan as the tentatively selected plan. First, the NED plan has lower residual damages (approximately $354,000 less EAD than Alterantive 3A-2.1) for only a minimal increase in construction cost (going from 3 40 4 feet average height increases project first cost by $59,000). In addition, it provides protection for the 0.1-percent ACE flood event with a minimum 90 percent conditional non-exceedance probability (CNP)[3], actually surpassing 99 percent assurance, and allows for 2-feet of freeboard (a requirement for FEMA accreditation), which is consistent with the performance levels desired by the non-Federal sponsor. Given these factors, the NED plan also provides for greater resiliency, as further discussed in Section 6.2.

It is true that the potential visual impacts associated with flood walls along the Ala Wai Canal, Alternative 3A-2.1 has the benefit of being a foot lower flood walls than the NED plan. However, the degree of visual impact between these two heights is considered to be relatively minimal (i.e. they would both impact aesthetics, but would maintain line-of-sight for the average pedestrian), such that this was not considered to be adequate justification for selection of Alternative 3A-2.1 as TSP. As previously noted, further optimization may be conducted prior the Final Report, which could result in slightly lower wall heights.

4.8. TSP/NED Plan Economic Data. As shown in Table B-16, Expected Annual Costs are $8,504,000 and Expected Annual Benefits are $20,256,000 for the TSP/NED Plan. As a result, the Net Benefits are $11,752,000, which equates to a BCR of 2.38. Interest during Construction (IDC) is over a 40-month period at the FY14 rate of 3.5 percent.

[3] This level of protection meets the City & County of Honolulu's Drainage Standards [Plate 6 curve].

Table B-16. TSP/NED Cost and Economic Data, June 2015
Price levels: Oct 2013

Ala Wai Optimization Analysis - EAC ($000)	
Cost Description	**TSP/NED**
Plans & Specs	29,647
Construction Management	16,536
Lands	7,488
Construction Contract	114,031
Total First Cost	**$166,592**
Interest During Construction	9,835
Total Investment	**$176,427**
Equivalent Annual Cost (50YRS@3.5%)	**$7,522**
Annual O&M	982
Expected Annual Cost (EAC)	**$8,504**

Ala Wai TSP - EAB ($000)	
Benefit Description	**TSP/NED**
Residential	9,445
Commercial	8,263
Public	2,548
Expected Annual Benefits (EAB)	**$20,256**

Ala Wai TSP - Net Benefits & BCR ($000)	
	TSP/NED
Net Benefits	**$11,752**
Benefit/Cost Ratio	**2.38**

5.0. RESIDUAL RISK

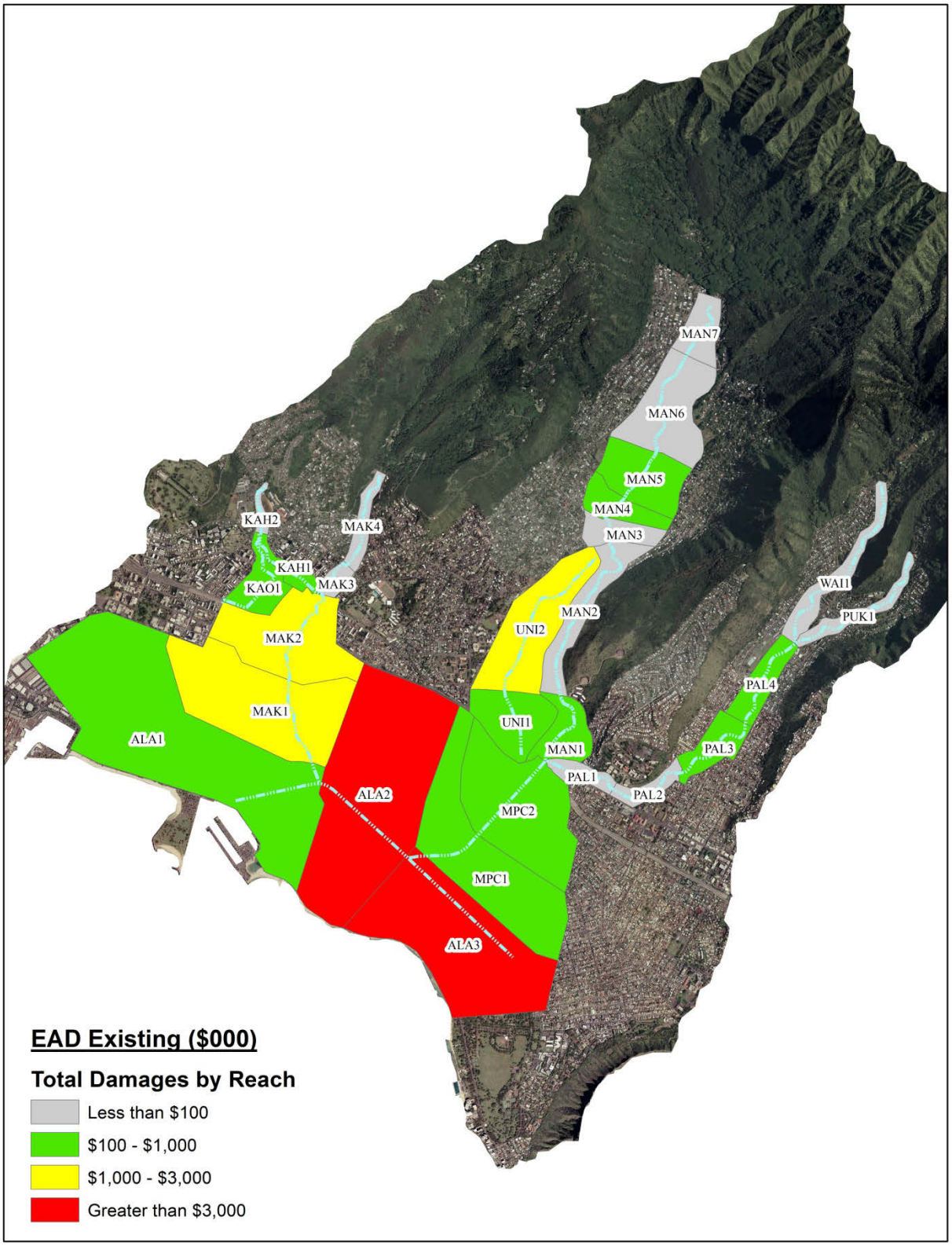
Residual risk is the risk remaining after implementation of a plan; that is, it is the difference in damages between the with- and without-project conditions. Depending on the current conditions and the changes created by the alternative plan, inundation at a reach usually starts to occur at different ACEs. These changes in ACEs are correlated to structure and content dollar damages. In the case of the Ala Wai Canal Project, the residual risk is computed as the remaining dollar damages to commercial, public, and residential structures and contents after implementing either the TSP or NED Plan.

5.1. Re-look at the Without-Project Expected Annual Damages. To avoid making the reader flip back many pages in the appendix, without-project tables and figures for the EAD are repeated here. Table B-17 and Figure B-6 repeat the reach by reach without-project EAD relationship shown in section 3.11.3.

Table B-17. Without-Project EAD by Reach

Ala Wai Canal Project TSP Without-Project Expected Annual Damages by Reach ($000)				
	Damage Categories			
Reach	Commercial	Public	Residential	EAD
ALA1	$646.9	$22.2	$70.1	$739.2
ALA2	$1,668.7	$203.3	$4,600.1	$6,472.1
ALA3	$4,650.8	$212.2	$1,921.6	$6,784.6
MPC1	$51.6	$0.0	$78.8	$130.4
MPC2	$128.0	$0.3	$221.5	$349.8
Ala Wai Subtotal	**$7,145.9**	**$438.0**	**$6,892.2**	**$14,476.1**
KAH1	$0.0	$0.0	$418.7	$418.7
KAH2	$0.0	$0.0	$9.4	$9.4
KAO1	$74.7	$0.0	$397.1	$471.8
MAK1	$439.9	$0.0	$674.9	$1,114.8
MAK2	$761.5	$7.5	$539.6	$1,308.5
MAK3	$0.2	$0.0	$38.5	$38.7
MAK4	$0.0	$0.0	$66.6	$66.6
Makiki Subtotal	**$1,276.2**	**$7.5**	**$2,144.8**	**$3,428.5**
MAN1	$0.0	$74.6	$192.5	$267.1
MAN2	$0.0	$62.6	$0.5	$63.1
MAN3	$23.1	$2.3	$49.9	$75.3
MAN4	$2.5	$0.0	$227.2	$229.7
MAN5	$3.9	$0.0	$165.6	$169.5
MAN6	$0.0	$0.0	$87.7	$87.7
MAN7	$0.0	$0.0	$10.4	$10.4
UNI1	$0.0	$688.2	$0.0	$688.2
UNI2	$0.0	$1,273.3	$0.0	$1,273.3
Manoa Subtotal	**$29.6**	**$2,101.0**	**$733.7**	**$2,864.3**
PAL1	$0.0	$0.0	$64.2	$64.2
PAL2	$0.8	$0.0	$89.6	$90.5
PAL3	$0.0	$0.0	$218.5	$218.5
PAL4	$0.0	$10.6	$100.7	$111.3
PUK1	$0.0	$0.7	$1.8	$2.5
WAI1	$0.0	$0.1	$0.0	$0.1
Palolo Subtotal	**$0.8**	**$11.4**	**$474.8**	**$487.0**
TOTAL	**$8,452.5**	**$2,557.9**	**$10,245.5**	**$21,255.9**

Figure B-6. Ala Wai Canal Watershed EAD Map under Without-Project Conditions



As stated earlier, without-project EAD by reach for the entire watershed totals $21,256,000. If the two Manoa-Palolo Canal reaches are included with the Ala Wai Canal reaches as shown in Table B-17, these lower reaches comprise about two-thirds of the without-project EAD. This area surrounding the Ala Wai Canal is clearly where most of the greater watershed's flood problems exist. The remainder of the overall watershed's flood problems in descending order shows that Makiki Stream reaches would contribute the next highest damage totals, followed closely by the Manoa Stream reaches and, lastly, the Palolo Stream reaches.

Of the total structure and content EAD picture for the entire watershed, about 48 percent is residential (includes large condominiums), 40 percent is commercial (includes large hotels) and 12 percent is public (includes University of Hawaii campus). The damage makeup of the Ala Wai Canal reaches (includes Manoa-Palolo Canal), which comprises 68 percent of the total EAD for the entire watershed, is similar but excludes the university buildings; that breakdown is 48 percent residential, 49 percent commercial and 3 percent public. An important takeaway point here is that despite the inclusion of Waikiki Beach, the State of Hawaii's principal economic engine for commerce, this flood risk management project is just as much, if not more, about protecting residential property.

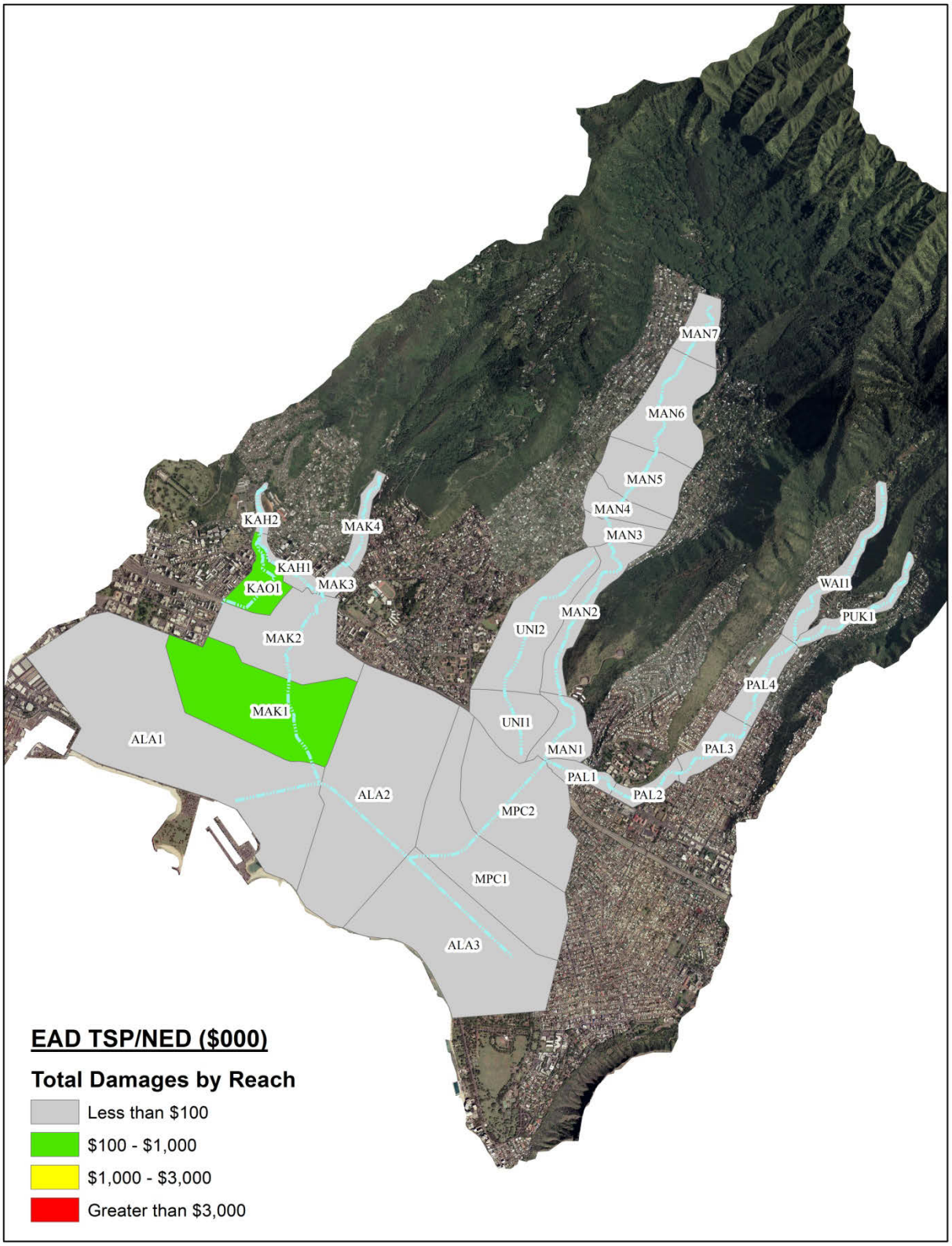
5.2. With-Project (TSP/NED Plan) Expected Annual Damages. Table B-18 shows residual EAD by damage categories and reaches for the with-project conditions (i.e., TSP/NED Plan). EAD are reduced from more than $21million to less than $1million, or about 95 percent. Figure B-7 shows a color-coded reach map of the Ala Wai Canal watershed EAD under with-project conditions. As for the 1 percent ACE event, total damages under the without-project conditions could be as high as $318 million. On the other hand, under with-project conditions that could be reduced to about $30million. The breakdown of those residual damages associated with the 1 percent ACE flood under the with- project condition would be about 89 percent residential, 10.5 percent commercial and 0.5 percent public buildings and contents. In terms of EAD, about 80 percent of the residual damages with the TSP/NED Plan in place would come from the residential category.

As shown in Table B-18 and Figure B-7, about two-thirds of the residual damages come from the Makiki Steam reaches. About 77 percent of the Makiki area residual damages are to commercial properties. However, the overall residual damages in the Makiki area are reduced about 80 percent (1-($703,200/$3,428,500)) by the TSP/NED Plan. The combination of the built-out nature of the Makiki reaches development, lack of space between the structures and stream banks, restricted space for detention basin development, underground conveyance systems, and limited opportunities for nonstructural measures made it difficult to further reduce flood damages in the Makiki Stream watershed.

Table B-18. Residual Expected Annual Damages With TSP/NED Plan
Price levels: Oct 2013

Ala Wai Canal Project TSP Residual Expected Annual Damages by Reach ($000)				
	Damage Categories			Residual
Reach	Commercial	Public	Residential	Damages
ALA1	$0.0	$0.0	$0.0	$0.0
ALA2	$5.8	$0.9	$8.1	$14.7
ALA3	$4.8	$0.3	$1.3	$6.3
MPC1	$10.6	$0.0	$18.2	$28.7
MPC2	$7.2	$0.0	$17.0	$24.1
Ala Wai Subtotal	**$28.3**	**$1.2**	**$44.4**	**$73.9**
KAH1	$0.0	$0.0	$76.0	$76.0
KAH2	$0.0	$0.0	$9.3	$9.3
KAO1	$67.9	$0.0	$358.8	$426.7
MAK1	$80.0	$0.0	$20.5	$100.4
MAK2	$11.4	$0.0	$16.0	$27.4
MAK3	$0.0	$0.0	$13.3	$13.3
MAK4	$0.0	$0.0	$50.1	$50.1
Makiki Subtotal	**$159.3**	**$0.0**	**$543.9**	**$703.2**
MAN1	$0.0	$6.8	$23.5	$30.4
MAN2	$0.0	$1.3	$0.0	$1.3
MAN3	$1.7	$0.0	$3.2	$4.8
MAN4	$0.0	$0.0	$11.7	$11.7
MAN5	$0.0	$0.0	$51.9	$51.9
MAN6	$0.0	$0.0	$1.6	$1.6
MAN7	$0.0	$0.0	$0.0	$0.0
UNI1	$0.0	$0.0	$0.0	$0.0
UNI2	$0.0	$0.0	$0.0	$0.0
Manoa Subtotal	**$1.7**	**$8.1**	**$91.9**	**$101.7**
PAL1	$0.0	$0.0	$49.7	$49.7
PAL2	$0.0	$0.0	$21.4	$21.4
PAL3	$0.0	$0.0	$39.7	$39.7
PAL4	$0.0	$0.4	$9.4	$9.8
PUK1	$0.0	$0.0	$0.0	$0.0
WAI1	$0.0	$0.0	$0.0	$0.0
Palolo Subtotal	**$0.0**	**$0.4**	**$120.1**	**$120.6**
TOTAL	**$189.3**	**$9.6**	**$800.3**	**$999.3**

Figure B-7. Estimated Annual Damages for the TSP/NED Plan



5.3. TSP/NED Plan – Other Residual Risks. The effects on life safety are not as easily measured as projecting property damage. For the most part, the Ala Wai Canal Project is not a floodplain with a high risk for loss of life from flooding. That is not to say that lives would not be endangered in the event of a major flood. After all, about 80 percent of the residual flooding that would remain in the watershed with the project in place would come from the residential category. In addition, flooding can be flashy or come with little warning. However, these conditions exist primarily in the steeply sloped, less populated hillside communities with relatively narrow floodplains. In the lower floodplain, it is much flatter and floodwater would rise much more slowly. It would also take an unprecedented amount of rainfall over several valleys to raise water surface elevations to heights equaling a 1 to 2 percent ACE event. With flooding of this magnitude, it is hard to imagine catching occupants unaware of the danger of potential high water in their neighborhoods. Such record flooding would more than likely come over a 4 to 12 hour period of intense rainfall. Under with-project conditions, there will be a new, basin-wide flood warning system added to the floodplain, ensuring that periods of intense and long duration rainfalls are highly monitored and occupants are given as much warning as practicable. People should have adequate warning and time to move to higher ground or upper floors and out of harm's way. However, under without-project conditions, with no such warning system in place, there is always a risk of loss of life in large flood events, especially at night. Further, long-term development trends will lead to more population density in the floodplain as high-rise buildings replace older, lower profile ones.

One area of significance that does not stand to benefit from a reduction in flood damages and risk of loss of life, as the project is now formulated, is the Iolani School buildings and campus grounds. Iolani is a kindergarten through 12th grade private school located on the right bank of Reach ALA2. With no project in place, the potential exists for flooding practically the entire 25-acre campus, inundating more than one dozen large school buildings and endangering the lives of many of the 1,800 students enrolled there and the 200 faculty and 160 administrators and staff who work there. In a 1 percent ACE event, with-project (TSP) condition, flood waters would come up to near floor levels of 4 or 5 classroom and/or administration buildings and flood as much as one-half of the campus, but this would be mostly athletic fields, courts and support facilities.

This limited level of protection for the school is provided not by the Ala Wai floodwalls, but entirely by detaining flood water upstream and within the adjacent Ala Wai Golf Course.
The risk of flooding Iolani School could be further reduced by extending the Ala Wai floodwalls to protect the school, but it would induce higher water surface elevations on the Waikiki side of the Ala Wai, as well as limit the effectiveness of the Ala Wai Golf Course detention improvement. H&H and economic modeling confirm that this would be an unacceptable trade-off as the additional induced damages caused to Waikiki would greatly exceed any benefit Iolani School would receive.

Nonstructural solutions for Iolani School were evaluated as a means of providing additional protection in lieu of extending the Ala Wai floodwalls, but none were found to be economically feasible. Additional work on a combination of nonstructural and structural flood reduction measures for Iolani School is deferred until the PED phase when more accurate elevation data on the school buildings and grounds can be ascertained.

Similarly, initial evaluation of adding a nonstructural solution to the overall TSP to lower the risk of flooding at the Ala Wai Golf Course clubhouse indicates that flood proofing the structure would not be necessary. Its floor elevation appears to be above the with-project water surface elevations, and the impact of large flood events to the clubhouse and its contents should be relatively minor under both with and without-project conditions. Again, this will need to be confirmed during the PED phase with actual surveyed elevation data. At this point, there are more than sufficient net benefits to cover any extra nonstructural additions that prove to be economically justified during PED.

6.0. EXCEEDANCE PROBABILITY AND LONG TERM RISK.

6.1. Project Performance. USACE guidelines on risk-based analysis for flood damage reduction studies directs the assigning of accuracies to flood frequency estimates determined by various methods in terms of equivalent years of record. Those estimates with the higher equivalent years of record are assumed to be more reliable than those with lower values. Each method used was assigned an accuracy value. The hydrologic uncertainty can be determined using guidance in EM 1110-2-1619 (Department of the Army, 1996) depending on which hydrologic methodology was used to determine the peak flow discharge magnitudes. The hydraulic uncertainty used in risk and uncertainty analysis is determined based on the accuracy of the hydraulic analysis and the reliability of the Manning's n-value for channel roughness (Department of the Army, 1996). To account for uncertainty, a Monte Carlo simulation of stage-frequency data was conducted using the HEC-FDA program (USACE, 2008). The Monte Carlo Simulation assesses the behavior of a statistic (in this case, a flood event) by using random samples from known populations of simulated data. With a large number of random samples, a relative frequency distribution of the resulting statistic can be constructed to account for uncertainty, and the project performance or risk probabilities can be estimated.

Table B-19 presents the three measures of project performance: annual exceedance probability, long-term risk analysis, and conditional non-exceedance probability. These values are based on the project performance target stage, where the target stage is the elevation where damages amount to 5 percent of the damage occurring at the 1 percent flood elevation or the top of floodwall elevation in the case of the Ala Wai Canal damages reaches ALA1, ALA2, and ALA 3, or other elevation relevant to the study at that damage reach. The annual exceedance probabilities are the probability that in a given year the water surface elevation will exceed the target stage and can be interpreted as the probability that significant damages (defined subjectively) will occur. The expected or mean probability is defined as the average of the true probabilities of all magnitude estimates. At damage reach ALA 3, the without project (WOP) median probability is 0.26 or 26 percent chance of exceedance; with the tentatively selected plan project, the median probability is 0.0001 or 0.01 percent. The long-term risk is the probability that the water surface elevation will exceed the target stage at least once in a given time period. The presented time periods in Table B-19 are 10, 30, and 50 years. This can be interpreted as the probability of incurring significant damages within a given time period. For damage reach ALA 1, there is a 100 percent chance that the WOP target stage will be exceeded once in a 30 year time period; with the with the tentatively selected plan project, this is reduced to a 0.05 percent chance of exceedance in a 30 year time period. The conditional non-exceedance probabilities

(CNP) are the probability that a given flood event, like the 1 percent ACE flood, will not exceed the target stage. The uncertainties in the peak flow discharge frequencies and stage-flow relationships are incorporated in the computation of this probability. For damage reach ALA 2, under existing conditions (WOP), given that a 1 percent ACE flood occurs, there is a 0.0133 probability or 1.3 percent chance that the water-surface elevation will not exceed the target stage; with the tentatively selected plan, given that a 1 percent ACE flood occurs, there is a 0.9977 probability or 99.8 percent chance that the water-surface elevation will not exceed the target stage. Another way to look at the CNP values is to state that for the tentatively selected plan, the target stage at ALA 2 (in this case the top of the floodwall) will provide a 99.8 percent chance of assurance against overtopping given that a 1 percent ACE flood occurs. In other words, the CNP values are conditional risk values that correspond to the reliability that particular floods can be conveyed without causing significant damages in this reach.

Table B-19. Project Performance of Selected Damage Reaches, Ala Wai Canal Watershed

Plan	Damage Reach	Target Stage	Annual Exceedence Probability		Long term Risk (years)			Conditional Non-Exceedance Probability					
			Median	Expected (mean)	10	30	50	10% (10-yr)	4% (25-yr)	2% (50-yr)	1% (100-yr)	0.4% (200-yr)	0.2% (500-yr)
WOP	ALA1	2.57	0.4326	0.3754	0.9910	1.000	1.000	0.0933	0.0713	0.0632	0.0570	0.0515	0.0514
TSP	ALA1	5.30	0.0001	0.0003	0.0029	0.0086	0.0142	0.9998	0.9973	0.9972	0.9972	0.9967	0.9965
NED	ALA1	5.30	0.0001	0.0003	0.0029	0.0086	0.0142	0.9998	0.9973	0.9972	0.9972	0.9967	0.9965
WOP	ALA2	5.17	0.3533	0.3730	0.9906	1.000	1.000	0.0353	0.0222	0.0174	0.0133	0.0076	0.0065
TSP	ALA2	8.75	0.0001	0.0002	0.0018	0.0053	0.0088	1.000	0.9980	0.9979	0.9977	0.9976	0.9976
NED	ALA2	8.75	0.0001	0.0002	0.0018	0.0053	0.0088	1.000	0.9980	0.9979	0.9977	0.9976	0.9976
WOP	ALA3	6.07	0.2603	0.2933	0.9689	1.0000	1.0000	0.0751	0.0299	0.0133	0.0047	0.0001	0.0000
TSP	ALA3	9.30	0.0001	0.0001	0.0009	0.0027	0.0045	1.000	0.9992	0.9983	0.9977	0.9973	0.9968
NED	ALA3	9.30	0.0001	0.0001	0.0009	0.0027	0.0045	1.000	0.9992	0.9983	0.9977	0.9973	0.9968
WOP	MPC2	16.0	0.0160	0.0449	0.3681	0.7477	0.8993	0.7162	0.5945	0.5162	0.4639	0.3862	0.3458
TSP	MPC2	16.0	0.0001	0.0064	0.0620	0.1748	0.2740	1.000	0.9275	0.9152	0.9022	0.8626	0.8393
NED	MPC2	16.0	0.0001	0.0065	0.0627	0.1766	0.2766	1.000	0.9212	0.9091	0.9022	0.8626	0.8394
WOP	MAK2	34.2	0.0040	0.0358	0.3052	0.6646	0.8381	0.8579	0.7567	0.6650	0.5744	0.4973	0.4459
TSP	MAK2	34.2	0.0001	0.0000	0.0000	0.0001	0.0002	0.9999	0.9999	0.9999	0.9998	0.9997	0.9997
NED	MAK2	34.2	0.0001	0.0000	0.0000	0.0001	0.0002	0.9999	0.9999	0.9999	0.9998	0.9997	0.9997
WOP	MAN4	162.3	0.0161	0.0450	0.3689	0.7486	0.8999	0.7102	0.5973	0.5167	0.4550	0.3893	0.3365
TSP	MAN4	162.3	0.0001	0.0002	0.0016	0.0047	0.0078	1.0000	0.9983	0.9980	0.9979	0.9976	0.9974
NED	MAN4	162.3	0.0001	0.0002	0.0016	0.0047	0.0078	1.000	0.9983	0.9980	0.9979	0.9976	0.9974
WOP	PAL4	187.9	0.0055	0.0344	0.2955	0.6504	0.8265	0.8456	0.7372	0.6485	0.5658	0.4731	0.4087
TSP	PAL4	187.9	0.0001	0.0019	0.0185	0.0546	0.0893	0.9934	0.9862	0.9774	0.9670	0.9545	0.9460
NED	PAL4	187.9	0.0001	0.0019	0.0185	0.0546	0.0893	0.9934	0.9862	0.9774	0.9670	0.9545	0.9460

NOTES:

[a] WOP = Without Project; TSP = Tentatively Selected Plan; NED= National Economic Development

[b] Project performance statistics were calculated in accordance EM 1110-2-1619 (Department of the Army, 1996) guidelines on risk-based analysis for flood damage reduction studies. Additional detail is provided in Appendix A. Hydrology and Hydraulic Analysis and Engineering Design.

6.2. Resiliency. Under the risk based concept, the system is expected to protect the project area up to the top of containment or in this case, the floodwall heights along the Ala Wai Canal. Resiliency would be how well the system performs in case of capacity exceedance or overtopping on the floodwalls. Resiliency can be incorporated as a structural measure into a levee and floodwall design by constructing a scour protection apron on the protected side of the levee or floodwall for the purpose of minimizing erosion during flood events that exceed the top of wall elevation. But it also can be incorporated on how well a community can recover from an overtopping event usually by limiting the impacts from an overtopping event. For the Ala Wai Canal floodwalls, impacts will be discussed based on an overtopping event on the north, east, and south sides.

Regardless of location of overtopping, flood peak flow events are very flashy and in case of overtopping, the peak flow period or crest of the flood peak for a 1% ACE event would be between 30 minutes to 1 hour. This would limit the amount of discharge that would overtop the flood walls or golf course berms. In case of overtopping on the north or right bank side of the Ala Wai canal, in reach ALA1, it would be expected that flood waters would first pond near the floodwall before flowing down the pedestrian path towards Ala Moana Blvd and then into the ocean. In reach ALA 2, again it would pond closest to the floodwall and in Ala Wai field before backing up onto Kapiolani Blvd and flowing towards Makiki Stream or ponding at the Ala Wai Community gardens and flowing towards the Manoa-Palolo drainage canal through the Ala Wai Elementary and Iolani Schools grounds which may inundated a few buildings must mostly impacting their athletic fields. This would also be the potential inundation area if the University Avenue interior drainage pump station were to fail. In reach ALA 3, along the golf course berm, flow would pond on Date Street and potentially in the residential area between Ekela Ave and Palani Ave. Due to the topography here, there would not be an opportunity for overtopping flow to re-enter the canal or flow towards the ocean. On the north side, the floodwall currently is located with the sidewalk between it and the canal, thus this floodwall has no overtopping scour protection. The golf course berm also has no landside scour protection, just a paved cart path on top.

On the east side, reach ALA 3, overtopping flows would pond on Kapahulu Ave and then flow down that road towards the ocean passing through the grounds of Jefferson Elementary school. The overtopping flow could be captured by the interior drainage system in this area and be pumped back into the canal. Failure of the interior drainage pump station would result in a similar inundation.

Overtopping on the south or left bank side of the canal would result in flow done Ala Wai Blvd towards the ocean in ALA 1 and flow through Waikiki for reaches ALA 2 and ALA 3. For the floodwalls along the Waikiki side or left bank of the canal, the design has the walls tied to the sidewalk; this provides the scour protection in case of overtopping.

In all cases of overtopping, the overtopping flows would result in sheet or shallow flow through parkland or residential areas on the north or right bank side and through Waikiki into the ocean on the south or left bank side of the canal. There is a low public safety risk as such flow is not deep or fast enough to cause dangerous conditions. Also there is not a ‘bathtub’ effect in any

overtopping area and ponding is expected to be in the 1 to 2 feet range. Damages would be related to those at the two feet depth for those overtopping areas.

Related to resilience is superiority. Superiority simply means providing higher levees at all points except where initial overtopping is desired. The overtopping reach is to provide a known initial exceedance location and to provide some warning/evacuation time before total system exceedance. Due to the highly urbanized areas all around the Ala Wai Canal, no superiority reach can be safely identified.

7.0. WORK TO BE DONE BEFORE FINAL FEASIBILITY AND IN PED

At the beginning of calendar year 2015, the H&H and economic appendices went through a District Quality Control (DQC) review, while the cost engineering appendix and key cost estimates were reviewed by the USACE Cost Center of Expertise in Walla Walla, Washington. As a result of these reviews, changes were made beginning with the H&H model that affected the water surface elevations under with- and without-project conditions that, in turn, lead to changes in the economic HEC-FDA model. The H&H model changes were mostly refinements to address some questionable hydraulic "jumps" in the HEC-RAS water surface profile results. Then, these refinements produced slightly different results from the economic model. These changes demonstrate how the modeling and results can and likely will change with further review and refinements.

One of the guiding principles of SMART Planning in effort to keep the action moving forward in a timely manner is to make the best decision possible when reasonably assured that an outcome is predictable or known. Based on what the PDT knew at the time and its member's willingness to accept the amount of risk and consequences of a possibly errant decision, decisions were made that moved the process forward. For example, making the chose between Alternative 3A over 2A was made with cost estimates that have since been refined several times over, at least for Alternative 31, the better of the two alternatives. Such is also the case with the revised TSP that emerged from the revisions made following the DQC, and further changes are imminent as the study makes its way through an arduous review process.

Much work remains to be done between this Draft Feasibility Report and the Final Feasibility Report, as well as in the Pre-engineering and Design Phase (PED), as this proposed flood risk management project moves closer to possible authorization and appropriation. For instance, another look may be warranted at including nonstructural components for individual structures that remain flood prone after the implementation of the TSP. More precise finished floor elevations and comprehensive structural engineering evaluations will be required for selective buildings where buying out, relocating, ring walling, elevating or flood proofing might be economically justified. Or, given the effectiveness of the TSP at reducing flood damages, there might not be sufficient remaining damages to justify and add nonstructural components to the structural measures.

A thorough economic update to Fiscal Year 2016 price levels and discount rate is definitely planned before releasing the Final Feasibility Report. Project costs will be recomputed to reflect 35% design completion and will be presented at FY2016 price levels.

Another job on the engineering side, which may be done in the PED Phase, would be based on the decision that a more sophisticated, unsteady flow model is required to further refine the hydraulics of the watershed. If this work is deemed necessary, changes to the floodplain limits and stage-frequency relationships and, thus, the project economics are quite possible.

On the economic side, more emphasis on developing most likely future with- and without-project conditions could significantly change the benefit side of the equation. Likewise, more benefit categories could be analyzed that as of yet have not been quantified. In addition to the structural and content damages analyzed in this analysis, other NED benefits such as reducing damages to motor vehicles, streets and utilities, and reducing traffic delays and emergency assistance related to flooding could be added to the analysis to strengthen the already healthy BCR of 2.4. As the study progresses, designs are refined and construction strategy and reliable schedule come together, benefits during construction could lead to another significant source of project benefits. It is also quite possible that, whereas today, the TSP and NED Plan appear to be one in the same, that could change as the project takes shape and necessitates further economic modeling and evaluation of these plans.

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C
REAL ESTATE

C1 Real Estate Plan Report

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

SECTION 209 OF FLOOD CONTROL ACT OF 1962 (PUBLIC LAW 87-874)

APPENDIX C

REAL ESTATE PLAN REPORT

Prepared for
Honolulu District, USACE

Prepared by
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22 May 2014
Updated 18 June 2015

THIS DRAFT DOCUMENT IS BASED ON THE INFORMATION AVAILABLE AT THE TIME OF PUBLICATION. The Corps of Engineers planning process is dynamic and responsive to public and stakeholder input; it is possible that the content herein may change as a result of review comments received. This document does not necessarily represent the perspective of higher review levels within the agencies involved or the Executive Branch of the federal government.

EXECUTIVE SUMMARY

The Ala Wai Watershed Project is a single purpose flood risk management project being investigated under Section 209 of the Flood Control Act of 1962 (Public Law 87-874). The local sponsor is the State of Hawaii, Department of Land and Natural Resources (DLNR). The City and County of Honolulu (CCH) by virtue of an agreement with DLNR is also a key partner. A Feasibility Cost Sharing Agreement was originally executed in January 2001 between USACE and the State of Hawaii. Amendments were executed in December 2006, and November 2012. Another amendment is scheduled to be completed in October 2015. The study is investigating and evaluating solutions to flood damage problems throughout the entire Ala Wai Watershed including Manoa, Palolo, and Makiki drainages into Waikiki and surrounding areas. The objective is to develop a comprehensive integrated plan that reduces riverine flood hazards to property and increases life safety in the Ala Wai Watershed to include improving water conveyance; use of environmentally sustainable design where practicable; and integrating non-structural approaches where practicable. The feasibility study is scheduled for completion in October 2015.

The Ala Wai Watershed encompasses over 16 square miles from the Ko'olau mountains to Waikiki and terminates in the Ala Wai Canal. This canal has degraded over the years by silt and debris from the upper Watershed. During the November 1965 and December 1967 storms and Hurricane Iniki in 1992 the Ala Wai Canal was overtopped and resulted in flooding in Waikiki.

The current proposed alternative consists of the construction of multiple debris and detention basins throughout the watershed, one debris catchment structure in Manoa Stream, and construction of floodwalls along the Ala Wai Canal. The project also includes in-stream improvements to improve passage for native aquatic species, as compensatory mitigation for impacts to Waters of the U.S.

Many of the upstream features and the floodwalls are located on sponsor owned lands and as such will not involve acquisitions. There are, however, approximately 28 acquisitions required from private owners for the entire project. Additionally there are 4 sites that are either wholly or partially owned by the CCH (Waihi, Waiakeakua, Monoa Park and Kanewai). The State of Hawaii will either have to acquire the requisite interests or the City and County will have to make their lands available for the project through a 3rd party agreement.

The estimated real estate costs associated with the proposed project is approximately $6,787,700, including all LERRD and administrative costs.

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C

REAL ESTATE PLAN

1. AUTHORITY/PURPOSE

The Ala Wai Watershed Project was authorized under Section 209 of the Flood Control Act of 1962(Public Law 87-874). The purpose is to achieve a flood risk management-designed project to meet existing laws, U. S. Army Corps of Engineers (USACE) regulations and policies such as the Environmental Operating Principles.

The USACE proposes to construct nine upstream debris and detention basins, one debris catchment structure, and floodwalls along the entire south side of the Ala Wai Canal and partially along the north side. Currently the project is in the feasibility phase of study with the Chief's report to be completed by January 2017.

The State of Hawaii, DLNR will be the local sponsor for the project, and has confirmed that the State is willing to condemn for acquisition if necessary. The CCH plans to evaluate the outcome of the feasibility study and will determine at that time whether or not to be a non-Federal Sponsor. They are currently participating as a key player in the feasibility study.

2. DESCRIPTION

The Ala Wai Watershed Project is located on the southeastern side of the island of Oahu, Hawai'i and encompasses the slopes from the Ko'olau Mountains to Waikiki. This study area encompasses over 16 square miles of a heavily populated area of greater Honolulu. Thousands of properties are within the study area. The upper reaches of the Watershed reach approximately 3,000 feet in elevation and it runs to the ocean.

Project features and mitigation measures for this study are located in the upper urban reaches of the stream basins at elevations approximating 500 feet and lower and down to near sea level at Ala Wai Canal. Some sites are located just above the residential development in the various valleys and some are located well within the urban developed areas. Much of the area is characterized as steep slopes but with more gentle terrain as the Watershed reaches Waikiki.

Access to the area is provided by numerous city streets throughout the study area but some of the sites have no public access.

a. Project Features

Project features on six of the nine sites (Waihi, Waiomao, Waiakeakua, Makiki, Woodlawn, and Pukele) involve an earthen berm constructed within the stream banks; access roads; flowage area; and temporary staging and construction areas.

The earthen berms are generally from about 20 to 24 feet in height and span from bank to bank. These berms will allow normal flow to pass through the berm but will temporarily hold flood water and debris until it can reenter the stream after the surge has subsided.

Behind the levee water will temporarily back up, generally within the stream banks, to accommodate the 100-yr. flood. An exception to extending beyond the stream banks is the Waiomao site, which requires excavating the channel to accommodate the 100-yr. pool.

1) Waihi

Waihi has no direct public access to the project site. Access will be brought in from Manoa Road to the west and will require approximately 300 feet of new road to connect to the berm feature. Fee value is given for the construction limits of the berm and a flowage easement will be necessary for the stream bed above the fee footprint. There is no severance damages associated with this site.

2) Waiakeakua

The Waiakeakua site also has no direct public access but does have a Board of Water Supply road that leads to the site. Since this is private access it will be necessary to acquire a road easement from Waaloa Way starting at the bridge crossing and running approximately 150 to 200 feet. The berm is somewhat of a "T" shape and has a much larger footprint. Fee value is given to the construction limits and a flowage easement is required above that footprint. There is no severance damage for this site.

3) Makiki

Makiki involves a narrow strip of state-owned land lying between Makiki Heights Drive and Round Top Drive and is essentially the stream that lies between the two. The berm at this site essentially spans the distance between the two streets. Access to this site will be provided from Makiki Heights Drive and will run from south of the berm a distance of about 400 feet to the fee site of the berm. There is no severance damage for this site.

4) Manoa Park

Manoa Park is strictly an in-stream catchment structure and will not impound water. This catchment structure consists of a concrete slab laid within the stream bed that will contain steel posts to catch the debris. This structure is minimal and will only impact the stream

bed of the park land and the private ownership on the opposite side of the stream. A nominal value is appropriate for this minor feature. Approximately 750 feet of access will need to be brought in from the parking lot to the structure along an existing walkway. There is no severance damage associated with this site.

5) Hausten Ditch and Kanewai Field

Hausten Ditch and Kanewai Field are similar feature sites which will consist of a combination of floodwalls and earthen levees that will trap flood water in a much larger pool within the enclosed area. As in the upstream sites, the water will be impounded until it is safe to release it back into the Watershed. These floodwalls and levees are generally 4 feet high. A short road of about 150 feet will be required for the Hausten Ditch site and it will run west from the parking lot. A slightly longer access road will be required at the Kanewai Site and it will come in from Dole Street around the basketball courts to the levee. Both sites will have a temporary construction area about 20' wide around the perimeter of the levee berm/floodwall. There is no severance damage with either site. In 2011, CCH obtained Land and Water Conservation Fund (L&WCF) Act grant funds to renovate Ala Wai Community Park which surrounds Hausten Ditch. DLNR is coordinating with the National Park Service's Pacific West Region to determine whether L&WCF assisted property would be affected by any of the proposed project features.

6) Ala Wai Golf Course

The Ala Wai Golf Course will have a similar function that involves constructing a berm partially around the perimeter of the course but the purpose of the berm is to protect adjacent developed areas of Waikiki from flooding. The golf course will continue to flood as in the natural condition. An additional feature at this site is the excavation of about 12.42 acres of the course rough that will serve to provide a sedimentation basin for flood water. There is no access requirement for this site since public access is readily available. There is also no severance damage associated with this site.

7) Ala Wai Canal

Features for the Ala Wai Canal consist entirely of floodwalls constructed the full length on the south side but only from the mouth to the Manoa Stream confluence on the north side. This floodwall will be approximately 4 feet in height and will require about 10 feet for the footprint. A temporary construction area approximately 20 feet wide will be required for the full length of the floodwall. An additional feature of this site is the need for three pump station sites and they have been estimated at 10,000 square feet each. A fee value is appropriate for these sites. Access is unnecessary due to readily available public access. No severance damages are appropriate for this site.

8) Woodlawn Ditch

The Woodlawn Ditch site involves a "U" shaped berm and the fee value is appropriate for the berm footprint plus the construction limits around the berm. A flowage easement will essentially encompass the area between the two ends of the "U". An access road will be necessary along the existing cemetery road plus an extension of the road in a level area slotted for additional grave sites. It appears that there are two sets of improvements that will be necessary for acquisition due to proximity to the berm. Severance damages are appropriate for a narrow strip of land lying south of the berm to Lower Road. This land is too narrow for any significant utility to the landowner and will need to be acquired or damages paid and left with the owner.

9) Waiomao

The Waiomao site primarily involves two private ownerships. Fee value is appropriate for the berm as well as the excavation area or to the construction limits. This site will essentially sever the back portions of these two lots and cause severance damages. Approximately 370 feet of access road will run from Waiomao Road along the north side of Tax Map **Key (**TMK) 1-3-4-016-059 to the fee area. This road is located on the only viable place on the lot for a residence and as such will eliminate the utility of the lot. Severance damages are appropriate for the remainder of this lot. The excavation area will contain most of the flowage area but a small area is projected to extend above this area on two other properties. This impact is considered nominal.

10) Pukele

The Pukele site is different in that it involves residential lots with existing houses. The construction limits around the berm are valued in fee and it appears that the proximity of the fee area will impact the two houses. These houses are constructed within about 10 feet of the stream bank. Severance damages are appropriate for both houses on TMKs 1-3-4-019-009 and 010. Additionally, TMK 1-3-4-019-008 will lose a significant portion of the potential building site and is considered damaged as well. This site has been redesigned to bring the access road in from the other side of the stream which will decrease damages to these lots, but essentially all three lots are damaged to the extent of their fee value due to the berm. A flowage easement will impact 6 additional lots but it will remain within the stream banks and have limited impact.

Table C-1 summarizes project sites and features in acres. It also provides a list of the impacted ownerships.

Table C-1. Summary of Project Features and Areas

Site	TMK's	Owners	Fee Area (ac)	Road Easement (ac)	Flowage Easement (ac)	Levee Easement (ac)	Temporary Easement (ac)	Total Area (ac)
Waihi	1-2-9-054-019	City/county	0.584	0.138	0.367		0.057	1.146
	1-2-9-054-029	City/county						
	1-2-9-055-009	City/county						
	1-2-9-055-001	State						
Waiakeakua	1-2-9-054-034	State	1.19	0.069	0.579		0.057	1.895
	1-2-9-054-004	City/county						
	1-2-9-054-002	City/county						
Makiki	1-2-5-020-005	State	0.271	0.184	0.396		0.057	0.908
	1-2-5-020-008	State						
	1-2-5-020-001	State						
Manoa Park	1-2-9-036-003	City/county	0.026	0.344			0.117	0.487
	1-2-9-029-053	Private						
Hausten Ditch	1-2-7-036-001	State		0.075	3.564	0.858	0.904	5.401
Ala Wai Canal		State	0.689			3.535	7.358	11.582
Woodlawn	1-2-9-043-002	Private	1.821	0.376	1.036		0.057	3.3
Waiomao	1-3-4-016-059	Private	1.095	0.17	nominal		0.057	1.322
	1-3-4-034-001	Private						
	1-3-4-034-008	Private						
	1-3-4-034-009	Private						
Pukele	1-3-4-019-008	Private	0.223	0.092	0.354		0.057	0.726
	1-3-4-019-009	Private						
	1-3-4-019-010	Private						
	1-3-4-019-007	Private						
	1-3-4-019-006	Private						
	1-3-4-019-005	Private						
	1-3-4-019-004	Private						
	1-3-4-019-003	Private						
	1-3-4-019-052	Private						
Kanewai	1-2-8-029-011	City/county		0.162	5.107	1.298	1.223	7.79
	1-2-8-029-004	City/county						
Ala Wai Golf Course	1-2-7-036-002	State			12.427	3.932	0.591	16.95

b. Mitigation Measures:

The purpose of the mitigation measures is to improve passage for native fish species. Table C-2 summarizes the mitigation sites and ownerships impacted.

1) Falls 8:

This site impacts 3 residential lots and access and staging are assumed available on the public street which borders the site.

2) Falls 7:

Falls 7 also impacts three residential lots but with an easement acquisition the impact is minimized. Access is assumed by foot only and along the stream bed from Falls 8. This

access was estimated at 10 feet wide and 233 feet long. A total of 4 ownerships are encumbered by the access trail.

Table C-2. Summary of Mitigation Sites and Areas

Mitigation Site	TMK	Owners	Channel Improvement Easement (sq.ft.)	Access Easement (sq.ft.)	Temporary Easement (ac.)	Total Area (sq.ft.)
Falls 8	1-2-9-067-015	private	4,400			4,400
	1-2-9-067-017	private	385			385
	1-2-9-067-016	private	715			715
Falls 7	1-2-9-067-009	private	3,300			3,300
	1-2-9-067-010	private	1,375	536		1,911
	1-2-9-067-008	private	825			825
	1-2-9-067-015	private		280		280
	1-2-9-067-012	private		420		420
	1-2-9-067-011	private		1,094		1,094

3. SPONSOR'S REAL ESTATE INTERESTS

As shown above six of the feature sites are either wholly or partially owned by the local sponsor. These six sites will not require acquisitions but all the remaining feature sites will require acquisition from private parties and or a provision for making the property available from the City and County of Honolulu. Including the mitigation sites, a total of 56 parcels are affected by the project, 13 owned by the City and County of Honolulu, 15 are State owned, and the remaining 28 are privately owned.

The CCH will have to either transfer the requisite interest in their ownerships to the State or they will have to enter into an agreement to make their lands available for the project. In either case the State as local sponsor will have to provide evidence that they have the required interest in order to receive credit for the lands, easements, rights-of-way, relocations (LERRD) value.

To my knowledge none of the properties were acquired using Federal funds. None of the sponsor owned parcels were acquired in anticipation of the proposed project.

4. ESTATES TO BE ACQUIRED

Project features consist of earthen berms in the stream channel, flood protection levees and floodwalls, road access, flowage easements, pump station sites, a debris catchment structure and temporary work areas.

The fee interest is normally required for permanent structures such as the in-stream berms, pump station sites, and catchment structure. It is also noted that each of the structures excluding the pump station sites have a requirement for a 20 feet wide band around the structure that must be kept mowed and free of any structures or vegetation other than grass. Although this 20 feet band is shown as the "construction limits" on the provided drawings, the fee interest is used for the total area within the "construction limits" area. Another site where the fee interest is deemed appropriate is at the Wiaomoa site for the channel excavation area. Although a channel improvement easement would provide sufficient interest for the excavation, this area is also encumbered by a perpetual flowage easement. In order to avoid overlapping easements the fee interest is considered realistic for this portion of the site features. The following standard estates are proposed for the project.

FEE

The fee simple title to (the land described in Schedule A) (Tracts Nos. , and), subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

TEMPORARY WORK AREA EASEMENT

A temporary easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos., and), for a period not to exceed 12 months, beginning with date possession of the land is granted to the United States, for use by the United States, its representatives, agents, and contractors as a (borrow area) (work area), including the right to borrow and/or deposit fill, spoil and waste material thereon). (move, store and remove equipment and supplies, and erect and remove temporary * structures on the land and to perform any other work necessary and incident to the construction of the Project, together with the right to trim, cut, fell and remove, therefore all trees, underbrush, obstructions, and any other vegetation, structures, or obstacles within the limits of the right-of-way; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

ROAD EASEMENT- PERPETUAL

A perpetual and assignable easement and right-of-way in, on, over and across (the land described in Schedule A) (Tracts Nos. _____, ____, and ____) for the location, construction, operation, maintenance, alteration, replacement of (a) road(s) and

appurtenances thereto; together with the right to trim, cut, fell and remove therefrom all trees, underbrush, obstructions and other vegetation, structures, or obstacles within the limits of the right-of-way; (reserving, however, to the owners, their heirs and assign, the right to cross over or under the right-of-way as access to their adjoining land at the locations indicated in Schedule B); 5/ subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

FLOOD PROTECTION LEVEE EASEMENT

A perpetual and assignable right and easement in (the land described in Schedule A) (Tracts Nos. _____, _____ and ____) to construct, maintain, repair, operate, patrol and replace a flood protection (levee) (floodwall)(gate closure)(sandbag closure), including all appurtenances thereto; reserving, however, to the owners, their heirs and assigns, all such rights and privileges in the land as may be used without interfering with or abridging the right and easement hereby acquired; subject, however, to existing easements for public roads and highways, public utilities, railroads and pipelines.

FLOWAGE EASEMENT (Occasional Flooding)

The perpetual right, power, privilege and easement occasionally to overflow, flood and submerge (the land described in Schedule A) (Tracts Nos. ____, ____ and ____). (and to maintain mosquito control)in connection with the operation and maintenance of the project as authorized by the Act of Congress approved _____, together with all right, title and interest in and to the structure; and improvements now situate on the land, except fencing [1](and also excepting _____ (here identify those structures not designed for human habitation which the District Engineer determines may remain on the land)) [2]; provided that no structures for human habitation shall be constructed or maintained on the land, that no other structures shall be constructed or maintained on the land except as may be approved in writing by the representative of the United States in charge of the project, and that no excavation shall be conducted and no landfill placed on the land without such approval as to the location and method of excavation and/or placement of landfill; [3] the above estate is taken subject to existing easements for public roads and highways, public utilities, railroads and pipelines; reserving, however, to the landowners, their heirs and assigns, all such rights and privileges as may be used and enjoyed without interfering with the use of the project for the purposes authorized by Congress or abridging the rights and easement

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[1] See footnote 3.

[2] Where substantial residential structures exist in areas subject to very infrequent flooding, and will not interfere with project operations, the following clause may be substituted, however, leaving these structures in place must be evaluated using the same criteria that would be used to grant permission for a new residential structure to be placed in the easement. See EC 405-1-80: "(and also excepting the structure(s) now existing on the land, described as _____, which may be maintained on the land provided that portion of the structure(s) located below elevation _____ feet, mean sea level, shall be utilized for human habitation to the extent that sleeping accommodations will be maintained therein)".The next clause would then be modified to read "provided that no other structures for . . . . . "

[3] See footnote 4

hereby acquired; provided further that any use of the land shall be subject to Federal and State laws with respect to pollution.

CHANNEL IMPROVEMENT EASEMENT

A perpetual and assignable right and easement to construct, operate, and maintain channel improvement works on, over and across (the land described in Schedule A) (Tracts Nos. _____, _____ and _____) for the purposes as authorized by the Act of Congress approved_____, including the right to clear, cut, fell, remove and dispose of any and all timber, trees, underbrush, buildings, improvements and/or other obstructions therefrom; to excavate: dredge, cut away, and remove any or all of said land and to place thereon dredge or spoil material; and for such other purposes as may be required in connection with said work of improvement; reserving, however, to the owners, their heirs and assigns, all such rights and privileges as may be used without interfering with or abridging the rights and easement hereby acquired; subject, however, to existing easements far public roads and highways, public utilities, railroads and pipelines.

5. FEDERAL PROJECTS/OWNERSHIP

There are no Federal lands within the project area and no previous Federal projects that impact any of the proposed project lands.

6. NAVIGATION SERVITUDE

The Ala Wai Watershed is not considered navigable and Navigation Servitude does not apply to these lands.

7. MAPS

Real Estate mapping is not typically provided by the district at this stage of the project. Since the features design is only at the 10 percent level, and the mitigation measures are at the 10 percent level, the exact locations of many of the features may change to some degree as design continues. Detailed mapping will be provided prior to the notification to the sponsor to provide the required LERRD. Maps depicting the project features are attached in the addendum.

8. INDUCED FLOODING

It does not appear that there will be any induced flooding caused by the flood control features of the project.

9. BASELINE COST ESTIMATE FOR REAL ESTATE

Table C-3. Baseline Cost Estimate

Fee Title (5.899 acres)	$794,600
Flowage Easement (23.830 acres)	$2,015,600
Perpetual Road Easement (1.663acres)	$102,800
Flood Protection Levee Easement (9.623 acres)	$482,500
Channel Improvement Easement (0.253 acres)	$22,400
Temporary Work Area Easement (10.535 acres)	$36,900
Improvements	$86,000
Hazard Removals	$0
Mineral Rights	$0
Severance Damages	$1,712,800
Incremental real estate costs (formally known as contingencies)	$1,054,100
Relocations	$0
Uniform Relocation Assistance (PL 91-646)	$80,000
Acquisition Administrative Costs	$400,000
TOTAL COST	**$6,787,700**

The values in the baseline cost estimate for the project feature sites were obtained from a gross appraisal prepared by Jim Doing, RAO, HQ, USACE dated 17 May 2014, and reviewed and approved by Doug Nelson, CEMVR-RE-A. The project features were at the 10 percent level of detail. The values for the mitigation sites were provided by Jim Doing in a preliminary cost estimate dated 1 April 2015, also at the 10 percent level of detail. These values are based on Estimates for the area requirements taken from the provided aerial photos by CH2MHILL dated 1/29/15 and attached to this document. Where public streets adjoin the project site and where access and or staging are provided for the detention structures, there are no additional requirements on the mitigation sites.

The value calculation for mitigation are based primarily on county assessed values and an analysis of the impact on the individual parcels. The cost estimates are intended for planning purposes only and do not reflect appraised values.

The costs for the mitigation sites are considered worst case scenario and each of the sites should be examined for any existing rights that the sponsor or city/county may have in existing easements or maintenance rights connected with the stream. The site size and or placement can significantly impact the probable cost.

Real Estate Cost Summary by Site

Table C-4. Real Estate Cost Estimates by Project Site

Site	Pump Station (fee)	Berm/Dam (fee)	Access (easement)	Flowage (easement)	Temp (easement)	Floodwall/levee (easement)	Channel Improvement (easement)	Improvements	PL 91-646	Severance	Contingency	Total
Waihi		$11,700	$2,600	$3,000	$500						$5,300	$23,100
Waiakeakua		$23,800	$1,000	$4,600	$500						$9,000	$38,900
Makiki		$5,400	$3,500	$3,200	$500						$3,800	$16,400
Manoa		$1,000	$6,500		$1,500						$2,700	$11,700
Hausten			$2,300	$57,000	$1,700	$16,800					$23,300	$101,100
Ala Wai Canal	$20,700				$13,200	$100,700					$40,400	$175,000
Woodlawn		$227,600	$16,000	$64,800	$500			$86,000	$20,000	$32,400	$118,500	$565,800
Waiomao		$174,100	$25,700	$1,000	$500					$306,900	$60,400	$568,600
Pukele		$330,300	$9,700	$19,600	$500				$60,000	$1,373,500	$108,000	$1,901,600
Kanewai			$30,800	$868,200	$14,700	$207,700					$336,400	$1,457,800
Golf course				$994,200	$2,800	$157,300					$346,300	$1,500,600
Falls 8 mitigation							$11,200					$11,200
Falls 7 mitigation			$4,700				$11,200					$15,900
Grand Total	$20,700	$773,900	$102,800	$2,015,600	$36,900	$482,500	$22,400	$86,000	$80,000	$1,712,800	$1,054,100	$6,387,700

10. PL 91-646 RELOCATION BENEFITS

Public Law 91-646, The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended, commonly called the Uniform Act, is the primary law for acquisition and relocation activities on Federal or federally assisted projects and programs. The local sponsor is required to follow the guidance in this public law. The sponsor is aware of this and has experience in the Uniform Act policies.

As the project is currently laid out it appears that there will be two displaced families at the Pukele site. There are two relatively newer homes that will be acquired as a result of the in-stream berm on the back of these two lots.

There is also the possibility that two tenants will be displaced at the Woodlawn site. There are a total of 11 residential structures on this property and two of the structures are very near the footprint of the berm and it may require the acquisition of these structures. It is not known if the improvements are occupied.

11. MINERALS

The State of Hawaii owns all mineral rights within the state and there are no surface or subsurface minerals that would impact the project or acquisition.

12. ASSESSMENT OF SPONSOR'S ACQUISITION CAPABILITY

The State of Hawaii is considered fully capable and has Eminent Domain authority, as it has been a local sponsor in other Federal projects. The State's Land Acquisition Capabilities Statement is being coordinated as of 21 July 2015, and will be incorporated in the final Real Estate Plan Report (REPR) of the *Ala Wai Canal Project, Oahu, Hawaii, Draft Feasibility Study Report with Integrated Environmental Impact Statement* (Draft Feasibility Report/EIS).

13. ZONING

By in large the prevalent zoning on the proposed project lands is either P-1 or P-2. These are conservation/preservation zonings with the intent to keep the lands in a natural state or to at least limit the extent of development. Within the zoning class allowable uses are watershed, parks, cemeteries and light recreational use, such as the Ala Wai Golf Course. This zoning classification applies to most of the land in all the sites with the exception of Pukele. Pukele parcels are all zoned R-5 for residential purposes. There are minor exceptions to the conservation zoning on small portions of Waiomoa upper reach, and Manoa Park on a parcel located across the stream. It is noted that the Ala Wai Canal itself is not zoned and does not have a TMK assigned to it. For all practical purposes this area is a city park and conservation is assumed for this site.

It should also be noted that the Hausten Ditch property, the Ala Wai Golf Course and Manoa Park are set aside as public recreation sites and cannot be used for any other purpose. These sites were set aside by Executive Order of the Governer.

14. MILESTONES

The following real estate milestones have been coordinated with real estate, and the PM. For those parcels that are currently owned in fee by the local sponsor they will need to demonstrate possession of the fee title prior to construction execution. For the private parcels that will be acquired the sponsor will have to accomplish the acquisition prior to advertisement of the construction contract. The environmental analysis will be included in the Draft Feasibility Report/EIS and the cultural analysis is to be completed in the Pre-engineering and Design Phase of the project planning. There is not a tentative date for Project Partnership Agreement (PPA) execution and construction will not be until 2020. The following timeline is realistic for LERRD requirements:

Survey/Maps/Title	90 Days
Legal Descriptions	30 Days
Appraisals	90 Days
LERRD certification	21 Days

15. PUBLIC UTILITIES RELOCATIONS

There are no known public utilities that are impacted by the project.

16. ENVIRONMENTAL IMPACTS

Environmental impacts, if any, are discussed in other sections of the Engineering Documentation Report.

17. ATTITUDES OF LANDOWNWERS

No information has been given as to public opinion about the project. The most significant area of public concern will be the presence of the floodwalls along the Ala Wai Canal. This will create a visual detraction that the locals will likely object to. It is also likely that the private owners of the impacted parcels will object to the acquisition of their land.

18. NOTIFICATION TO SPONSOR

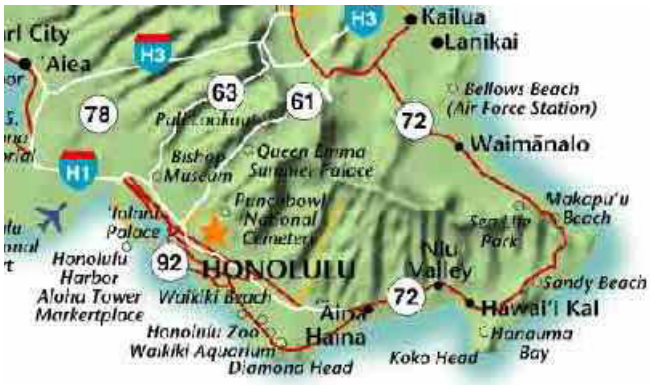
The non-Federal sponsor and the CCH are fully involved in the planning process. They are also experienced in working with USACE on similar projects. There is little risk of premature acquisition by the local sponsor at this stage of the project. Notification of the risk of premature acquisition is being drafted as of 21 July 2015, and a copy of the notice will be incorporated in the final REPR, FS/EIS.

19. ADDENDUM

Map of Oahu
Project Overview Aerial
Feature Sites Location
Feature Site Location Aerials
Feature Aerials
Feature Photos
Mitigation Measures Location
Mitigation Measure Sites Location Aerials
Mitigation Measure Aerials
Mitigation Photos

Map of Oahu

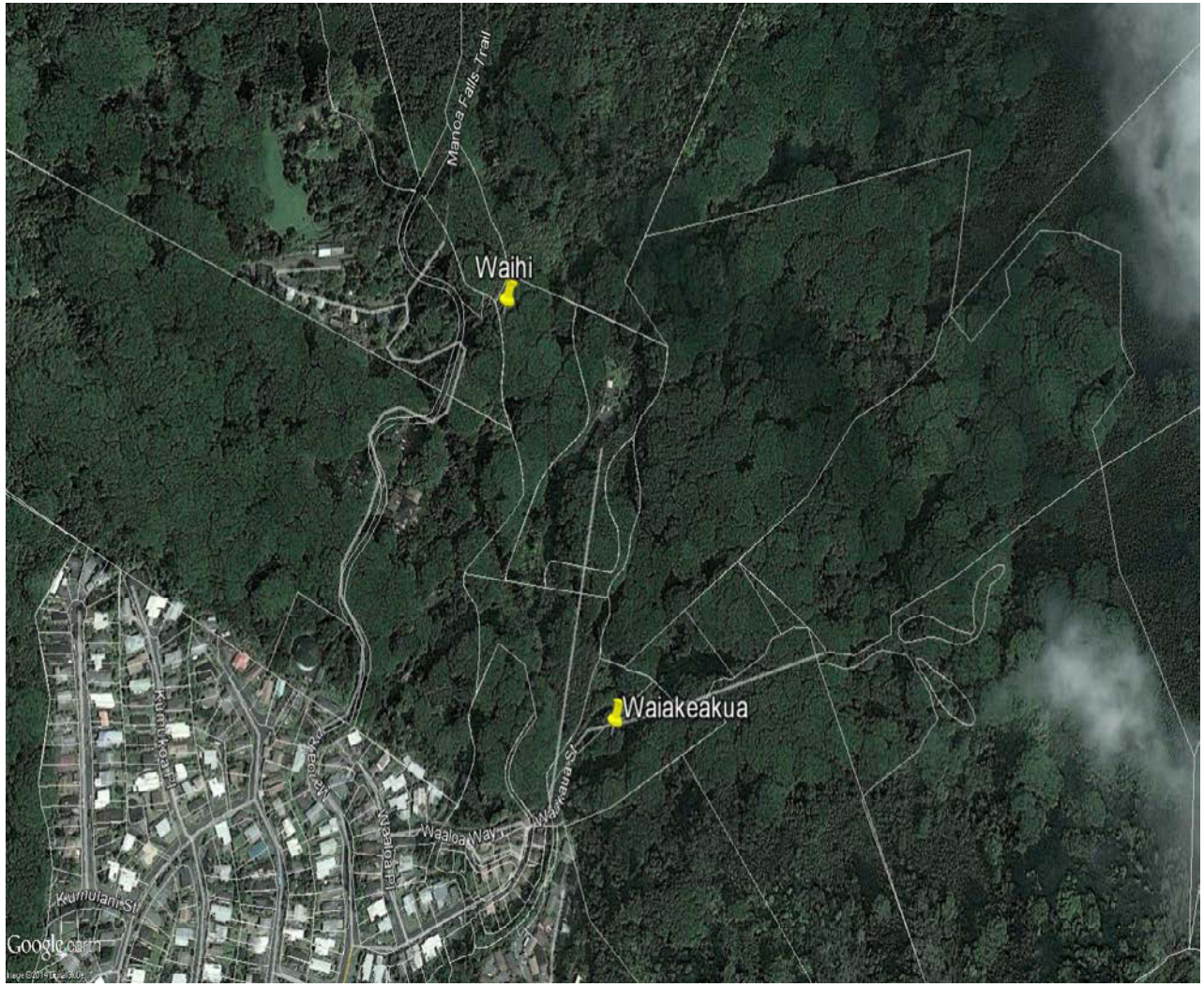
Project Area



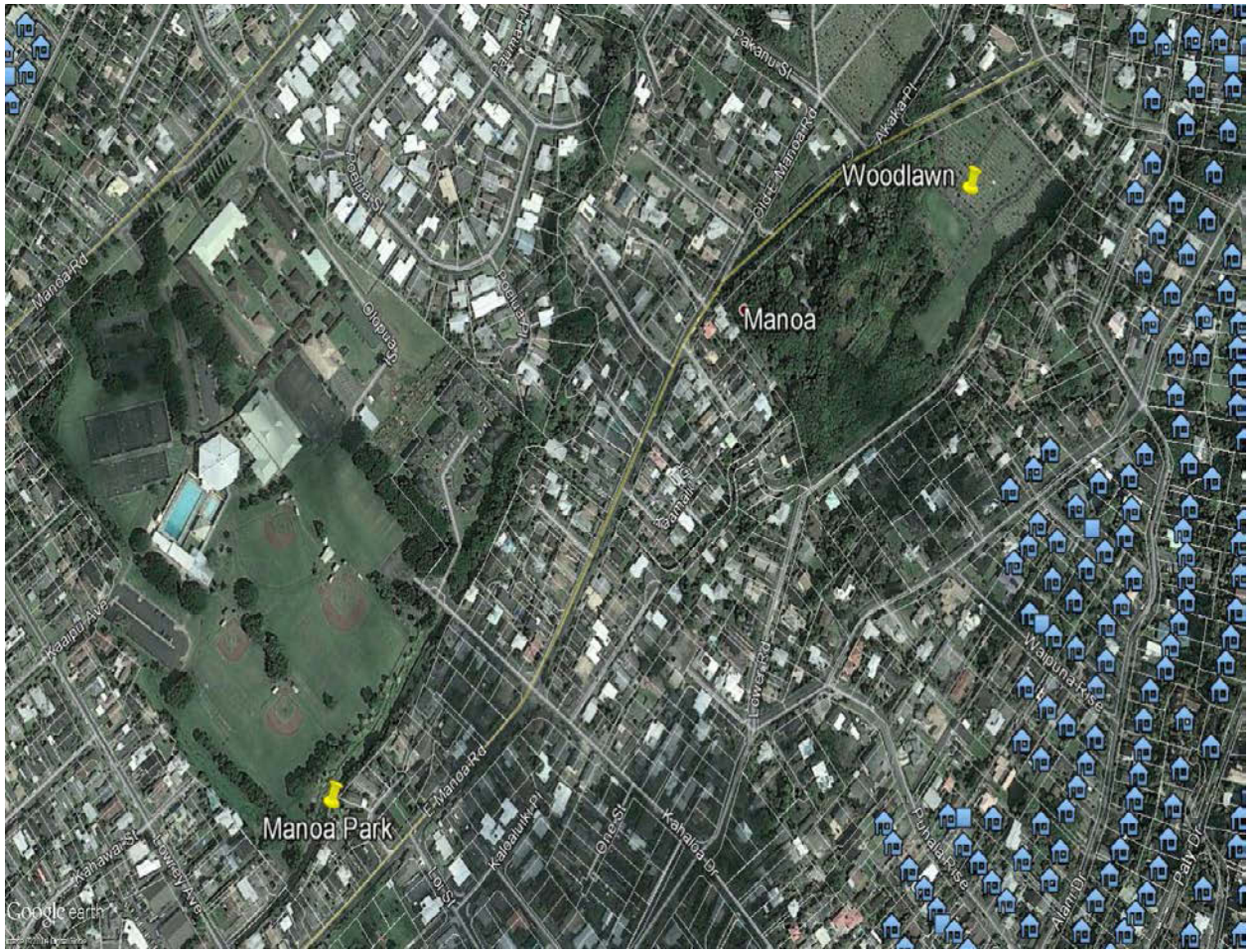
Feature Sites Location

Feature Site Location Aerials

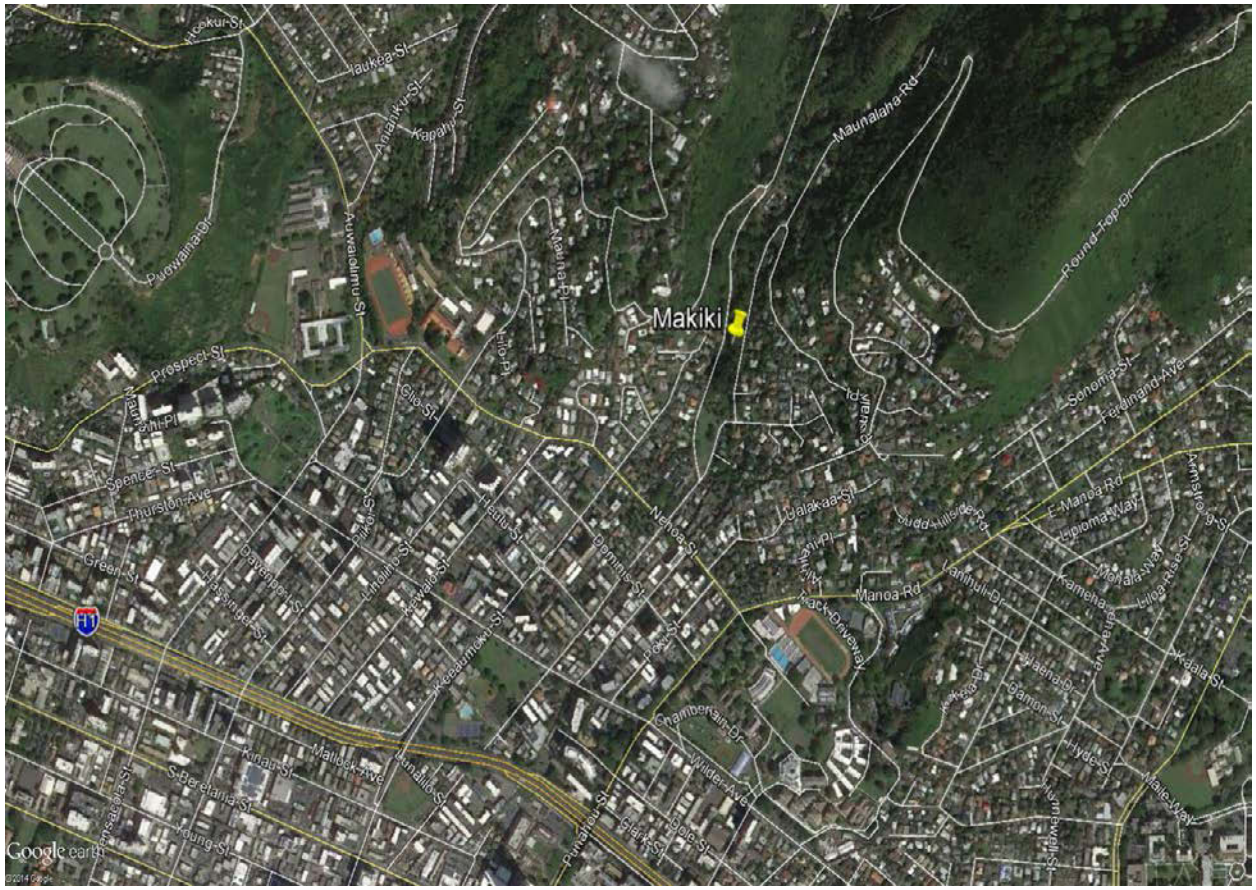
Waihi and Waiakeakua Location



Woodlawn and Manoa Park

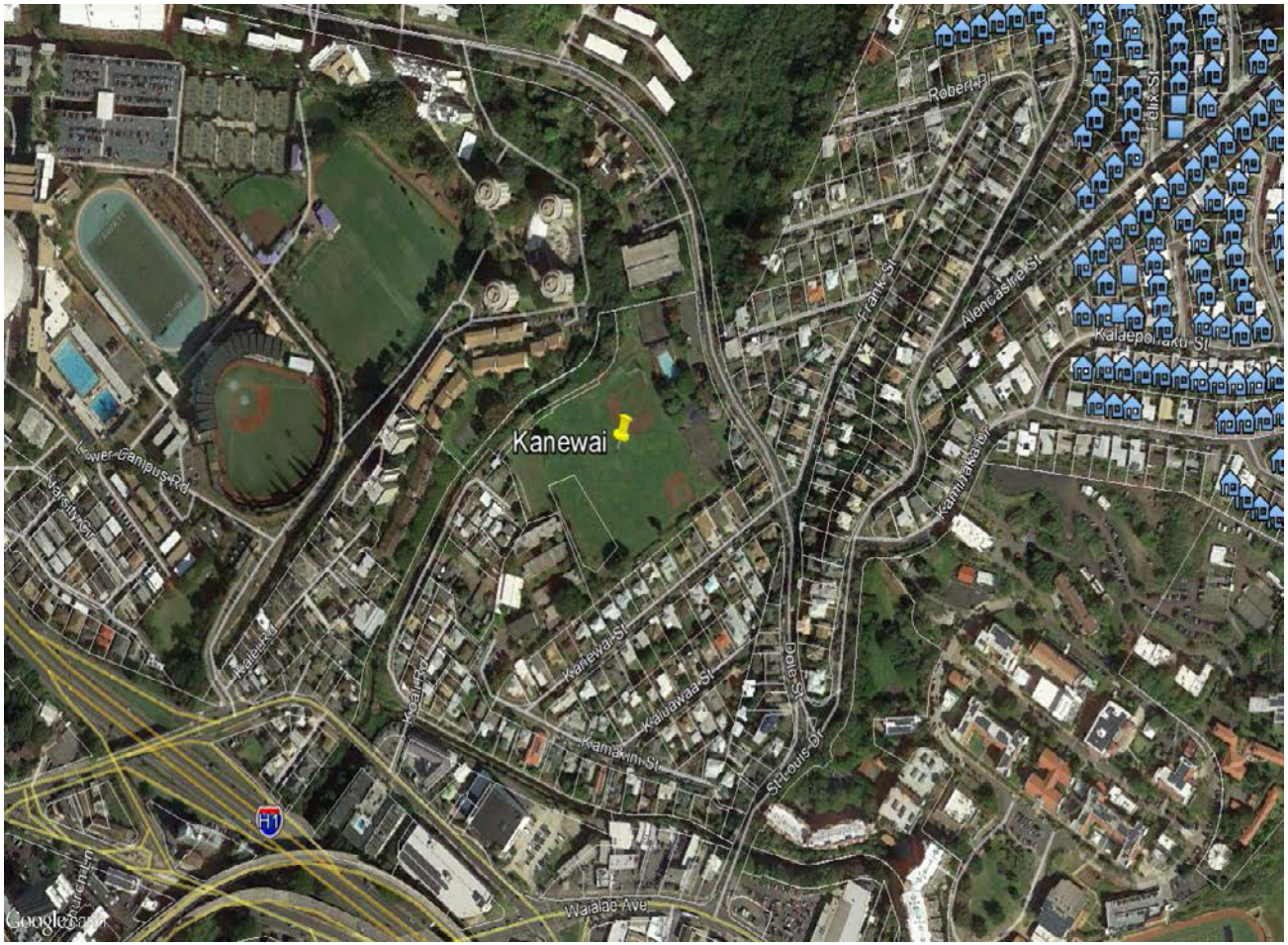


Makiki


Makiki
Maunalaha Rd
Round Top Dr
Prospect St
Thurston Ave
Spencer St
Green St
Nehoa St
Manoa Rd
Ferdinand Ave
Sonoma St
Wilder Ave
Young St
Hyde St
Wale Way
Google earth

Pukele and Waiomao

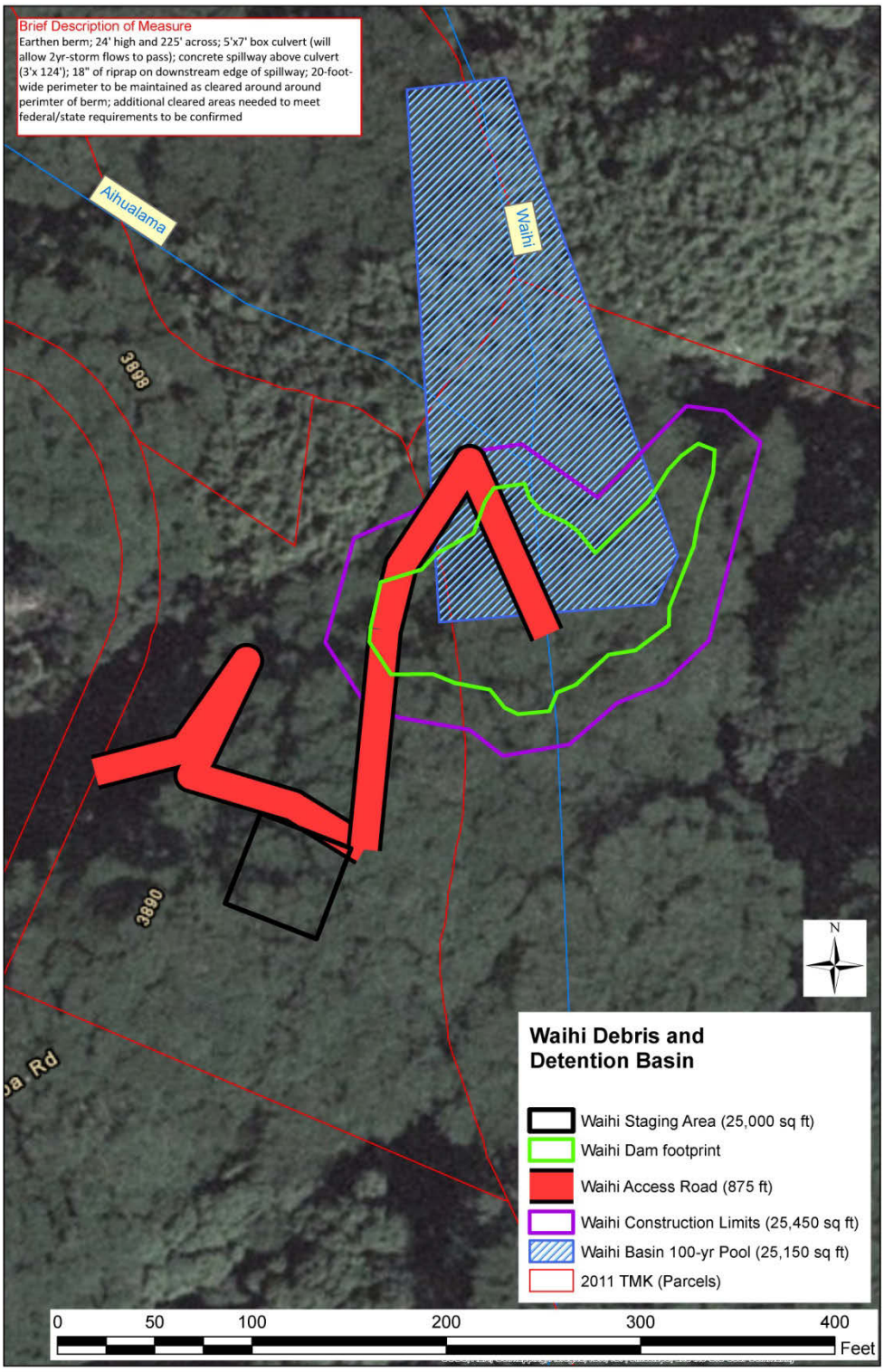
Kanewai

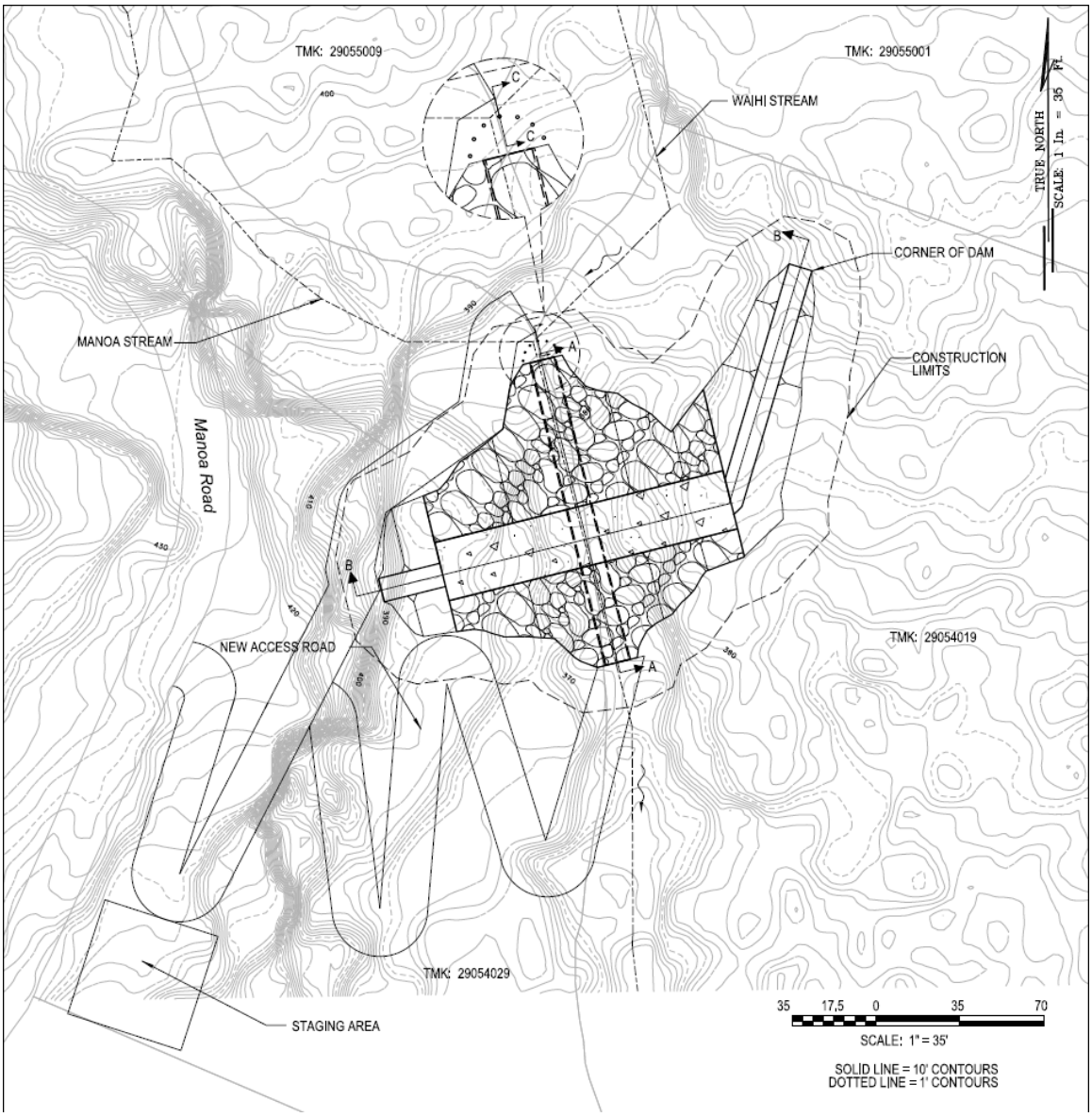

Kanewai
Lower Campus Rd
Varsity Cir
Kalei Rd
Kealia Rd
Kaiwa Pl
Kanewai St
Kaiwawaa St
Kamakini St
St Louis Dr
Waialae Ave
Frank St
Alencastre St
Kamuiakaiki St
Kalaepoiaku St
Robert Pl
Felix St
H1
Google

Hausten Ditch, Ala Wai Golf Course and Ala Wai Canal

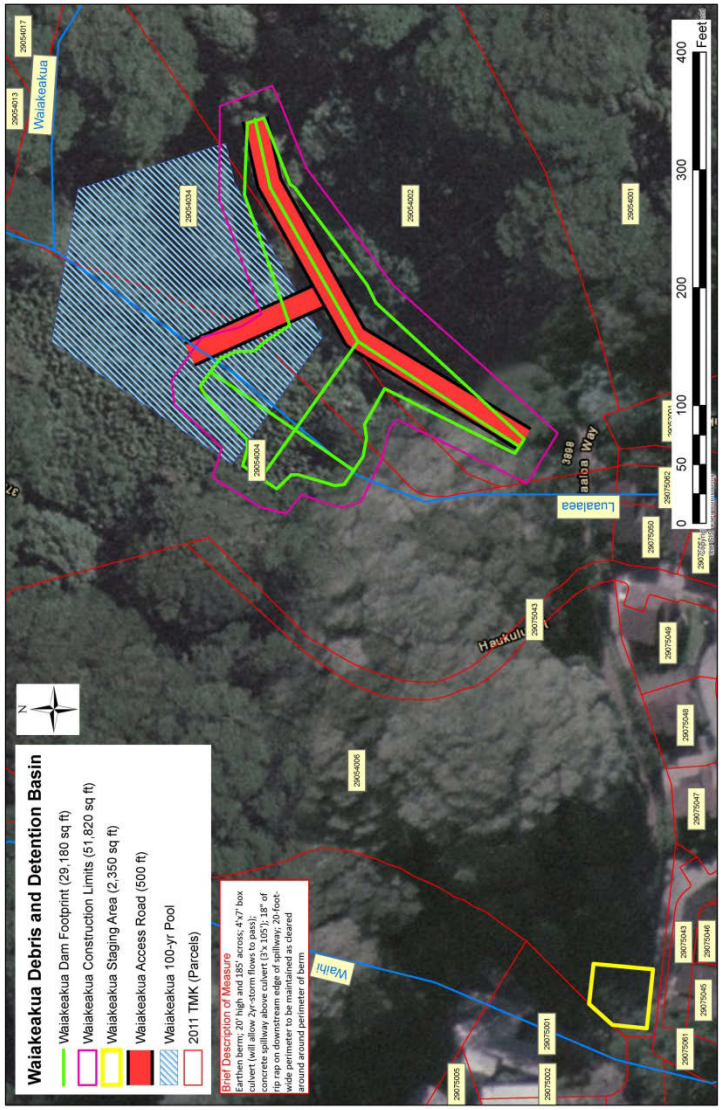
Site Feature Aerials

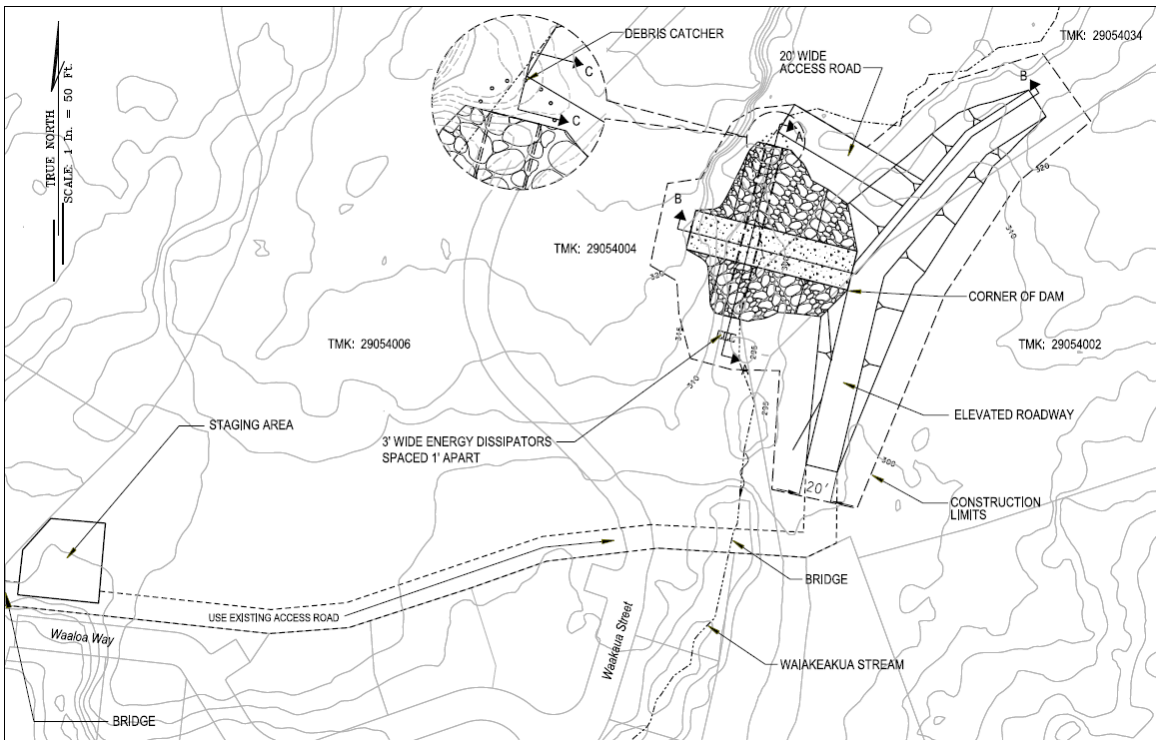
Waihi



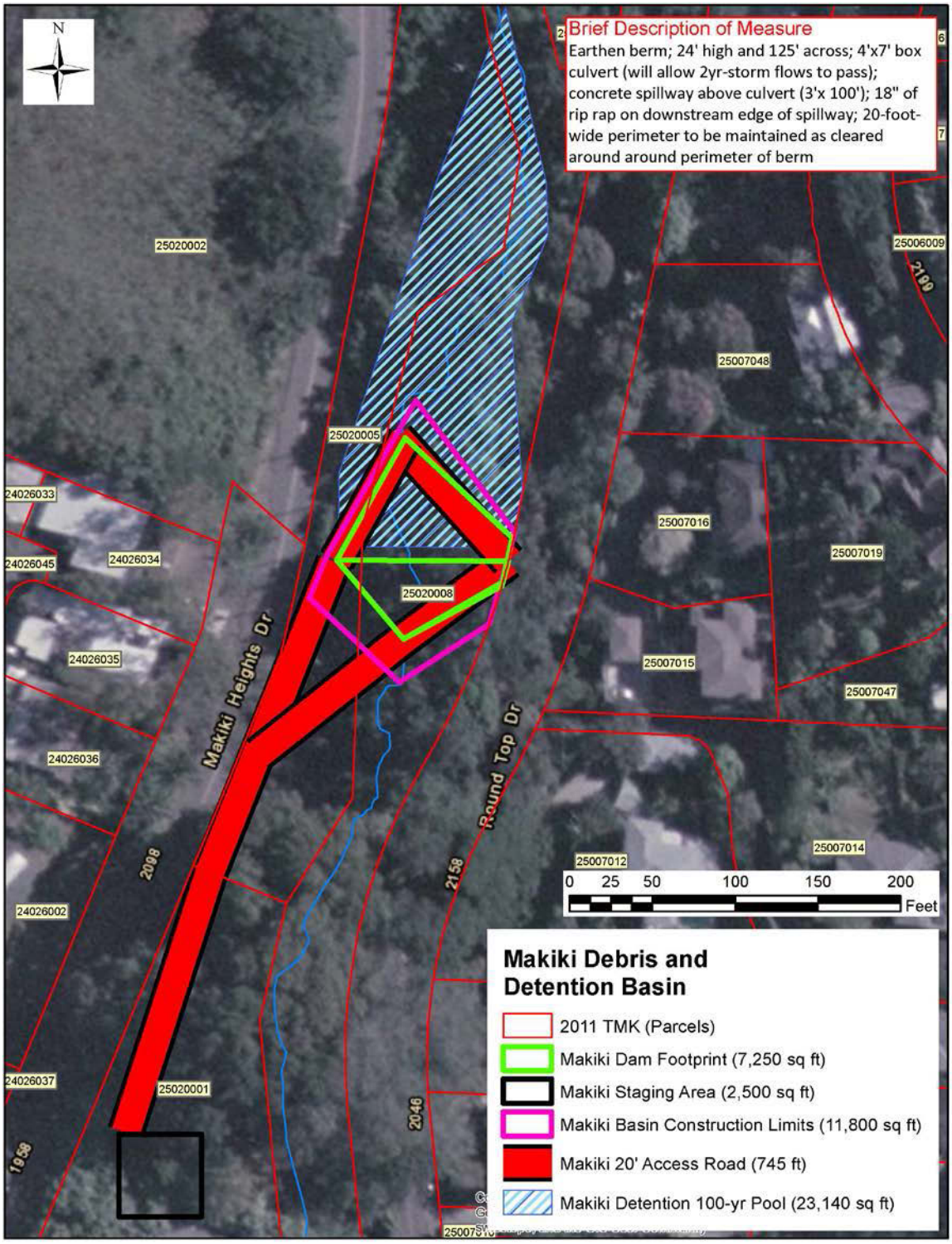

TMK: 29055009
TMK: 29055001
WAIHI STREAM
TRUE NORTH
SCALE: 1 In. = 35 Ft.
CORNER OF DAM
MANOA STREAM
CONSTRUCTION LIMITS
Manoa Road
NEW ACCESS ROAD
TMK: 29054019
TMK: 29054029
STAGING AREA
35 17.5 0 35 70
SCALE: 1" = 35'
SOLID LINE = 10' CONTOURS
DOTTED LINE = 1' CONTOURS

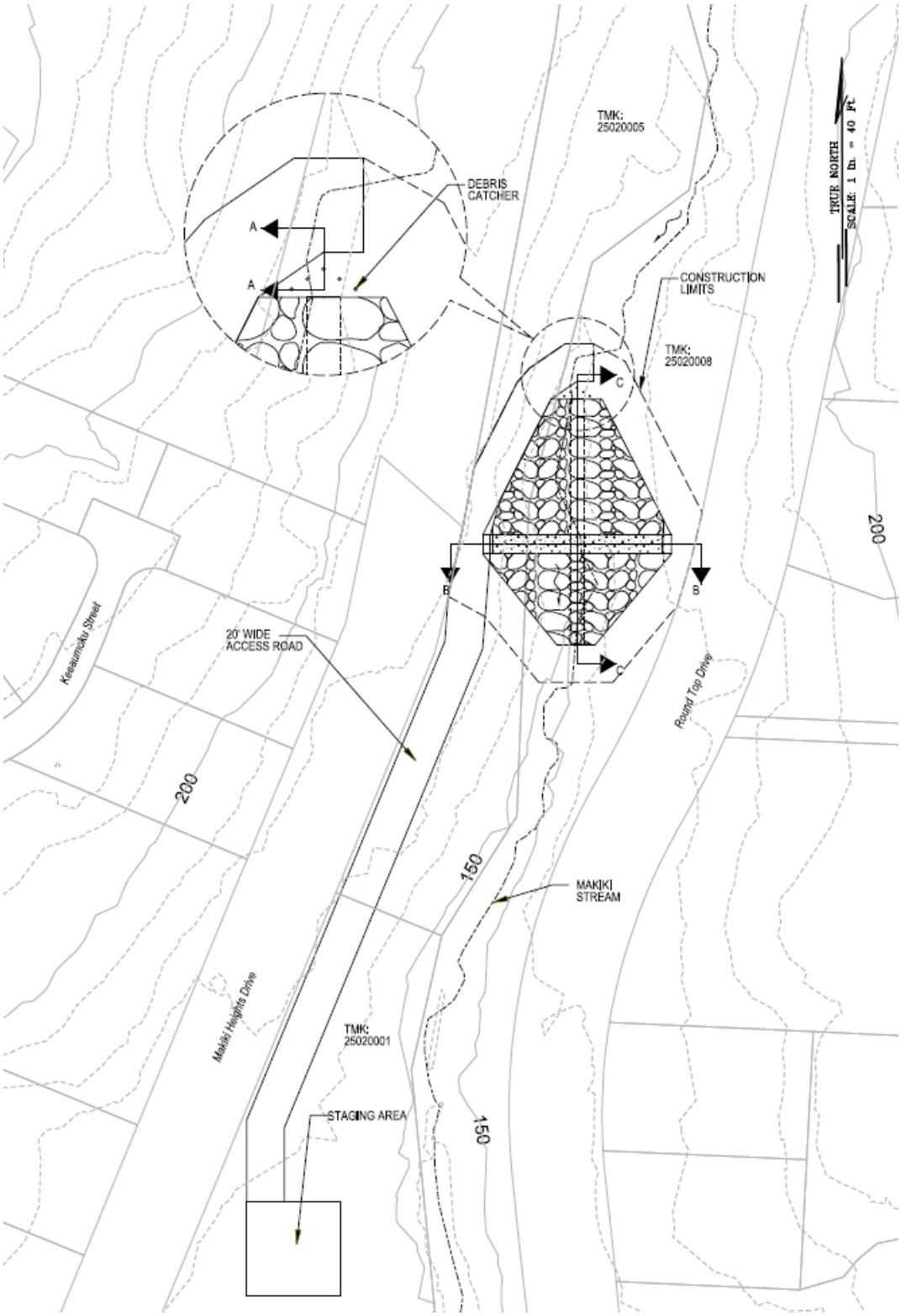
Waiakeakua


Waiakeakua Debris and Detention Basin
Waiakeakua Dam Footprint (29,180 sq ft)
Waiakeakua Construction Limits (51,820 sq ft)
Waiakeakua Staging Area (2,350 sq ft)
Waiakeakua Access Road (500 ft)
Waiakeakua 100-yr Pool
2011 TMK (Parcels)
Brief Description of Measure
Earthen berm; 20' high and 185' across; 4'x7' box culvert with 20' wide bottom (Invert Elev 245); concrete spillway above culvert (3'x 105'); 18" of rip rap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimeter of berm
Waiakeakua
Waihi
Luaalaea
Haukulima
Waiakea
Waiakea
0
50
100
200
300
400
Feet

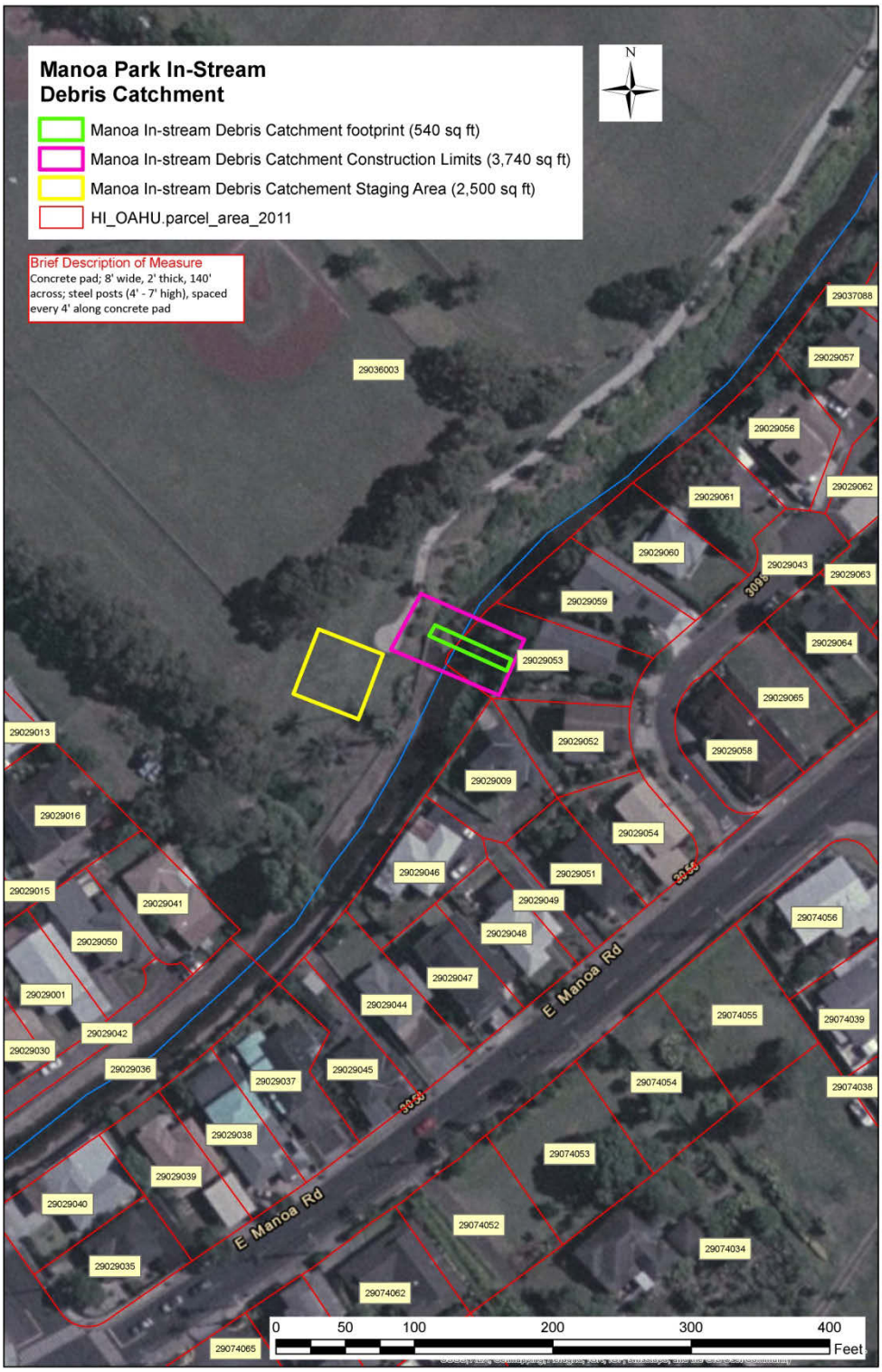

TRUE NORTH
SCALE: 1 in. = 50 Ft.
DEBRIS CATCHER
C
C
20' WIDE
ACCESS ROAD
TMK: 29054034
B
A
B
TMK: 29054004
CORNER OF DAM
TMK: 29054006
TMK: 29054002
ELEVATED ROADWAY
STAGING AREA
3' WIDE ENERGY DISSIPATORS
SPACED 1' APART
20'
CONSTRUCTION
LIMITS
BRIDGE
USE EXISTING ACCESS ROAD
Waaloa Way
Waakaua Street
WAIAKEAKUA STREAM
BRIDGE

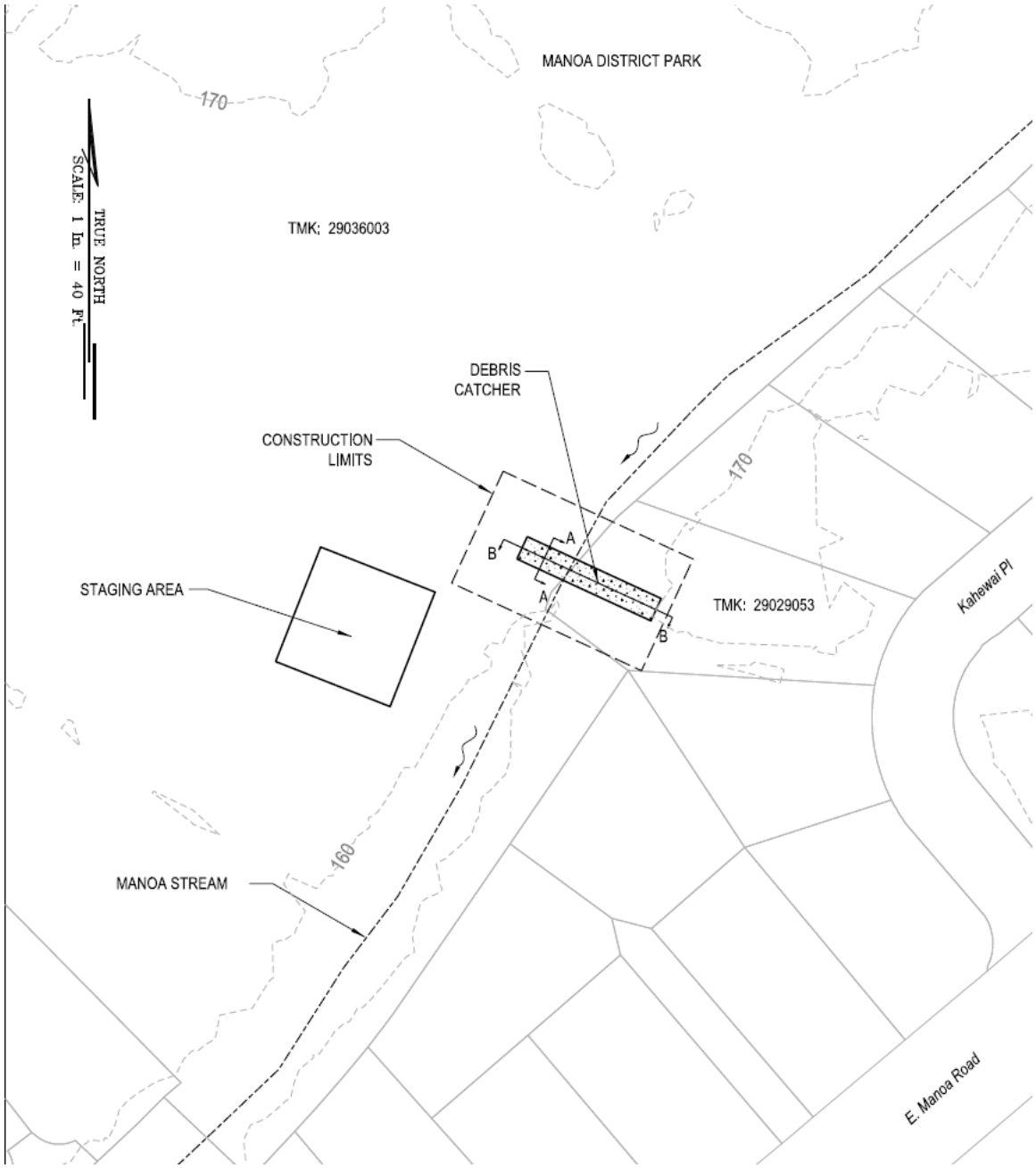
Makiki


Brief Description of Measure
Earthen berm; 24' high and 125' across; 4'x7' box culvert (will allow 2yr-storm flows to pass); concrete spillway above culvert (3'x 100'); 18" of rip rap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimeter of berm
N
25020002
25006009
2199
25007048
25020005
24026033
24026045
24026034
25007016
25007019
25020008
24026035
25007015
25007047
Makiki Heights Dr
Round Top Dr
24026036
2098
2158
25007012
25007014
0 25 50 100 150 200
Feet
24026002
Makiki Debris and Detention Basin
2011 TMK (Parcels)
Makiki Dam Footprint (7,250 sq ft)
Makiki Staging Area (2,500 sq ft)
Makiki Basin Construction Limits (11,800 sq ft)
Makiki 20' Access Road (745 ft)
Makiki Detention 100-yr Pool (23,140 sq ft)
24026037
25020001
2046
1958

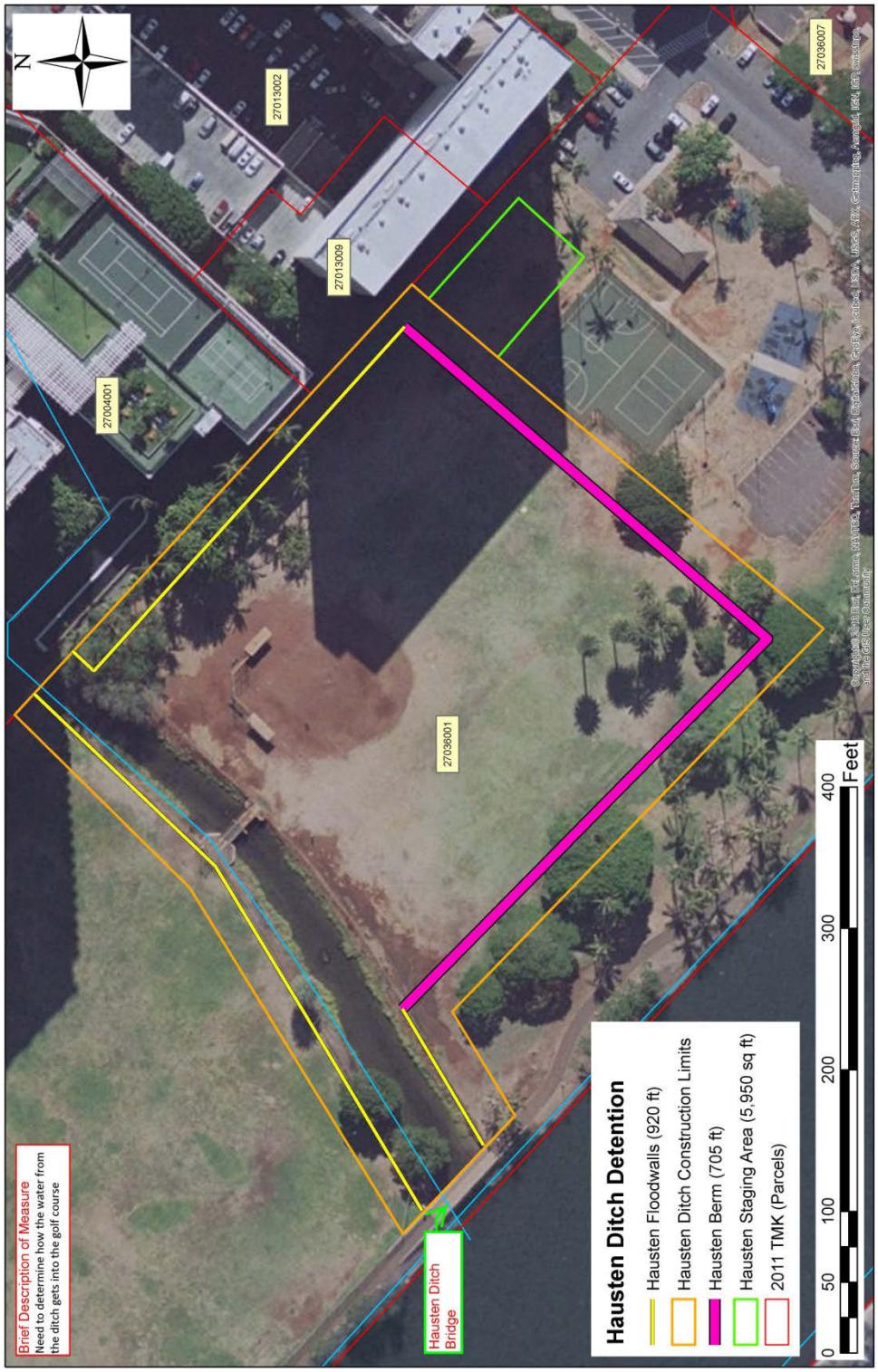

TRUE NORTH
SCALE: 1 in. = 40 ft.
TMK:
25020005
DEBRIS
CATCHER
A
A
CONSTRUCTION
LIMITS
TMK:
25020008
C
C
B
B
200
20' WIDE
ACCESS ROAD
Keeaumoku Street
Round Top Drive
200
150
MAKIKI
STREAM
Makiki Heights Drive
TMK:
25020001
STAGING AREA
150

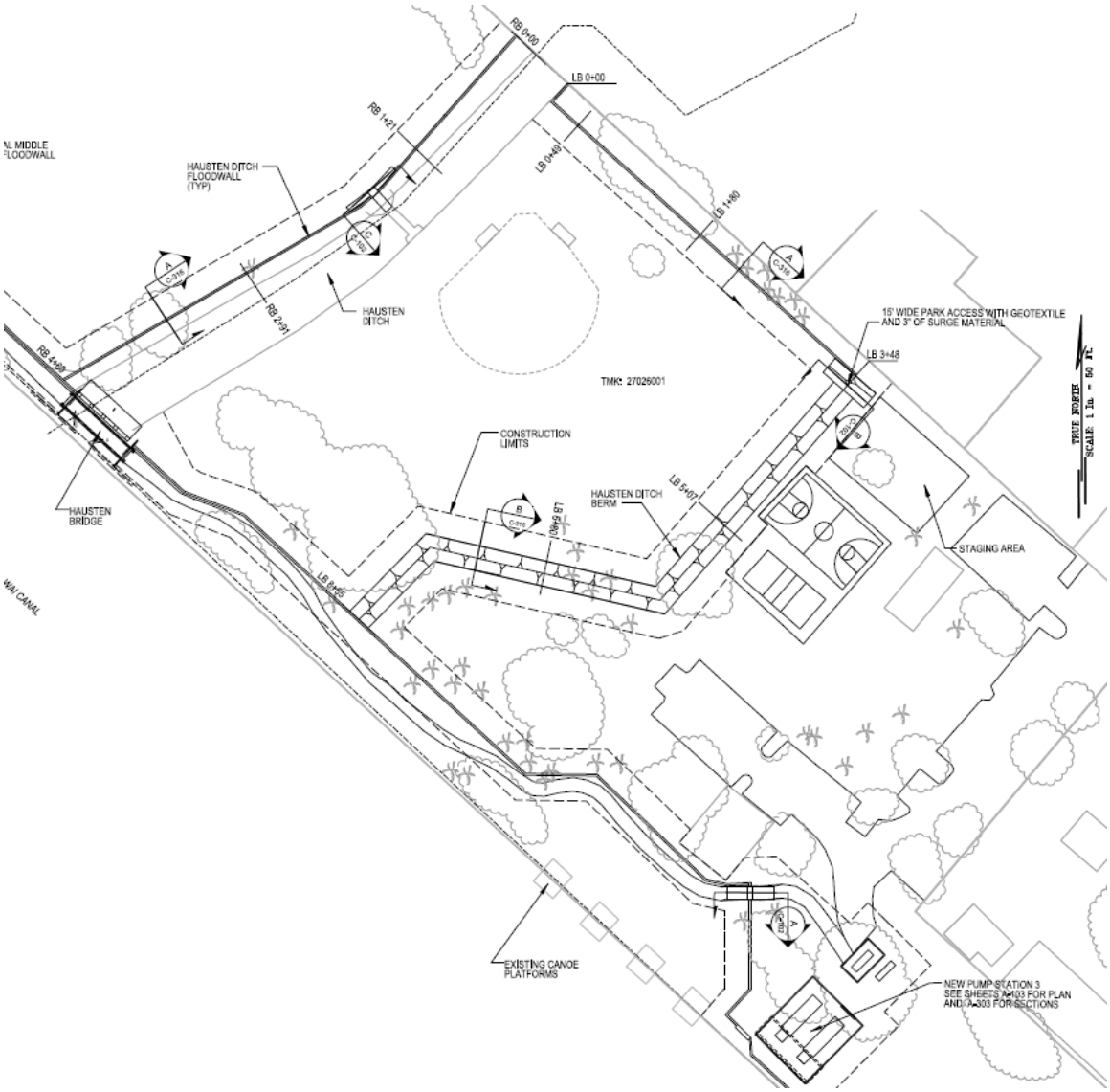
Manoa Park


Manoa Park In-Stream
Debris Catchment
Manoa In-stream Debris Catchment footprint (540 sq ft)
Manoa In-stream Debris Catchment Construction Limits (3,740 sq ft)
Manoa In-stream Debris Catchement Staging Area (2,500 sq ft)
HI_OAHU.parcel_area_2011
N
Brief Description of Measure
Concrete pad; 8' wide, 2' thick, 140' across; steel posts (4' - 7' high), spaced every 4' along concrete pad
29036003
29037088
29029057
29029056
29029062
29029061
29029060
29029043
29029063
29029059
29029064
29029053
29029065
29029013
29029052
29029058
29029009
29029016
29029054
29029046
29029051
29029015
29029041
29029049
29074056
29029050
29029048
29029047
29029001
29029044
29074055
29074039
29029042
29029030
29029036
29029037
29029045
29074054
29074038
29029038
29074053
29029039
29029040
29074052
29074034
29029035
29074062
29074065
E Manoa Rd
E Manoa Rd
0
50
100
200
300
400
Feet


MANOA DISTRICT PARK
170
TRUE NORTH
SCALE: 1 In. = 40 Ft.
TMK: 29036003
DEBRIS
CATCHER
CONSTRUCTION
LIMITS
170
A
B
A
B
STAGING AREA
TMK: 29029053
Kahewai Pl
160
MANOA STREAM
E. Manoa Road

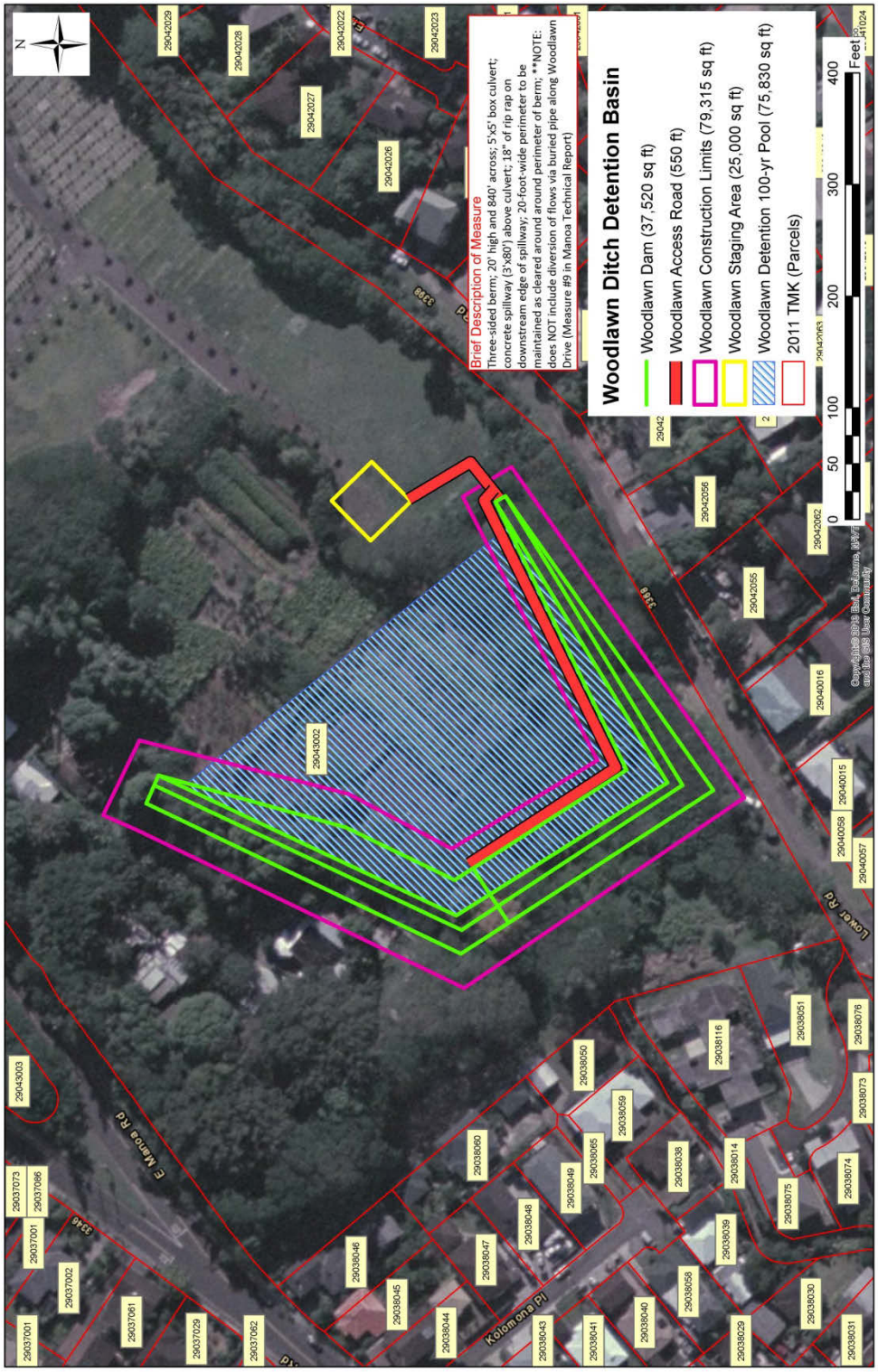
Hausten Ditch

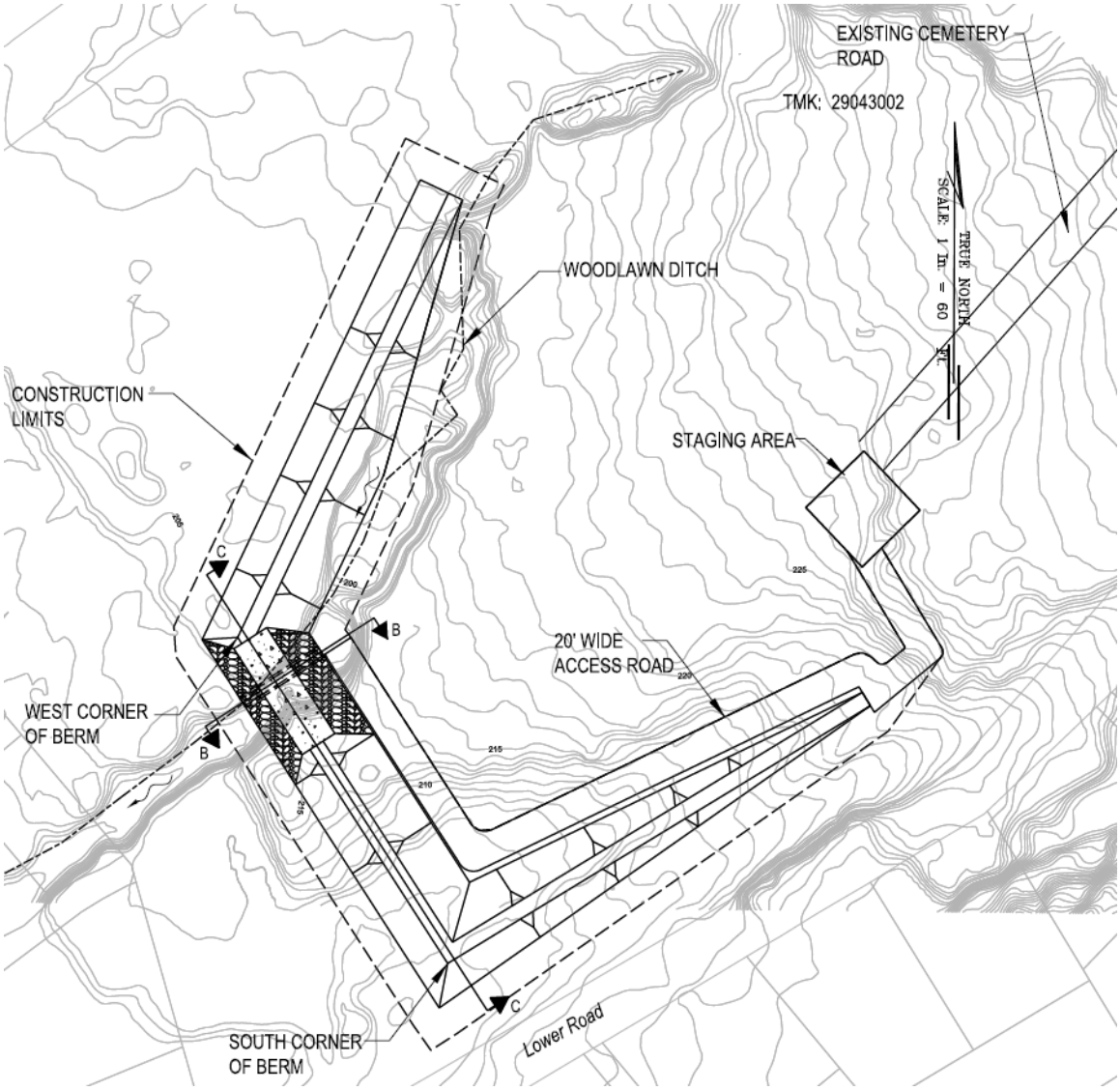



NL MIDDLE
FLOODWALL
HAUSTEN DITCH
FLOODWALL
(TYP)
RB 0+00
RB 1+21
RB 2+91
RB 4+99
HAUSTEN
DITCH
HAUSTEN
BRIDGE
LB 0+00
LB 0+49
LB 1+80
LB 3+48
LB 5+07
LB 6+45
LB 6+80
15' WIDE PARK ACCESS WITH GEOTEXTILE
AND 3" OF SURGE MATERIAL
TMK: 27026001
CONSTRUCTION
LIMITS
HAUSTEN DITCH
BERM
STAGING AREA
EXISTING CANOE
PLATFORMS
NEW PUMP STATION 3
SEE SHEETS A-103 FOR PLAN
AND A-303 FOR SECTIONS
TRUE NORTH
SCALE: 1" = 60'-0"
WAI CANAL

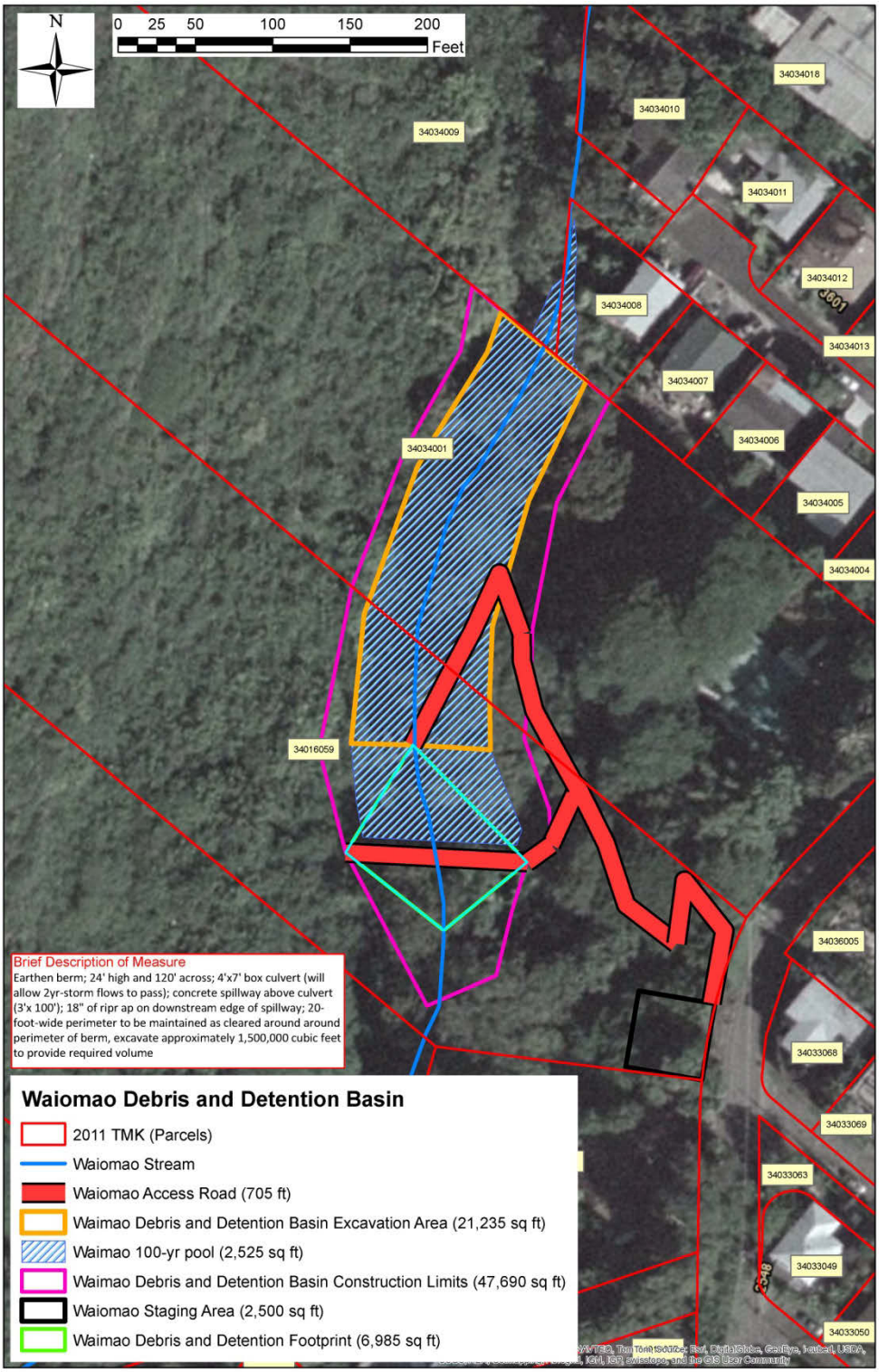
Ala Wai Canal

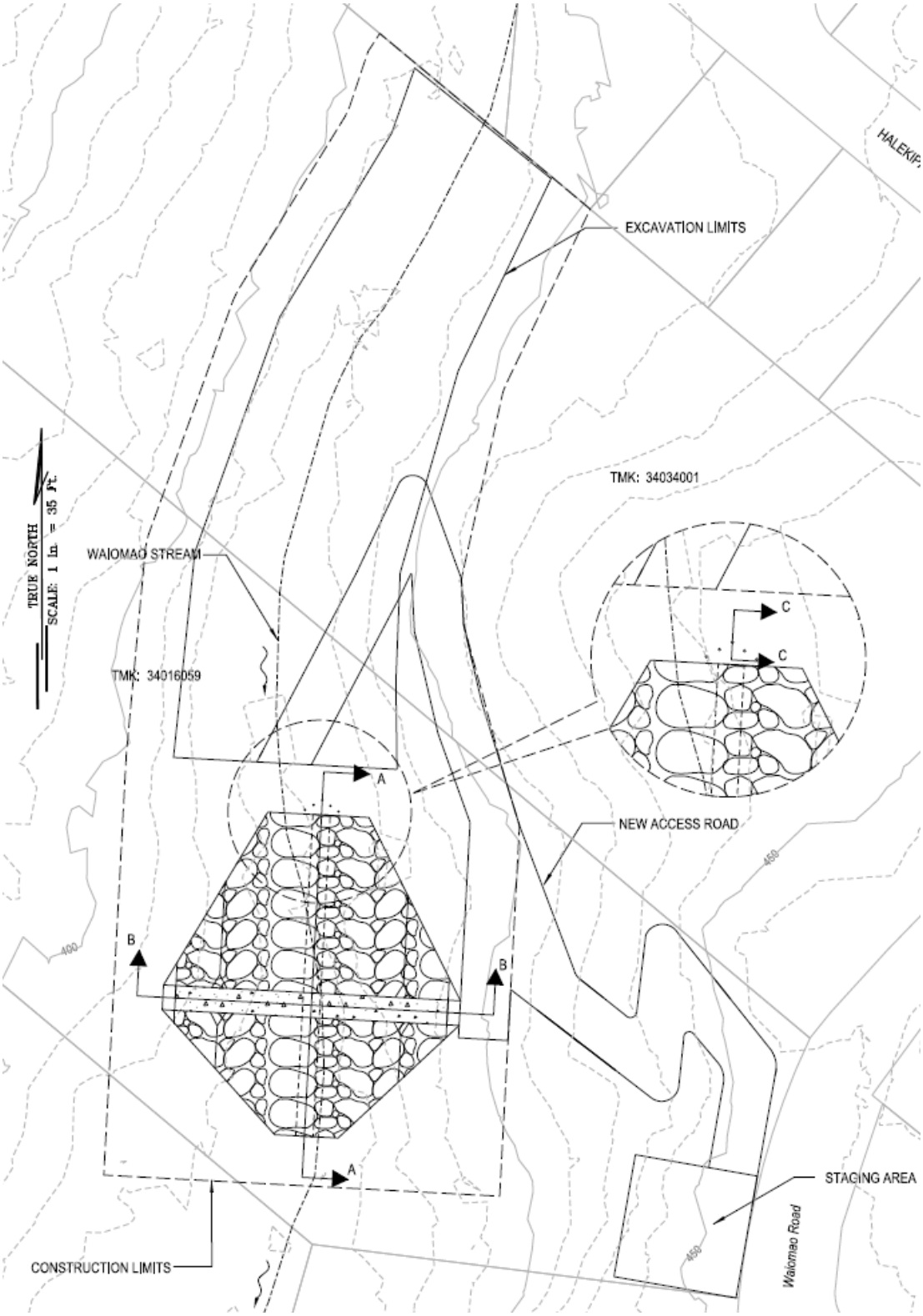
Woodlawn


Woodlawn Ditch Detention Basin
Woodlawn Dam (37,520 sq ft)
Woodlawn Access Road (550 ft)
Woodlawn Construction Limits (79,315 sq ft)
Woodlawn Staging Area (25,000 sq ft)
Woodlawn Detention 100-yr Pool (75,830 sq ft)
2011 TMK (Parcels)
Brief Description of Measure
Three-sided berm; 20' high and 840' across; 5'x5' box culvert; concrete spillway (3'x80') above culvert; 18" of rip rap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimeter of berm; **NOTE: does NOT include diversion of flows via buried pipe along Woodlawn Drive (Measure #9 in Manoa Technical Report)
0 50 100 200 300 400
Feet
N
E Manoa Rd
Kolomona Pl
Lower Rd
29043002
29042029
29042028
29042027
29042026
29042022
29042023
29042056
29042055
29042062
29040016
29040015
29040058
29040057
29038051
29038078
29038073
29038074
29038075
29038116
29038014
29038039
29038029
29038030
29038031
29038058
29038040
29038041
29038043
29038044
29038045
29038046
29038047
29038048
29038049
29038065
29038059
29038050
29038060
29038038
29043003
29037073
29037086
29037001
29037002
29037061
29037029
29037062

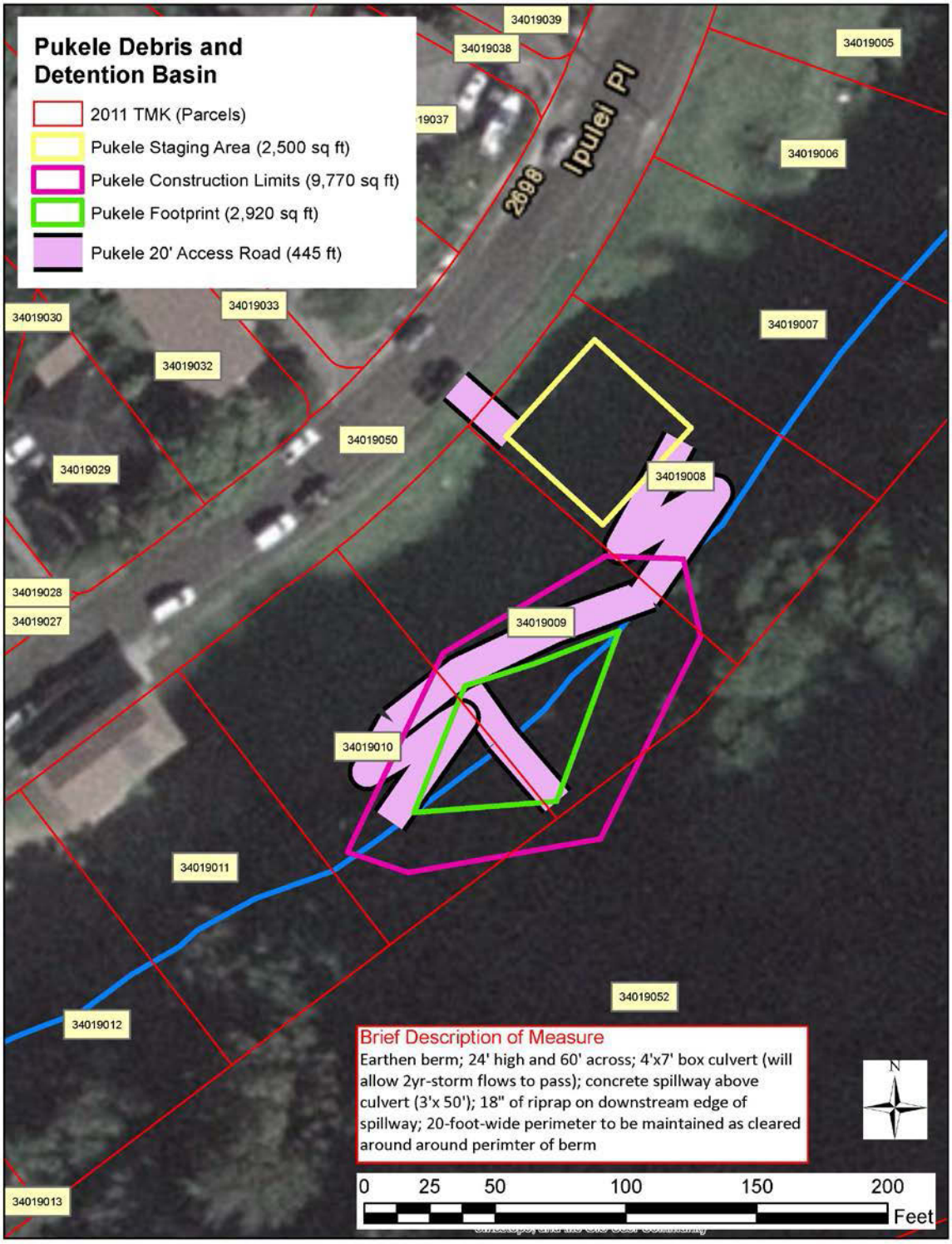

EXISTING CEMETERY ROAD
TMK: 29043002
TRUE NORTH
SCALE: 1 In. = 60 Ft.
WOODLAWN DITCH
CONSTRUCTION LIMITS
STAGING AREA
20' WIDE ACCESS ROAD
WEST CORNER OF BERM
SOUTH CORNER OF BERM
Lower Road
C
B
B
C
200
205
210
215
220
225

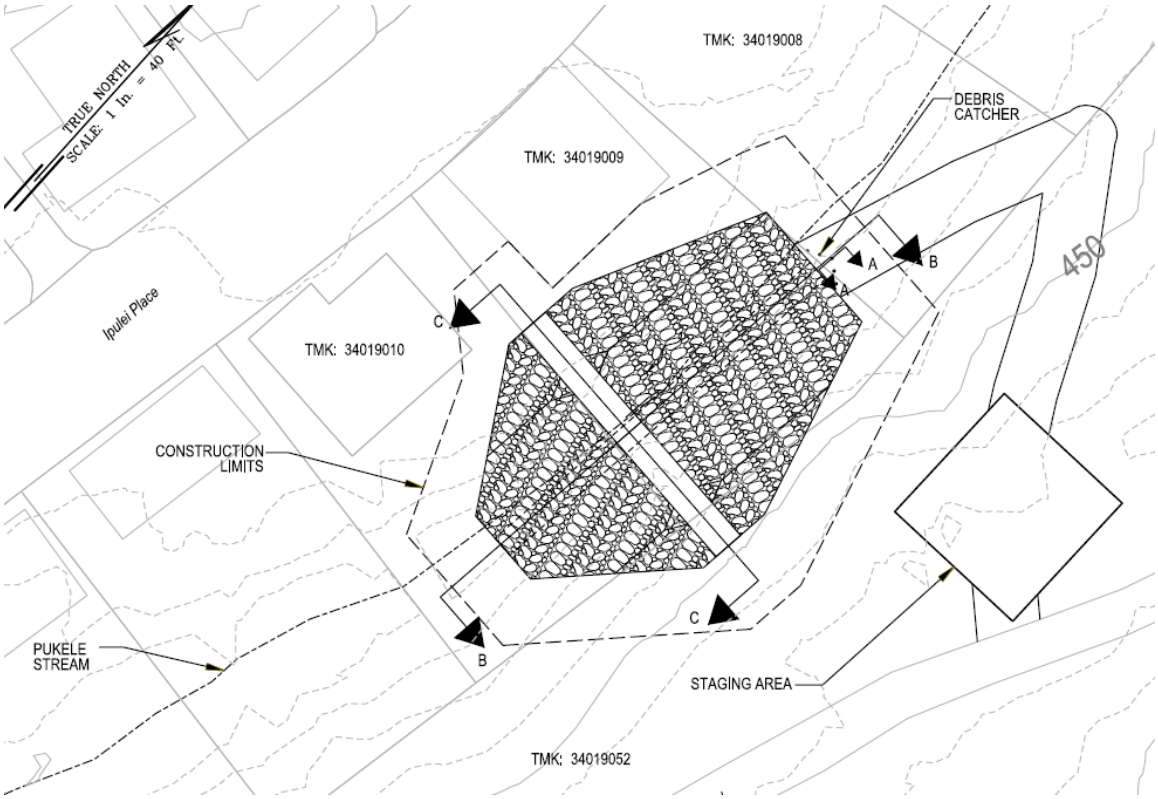
Wiaomao


N
0 25 50 100 150 200
Feet
34034018
34034010
34034009
34034011
34034012
34034008
34034013
34034007
34034006
34034001
34034005
34034004
34016059
34036005
34033068
34033069
34033063
34033049
34033050
Brief Description of Measure
Earthen berm; 24' high and 120' across; 4'x7' box culvert (will allow 2yr-storm flows to pass); concrete spillway above culvert (3'x 100'); 18" of ripr ap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimeter of berm, excavate approximately 1,500,000 cubic feet to provide required volume
Waiomao Debris and Detention Basin
2011 TMK (Parcels)
Waiomao Stream
Waiomao Access Road (705 ft)
Waimao Debris and Detention Basin Excavation Area (21,235 sq ft)
Waimao 100-yr pool (2,525 sq ft)
Waimao Debris and Detention Basin Construction Limits (47,690 sq ft)
Waiomao Staging Area (2,500 sq ft)
Waimao Debris and Detention Footprint (6,985 sq ft)

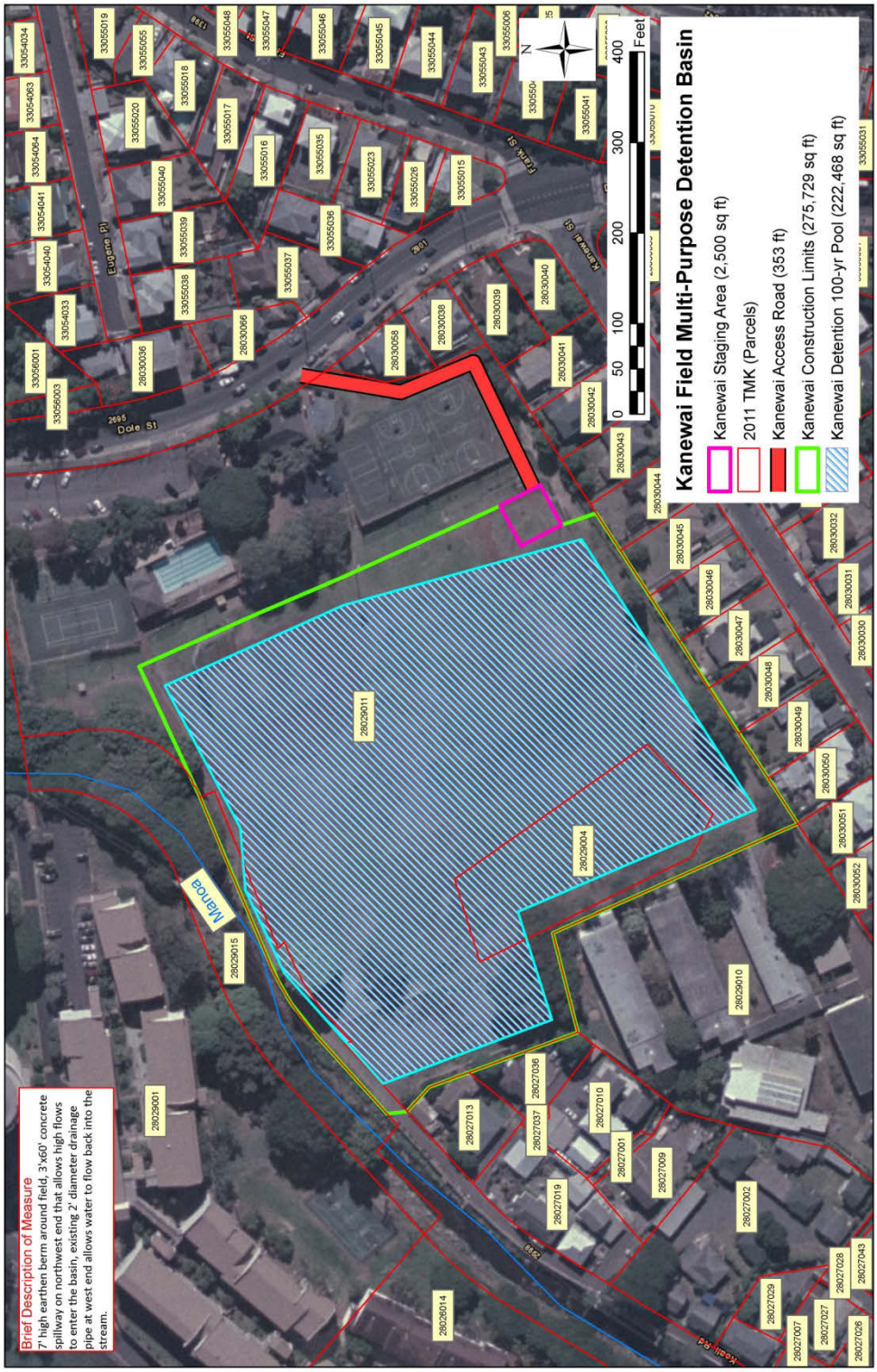

EXCAVATION LIMITS
HALEKIP
TMK: 34034001
TRUE NORTH
SCALE: 1 In. = 35 Ft.
WAIOMAO STREAM
TMK: 34016059
C
C
A
NEW ACCESS ROAD
450
400
B
B
A
STAGING AREA
450
Waiomao Road
CONSTRUCTION LIMITS

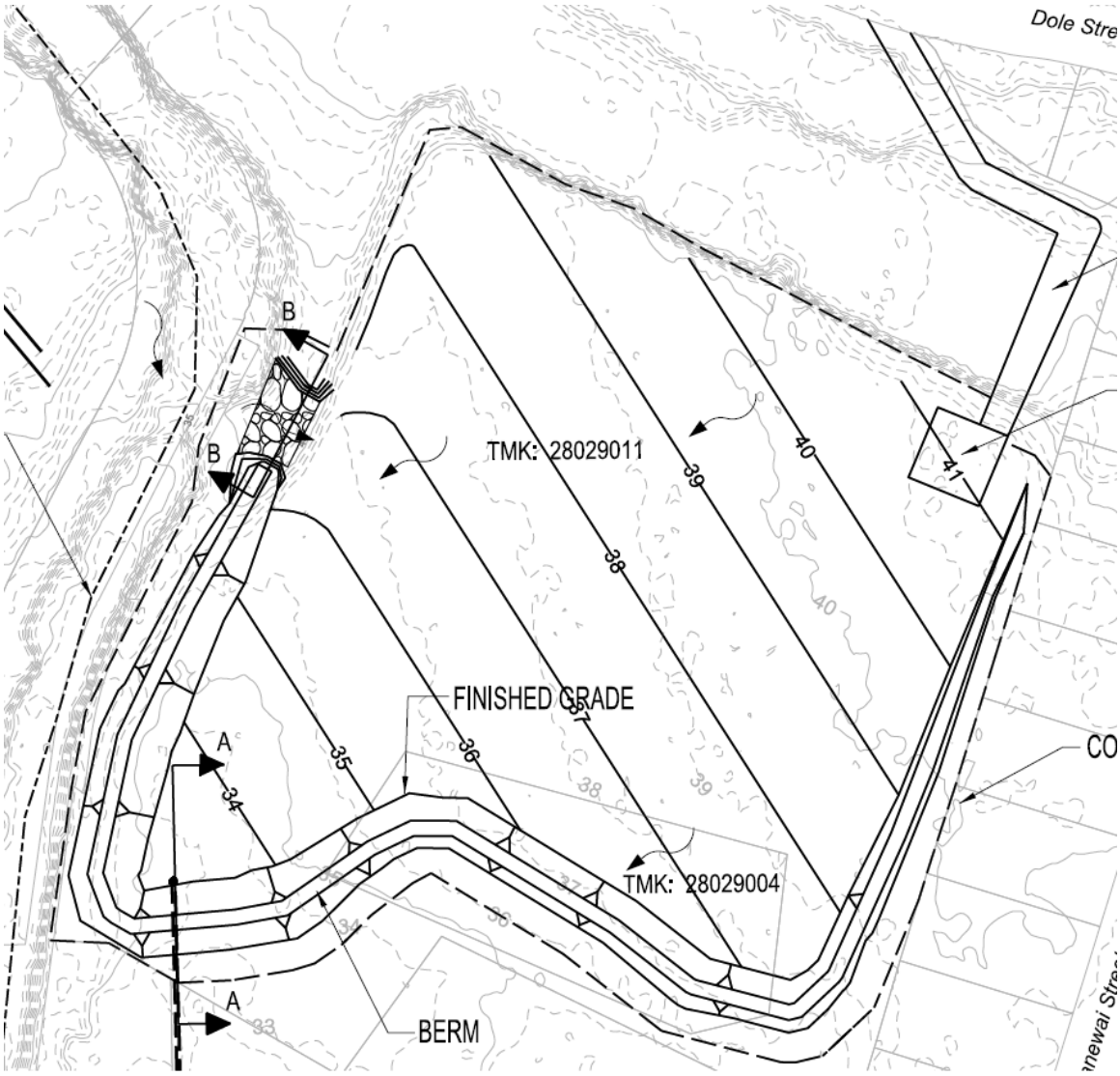
Pukele


Pukele Debris and Detention Basin
2011 TMK (Parcels)
Pukele Staging Area (2,500 sq ft)
Pukele Construction Limits (9,770 sq ft)
Pukele Footprint (2,920 sq ft)
Pukele 20' Access Road (445 ft)
34019039
34019038
34019005
34019006
34019007
34019008
34019009
34019010
34019011
34019012
34019013
34019052
34019050
34019033
34019032
34019030
34019029
34019028
34019027
Ipulei Pl
2698
Brief Description of Measure
Earthen berm; 24' high and 60' across; 4'x7' box culvert (will allow 2yr-storm flows to pass); concrete spillway above culvert (3'x 50'); 18" of riprap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimter of berm
N
0 25 50 100 150 200
Feet

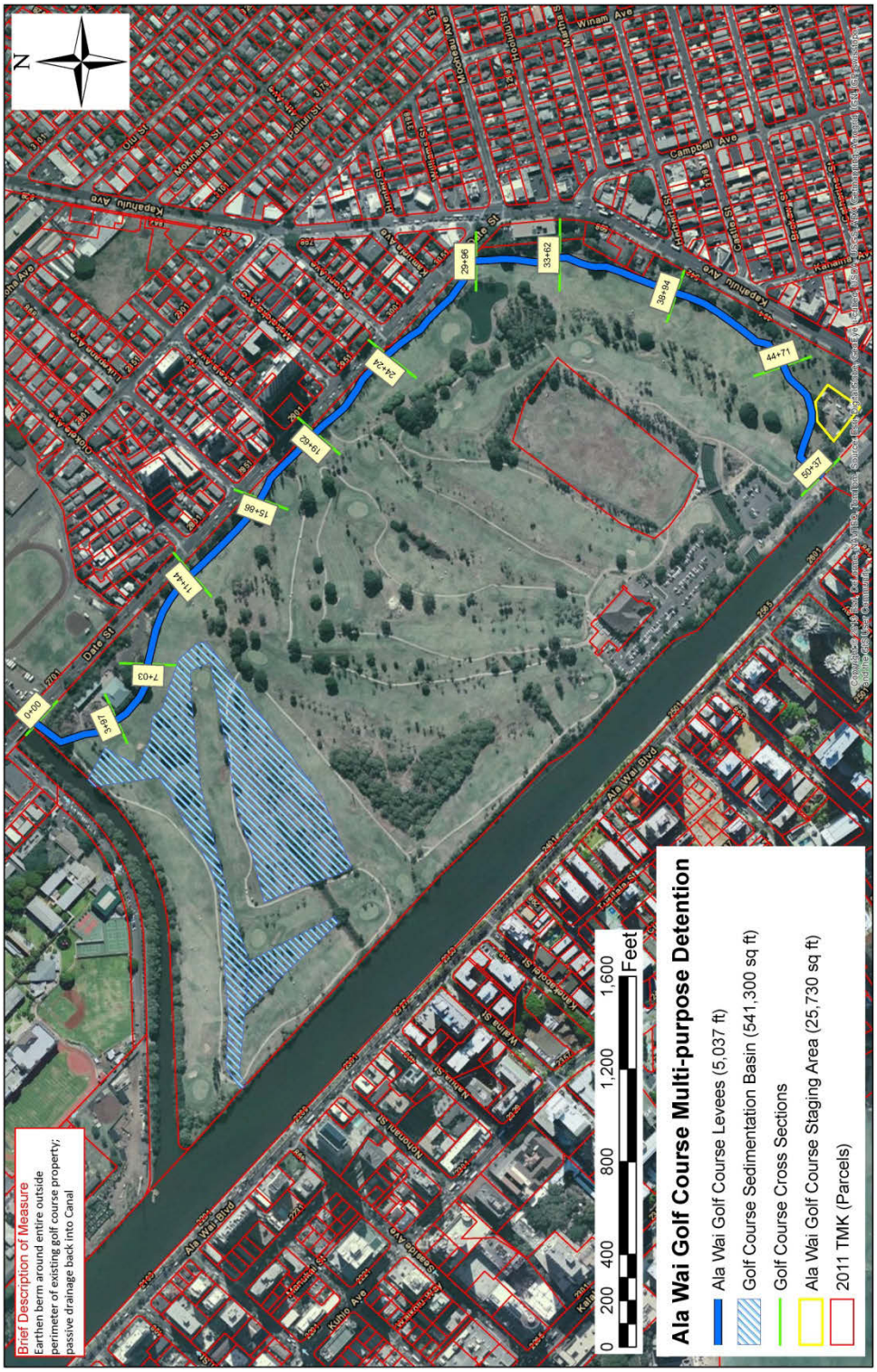

TRUE NORTH
SCALE: 1 In. = 40 FT.
TMK: 34019008
DEBRIS CATCHER
TMK: 34019009
A
B
A
450
Ipulei Place
C
TMK: 34019010
CONSTRUCTION LIMITS
C
PUKELE STREAM
B
STAGING AREA
TMK: 34019052

Kanewai

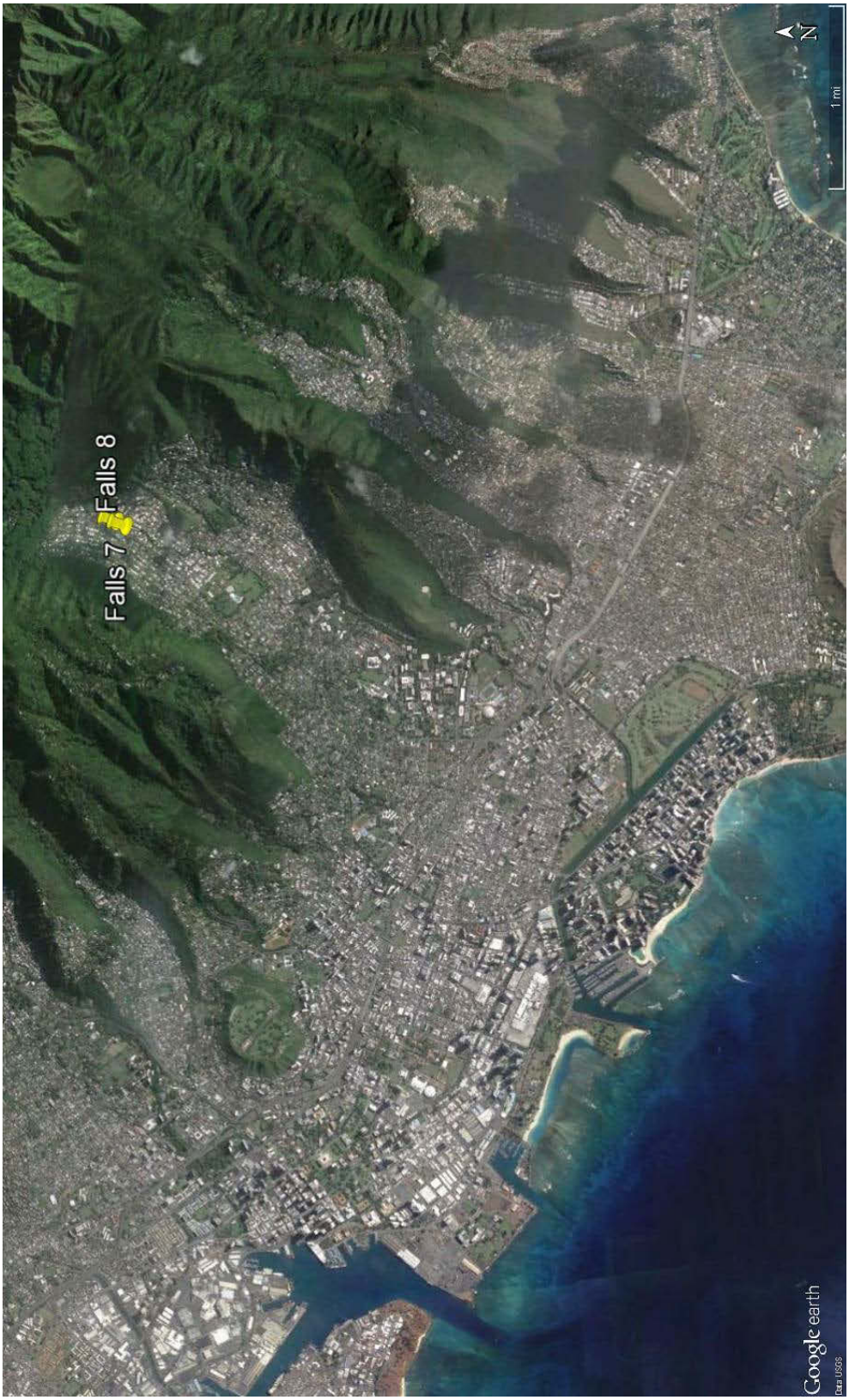

Brief Description of Measure
7' high earthen berm around field, 3'x60' concrete spillway on northwest end that allows high flows to enter the basin, existing 2' diameter drainage pipe at west end allows water to flow back into the stream.
Kanewai Field Multi-Purpose Detention Basin
Kanewai Staging Area (2,500 sq ft)
2011 TMK (Parcels)
Kanewai Access Road (353 ft)
Kanewai Construction Limits (275,729 sq ft)
Kanewai Detention 100-yr Pool (222,468 sq ft)
0 50 100 200 300 400 Feet
N
Dole St
Eugene Pl
Frank St
Kanewai St
Manoa
28029011
28029004
28029015
28029001
28029010
28028014
28027013
28027036
28027037
28027010
28027001
28027009
28027019
28027032
28027029
28027007
28027027
28027028
28027026
28027043
28030044
28030045
28030046
28030047
28030048
28030049
28030050
28030051
28030052
28030030
28030031
28030032
28030043
28030042
28030041
28030040
28030039
28030038
28030058
28030066
28030036
33056003
33056001
33054033
33054040
33054041
33054064
33054063
33054034
33055040
33055039
33055038
33055020
33055055
33055019
33055018
33055017
33055016
33055037
33055035
33055036
33055023
33055026
33055015
33055044
33055045
33055046
33055047
33055048
33055043
33055006
33055041
33055031


Dole Stre
B
B
TMK: 28029011
40
39
38
41
40
FINISHED GRADE
37
35
36
A
34
38
39
CO
TMK: 28029004
34
36
A
33
BERM
nnewai Stre

Ala Wai Golf Course



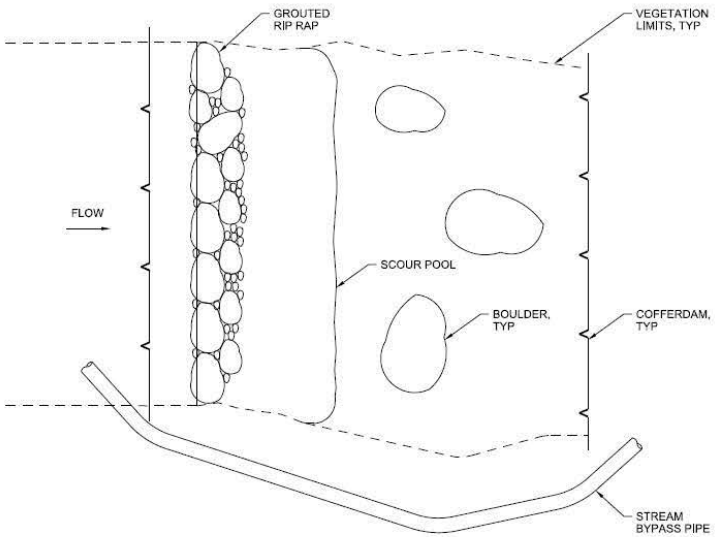
Mitigation Measures Sites Location



Mitigation Measures Site Location Aerials

Falls 7 and 8

Falls 8



PLAN
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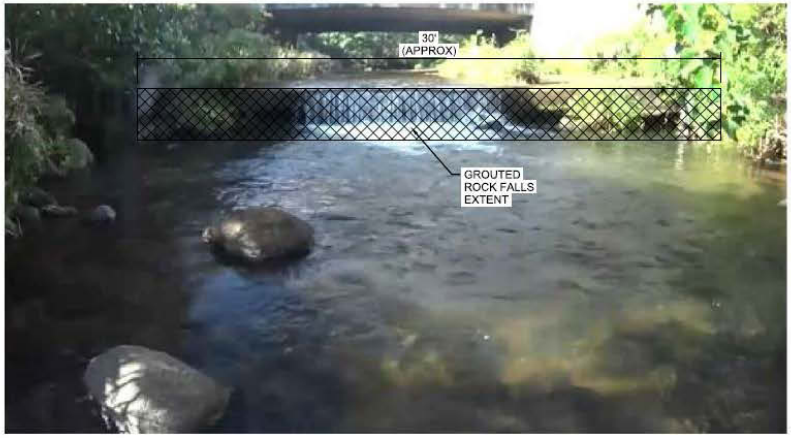

NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SITE PHOTO
NTS

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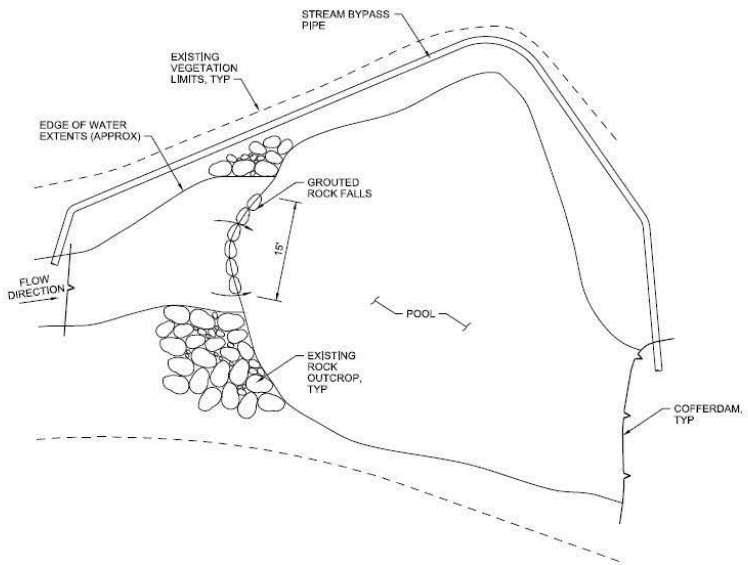

PLAN
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NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

SITE PHOTO
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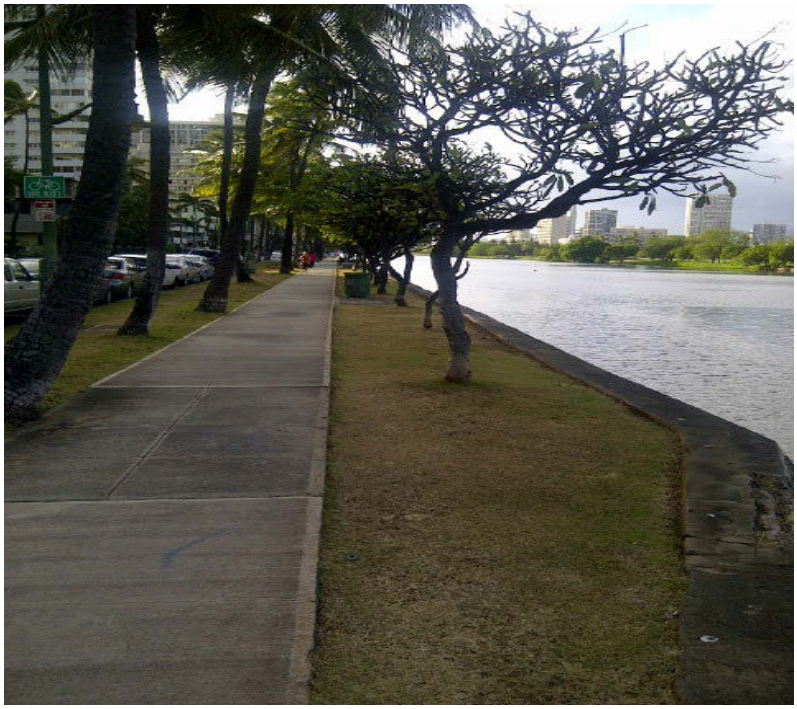
Feature Photos

AlaWai Canal (from Ala Moana)

Ala Wai Canal (convention center)



Canal South Side Pedestrian Walk

Canal North Side Pedestrian Walk

Canal North Side Canoe Launch Site

Stairs to Canal (south side)

Canal East Pump Station Footprint

Golf Course Cart Path To Be Elevated

Golf Course Floodgate Approximate Footprint (over road)

Hausten Ditch Detention Site

Pukele West Side

Pukele West Side Facing North

Waiakeakua Bridge To Be Reinforced

Waiakeakua Access Road Facing South

Waiakeakua East Side

Manoa District Park Debris Catchment Footprint

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX D
COST ENGINEERING

D1 Cost Report

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

SECTION 209 OF FLOOD CONTROL ACT OF 1962 (PUBLIC LAW 87-874)

APPENDIX D1

COSTS

(PN#102703)

(Rev 17 June 2015)

THIS DRAFT DOCUMENT IS BASED ON THE INFORMATION AVAILABLE AT THE TIME OF PUBLICATION (AUGUST 23, 2015). The Corps of Engineers planning process is dynamic and responsive to public and stakeholder input; it is possible that the content herein may change as a result of review comments received. This document does not necessarily represent the perspective of higher review levels within the agencies involved or the Executive Branch of the federal government.

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX D

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APPENDIX D

COSTS

1. PROJECT DESCRIPTION

The project consists of various measures to manage flood risk in Makiki, Manoa, Palolo and Ala Wai subwatersheds. The measures included in the alternatives are indicated in Table D-1. Measures such as detention/debris basin or debris catchment are located in the upper watershed for Makiki, Manoa and Palolo. Measures in the Ala Wai Canal area include levees, floodwalls, pump stations, flood gates, and sediment basin. The project also includes cultural monitoring during construction, adaptive management during the environmental monitoring stage after construction is complete. Table D-1 describes the measures included in the Viable Alternatives.

Table D-1. Measures

Subwatershed	Measure	Location	Alternative	
			2A	3A
Structural				
Palolo	Debris & Detention Basin	Waiakeakua Stream		x
	Debris & Detention Basin	Waihi Stream		x
	Debris Catchment	Waiakeakua Stream	x	
	Debris Catchment	Waihi Stream	x	
	Debris & Detention Basin	Woodlawn Ditch	x	x
	Debris Basin	Po`elua Place	x	
	In-Stream Debris Catchment	Below Manoa District Park		x
	Detention Basin	Manoa District Park	x	
	In-Stream Debris Catchment	Innovation Center	x	x
	Multi-purpose Detention Basin	Kanewai Field	x	
	Debris & Detention Basin	Waiomao Stream		x
	Debris Catchment Basin	Waiomao Stream	x	
	Debris & Detention Basin	Pukele Stream		x
	Debris Catchment Basin	Pukele Stream	x	
	Drainage Canal Floodwall	Downstream of Manoa/Palolo Stream	x	
Makiki	Debris & Detention Basin	Makiki Stream	x	x
	Debris & Detention Basin	Roosevelt High School	x	x
Ala Wai	Floodwalls	Both sides of Ala Wai Canal	x	x
	Multi-purpose Detention	Golf course	x	x
	Hausten Ditch Detention	Hausten Ditch	x	x
	Pump Stations	Ala Wai	x	x
Non-structural				
	Flood Warning System		x	x
	Flood proofing		x	x

2. BASIS OF ESTIMATE AND QUANTITY

This feasibility cost estimate is based on the *Ala Wai Canal Project, Oahu, Hawaii, Draft Feasibility Study Report with Integrated Environmental Impact Statement* (Draft Feasibility Report/EIS)). Input for the estimate was obtained from the Project Delivery Team (PDT). Following Engineering Regulation (ER) 1110-2-1302, *Engineering and Design Civil Works Cost Estimating*, cost estimates were prepared at three levels:

- **Class 5** for screening of the initial viable array of alternatives which based the costs on historical cost data from the November 2008 Natural Resources Conservation Service, US Department of Agriculture and US Army Corps of Engineers (USACE), Honolulu District report titled *Technical Summary Report Manoa Watershed Project Honolulu, Hawaii*. Where costs were unavailable, Random Order of Magnitude cost were used by scaling available costs from the report.
- **Class 4** for the refinement of the final viable array of alternatives, which was based on a concept design. Cost was developed from rough quantity take-offs and supplemented with best professional judgment based on similar projects.
- **Class 3** for inclusion in the Draft Feasibility Report/EIS which was based on a 35 percent level of design. Quantities for this level of design were calculated from 10 to 60 percent quality of project definition. Quantity calculations were aided by the use of Microstation, Google Earth, and Excel software. Major cost items were obtained from material suppliers.

3. ESTIMATED DESIGN AND CONSTRUCTION SCHEDULE

The estimate was initially based is based on the entire contract awarded to a single contractor with multiple contractors. Table D-2 shows the estimated schedule is:

Table D-2. Estimated Project Schedule

Phase	Estimated Start	Estimated End	Estimated Midpoint
Sign Design Agreement	Nov 2015	Sep 2016	N/A
Sign PPA	Nov 2019	Nov 2020	N/A
Real Estate Acquisition	Oct 2016	June 2020	Sep 2018
Planning, Engrg & Design	Oct 2016	Dec 2019	May 2018
Solict/Award	Nov 2020	Feb 2021	N/A

The Tentatively Selected Plan (TSP) construction schedule is presented in this Appendix. The estimated construction time is based on:

- **Typical Construction Crew:** (1 shift) working 8 hr/day and x 5 day weeks.
- **Overall Production Efficiency Rate:** 90 percent which is based on anticipated project difficulty, method of construction, labor availability, supervision, job

conditions, weather and expected delays. Anticipated weather delays are included in the construction schedule.

Table D-3. Estimated Construction Duration

	Alternative 2A	Alternative 3A	Initial TSP
Construction Start	Mar 2021	Mar 2021	Mar 2021
Construction End	Dec 2024	June 2024	June 2024
Midpoint	Feb 2023	Oct 2022	Oct 2022
Adaptive Mgt Midpoint (3 yrs after Construction Complete=Yr 0)	June 2026	Dec 2025	Dec 2025

- **Construction Windows:** None
- **Overtime:** This estimate contains no overtime to complete the project.

4. ACQUISITION PLAN

4.1. Estimate: The estimate is based on a single contract being awarded to the Prime Contractor with multiple sub contractors. The acquisition strategy is assumed as Full and Open Invitation for Bid. The prime contractor will be responsible for oversight of the contract the rest of the work is assumed performed by subcontractors.

4.2. Sub-Contracting: At the 10 percent level of design estimate, the assumption of multiple subcontractors was not used. A single subcontractor markup was used for any subcontractor effort. For the TSP estimate, the subcontractors are broken out as:

- Sitework
- Hauling
- Material Supplier (concrete, soil, rocks, pipes)
- Disposal Cost
- Concrete Sub
- Reinforcing Sub
- Piping Sub

It is assumed that the prime contractor will perform the rest of the work.

5. PROJECT CONSTRUCTION

5.1. Mobilization, Demobilization and Preparatory Work

Mobilization/Demobilization: The estimate for this study assumed that the Contractors will be from Oahu. This does not exclude any work effort to contractors from other locations during the bidding process.
Temporary Facilities: The estimate includes the assumption office trailers and temporary utilities for the Prime Contractor and Government. The electricity will be supplemented by diesel generator.

5.2. Surveys: Assume site pre-construction survey and layout, survey during construction and installation three benchmarks per site.

5.3. Disposal: Approved on-island landfill with green waste and excavated rock to a recycler.

5.4. Features and Discussion

- **Site Access:** The sites are located in urban Honolulu, Island of Oahu. Where access to the construction site is not available, new access roads will be constructed. Where the haul road is steep, the final access road is assumed constructed of grooved 8" thick concrete. This assumption will be refined in the PED phase.
- **Borrow Areas:** The borrow sources is assumed from an on-island commercial source. Borrow areas for topsoil and fill is assumed to be from on-island.
- **Construction Methodology:** The construction methodology will be industry standard.
- **Unusual Conditions (Soil, Water, and Weather):** Locations in perpetual streams are assumed dewatered using cofferdams. Actual dewatering plan will be determined by the Contractor performing the work after award of the construction project. The project schedule includes anticipated weather delays.
- **Unique Techniques of Construction:** None
- **Equipment and Labor Availability:** The cost assumes equipment and labor is readily available on Oahu or from the other locations.
- **Environmental Concerns:** The estimate includes cost for Adaptive management for stream mitigation and is expected to include physical changes to habitat in localized areas (e.g., modifications to reduce unanticipated barriers to fish passage, bank/channel stabilization, etc.); cost is assumed to be 5 percent of the total mitigation construction cost.

Standard Best Management Practices such as silt fences, gravel entrances to the contractor's storage area are included in the estimate.

6. COST ESTIMATE ASSUMPTIONS

6.1. Effective Price Level: Project costs are presented in October 2013 (1Q2014) dollars.

6.2. Construction Cost Estimate. The construction cost estimate was developed using MCASES 2nd Generation estimating software in accordance with EF 1110-2-1302, *Civil Works Cost Engineering*, 15 Sep 2008; UFC 3-740-05, Handbook: *Construction Cost*

Estimating, 8 November 2010, Change 1, June 2011. The construction cost estimate was prepared using MII Version 4.2, and the latest 2012 English Cost Book and 2011 Equipment Library (Region 10).

6.3. Labor Rates. The labor rates used are from the State of Hawaii Department of Labor & Industrial Wage Rate Schedule Bulletin#482 16 Sep 2013 effective until September 2014 for the State of Hawaii for building, heavy (heavy and dredging), highway, and residential construction types for all counties in Hawaii statewide.

6.4. Labor and Equipment Productivity: The overtime hours listed in Table D-xxxx, has been implemented into the MCASES estimate to account for additional labor and equipment adjustments. The estimate includes an overall Production Index of 90 percent which is based on anticipated project difficulty, method of construction, labor availability, supervision, job conditions, weather and expected delays.

6.5. Escalation: Escalation has been calculated within the estimate. Price levels have been escalated from price levels of the construction cost estimate to the midpoint of construction indicated in Table D-3.

6.6. Functional Costs: Functional costs using the Civil Works Breakdown Structure (CWBS) associated with this work were developed from quantity take-offs using CAD drawings, historical costs and input from PDT members as follows:

01 – Lands and Damages: This account covers costs Lands and Damages for Construction. The initial estimate for real estate costs were derived from the tax map key full replacement. Market cost will be determined at TSP level by an appraiser. Based on real estate's judgment, TMK costs are typically much lower than market costs.

04 – Dams: This account covers detention & debris basins. The detention and debris basis consists of a trapezoidal shaped structure crossing the stream. The interior of the debris & detention basin consists of impermeable fill. The spillway consists of a concrete top with 2' thick riprap on the upstream side and downstream side of the sloped part of the structure. A single radius arch culvert allows the stream to pass thru the structure. Debris will be caught on the upstream side of the structure with debris catching posts. An access road will be constructed for O&M maintenance. This account also includes adaptive management for habitat impacted areas.

11 - Levees and Floodwalls: This account covers cost for levees and floodwalls. The Floodwalls is constructed of concrete with moss rock façade. The levee/berm consists of compacted impermeable fill and grass.

13 – Pumping Plants: This covers the pump stations near the Ala Wai Canal. Initial costs for the viable array were based on historical cost. Pump station design will be further refined in the TSP and PED phase.

15 – Floodway Control and Diversion Structures: This account covers slide gates and flap gates along the Ala Wai Canal for interior drainage and debris catchment systems consisting of concrete footing and metal posts crossing existing streams. This account also includes adaptive management for habitat impacted areas.

18 – Cultural Resource Preservations: This account covers cultural monitoring during construction. The cost for this account was developed by the PDT Archeologist. Further investigations will be conducted during the PED phase.

19 – Buildings, Grounds and Utilities: This account covers the cost for flood proofing structures in Manoa in Alternative 2A, and a flood warning system in Alternative 2A and 3A. The initial flood proofing cost was prepared by the Economist using National Data, localized for Honolulu. The cost includes flood proofing of 2 commercial buildings - Ring Wall or Dry Flood Proofing. 2444 Dole St, Bachman Hall: Ring Wall 4'H X 1,000' Long; 2695 Dole St., Kanekai Park Equipment Storage: Dry Flood Proofing 3'H X 250' long.

This account also covers floodwarning system. The initial flood warning system cost was based on historical costs obtained from the USGS. The location & type of stream gauge system will be determined after a study during PED determines the flood warning thresholds required. The initial estimate assumes 3 gauges, one each for Makiki, Palolo and Manoa Watershed.

30 – Planning, Engineering and Design (PED): This account covers construction management during the construction cost. Initial cost was based on a percent of construction. PED cost will be refined in the TSP estimate.

31 Construction Management (CM): This account covers supervision and administration costs during construction. The initial cost for the viable array was based on a percent of construction based on typical projects. CM costs will be further refined in the TSP estimate.

6.7. Estimate Assumptions: Key assumptions used for estimating the construction cost of the proposed alternative are as follows:

1) Analysis performed on major cost items based on level of design. The viable array conceptual design is at approximately 10 percent quality of project definition and the TSP at approximately a 35 percent level of design effort.

2) Excavated material associated with the feature will be calculated for the structure. Where it is assumed the excavation consists of soil and rocks, the rocks will be screened out. Areas of clear and grubbed material will be mulched. Soil, rocks, and green waste will be hauled off site for either disposal or recycling.

3) The debris and detention basin structure is assumed constructed in halves to allow the streams to flow. It is assumed the construction of cofferdams will assist in keeping the structure construction area dry while the stream is normally flowing.

4) Access to structures will be constructed and used as permanent access roads for operations and maintenance (O&M). Entrances to access roads will be restricted by use of pipes and chains or where necessary, chain link fence. Public access for the Ala Wai Floodwalls not developed at this stage. Will be refined for the TSP.

5) Actual site of the Ala Wai Floodwalls is approximate for the alternatives. The footprint of the floodwalls will be refined for the TSP.

6) The pump station is assumed to have a metal building, 50' x5 0' with two each pump, wet well, sluice gates, mechanical and electrical work. The design will be refined in the PED phase. The initial estimate is based on a flood mitigation awarded. This assumed cost includes 1 ea 12,000 gpm/150hp & 1 ea 15,600 gpm/150 HP pump vertical turbine well pumps & 2 each 350 gpm/10HP submersible sump pump and controls, metal building & standby generator & building...

7) General percent markups will be used for the initial estimate. Markups will be refined for the TSP.

6.8. Contingencies by Feature or Sub-Feature: Current Headquarters USACE guidance requires a formal analysis on all projects where the projected cost exceeds $40 million. In accordance with ER 1110-2-1302 and ECB 2007-17, 10 Sep 2007, Cost Risk Analysis was used to identify and measure the cost impact of project uncertainties within the estimated total project cost. The risk model used was an Abbreviated Cost Risk Analysis template created by the Cost MCX to determine the contingencies by Civil Works Features for the initial viable alternatives, incremental cost and optimized design cost prior to selection of the recommended plan.

Oracle Crystal Ball analysis will be used to develop contingencies for the Recommended Plan.

Contingencies are added to the cost estimate based on results of risk analysis. Results yielded contingencies added to the construction costs. Table D-4 summarizes the contingency amounts.

Unknowns that could affect the project costs and design assumptions prior to the detailed PED phase include:

- Site relocation of measures
- Under-designed floodwall footings
- Variation in estimated quantities
- Increased compliance with viewing planes, historical features or recreational access

- Additional appurtenances for features
- Unanticipated cultural deposits or artifacts
- Changes in Acquisition strategy
- Changes in bid schedule
- Unexpected contaminated soils
- Dewatering and control of water uncertainties
- Unexpected geotechnical or ground water issues
- Unanticipated underground utilities
- Increased landfill disposal rates
- Further refinement of designs based on refinement of hydraulic models
- Delays in real estate acquisition or funding
- Increased permitting regulations affecting designs
- Community opposition
- Responsibility of O&M between City and State Government
- Changes in interior drainage leading to the canal
- Changes in material to construct the hydraulic structures
- Changes in structural foundation designs
- Changes to adaptive management and duration
- Restrictions of public access during construction to recreational areas
- Traffic delays during construction of the features
- Unseasonal weather delays (hurricanes, tsunamis, flooding) during construction
- Unanticipated phasing requirements
- Single or multiple contracts over multiple years

Real Estate Contingency was based on judgment by the Real Estate Project Delivery Team for the viable array. TMK costs are typically much lower than market costs. Real Estate Contingency will be refined in the TSP estimate.

6.9. Total Project Cost Summary: The Total Project Cost Summary (TPCS) Sheet includes the construction costs from the MCASES estimate, project markups, as well as costs for Lands and Damages, Planning, Engineering & Design, and Construction Management.

Table D-4. Viable Array of Alternatives Total Project Cost [1, 2, 3]
Alternatives Total Project Cost (Fully Funded) Budget Year 2016 based on 10% Level of Design (Class 4 Historical/Parametric)

	Alternative 2A			Alternative 3A		
CWBS Acct	**Total Cost @ EPL 1 Oct 13 ($K)**	**% Contingency**	**Fully Funded Cost @ FY17 ($K)**	**Total Cost @ EPL 1 Oct 13 ($K)**	**% Contingency**	**Fully Funded Cost ($K) @ FY17**
01 Real Estate	$28,419	50%	$31,040	$9,509	50%	$10,385
Construction						
04 Debris/Detention Basin	$48,778	31%	$57,856	$68,131	31%	$80,182
11 Levees/Floodwalls	$30,184	29%	$35,313	$25,175	29%	$29,616
13 Pumping Station	$25,500	50%	$29,848	$24,318	50%	$28,608
15 Floodway Control/ Diversion Structure (Debris Catchment/Slide Gates)	$32,352	28%	$38,569	$4,290	34%	$5,064
18 Cultural Resource Preservation	$885	23%	$1,042	$852	21%	$999
19 Bldgs, Grounds & Utility (Floodproofing Structures in Manoa & Flood Warning System)	$1,959	20%	$2,228			
19 Bldgs, Grounds & Utility (Flood Warning System)				$164	25%	$196
TOTAL CONSTRUCTION COST	**$139,658**		**$164,856**	**$122,930**		**$144,665**
30 Planning, Engineering, and Design	$36,314	33%	$43,878	$31,957	34%	$38,531
31 Construction Mgt	$20,251	33%	$28,351	$17,824	34%	$24,711
PROJECT COST TOTAL	**$224,642**		**$268,125**	**$182,220**		**$218,292**

[1]. Total Project Cost (TPC) – includes contingency & escalation of a fully funded project. The Alternative cost was refined using preliminary designs after screening of the initial viable array of alternatives.

[2] Effective Price Level

[3] Contingency determined by Cost Risk Analysis[4]. $K = $100,000

7. INCREMENTAL & OPTIMIZATION COSTS

7.1. Incremental Costs. Incremental costs were developed to demonstrate whether each measure added additional benefits aside from cost (net benefits). The combination of measures was determined by the hydraulic engineer. The Economist analyzed whether additional measures maximized net benefits (refer to Appendix B, *Economics*).

Incremental Costs were developed using the estimate prepared for Alternative 3, the tentatively selected alternative. The estimate structure was broken down by measures so incremental costs could be extracted for each measure. Risks determined for Alternative 3 were used to determine the contingencies for each incremental cost. Table D-5 indicates the measures included in the incremental cost.

7.2. Proposed National Economic Development Plan. Following incremental cost**,** the proposed National Economic Development (NED) Plan, Alternative 3, Increment 6 was further optimized by adjusting the Ala Wai floodwall heights to determine the optimum level of protection and to maximize net benefits.

7.3. Optimized Costs. The following describes the optimized cost and the costs are summarized in Table D-6.

- Optimized (0). Opt (0), Alternative 3A, Increment 6, became the basis of the Opt (0) cost which is an average 4-foot high floodwall in the Ala Wai Canal Area.
- Optimized (-1). Opt (0) with a 1-foot decrease in all Ala Wai floodwall heights which equates to an average 3-f00t high and includes stairs and ramps for canal access.
- Optimized (+1) Alternative 3A, Increment 6, with 1-foot increase in all Ala Wai floodwall heights from Opt (0), which equates to an average 5 ft floodwall height includes stairs and ramps for canal access.
- Optimized (+2) Alternative 3A, Increment 6,with 2-foot increase in all Ala Wai floodwall heights from Opt (0), which equates to an average 6-foot floodwall height and includes rolling floodgates for canal access. This Optimized cost is the proposed NED plan.
- Proposed TSP. Alternative 3A, Increment 6, increases Ala Wai Floodwall heights from an average 4-foot high floodwall to 4.7-foot high and includes stairs and ramps for canal access.
- Optimized (+3) Alternative 3A, Increment 6, with 3-foot increase in all Ala Wai floodwall heights which equates to a 7-foot floodwall height.

Table D-5. Incremental Summary

Sub watershed	Measure	Location	Increment of Alternative 3A							
			0	1	2	3	3.5	4	5	6
Structural										
Manoa	Detention and debris basin	Waiakeakua Stream		x	x	x	x	x	x	x
	Detention and debris basin	Waihi Stream		x	x	x	x	x	x	x
	Detention basin	Below Woodlawn Cemetery						x	x	x
	In-stream debris catchment	Below Manoa District Park		x	x	x	x	x	x	x
	Multi-purpose detention basin	Kanewai Park								x
Palolo	Detention and debris basin	Waiomao Stream			x	x	x	x	x	x
	Detention and debris basin	Pukele Stream			x	x	x	x	x	x
Makiki	Detention basin	Upstream of Makiki BWS Tank					x	x	x	x
	Detention basin	Roosevelt High School				x				
Ala Wai	Floodwalls	Both sides of canal	x	x	x	x	x	x	x	x
	Multi-purpose detention basin	Golf course	x	x	x	x	x	x	x	x
	Pump system or detention basin	Hausten Ditch	x	x	x	x	x	x	x	x
Non-Structural										
	Flood Warning System		x	x	x	x	x	x	x	x

Table D-6. Incremental Cost [1, 2, 3, 4]

Alternative	Est. Cost Including Contingency (1st Column of TPCS) @ EPL 1 Oct 2013 (FY14)					FY16
	Construct ($K)	Lands & Damages ($K)	PED ($K)	CM ($K)	Total ($K)	TPC (Fully Funded) $(K)
2 A	$139,657	$28,419	$36,314	$20,251	$224,641	$268,125
3 A	$122,931	$9,509	$31,957	$17,824	$182,221	$218,291

Alternative	Est. Cost Including Contingency (1st Column of TPCS) @ EPL 1 Oct 2013					FY16
	Construct ($K)	Lands & Damages ($K)	PED ($K)	CM ($K)	Total ($K)	TPC (Fully Funded) $(K)
Increment						
0	$51,980	$ -	$13,513	$7,537	$73,030	$87,473
1	$72,633	$2,715	$18,884	$10,531	$104,763	$125,284
2	$89,290	$6,738	$23,214	$12,946	$132,188	$157,592
3	$95,855	$6,738	$24,922	$13,899	$141,414	$169,729
3.5	$98,805	$6,738	$25,684	$14,325	$145,552	$174,305
4	$108,463	$6,738	$28,198	$15,726	$159,125	$191,318
5	$111,108	$7,488	$28,882	$16,110	$163,588	$196,163
Increment 6 /Optimized 0, (Avg 4'H Walls) (Base Cost for Optimization)	$113,240	$7,488	$29,443	$16,420	$166,591	$200,124
Optimized 6(-1) (1' lower floodwall, Avg 3'H wall)	$113,200	$7,488	$29,429	$16,415	$166,532	$200,077
Alt 3A-2.4: Proposed TSP (Avg 4.7'H walls)	$114,031	$7,488	$29,647	$16,536	$167,702	$201,305
Alt 3A-2.2: Optimized 6(+1) (Avg 5'H Walls)	$121,369	$7,488	$31,552	$17,598	$178,007	$213,813
Alt 3A-2.2: Optimized 6(+2) Proposed NED (Avg 6'H Walls)	$123,263	$7,488	$32,049	$17,875	$180,675	$216,908

[1,] Construction Cost at the EPL includes Contingencies determined by Cost Risk Analysis.

[2,] $K = $100,000.

[3,] Total Project Cost (fully funded) includes all Lands and Damages; Construction; Planning, Engineering & Design; and Construction Management. The cost is the constant dollar cost fully funded with escalated to the midpoint of construction.

[4,] Determined by H&H & the Economist.

8. NATIONAL ECONOMIC DEVELOPMENT AND TENTATIVELY SELECTED PLAN COST

After optimizing the costs, the design and economics determined the preliminary TSP and NED plan. The preliminary TSP is the lowest floodwalls along Ala Wai with a 90 percent assurance according to the FDA model NED are the plan that maximizes the most net benefits. Refer to Appendix B, *Economics*, for further information.

The TPCS Sheet includes the construction costs from the MCASES estimate, project markups, as well as costs for Lands and Damages, Planning, Engineering & Design, and Construction Management. Feasibility costs thru 1 Oct 2014 of $5,870,646 was provided by the Program Analyst. Table D-7 summarizes the TPCS.

Table D-7. Total Project Cost Summary

Estimated Cost (EPL Oct 2013, FY14)	Project First Cost (1 Oct 15)	Total Project Cost (Fully Funded)
$166,592,000	$173,364,000	$200,124,000

Based on 1 Oct 2015 (Budget Year 2016) price levels, the estimated project first cost is $173,364,000. In accordance with the cost share provisions in Section 103(c) of the Water Resources Development Act of 1986, as amended (33 U.S.C. 2213(c)), the Federal Share of the Total Project Cost (Fully Funded) is estimated to be $130,080,000 which equates to 65 percent of the Total Project Cost (Fully Funded). The non-Federal share is estimated to be $70,043,000 which equates to 35 percent of the Total Project Cost (Fully Funded). The non-Federal costs include the value of lands, easements, rights-of-way, relocations estimated to be $8,179,000.

Cost Appendix Attachments

**** TOTAL PROJECT COST SUMMARY ****

PROJECT: Ala Wai Canal, TSP/NED
PROJECT NO: #102703
LOCATION: Honolulu, Island of Oahu, Hawaii

DISTRICT: POH

PREPARED: 7/22/2014
POC: CHIEF, COST ENGINEERING, Gary F

This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)						TOTAL PROJECT COST (FULLY FUNDED)			
						Program Year (Budget EC): 2016									
						Effective Price Level Date: 1 OCT 15									
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: **10/1/2013** ($K)	**TOTAL FIRST COST**	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*				*M*	*N*	*O*
04	DAMS	$41,483	$13,813	33%	$55,296	3.5%	$42,917	$14,290	$57,206	$0		15.1%	$49,390	$16,435	$65,825
11	LEVEES & FLOODWALLS	$22,398	$6,964	31%	$29,362	3.5%	$23,172	$7,204	$30,376	$0		13.1%	$26,217	$8,151	$34,368
13	PUMPING PLANT	$16,235	$8,083	50%	$24,318	3.5%	$16,796	$8,363	$25,159	$0		13.1%	$19,003	$9,462	$28,465
15	FLOODWAY CONTROL & DIVERSION STRU	$2,314	$915	40%	$3,229	3.5%	$2,394	$946	$3,340	$0		13.7%	$2,724	$1,075	$3,799
18	CULTURAL RESOURCE PRESERVATION	$719	$152	21%	$871	3.5%	$744	$157	$901	$0		14.1%	$849	$179	$1,028
19	BUILDINGS, GROUNDS & UTILITIES	$144	$21	15%	$165	3.5%	$149	$22	$171	$0		14.8%	$171	$25	$196
	CONSTRUCTION ESTIMATE TOTALS:	$83,293	$29,947		$113,240	3.5%	$86,172	$30,982	$117,154	$0	$0	14.1%	$98,355	$35,326	$133,681
01	LANDS AND DAMAGES	$4,992	$2,496	50%	$7,488	3.5%	$5,165	$2,582	$7,747	$0		5.6%	$5,452	$2,726	$8,179
30	PLANNING, ENGINEERING & DESIGN	$21,657	$7,786	36%	$29,443	5.7%	$22,884	$8,228	$31,112	$0		14.1%	$26,112	$9,388	$35,500
31	CONSTRUCTION MANAGEMENT	$12,078	$4,342	36%	$16,420	5.7%	$12,763	$4,589	$17,351	$0		31.2%	$16,744	$6,020	$22,764
	PROJECT COST TOTALS:	$122,020	$44,572	37%	$166,592		$126,983	$46,381	**$173,364**	$0	**$0**	15.4%	$146,663	$53,461	$200,124

Mandatory by Regulation	CHIEF, COST ENGINEERING, Gary F. Yamauchi	ESTIMATED FEDERAL COST:	**65%**	**$130,080**
Mandatory by Regulation	PROJECT MANAGER,	ESTIMATED NON-FEDERAL COST:	**35%**	**$70,043**
Mandatory by Regulation	CHIEF, REAL ESTATE, Stephen N. Cayetano	**ESTIMATED TOTAL PROJECT COST:**		**$200,124**
	CHIEF, PROJECT MGT, Anthony J. Paresa			
	CHIEF, ENGRG & CONSTR, Todd C. Barnes			
	CHIEF, Civil Works Tech Branch, Michael F. Wong			
	CHIEF, CONSTRUCTION, Olson T. Okada			
	CHIEF, CONTRACTING, Marilyn Clark			
	CHIEF, REAL ESTATE, Stephen N. Cayetano			
	CHIEF, PROJECT MGT, Anthony J. Paresa			

Filename: Ala Wai (Alt3-Incr6-R13Apr15Non-CAP TPCS Mar 2014 Rev 01.xlsx
TPCS

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Estimate Prepared: **7/22/2014**
Effective Price Level: 10/1/2013

Program Year (Budget EC): 2016
Effective Price Level Date: 1 OCT 15

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	RISK BASED CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Makiki Watershed													
04	DAMS	$8,583	$2,661	31%	$11,244	3.5%	$8,880	$2,753	$11,632	2022Q4	14.3%	$10,147	$3,146	$13,293
11	LEVEES & FLOODWALLS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
13	PUMPING PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
18	CULTURAL RESOURCE PRESERVATION	$122	$24	20%	$146	3.5%	$126	$25	$151	2022Q4	14.3%	$144	$29	$173
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$8,705	$2,685	31%	**$11,390**		$9,006	$2,778	$11,784			$10,291	$3,174	$13,466
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$218	$67	31%	$285	5.7%	$230	$71	$301	2018Q3	10.0%	$253	$78	$332
5.0%	Planning & Environmental Compliance	$435	$134	31%	$569	5.7%	$460	$142	$601	2018Q3	10.0%	$506	$156	$662
8.5%	Engineering & Design	$740	$228	31%	$968	5.7%	$782	$241	$1,023	2018Q3	10.0%	$860	$265	$1,126
0.5%	Reviews, ATRs, IEPRs, VE	$44	$14	31%	$58	5.7%	$46	$14	$61	2018Q3	10.0%	$51	$16	$67
0.5%	Life Cycle Updates (cost, schedule, risks)	$44	$14	31%	$58	5.7%	$46	$14	$61	2018Q3	10.0%	$51	$16	$67
2.0%	Contracting & Reprographics	$174	$54	31%	$228	5.7%	$184	$57	$241	2018Q3	10.0%	$202	$62	$265
3.0%	Engineering During Construction	$261	$81	31%	$342	5.7%	$276	$85	$361	2023Q1	31.2%	$362	$112	$473
2.0%	Planning During Construction	$174	$54	31%	$228	5.7%	$184	$57	$241	2023Q1	31.2%	$241	$74	$316
2.0%	Project Operations	$174	$54	31%	$228	5.7%	$184	$57	$241	2018Q3	10.0%	$202	$62	$265
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$871	$269	31%	$1,140	5.7%	$920	$284	$1,204	2023Q1	31.2%	$1,208	$372	$1,580
2.0%	Project Operation:	$174	$54	31%	$228	5.7%	$184	$57	$241	2023Q1	31.2%	$241	$74	$316
2.5%	Project Management	$218	$67	31%	$285	5.7%	$230	$71	$301	2023Q1	31.2%	$302	$93	$395
	CONTRACT COST TOTALS:	$12,232	$3,773		**$16,005**		$12,733	$3,928	$16,660			$14,772	$4,557	**$19,329**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 7/22/2014 Effective Price Level: 10/1/2013				Program Year (Budget EC): 2016 Effective Price Level Date: 1 OCT 15								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Manoa Watershed													
04	DAMS	$22,667	$8,425	37%	$31,092	3.5%	$23,450	$8,716	$32,167	2023Q1	14.8%	$26,927	$10,009	$36,936
11	LEVEES & FLOODWALLS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
13	PUMPING PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$616	$165	27%	$781	3.5%	$637	$171	$808	2023Q1	14.8%	$732	$196	$928
18	CULTURAL RESOURCE PRESERVATION	$284	$66	23%	$350	3.5%	$294	$68	$362	2023Q1	14.8%	$337	$78	$415
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0%	$0	0.0%	$0 $0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$23,567	$8,656	37%	**$32,223**		$24,381	$8,955	$33,336			$27,996	$10,283	$38,279
01	LANDS AND DAMAGES	$2,310	$1,155	50%	$3,465	3.5%	$2,390	$1,195	$3,585	2018Q4	5.6%	$2,523	$1,262	$3,785
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$589	$216	37%	$805	5.7%	$622	$229	$851	2018Q3	10.0%	$685	$252	$936
5.0%	Planning & Environmental Compliance	$1,178	$433	37%	$1,611	5.7%	$1,245	$457	$1,702	2018Q3	10.0%	$1,370	$503	$1,873
8.5%	Engineering & Design	$2,003	$736	37%	$2,739	5.7%	$2,117	$777	$2,894	2018Q3	10.0%	$2,329	$855	$3,184
0.5%	Reviews, ATRs, IEPRs, VE	$118	$43	37%	$161	5.7%	$125	$46	$170	2018Q3	10.0%	$137	$50	$188
0.5%	Life Cycle Updates (cost, schedule, risks)	$118	$43	37%	$161	5.7%	$125	$46	$170	2018Q3	10.0%	$137	$50	$188
2.0%	Contracting & Reprographics	$471	$173	37%	$644	5.7%	$498	$183	$680	2018Q3	10.0%	$548	$201	$749
3.0%	Engineering During Construction	$707	$260	37%	$967	5.7%	$747	$274	$1,021	2023Q1	31.2%	$980	$360	$1,340
2.0%	Planning During Construction	$471	$173	37%	$644	5.7%	$498	$183	$680	2023Q1	31.2%	$653	$240	$893
2.0%	Project Operations	$471	$173	37%	$644	5.7%	$498	$183	$680	2018Q3	10.0%	$548	$201	$749
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$2,357	$866	37%	$3,223	5.7%	$2,491	$915	$3,405	2023Q1	31.2%	$3,268	$1,200	$4,468
2.0%	Project Operation:	$471	$173	37%	$644	5.7%	$498	$183	$680	2023Q1	31.2%	$653	$240	$893
2.5%	Project Management	$589	$216	37%	$805	5.7%	$622	$229	$851	2023Q1	31.2%	$817	$300	$1,116
	CONTRACT COST TOTALS:	$35,420	$13,316		**$48,736**		$36,855	$13,854	$50,709			$42,643	$15,997	**$58,639**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 7/22/2014 Effective Price Level: 10/1/2013				Program Year (Budget EC): 2016 Effective Price Level Date: 1 OCT 15								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Palolo Watershed													
04	DAMS	$7,659	$2,057	27%	$9,716	3.5%	$7,924	$2,128	$10,052	2022Q4	14.3%	$9,055	$2,432	$11,487
11	LEVEES & FLOODWALLS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
13	PUMPING PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
18	CULTURAL RESOURCE PRESERVATION	$58	$10	17%	$68	3.5%	$60	$10	$70	2022Q4	14.3%	$69	$11	$80
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$7,717	$2,067	27%	**$9,784**		$7,984	$2,138	$10,122			$9,123	$2,444	$11,567
01	LANDS AND DAMAGES	$2,682	$1,341	50%	$4,023	3.5%	$2,775	$1,387	$4,162	2018Q4	5.6%	$2,929	$1,465	$4,394
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$193	$52	27%	$245	5.7%	$204	$55	$259	2018Q3	10.0%	$224	$60	$284
5.0%	Planning & Environmental Compliance	$386	$103	27%	$489	5.7%	$408	$109	$517	2018Q3	10.0%	$449	$120	$569
8.5%	Engineering & Design	$656	$176	27%	$832	5.7%	$693	$186	$879	2018Q3	10.0%	$763	$204	$967
0.5%	Reviews, ATRs, IEPRs, VE	$39	$10	27%	$49	5.7%	$41	$11	$52	2018Q3	10.0%	$45	$12	$57
0.5%	Life Cycle Updates (cost, schedule, risks)	$39	$10	27%	$49	5.7%	$41	$11	$52	2018Q3	10.0%	$45	$12	$57
2.0%	Contracting & Reprographics	$154	$41	27%	$195	5.7%	$163	$44	$206	2018Q3	10.0%	$179	$48	$227
3.0%	Engineering During Construction	$232	$62	27%	$294	5.7%	$245	$66	$311	2023Q1	31.2%	$322	$86	$408
2.0%	Planning During Construction	$154	$41	27%	$195	5.7%	$163	$44	$206	2023Q1	31.2%	$213	$57	$271
2.0%	Project Operations	$154	$41	27%	$195	5.7%	$163	$44	$206	2018Q3	10.0%	$179	$48	$227
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$772	$207	27%	$979	5.7%	$816	$218	$1,034	2023Q1	31.2%	$1,070	$287	$1,357
2.0%	Project Operation:	$154	$41	27%	$195	5.7%	$163	$44	$206	2023Q1	31.2%	$213	$57	$271
2.5%	Project Management	$193	$52	27%	$245	5.7%	$204	$55	$259	2023Q1	31.2%	$268	$72	$339
	CONTRACT COST TOTALS:	$13,525	$4,245		**$17,770**		$14,062	$4,410	$18,472			$16,024	$4,972	**$20,996**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			7/22/2014	Program Year (Budget EC):			2016					
		Effective Price Level:			10/1/2013	Effective Price Level Date:			1 OCT 15	FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Ala Wai													
04	DAMS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
11	LEVEES & FLOODWALLS	$22,398	$6,964	31%	$29,362	3.5%	$23,172	$7,204	$30,376	2022Q2	13.1%	$26,217	$8,151	$34,368
13	PUMPING PLANT	$16,235	$8,083	50%	$24,318	3.5%	$16,796	$8,363	$25,159	2022Q2	13.1%	$19,003	$9,462	$28,465
15	FLOODWAY CONTROL & DIVERSION STRU	$1,648	$737	45%	$2,385	3.5%	$1,705	$762	$2,467	2022Q2	13.1%	$1,929	$863	$2,792
18	CULTURAL RESOURCE PRESERVATION	$255	$52	20%	$307	3.5%	$264	$54	$317	2022Q2	13.1%	$298	$61	$359
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$40,536	$15,836	39%	**$56,372**		$41,937	$16,383	$58,320			$47,448	$18,536	$65,984
01	LANDS AND DAMAGES	$0	$0	50%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$1,013	$396	39%	$1,409	5.7%	$1,070	$418	$1,489	2018Q3	10.0%	$1,178	$460	$1,638
5.0%	Planning & Environmental Compliance	$2,027	$792	39%	$2,819	5.7%	$2,142	$837	$2,979	2018Q3	10.0%	$2,357	$921	$3,277
8.5%	Engineering & Design	$3,446	$1,346	39%	$4,792	5.7%	$3,641	$1,423	$5,064	2018Q3	10.0%	$4,007	$1,565	$5,572
0.5%	Reviews, ATRs, IEPRs, VE	$203	$79	39%	$282	5.7%	$215	$84	$298	2018Q3	10.0%	$236	$92	$328
0.5%	Life Cycle Updates (cost, schedule, risks)	$203	$79	39%	$282	5.7%	$215	$84	$298	2018Q3	10.0%	$236	$92	$328
2.0%	Contracting & Reprographics	$811	$317	39%	$1,128	5.7%	$857	$335	$1,192	2018Q3	10.0%	$943	$368	$1,311
3.0%	Engineering During Construction	$1,216	$475	39%	$1,691	5.7%	$1,285	$502	$1,787	2023Q1	31.2%	$1,686	$659	$2,344
2.0%	Planning During Construction	$811	$317	39%	$1,128	5.7%	$857	$335	$1,192	2023Q1	31.2%	$1,124	$439	$1,564
2.0%	Project Operations	$811	$317	39%	$1,128	5.7%	$857	$335	$1,192	2018Q3	10.0%	$943	$368	$1,311
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$4,054	$1,584	39%	$5,638	5.7%	$4,284	$1,673	$5,957	2023Q1	31.2%	$5,620	$2,196	$7,816
2.0%	Project Operation:	$811	$317	39%	$1,128	5.7%	$857	$335	$1,192	2023Q1	31.2%	$1,124	$439	$1,564
2.5%	Project Management	$1,013	$396	39%	$1,409	5.7%	$1,070	$418	$1,489	2023Q1	31.2%	$1,404	$549	$1,953
	CONTRACT COST TOTALS:	$56,955	$22,250		**$79,205**		$59,287	$23,161	$82,447			$68,306	$26,684	**$94,991**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			7/22/2014	Program Year (Budget EC):			2016					
		Effective Price Level:			10/1/2013	Effective Price Level Date:			1 OCT 15	FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Adaptive Mgt													
04	DAMS	$2,574	$669	26%	$3,243	3.5%	$2,663	$692	$3,355	2026Q2	22.5%	$3,261	$848	$4,109
11	LEVEES & FLOODWALLS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
13	PUMPING PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$50	$13	26%	$63	3.5%	$52	$13	$65	2026Q2	22.5%	$63	$16	$80
18	CULTURAL RESOURCE PRESERVATION	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
19	BUILDINGS, GROUNDS & UTILITIES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$2,624	$682	26%	**$3,306**		$2,715	$706	$3,421			$3,325	$864	$4,189
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$66	$17	26%	$83	5.7%	$70	$18	$88	2018Q3	10.0%	$77	$20	$97
5.0%	Planning & Environmental Compliance	$131	$34	26%	$165	5.7%	$138	$36	$174	2018Q3	10.0%	$152	$40	$192
8.5%	Engineering & Design	$223	$58	26%	$281	5.7%	$236	$61	$297	2018Q3	10.0%	$259	$67	$327
0.5%	Reviews, ATRs, IEPRs, VE	$13	$3	26%	$16	5.7%	$14	$4	$17	2018Q3	10.0%	$15	$4	$19
0.5%	Life Cycle Updates (cost, schedule, risks)	$13	$3	26%	$16	5.7%	$14	$4	$17	2018Q3	10.0%	$15	$4	$19
2.0%	Contracting & Reprographics	$52	$14	26%	$66	5.7%	$55	$14	$69	2018Q3	10.0%	$60	$16	$76
3.0%	Engineering During Construction	$79	$21	26%	$100	5.7%	$83	$22	$105	2023Q1	31.2%	$110	$28	$138
2.0%	Planning During Construction	$52	$14	26%	$66	5.7%	$55	$14	$69	2023Q1	31.2%	$72	$19	$91
2.0%	Project Operations	$52	$14	26%	$66	5.7%	$55	$14	$69	2018Q3	10.0%	$60	$16	$76
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$262	$68	26%	$330	5.7%	$277	$72	$349	2023Q1	31.2%	$363	$94	$458
2.0%	Project Operation:	$52	$14	26%	$66	5.7%	$55	$14	$69	2023Q1	31.2%	$72	$19	$91
2.5%	Project Management	$66	$17	26%	$83	5.7%	$70	$18	$88	2023Q1	31.2%	$91	$24	$115
	CONTRACT COST TOTALS:	$3,685	$958		**$4,643**		$3,836	$997	$4,833			$4,672	$1,215	**$5,887**

****** TOTAL PROJECT COST SUMMARY ******

****** CONTRACT COST SUMMARY ******

PROJECT: Ala Wai Canal, TSP/NED
LOCATION: Honolulu, Island of Oahu, Hawaii
This Estimate reflects the scope and schedule in report; Ala Wai Canal Feasibility Study

DISTRICT: POH
POC: CHIEF, COST ENGINEERING, Gary F. Yamauchi
PREPARED: 7/22/2014

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 7/22/2014 Effective Price Level: 10/1/2013				Program Year (Budget EC): 2016 Effective Price Level Date: 1 OCT 15				FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	ESC (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Flood Warning System													
04	DAMS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
11	LEVEES & FLOODWALLS	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
13	PUMPING PLANT	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
15	FLOODWAY CONTROL & DIVERSION STRU	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
18	CULTURAL RESOURCE PRESERVATION	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
19	BUILDINGS, GROUNDS & UTILITIES	$144	$21	15%	$165	3.5%	$149	$22	$171	2023Q1	14.8%	$171	$25	$196
	CONSTRUCTION ESTIMATE TOTALS:	$144	$21	15%	**$165**		$149	$22	$171			$171	$25	$196
01	LANDS AND DAMAGES	$0	$0	0%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
2.5%	Project Management	$4	$1	15%	$5	5.7%	$4	$1	$5	2018Q3	10.0%	$5	$1	$5
5.0%	Planning & Environmental Compliance	$7	$1	15%	$8	5.7%	$7	$1	$8	2018Q3	10.0%	$8	$1	$9
8.5%	Engineering & Design	$12	$2	15%	$14	5.7%	$13	$2	$15	2018Q3	10.0%	$14	$2	$16
0.5%	Reviews, ATRs, IEPRs, VE	$1	$0	15%	$1	5.7%	$1	$0	$1	2018Q3	10.0%	$1	$0	$1
0.5%	Life Cycle Updates (cost, schedule, risks)	$1	$0	15%	$1	5.7%	$1	$0	$1	2018Q3	10.0%	$1	$0	$1
2.0%	Contracting & Reprographics	$3	$0	15%	$3	5.7%	$3	$0	$4	2018Q3	10.0%	$3	$1	$4
3.0%	Engineering During Construction	$4	$1	15%	$5	5.7%	$4	$1	$5	2023Q1	31.2%	$6	$1	$6
2.0%	Planning During Construction	$3	$0	15%	$3	5.7%	$3	$0	$4	2023Q1	31.2%	$4	$1	$5
2.0%	Project Operations	$3	$0	15%	$3	5.7%	$3	$0	$4	2018Q3	10.0%	$3	$1	$4
31	CONSTRUCTION MANAGEMENT													
10.0%	Construction Management	$14	$2	15%	$16	5.7%	$15	$2	$17	2023Q1	31.2%	$19	$3	$22
2.0%	Project Operation:	$3	$0	15%	$3	5.7%	$3	$0	$4	2023Q1	31.2%	$4	$1	$5
2.5%	Project Management	$4	$1	15%	$5	5.7%	$4	$1	$5	2023Q1	31.2%	$6	$1	$6
	CONTRACT COST TOTALS:	$203	$30		**$233**		$211	$31	$242			$246	$36	**$282**

AlaWai(TSP)(21Jul14)

Estimated by	CEPOH-EC-S, Tracy Kazunaga
Designed by	CEPOH-EC-T, Jarrett Hara
Prepared by	Tracy Kazunaga
Preparation Date	7/21/2014
Effective Date of Pricing	10/1/2013
Estimated Construction Time	1,197 Days

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Description	ContractCost
Contract Cost Summ (ECC)	**83,292,911.50**
MAK Makiki Watershed	**8,705,692.75**
04-MAK Debris/Detention Basin (MAK)	**8,583,319.27**
18-MAK Cultural Resource Preservation, Makiki	**122,373.49**
MAN Manoa Watershed	**23,566,891.61**
04-MAN Detention Basin (MAN)	**22,666,528.07**
15-MAN Floodway Control-Diversion Struc	**616,590.31**
18-MAN Cultural Resource Preservation, Manoa	**283,773.23**
PAL Palolo Watershed	**7,716,810.21**
04-PAL Debris & Detention Basin (PAL)	**7,658,632.65**
18-PAL Cultural Resource Preservation, Palolo	**58,177.56**
ALA Ala Wai	**40,535,416.83**
11 Levees and Floodwalls	**22,398,155.17**
13 Pumping Plant	**16,234,373.93**
15 Floodway Control-Diversion Struc	**1,647,708.90**
18-ALA Cultural Resource Preservation, Ala Wai (ALA)	**255,178.82**
AD-MGT Adaptive Mgt (After Constr Complete)	**2,623,794.56**
04AM Debris & Detention Basin, Adaptive Mgt	**2,574,021.47**
15AM Floodway Control-Diversion Structure, Adaptive Mgt	**49,773.09**
FW Flood Warning System	**144,305.55**
19 Buildings, Grounds, & Utilities	**144,305.55**

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Makiki Watershed (1 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 8,705,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.00%	$ -	$ -
1	04 02 SPILLWAY	**Makiki Debris & Detention**	$ 8,583,000		31.08%	$ 2,667,243	$ 11,250,242.67
2	18 CULTURAL RESOURCE PRESERVATION	**Cultural Monitoring**	$ 122,000		20.32%	$ 24,790	$ 146,790.24
3			$ -		0.00%	$ -	$ -
4			$ -		0.00%	$ -	$ -
5			$ -		0.00%	$ -	$ -
6			$ -		0.00%	$ -	$ -
7			$ -		0.00%	$ -	$ -
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		**Remaining Construction Items**	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 2,264,000		20.73%	$ 469,334	$ 2,733,334.28
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 1,263,000		16.91%	$ 213,601	$ 1,476,600.84

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 8,705,000	30.93%	$ 2,692,033	$ 11,397,033	
Total Planning, Engineering & Design	$ 2,264,000	20.73%	$ 469,334	$ 2,733,334	
Total Construction Management	$ 1,263,000	16.91%	$ 213,601	$ 1,476,601	
Total	$ 12,232,000		$ 3,374,968	$ 15,606,968	

Ala Wai Canal (TSP) - Makiki Watershed (1 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 1/28/2014; Rev 7/22/14

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	**75%**
PS-1	Makiki Debris & Detention	• Potential for scope growth, added features and quantities?	If any of the measures are screened out in incremental analysis during TSP, the conceptual designswill not be altered, scope growth is not anticipated.	It is possible Roosevelt & Makiki BWS detention basin measures are removed from the alternative, it is unlikely additional featurs will be added. The cost would be negligible.	Possible	Negligible	0
PS-2	Cultural Monitoring	• Investigations sufficient to support design assumptions?	The assumption of the scope for the measures is that no cultural resources are located at the location.	Cultural resource investigations has not not been done at this site. The surveys will be conducted in the PED phase. It is possible cultural resources will be found at the old Makiki BWS site since there was development. If anything is found in the PED phase, then the resource would have to be mitigated during the PED phase. This could significantly increase the mitigation cost.	Possible	Significant	2
PS-12	Remaining Construction Items	• Potential for scope growth, added features and quantities?	None	None	Unlikely	Negligible	0
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	Conceptual design assumptions may be affected by changed geotechnical informations (soils and geology map).	Investigations could reveal unsuitable material for the detention basins. It is unlikely the design would change because the excavation quantity is not a lot for the sites. The impact to cost would be marginal.	Unlikely	Marginal	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	None	None	Unlikely	Negligible	0

Acquisition Strategy

						Max Potential Cost Growth	30%
AS-1	Makiki Debris & Detention	• Contracting plan firmly established?	Contracting Acquisition Strategy not determined at this stage. It is assumed the best scenario the entire project is awared to one Prime Contractor.	The Acquisition Strategy will not be determined until the PED Phase. As the design and scope is finalized in the PED phase Contracting will do Market Research to determine the type of interested parties (contractors able and willing to perform the work). If determined there are available contractors to meet the bonding requirements of the project, the project could be issued as one contract with one Prime Contractor. Then Contracting will request approval from the Regional Principal Assistant Responsible for Contracting (PARC) to approve a consolidation of the project. Market research could also determine if the project will be awarded to Small Business, Unrestricted, or to multiple contractor. The estimate assumed the best scenario of one Prime Contractor for coordination purposes. If it is determined otherwise, the cost of the construction could significantly increase due to higher overheads with multiple contractors or small business. Since this project covers multiple areas, it is very likely it would be broken up into multiple contracts by watershed or measures.	Likely	Significant	3
AS-2	Cultural Monitoring	• Contracting plan firmly established?	Same AS AS-1	Same as AS-1	Likely	Significant	3
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	Same as AS-1	If the project is broken up into multiple contracts, the design could also be broken up into multiple contracts (multiple Engineering firms) to provide equal opportunitity for each firm engineering work. For a project of multiple areas, it is likely this will happen. This will significicantly affect the PED cost since their overhead costs will be different.	Likely	Significant	3
AS-14	Construction Management	• Contracting plan firmly established?	Additional construction mg personnel would be required for multiple contracts.	If the project is broken up into multiple contracts, it is unlikely to increase Construction Management costs since all measures woul d be managed. Additonal contract mgangement personnel would be required inspecting fewer areas. Therefore the increase to cost is marginal.	Unlikely	Significant	1

Construction Elements

							Max Potential Cost Growth	25%
CE-1	Makiki Debris & Detention	• Water care and diversion plan?	Water Care and diversion plan not fully developed for the 10% design.	Diversion of water using sheetpiles as an assumption is unikely to be wrong. With a normally flowing stream, is important to meet water quality standards and the NPDES permit. The diversion would be designed by the Contractor's Engineer after the project is awarded for construction. The probablity cost growth could be significant if there is a different site condition.	Unlikely	Significant		1
CE-2	Cultural Monitoring	• Accelerated schedule or harsh weather schedule?	Any harsh weather during construction could extend the project schedule and increase the archeological monitoring duration.	The 10% estimate includes provisions for weather delays. It is unlikely extended archeological monitoring will be required, this is negligible cost when compared to the overall cost of the project.	Unlikely	Negligible		0
CE-13	Planning, Engineering, & Design	• Accelerated schedule or harsh weather schedule?	None	None	Unlikely	Negligible		0
CE-14	Construction Management	• Potential for construction modification and claims?	Any unanticipated weather events could wash out the project measure being constructed in the stream.	The project schedule includes anticipated weather delays. Any major flooding could wash out the project debris/detention basin and cause delays, significant re-work and costs to the project. It is unlikely that standard best management practices/care of water/divsersion water is inadequate during major storm events, and damages to the project being constructed in a flowing stream significantly cause an increase in claims/cost.	Unlikely	Significant		1

Quantities for Current Scope

						Max Potential Cost Growth	20%
Q-1	Makiki Debris & Detention	• Sufficient investigations to develop quantities?	Estimate is based on 10% level of detail Where details/information is lacking, engineering judgement based on historical cost were used.	Estimate captured majority of the major features. It is likely quantities are missing such as rebar quantity. Excavation quantities were based on average cross-sections. It is also likely the quantity is off. This is a major cost and could significantly affect the cost of this measure.	Likely	Significant	3
Q-2	Cultural Monitoring	• Level of confidence based on design and assumptions?	Uncertain subsurface soil conditions.	Cultural monitoring was based on uncertain subsurface soil conditions. It is unlikely additional monitoring is required and any additional cost would be negligible.	Unlikely	Negligible	0
Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	A general percentage was used to obtain PED Costs.	The PED cost is likely to be increased as more information is obtained for environmental, cultural, archeological and geotech. Any findings could significantly impact the scope of the design and the measure location adjusted within the general area.	Likely	Significant	3
Q-14	Construction Management	• Level of confidence based on design and assumptions?	A general percentage was used to obtain CM Costs.	As the project design/estimate/project schedule is developed, it is likely the Construction Management Cost will increase significantly if the schedule is revised to multiple contracts.	Likely	Significant	3

Specialty Fabrication or Equipment

						Max Potential Cost Growth	75%
FE-1	Makiki Debris & Detention	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-2	Cultural Monitoring	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-12	Remaining Construction Items	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-13	Planning, Engineering, & Design	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-14	Construction Management	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0

Cost Estimate Assumptions

						Max Potential Cost Growth	35%
CT-1	Makiki Debris & Detention	• Assumptions related to prime and subcontractor markups/assignments?	The initial estimate assumed one prime contractor and multiple sub contractors.	It is likely the assumption is wrong and multiple contractors will be used. These multiple contractors could be small business. This won't be determined until the PED Phase. If the assumption is wrong, it could significantly affect the markup and contractor assignements and significantly affect the constrution cost.	Likely	Significant	3
CT-2	Cultural Monitoring	• Reliability and number of key quotes?	The initial Cost Estimate assumptions were developed by the Archeologist using the general area and cost/area of mitigation.	It is unlikely the cost will change because the site location will not change, and the quantity wouldn't change, the affect to cost is negligible.	Unlikely	Negligible	0
CT-12	Remaining Construction Items	• Reliability and number of key quotes?	The cost of disposal of excavated soil is assumed no cost at this point according to the PVT Landfill Fee Schedule effective July 2013. As the landfill capacity decreases, a fee could be imposed for screened soil.	It is possible the landfill could imposes a fee for screened soil as the capacity of the landfill decreases by the time this project is contracted out. If there is a fee imposed, it could significantly increase the disposal cost of excavated screened soil.	Possible	Significant	2
CT-13	Planning, Engineering, & Design	• Assumptions related to prime and subcontractor markups/assignments?	None	None	Unlikely	Negligible	0
CT-14	Construction Management	• Overuse of Cost Book, lump sum, allowances?	The estimate assumes site access is available.	Access to the construction area will be thru a new haul road. The haul road has not been tied down with proper radius and slopes. It is likely the road will be re-aligned/tied down to the proper grades and dimensions in the TSP and PED phase. The cost of the road is unlikely to affect the overall construction cost of the measure, therefore the risk leve is marginal.	Unlikely	Marginal	0

External Project Risks

						Max Potential Cost Growth	40%
EX-1	Makiki Debris & Detention	• Political influences, lack of support, obstacles?	Any neighborhood objections could affect the appearance & location of the measure.	These concerns are expected to be resolved thru public outreach meetings prior to PED. It is possible the measure will be altered in size and location. This would be a negligible cost since the feature would be the same.	Possible	Negligible	0
EX-2	Cultural Monitoring	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-12	Remaining Construction Items	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-13	Planning, Engineering, & Design	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-14	Construction Management	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0

Ala Wai Canal (TSP) - Makiki Watershed (1 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Makiki Debris & Detention	Cultural Monitoring	0	0	0	0	0	0	0	0	0	Remaining Construction Ite	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Acquisition Strategy	3	3	-	-	-	-	-	-	-	-	-	-	3	1
Construction Elements	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Quantities for Current Scope	3	-	-	-	-	-	-	-	-	-	-	-	3	3
Specialty Fabrication or Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cost Estimate Assumptions	3	-	-	-	-	-	-	-	-	-	-	2	-	-
External Project Risks	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP)- Manoa Watershed (2 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 23,567,000**

	CWWBS	Feature of Work		Contract Cost		% Contingency		$ Contingency		Total
	01 LANDS AND DAMAGES	Real Estate	$	2,310,000		50.00%	$	1,155,000	$	3,465,000.00
1	04 02 SPILLWAY	Debris Basins Waiakeakua, Waihi, Woodla	$	22,667,000		37.17%	$	8,425,227	$	31,092,226.75
2	15 FLOODWAY CONTROL AND DIVERSION STRUCTURES	Manoa In-Stream Catchment	$	616,000		26.76%	$	164,854	$	780,853.59
3	18 CULTURAL RESOURCE PRESERVATION	Cultural Monitoring	$	284,000		23.12%	$	65,653	$	349,652.88
4			$	-		0.00%	$	-	$	-
5			$	-		0.00%	$	-	$	-
6			$	-		0.00%	$	-	$	-
7			$	-		0.00%	$	-	$	-
8						0.00%	$	-	$	-
9						0.00%	$	-	$	-
12		Remaining Construction Items	$	-	*0.0%*	0.00%	$	-	$	-
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$	6,126,000		20.73%	$	1,269,939	$	7,395,938.95
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$	3,417,000		28.37%	$	969,565	$	4,386,564.76

Totals								
Real Estate	$	2,310,000		50.00%	$	1,155,000	$	3,465,000.00
Total Construction Estimate	$	23,567,000		36.73%	$	8,655,733	$	32,222,733
Total Planning, Engineering & Design	$	6,126,000		20.73%	$	1,269,939	$	7,395,939
Total Construction Management	$	3,417,000		28.37%	$	969,565	$	4,386,565
Total	$	35,420,000			$	12,050,237	$	47,470,237

Ala Wai Canal (TSP)- Manoa Watershed (2 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 1/28/2014 (Rev 22 Jul14)

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	**75%**
PS-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Potential for scope growth, added features and quantities?	If any of the measures are screened out in incremental analysis during TSP, the conceptual designswill not be altered, scope growth is not anticipated.	It is possible detention/Debris basin measures are removed from the alternative, it is unlikely additional features will be added. The cost would be negligible.	Unlikely	Negligible	0
PS-2	Manoa In-Stream Catchment	• Potential for scope growth, added features and quantities?	If any of the measures are screened out in incremental analysis during TSP, the conceptual designs could be altered.	It is possible measures are removed from the alternative, it is unlikely additional features will be added. The cost would be negligible.	Unlikely	Negligible	0
PS-3	Cultural Monitoring	• Potential for scope growth, added features and quantities?	The assumption of the scope for the measures is that no cultural resources are located at the location.	Cultural resource investigations has not not been done at this site. The surveys will be conducted in the PED phase. It is possible cultural resources will be found at the site(s). If anything is found in the PED phase, then the resource would have to be mitigated during the PED phase. This could marginally increase the mitigation cost.	Possible	Marginal	1
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	Conceptual design assumptions may be affected by changed geotechnical informations (soils and geology map).	Investigations could reveal unsuitable material for the detention basins. It is unlikely the design would change because the excavation quantity is not a lot for the sites. The impact to cost would be marginal.	Unlikely	Negligible	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	None	None	Unlikely	Negligible	0

Acquisition Strategy

						Max Potential Cost Growth	30%
AS-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Contracting plan firmly established?	Contracting Acquisition Strategy not determined at this stage. It is assumed the best scenario the entire project is awared to one Prime Contractor.	The Acquisition Strategy will not be determined until the PED Phase. As the design and scope is finalized in the PED phase Contracting will do Market Research to determine the type of interested parties (contractors able and willing to perform the work). If determined there are available contractors to meet the bonding requirements of the project, the project could be issued as one contract with one Prime Contractor. Then Contracting will request approval from the Regional Principal Assistant Responsible for Contracting (PARC) to approve a consolidation of the project. Market research could also determine if the project will be awarded to Small Business, Unrestricted, or to multiple contractor. The estimate assumed the best scenario of one Prime Contractor for coordination purposes. If it is determined otherwise, the cost of the construction could significantly increase due to higher overheads with multiple contractors or small business. Since this project covers multiple areas, it is very likely it would be broken up into multiple contracts by watershed or measures.	Likely	Significant	3
AS-2	Manoa In-Stream Catchment	• Contracting plan firmly established?	Same as AS-1	Same as AS-1	Likely	Significant	3
AS-3	Cultural Monitoring	• Contracting plan firmly established?	Same as AS-1	Same as AS-1	Likely	Significant	3
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	Same as AS-1.	If the project is broken up into multiple contracts, the design could also be broken up into multiple contracts (multiple Engineering firms) to provide equal opportunitity for each firm engineering work. For a project of multiple areas, it	Likely	Significant	3
AS-14	Construction Management	• Contracting plan firmly established?	Additional construction mg personnel would be required for multiple contracts.	If the project is broken up into multiple contracts, it is unlikely to increase Construction Management costs since all measures woul d be managed. Additonal contract mgangement personnel would be required inspecting fewer areas. Therefore the increase to cost is marginal.	Unlikely	Marginal	0

Construction Elements

						Max Potential Cost Growth	25%
CE-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Water care and diversion plan?	Water Care and diversion plan not fully developed for the 10% design.	Diversion of water using sheetpiles as an assumption is likely wrong. With a normally flowing stream, is important to meet water quality standards and the NPDES permit. The diversion would be designed by the Contractor's Engineer after the project is awarded for construction. It is possible the assumption is wrong but the additional cost marginal since some dewatering costs were included in the estimate.	Likely	Marginal	2
CE-2	Manoa In-Stream Catchment	• Water care and diversion plan?	Water Care and diversion plan not fully developed for the 10% design.	Diversion of water using sheetpiles as an assumption is likely wrong. With a normally flowing stream, is important to meet water quality standards and the NPDES permit. The diversion would be designed by the Contractor's Engineer after the project is awarded for construction. It is possible the assumption is wrong but the additional cost marginal since some dewatering costs were included in the estimate.	Likely	Marginal	2
CE-3	Cultural Monitoring	• Accelerated schedule or harsh weather schedule?	Any harsh weather during construction could extend the project schedule and increase the archeological monitoring duration.	The 10% estimate includes provisions for weather delays. While it is possible extended archeological monitoring will be required, this is a marginal cost when compared to the overall cost of the project.	Possible	Marginal	1
CE-13	Planning, Engineering, & Design	• Accelerated schedule or harsh weather schedule?	None	None	Unlikely	Negligible	0
CE-14	Construction Management	• Accelerated schedule or harsh weather schedule?	Any unanticipated weather events could wash out the project measure being constructed in the stream and cause significant re-work (claims).	The project schedule includes anticipated weather delays. Any major flooding could wash out the project debris/detention basin and cause delays, significant re-work and costs to the project. It is possible that standard best management practices/care of water/diversion water is inadequate during major storm events, and damages to the project being constructed in a flowing stream significantly cause an increase in claims/cost.	Likely	Significant	3

Quantities for Current Scope

						Max Potential Cost Growth	20%
Q-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Sufficient investigations to develop quantities?	Estimate is based on 10% level of detail Where details/information is lacking, engineering judgement based on historical cost were used.	Estimate captured majority of the major features. It is likely quantities are missing such as rebar quantity. Excavation quantities were based on average cross-sections. It is also likely the quantity is off. This is a major cost and could significantly affect the cost of this measure.	Likely	Significant	3
Q-2	Manoa In-Stream Catchment	• Level of confidence based on design and assumptions?	Footing design may not be adequate.	Design will be coordinated with the structural engineer in TSP. It is possible the quantity (footing/length of posts) will be increased, however, the alignment will be the same as the conceptual design. Therfore the increased quantity is negligible.	Possible	Negligible	0
Q-3	Cultural Monitoring	• Level of confidence based on design and assumptions?	Cultural monitoring was based on uncertain subsurface soil conditions.	Cultural monitoring was based on uncertain subsurface soil conditions. It is unlikely additional monitoring is required and any additional cost would be negligible.	Unlikely	Negligible	0
Q-12	Remaining Construction Items	• Level of confidence based on design and assumptions?	The quantities for any excavations does not include any relocation of utilities.	It is likely that utilities will be encountered during demolition. Any relocations to sewer lines could be significant cost when compared to relocating water-lines, cable and electrical lines. Exploration of utilities will be investigated during the PED phase.	Likely	Significant	3
Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	A general percentage was used to obtain PED Costs.	The PED cost is likely to be increased as more information is obtained for environmental, cultural, archeological and geotech. Any findings could significantly impact the scope of the design and the measure location adjusted within the general area.	Likely	Significant	3
Q-14	Construction Management	• Level of confidence based on design and assumptions?	A general percentage was used to obtain CM Costs.	As the project design/estimate/project schedule is developed, it is likely the Construction Management Cost will increase significantly if the schedule is revised to multiple contracts.	Likely	Significant	3

Specialty Fabrication or Equipment

						Max Potential Cost Growth	75%
FE-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-2	Manoa In-Stream Catchment	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-3	Cultural Monitoring	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-13	Planning, Engineering, & Design	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-14	Construction Management	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0

Cost Estimate Assumptions

						Max Potential Cost Growth	35%
CT-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Assumptions related to prime and subcontractor markups/assignments?	The 10% estimate assumed one prime contractor and multiple sub contractors.	It is likely the assumption is wrong and multiple contractors will be used. These multiple contractors could be small business. This won't be determined until the PED Phase. If the assumption is wrong, it could significantly affect the markup and contractor assignements and significantly affect the constrution cost.	Likely	Significant	3
CT-2	Manoa In-Stream Catchment	• Assumptions related to prime and subcontractor markups/assignments?	Same as CT-1	Same as CT-1	Likely	Significant	3
CT-3	Cultural Monitoring	• Reliability and number of key quotes?	10% Cost Estimate assumptions were developed by the Archeologist using the general area and cost/area of mitigation.	It is possible the archeological assumptionsis wrong which would significantly affect the cost of the measure. The measure may have to be relocated or re-sized.	Possible	Significant	2
CT-12	Remaining Construction Items	• Reliability and number of key quotes?	The cost of disposal of excavated soil is assumed no cost at this point according to the PVT Landfill Fee Schedule effective July 2013. As the landfill capacity decreases, a fee could be imposed for screened soil.	It is possible the landfill could imposes a fee for screened soil as the capacity of the landfill decreases by the time this project is contracted out. If there is a fee imposed, it could significantly increase the disposal cost of excavated screened soil.	Possible	Significant	2
CT-13	Planning, Engineering, & Design	• Reliability and number of key quotes?	None	None	Unlikely	Negligible	0
CT-14	Construction Management	• Assumptions related to prime and subcontractor markups/assignments?	Project could be broken into multiple prime contractors with different markups/assignments.	Conceptual design estimate assumes one Prime Contractor & multiple subconractor. It is likely the project will be broken up into multiple contracts, however this will nto be determined until the later PED phase when Contracting does a Market Survey. The likelyhood of cost increases to the project is significant if the project is broken up int o multiple contracts (see Discussions in AS-1)	Likely	Significant	3

External Project Risks

						Max Potential Cost Growth	40%
EX-1	Debris Basins Waiakeakua, Waihi, Woodlawn & Kanewai	• Political influences, lack of support, obstacles?	Manoa District Park and Kanewai Field are heavily used athletic fields. Any flooding events would limit access to park use and not be acceptable to the community.	It is very likely that the community would opposed these measures. If alternative measures are added or significantly altered, the measure may be dropped which would decrease the costs. Therefore the rating is negligible.	Very LIKELY	Negligible	2
EX-2	Manoa In-Stream Catchment	• Political influences, lack of support, obstacles?	Lack of support from the community could cause re-design of the measure.	It is possible thatl the Innovation Center would have less support than Manoa Stream because of the land acquisition. Lack of support may result in dropping of the measure. Therfore the impact cost is negligible.	Possible	Negligible	0
EX-3	Cultural Monitoring	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-12	Remaining Construction Items	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-13	Planning, Engineering, & Design	• Potential for severe adverse weather?	Lack of support from the community could cause major re-design of the measure.	It is unlikely a major re-design would happen. Any re-designs would be refinements of the 10% design, therefore a marginal cost to PED.	Unlikely	Marginal	0
EX-14	Construction Management	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0

Ala Wai Canal (TSP)- Manoa Watershed (2 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Debris Basins Waiakeakua, Wai Woodlaw Ka	Manoa In-Stream Catchment	Cultural Monitoring	0	0	0	0	0	0	0	0	Remaining Construction Ite	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Acquisition Strategy	3	3	3	-	-	-	-	-	-	-	-	-	3	-
Construction Elements	2	2	1	-	-	-	-	-	-	-	-	-	-	3
Quantities for Current Scope	3	-	-	-	-	-	-	-	-	-	-	3	3	3
Specialty Fabrication or Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cost Estimate Assumptions	3	3	2	-	-	-	-	-	-	-	-	2	-	3
External Project Risks	2	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Palolo Watershed (3 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 7,717,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ 2,682,000		50.00%	$ 1,341,000	$ 4,023,000.00
1	04 02 SPILLWAY	Waiomao & Pukele Det Basin	$ 7,659,000		26.86%	$ 2,057,381	$ 9,716,381.00
2	18 CULTURAL RESOURCE PRESERVATION	Cultural Monitoring	$ 58,000		16.60%	$ 9,628	$ 67,627.88
3			$ -		0.00%	$ -	$ -
4			$ -		0.00%	$ -	$ -
5			$ -		0.00%	$ -	$ -
6			$ -		0.00%	$ -	$ -
7			$ -		0.00%	$ -	$ -
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		Remaining Construction Items	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 2,007,000		20.73%	$ 416,057	$ 2,423,057.38
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 1,119,000		19.93%	$ 223,048	$ 1,342,048.31

Totals					
Real Estate	$ 2,682,000	50.00%	$ 1,341,000	$ 4,023,000.00
Total Construction Estimate	$ 7,717,000	26.79%	$ 2,067,009	$ 9,784,009
Total Planning, Engineering & Design	$ 2,007,000	20.73%	$ 416,057	$ 2,423,057
Total Construction Management	$ 1,119,000	19.93%	$ 223,048	$ 1,342,048
Total	$ 13,525,000		$ 4,047,115	$ 17,572,115

Ala Wai Canal (TSP) - Palolo Watershed (3 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 1/28/2014; Rev 7/22/14

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	**75%**
PS-1	Waiomao & Pukele Det Basin	• Potential for scope growth, added features and quantities?	If any of the measures are screened out in incremental analysis during TSP, the conceptual designswill not be altered, scope growth is not anticipated.	It is unlikely additional features will be added. The cost would be negligible.	Unlikely	Negligible	0
PS-2	Cultural Monitoring	• Potential for scope growth, added features and quantities?	The assumption of the scope for the measures is that no cultural resources are located at the location.	Cultural resource investigations has not not been done at this site. The surveys will be conducted in the PED phase	Unlikely	Negligible	0
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	Conceptual design assumptions may be affected by changed geotechnical informations (soils and geology map).	Investigations could reveal unsuitable material for the detention basins. It is unlikely the design would change because the excavation quantity is not a lot for the sites. The impact to cost would be marginal.	Unlikely	Marginal	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	None	None	Unlikely	Negligible	0

Acquisition Strategy

						Max Potential Cost Growth	30%
AS-1	Waiomao & Pukele Det Basin	• Contracting plan firmly established?	Contracting Acquisition Strategy not determined at this stage. It is assumed the best scenario the entire project is awared to one Prime Contractor.	The Acquisition Strategy will not be determined until the PED Phase. As the design and scope is finalized in the PED phase Contracting will do Market Research to determine the type of interested parties (contractors able and willing to perform the work). If determined there are available contractors to meet the bonding requirements of the project, the project could be issued as one contract with one Prime Contractor. Then Contracting will request approval from the Regional Principal Assistant Responsible for Contracting (PARC) to approve a consolidation of the project. Market research could also determine if the project will be awarded to Small Business, Unrestricted, or to multiple contractor. The estimate assumed the best scenario of one Prime Contractor for coordination purposes. If it is determined otherwise, the cost of the construction could significantly increase due to higher overheads with multiple contractors or small business. Since this project covers multiple areas, it is very likely it would be broken up into multiple contracts by watershed or measures.	Likely	Significant	3
AS-2	Cultural Monitoring	• Contracting plan firmly established?	Same as AS-1	Same as AS-1	Likely	Significant	3
AS-12	Remaining Construction Items	• Contracting plan firmly established?	None	None	Unlikely	Negligible	0
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	Same as AS-1	If the project is broken up into multiple contracts, the design could also be broken up into multiple contracts (multiple Engineering firms) to provide equal opportunitity for each firm engineering work.	Likely	Significant	3
AS-14	Construction Management	• Contracting plan firmly established?	Additional construction managemet personnel would be required for multiple contracts.	If the project is broken up into multiple contracts, it is unlikely to increase Construction Management costs since all measures woul d be managed. Additonal contract mgangement personnel would be required inspecting fewer areas. Therefore the increase to cost is marginal.	Unlikely	Marginal	0

Construction Elements

						Max Potential Cost Growth	25%
CE-1	Waiomao & Pukele Det Basin	• Water care and diversion plan?	Water Care and diversion plan not fully developed for the 10% design.	Diversion of water using sheetpiles as an assumption is likely wrong. With a normally flowing stream, is important to meet water quality standards and the NPDES permit. The diversion would be designed by the Contractor's Engineer after the project is awarded for construction. It is possible the assumption is wrong but the additional cost marginal since some dewatering costs were included in the estimate.	Possible	Marginal	1
CE-2	Cultural Monitoring	• Accelerated schedule or harsh weather schedule?	Any harsh weather during construction could extend the project schedule and increase the archeological monitoring duration.	The 10% estimate includes provisions for weather delays. While it is possible extended archeological monitoring will be required, this is a marginal cost when compared to the overall cost of the project.	Possible	Marginal	1
CE-13	Planning, Engineering, & Design	• Accelerated schedule or harsh weather schedule?	None	None	Unlikely	Negligible	0
CE-14	Construction Management	• Accelerated schedule or harsh weather schedule?	Any unanticipated weather events could wash out the project measure being constructed in the stream and cause significant re-work (claims).	The project schedule includes anticipated weather delays. Any major flooding could wash out the project debris/detention basin and cause delays, significant re-work and costs to the project. It is possible that standard best management practices/care of water/diversion water is inadequate during major storm events, and damages to the project being constructed in a flowing stream significantly cause an increase in claims/cost.	Likely	Significant	3

Quantities for Current Scope

						Max Potential Cost Growth	20%
Q-1	Waiomao & Pukele Det Basin	• Sufficient investigations to develop quantities?	Estimate is based on 10% level of detail Where details/information is lacking, engineering judgement based on historical cost were used.	Estimate captured majority of the major features. It is likely quantities are missing such as rebar quantity. Excavation quantities were based on average cross-sections. It is also likely the quantity is off. This is a major cost and could significantly affect the cost of this measure.	Unlikely	Significant	1
Q-2	Cultural Monitoring	• Sufficient investigations to develop quantities?	Cultural monitoring was based on uncertain subsurface soil conditions.	Cultural monitoring was based on uncertain subsurface soil conditions. It is unlikely additional monitoring is required and any additional cost would be negligible.	Unlikely	Negligible	0
Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	A general percentage was used to obtain PED Costs.	The PED cost is likely to be increased as more information is obtained for environmental, cultural, archeological and geotech. Any findings could significantly impact the scope of the design and the measure location adjusted within the general area.	Likely	Significant	3
Q-14	Construction Management	• Level of confidence based on design and assumptions?	A general percentage was used to obtain CM Costs.	As the project design/estimate/project schedule is developed, it is likely the Construction Management Cost will increase significantly if the schedule is revised to multiple contracts.	Likely	Significant	3

Specialty Fabrication or Equipment

						Max Potential Cost Growth	75%
FE-1	Waiomao & Pukele Det Basin	• Confidence in contractor's ability to install?	N/A	N/A	Unlikely	Negligible	0
FE-2	Cultural Monitoring	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-13	Planning, Engineering, & Design	• Unusual parts, material or equipment manufactured or installed?	N/A	N/A	Unlikely	Negligible	0
FE-14	Construction Management	• Unusual parts, material or equipment manufactured or installed?	N/A	N/A	Unlikely	Negligible	0

Cost Estimate Assumptions

						Max Potential Cost Growth	35%
CT-1	Waiomao & Pukele Det Basin	• Assumptions related to prime and subcontractor markups/assignments?	The initial estimate assumed one prime contractor and multiple sub contractors.	It is likely the assumption is wrong and multiple contractors will be used. These multiple contractors could be small business. This won't be determined until the PED Phase. If the assumption is wrong, it could significantly affect the markup and contractor assignements and significantly affect the constrution cost.	Likely	Significant	3
CT-2	Cultural Monitoring	• Reliability and number of key quotes?	The initial Cost Estimate assumptions were developed by the Archeologist using the general area and cost/area of mitigation.	It is unlikely the cost will change because the site location will not change, and the quantity wouldn't change, the affect to cost is negligible.	Unlikely	Negligible	0
CT-12	Remaining Construction Items	• Reliability and number of key quotes?	The cost of disposal of excavated soil is assumed no cost at this point according to the PVT Landfill Fee Schedule effective July 2013. As the landfill capacity decreases, a fee could be imposed for screened soil.	It is possible the landfill could imposes a fee for screened soil as the capacity of the landfill decreases by the time this project is contracted out. If there is a fee imposed, it could significantly increase the disposal cost of excavated screened soil.	Possible	Significant	2
CT-13	Planning, Engineering, & Design	• Reliability and number of key quotes?	None	None	Unlikely	Negligible	0
CT-14	Construction Management	• Site accessibility, transport delays, congestion?	The estimate assumes site access is available.	Access to the construction area will be thru a new haul road. The haul road has not been tied down with proper radius and slopes. It is likely the road will be re-aligned/tied down to the proper grades and dimensions in the TSP and PED phase. The cost of the road is unlikely to affect the overall construction cost of the measure, therefore the risk leve is marginal.	Unlikely	Negligible	0

External Project Risks

						Max Potential Cost Growth	40%
EX-1	Waiomao & Pukele Det Basin	• Political influences, lack of support, obstacles?	Any neighborhood objections could affect the appearance & location of the measure.	These concerns are expected to be resolved thru public outreach meetings prior to PED. It is possible the measure will be altered in size and location. This would be a negligible cost since the feature would be the same.	Unlikely	Negligible	0
EX-2	Cultural Monitoring	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-13	Planning, Engineering, & Design	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-14	Construction Management	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0

Ala Wai Canal (TSP) - Palolo Watershed (3 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Waiomao & Pukele Det Basin	Cultural Monitoring	0	0	0	0	0	0	0	0	0	Remaining Construction Ite	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acquisition Strategy	3	3	-	-	-	-	-	-	-	-	-	-	3	-
Construction Elements	1	1	-	-	-	-	-	-	-	-	-	-	-	3
Quantities for Current Scope	1	-	-	-	-	-	-	-	-	-	-	-	3	3
Specialty Fabrication or Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cost Estimate Assumptions	3	-	-	-	-	-	-	-	-	-	-	2	-	-
External Project Risks	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Ala Wai (4 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 40,535,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		50.00%	$ -	$ -
1	11 01 LEVEES	Levees - Hausten Ditch	$ 620,000		14.70%	$ 91,116	$ 711,116.05
2	11 02 FLOODWALLS	Floodwalls - Hausten	$ 3,931,000		16.52%	$ 649,271	$ 4,580,271.50
3	11 02 FLOODWALLS	Floodwalls - Ala Wai Canal	$ 13,176,000		38.35%	$ 5,053,435	$ 18,229,435.46
4	11 01 LEVEES	Levees - Golf Course	$ 4,671,000		25.04%	$ 1,169,698	$ 5,840,697.92
5	13 PUMPING PLANT	Ala Wai Pump Stations	$ 16,234,000		49.79%	$ 8,082,263	$ 24,316,263.20
6	15 FLOODWAY CONTROL AND DIVERSION STRUCTURES	Hausten Ditch Sluice Gates	$ 1,648,000		44.72%	$ 737,019	$ 2,385,018.71
7	18 CULTURAL RESOURCE PRESERVATION	Cultural Monitoring	$ 255,000		20.32%	$ 51,816	$ 306,815.66
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		Remaining Construction Items	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 10,541,000		25.19%	$ 2,655,598	$ 13,196,597.54
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 5,878,000		23.38%	$ 1,374,261	$ 7,252,261.26

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 40,535,000	39.06%	$ 15,834,618	$ 56,369,618	
Total Planning, Engineering & Design	$ 10,541,000	25.19%	$ 2,655,598	$ 13,196,598	
Total Construction Management	$ 5,878,000	23.38%	$ 1,374,261	$ 7,252,261	
Total	$ 56,954,000		$ 19,864,477	$ 76,818,477	

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Ala Wai (4 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 40,535,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		50.00%	$ -	$ -
1	11 01 LEVEES	Levees - Hausten Ditch	$ 620,000		14.70%	$ 91,116	$ 711,116.05
2	11 02 FLOODWALLS	Floodwalls - Hausten	$ 3,931,000		16.52%	$ 649,271	$ 4,580,271.50
3	11 02 FLOODWALLS	Floodwalls - Ala Wai Canal	$ 13,176,000		38.35%	$ 5,053,435	$ 18,229,435.46
4	11 01 LEVEES	Levees - Golf Course	$ 4,671,000		25.04%	$ 1,169,698	$ 5,840,697.92
5	13 PUMPING PLANT	Ala Wai Pump Stations	$ 16,234,000		49.79%	$ 8,082,263	$ 24,316,263.20
6	15 FLOODWAY CONTROL AND DIVERSION STRUCTURES	Hausten Ditch Sluice Gates	$ 1,648,000		44.72%	$ 737,019	$ 2,385,018.71
7	18 CULTURAL RESOURCE PRESERVATION	Cultural Monitoring	$ 255,000		20.32%	$ 51,816	$ 306,815.66
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		Remaining Construction Items	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 10,541,000		25.19%	$ 2,655,598	$ 13,196,597.54
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 5,878,000		23.38%	$ 1,374,261	$ 7,252,261.26

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 40,535,000	39.06%	$ 15,834,618	$ 56,369,618	
Total Planning, Engineering & Design	$ 10,541,000	25.19%	$ 2,655,598	$ 13,196,598	
Total Construction Management	$ 5,878,000	23.38%	$ 1,374,261	$ 7,252,261	
Total	$ 56,954,000		$ 19,864,477	$ 76,818,477	

Ala Wai Canal (TSP) - Ala Wai (4 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Levees - Hausten Ditch	Floodwalls - Hausten	Floodwalls - Ala Wai Canal	Levees - Golf Course	Ala Wai Pump Stations	Hausten Ditch Sluice Gates	Cultural Monitoring	0	0	0	0	Remaining Construction Ite	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	-	2	-	2	3	2	-	-	-	-	-	-	-
Acquisition Strategy	3	3	3	3	3	3	3	-	-	-	-	-	3	-
Construction Elements	-	-	1	1	-	2	-	-	-	-	-	-	-	1
Quantities for Current Scope	-	1	2	-	2	2	-	-	-	-	-	1	3	3
Specialty Fabrication or Equipment	-	-	-	-	3	2	-	-	-	-	-	-	1	-
Cost Estimate Assumptions	-	-	3	3	3	1	-	-	-	-	-	3	-	3
External Project Risks	-	-	2	-	2	1	-	-	-	-	-	-	1	-

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Adaptive Mgt (5 of 6)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 2,624,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.00%	$ -	$ -
1	04 DAMS	Adaptive Mgt (Det/Debris Basin)	$ 2,574,000		25.50%	$ 656,275	$ 3,230,275.04
2	15 FLOODWAY CONTROL AND DIVERSION STRUCTURES	Debris Catchment; Gates	$ 50,000		25.50%	$ 12,748	$ 62,748.16
3			$ -		0.00%	$ -	$ -
4					0.00%	$ -	$ -
5			$ -		0.00%	$ -	$ -
6			$ -		0.00%	$ -	$ -
7			$ -		0.00%	$ -	$ -
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		Remaining Construction Items	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	$ 681,000		14.21%	$ 96,787	$ 777,787.22
14	31 CONSTRUCTION MANAGEMENT	Construction Management	$ 380,000		12.62%	$ 47,970	$ 427,970.18

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 2,624,000	25.50%	$ 669,023	$ 3,293,023	
Total Planning, Engineering & Design	$ 681,000	14.21%	$ 96,787	$ 777,787	
Total Construction Management	$ 380,000	12.62%	$ 47,970	$ 427,970	
Total	$ 3,685,000		$ 813,781	$ 4,498,781	

Ala Wai Canal (TSP) - Adaptive Mgt (5 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 28-Jan-14

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	**75%**
PS-1	Adaptive Mgt (Det/Debris Basin)	• Design confidence?	Adaptive Management will not be be determined until after construction is completed.	An Adaptive Management Plan will not be developed until the construction phase. It is lkeley that the adaptive management plan could increase or decrease the cost, if determined during monitoring after construction that it has to be implemented. The risk level would be marginal because the cost could go either downwards or upwards.	Likely	Marginal	2
PS-2	Debris Catchment; Gates	• Potential for scope growth, added features and quantities?	Same as PS-1	Same as PS-1	Likely	Marginal	2
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	N/A	N/A	Unlikely	Negligible	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	Same as PS-1	Same as PS-1	Likely	Marginal	2

Acquisition Strategy

						Max Potential Cost Growth	30%
AS-1	Adaptive Mgt (Det/Debris Basin)	• Contracting plan firmly established?	Contracting Acquisition Strategy not determined at this stage. It is assumed Adaptive Management performed by the Prime Contractor.	The Acquisition Strategy will not be determined until after the Construction is completed & Monitoring after Construction is performed for 10 years. It is assumed that Adaptive Managemet will be required by the 3rd yr. It is possible that the Adaptive management could be one Prime with a subcntractor. The cost increase could be significant siince the conceptual estimate assumes one Prime performing all the work.	Possible	Significant	2
AS-2	Debris Catchment; Gates	• Contracting plan firmly established?	Same as AS-1	Same as AS-1.	Possible	Significant	2
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	Same as AS-1	Same as AS-1	Likely	Marginal	2
AS-14	Construction Management	• Contracting plan firmly established?	None	None	Unlikely	Negligible	0

Construction Elements

						Max Potential Cost Growth	25%
CE-1	Adaptive Mgt (Det/Debris Basin)	• Accelerated schedule or harsh weather schedule?	Adaptive Management will not be be determined until after construction is completed.	An Adaptive Management Plan will not be developed until the construction phase. It is likeley that the adaptive management plan could increase or decrease the cost, if determined during monitoring after construction that it has to be implemented. The risk level would be marginal because the cost could go either downwards or upwards.	Likely	Marginal	2
CE-2	Debris Catchment; Gates	• Accelerated schedule or harsh weather schedule?	Same as CE-1.	Same as CE-1.	Likely	Marginal	2
CE-13	Planning, Engineering, & Design	• Accelerated schedule or harsh weather schedule?	None	None	Unlikely	Negligible	0
CE-14	Construction Management	• Accelerated schedule or harsh weather schedule?	None	None	Unlikely	Negligible	0

Quantities for Current Scope

						Max Potential Cost Growth	20%
Q-1	Adaptive Mgt (Det/Debris Basin)	• Level of confidence based on design and assumptions?	Adaptive Management will not be be determined until after construction is completed.	An Adaptive Management Plan will not be developed until the construction phase. It is likeley that the adaptive management plan could increase or decrease the cost, if determined during monitoring after construction that it has to be implemented. The risk level would be marginal because the cost could go either downwards or upwards.	Likely	Marginal	2
Q-2	Debris Catchment; Gates	• Level of confidence based on design and assumptions?	Same as Q-1.	Same as Q-1.	Likely	Marginal	2
Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	Same as Q-1	Same as Q-1	Likely	Marginal	2
Q-14	Construction Management	• Level of confidence based on design and assumptions?	None	None	Unlikely	Negligible	0

Specialty Fabrication or Equipment

						Max Potential Cost Growth	75%
FE-1	Adaptive Mgt (Det/Debris Basin)	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-2	Debris Catchment; Gates	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-3	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-4	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-5	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-6	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-7	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-8	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-9	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-10	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-11	0	• Unusual parts, material or equipment manufactured or installed?			Unlikely	Negligible	0
FE-12	Remaining Construction Items	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-13	Planning, Engineering, & Design	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-14	Construction Management	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0

Cost Estimate Assumptions

						Max Potential Cost Growth	35%
CT-1	Adaptive Mgt (Det/Debris Basin)	• Assumptions related to prime and subcontractor markups/assignments?	The asumption is one prime contractor for Adaptive Management.	It is as likely that monitoring after construction will determine if any adaptive mangament is needed. The likelyhood of significant cost equally decrease or increase, therefore the rating is negligible.	Likely	Negligible	1
CT-2	Debris Catchment; Gates	• Assumptions related to prime and subcontractor markups/assignments?	Same as CT-1	Same as CT-1	Likely	Negligible	1
CT-3	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-4	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-5	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-6	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-7	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-8	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-9	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-10	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-11	0	• Reliability and number of key quotes?			Unlikely	Negligible	0
CT-12	Remaining Construction Items	• Reliability and number of key quotes?	N/A	N/A	Unlikely	Negligible	0
CT-13	Planning, Engineering, & Design	• Reliability and number of key quotes?	N/A	N/A	Unlikely	Negligible	0

CT-14	Construction Management	• Reliability and number of key quotes?	N/A	N/A	Unlikely	Negligible	0

External Project Risks

						Max Potential Cost Growth	40%
EX-1	Adaptive Mgt (Det/Debris Basin)	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-2	Debris Catchment; Gates	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-3	0	• Potential for severe adverse weather?			Unlikely	Negligible	0
EX-4	0	• Potential for severe adverse weather?			Unlikely	Negligible	0
EX-5	0	• Potential for severe adverse weather?			Unlikely	Negligible	0
EX-6	0	• Potential for severe adverse weather?			Unlikely	Negligible	0
EX-13	Planning, Engineering, & Design	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0
EX-14	Construction Management	• Potential for severe adverse weather?	None	None	Unlikely	Negligible	0

Ala Wai Canal (TSP) - Adaptive Mgt (5 of 6)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Adaptive Mgt (Det/Debris Basin)	Debris Catchment; Gates	0	0	0	0	0	0	0	0	0	Remaining Construction Items	Planning, Engineering, & Design	Construction Management
Project Scope Growth	2	2	-	-	-	-	-	-	-	-	-	-	-	2
Acquisition Strategy	2	2	-	-	-	-	-	-	-	-	-	-	2	-
Construction Elements	2	2	-	-	-	-	-	-	-	-	-	-	-	-
Quantities for Current Scope	2	2	-	-	-	-	-	-	-	-	-	-	2	-
Specialty Fabrication or Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cost Estimate Assumptions	1	1	-	-	-	-	-	-	-	-	-	-	-	-
External Project Risks	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Abbreviated Risk Analysis

Project (less than $40M): **Ala Wai Canal (TSP) - Flood Warning (5 of 5)**
Project Development Stage: **Feasibility (Alternatives)**
Risk Category: **Moderate Risk: Typical Project or Possible Life Safety**

Total Construction Contract Cost = **$ 144,000**

	CWWBS	Feature of Work	Contract Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.00%	$ -	$ -
1	19 BUILDINGS, GROUNDS, AND UTILITIES	**Flood Warning System**	$ 144,000		14.70%	$ 21,162	$ 165,162.44
2			$ -		0.00%	$ -	$ -
3			$ -		0.00%	$ -	$ -
4					0.00%	$ -	$ -
5			$ -		0.00%	$ -	$ -
6			$ -		0.00%	$ -	$ -
7			$ -		0.00%	$ -	$ -
8			$ -		0.00%	$ -	$ -
9			$ -		0.00%	$ -	$ -
12		**Remaining Construction Items**	$ -	*0.0%*	0.00%	$ -	$ -
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 38,000		14.70%	$ 5,585	$ 43,584.53
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 21,000		7.00%	$ 1,470	$ 22,470.00

Totals					
Real Estate	$ -	0.00%	$ -	$ -	
Total Construction Estimate	$ 144,000	14.70%	$ 21,162	$ 165,162	
Total Planning, Engineering & Design	$ 38,000	14.70%	$ 5,585	$ 43,585	
Total Construction Management	$ 21,000	7.00%	$ 1,470	$ 22,470	
Total	$ 203,000		$ 28,217	$ 231,217	

Ala Wai Canal (TSP) - Flood Warning (5 of 5)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Meeting Date: 1/28/2014 (Rev 7/22/14)

Risk Level

	Negligible	Marginal	Significant	Critical	Crisis
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Element	Feature of Work	Concerns Pull Down Tab (ENABLE MACROS THRU TRUST CENTER) (Choose ALL that apply)	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Likelihood	Impact	Risk Level
Project Scope Growth							
						Max Potential Cost Growth	**75%**
PS-1	Flood Warning System	• Potential for scope growth, added features and quantities?	Floodwarning system not currently designed.	A best professional judgement cost based on the number of stream gages. A study during PED will be required to determine flood warning threshholds. It is possible the sponsor/community wants more stream gages. The cost of the gages are negligible since it is a small cost.	Possible	Negligible	0
PS-13	Planning, Engineering, & Design	• Potential for scope growth, added features and quantities?	Floodwarning system not currently designed.	A best professional judgement cost based on the number of stream gages. A study during PED will be required to determine flood warning threshholds. It is possible the sponsor/community wants more stream gages. The cost increase of the study during PED is negligible.	Unlikely	Negligible	0
PS-14	Construction Management	• Potential for scope growth, added features and quantities?	None	None	Unlikely	Negligible	0

Acquisition Strategy

						Max Potential Cost Growth	30%
AS-1	Flood Warning System	• Contracting plan firmly established?	Contracting Acquisition Strategy not determined at this stage. It is assumed the best scenario the entire project is awared to one Prime Contractor.	The Acquisition Strategy will not be determined until the PED Phase. As the design and scope is finalized in the PED phase Contracting will do Market Research to determine the type of interested parties (contractors able and willing to perform the work). If determined there are available contractors to meet the bonding requirements of the project, the project could be issued as one contract with one Prime Contractor. Then Contracting will request approval from the Regional Principal Assistant Responsible for Contracting (PARC) to approve a consolidation of the project. Market research could also determine if the project will be awarded to Small Business, Unrestricted, or to multiple contractor. The estimate assumed the best scenario of one Prime Contractor for coordination purposes. If it is determined otherwise, the cost of the construction could significantly increase due to higher overheads with multiple contractors or small business. Since this project covers multiple areas, it is very likely it would be broken up into multiple contracts by watershed or measures.	Likely	Significant	3
AS-13	Planning, Engineering, & Design	• Contracting plan firmly established?	Same as AS-1	If the project is broken up into multiple contracts, the design could also be broken up into multiple contracts (multiple Engineering firms) to provide equal opportunitity for each firm engineering work. This coud significantly add costs to PED.	Likely	Significant	3
AS-14	Construction Management	• Contracting plan firmly established?	Additional construction mg personnel would be required for multiple contracts.	If the project is broken up into multiple contracts, it is unlikely to increase Construction Management costs since all measures woul d be managed. Additonal contract mgangement personnel would be required inspecting fewer areas. Therefore the increase to cost is marginal.	Unlikely	Marginal	0

Construction Elements

						Max Potential Cost Growth	25%
CE-1	Flood Warning System	• Accelerated schedule or harsh weather schedule?	N/A	N/A	Unlikely	Negligible	0
CE-13	Planning, Engineering, & Design	• Potential for construction modification and claims?	None	None	Unlikely	Negligible	0
CE-14	Construction Management	• High risk or complex construction elements, site access, in-water?	None	None	Unlikely	Negligible	0

Quantities for Current Scope

						Max Potential Cost Growth	20%
Q-1	Flood Warning System	• Level of confidence based on design and assumptions?	Floodwarning system not currently designed.	A best professional judgement cost will be used to estimate the number of stream gages for the conceptual desting. A study during PED will be required to determine flood warning threshholds. It is possible the sponsor/community wants more stream gages. The quantity increase is negligible.	Possible	Negligible	0
Q-12	Remaining Construction Items	• Level of confidence based on design and assumptions?	None	None	Unlikely	Negligible	0
Q-13	Planning, Engineering, & Design	• Level of confidence based on design and assumptions?	Flood warning system designed in PED.	A study during PED will be required to determine flood warning threshholds. It is possible the sponsor/community wants more stream gages. The cost increase of the study during PED is negligible.	Unlikely	Negligible	0
Q-14	Construction Management	• Level of confidence based on design and assumptions?	N/A	N/A	Unlikely	Negligible	0

Specialty Fabrication or Equipment

						Max Potential Cost Growth	75%
FE-1	Flood Warning System	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-13	Planning, Engineering, & Design	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0
FE-14	Construction Management	• Unusual parts, material or equipment manufactured or installed?	None	None	Unlikely	Negligible	0

Cost Estimate Assumptions

						Max Potential Cost Growth	35%
CT-1	Flood Warning System	• Reliability and number of key quotes?	Flood warning system quote not included at this time.	Refinement of the flood warning system will be determined after the flood warning study is done in PED. The quantity is unlikely to increase in quantity from 10% conceptual design to TSP. Quotes will be obtained in the PED phase. The cost of additional stream gages is expected to be negligible.	Unlikely	Negligible	0
CT-13	Planning, Engineering, & Design	• Reliability and number of key quotes?	None	None	Unlikely	Negligible	0
CT-14	Construction Management	• Reliability and number of key quotes?	None	None	Unlikely	Negligible	0

External Project Risks

						Max Potential Cost Growth	40%
EX-1	Flood Warning System	• Political influences, lack of support, obstacles?	None	None	Unlikely	Negligible	0
EX-12	Remaining Construction Items	• Political influences, lack of support, obstacles?	None	None	Unlikely	Negligible	0
EX-13	Planning, Engineering, & Design	• Political influences, lack of support, obstacles?	None	None	Unlikely	Negligible	0
EX-14	Construction Management	• Political influences, lack of support, obstacles?	None	None	Unlikely	Negligible	0

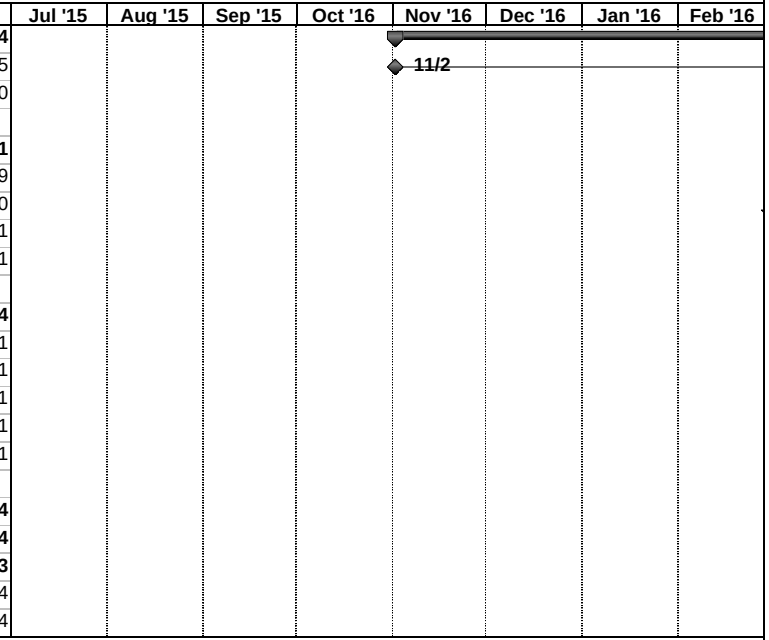
Ala Wai Canal (TSP) - Flood Warning (5 of 5)
Feasibility (Alternatives)
Abbreviated Risk Analysis

Typical Risk Elements	Potential Risk Areas													
	Flood Warning System	0	0	0	0	0	0	0	0	0	0	Remaining Construction Ite	Planning, Engineering, & Design	Construction Management
Project Scope Growth	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acquisition Strategy	3	-	-	-	-	-	-	-	-	-	-	-	3	-
Construction Elements	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quantities for Current Scope	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specialty Fabrication or Equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cost Estimate Assumptions	-	-	-	-	-	-	-	-	-	-	-	-	-	-
External Project Risks	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration	Start	Finish
1	**Ala Wai Canal TSP**	**2184.88 days**	**Mon 11/2/15**	**Tue 7/16/24**
2	Sign Design Agreement	0 days	Mon 11/2/15	Mon 11/2/15
3	Sign PPA	0 days	Mon 11/30/20	Mon 11/30/20
4				
5	**PED Start**	**1101.88 days**	**Mon 10/3/16**	**Fri 2/26/21**
6	Planning, Engrg & Design (PED)	811.88 days	Mon 10/3/16	Tue 12/31/19
7	Real Estate Acquisition	937.88 days	Mon 10/3/16	Tue 6/30/20
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons	Mon 11/30/20	Fri 1/29/21
9	Award	0 days	Fri 2/26/21	Fri 2/26/21
10				
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**	**Fri 3/12/21**	**Tue 7/16/24**
12	NTP	0 days	Fri 3/12/21	Fri 3/12/21
13	Construction Start	1 day	Fri 3/12/21	Mon 3/15/21
14	Submittals, Permits	5 mons	Mon 3/15/21	Wed 8/4/21
15	Public Meeting	3 days	Wed 8/4/21	Mon 8/9/21
16	Ground Breaking/Blessing Ceremony	1 day	Mon 8/9/21	Tue 8/10/21
17				
18	**Makiki-Palolo (Sub #1)**	**634 days**	**Tue 8/10/21**	**Wed 2/21/24**
52	**Manoa - SW Sub #2**	**736 days**	**Tue 8/10/21**	**Tue 7/16/24**
103	**Ala Wai - SW Sub #3**	**410 days**	**Tue 8/10/21**	**Fri 3/31/23**
131	Construction Complete	0 days	Tue 7/16/24	Tue 7/16/24
132	Project complete	0 days	Tue 7/16/24	Tue 7/16/24



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

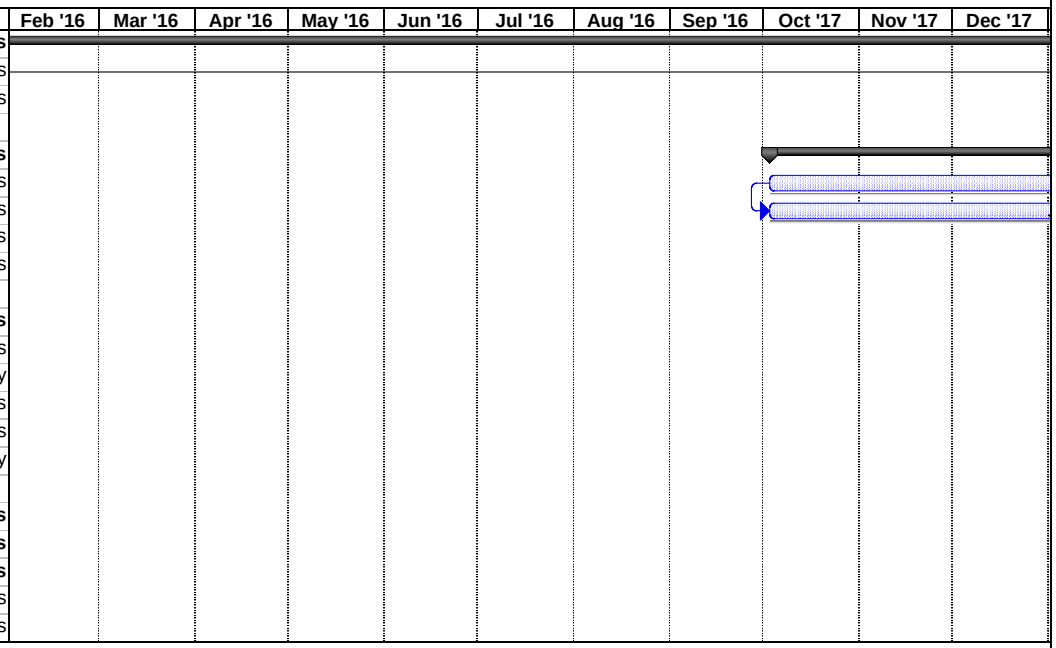
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 1

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

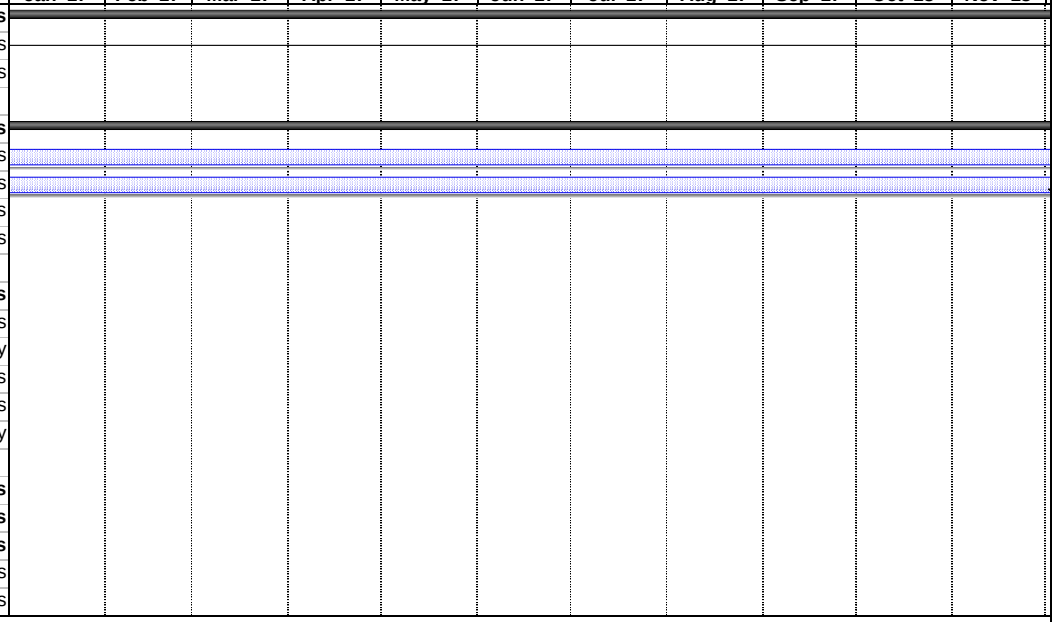
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 2

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

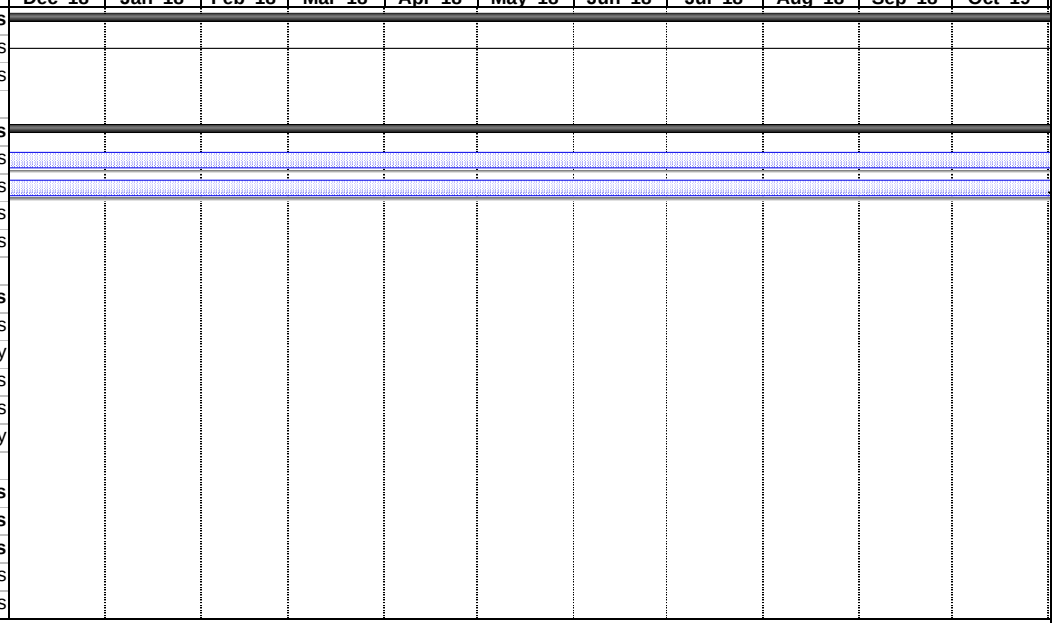
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 3

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

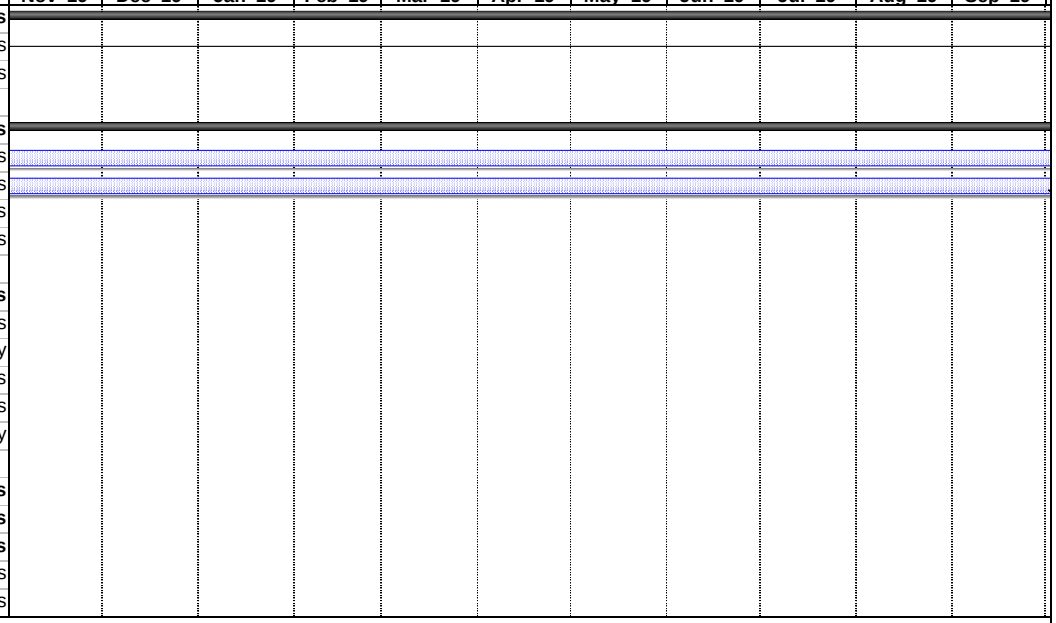
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 4

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 5

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
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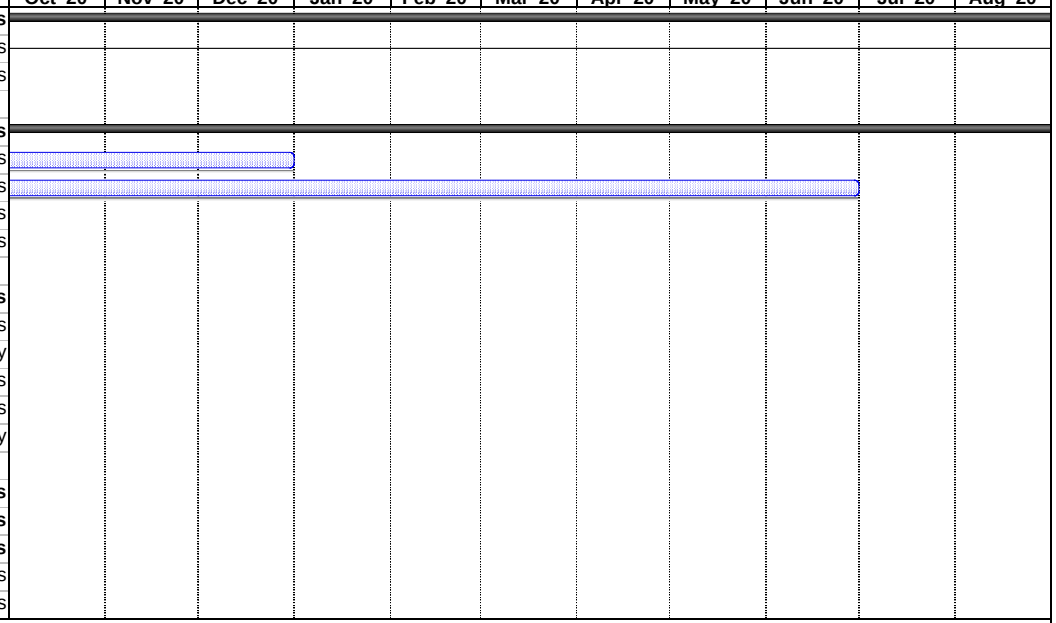
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

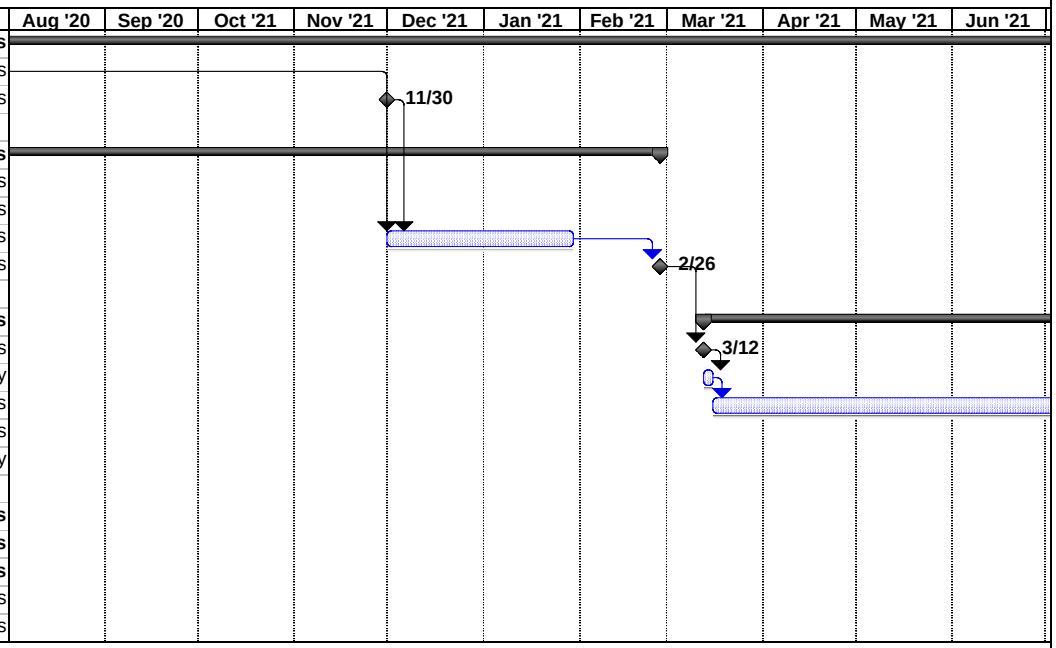
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 6

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

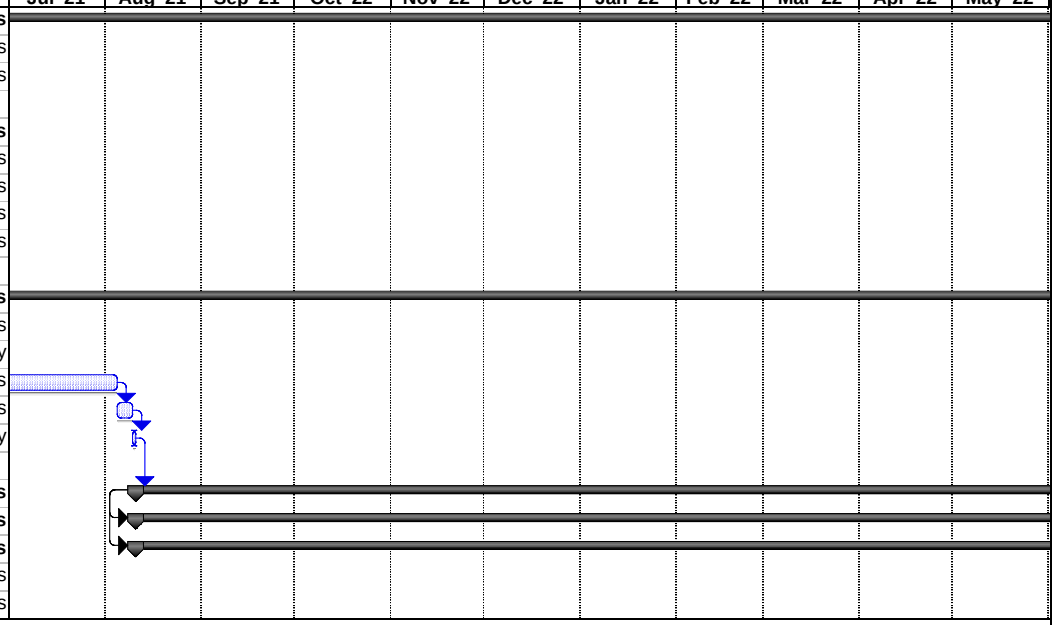
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 7

Ala Wai Canal TSP

Thu 5/7/15

ID		Task Name	Duration
1		**Ala Wai Canal TSP**	**2184.88 days**
2		Sign Design Agreement	0 days
3		Sign PPA	0 days
4			
5		**PED Start**	**1101.88 days**
6		Planning, Engrg & Design (PED)	811.88 days
7		Real Estate Acquisition	937.88 days
8		Contracting Coord, Solicit, LPTA Eval	2.05 mons
9		Award	0 days
10			
11		**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12		NTP	0 days
13		Construction Start	1 day
14		Submittals, Permits	5 mons
15		Public Meeting	3 days
16		Ground Breaking/Blessing Ceremony	1 day
17			
18		**Makiki-Palolo (Sub #1)**	**634 days**
52		**Manoa - SW Sub #2**	**736 days**
103		**Ala Wai - SW Sub #3**	**410 days**
131		Construction Complete	0 days
132		Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

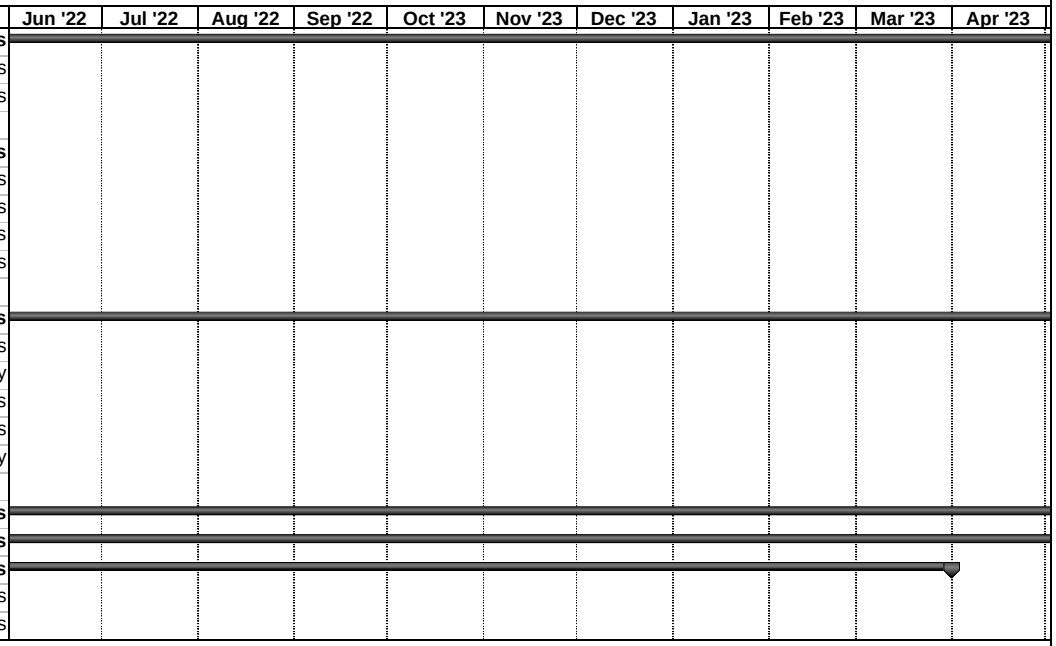
Task		Rolled Up Task		External Tasks	
Critical Task		Rolled Up Critical Task		Project Summary	
Progress		Rolled Up Milestone		External MileTask	
Milestone		Rolled Up Progress		Critical Task	
Summary		Split		Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 8

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

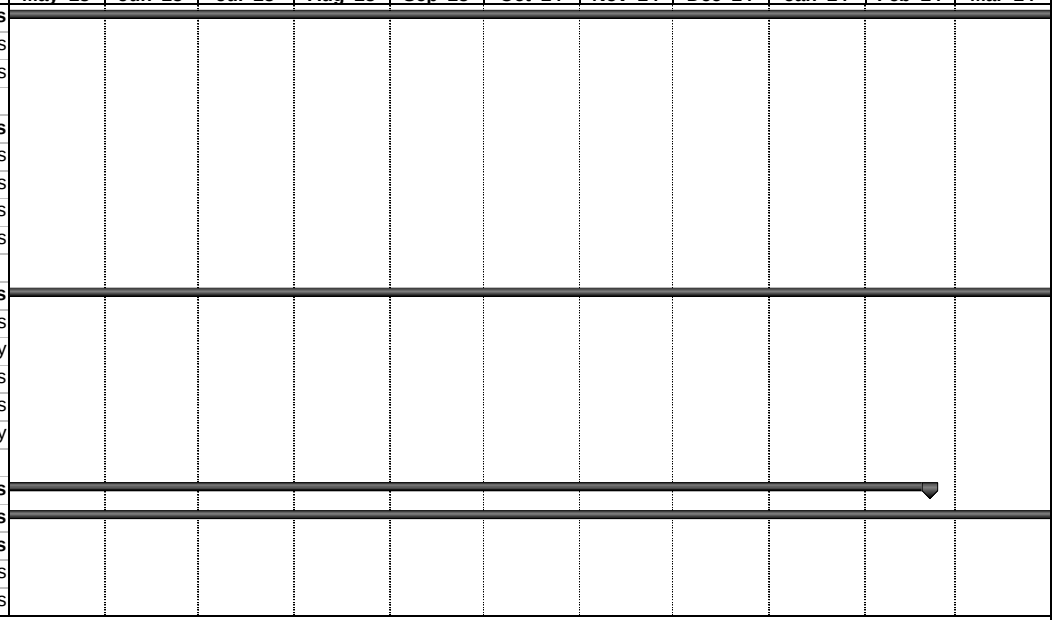
Task	Rolled Up Task	External Tasks
Critical Task	Rolled Up Critical Task	Project Summary
Progress	Rolled Up Milestone	External MileTask
Milestone	Rolled Up Progress	Critical Task
Summary	Split	Progress

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 9

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

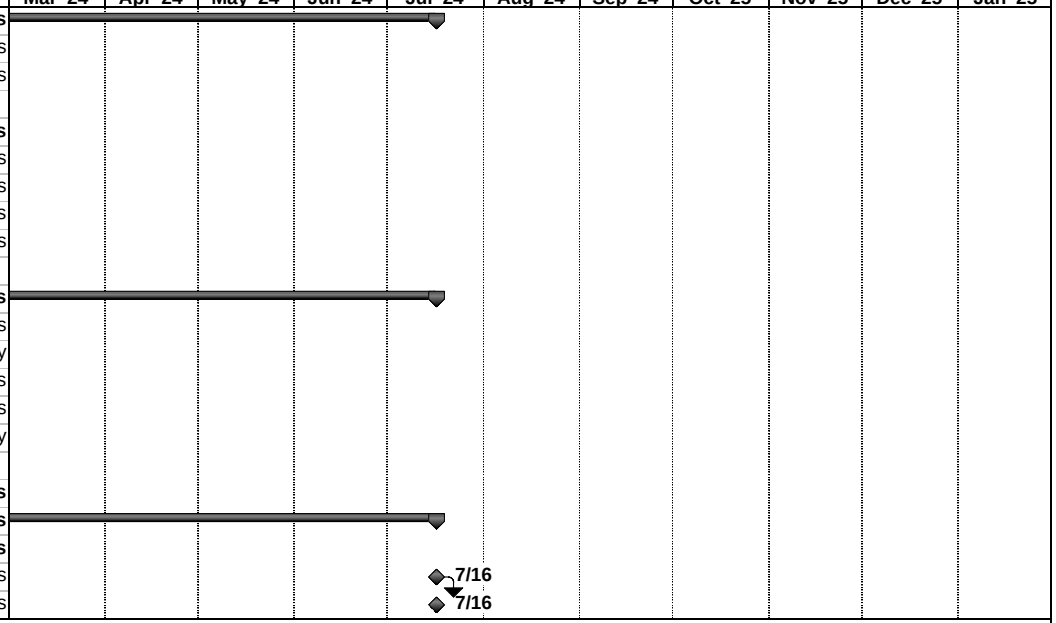
Task	Rolled Up Task	External Tasks
Critical Task	Rolled Up Critical Task	Project Summary
Progress	Rolled Up Milestone	External MileTask
Milestone	Rolled Up Progress	Critical Task
Summary	Split	Progress

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 10

Ala Wai Canal TSP

Thu 5/7/15

ID	Task Name	Duration
1	**Ala Wai Canal TSP**	**2184.88 days**
2	Sign Design Agreement	0 days
3	Sign PPA	0 days
4		
5	**PED Start**	**1101.88 days**
6	Planning, Engrg & Design (PED)	811.88 days
7	Real Estate Acquisition	937.88 days
8	Contracting Coord, Solicit, LPTA Eval	2.05 mons
9	Award	0 days
10		
11	**Construction (1 Prime & 3 Sitework Subs)**	**841 days**
12	NTP	0 days
13	Construction Start	1 day
14	Submittals, Permits	5 mons
15	Public Meeting	3 days
16	Ground Breaking/Blessing Ceremony	1 day
17		
18	**Makiki-Palolo (Sub #1)**	**634 days**
52	**Manoa - SW Sub #2**	**736 days**
103	**Ala Wai - SW Sub #3**	**410 days**
131	Construction Complete	0 days
132	Project complete	0 days



Ala Wai Canal (TSP)
Honolulu, Island of Oahu, Hawaii
Date: Thu 5/7/15

Task	Rolled Up Task	External Tasks	
Critical Task	Rolled Up Critical Task	Project Summary	
Progress	Rolled Up Milestone	External MileTask	
Milestone	Rolled Up Progress	Critical Task	
Summary	Split	Progress	

Ala Wai - Initial TSP(18Nov14).mpp; CPM Page 11

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E
ENVIRONMENTAL AND REGULATORY COMPLIANCE

E1	**Summary of Federal and State Regulatory Compliance**
E2	**Draft Mitigation and Monitoring Plan**
E3	**Clean Water Act Section 404(b)(1) Evaluation**
E4	**Coastal Zone Management Federal Consistency Review**
E5	**Endangered Species Act Section 7 Consultation Documentation**
E6	**Renderings of Flood Risk Management Measures**
E7	**Draft Record of Decision**

Appendix E1
Summary of Federal and State Regulatory Compliance

Federal and State Regulatory Compliance

Following is a discussion of the various regulations and policies that are applicable to the Ala Wai Canal Project, and the status of compliance with each regulation and policy.

Federal Regulations and Policies

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals (42 United States Code [U.S.C.] 4321 *et seq*.). NEPA requires federal agencies to incorporate environmental considerations in their planning and decision-making process through a systematic interdisciplinary approach. Specifically, it requires full disclosure of the environmental effects, alternatives, potential mitigation, and environmental compliance procedures of the proposed action.

This draft Feasibility Study Report with integrated Environmental Impact Statement (EIS) has been prepared in compliance with NEPA and its implementing regulations (40 CFR Part 1500 through 1508). Pursuant to these regulations, the document describes the existing environmental conditions within the project site, the proposed action and alternatives, potential environmental impacts of the proposed project, and measures to minimize environmental impacts. Full compliance will be achieved when the Final EIS and Record of Decision (ROD) are filed with the EPA.

Clean Water Act

The purpose of the Clean Water Act (CWA; 33 U.S.C. 1251 *et seq*.) is to "restore and maintain the chemical, physical and biological integrity of the nation's waters." Section 404 of the CWA regulates the discharge of dredged or fill material into Waters of the U.S., which are defined to include rivers, streams, estuaries, the territorial seas, ponds, lakes, and wetlands; the USACE retains primary responsibility for this permit program (with oversight provided by EPA). USACE does not issue itself a permit under this program, but rather demonstrates compliance with the environmental criteria set forth in the Clean Water Act Section 404(b)(1) guidelines (40 CFR 230).[1] Section 404(b)(1) specifies that impacts to waters of the United States may only be permitted if there is no other practicable alternative that would have less adverse impact on the aquatic ecosystem and the action would not cause or contribute to significant degradation of the waters. As described in Section 5.4 of the Draft Feasibility Report/EIS, the project would result in discharge of fill material into Waters of the U.S. The Section 404(b)(1) evaluation for this project, which is contained in Appendix E, concludes that the proposed action is consistent with the specified guidelines, and that the tentatively selected plan is the least environmentally damaging alternative (LEDPA).

Under Section 401 of the CWA, applicants for a federal permit to conduct any activity that may result in a discharge of dredged or fill material to Waters of the U.S. must also obtain certification that any such discharge would comply with State water quality standards. The State of Hawai`i Department of Health

[1] If certain conditions are met, Clean Water Act Section 404(r) states that the discharge of dredged or fill material is not prohibited by or otherwise subject to regulation under Clean Water Act Section 404, Section 301(a), or Section 402 (except for effluent standards or prohibitions under Section 307). This applies only if information on the effects of such discharge, including consideration of the guidelines developed under Section 404(b)(1), is included in an EIS for such project pursuant to NEPA and such EIS has been submitted to Congress before (1) the actual discharge of dredged or fill material in connection with the construction of such project and (2) either authorization of such project or an appropriation of funds for each construction.

(DOH) administers the Section 401 water quality certification program, pursuant to HRS §342D, as discussed below.

Section 402 of the Clean Water Act regulates discharges of pollutants and stormwater to surface waters through the National Pollutant Discharge and Elimination System (NPDES) program; the program is administered by EPA, who has delegated oversight authority to the State of Hawaii DOH. The NPDES program is governed at the State level under HRS Chapter 342D, also discussed below.

Endangered Species Act

Section 7 of the Endangered Species Act (ESA; 16 U.S.C. 1536) prohibits Federal agencies from authorizing, funding, or carrying out activities that are likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat. The USFWS is the administering agency for this authority regarding non-marine species. Through consultation with USFWS, agencies review their actions prior to implementation to determine if these could adversely affect listed species or their habitat.

In compliance with ESA consultation requirements, USACE requested information from USFWS regarding threated and endangered species and designated critical habitat within the overall Ala Wai watershed in April 2008. The USFWS responded in May 2008, and provided a list of federal listed species and designed critical habitat that could occur within the watershed. Follow-up meetings were held with agency staff on October 14, 2014; January 23, 2015; April 14, 2015; May 26, 2015; June 5, 2015; June 29, 2015; and July 29, 2015. The purpose of these meetings was to update agency staff on the current project status, discuss the project features, and to obtain any additional input on ESA-related issues.

Consultation was also initiated with NMFS in 2008; in response to USACE's request, NMFS provided a complete list of ESA-listed species under their jurisdiction in the Hawaiian Archipelago on April 25, 2008. At the time of the original consultation, the project scope and objectives were more broadly defined, with the project area extending to include the nearshore marine waters. As the objectives and scope of the project were subsequently narrowed to focus on riverine-based flood risk management, the project is not expected to directly or indirectly affect the nearshore marine waters.

Based on this ongoing consultation, the USACE evaluated the potential impacts of the proposed project and summarized the results in a Draft Biological Assessment. As documented in the Draft Biological Assessment, USACE determined that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, O'ahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen), with no effect on all other Federally listed/candidate species or designated critical habitat. As the blackline Hawaiian damselfly was initially thought to be restricted to higher elevations of the watershed (and therefore have no potential to occur within the project area), the Draft Biological Assessment included a no effect determination for this species. However, on July 28, 2015, USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin (D. Polhemus, personal communication, July 29, 2015). Detailed information from USFWS regarding this species is still pending; however, USACE provided a letter to USFWS on August 5, 2015, with submittal of the Draft Biological Assessment, indicating USACE's intention to initiate formal Section 7 consultation on the endangered blackline Hawaiian damselfly upon receipt of the species information.

A copy of the Draft Biological Assessment and ESA Section 7 correspondence is contained in Appendix E5; documentation of the completed Section 7 consultation process will be included in the Final Feasibility Report/EIS.

Migratory Bird Treaty Act

Native migratory birds of the United States are protected under the MBTA of 1918, as amended (16 U.S.C. 703-712 et. seq.); the list of birds protected under MBTA implementing regulations is provided at 50 CFR 10.13. This Act states that it is unlawful to pursue, hunt, take, capture or kill; attempt to take, capture or kill; possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product. "Take" is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect (16 U.S.C. 703-712)." Consistent with the analysis provided relative to the ESA, the project is not expected to adversely affect migratory species.

Magnuson-Stevens Fishery Conservation and Management Act

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)) establish provisions relative to Essential Fish Habitat (EFH), in order to identify and protect important habitats for federally managed marine and anadromous fish species. Federal agencies which fund, permit, or undertake activities that may adversely affect EFH are required to consult with the National Marine Fisheries Service (NMFS) regarding the potential effects of their actions on EFH, and respond to NMFS recommendations.

As described in the Draft Integrated Feasibility Report and Environmental Impact Statement (EIS), no portion of the project area has been designated as EFH, but the nearshore waters to which the streams and Canal drain (i.e. Mamala Bay) include EFH for various lifestages of bottomfish, pelagics, coral reef ecosystem, and crustaceans. An overview of the proposed project and a discussion of potential project-related impacts was the subject of a meeting with NMFS on June 29, 2015; based on this discussion and the analysis contained in the Draft Report, USACE has determined that there would be no adverse effect to EFH, such that consultation is not required.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661) was established to provide for the protection of fish and wildlife as part of federal water resource development projects. It requires Federal agencies to coordinate with USFWS and State wildlife agencies during the planning of new projects or for modifications of existing projects so that wildlife conservation receives equal consideration with other features of such projects throughout the decision making process. Wildlife resources are conserved by minimizing adverse effects, compensating for wildlife resources losses, and enhancing wildlife resource values.

Coordination with USFWS and DLNR (including both the Division of Forestry and Wildlife (DOFAW) and Division of Aquatic Resources (DAR)) has been conducted under the FWCA throughout the planning process; specific meeting dates are summarized in Section 6.2 of the Draft Feasibility Report/EIS. Through this coordination, input has been requested from the agencies relative to the potential impacts to fish and wildlife species, and approaches to avoid, minimize and mitigate for those impacts (including compensatory mitigation). In addition to site visits to the proposed measure locations, discussions have included a detailed review of the proposed design drawings for both the flood risk management and the compensatory mitigation measures. Input received to date relates to: (1) consideration of potential impacts to Federally listed species and (2) consideration of water quality impacts due to flushing and mobilization of contaminants in multi-purpose detention basins. These considerations have been integrated into the planning process, as summarized throughout the Draft Feasibility Report/EIS. No high-risk issues or other significant concerns have been identified to date. A formal record of the agencies' recommendations will be documented in a FWCA Section 2(b) Report, which will be included in the Final Feasibility Report/EIS.

National Historic Preservation Act

The National Historic Preservation Act (NHPA; 16 U.S.C. 470f), as amended, governs the preservation of cultural and historic resources. Specific to the proposed project, NHPA Section 106 requires Federal agencies to consider the effects of a proposed undertaking on properties that have been listed (or determined to be eligible for listing) in the National Register of Historic Places; properties that are listed (or are eligible for listing) in the National Register are referred to as "historic properties."

As described in 36 CFR Part 800.1, which are the implementing regulations for the historic preservation review process, the Section 106 process seeks to accommodate historic preservation concerns with the needs of federal undertakings through consultation. The goal of consultation is to obtain input as needed to identify historic properties potentially affected by the undertaking, assess the potential effects and seek ways to avoid, minimize or mitigate any adverse effects on historic properties. Consulting parties that should be involved in the Section 106 process include the State Historic Preservation Officer (SHPO), Native Hawaiian Organizations (NHOs), jurisdictional agency representatives, and other interested parties. Additionally, federal agencies must give the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on the undertaking.

Section 106 compliance for projects for which no historic properties are identified within the area of potential effects (APE), or for which adverse effects are either not anticipated or are easily resolved, can typically be achieved through a standard consultation process. In certain circumstances, including projects for which the effects cannot be fully determined prior to approval of the undertaking, a memorandum of agreement (MOA) or a programmatic agreement may be executed to guide the resolution of adverse effects and mitigation. Such agreements are negotiated between the Federal agency, the SHPO, and possibly the ACHP; other individuals or entities, such as NHOs, may be invited to participate as consulting parties. In addition, the federal agency must make information available to the public, and provide an opportunity for public input.

In compliance with NHPA Section 106, consultation with the SHPO was initiated in a letter dated August 21, 2014. Ongoing consultation has been conducted with SHPO and other consulting parties, with input sought relative to definition of the APE, identification of historic properties within the APE, and determination of potential effects to those properties; a copy of the Section 106 consultation documents is contained in Appendix F. Consistent with the summary of impacts and mitigation described in the consultation documents, the USACE determined that there would be an adverse effect to historic properties. Treatment recommendations have been proposed to reduce many of the impacts to no adverse effect with conditions. In addition, a Programmatic Agreement is being developed to further identify resources, determine effects and establish the process for resolving adverse effects that may arise throughout the remaining planning, design, and construction phases of the project. This determination, with a request for concurrence, was provided to the SHPO and other consulting parties in a letter dated June 29, 2015; responses from SHPO and other consulting parties are pending. Responses received, as well as the Final Programmatic Agreement will be included as part of the Final Feasibility Report/EIS.

Coastal Zone Management Act

In response to the increasing pressure of development on coastal resources, the United States Congress enacted the Coastal Zone Management Act (16 U.S.C 1451-1464; CZMA) in 1972 and the Coastal Zone Act Reauthorization Amendments in 1990. These laws make federal financial assistance available to any coastal state or territory that is willing to develop and implement a comprehensive coastal management program. Hawai`i's CZM program was approved as HRS Chapter 205A in 1977; compliance with the various components of the State's program is further described below.

Clean Air Act

Clean Air Act, as amended, authorizes the EPA to establish NAAQS for major air pollutants. Based on measurements of ambient criteria pollutant data, EPA designates areas of the United States as having air quality equal to or better than NAAQS (attainment) or worse than NAAQS (non-attainment). The general conformity rule requires Federal agencies to ensure that actions they undertake in nonattainment and maintenance areas are consistent with air quality management plans for those areas. Because Hawai'i is, and always has been, in attainment for all pollutants, conformity analysis procedures do not apply to this project.

Air quality in the State of Hawai`i is delegated to the Clean Air Branch of DOH, and is governed at the State level under HRS §342B (Air Pollution Control); compliance with these requirements is further discussed below.

Uniform Relocation Assistance and Real Property Acquisition Policies Act

Federal, state, local government agencies, and others receiving Federal financial assistance for public programs and projects that require the acquisition of real property must comply with the policies and provisions set forth in the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended in 1987 (42 USC 4601 et seq.), and implementing regulation, 49 C.F.R. Part 24. The act provides for relocation advisory services, moving costs reimbursement, replacement housing, and reimbursement for related expenses and rights of appeal.

While some land may need to be acquired to construct certain flood risk management measures, it is not anticipated that the project would require construction of new housing. However, if necessary, property acquisition and relocation services, compensation for living expenses for temporarily relocated residents, and negotiations regarding any compensation for temporary loss of business would be accomplished in accordance with this act.

Executive Orders

Executive Orders that are relevant to the proposed project and have been considered in the feasibility planning process include the following:

- **Executive Order 11514, Protection and Enhancement of Environmental Quality**: The objective of this executive order is to protect and enhance the quality of the Nation's environment to sustain and enrich human life. As summarized in this document, the potential effects of the project were assessed, in consultation with project stakeholders; compliance with all applicable environmental regulations is being obtained.
- **Executive Order 11988, Floodplain Management**: The objective of this executive order is to avoid, to the extent possible, long- and short-term adverse impacts associated with the occupancy and modification of the base floodplain, and avoid direct and indirect support of development in the base floodplain whenever there is a practicable alternative. Compliance with this executive order, based on the procedures outlined in ER 1165-2-26 (*Implementation of Executive Order 11988 on Flood Plain Management*; 30 March 1984), is discussed in Section 8.6 of the Draft Feasibility Report/EIS.
- **Executive Order 11990, Protection of Wetlands**: The objective of this executive order is to minimize the loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. As discussed in Section 5.7 of the Draft Report, some small pockets of wetlands may exist within the limits of the channels, but no adjacent wetland features have been identified. Impacts to aquatic habitat within the stream channels will be mitigated so as to achieve no net loss of habitat function.

- **Executive Order 12898, Environmental Justice**: The objective of this executive order is to make it a high priority to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of programs, policies and activities on minority and low-income populations. As discussed in Section 5.18 of the Draft Feasibility Report/EIS, the project alternatives are not expected to have a disproportionate effect on minority or low-income populations in the project area.
- **Executive Order 13045, Protection of Children From Environmental Health Risks and Safety Risks**: The objective of this executive order is to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children. As discussed in Section 5.18 of the Draft Feasibility Report/EIS, the project is not expected to involve risks that would disproportionately affect children.
- **Executive Order 13112, Invasive Species**: The objective of this executive order is to prevent the introduction of invasive species, provide restoration of native species and habitat conditions in ecosystems that have been invaded, and promote public education and the means to address invasive species. The proposed project would include BMPs intended to address the introduction or spread of invasive species, and would incorporate native species as part of revegetation and mitigation efforts, where practicable.

State Regulations and Policies

Hawaii Environmental Impact Review Law (HRS Chapter 343)

HRS Chapter 343 is designed to "establish a system of environmental review which will ensure that environmental concerns are given appropriate consideration in decision making along with economic and technical considerations." The regulations identify nine specific activities that trigger the need for compliance. The proposed action involves multiple activities that are triggers for compliance with HRS Chapter 343: (1) use of State or County lands or funds, (2) use within any land classified as Conservation District, (3) use within any historic site as designated in the National Register or Hawai`i Register, and (4) use within the Waikiki area. This Draft Feasibility Report/EIS has been prepared in compliance with HRS Chapter 343; DLNR is the proposing agency and the Governor will be the accepting authority. Full compliance will be achieved when the Final EIS is accepted by the Governor.

Hawaii State Environmental Policy (HRS Chapter 344)

The purpose of HRS Chapter 344 is to "establish a State policy which will encourage productive and enjoyable harmony between people and their environment, promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humanity, and enrich the understanding of the ecological systems and natural resources important to the people of Hawai`i." It specifies that the programs, authorities, and resources of the State be used to conserve natural resources and improve the quality of life. Particular aspects of the policy that relate to the project includes a focus on encouraging "productive and enjoyable harmony between people and their environment" and "the health and welfare of humanity." Consistent with the policy and guidelines, the project seeks to balance protection of the environment and quality of life through protection against flood risks.

Coastal Zone Management (HRS Chapter 205A)

In response to the federal CZMA (16 U.S.C. §1451-1456), Hawai`i's CZM program was enacted as HRS Chapter 205A in 1977, and is administered by the State of Hawai`i Department of Business, Economic Development and Tourism (DBEDT) Office of Planning. The CZM area encompasses the entire state, including all marine waters seaward to the extent of the State's police power and management

authority, including the 12-mile U.S. territorial sea and all archipelagic waters. The Hawai`i CZM program integrates decisions made by state and county agencies such as the Land Use Commission, DLNR, DOH, Department of Transportation, and Department of Agriculture to provide greater coordination and compliance with existing laws and rules. Specifically, the program focuses on ten policy objectives:

- Recreational Resources
- Historic Resources
- Scenic and Open Space Resources
- Coastal Ecosystems
- Economic Uses
- Coastal Hazards
- Managing Development
- Public Participation
- Beach Protection
- Marine Resources

Key components of Hawaii's CZM program include (1) regulation of development within the SMA, a designated area extending inland from the shoreline, (2) a Shoreline Setback Area, which serves as a buffer against coastal hazards and erosion, and protects view planes, and (3) a Federal Consistency provision, which requires that federal activities, permits, and financial assistance be consistent with the Hawai`i CZM program. The project would not involve any work within the Shoreline Setback Area or SMA. In compliance with the Federal Consistency provision, the USACE evaluated the proposed project for consistency with the policies of the Hawai`i CZM program. Based on this evaluation, the project was found to be consistent to the maximum extent practicable with the State coastal zone management program; the USACE's Federal Consistency determination was submitted to the Office of Planning for their certification on August 5, 2015 (see Appendix E4). Documentation of concurrence will be included in the Final Report.

Conservation District (HRS Chapter 183C)

The Conservation District was created to protect important natural resources essential to the preservation of the state's fragile natural ecosystems and the sustainability of the State's water supply. Land uses within the Conservation District are under the sole jurisdiction of the State and are governed by HRS Chapter 183C and HAR §13-5. The Conservation District is divided into five subzones: protective, limited, resource, and general, and a "special" subzone to accommodate unique projects (HRS §183C-1).

The DLNR Office of Conservation and Coastal Lands (OCCL) is responsible for regulating land uses within the Conservation District, in accordance with HAR §13-5-22. The project would involve work within the Conservation District at several of the measure locations in the upper portions of the watershed. A Conservation District Use Permit would be obtained from OCCL prior to construction.

Forest Reserve (HRS Chapter 183)

The State's Forest Reserve System was created by the Territorial Government of Hawai'i through Act 44 in 1903. It is managed by the State DLNR Division of Forestry and Wildlife (DOFAW) under HRS Chapter 183, and implementing rules (HAR Section 104). Through these directives, DOFAW focuses on protection, management, restoration, and monitoring of natural resources in the State's Forest Reserves. The proposed project would involve work within the Honolulu Watershed Forest Reserve. Consistent with the requirements of HAR Section 104, it is expected that a Forest Reserve Special Use Permit would be required; this permit would be obtained prior to construction.

State Water Code (HRS Chapter 174C)

HRS Chapter 174C, the State Water Code, was enacted into law by the 1987 Hawai`i State Legislature for the purpose of establishing a comprehensive water resource planning program to protect Hawai`i's water resources. It is intended to obtain maximum beneficial use of the waters of the State, while providing for protection of traditional and customary Hawaiian rights, protection and procreation of fish and wildlife, and other uses in the public interest.

As specified in the implementing rules (HAR Section 169), a Stream Channel Alteration Permit is required for any temporary or permanent activity within the stream bed or banks that may: 1) obstruct, diminish, destroy, modify, or relocate a stream channel; 2) change the direction of the flow of water in a stream channel; or 3) remove any material or structure from a stream channel. Routine streambed and drainageway maintenance activities and the repair of existing facilities are generally exempt from the SCAP requirements. As the project will involve channel alterations for construction of some of the measures, a SCAP will be obtained from CWRM prior to construction.

Conservation of Aquatic Life, Wildlife and Land Plants (HRS Chapter 195D)

HRS §195D, administered by DLNR, prohibits any taking, transport or commerce of aquatic, wildlife, or plant species deemed to be in need of conservation. It adopts the status of all species listed as threatened or endangered under the ESA, and allows further designation of additional species. For actions that may result in take of a State listed species, an incidental take license may be obtained as part of a habitat conservation plan, which includes consultation with the Endangered Species Recovery Committee. As described relative to the ESA, the USACE has determined that the project is not likely to adversely affect threatened or endangered species. The non-Federal sponsor is responsible for confirming compliance with HRS Chapter 195D.

Historic Preservation (HRS Chapter 6E)

HRS Chapter 6E establishes a comprehensive historic preservation program that is intended to preserve, restore and maintain historic and cultural properties. The regulations are implemented by SHPD, and require review of any project that is funded or permitted by the State. This process is the State counterpart to the Section 106 consultation requirement to identify historic properties potentially affected by a proposed project and can be an additional avenue of information gathering for fulfilling the Section 106 consultation mandate.

Specifically, HRS Chapter 6E (§6E-8 and §6E-42) requires that: “Before any agency or officer of the State or its political subdivisions commences any project which may affect historic property, aviation artifact, or a burial site, the agency or officer shall advise the department and allow the department an opportunity for review of the effect of the proposed project on historic properties, aviation artifacts, or burial sites, consistent with Chapter 6E-43, especially those listed on the Hawai`i register of historic places. The proposed project shall not be commenced, or in the event it has already begun, continued, until the department shall have given its written concurrence.” HRS Chapter 6E-43 governs burial sites, and gives authority to the appropriate island burial council relative to treatment of burial sites.

The implementing rules for the historic property review process are contained in HAR Chapter 13-275; these rules apply to “all state or county agencies funding or directly undertaking a project, or having a project undertaken on lands under its ownership or control which may affect historic properties” (§13-275-1b). They address the specific requirements relative to conducting archaeological, ethnographic and/or architectural inventory surveys. Consistent with these requirements, HRS Chapter 343 includes a requirement to consider cultural practices as part of an environmental review of the effects of a proposed action; a cultural impact assessment has been completed in compliance with this requirement (see Appendix F2).

Project information, including archaeological studies and the cultural impact assessment have been provided to SHPD, in conjunction with the NHPA Section 106 process. The non-Federal sponsor is responsible for completing any requirements in compliance with HRS Chapter 6E.

Air Pollution Control (HRS Chapter 342B)

Air quality in the State of Hawai`i is regulated by the Clean Air Branch of DOH, as authorized under HRS §342B (Air Pollution Control). HAR Title 11, Chapter 59 (Ambient Air Quality Standards) establishes State ambient air quality standards, which in some cases are more stringent than the comparable Federal standards or address pollutants that are not covered by the Federal standards established under the Clean Air Act. These standards are monitored and enforced by the Clean Air Branch.

The implementing rules relating to air pollution control are set forth in HAR Section Chapter 60. Under these rules, an Air Pollution Control Permit is required before constructing, reconstructing, modifying, or operating a stationary air pollution source. Certain air pollution sources are exempt from these requirements including vehicles, trucks, cranes, graders, and loaders (HAR §11-60.1-62d). Stationary sources with potential emissions of less than 1.0 ton per year for each air pollutant are also exempt from Air Pollution Control Permit requirements. Because of the type of equipment anticipated for use during construction and operation of the project, and the low levels of emissions anticipated as described in Section 5.13 of the Draft Report, the project is not expected to require an Air Pollution Control Permit from the Clean Air Branch.

Water Pollution (HRS Chapter 342D)

The authority to administer both CWA Section 401 and Section 402 have been delegated to the State of Hawaii. The Department of Health (DOH) implements the State's Water Quality Certification Program and National Pollution Discharge Elimination System (NPDES) program, respectively, under HRS Chapter 342D.

As required by CWA Section 401, the objective of the Water Quality Certification Program is to ensure that any federally permitted activity will not adversely impact the existing uses, designated uses, and applicable water quality criteria of the receiving State waters. These requirements are based on the implementing rules contained in HAR 11-54. A Section 401 water quality certification will be obtained from the DOH prior to construction.[2]

Consistent with the requirements of CWA Section 402, Hawai`i's NPDES program regulates point source pollutant discharges and storm water. The implementing rules of the program are contained in HAR 11-55. Specifically, HAR 11-55-04 states that "before discharging any pollutant, or beginning construction activities that disturb one or more acres of land, or substantially altering the quality of any discharges, or substantially increasing the quantity of any discharges, a person shall submit a complete NDPES permit application…, submit a complete notice of intent…, or for certain storm water discharges, meet all requirements for a conditional "no exposure" exclusion." Issuance of an NPDES permit typically requires development and implementation of a Stormwater Pollution Prevention Plan (SWPPP), which should include measures to avoid or minimize adverse effects of sediment, erosion, and pollutants on surface waters. The specific requirements for the project will be determined in coordination with DOH and the permit will be obtained prior to construction.

[2] Prior to issuance of the Final Feasibility Report/EIS, USACE will seek reasonable assurance from DOH that Water Quality Certification can be obtained for this project.

Noise Pollution (HRS Chapter 342F)

The Noise Control Act of 1972, along with its subsequent amendments (Quiet Communities Act of 1978 [42 U.S.C. Parts 4901-4918]), delegates the authority to regulate environmental noise to each state. For Hawai`i, regulations to prevent, control, and abate noise pollution are set forth in HRS Chapter 342F. The implementing rules, which include statewide noise standards, are provided in HAR §11-46 ("Community Noise Control"); these are administered by HDOH. The stated purpose of the standards is to "provide for the prevention, control, and abatement of noise pollution in the State from the following noise sources: stationary noise sources (such as air-conditioning units, exhaust systems, generators, compressors, and pumps); and equipment related to agricultural, construction, and industrial activities" (HAR §11-46). The noise standards are the maximum permissible sound levels (as measured from the property line) and vary according to land use district. It is anticipated that noise levels during construction could exceed the maximum permissible sound levels; pursuant to HAR §11-46-7, a permit would be obtained from HDOH, as needed.

Appendix E2
Draft Mitigation and Monitoring Plan

Draft

Mitigation, Monitoring and Adaptive Management Plan

Ala Wai Canal Project; Oahu, Hawaii

U.S. Army Corps of Engineers, Honolulu District

August 2015

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1.0 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR) and as authorized under Section 209 of the Flood Control Act of 1962, the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii[1] (hereafter referred to as "the project"). The purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding within the Ala Wai Watershed.

The Ala Wai Watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (mi^2) (12,064 acres) and extends from the ridge of the Ko`olau Mountains to the nearshore waters of Mamala Bay. It includes Maikiki, Manoa, and Palolo Streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki district.

The project is currently a feasibility study, considering a variety of non-structural and structural flood risk management measures. Plan formulation and evaluation resulted in tentative selection of an alternative plan for implementation (referred to as the tentatively selected plan). A detailed discussion of the plan formulation process and the components of the tentatively selected plan are provided in the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as "Feasibility Report/EIS."

As detailed in the Implementation Guidance for Section 2036(a) of the Water Resources Development Act (WRDA) of 2007– Mitigation for Fish and Wildlife and Wetland Losses, it is the policy of the USACE Civil Works program to demonstrate that damages to all significant ecological resources have been avoided and minimized to the extent practicable, and that any remaining unavoidable damages have been compensated to the extent possible. The mitigation planning process should seek to compensate for non-negligible impacts to the extent incrementally justified and ensure that the recommended project will not have more than negligible adverse impacts on ecological resources. Engineering Regulation (ER) 1105-2-100 ("Planning Guidance Notebook") requires the use of a habitat-based methodology, supplemented with other appropriate information to describe and evaluate the impacts of the alternatives plans, and to identify the mitigation need of the with-project condition as measured against the future without-project condition. Once a mitigation need has been identified, mitigation objectives must be developed to address the identified losses. Mitigation objectives are used to guide formulation of appropriate mitigation management features and to establish benchmarks for evaluating the performance of the mitigation plans.

The regulations require assessment of environmental impacts and associated mitigation actions in a manner that addresses changes in ecological resource quality. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and/or quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Mitigation actions also need to go through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Preparation of a mitigation plan is required, and should present the objectives, plan design, determination of success criteria and monitoring needs, all of which should be developed in coordination with Federal and State resource agencies to the extent practicable. The mitigation plan should include the following:

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[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the Congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

(1) a description of the physical action to be undertaken to achieve the mitigation objectives within the watershed in which such losses occur;

(2) the type, amount, and characteristics of the habitat being restored;

(3) ecological success criteria for mitigation based on replacement of lost functions and values of the habitat, including hydrologic and vegetative characteristics;

(4) a plan for monitoring to determine the success of the mitigation, including the cost and duration of any monitoring and the entities responsible for any monitoring;

(5) a contingency plan (i.e. adaptive management) for taking corrective actions in cases where monitoring demonstrates that mitigation measures are not achieving ecological success; and

(6) should land acquisition be proposed as part of the mitigation plan, a description of the lands or interests in lands to be acquired for mitigation and the basis for a determination that such lands are available for acquisition.

This mitigation and monitoring plan has been developed in compliance with these requirements. It includes a discussion of the quantification of habitat impacts, identification of mitigation objectives and proposed mitigation actions, and development of the proposed monitoring and adaptive management approach.

2.0 Assessment of Impacts to Aquatic Habitat

As described above, USACE regulations require the use of a habitat-based methodology to describe and evaluate the impacts of alternative plans, as well as to identify the need for mitigation to offset unavoidable ecological impacts of the with-project conditions as measured against the future without-project condition. As the outputs of ecosystem restoration are not readily convertible to actual monetary units (as is required for traditional benefit-cost analyses), ecosystem outputs must be clearly identified and quantified in appropriate units, preferably ones that measure change in ecosystem value and productivity. Measurable changes in ecosystem values are typically described in terms of suitability indices or habitat units, with an ecosystem output model used to quantify the changes over a 50-year period of analysis. Following is a description of the ecosystem output model selected for use on the project, and a summary of the modeling results for the existing (without-project) condition and with implementation of the tentatively selected plan.

2.1 Description of Ecosystem Model

Analogous with Habitat Evaluation Procedure (HEP) method and Habitat Suitability Index models developed by natural resource biologists elsewhere, the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) is a habitat-based model that was developed as a tool to support management of Hawaii's streams and associated habitat for freshwater flora and fauna. Specifically, the model is intended to provide managers with the ability to quantify changes in habitat for native Hawaiian stream animals in response to actions such as channel alterations, flow modifications, land use change and watershed development, or construction of in-channel structures. It captures the major aspects of native stream animal ecology, the typical geomorphology of Hawaiian streams, and common modifications to the environment.

The HSHEP model is an outgrowth of a history of collaboration among biologists at the State of Hawaii Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. The collaborative effort focused on understanding the different aspects of the ecology and management of amphidromous stream animals, which have a life history involving downstream and upstream migration (Fitzsimons and Nishimoto, 2007). In recent years, efforts have focused on combining the information gained from the wide range of studies into an integrated model

of Hawaiian streams that include the life history characteristics of amphidromous animals, island hydrology and geomorphology, and critical management issues.

The HSHEP model follows the overall Habitat Evaluation Procedure (HEP) model concepts developed by the U.S. Fish and Wildlife Service (USFWS) to evaluate the quantity and quality of habitat available for a species of concern (USFWS, 1980a,b; USFWS, 1981). In general, a Habitat Evaluation Procedure (HEP) model uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. This process may be used to assess changes associated with different management scenarios for a specific area, or to allow comparison across multiple sites. The HSHEP merges this traditional HEP approach with multi-spatial modeling capabilities for Hawaiian streams (Parham, 2002; Kuamo'o et al., 2006; Parham, 2008). The multi-spatial component addresses issues of scale in understanding differences in habitat availability and species distribution.

A detailed description of the HSHEP model development and design is provided in Attachment 1. The USACE Ecosystem Center of Expertise (ECO-PCX) reviewed this information, and granted approval for its use on the Ala Wai Canal Project on May 19, 2015 (Attachment 2).

2.2 Methodology

Detailed stream and fish surveys to support the HSHEP modeling effort were conducted by aquatic biologists, Dr. James Parham (Bishop Museum) and Glenn Higashi (DAR). As part of this effort, the streams in the Ala Wai Watershed were surveyed, including approximately 8.7 kilometers of Manoa Stream, 1.6 kilometers of Makiki Stream, and 3.7 kilometers of Palolo Stream. The stream surveys were recorded using high-definition video, and the survey data were subsequently processed according to the variables in the HSHEP model. Using the HSHEP model, the habitat suitability was then determined for each of the native aquatic species along approximately each meter of stream; the average suitability was then calculated for defined stream segments. A combination of the habitat suitability and the area of each segment were then used to calculate HUs for each individual species, as well as for the combination of all native species within each segment.

Despite the robust dataset available for native species in Hawaii's streams, there is still some degree of inherent uncertainty in the underlying assumptions used to model habitat quality. In particular, the extent to which in-stream structures restrict upstream migration (e.g., in response to varying flow regimes over time) has not previously been quantified, but has an important bearing on the modeling of upstream habitat quality. As such, the resource agencies requested consideration of different assumptions of species passage, in order to better understand the possible range of resulting habitat quality values. In response to this request, both the "expected scenario" and a "worst-case scenario" were modeled, as described below.

- The "expected scenario" reflects the project team's best professional judgement; it assumes that existing in-stream structures with an overhanging lip create a passage barrier for native species 50% of the time, and channelized reaches reduce passage by 10% for every 100 meters. These assumptions were used as the basis for calculation of the baseline impact and evaluation of mitigation requirements.
- The "worst-case scenario" reflects a more conservative set of assumptions that overhanging structures only allow for passage of native species approximately 35% of the time, and channelized reaches reduce passage by 15% for every 100 meters. This scenario is intended to bound the range of possible conditions, thus providing a basic sensitivity analysis of the model

results. It was used as a means to validate the outcomes of the mitigation development process (that is, to confirm that the mitigation would still adequately compensate for the habitat impacts even with a more conservative set of assumptions).

The model results for the existing and future-without project condition, as well as the conditions based on implementation of the tentatively selected plan are presented below. Application of the model for the mitigation measures is discussed in Section 3.3. Additional detail regarding model application is provided in Attachment 3.

2.3 Model Results

2.3.1 Existing and Future Without-Project Condition

Based on the methodology described above, the HSHEP model was used to determine existing quality of the streams and associated aquatic habitat within the Ala Wai Watershed. The analysis also considered the future without-project condition (i.e., the most likely condition expected to exist in the future in the absence of the proposed project), as this defines the benchmark against which alternative plans are evaluated.

Future changes in watershed and stream conditions have the potential to influence the amount and/or quality of freshwater stream habitat. For example, future watershed improvements could positively influence stream health, thus increasing habitat quality over time. Conversely, continued degradation could reduce the amount and/or quality of stream habitat. Based on the extent of existing urbanization and development within the Ala Wai Watershed, and more specifically along the streams, it is expected that further development will be minimal. Some degree of redevelopment may occur in the neighborhoods throughout the watershed, however this is not expected to substantially affect the physical or biological characteristics of the streams. While there may be some slight changes in localized conditions, the overall species composition and habitat structure is not expected to change dramatically over the period of analysis. Therefore, for the purposes of this analysis, it is assumed that habitat conditions will remain relatively constant over time, such that the HUs associated with the existing and future without-project conditions will be commensurate.

The HUs associated with the existing and future without-project conditions are summarized in Table 1; a detailed discussion of the results is provided in Attachment 3.

TABLE 1
Habitat Units Associated with the Existing and Future Without-Project Condition

Location	Habitat Units (HUs)	
	Expected Scenario	**Worst-Case Scenario**
Manoa Stream	36,713	35,391
Palolo Stream	1,377	834
Makiki Stream	7,800	7,495
Hausten Ditch	8,681	8,681
Total	**54,572**	**52,401**

2.3.2 Tentatively Selected Plan

The tentatively selected plan for the Ala Wai Canal Project is comprised of a series of flood risk management measures, including debris and detention basins, debris catchment structures, flood walls, and improvements to the flood warning system. A description of each measure and the estimated area

of impact is provided in Table 2. A detailed discussion of the tentatively selected plan (and the plan formulation process) is provided in the Draft Feasibility Report/EIS.

The characteristics of the proposed measures were used to define changes in habitat quality using the HSHEP model, as needed to calculate HUs based on implementation of the tentatively selected plan. Changes in habitat quality associated with implementation of the tentatively selected plan include potential loss of aquatic habitat (e.g., due to placement of structures within the stream) and decreased passage for native aquatic species. As described in Section 3.6 of the Draft Feasibility Report/EIS, design features have been incorporated to avoid and minimize these impacts to the extent practicable (e.g., use of natural bottom arch culverts to maintain species passage); however, some degree of impact is unavoidable. The anticipated changes in habitat conditions were based on professional judgment of the project team, including input from the resource agencies.

Key assumptions that were made as part of the HSHEP modeling of the with-project condition are listed below. The assumptions were discussed and agreed upon with the resource agencies (as part of a meeting with USFWS and DAR on January 23, 2015), and were subsequently refined as part of the model application process.

- The area to be impacted by each measure was defined as the length of stream within the permanent structure footprint plus the area needed for O&M (generally the entire length of stream within the construction limits).
    - The aquatic habitat to be impacted by the Kanewai Detention Basin and the Ala Wai Golf Course Detention Basin is limited to the streambank within the notched spillway footprint.
    - The Ala Wai Canal floodwalls will not result in any impacts to the aquatic environment.
    - Improvements to the flood warning system will involve negligible work in the streams; as such, it is assumed there would be no impact to the aquatic environment.
- To be conservative, it has been assumed that habitat for aquatic species would be entirely eliminated within the permanent footprint of the debris catchment and detention structures (and stand-alone debris catchment structures), but that species passage would be maintained via a natural bottom arch culvert.
    - Within the area to be excavated behind the Waiomao Debris and Detention Basin, a low-flow channel will be reformed and the existing substrate will be replaced following construction. Recognizing that there could be some degree of long-term habitat degradation associated with the excavation (and ongoing vegetation management), it is assumed that there would be an approximately 50% decrease in habitat quality within this area. The “worst-case scenario” assumes 100% loss of habitat within the area to be excavated.
    - An in-stream structure associated with an abandoned USGS gaging station is located within the area to be excavated for the Waiomao Debris and Detention Basin, and will be removed as part of project construction. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat (thereby offsetting some of the habitat losses). This benefit is reflected in the with-project condition.
    - It is assumed that there would be an approximately 20% loss of habitat quality within the reach directly affected by the notched spillways for the Kanewai and Ala Wai Golf Course detention basins. The “worst-case scenario” assumes 100% loss of habitat within these reaches.

TABLE 2
Flood Risk Management Measures Included in the Tentatively Selected Plan

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements	Length of Stream Within Construction Limits (linear feet)	Length of Stream Within Permanent Structure Footprint (linear feet)	Length of Stream Within O&M Area (linear feet)
Waihi Debris and Detention Basin	Earthen dam, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	160	130	40
Waiakeakua Debris and Detention Basin	Earthen dam, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	190	110	40
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area.	120	60	40
Manoa In-Stream Debris Catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	48	8	40
Kanewai Field Multi-purpose Detention Basin	Earthen berm, approximately 7' high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Manoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.	70	70	0
Waiomao Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip rap on upstream and downstream side debris catchment feature located on upstream end of culvert. Excavation of approx. 2,015 cubic yards to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam and excavation area) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	455	130	40
Pukele Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	170	130	40
Makiki Debris and Detention Basin	Earthen dam, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	175	130	40
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 5 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area. Periodically inspect drainage pipes and gates, and remove any impediments to movement. Paint and/or grease metal parts, as needed.	0	0	0
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (4.3' high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm and floodwalls) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for recreational use during non-flood conditions. Periodically inspect slide gates and actuators and remove any impediments to movement. Paint and/or grease metal parts, as needed.	70	35	35
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, up to approximately 7' high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Manoa Palolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of levee) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a golf course (with no woody vegetation in sediment basin) for recreational use during non-flood conditions. Periodically inspect floodgate and remove any impediments to movement. Paint and/or grease metal parts, as needed. Inspect, test, and maintain pump system annually. Paint and/or grease metal parts, as needed.	70	70	0
Floodwarning system	Improvements to existing flood warning system in Ala Wai Watershed, including installation of 3 real-time rain gages (Manoa, Makiki and Palolo Streams) and 1 real-time streamflow or stage gage (Ala Wai Canal); exact locations to be determined	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection.	0	0	0

- The debris and detention structures are not designed to trap sediment (except for the sediment basin at the Ala Wai golf course). Therefore, it has been assumed that there would be no substantial changes in substrate/embeddedness in downstream habitat.
- The inundation area behind each detention structures is not included as part of the impact area. Inundation of these areas would be infrequent and short in duration; for example, inundation resulting from the 1% annual chance exceedance (ACE) flood would last less than 12 hours. As such, there are expected to be little to no potential effects to stream habitat and aquatic species.

The results of the HSHEP modeling for the with-project condition are summarized in Table 3; a detailed discussion of the results is provided in Attachment 3. Based on a comparison of these results to those for the future without-project condition, implementation of the project is expected to result in a loss of 192 HUs as shown in Table 3.

As it is expected that the impacts would be immediately realized following construction of the project features (i.e., there would not be a delay or "compounding" effect on habitat quality over time), it is therefore assumed that habitat conditions would remain constant over the life of the project.

TABLE 3
Loss of Habitat Units Associated with Implementation of the Tentatively Selected Plan (As Compared to the Future Without-Project Condition)

Location	Habitat Units (HUs)				
	Existing Conditions	With-Project Conditions			Net Loss
		Lost	Gained[a]	Total	
EXPECTED SCENARIO					
Manoa Stream	36,713	191	0	36,522	**191**
Palolo Stream	1,377	11	118	1,484	**-107**
Makiki Stream	7,800	24	0	7,777	**24**
Hausten Ditch	8,681	84	0	8,597	**84**
Total	**54,572**	**310**	**118**	**54,380**	**192**
WORST-CASE SCENARIO					
Manoa Stream	35,391	808	0	34,584	**808**
Palolo Stream	834	3	32	863	**-29**
Makiki Stream	7,495	11	0	7,484	**11**
Hausten Ditch	8,681	420	0	8,261	**420**
Total	**52,401**	**1,242**	**32**	**51,192**	**1,210**

Note:
[a] The "expected scenario" reflects the project team's best professional judgement, and serves as the basis for calculation of the baseline impact and evaluation of mitigation requirements. The "worst-case scenario" reflects a more conservative set of assumptions and is intended to provide a basic sensitivity analysis of the model results (to help validate the outcomes of the mitigation development process).
[b] The anticipated gain of HUs for the with-project condition is associated with removal of an abandoned USGS gaging station within the area to be excavated for the Waiomao Debris and Detention Basin. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat.

3.0 Description of Proposed Mitigation

3.1 Mitigation Objectives

Based on the type of habitat to be impacted, and within the context of the habitat requirements for native Hawaiian aquatic species (as defined in the HSHEP model), the following objectives were developed to guide the mitigation development effort:

- Restore and/or enhance physical conditions to improve in-stream habitat for native Hawaiian aquatic species
- Improve passage for native Hawaiian aquatic species to increase access to upstream areas of high-quality habitat

In consultation with the resource agencies, it was determined that application of these mitigation objectives should not be limited to the specific habitat parameters or areas impacted by the project, but rather should be considered within the context of the overall watershed. In other words, the mitigation development process should entail a watershed approach, wherein the conditions throughout the watershed are assessed to identify those habitat parameters and locations where mitigation might provide the greatest benefit for native aquatic species as a whole.

3.2 Mitigation Development Approach

To support the mitigation development effort, a framework was developed based on a series of iterative tasks informed by the stream surveys and HSHEP modeling results. Each task was conducted within the context of the SMART planning approach employed for the overall flood risk management project, as described in the Draft Feasibility Report/EIS. First, as shown in Figure 1, the key stressors and primary factors limiting habitat quality for native aquatic species in the Ala Wai Watershed were broadly defined based on best professional judgment and the results of the stream surveys. This information was used as the basis for identifying potential mitigation concepts, or actions that could be implemented to address the various stressors. Using the HSHEP model results for the existing conditions, these concepts were further refined and applied to site-specific locations. A site visit was conducted for each of the potential mitigation locations to validate and refine the mitigation concept. In addition, other relevant information was gathered, including land ownership and existing channel maintenance activities. This information was then considered as part of a detailed screening process, which involved a comprehensive set of criteria (based on those used for the overall flood risk management project, and tailored to the mitigation effort). Those measures carried forward from the screening process were then combined into various mitigation alternatives that could be implemented to compensate for the habitat impacts associated with the overall flood risk management project. Conceptual design drawings were prepared for the range of mitigation measures/alternatives (to an approximately 10 percent level of design), based upon which cost estimates were developed. In addition, the habitat benefits associated with each alternative were quantified using the HSHEP model. The costs and benefits were then used as inputs to a CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The resource agencies were consulted throughout this process, and their input was incorporated as appropriate. The results of this process are described in the subsequent sections.

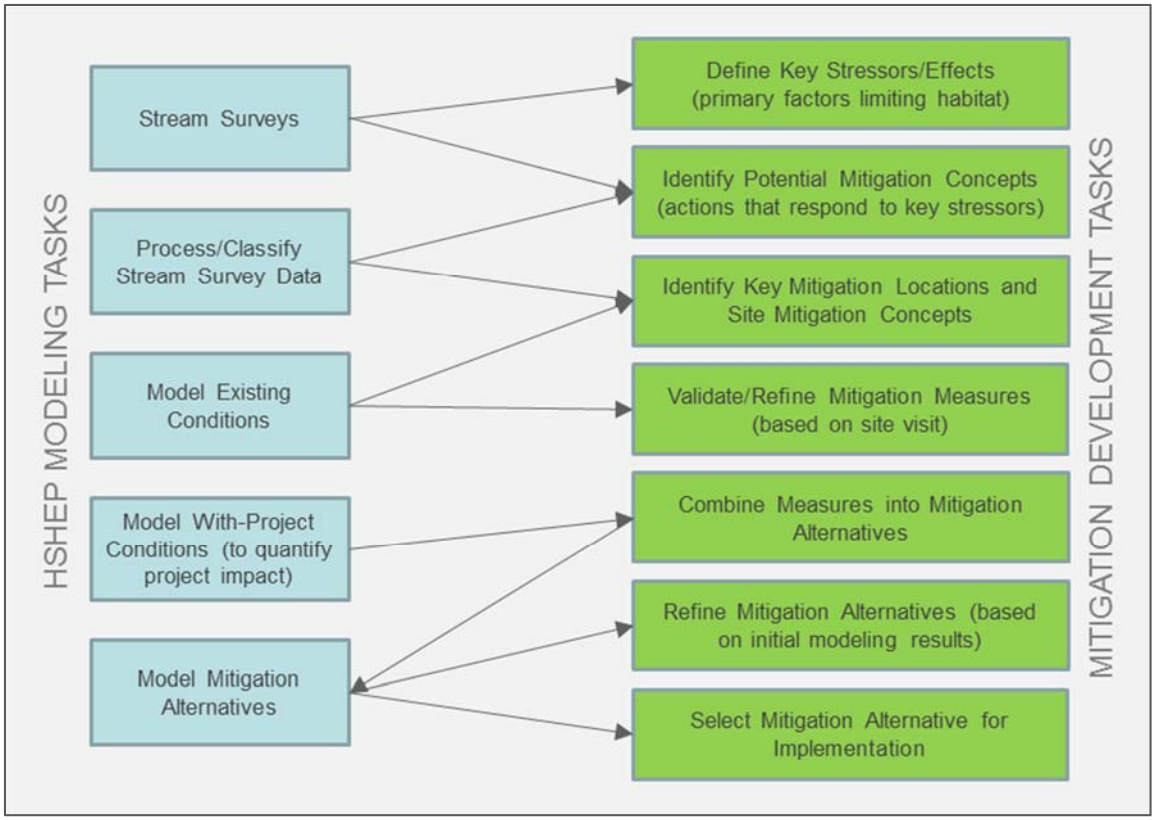


FIGURE 1
Overview of the HSHEP Modeling and Mitigation Development Process

3.3 Development of Mitigation Measures/Alternatives

3.3.1 Mitigation Concepts

As described above, the initial list of mitigation concepts was developed in response to the primary factors believed to be limiting habitat quality for native aquatic species in the Ala Wai Watershed; this effort was primarily based on best professional judgment and the results of the stream surveys. The list of initial mitigation concepts is provided in Table 4.

It is important to note that there are some stressors that are generally understood to be contributing to degradation of Hawaii's stream habitat and faunal assemblage, but were determined to either be outside the scope of mitigation efforts for this project or are not considered key limiting factors in the Ala Wai Watershed (given other overriding conditions). These include prevalence of invasive aquatic species and inputs of stormwater runoff. Although both of these stressors are common throughout the Ala Wai Watershed, it was determined that the project could result in a limited response to these conditions, and as such, mitigation efforts should focus on key strssors related to physical habitat conditions.

TABLE 4
Initial Mitigation Concepts

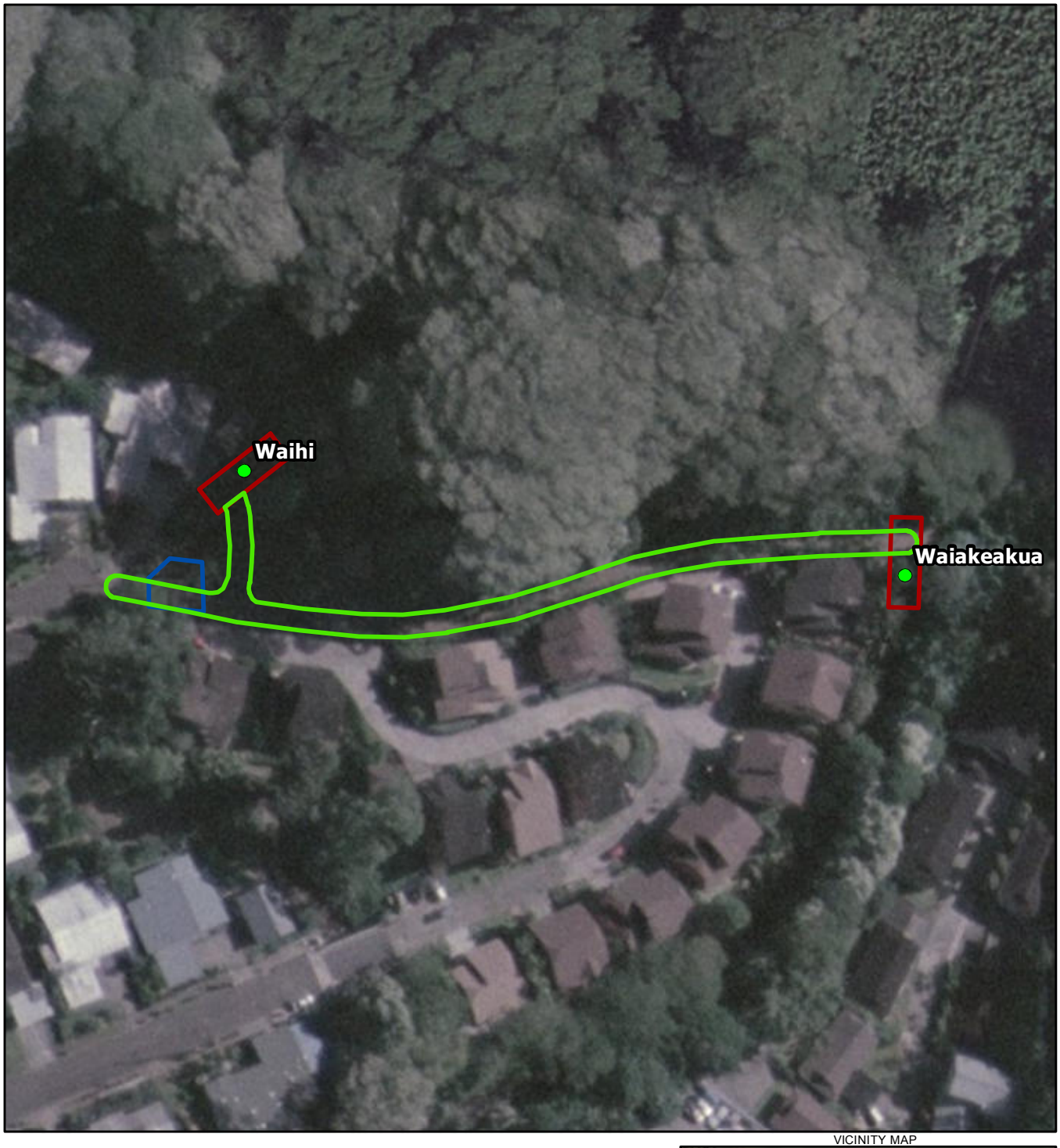
Response to Key Stressors	Mitigation Concept
Improve migratory pathway	Remove passage barrier (e.g., overhung structures)
	Install low-flow channel along channelized reach
	Install resting riffles along channelized reach
Improve in-stream habitat	Add new habitat pools in channelized reach
	Enhance existing in-stream habitat in unchannelized reach
Provide bank stabilization	Stabilize exposed/eroding banks
	Stabilize failing walls
Improve riparian habitat	Restore/enhance riparian habitat

The initial concepts were further reviewed and validated within the context of the HSHEP model source data and preliminary results for the existing habitat conditions. Through this effort, several of the concepts were eliminated from further consideration, as follows:

- **Enhance existing in-stream habitat in unchannelized reach:** Although there are reaches of unchannelized habitat with less than ideal conditions (e.g., degraded channel form, presence of trash, etc.), the results of the stream surveys indicate that these reaches still provide adequate habitat for native aquatic species, especially when compared to channelized reaches. As such, it was determined that enhancement of habitat in unchannelized reaches would not address a key stressor for native aquatic species in the Ala Wai Watershed.
- **Stabilize failing walls:** Although a wall failure could certainly affect in-stream habitat, should one occur, it was determined that stabilization of existing channel infrastructure is more of a channel maintenance issue than a habitat management issue. Therefore, this measure was eliminated from further consideration.
- **Restore/enhance riparian habitat:** Given the heavy urbanization and encroachment of development in the areas directly adjacent to the streams, there is very little opportunity for restoration of the riparian corridor in the Ala Wai Watershed without extensive land acquisition (which is beyond the scope of mitigation for this project). Although dominated by non-native species, the extant riparian habitat is not believed to be key limiting factor relative to in-stream habitat quality for native aquatic species (especially when considered in context with other factors, such as channelization). As such, this measure was also eliminated from further consideration.

3.3.2 Preliminary Mitigation Measures

The remaining mitigation concepts were carried forward for further consideration, and based on the review of the HSHEP model source data and preliminary results, key areas for habitat improvement were identified based on those concepts. This information was used as the basis for siting each of the mitigation concepts in locations where habitat benefits could be maximized. A site visit was conducted for each of the potential mitigation locations to validate and refine the various mitigation concepts. The resulting measures are summarized in Table 5, and the locations are shown in Figure 2.



LEGEND

Impact Area Description

- **Construction Limits**
- **Access**
- **Staging**

Notes:

1. Area of interest subject to change.

N

0 50 100

Feet

VICINITY MAP

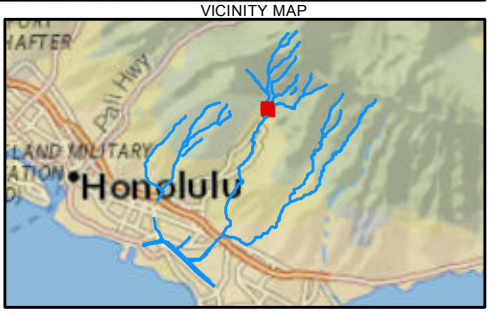
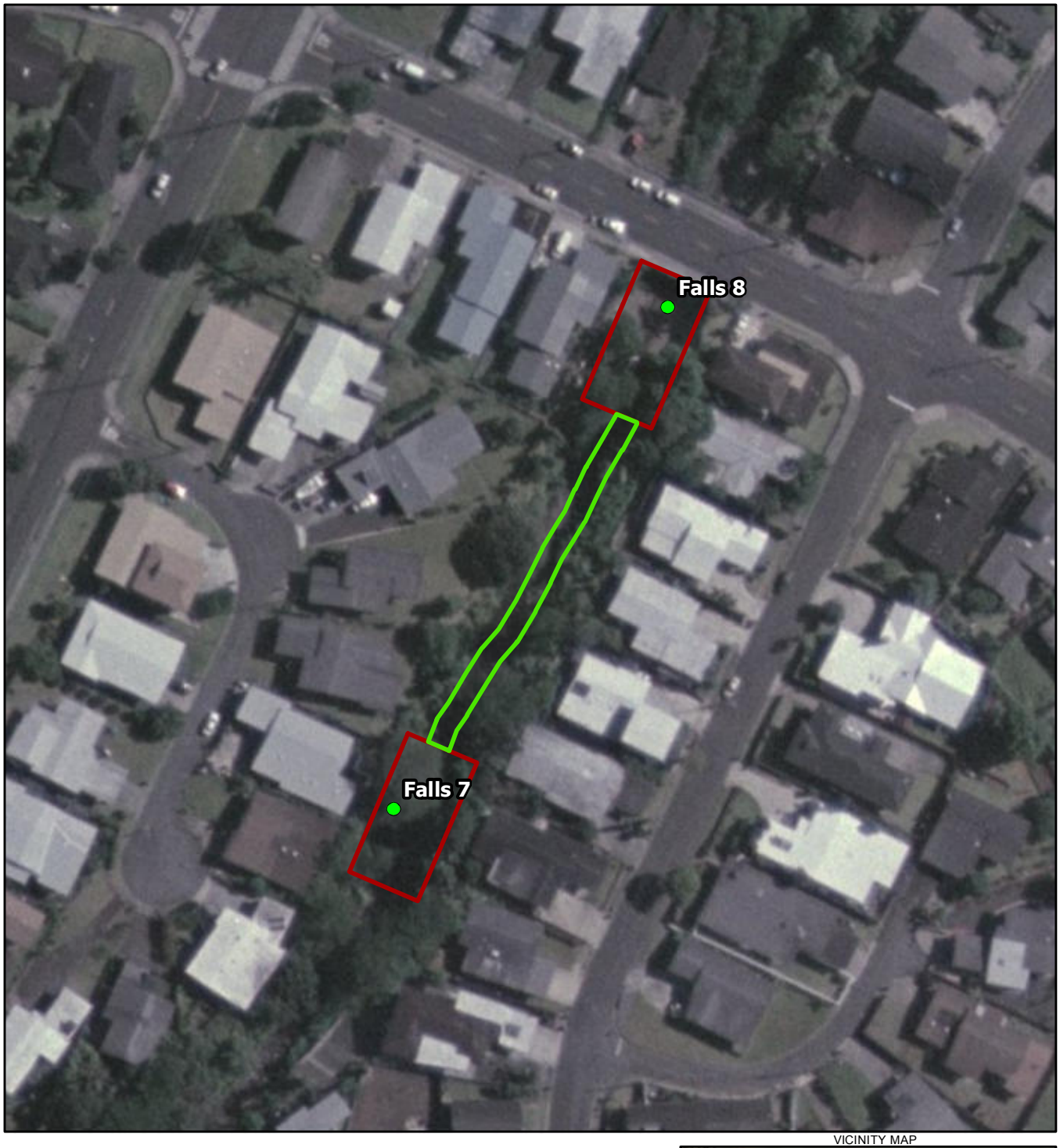


FIGURE 2a
Falls 11 and 12
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL.



LEGEND

Impact Area Description

- **Construction Limits**
- **Access**
- **Staging**

Notes:

1. Area of interest subject to change.

N

0 50 100

Feet

VICINITY MAP

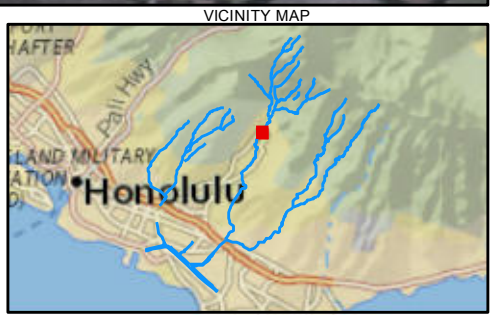


FIGURE 2b
Falls 7 and 8
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL®

LEGEND

Impact Area Description

- **Construction Limits**
- **Access**
- **Staging**

Notes:

1. Area of interest subject to change.

N

0 100 200

Feet

VICINITY MAP

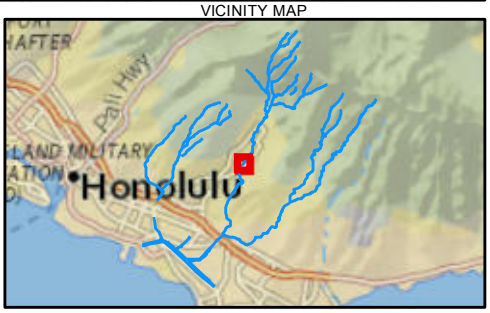


FIGURE 2c
Manoa Concrete Channel
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL®

TABLE 5
Preliminary Mitigation Measures

Mitigation Measure	Location	Description
Remove Passage Barrier		
Falls 6	Manoa Stream, approximately 0.3 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing utility line crossing
Falls 7	Manoa Stream, approximately 0.6 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing in–stream structure
Falls 8	Manoa Stream, approximately 0.7 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing in–stream structure
Falls 11	Waihi Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls 12	Waiakeakua Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls P5	Waiomao Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Install Low-flow Channel and/or Habitat Pools Along Channelized Reach[a]		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Palolo Stream	Approx. 1.5 miles of concrete channel through Palolo Valley	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Install Resting Riffles Along Channelized Reach[a]		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Palolo Stream	Approx. 1.5 miles of concrete channel through Palolo Valley	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Bank Stabillization		
Manoa Stream	Above Kahaloa Bridge near Manoa District Park	Reduce slope and install geotextile fabric and vegetation to stabilize ~300 feet of eroding bank

NOTE:
[a] Installation of a low-flow channel, habitat pools and/or resting riffles was initially considered for the channelized reach of Makiki Stream. However, it was determined that the extensive section of underground channel that is upstream of the channelized reach would severely limit the benefits gained by these measures. As such, these measures were eliminated from further consideration.

3.3.3 Screening and Refinement of Mitigation Measures

In order to ensure that the mitigation measures carried forward for further consideration meet a set of minimum standards, a detailed screening process was conducted. This process utilized a comprehensive set of criteria based on those used for the overall flood risk management project (which were defined within the context of the federal criteria specified in the Engineer Regulation [ER] 1105-2-100; “USACE Planning Guidance Notebook”) and tailored to the mitigation effort. The screening criteria that were applied to the mitigation measures are summarized in Table 6.

TABLE 6
Criteria Used to Screen Mitigation Measures

Criteria	Description
Technical feasibility	Is it feasible/viable to construct measure?
Application in Hawaii	Has the measure been successfully applied in Hawaii?
Compatibility/Dependency	Is the measure dependent on another action to be functional?
Flood reduction	Does measure substantially increase potential for flooding?
Implementation cost[a]	What is the ROM cost to construct the measure?
Cost effectiveness[a]	Is the habitat gain worth the cost?
Land availability and ownership	Is there enough space to implement measure (including staging/access?)
	Is the land owned by State/C&C or a few private landowner?
	Can real estate rights be reasonably obtained?
O&M requirements	What is the estimated level of effort (need for new practice/equipment)?
	Would the measure conflict with existing O&M practices?
Acceptability	Will the measure displace people/activities? It is legally acceptable?
Biological resources	Would the measure adversely affect any known sensitive biological resources?
	Would the measure increase the potential for passage of non-native (invasive) species?
Historic/archaeological resources	Would the measure adversely affect any known historic/archaeological resources?
Sediment contamination	Would the measure be located in an area with known (or high potential for) sediment contamination?

NOTE:
[a] Recognizing that the purpose of the CE/ICA is to provide a quantifiable basis for evaluation of cost-effectiveness, the criteria related to implementation cost and cost-effectiveness were used to screen out measures that were considered to be excessively expensive or ineffective, so as to focus the mitigation development effort on reasonable and practicable mitigation solutions, consistent with the SMART planning approach.

The information required to complete the screening process was subsequently compiled, including consultation and coordination with State and County agencies, and other entities as needed. This effort resulted in the elimination of the measures listed below; the detailed screening results are contained in Attachment 4. In addition, based on additional information obtained through consultation, it was determined that two of the measures were no longer warranted, such that they were also eliminated from further consideration, as listed below.

- **Remove Passage Barrier at Falls 6:** Based on coordination with the City & County of Honolulu, it was determined that the Department of Facilities Maintenance (DFM) is in the process of resolving the erosion and undercutting associated with this structure. The design effort has been completed and the proposed design is expected to adequately address fish passage requirements; therefore, this measure was eliminated from further consideration (and instead is reflected in the future without-project conditions).
- **Remove Passage Barrier at Falls P5:** The specific location of this structure was verified based on the stream survey data, and was determined to be within the footprint of the excavation area for the Waiomao Debris and Detention Basin. It was confirmed that the

structure would be removed as part of construction of the debris and detention basin, such that the mitigation measure was eliminated from further consideration (and instead is reflected in the with-project condition).

- **Install Low-Flow Channel, Habitat Pools and/or Resting Riffles Along Channelized Portion of Palolo Stream:** Based on initial review of the real estate requirements, it was determined that this measure involved a multitude of property owners, and obtaining the real estate rights would require extensive coordination and would be cost-prohibitive. Therefore, these measures were eliminated from further consideration.

The remaining measures were carried forward for further consideration as part of the identification of mitigation alternatives.

3.3.4 Conceptual Design of Mitigation Measures

For the measures carried forward from the screening process, conceptual design drawings were developed to a 10-percent level of design. This effort incorporated the best available information and collective knowledge of the habitat requirements for native aquatic species; it also considered lessons learned from other past projects and input from the resource agencies. Key design considerations are discussed below.

The passage barrier removal design was based on previous passage barrier removal efforts completed by DAR (and others) on Waihe'e Stream (see Figure 3). Based on information gained from this successful effort, the measure would restore a near vertical surface to the face of the existing in-stream structure, which is expected to allow for native aquatic species passage, while deterring upstream passage of non-native species. It would be comprised of non-systematic placement of grouted stones that would mimic natural stream features and allow multiple pathways for water flow.

FIGURE 3
Previous Passage Barrier Removal Efforts on Waihe'e Stream (photos provided by Glenn Higashi [DAR])

The design for installation of in-stream habitat and passage within the channelized reach of Manoa Stream incorporates design features and dimensions based on best professional judgment regarding native species habitat requirements. Specifically, the conceptual designs assume that up to 6 inches of water is required to maintain passage (e.g., for the resting riffles), and at least 18 inches of water is needed to provide in-stream habitat (e.g., for the habitat pools and low-flow channel); the dimensions and spacing of these features reflects characteristics of natural stream habitat. Passage and/or habitat would be installed over the full 1,100 feet of the channelized reach in Manoa Stream; given the mitigation objectives, shorter increments were not considered.

The 10-percent design drawings for each of the mitigation measures carried forward from the screening process are contained in Attachment 5.

3.3.5 Identification of Mitigation Alternatives

Based upon the 10-percent design concepts, the mitigation measures were then combined into alternatives that could be implemented to adequately compensate for the habitat impacts associated with the overall flood risk management project. Specifically, this effort sought to identify alternatives comprised of measures that either alone or in combination would provide a gain of HUs equal to or greater than the loss of HUs anticipated from implementation of the tentatively selected plan, thus compensating for the loss of habitat quality associated with project implementation. Recognizing that there are many possible measure combinations, consistent with SMART planning principles, a focused number of alternatives were defined based on estimated habitat benefits and functionality, as discussed below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. As preliminary analyses indicated that the concrete channel improvements were not cost effective, they were not considered in combination with any other measures. Based on these concepts, the following alternatives were identified:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

Cost estimates were prepared for each alternative based on the conceptual design drawings. In addition, the habitat benefits were determined for each alternative, based on the HSHEP model outputs. The results of these efforts were then used to support the CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The results of this process are described in the subsequent sections.

3.4 Evaluation of Mitigation Alternatives

3.4.1 Habitat Benefits

Using the same methodology as described in Section 2, the HSHEP model was used to quantify the HUs associated with the various mitigation alternatives; the results are summarized in Table 7. As shown in Table 7, the mitigation alternatives involving removal of passage barriers provide a

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

significant increase in HUs relative to the concrete channel improvements. Despite the relatively small footprint of the barrier removal measures, the large gain of HUs reflects the overall extent of upstream habitat that would be made available to migrating native species. In contrast, the improvements along the channelized reach of Manoa Stream would only affect a relatively small, localized area.

However, in all cases, the mitigation alternatives would provide substantially more HUs than needed to offset the impacts of the flood risk management project. Because the flood risk management measures would only affect in-stream habitat within the footprint of the proposed flood risk management structures (with no anticipated impacts to species passage), a relatively small number of HUs are expected to be lost. Although the mitigation benefit would far exceed the impact of the proposed project, the mitigation alternatives reflect a reasonable range of options to improve instream habitat for native species, based on the best professional judgment of the project team. Despite the large number of HUs provided relative to the anticipated project impact, the estimated costs and level of effort of the mitigation alternatives is within the range that is appropriate for the scale and level of detail available for the proposed flood risk management project. Although different mitigation options or smaller-scale efforts that would result in fewer HUs (i.e. an increase in HUs more commensurate with the number of HUs lost) could certainly be identified, these would not address the key habitat needs identified for native aquatic species in the Ala Wai Watershed.

TABLE 7
Gain of Habitat Units Associated with Implementation of Mitigation Alternatives (As Compared to the With-Project Condition)

Location	With-Project (HUs Lost)	Mitigation Alternatives (HUs Gained)							
		Falls 7	Falls 7, 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11 and 12	Low-Flow Channel	Habitat Pools	Resting Riffles
EXPECTED SCENARIO									
Manoa Stream	191	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Palolo Stream	-107	0	0	0	0	0	0	0	0
Makiki Stream	24	0	0	0	0	0	0	0	0
Hausten Ditch	84	0	0	0	0	0	0	0	0
Total	**192**	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
WORST-CASE SCENARIO									
Manoa Stream	808	803	2,817	4,457	5,105	6,745	1,299	1,225	1,219
Palolo Stream	-29	0	0	0	0	0	0	0	0
Makiki Stream	11	0	0	0	0	0	0	0	0
Hausten Ditch	420	0	0	0	0	0	0	0	0
Total	**1,210**	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**

3.4.2 Cost Estimates

An estimate of the implementation costs was developed as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. In addition to the estimated costs, the CE/ICA also considers the O&M costs, as these are considered necessary to achieve the habitat

benefits over the lifetime of the project. The estimated costs for each mitigation alternative is summarized in Table 8. Annualization of these costs, as needed to support the economic analysis is included in Attachment 6.

TABLE 8
Summary of Estimated Costs for Mitigation Alternatives (FY2014 Price Level)

Cost Component[1]	**Falls 7**	**Falls 7 and 8**	**Falls 7, 8 and 11**	**Falls 7, 8 and 12**	**Falls 7, 8, 11 and 12**	**Low-Flow Channel**	**Habitat Pools**	**Resting Riffles**
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
Real Estate	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre-construction Monitoring	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250
Post-construction Monitoring	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250
O&M	$29,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction	$1,491	$2,918	$3,729	$3,746	$4,557	$17,526	$3,786	$3,916
Contingency[2]	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Total Estimated Cost	$240,526	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,264

NOTES:
[1] Based on FY2014 (October 2013) price levels) and 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS.
[2] Assumes contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, and OMRR&R costs

3.4.3 Cost Effectiveness and Incremental Cost Analysis (CE/ICA)

As specified in the USACE regulations, the outputs of ecosystem restoration are not monetized, as is required for traditional benefit-cost analyses. Rather, evaluation of alternative restoration plans considers the relationship of habitat benefits to project costs to identify the most cost-effective plans for various levels of restoration output and provide a basis for determining whether increasing levels of restoration output are worth the added cost.

The evaluation process includes two distinct analyses to identify cost-effective and incrementally justified plans. First, the cost effectiveness analysis is conducted to identify which alternative plans have output levels that cannot be produced more cost effectively by another plan. “Cost effective” means that, for a given level of output, no other plan costs less, and no other plan yields more output for less money. Subsequently, through the incremental cost analysis, the range of plans is evaluated to arrive at a “best” level of output. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of restoration benefits; these are referred to as “best buy plans.” They provide the greatest increase in output for the least increase in cost. That is, they have the lowest incremental cost per unit of output. The incremental analysis will not necessarily identify an optimal plan; rather, there may be a series of best buy plans. In this case, the results must be synthesized with other decision-making criteria (for example, acceptability, completeness, effectiveness, reasonableness of costs, risk and uncertainty) to provide the basis for selection of a particular plan.

The IWR Planning Suite software (IWR Plan, version 1.0.11.0) was used to conduct the CE/ICA for this project. Inputs to the CE/ICA included average annual habitat units (AAHUs) and estimated average annual cost (AAC), which are calculated based on the benefits and costs (as presented in

Tables 7 and 8, respectively) averaged over the 50-year period of analysis. As previously noted, the analysis was based on the "expected scenario."

As listed in Table 9, the results of the CE/ICA indicate that the following mitigation alternatives are cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8 and 12; and Falls 7, 8, 11 and 12. Only Falls 7, 8, 11 and 12 and the No Action Alternative are considered best buy plans. A detailed discussion of the CE/ICA and the results are provided in Attachment 6.

TABLE 9
CE/ICA Results

Alternative	Estimated Cost for CE/ICA[1,2]	AAC	AAHUs	Cost-Effective	AAC/ AAHU	Best Buy?	Incremental Cost of BB Plan over Last BB Plan	Incremental Output of BB Plan over Last BB Plan	Incremental Cost/Output of Best Buy Plan
No Action	$0	$0	0	Yes	-	Yes	-	-	-
Resting Riffles	$403,264	$15,105	1,195	No	$12.64	No	N/A	N/A	N/A
Habitat Pools	$393,958	$14,753	1,202	No	$12.27	No	N/A	N/A	N/A
Low-Flow Channel	$1,236,900	$49,564	1,279	No	$38.75	No	N/A	N/A	N/A
Falls 7	$240,526	$9,014	1,340	Yes	$6.73	No	N/A	N/A	N/A
Falls 7 and 8	$354,197	$13,362	3,831	Yes	$3.49	No	N/A	N/A	N/A
Falls 7, 8 and 11	$433,070	$16,101	5,401	No	$2.98	No	N/A	N/A	N/A
Falls 7, 8 and 12	$430,841	$16,000	6,021	Yes	$2.66	No	N/A	N/A	N/A
Falls 7, 8, 11 and 12	$494,715	$18,440	7,591	Yes	$2.43	Yes	$19,102	7,783	$2.45

NOTES:
[1] The estimated costs utilized for CE/ICA are equal to the investment costs plus future costs, in present value terms. For each alternative, the investment costs include construction, real estate, PED, and construction management; future costs include post-construction monitoring, and O&M.
[2] The costs for the mitigation alternatives all fall within the estimated cost that is currently assumed for the tentatively selected plan, as described in the Cost Engineering Appendix.

3.5 Selection of Mitigation Plan

While the selected alternative need not be a best buy plan for the purposes of mitigation, it must be cost-effective; other decision-making criteria may include acceptability, completeness, effectiveness, reasonableness of costs, and risk and uncertainty. As summarized in Table 9, four of the passage barrier removal alternatives are cost-effective; only Falls 7, 8, 11 and 12 is a best buy plan (along with the No Action alternative).

Although Falls 7 alone is cost-effective, there is some degree of risk and uncertainty that this alternative would not adequately meet the required mitigation burden. Although there is assumed to be some degree of existing passage through Falls 8 (such that the habitat model indicates an adequate gain of HUs for removal of Falls 7 under the "expected scenario"), there is inherent risk in this assumption, such that it is possible that there is little to no existing passage through Falls 8. Based on this assumption, removal of Falls 7 alone would only measurably increase access to the approximately 100 meters of in-stream habitat between Falls 7 and Falls 8, and would not adequately meet the mitigation burden (as indicated by the "worst-case scenario").

Furthermore, the incremental cost per habitat unit (AAC/AAHU) drops significantly with the addition of Falls 8, such that substantially more benefits would be realized for a relatively small increase in cost. As shown in Table 9, the incremental cost of implementing Falls 7 is $6.73 per unit output, but is only $3.49 for Falls 7 and 8. Given the proximity of these features and the nature of the required work, the added cost of addressing Falls 8 is minimal, but the added benefit would be substantial (as a much greater extent of upstream habitat would be made available). Although the incremental cost of adding Falls 12 and/or Falls 11 and 12 is even lower ($2.66 and $2.43, respectively), these alternatives provide an excessive amount of habitat benefit relative to the project impacts, that the project team determined these were not worth the added cost.

These considerations, which are consistent with the USACE's Environmental Operating Principles[3] (USACE, 2012), were used the project team as the basis for selection of Falls 7 and 8 as the selected mitigation alternative for the project.

4.0 Monitoring and Adaptive Management

As specified in the guidance, monitoring includes the systematic collection and analysis of data that provides information needed to assess project performance, determine whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits. The monitoring plan should include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring (recognizing that monitoring should continue until such time as the Secretary determines that the success criteria have been met).

A preliminary description of these items is provided below. It is expected that this information would continue to be refined as the detailed designs are further refined, and the monitoring plan would be finalized during the next phase of the project.

4.1 Monitoring Approach and Activities

In order to capitalize on the detailed baseline data and comprehensive approach to quantifying aquatic habitat quality, monitoring of the mitigation efforts would involve repeated stream and fish surveys, with analysis as part of the HSHEP model. The information gathered as part of these efforts directly relate to the mitigation objectives, which focus on the physical in-stream habitat conditions and passage for native species. Specifically, the stream surveys would record the physical in-stream conditions, with the HSHEP model outputs translating those conditions into habitat quality for native aquatic species. The fish surveys would directly measure the presence and abundance of native species along the stream gradient, particularly in reaches where passage has been restored. Consideration of these data relative to the HSHEP model results would help to correlate species presence/abundance with habitat quality and passage. Direct comparison with the baseline conditions data (and each subsequent year of monitoring data) would also allow for a clear understanding of the change in conditions over time.

4.2 Performance Criteria

Performance criteria represent the desired conditions to be achieved by the end of the performance monitoring period, as needed to determine project success. To the extent possible, performance criteria should be SMART (specific, measurable, achievable, relevant, and time-bound), and include target values and ranges, as appropriate, accounting for natural variability and management actions.

[3] In particular, the USACE's Environmental Operating Principles direct the USACE to "create mutually supporting economic and environmentally sustainable solutions," as well as to "consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs."

The proposed criteria are summarized in Table 10; specific quantities for these criteria would be developed as part of the final design phase.

TABLE 10
Performance Standards and Monitoring Requirements

Mitigation Objective	Performance Criteria	Monitoring Approach
Restore and/or enhance physical in-stream conditions to improve habitat for native Hawaiian aquatic species	Increased habitat units (HSHEP); specific quantification to be determined in final design phase	Stream surveys with HSHEP model
Improve passage for native Hawaiian aquatic species to upstream areas of high-quality habitat	Increased presence (either in total, or as a percentage) of native species in upper reaches; specific quantification to be determined in final design phase	Fish surveys with species counts

4.3 Analysis and Reporting

To provide the basis for evaluating project performance, the data collected as part of the above-described monitoring efforts would be compiled and analyzed. The analysis would use the performance criteria to evaluate whether the mitigation measures are achieving restoration success. The results of the analysis would be presented in a report; a report would be produced annually for each year that monitoring is conducted (see Section 4.5 for a discussion of the monitoring schedule). After the final year of monitoring, assuming the performance criteria have been met, the project sponsors would be responsible for preparing a close-out report.

In the event that the evaluation indicates that the project has not met the performance criteria, the project sponsors would consider implementation of adaptive management actions as needed to attain the ecosystem objectives for the project. Considerations for the adaptive management approach are discussed below.

4.4 Adaptive Management

Adaptive management is a structured process of learning and using newly-acquired knowledge to adjust and improve project implementation. The adaptive management process promotes flexible decision-making as outcomes from management actions are better understood. This approach helps to reduce the risk of not achieving ecosystem restoration goals. Implementation guidance for WRDA 2007 specifies that an adaptive management plan should be developed for all ecosystem restoration projects. Specifically, the information generated by the performance monitoring, as described above should be used by the project sponsors to guide decisions relative to operational or structural changes that may be needed to ensure that the ecosystem restoration project meets the success criteria. This decision-making process may depend on a number of variables, including the timing and/or spatial scale of the performance issue, the urgency with which the issue must be addressed, and/or the type of adjustment that is needed to respond to the issue. The guidance specifies that if an adjustment is anticipated due to high uncertainty in achieving the desired outputs/results, the nature and cost of such actions should be explicitly described as part of the decision document and expressed in each of the monitoring reports as they are performed.

To evaluate the adaptive management measures that may be required for the proposed project, the potential risk and uncertainty relative to achieving the performance standards was assessed and potential adaptive management measures were identified. Specific measures that were considered included changes to project-related conditions, as well as external factors. As part of the

assessment, the extent to which these adaptive management measures could address the potential deficiencies was considered.

In general, this assessment concluded that there is little risk that the structural components of the mitigation actions would require modification, such that the adaptive management does not need to account for physical changes to the in-stream structures. Similar efforts to eliminate passage barriers have been conducted on Oahu with high levels of success, and the proposed mitigation design would build upon these efforts. Structural repairs to address erosion and/or settlement that might occur over time would be covered as part of standard O&M. In terms of achieving the performance standards, the primary risk that was identified is associated with increased abundance and predation by non-native aquatic species. As previously described, prevalence of non-native species is not currently believed to be a key limiting factor for native aquatic species in the Ala Wai Watershed (given the overall habitat conditions); however, to the extent that the monitoring results indicate that this may be the case in the future, the adaptive management approach for the project incorporates non-native species removal. It is assumed that this effort would be similar to those previously conducted by the State of Hawaii DAR staff (assumed to cost approximately $30,000); any adaptive management costs incurred during the monitoring period would be cost-shared with the non-federal sponsor.

4.5 Monitoring Schedule

The implementation guidance for Section 2039 of WRDA 2007 specifies that monitoring would be initiated upon completion of construction, and should continue until ecological success has been documented; the law allows for but does not require a 10-year cost-shared monitoring plan. If monitoring is required beyond the 10-year period, it would be the responsibility of the non-federal sponsor. Based on the nature of the proposed mitigation measures, it is assumed that monitoring would be conducted annually over a 5-year period, which would start upon completion of construction.[4] The exact timing of monitoring would be determined in the final design phase.

4.6 Responsibilities and Cost

Consistent with the requirements of WRDA 2007, the cost of monitoring would be included as part of the total project costs and be cost-shared, with 65 percent of the costs paid by USACE and the other 35 percent paid by the State of Hawaii, as the non-federal sponsor. The estimated cost for the proposed monitoring activities is summarized in Table 11. Any additional post-construction monitoring past the designated monitoring period would be entirely the responsibility of the non-federal sponsor. As the non-federal sponsor, the State of Hawaii would also be responsible for O&M activities for the mitigation measures implemented as part of the tentatively selected plan.

TABLE 11
Estimated Monitoring Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Stream and fish surveys	Assumes a total of 20 person-days per monitoring event	$5,000
Data processing	Assumes a total of 5 person-days per monitoring event	$1,250

[4] In many cases, pre-project monitoring is conducted, as needed to establish the basis for measuring restoration success. It is assumed that a single pre-monitoring event would be conducted prior to construction.

TABLE 11
Estimated Monitoring Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Analysis and reporting	Assumes a total of 10 person-days per monitoring event; assumes $500 in expenses per monitoring event	$3,000
Total (per monitoring event)		**$9,250**
Project Total (assuming 5 monitoring events)		**$46,250**

NOTE: Assumes $250 in labor charges per person-day.

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Attachment 1. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) Model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat

The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat

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Introduction:

In Hawaii, The Department of Land and Natural Resources (DLNR) is the lead agency in the state tasked with managing natural resources and the plants and animals that depend on them. In the case of Hawaiian streams, the waters that accumulate from rainfall on headwater slopes and flow downstream to the ocean provide essential habitat for Hawaii's unique freshwater flora and fauna. While the stream habitats are critical to native fish and macro-invertebrates, an open and direct link to the sea also is vital to their existence. Understanding and managing for the continuation of healthy instream habitats and suitable migratory pathways for native amphidromous stream animals is the responsibility of the Hawaii Division of Aquatic Resources (DAR), a division within the broader DLNR. Also within DLNR is the Commission on Water Resource Management (CWRM) which has the responsibility of balancing the benefits of current and future uses of water when rendering its decisions on specific water allocations. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model was created as a tool to support these management responsibilities. This model helps assess the impact of the stream diversions and other stream channel modifications on native stream animal habitat.

The presence of suitable habitat is considered fundamental to the sustained occurrence of an animal species. Changes to the naturally occurring habitat brought about by man's modification of the environment may have a positive or negative affect on the quantity or distribution of a species' suitable habitat. The HSHEP model is an attempt to quantify how various man-made changes affect native Hawaiian stream animals. While suitable habitat is fundamental for a species persistence and is the focus of the HSHEP model, it is not the only thing that may affect species populations. We fully realize that other factors, such as pollution, disease, or competition with introduced species may also greatly influence the observed distribution and densities of native animals, yet understanding the natural distribution of animals without the presence of these additional factors is still important. Providing managers the ability to assess change to native species habitat with respect to flow modifications, watershed development, or in channel structures is important in understanding the positive or negative implications of various actions. The HSHEP model is intended to capture the major aspects of native stream animal ecology, the typical geomorphology of Hawaiian streams, and common modifications to the environment

within a single model. Additional factors outside of habitat can be modeled with the HSHEP approach, but need additional modeling steps that are best addressed on a case-by-case basis at this point.

The HSHEP model is an outgrowth of a history of collaboration among biologists at Hawaii Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. The collaborative effort focused on understanding the different aspects of the ecology and management of amphidromous stream animals (Fitzsimons and Nishimoto 2007). In recent years, efforts have focused on combining the information gained from the wide range of studies into an integrated model of Hawaiian streams that include the life history characteristics of amphidromous animals, island hydrology and geomorphology, and critical management issues. This report documents results of these efforts and describes the current version of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model.

The HSHEP model follows the overall Habitat Evaluation Procedure (HEP) model concepts developed by the U.S. Fish and Wildlife Service (USFWS) to evaluate the quantity and quality of habitat available for a species of concern (USFWS 1980 a,b, USFWS 1981). In general, a Habitat Evaluation Procedure (HEP) model has several characteristics:

1. It is a habitat-based assessment method.
2. It assumes that habitat quality and quantity are related to the number of animals using a habitat over the long term.
3. It uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density.
4. It converts suitability relationships into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions.
5. The HSI values range from 0 (unsuitable habitat) to 1 (most suitable habitat).
6. It multiplies the habitat quality (value from the HSI) with the habitat quantity (area) to determine overall Habitat Units (HU) within the area of concern.

As a result of the model design, HEP impact analyses are intended to allow the user to:

1. provide defined suitability-based estimates of HU within a study area,

2. provide impact assessments of the changes of HU within the study area under different management scenarios,
3. provide objective comparable unit measures for multi-site comparisons,
4. quantify changes in HU to be annualized and comparable with other cost/benefit analyses,
5. create plots of the distribution of HU in map-based formats (GIS analyses) to address issues of habitat fragmentation or connectivity.

The HEP user manual describes a HEP model like this, "HEP is a convenient means of documenting and displaying, in standard units, the predicted effects of proposed actions." USFWS designed HEP to be a legally defensible, standardized format for impact assessment in natural resource settings (USFWS 1980 a). While HEP models have been developed and used for impact assessment nationally for hundreds of species of birds, mammals, and fish, this was the first HEP model to assess changes in stream animal habitat in Hawaii.

Traditional HEP procedures have been joined with multi-spatial modeling efforts for Hawaiian streams (Parham 2002, Kuamo'o et al. 2006, Parham 2008). The multi-spatial models address issues of scale in understanding differences in habitat availability and species distributions. For example, the presence or density of amphidromous animals is influenced by the location of the sample site within a stream. Similar habitats found near the ocean may have different species assemblages than habitats found further inland. Additionally, characteristics of different watersheds and their streams influence the observed species assemblages. For example, streams with terminal waterfalls have different species assemblages than streams without terminal waterfalls. By assessing suitability at multiple spatial scales, different aspects of amphidromous animal ecology can be more appropriately modeled (Figure 1). As a result of the combination of the HEP method with multi-scale analysis, management issues can be addressed on a site, stream segment, whole stream, or region level. The HSHEP model is intended to be useful to assess the impacts of stream channel modification, flow alteration, land use change, climate change, stream restoration, and barrier modifications.

The general purpose of this report is three fold:

1. to explain the influence of stream modifications on the distribution and habitat availability of native stream animals;
2. to describe the HSHEP model's intent, design, and application, and
3. to document the source and use of data on habitat and fish occurrence.

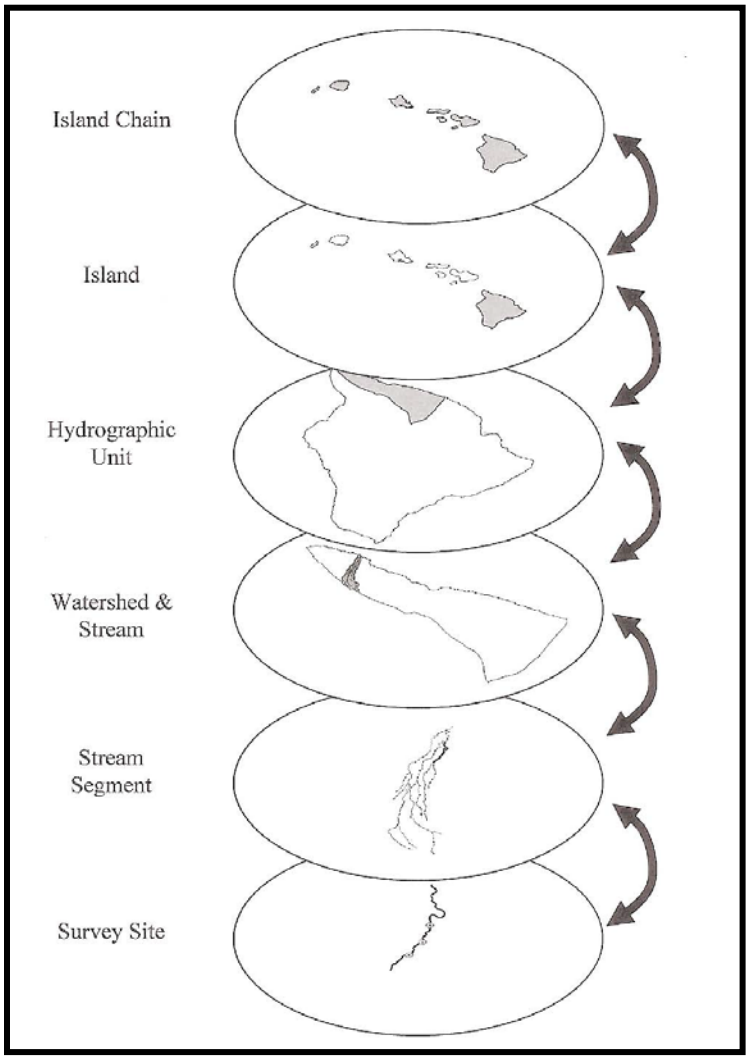

Figure 1: Spatially-nested hierarchy of the DAR Aquatic Surveys Database and predictive levels within the HSHEP model.

The Effect of Flow Diversion and Stream Channel Modifications on Native Amphidromous Stream Animals

From a management perspective, flow diversion and physical channel modifications have differing effects on the life history traits of native stream animals. While the HSHEP model attempts to capture many of the potential effects, not all can be adequately modeled at this time. Even though some of the potential issues caused by flow diversion and physical modifications are not addressed in the HSHEP model at this time, the design of the HSHEP model will allow for the inclusion of information on these issues as data become available. The following is a discussion of the potential affects that flow diversion and physical modifications may have on the different aspects of amphidromous animals' life history. The specifics regarding how the HSHEP addresses these issues are provided in the methods section.

Native amphidromous animals in Hawaiian streams share similar life history traits (McDowall 2007). In general, the animals have an oceanic larval phase during which they develop in the open ocean for up to six months. This is followed by recruitment to stream as the larvae metamorphose to postlarvae. The postlarve then migrate upstream to suitable habitat and complete their development into juvenile animals. Within the suitable stream habitat, the juveniles grow to adults and then reproduce. The newly hatched larvae drift downstream back to the ocean to undergo their oceanic larval phase. As a general model, the important phases can be separated into (1) oceanic larval phase, (2) recruitment, (3) upstream migration, (4) residence in local habitat, and (5) downstream migration and drift.

<u>**O**ceanic Larval phase:</u>

Amphidromous animal larvae living in the ocean as zooplankton during their oceanic larval phase are situated in full strength sea water (Radke et al. 1988). Whether the larvae drift widely offshore or stay near the islands in nearshore currents is unknown (Hobson et al. 2007, Murphy and Cowan 2007), but in either case there would be little or no influence of stream flow or stream habitat on this phase, and therefore no management actions related to instream structures would influence the species' oceanic larval phase.

While no direct management actions regarding flow diversion or stream channel modifications would influence the success of the oceanic larval phase, the oceanic larval phase has a role in the

overall management philosophy of amphidromous animals. Murphy and Cowan (2007) discussed the possible patterns and implications of the oceanic larval phase. Although it is unknown at this time if the larvae drift passively on the ocean currents or show directed movement to stay near the islands, the larvae face many obstacles to complete their oceanic larval phase and successfully recruit to a stream. Larvae may be eaten, starve, or drift off into the open ocean. The chance for all necessary conditions lining up correctly for larvae to successfully complete this phase and recruit to suitable habitat has been likened to a winning a lottery (Sale 1978). As a result, a direct linear relationship between larvae spawned in a stream and larvae returning to a stream is highly unlikely. Given the unknowns and uncertainties associated with the oceanic larval phase, management strategies that maximize the production of larvae to the oceanic plankton pool and maximize the distribution of suitable habitat where larvae may recruit will improve the "odds of winning the recruitment lottery." While predicting the specific species, number, or time of recruitment to a specific stream may prove difficult, management actions that improve instream habitat and ultimately reproductive output are likely to result in more successful recruitment events and thus promote more stable populations among a group of streams.

In summary-

- Management actions that improve reproductive output will likely increase chances that some animals survive the oceanic larval phase.
- Management actions that improve instream habitat across a group of streams will increase the chance that suitable habitat will be encountered as the larvae end their oceanic phase and begin recruitment.

<u>Recruitment:</u>

There is some evidence that the freshwater plume created by stream discharge into the ocean draws recruiting animals to a stream (Nishimoto and Kuamoʻo 1997). It is theorized that larger freshwater plumes attract more recruiting animals. Amphidromous animals tend to recruit *en masse* (Nishimoto and Kuamoʻo 1997). As a result, the number of recruiting animals during a single recruitment event may not be tightly linked to the size of the freshwater plume, but the chance of the recruitment event occurring should be related to the ability of the animals to detect the stream (Figure 2 and Figure 3). In other words, if the mass of recruits is viewed as a single

group or unit, the number of recruitment units that detect a stream's freshwater plume will be greater for a stream with a larger plume that occurs for a larger percentage of the time.

Figure 2: Two images of the mouth of Pi'ina'au Stream, Maui. The left image shows the amount of freshwater discharged into the ocean at low flows and the right image shows the amount of water discharged at high flows. Notice the color change in the ocean in the right image, where increased discharge (and increased sediment load) has a much larger area of influence in the ocean.

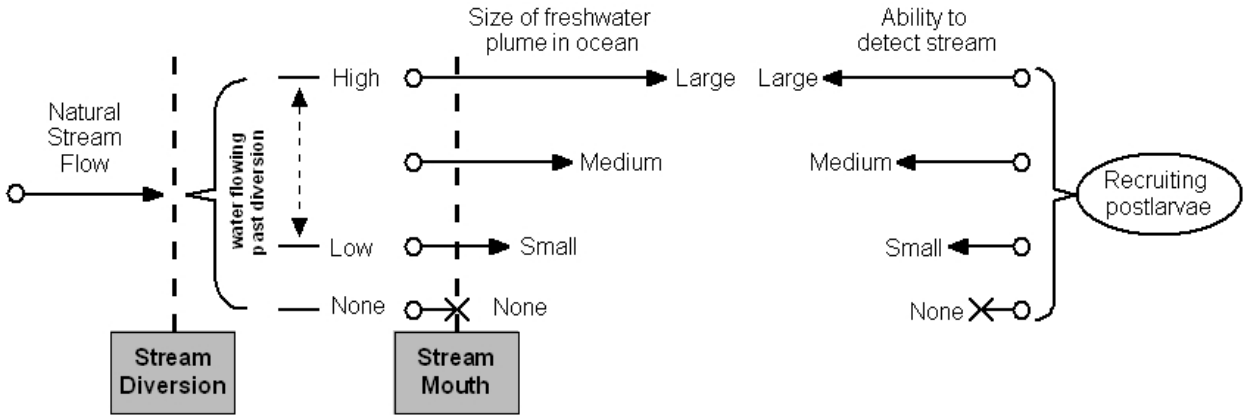

Figure 3: A conceptual model describing the role of streamflow into the ocean in attracting recruiting postlarval animals to the stream. Stream diversions decrease the size of the freshwater plume and therefore make it harder for recruiting animals to detect the freshwater from their offshore larval development areas.

In addition to the size of the freshwater plume, in many streams a stream mouth berm is created when deposition from wave action is greater than erosion by stream flow (Figure 4). The stream mouth berm acts as a barrier to recruitment. While the creation and destruction of a stream mouth berm is a natural phenomenon for many streams, decreases in stream flow as a result of stream diversion will decrease the erosive power of the stream water and increase the period of time that a berm may exist (Figure 5). Conversely, increased stream flow will decrease the amount of time that a stream remains closed by a berm and therefore blocked to recruitment. Changes in sediment quantity in the stream can also influence berm formation. Actions within the stream's watershed that increase the amount of sediment moving from the land into the stream channel likely will increase sediment deposition in stream mouths. Actions that restrict sediment input or downstream movement would likely decrease the size and thus period of time that a berm may exist.

Figure 4: Two photographs of the mouth of Kopiliÿula Stream, Maui. The image on the left shows a closed stream mouth berm and the image on the right show the berm open. Notice the

lower stream discharge on the left (i.e., more exposed rocks in stream and no white water in the upper riffle) as compared to the higher discharge on the right.

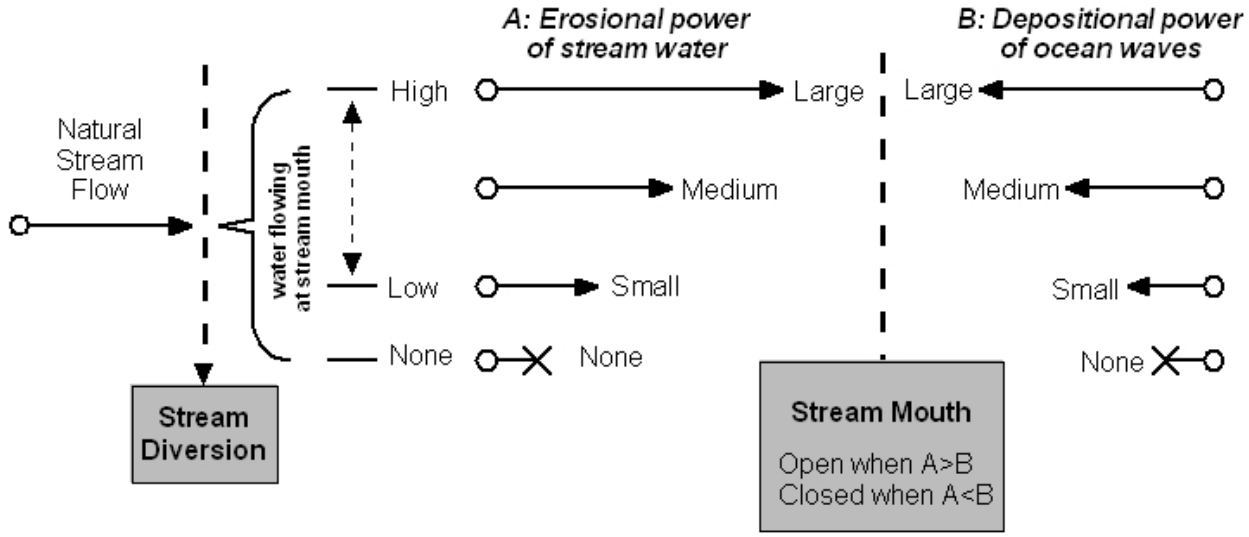

Figure 5: Conceptual model of the balance between stream power and ocean power in controlling the presence or absence of a berm at the stream mouth. When the stream mouth is open, recruiting stream animals can easily move upstream, while when a stream is closed by a berm, recruitment into the stream is highly restricted.

Management actions that increase freshwater discharge into the ocean are likely to improve recruitment by attracting more groups of recruiting animals and expanding the window of opportunity for recruits to enter an open stream mouth. Additionally, there is evidence that the presence of adult animals within a stream may draw recruiting individuals of the same species (Hobson et al. 2007). Therefore, management actions that improve adult populations in a stream may improve overall recruitment to the stream.

In summary-

- Management actions that increase the size of the freshwater plume will likely result in more recruitment events.
- Management actions that increase the time that the stream mouth is open will provide a longer window for recruitment events to occur.
- Management actions that increase instream adult population may attract more recruits.

Upstream migration:

Different species display different upstream migration capabilities (Schoenfuss and Blob 2007). Instream obstacles that prevent upstream movement for one species may be easily surmounted by different species (Figure 6). In general, differences in stream gradient or waterfalls height are measurable natural barriers to upstream migration for specific species.

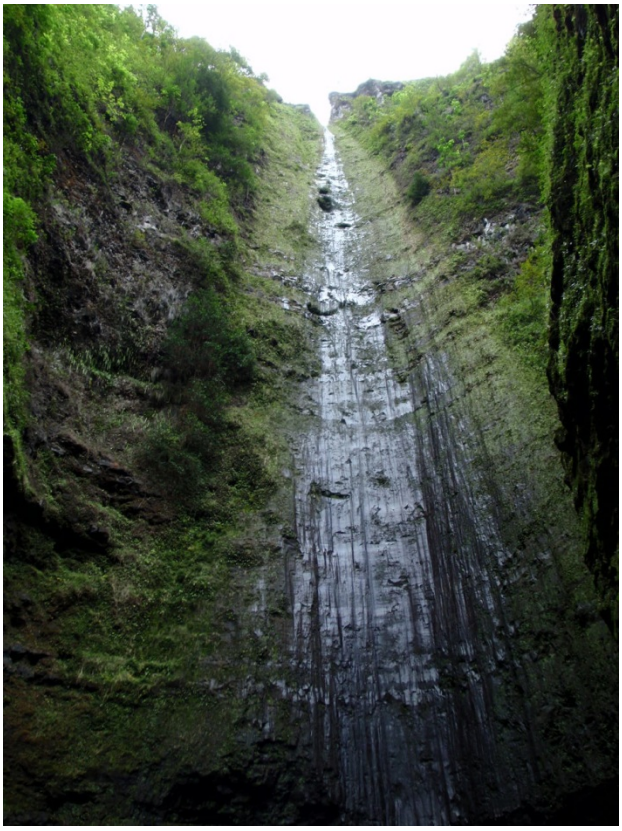

Figure 6: Examples of potential natural barriers to upstream migration. Waterfalls are barriers to some species, while other species with the ability to climb may surmount the waterfall and continue moving upstream. The images show two different waterfalls in Maui streams. The left image (Honomanū Stream) shows a tall waterfall where the water is in contact with the face of the waterfall. Some species will be able to pass this type of waterfall. The right image (Honopou Stream) shows an undercut waterfall. An undercut waterfall will be a barrier to upstream migration for amphidromous species unless a wetted pathway exists for the animals to bypass the undercut.

Just as natural barriers exist in streams, some instream structures can act as barriers to upstream migration. A structure can be a physical barrier, while a stream diversion can create dry sections that prohibit movement by aquatic species, or entrain animals as they attempt to pass over the diversion structure. While the dry section is a direct result of water withdrawals, the other two factors (physical barrier or entrainment) are related to the design of the structure. As with natural barriers, species-specific differences in migratory ability influence whether or not an instream diversion structure is an actual barrier to a species.

Physical barriers that prevent the upstream migration of amphidromous animals are perhaps the most obvious barrier effect of stream diversions. Physical barriers can result from many different designs, but the major issues are height of the dam wall, inappropriate hydraulic conditions, or the creation of an overhanging drop-off in the stream channel (Figure 7 and Figure 9). Given the climbing ability of most amphidromous animals found in the middle reach to the headwaters of Hawaiian streams, as long as the height of structure is not substantially greater than natural waterfalls occurring downstream of the diversion location, then the vertical wall should have minimal impact on upstream migration. In cases where a structure is located in a relatively low gradient stream, blockage of upstream migration may be a problem.

Physical structures may also form hydraulic or behavioral barriers. If the structure creates a flow that is too fast or turbulent for animals to pass through then it can stop upstream migration. Additionally, some animals may have behavioral responses to the physical structure that prevent them from passing through the structure. For example, an animal may avoid passing through a pipe due to its darkness or its smooth sides. Currently, no studies address the hydraulic or behavioral aspects of barriers in Hawaiian streams, although preliminary studies suggest the larvae move mostly during the day and may avoid black plastic pipes (Burky et al. 1999).

In contrast to the height of the diversion, the creation of an overhanging drop-off is a problem for migrating animals wherever it is encountered in the stream. Amphidromous animals require a continuous wetted surface in order to climb an obstacle. If the water falls freely from the lip of the drop-off to the pool below then the animals cannot pass the structure (Figure 8). This situation typically occurs where a structure has been undercut by erosion on the downstream side

or where a pipe is used to convey water downstream and the downstream pipe outlet is higher than the surface of the water below and extends out beyond the surface that supports it. Both of these situations can completely eliminate upstream migration, but are relatively easy to remedy by re-engineering the structure to remove the overhang.

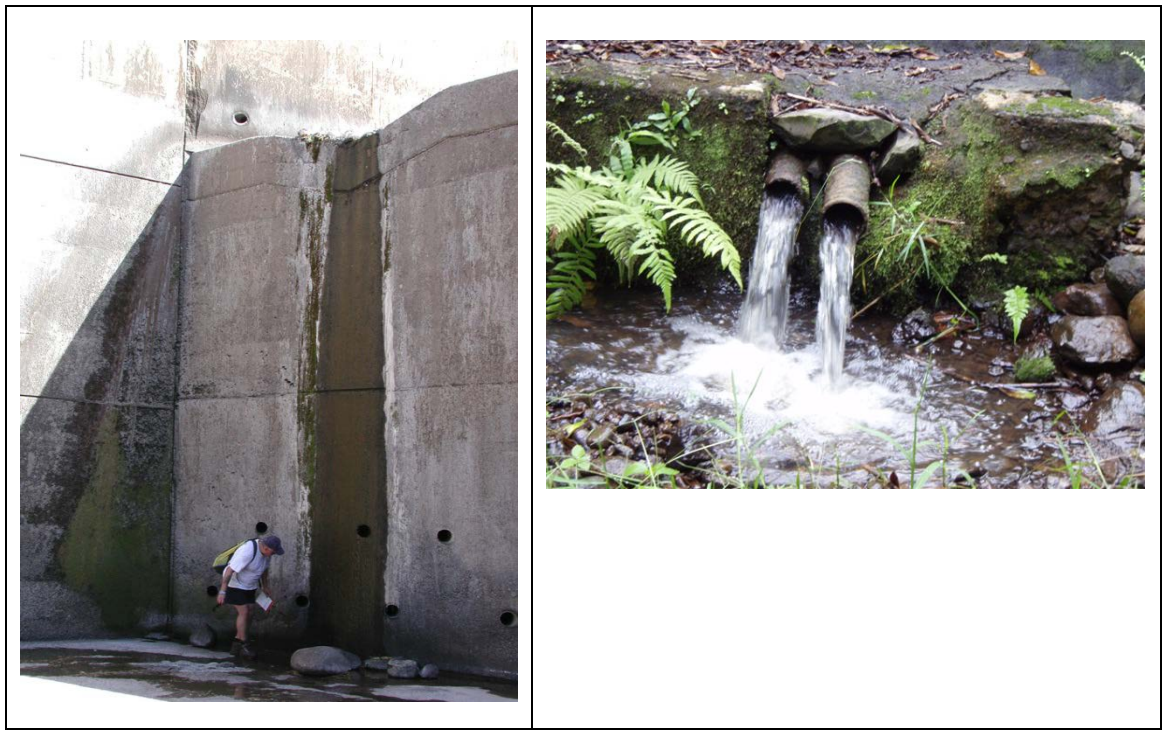

Figure 7: Vertical drop as a barrier on ‘Īao Stream, Maui (left) and a pipe providing for water flow downstream over a diversion on Hanehoi Stream, Maui. While not actual stream diversions, the images show potential obstacles that animals migrating upstream may encounter. Notice the extent of the drop in comparison to the normal channel gradient in left image. In the right set of images, it is unknown if hydraulic conditions (too swift or turbulent flow) or the unsuitable substrate (smooth pipe may prevent animals from holding on to pipe sides) would prevent upstream migration. Additional behavioral issues may also be a factor in the extent of fish passage through the pipe (fish may avoid dark areas).

Figure 8: Over hanging diversions on Honopou Stream, Maui (left) and on the middle reach of Waihe‘e Stream, Maui (right). Notice how the water free falls and leaves no pathway for upstream migration.

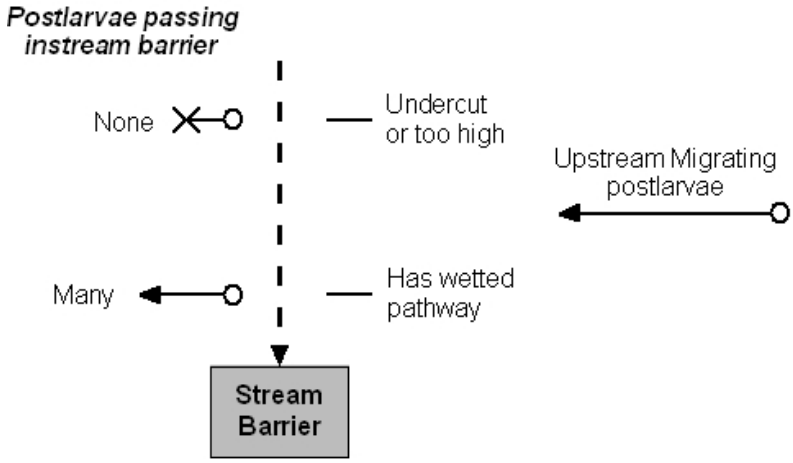

Figure 9: Conceptual model of the physical blockage of upstream migration instream structures.

Stream diversions may also result in the dewatering of a section of stream. This disruption of the physical connection between the upstream and downstream sections prevents the passage of migrating postlarvae to suitable adult habitats (Figure 11). In most native amphidromous fishes, the majority of upstream movement is accomplished prior to adulthood (Schoenfuss and Blob 2007). As the fish grow they become less capable climbers, therefore, the extent of time that a stream section is dewatered is critical to upstream migration of native stream animals. The issue

of the time available for upstream movement is also important for the freshwater snail, *Neritina granosa*, as it moves slowly during migration and is susceptible to being stranded in dry sections (Hau 2007). A dewatered stream section can be viewed as a gate with respect to upstream migration (Figure 11). When water is present and flowing through the section, the section is open to upstream migration and when the stream section is dry, the section is closed to upstream migration. The following pictures show a stream bed closed and open to upstream migration as a result of stream diversion and rainfall (Figure 10). A different form of barrier may exist in channelized segments of streams. In these situations long stretches of shallow flow across open cement bottom channels can create a situation where no resting areas exist for migrating animals. Changes in flow can rapidly leave animals stranded. During sunny afternoons, water temperature can rise to very warm conditions resulting in stressful or lethal conditions for stream animals.

Figure 10: Two photographs of Kopili‘ula Stream, Maui.Both images are from stream sections downstream of the stream diversion. Notice how during periods of low stream discharge (left image) the stream pools are disconnected with dry streambed between the pools, while during periods of higher stream discharge (right image) the stream is fully connected and provides a migratory pathway for animals moving upstream.

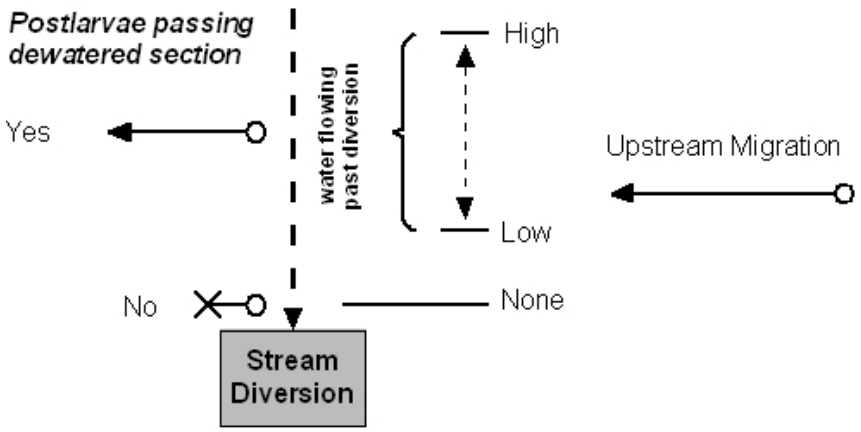

Figure 11: Conceptual model showing the probability of upstream passage by postlarvae of native amphidromous stream animals. Upstream movement would be possible when water is flowing past the diversion and provides a continuous pathway through previously dewatered stream section.

The final impact stream diversions may have on upstream migration is entrainment of individual postlarvae as they pass over the diversion structure. Depending on the design of the diversion structure, migrating animals may be entrained in the diversion and removed from the stream population (Figure 12 and Figure 13). Many diversion structures on Hawaiian streams divert water through a grate into a diversion ditch. Entrainment into the ditch would not only be possible, but likely with the typical diversion design.

Figure 12: Two images of Honopou Stream, Maui at low (left) and high (right) flows. At low flow the barrier is a complete blockage to upstream migration and at high flow most of the water flows through the diversion structure. As postlarvae move upstream through the structure, many would be entrained in the diverted waters and removed from the stream.

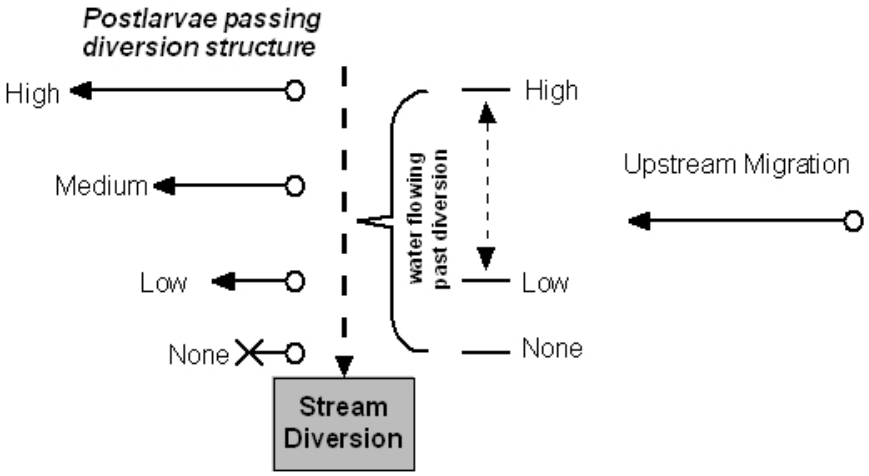

Figure 13: Conceptual model of the extent of upstream passage by postlarvae of native amphidromous stream animals. Entrainment of postlarvae would be a function of the proportion of amount of water passing the diversion and the amount flowing into the diversion.

From a management perspective, the maintenance of connectivity between the stream mouth and upstream habitats is critical for amphidromous animals. Given the vagaries of the timing of recruitment and the short developmental window for upstream movement, minimizing the time that barriers to upstream movement exist will increase the chance that suitable upstream habitat will be colonized by newly recruiting animals. The entrainment by diversion structures of migrating animals results in a direct loss of animals. After an animal has successfully survived the oceanic larval phase, found a suitable stream to recruit to, undergone substantial development changes, and moved upstream, the loss of an individual at this stage is costly to the adult population. Allowing for passage through stream diversion structures to suitable upstream habitat will likely result in greater upstream population densities of amphidromous animals.

In summary-

- Management actions that minimize barriers to upstream migration will increase settlement of juveniles in suitable upstream habitats.
- Management actions that increase the window of time that a pathway from the stream mouth upstream to suitable habitats is available will increase the chances that when a recruitment event occurs the postlarve will be able to move upstream to suitable habitats.
- Management actions that decrease entrainment of upstream migrating animals will increase the number of juveniles that settle in suitable upstream habitats.

Instream habitats:

Native Hawaiian stream animals move upstream to select suitable instream habitats for growth and reproduction. These habitats are typically described in terms of their physical characteristics (i.e. depth, velocities, substrates, water quality) or descriptive characteristics (i.e. riffle, run, pool). The instream habitats are influenced by the surrounding land cover and upstream conditions. From a hydraulic perspective, stream habitats observed at low discharge are created and maintained at high discharge. For example, while a stream pool is a slow, deep habitat at low discharge, at high discharge the pool is an erosional zone with swift scouring flow. A riffle is a depositional zone at high discharge and swift, shallow water at low discharge. Runs typically transport sediment over a range of discharge rates. It is important to remember that observed instream habitats are result of both high and low discharge events.

Stream diversions and other instream structures influence instream habitat in several ways. First, there is the physical structure that replaces the local instream habitat. In the case of stream diversions, this is generally a minor change to the overall stream habitat as most diversions act as a pool/riffle or pool/waterfall combination. In numerous places, native stream animals have been observed in the pool created by the diversion and in terms of total area of habitat, the stream diversion itself modifies a relatively small area. In contrast, channelized stream segments may result in the loss of habitat over the entire area they occupy. In some locations these channelized stream segments may be more than a kilometer in length. Thus the physical disruption of instream habitat by the instream structure is dependent on the size and construction of the particular structure.

In addition to the physical changes in stream habitat, stream diversions also decrease habitat area as a result of the removal of water from the downstream channel (Figure 14 and Figure 15). In the most extreme cases, the diverting of 100% of the water can result in the elimination of all habitats downstream of the diversion by dewatering the downstream sections. At lower percentages of diversion there is a decrease in wetted area, depths, and velocities (Kinzie et al. 1986). The exact relationship between the change in habitat area and discharge is controlled by the geomorphology of the site in question. Habitat models suggest that changes in wetted area are closely related to available habitat for native Hawaiian stream animals (Gingerich and Wolff 2005).

In addition to the loss of habitat area, water removal may result in a decrease of the suitability of the remaining habitat. While the amount of habitat available at low discharge levels is important, the timing and duration of these low discharge events are also important. Instream habitat is a balance between sediment transport dynamics at high and low discharge and holding a stream permanently at low discharge levels will result in a gradual change in the observed instream habitats. Lack of scouring flow generally leads to the infilling of deeper habitats and embedding of larger substrates with smaller sediment and these are not suitable characteristics of native animal habitat (Kido 2002). Lower discharge rates can also result in warmer water temperatures with the sun heating the slower, shallower water more quickly than the deeper and swifter waters. Warmer water holds less oxygen than cooler water and increases bioenergetic demands on the ecothermic stream animals.

Figure 14: Changes in instream habitat after stream diversion on Hononmanū Stream, Maui. The diversion, downstream of the surveyors, was diverting 100% of stream flow (left picture). Downstream of diversion (right picture) there is no water flow and no habitat for aquatic animals.

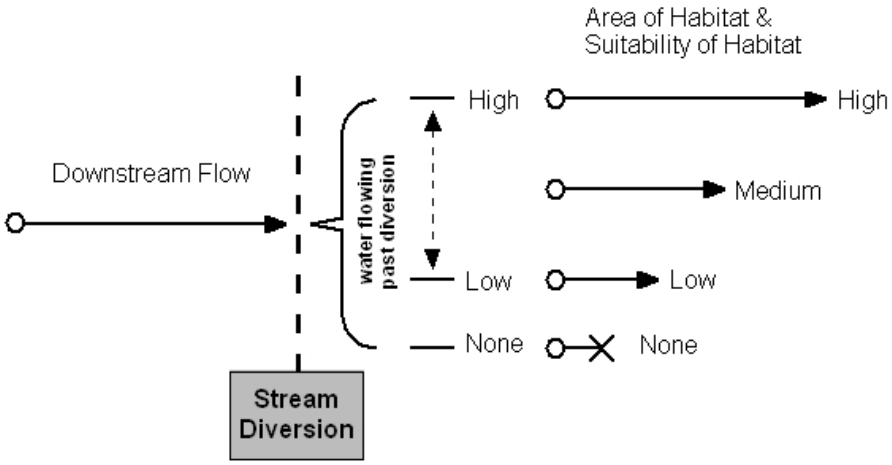

Figure 15: Conceptual model of the influence of stream diversion on instream habitat.

From a management perspective, instream habitat needs to provide adequate conditions for the animals to survive during drought conditions, provide cover to avoid predation and high flow events, supply enough food resources to grow, and provide suitable reproductive habitats. The presence of an animal in a site is not the only criteria needed to determine if the site has all characteristics necessary for the animal to complete its life cycle.

In summary-

- Management actions that provide stream discharge patterns in diverted streams that mimic natural discharge patterns with both high and low flows are likely to sustain suitable instream habitats and amphidromous animal populations.

- Management actions that avoid dewatering a streambed will provide substrate for algae (especially diatoms) and habitat for aquatic invertebrates which provide food sources for amphidromous animals

- Management actions that maintain water flow throughout the stream will minimize water quality problems, improve instream habitats, and allow movement of amphidromous animals among habitats.

- Instream structures that maintain suitable water depth in pools and runs, especially at low flows, will improve instream habitat conditions.

- Instream structures that maintain suitable water depth and appropriate substrates, especially at low flows, will provide for nest locations and assure the nests and eggs of amphidromous animals do not dry up.

<u>Downstream movement (migration and drift):</u>

Downstream movement in amphidromous animals may involve both adult and larval phases. In some species, adults may migrate from upstream locations to downstream locations to spawn (Kido and Heacock 1992, Fitzsimons et al. 2007). In all native amphidromous animals, downstream larval movement is accomplished by drifting with the stream current. The timing of the larval metamorphosis from a freshwater to saltwater larvae is measured in days and the larvae must reach saltwater to complete this transformation (Lindstrom 1998, Iguchi and Mizuno 1999, Iguchi 2007, McRae 2007). Therefore, travel time from hatching site to the ocean is critical to downstream migration of native stream animals (McRae 2007).

Similar to upstream migration issues, stream diversions and instream structures result in two separate mechanisms to prevent or reduce downstream migration and drift. Stream diversion may result in the dewatering of a section of stream. The dewatered stream section is a disruption of the physical connection of upstream sections with downstream sections preventing the passage of adults moving downstream or newly hatched larvae drifting to the ocean. Even if a stream diversion does not create a dewatered stream section, the diversion may decrease downstream water velocities as a result of the overall decrease in stream discharge. Average water velocity is a function of stream discharge and gradient. A decrease in the amount of water will result in slow stream flow velocities. As stream velocities decrease, fewer larvae can reach the ocean within an appropriate time to allow for metamorphosis into their larval phase (Figure 16) (Bell 2007). A diverted stream section can be viewed as a dial with respect to downstream drift (Figure 17). As one turns the dial upward, stream flow increases and a larger number of drifting larvae will successfully reach the ocean from their hatching sites upstream.

Figure 16: Three images of Hakalau Stream, Hawaii captured at different stream discharge rates. Notice the increased amount of swift water (i.e. white water) as stream discharge increases. The time for a drifting embryo to transit the distance of the image would decrease with increased stream discharge.

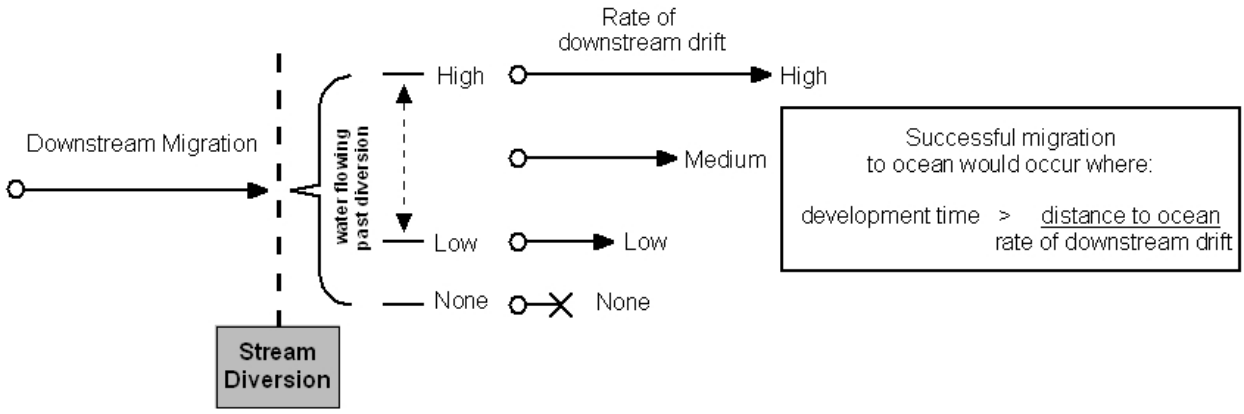

Figure 17: . Conceptual model of the influence of stream diversion on travel time and success of downstream drifting embryos reaching the ocean within a suitable development period. Successful downstream migration would be a function of rate of downstream drift and the distance to the ocean.

Stream diversions have a second effect on downstream movement. Depending on the design of the diversion structure, both adult and larval animals may be entrained in the diversion and removed from the stream population (Figure 18). Many diversion structures on Hawaiian streams divert water through a grate into a diversion ditch. Entrainment into the ditch would be possible and likely with the typical diversion design. Typical stream diversion structures divert 100% of the water at low to moderate flows. Under these conditions, 100% of downstream moving individuals would be entrained by the diversion. As stream flows overtop the diversion, a portion of the animals would likely pass the diversion and continue downstream (Figure 19).

Figure 18: Stream diversion intakes on Waiheʻe Stream (left) and Honopou Stream, Maui (right). Notice how 100% of the water flows into the diversion at the observed discharge. An animal moving downstream would be transported with the water and entrained in the diversion structure resulting in 100% mortality.

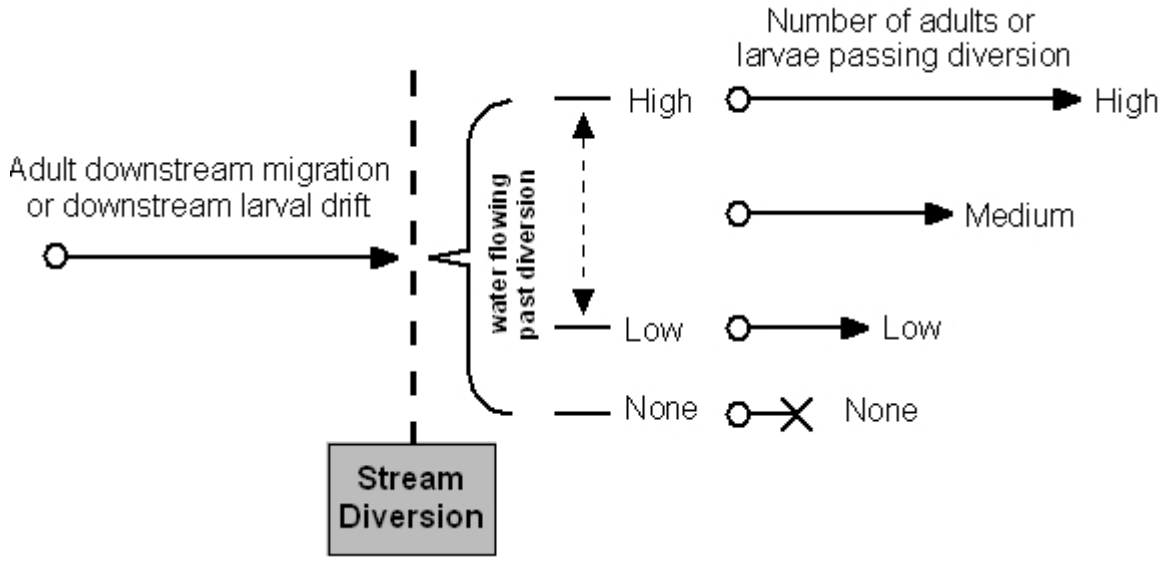

Figure 19: Conceptual model of the extent of diversion passage by downstream drifting larvae of native amphidromous stream animals. Entrainment of larvae would be related to the percent of water passing over the diversion compared to percent of water diverted.

From a management perspective, providing for adequate passage and timely transport of newly-hatched larvae to the ocean are important factors in successful downstream migration. In this respect, suitable stream habitat is more valuable if it is located near the ocean than if it is far inland or above a stream diversion site (McRae 2007). Assuring that newly hatched larval animals reach the ocean from the upstream nesting sites, coupled with successful completion of the other phases of the amphidromous animal's life history, results in ecological connectivity between ocean and stream habitats.

In summary-

- Management actions that decrease travel time from the nest site to the ocean for newly hatched larvae will increase the number of larvae that survive and successfully reach the ocean.

- Management actions that decrease entrainment of migrating adults and downstream drifting larvae will increase the number of adults that survive downstream migration to spawning sites and increase larvae that survive and successfully reach the ocean.

General Conceptual Summary

Overall, stream diversions and other instream structures interact with the native amphidromous animals found in Hawaiian stream in multiple ways. Fundamentally, aquatic animals live in the water. Diversions remove that water from the stream and instream structures remove habitat from the stream. Therefore, it is not a question of whether stream diversions and other instream structures have an impact on stream animals and their habitats, but rather of how can we minimize the impacts on native stream animals while still meeting other societal needs (such as drinking water or the minimization of flood impacts (Devick 2007)).

The following sections of this document outline the development and application of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP). The HSHEP model is a standardized way to assess flow or channel modification's impact on stream animal habitat and also help prioritizes restoration opportunities that would result in the most positive benefits to stream animal populations.

Hawaiian Stream Habitat Evaluation Procedure Model:

To quantify the current conditions of the stream and to estimate the effects of the stream diversions or other stream channel modifications in the Hawaiian streams on native stream animal habitat, a specific application of the HSHEP model follows a general modeling process. This modeling process was first used for the East Maui streams (Parham et al. 2009), and further refined on Wailoa River, Kauai (Parham 2014), the Nā Wai ʻEhā Streams, Maui (Parham 2013), and Waiheʻe Stream, Oahu (Parham and Higsahi 2012 an internal DAR working project). To document the modeling process, the following sections are covered:

- general modeling process,
- selection of evaluation species,
- description of model steps,
- scenarios modeled.

General Modeling Process:

To characterize habitat availability, the HSHEP model applies a nested spatial hierarchy (Figure 1). Depending on the scenario being modeled, various levels of the hierarchy may be applied. For completed models, the site, stream segment, and stream and its watershed scales have been used in assessing project impacts. The spatial levels of island chain, island, and region have not yet been used and although the modeling design supports these spatial levels if needed, they will not be discussed further in this document.

Using the previously reported HSHEP model (Parham et al. 2009), variables at the watershed level were stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. The ratings for these variables were presented in the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e) and the variables for all 430 streams included in the atlas were used to develop the model at this level. Inclusion of the watershed scale in the HSHEP model allows for comparisons of the results among streams in different watersheds.

To describe variation of instream habitat and animal distributions, variables included at the stream segment included elevation, distance inland from the ocean, and the presence of instream barriers. Native amphidromous animals are diadromous, requiring a connection between the freshwater streams and the ocean to complete their life cycle (McDowall 2007). Thus the ability of the animal to move upstream from the ocean will influence its observed distribution.

At the site level, more specific habitat characteristics are important. For the HSHEP analysis generalized suitability indices (depth, velocity, and substrate for flow studies) or (habitat type, depth, substrate, and temperature for habitat studies) are dependent on the data availability. In most cases, data is retrieved from the DAR point quadrat survey data within the DAR Aquatic Surveys Database as these surveys consistently used the same methodology to collect these habitat variables.

To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution. Categorical suitability criteria (e.g., habitat types or substrate types) were not smoothed. See Appendix 3 for the site scale data.

By combining HSHEP model results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable to all other streams in the Hawaiian Islands. The presence of suitable characteristics at a site is not the only important variable when determining site occupancy. A site can only be occupied by a species if that species can reach the habitat. For example, a deep stream pool with a mixture of cobble and boulder habitat may be highly suitable for a number of native species, yet if that pool is found far inland and above a high waterfall, only a few species would be expected to inhabit the pool. The HSHEP model's use of multiple spatial scales, accounts for local, network (up and downstream conditions), and watershed differences among sites.

Selection of Evaluation Species:

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Hawaiian Streams (Table 1). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 1: Species habitat evaluated within the Hawaiian Streams using the HSHEP model. *Identified as "Species of Greatest Conservation Need" in the Hawaii Statewide Aquatic Wildlife Conservation Strategy (Meadows et al. 2005).

Organism Type and Family	**Scientific name**	**Hawaiian name**
Freshwater fish (family Gobiidae)	*Awaous guamensis**	ʻOʻopu nākea
	*Lentipes concolor**	ʻOʻopu alamoʻo
	*Stenogobius hawaiiensis**	ʻOʻopu naniha
	*Sicyopterus stimpsoni**	ʻOʻopu nōpili
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	ʻOʻopu akupa
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	ʻŌpae kalaʻʻole
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	ʻŌpae ʻoehaʻa
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai

The selection of the complete set of amphidromous stream animals is appropriate in this case for several reasons.

- The DAR Aquatic Surveys Database has distribution and habitat use information for each of these species.
- All of these species have a diadromous life history, meaning that they migrate from the freshwater stream to the ocean and back again (McDowall 2007). This potentially exposes the migrating animals to barriers in the stream pathway, entrainment into water diversion systems, and elimination of suitable habitat resulting from water diversions or channel modifications.
- These species are characteristic of all reaches found in Hawaiian streams. Some are found in the lower reaches, a number in the middle reaches, and some even make it to the extreme upper ends of Hawaiian streams. This allows the HSHEP model to be applied to the appropriate species within any stream segment.
- The HSHEP model has habitat suitability indices developed for each of these species.

Description of HSHEP model steps:

To create the HSHEP models that compare the expected current distribution and habitat suitability in Hawaiian Streams for each species independently, a series of steps is followed. It is important to understand that the HSHEP model was designed to work closely with the DAR Aquatic Surveys Database and available geospatial data. As more data are collected and stored in the DAR Aquatic Surveys Database, the underlying relationships can be updated to reflect the new information. This is also true of available geospatial data. As higher resolution digital elevation models or improved flow models become available, the data could be recalculated using this improved data set. This document describes the current version of the data used for the HSHEP model.

Changes to the model are fully appropriate when developing a model to represent a specific location and address a specific management concern. These changes to the model generally occur for two separate reasons. First, the necessary spatial levels required for an individual

model varies. For example, if one compares multiple watersheds then the watershed suitability scale is required, but when the management actions are fully contained within one watershed then the application of the watershed suitability scale is unnecessary. The watershed suitability values do not change within a watershed, therefore these values will not have a variable impact within watershed results. The second type of change likely to occur is the use of specific available data to describe local conditions. For example an instream flow study would be concerned with changes in discharge and its effect on habitat while a flood control project may be more concerned with the physical changes to the stream channel. As a result the specific data required to assess a specific project may vary, but overall, the steps described below are followed for each project.

Watershed scale suitability:

1. Watershed scale metrics were created from available GIS data for variables that covered all 430 perennial streams statewide. The creation of these metrics is detailed in the *Atlas of Hawaiian Watersheds and their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e and reproduced in Appendix 1). The watershed scale metrics included ratings for watershed size, wetness, stewardship, stream reach diversity, the amount of estuary and shallow nearshore marine habitat, and land cover. These metrics were intended to capture the range of the spatial variability for perennial streams in the state of Hawaii.

2. The complete set of 430 watershed suitability values was range standardized so that the range of all values had a minimum value of 0 and a maximum value of 1. This resulted in a comparable range of values for each species among the watersheds statewide.

3. For each species, the watershed scale suitability was determined by plotting the proportion of watersheds in which a species occurred against each watershed scale metric. The watersheds were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 5 of the 430 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples.

4. Multiple logistic regression was used to select the group of metrics that most appropriately predicted the occurrence of a species based on overall watershed characteristics.

5. The current modeled watershed scale suitability relationships are presented for each species in Appendix 1. It is important to realize that these relationships can be updated based on new collection information stored in the DAR aquatic surveys database.

6. There are several assumptions implicit in the watershed scale suitability metrics.
    a. That the set of metrics including watershed size, wetness, stewardship, stream reach diversity, the amount of estuary and shallow nearshore marine habitat, and land cover have any influence on the occurrence of native stream animals. From a general thought, the concept that larger, wetter and undisturbed watersheds with streams containing a wide variety of habitats may potentially contain a wider variety of native species is well supported in the general fisheries literature and has been observed in Hawaii. Also, the use of multiple logistic regression eliminated metrics that did not aid in predicting a species occurrence within a watershed.
    b. The relationship also assumes that there is even sampling within all watersheds. This is clearly not the case. A rating strength metric is reported within the *Atlas of Hawaiian Watersheds and their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e). The rating strength metric reflects the number of surveys the type of surveys and the distribution of surveys within various stream reaches to estimate how confident we are with our underlying information. The rating strength metric is not currently used in the watershed suitability relationships but may be incorporated in subsequent versions of the HSHEP model.

<u>Instream distribution suitability:</u>

7. All native amphidromous stream animals share a common life history pattern and as a result migrate from the ocean to upstream habitats in each generation. As a result of differential climbing abilities among species, each species has its own characteristic instream distribution.

8. To account for this differential instream distribution within the HSHEP model, variables for site elevation, distance inland, and maximum downstream slope (a measure of waterfall or barrier height) are included.

9. The underlying data for these three variables comes from the USGS 10 m digital elevation model for each of the Hawaiian Islands. Digital flow models delineating watershed boundaries, stream channels, flow direction, and numerous other flow metrics were created for each Hawaiian island (Parham 2003a).

10. For each 10 m cell representing the path of the stream channel, each of the three variables was determined using ArcGIS software.

11. Elevation directly reflects the data from the underlying digital elevation model for each 10 m stream cell.

12. Distance inland is the reverse accumulation of distance against the downstream flow direction.

13. Maximum downstream slope is the reverse accumulation of the maximum change in

elevation between two adjacent cells. In some cases in specific HSHEP model applications, maximum downstream slope is replaced by actual measurements of barrier height or the extent at which a barrier is undercut from actual field measures.

14. Unlike in the watershed models, the variables used in the stream reach models were not linear; therefore, multiple logistic regressions could not be used to select the relationship between the instream distribution of the animals and the reach variables. To determine the suitability index based on the instream distribution for each species, the variables for elevation, distance inland, and downstream barrier height were combined with two different relationships and then the more appropriate relationship was selected for use. The two relationships were:

- Instream Distribution Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)
  where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

- Instream Distribution Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

15. Each relationship was range standardized with a minimum value of 0 and a maximum value of 1.

16. To select the more appropriate relationship, the results of each relationship for all sites with all data for each variable in the database were calculated. The sites were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 100 of the 8300 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples.

17. The results of the comparison of predicted suitability with the proportion of samples containing a species were plotted on a graph and analyzed using linear regression.

18. To select the more appropriate relationship, two criteria were used. First, the distribution of predicted results to observed proportions was visually compared. If predicted values between 0 and 1 resulted in a range of proportions between 0 and 1, the relationship was considered acceptable. If both relationships were acceptable to the first criteria, then the relationship with the higher r^2 value for the linear regression was chosen.

19. The selected instream suitability relationship for each species is shown in Appendix 2.

20. The selected relationship for each species was used to combine the three underlying source data grids within ArcGIS.

21. The instream suitability for all sites statewide was range standardized from a minimum of 0 and the maximum was 1 for each species. This resulted in a comparable range of values for each species among all stream segments statewide.

22. There are several assumptions implicit in the development of the instream distribution suitability metric:
    a. Probably the largest assumption in the instream distribution suitability metric results from the calculation of maximum downstream slope as a representation of downstream barrier height. A digital elevation model only contains a single elevation value for each 10 m cell. As a result, slope is calculated as the change between the two adjacent cells. It is impossible to tell whether the slope change is an even percent change or an abrupt drop off. To decrease this issue, if field verified data exists, it should replace the digitally derived metric. With that said, maximum downstream slope has proved effective at finding larger barriers within the stream channels throughout the state of Hawaii.
    b. Like the watershed metric, the relationships assume even sampling within all conditions. This is not true. Sampling is clearly uneven within stream reaches, but the large number of samples (8300+ for this report around the state) has helped decrease the impact of the uneven sampling effort.

<u>Combining Watershed and Instream Distribution Results:</u>

23. The resulting values for each of the relationships (watershed and stream segment suitability for each species) were appended to separate 10 m grids for each island in ArcGIS.

24. Each grid (watershed and stream segment suitability) was weighted by the r^2 value for the linear relationship developed for the species. The r^2 value was used as an estimator of the strength of the watershed or stream segment suitability model's results in predicting a species occurrence.

25. The grids for each scale were multiplied together in ArcGIS into a multi-scale habitat suitability grid.

26. The GIS layer for DAR streams was converted from vector to grid format and all non-stream cells were set to 0 and all stream cells were set to 1 in ArcGIS.

27. The multi-scale habitat suitability grid was multiplied by the stream grid to remove non-stream cells from the analysis in ArcGIS.

28. The resulting range of values for the multi-scale habitat suitability grid was again range standardized so that the minimum value for grid cells statewide was 0 and the maximum was 1 for each species.

At this point, we have combined and range-standardized the watershed and stream scale model with the stream segment scale model and have the values for habitat suitability for each 10 m cell of 430 streams statewide. For each species, the values for the habitat units range from 0 to 1 to

reflect suitability. This step results in predictions of the non-locally corrected amount of suitable habitat for each species within each watershed statewide.

Adjusting the HSHEP model for local conditions:

To adjust the HSHEP model for local habitat conditions found in various segments of the stream, several different options are possible. The selection of the input data is usually dependent on two factors. The first factor is the availability and detail of site surveys and the second factor is the type of scenario being modeled. In general, site level measures will include variables such as depth, velocity, substrate, habitat type, and water temperature. There are numerous additional variables that may be useful in describing instream animal habitat, but may or may not be available for a specific project area. Traditionally, the field data used to describe local conditions comes from either point samples, small area transect samples, or possibly generalized reach scale estimates of conditions (Polhemus et al. 1992 , Parham 2003b). In all of these cases, we assume that un-surveyed areas are similar to the habitats observed in our survey areas. A newer survey technique, High Definition Stream Surveys (HDSS) may be used to document a wide range of variables for all or nearly all of the stream area under study. The HDSS approach is the preferred approach for HSHEP modeling when possible and is further described in Appendix 4.

With any of the local condition sampling approaches, the application of the information to the model is similar. The stream is segmented into areas with similar instream habitat characteristics. These segments begin or end in locations where there is a change in habitat, a barrier, or at the location of a potential modification. This results in a series of connected stream segments that are assumed to react to changes in a similar fashion. For example, we may have survey sites located in the lower, middle, and upper reaches of the stream. From the survey data, we know the distribution and average amount of various habitat types found in each reach. We then apply the results from the surveyed amounts of habitat types to the rest of the appropriate stream reaches. This, of course, assumes that our survey area is representative of the rest of the reach. As with any model, greater sampling and a wider variety of locations will result in a more accurate output. Depending on the size and importance of the project, the amount of fieldwork to characterize local habitat conditions will vary.

Specific local habitat steps:

29. From a vector (line) representation of the stream in ArcGIS, separate the stream into its appropriate segments based on reach breaks, barriers, project locations, or any other appropriate division.

30. Link a table containing average habitat characteristics to each segment.

31. Determine local habitat suitability for individual species by applying appropriate weighting factors to the description of locally available habitat. The species specific weighting factors are typically created from information contained in the DAR Aquatic Surveys Database. This database contains many thousands of samples and species observations from streams across the state of Hawaii and is considered the best source for this information.

32. Convert the stream segments (with their appropriate local habitat suitability score) into a grid of the same size and dimensions as used in the instream distribution portion of the model.

33. Multiply this local habitat suitability grid to the combined watershed and instream distribution suitability grid. This will result in a locally-corrected representation of habitat suitability for a species for each 10 m of stream. It also addresses its instream distribution and larger stream and watershed characteristics.

Scenario Models:

In general, the HSHEP model was designed to address the effects of two common instream modifications: the diversion or modification of stream flow and physical changes to the stream corridor. The impact of these two modification types can result in changes in a site's habitat suitability, changes to passage, and/or entrainment of animals during migratory events. The HSHEP model takes into account that not all actions will result in all possible impacts. Thus, the description and definition of the project impact must be clearly defined and related to available data describing local conditions.

To address specific project conditions and available local data, a graphical box model representing the modeling scenario features and their impacts is created. The following is a

description of the box model process using an example from Iao Stream on Maui (Figure 20). Not all possibilities are shown in this example, but it highlights the conceptual approach well.

The box model for a stream contains the stream and its tributaries from the ocean upstream to the headwater reaches. The stream contains breaks at the various segments determined in the local habitat suitability section. It also contains representations for barriers or project modifications where appropriate. To the right of the stream representation are three additional columns. The first provides labels to each stream segment and is associated with available instream habitat. The second column describes impacts to downstream moving animals and the third column describes impacts to upstream moving animals. This box model provides a useful mechanism to track the label, type, location, and sequence for various possible scenario modifications.

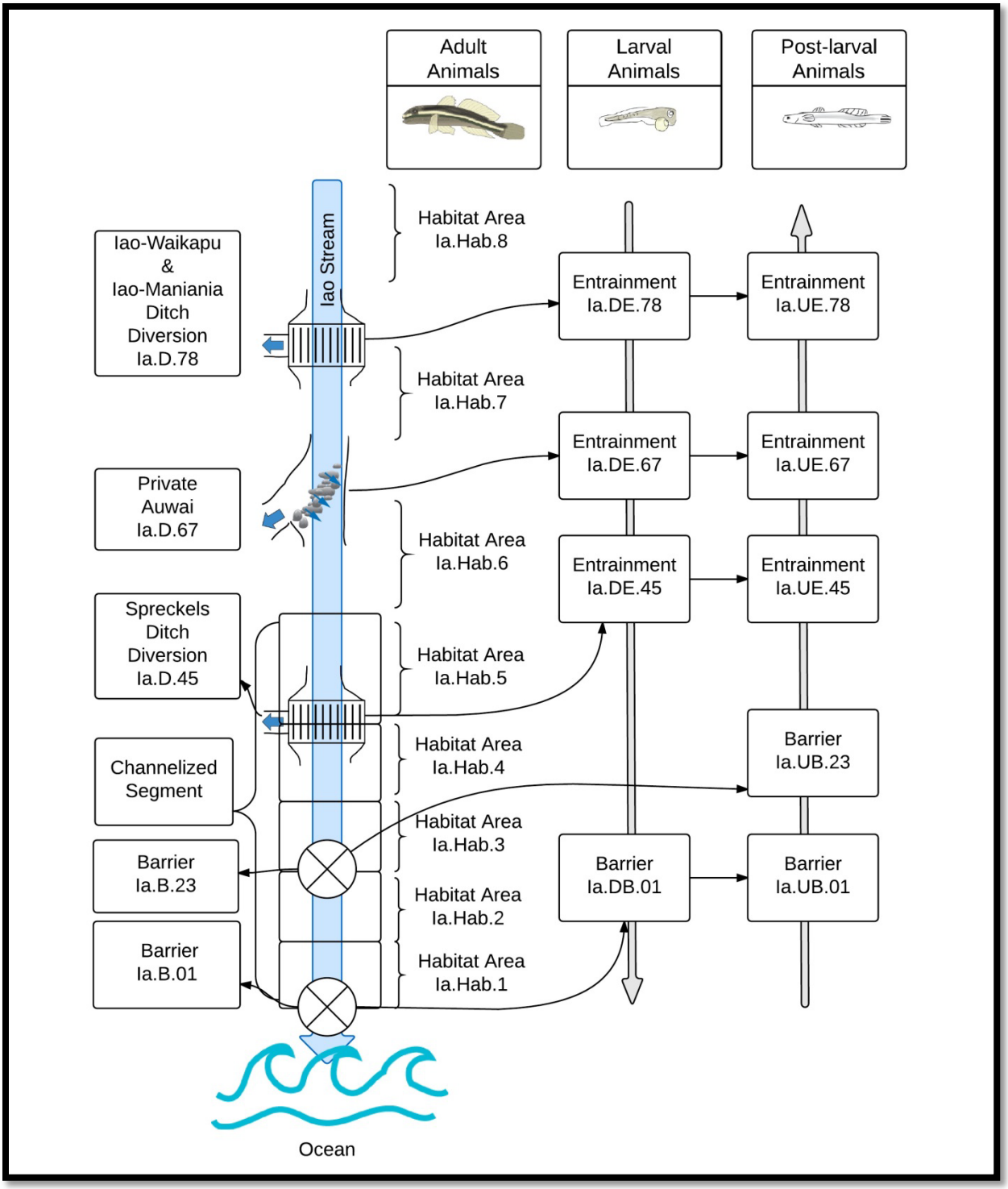

Figure 20: Example HSHEP graphic box model from Iao Stream, Maui. Box models are not to scale.

The impacts of stream diversions, barriers, and other instream modifications are estimated by describing a modification and then applying an impact factor based on the specific design criteria of the modification. In general, all of these potential modifications will share four possible impact factor criteria: (1) local habitat, (2) barrier, (3) upstream entrainment, and (4) downstream entrainment. An impact criterion can range from 0 to 1 with 0 representing the complete elimination of habitat and 1 representing no impact on habitat. In many cases, the specific modification will not influence a specific impact criterion and as a result will have that criterion set to one or no impact.

The description of the main modification types (Figure 21) are as follows:

> Side Diversion – This type of diversion removes water from the stream through a side intake structure (Figure 18). The water in natural stream channel flows downstream past the diversion and a portion is removed by the intake. These side diversions typically have a small dam to help increase the amount of water diverted. Both ditch and auwai diversion can fall into this group. Unless noted, there is no effect on instream habitat or as a barrier to upstream movement. Entrainment is directly related to the proportion of water removed by the diversion. When 100% of baseflow is diverted, the downstream entrainment is modeled at 80%. This would represent the entrainment of all animals drifting downstream in the baseflow and a portion of the animals that overtop the diversion at higher flows. At diversion rates lower than total baseflow removal, the entrainment value is a portion of baseflow (Q_{70}) remaining after the diversion compared to natural baseflow (Q_{70}), multiplied by the maximum entrainment rate. Upstream entrainment is modeled at a maximum of 50% of downstream entrainment. Upstream entrainment is lower because animals moving upstream are moving against the current and this will lead them upstream as opposed to downstream into the diversion. With that said, at high diversion rates, some animals will get entrained when moving upstream.
>
> Bottom Grate Diversion – This diversion type removes water from a grate covered channel that usually spans the stream channel bottom (Figure 18). Bottom grate diversions are usually found on larger stream diversions and are sized to remove 100% of baseflow. As with side diversions, unless noted there is no effect on instream habitat or as a barrier to upstream movement. Downstream and upstream entrainment rates are

modeled at a maximum of 80%. Upstream entrainment is higher than side diversion as upstream moving animals are easily trapped in the diversion as they try to pass over the bottom grate. At diversion rates lower than total baseflow removal, the entrainment value is a portion of baseflow (Q_{70}) remaining after the diversion, compared to natural baseflow (Q_{70}) multiplied by the maximum entrainment rate for both up and downstream entrainment.

Barriers – Barriers can be both natural (i.e. waterfalls) or man-made (i.e. dam). In a strict sense, barriers have two possible conditions, either open or closed. But when viewed over time and various flow conditions, the barrier may be open a percentage of the time. Therefore barrier impact value (% of time closed to migration) for each barrier is estimated from a combination of the barrier characteristics and flow characteristics at that site. Barriers usually have no local habitat or entrainment impact unless otherwise noted.

Undercut Barriers – Undercut barriers are considered a special type of barrier. Their impact is not correctly modeled from only height and flow conditions. Undercut barriers can transform an otherwise passable drop into a complete migratory barrier. From a modeling perspective the criteria are very similar, but the barriers impact value will be set to a much higher level than would be expected for similar non-undercut barrier.

Instream Structures - Instream structures can be anything built in the stream channel. Typical types of instream structures are those associated with flood control projects, bridges, or other development. The primary impact of these structures is to change in stream habitat. The structure may have differential impact within the project footprint as compared to above or below the project and therefore these extra regions are included where needed. An example of this is a debris basin. There may be little to no habitat where the debris trapping structure is located, while upstream the stream channel is occasionally cleared of debris. These two areas could be modeled with independent local habitat impact. Unless otherwise noted, instream structures will have no barrier or entrainment impact.

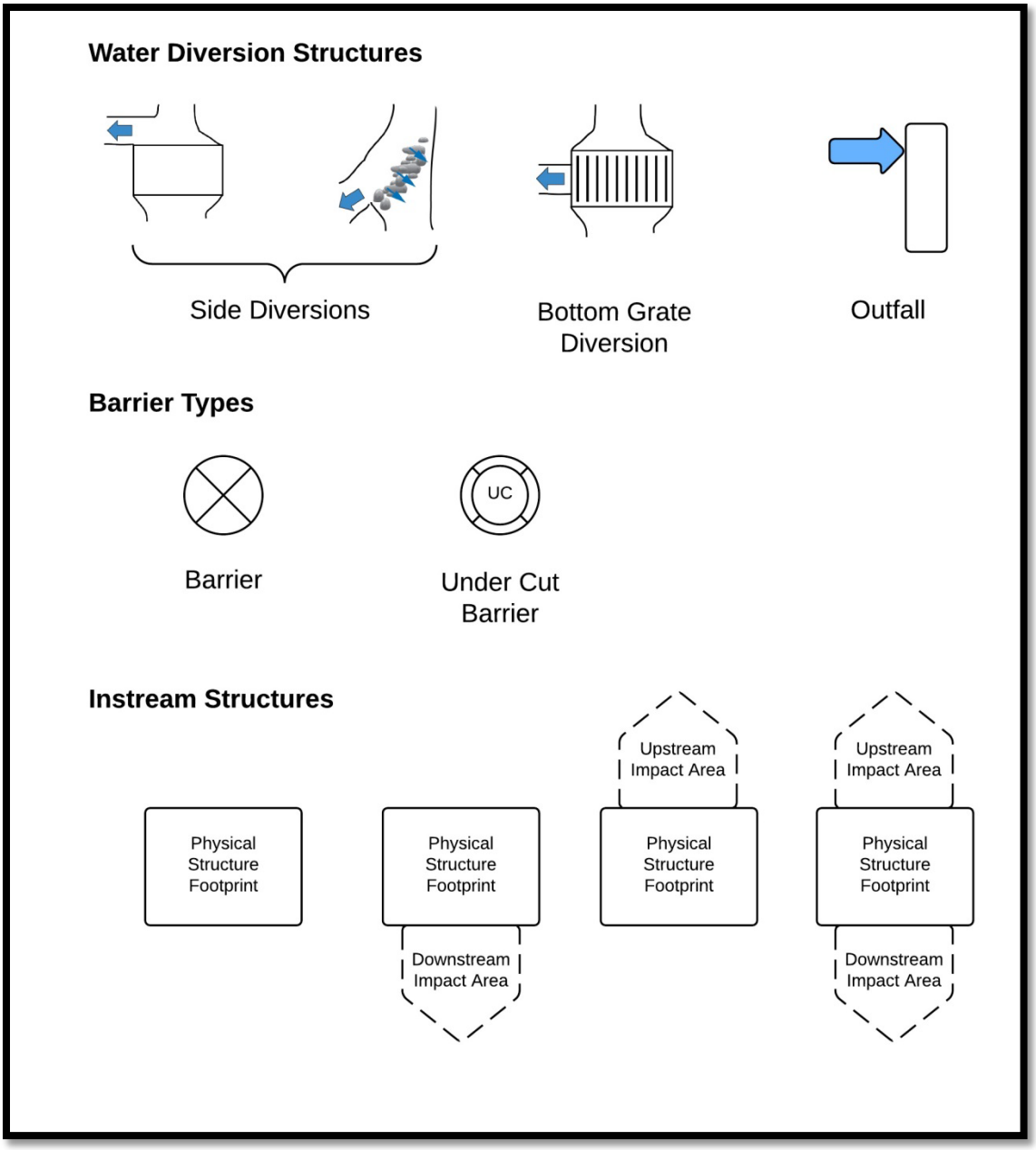

Figure 21: Modification graphics used in the HSHEP box models for each stream. Specifics used to model each type of modification would be project specific.

General Scenario Testing Steps:

34. Impact factors for the four criteria of instream habitat, barriers, downstream and upstream entrainment are determined for all potential impacted locations.
35. The barrier or entrainment impact value affects all upstream cells within the modeled stream network. For example, a barrier (A) that blocked 80% of fish passage would decrease suitable habitat in all cells above Barrier A by 80%. A second barrier (B), located upstream of Barrier A, may block an additional 50% of fish passage. Barrier B would decrease habitat suitability at sites upstream of Barrier B an additional 50%. The combination of passage impact values for both Barriers A (80%) and B (50%) would result in a total passage impact value of 90% at sites upstream of Barrier B. The inverse of the percent of fish blocked would be the percent of fish passing the barriers. In this case, 10% of fish would be expected to pass Barrier B (10% Fish pass = 20% fish pass Barrier A * 50% fish pass Barrier B).
36. If decreases in suitable habitat were the result of physical habitat modification, the estimated percent of lost habitat was multiplied with all habitat units within the affected area. This value did not impact upstream areas as described with passage impacts as it only affected the area where habitat was lost.
37. To address changes in habitat in response to changes in discharge (flow modification), the relationships between the baseflow (Q_{70}) remaining after diversion and natural baseflow (Q_{70}) typically applied. In general, the flow to habitat relationships account for changes in microhabitat variables (water depth, velocity, and substrate) with respect to changes in discharge. The microhabitat variables are weighted by their suitability to a species or species life stage, and as a result, changes in suitable habitat can be predicted from changes in discharge.
38. The amount of suitable habitat derived from the flow to habitat equations are intended to represent the average conditions for the area downstream of the diversion. There may be less available habitat immediately downstream of the diversion and more available habitat near the end of the stream segment after the stream has regained water. Therefore, the baseflow calculated at the start and end of the stream segment were averaged to provide an estimate of average baseflow within the whole segment.
39. The impacts associated with habitat loss due to water diversion (flow modification) were calculated within the specific area in which they occurred and did not impact areas up or downstream of the segment.
40. For each species in each area, the amount of habitat units lost due to changes in passage, entrainment, physical habitat modification, and flow modification were calculated. This approach allowed impacts associated with each type of impact to be considered separately as well as combined.
41. To assess the impact of the various modeled scenarios, the model was repeated with the appropriate scenario values changed.

42. Results for each scenario were created to show Habitat Units available to each species within each stream segment and the streams as a whole, as well as Habitat Units lost due to specific modifications within each scenario.

Conclusions

The HSHEP modeling approach was intended to account for the amphidromous life history strategy of native stream animals, differential instream habitat suitability, and a broad array of man-made changes to the environment. The approach is relatively straightforward yet still flexible enough to address the needs of migratory animals, changes in flow diversions, and different channel corridor construction impacts.

The strength of the HSHEP modeling approach is derived from several features. The first of these is its fundamental design which is derived from the widely used Habitat Evaluation Procedure framework. This framework allows for direct comparisons of different scenarios and supports a wide range of different impact assessments. Another strong feature of the approach is the incorporation of a multi-spatial structure. This provides the ability to differentiate local variances in habitat as well as the impact of network connectivity and watershed differences. Finally, the tight integration with the DAR Aquatic Surveys Database provides the HSHEP model a large and constantly growing source of information to better understand Hawaiian streams, available habitat, and species habitat suitability.

The HSHEP model has been used in multiple Instream Flow contested cases, in hydropower re-licensing, in barrier assessment and passage improvement, and in flood control projects. The range of projects has improved the HSHEP model as well as supported its underlying design. While the HSHEP model is specifically focused on Hawaiian streams, the underlying design should apply to oceanic islands worldwide where amphidromous and other diadromous animals are common.

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Appendix 1: Watershed and Stream Scale Metrics:

The watershed and stream scale metrics are intended to capture broad differences among the watersheds observed throughout Hawaii. Differences in stream size, the amount of rainfall, land management practices, the complexity of estuary and nearshore marine conditions, and land cover can result in differential suitability for native amphidromous stream animals. To capture these differences, standardized metrics were developed for each variable.

Size Rating:

This rating compares stream size. This rating combines the standardized overall length of a stream with the standardized stream order to estimate stream size. The length and stream order were determined from the DAR Streams GIS layer. Stream order followed the Strahler stream ordering system (Strahler, 1952). This rating assumes a larger stream with more tributaries has more habitat than a smaller stream.

Wetness Rating:

This rating compares the average annual rainfall within a watershed to estimate the wetness of a watershed. Rainfall was determined from gridded rainfall layers reported in:

> Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai‘i. *Bull. Amer. Meteor. Soc.* 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

The mean value for the average annual rainfall within the watershed is used for comparison with other watersheds. This rating assumes that a wetter watershed will have a larger stream with more stable flow than a drier watershed and less consistent flow.

Stewardship Rating:

Land stewardship information comes from the Hawaii Gap Analysis Program (GAP) (http://www.higap.org). Land Stewardship is not necessarily land ownership; instead, stewardship reflects who is taking care of the land.

This rating scores the stewardship categories as 1 = no biodiversity protection; 2 = protected but unmanaged; 3 = managed for multiple uses; and 4 = biodiversity protection. The percent of land

in each category is multiplied by the weighting score, and the sum for the watershed is calculated. The overall sum is standardized to provide the rating.

Shallow Waters Rating:

This rating reflects the extent of estuarine and shallow marine waters associated with the stream. The estuary is the length of the stream from the coast inland to 1m elevation from the Digital Elevation Model for the Hawaiian Islands. Shallow water marine area was the distance from the stream mouth at the coast to the 60-ft contour line (10 fathoms) as digitize from bathymetric maps of the Hawaiian Islands. The length of the estuary and length from the stream mouth to the 60-ft contour line (10 fathoms) was measured and combined to estimate the amount of interaction the freshwater would have with the estuary and nearshore environments. Each category (estuary and shallow nearshore marine waters) was standardized prior to combining to weigh each category equally in the rating. This rating assumes that a stream with more associated shallow water would have greater habitat diversity than a stream that empties nearly directly into deep ocean waters.

Land Cover Rating:

Land use and land cover information was downloaded from National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (http://www.csc.noaa.gov/crs/lca/hawaii). Data from the Costal Change Analysis Program (C-CAP) were used to classify land cover. The information is based on images collected in 2000 for all islands except Hawaii where the information was collected in 2001.

In general, this rating scores the amount of forested lands positively and the amount of developed lands negatively in a watershed, and other land cover types are assumed to have a neutral association with stream quality. Specifically, the percent of land cover type within the watershed was multiplied by a value to weight the land cover type with respect to its positive or negative value associated with a high quality stream. These values are:

- Evergreen Forest: +1
- Estuarine Forested Wetland: +1
- Palustrine Forested Wetland: +1
- Estuarine Forested Wetland: +1
- Palustrine Emergent Wetland: +1

- High Intensity Developed: -4
- Low Intensity Developed: -2
- Cultivated Land: -1
- Bare Land: -1
- Grassland: 0
- Palustrine Scrub/Shrub Wetland: 0
- Scrub/Shrub: 0
- Unconsolidated Shore: 0
- Unclassified: 0
- Water: 0

The higher negative values for High Intensity Developed and Low Intensity Developed lands reflect the typical increase in pollution, sedimentation, discharge modification, and habitat degradation in comparison with streams near cultivated lands.

Watershed and stream metric combination:

To develop a relationship between a species occurrence in the various watershed and stream metrics, several comparisons were made. First, the presence or absence of a species within an individual watershed was determined from all data within the DAR Aquatic Surveys Database. This resulted in a data set of 430 watersheds (those containing perennial streams) along with each of their watershed and stream metric scores (from 1 to 10) and the presence or absence of each of the eight native amphidromous stream animals.

Next, linear regressions were used to compare the proportional occurrence of a species against each watershed and stream metric score. For each species, the watershed scale suitability was determined by plotting the proportion of watersheds in which a species occurred against each watershed scale metric. The watersheds were grouped with the predicted results into bins from 1 to 10, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (fewer than 5 of the 430 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples. The combination of bins usually happened at the largest size categories. For example small watersheds occur much more frequently than the largest watersheds therefore the larger size classes were grouped into one bin. Thus the metric scale does not necessarily run from 1 to 10. The intent of these species by metric comparisons was to better understand the underlying

relationships associated with these metrics that may be obscured in the results of the multiple linear regression described in the following section. Figure 22 to Figure 31 display these results and show the linear relationship, P value, r^2 statistic, and confidence intervals for these relationships. Multiple logistic regression was used to select the group of watershed and stream metrics that most appropriately predicted the occurrence of a species based on overall watershed characteristics. Multiple logistic regression was used as the dependent variable is nominal (either 0 or 1) based on a species presence or absence within a watershed and there are multiple (5) independent variables. The null hypothesis in these multiple logistic regressions is that there is no relationship between a species occurrence in a watershed and any of the watershed or stream metrics. The selection of independent variables used a stepwise selection approach. An objective selection approach was used so that the results could be rerun as new data is collected and added to the DAR Aquatic Surveys Database without having to examine the data and results independently with each new run. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of a species, the predicted watershed suitability value based on the multiple logistic regression was plotted against the proportion of watersheds in which the species occurred to the overall number of watersheds within an 0.1 sized suitability bin. Figure 32 to Figure 39 show the final multiple logistic regression for each species, the test statistics, and the graphical relationship.

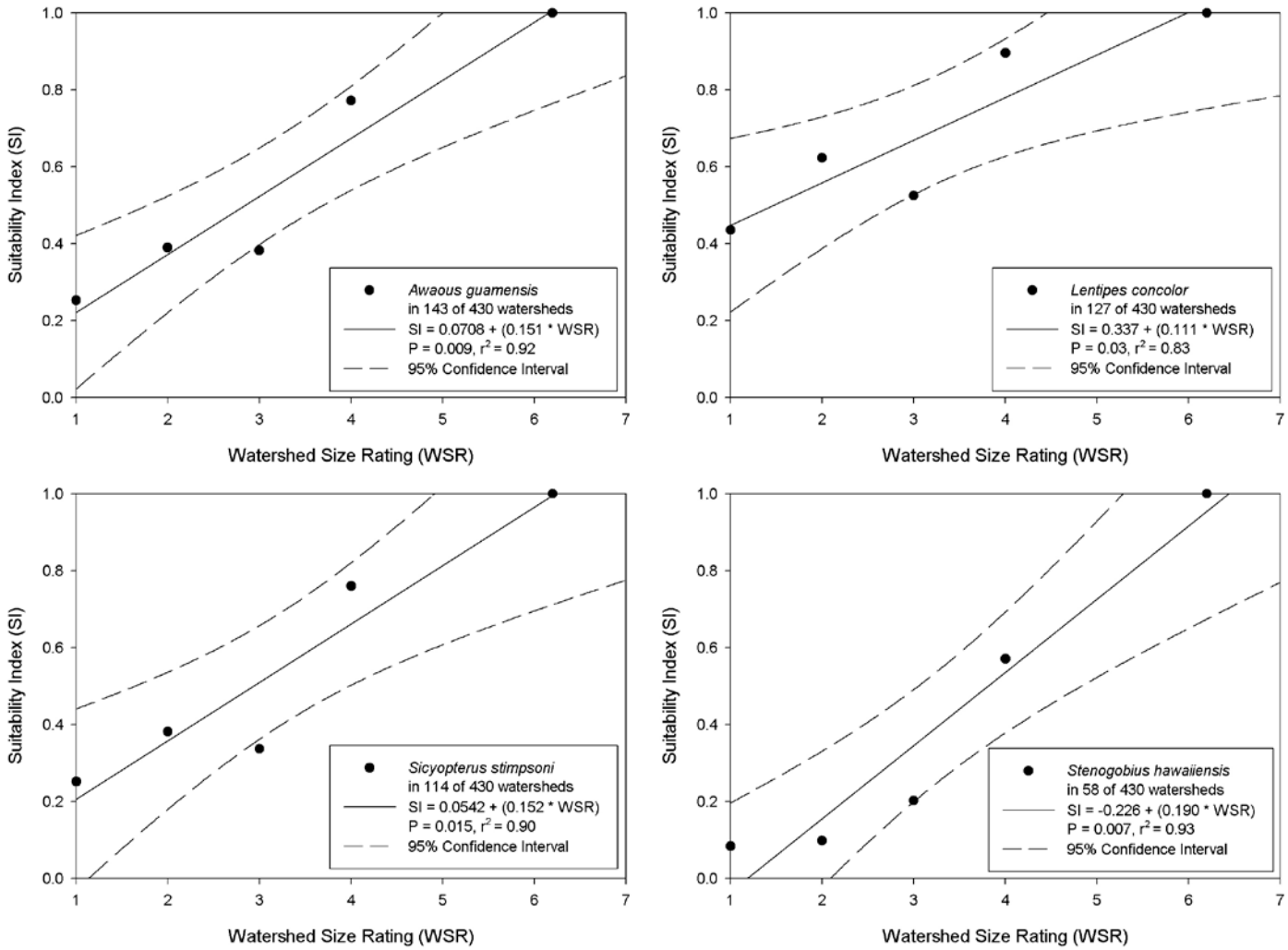

Figure 22: Suitability Indices for Watershed Size Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

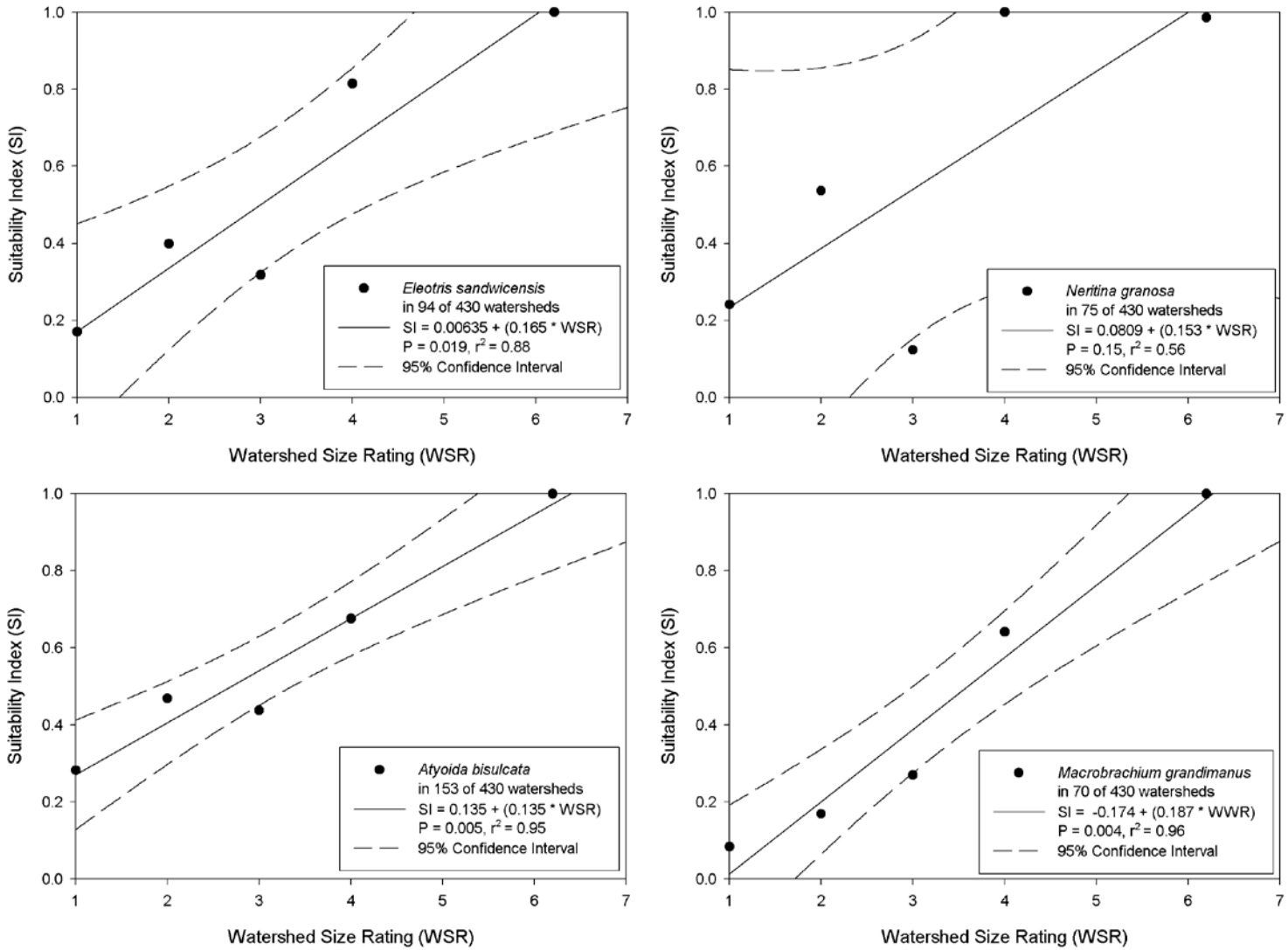

Figure 23: Suitability Indices for Watershed Size Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

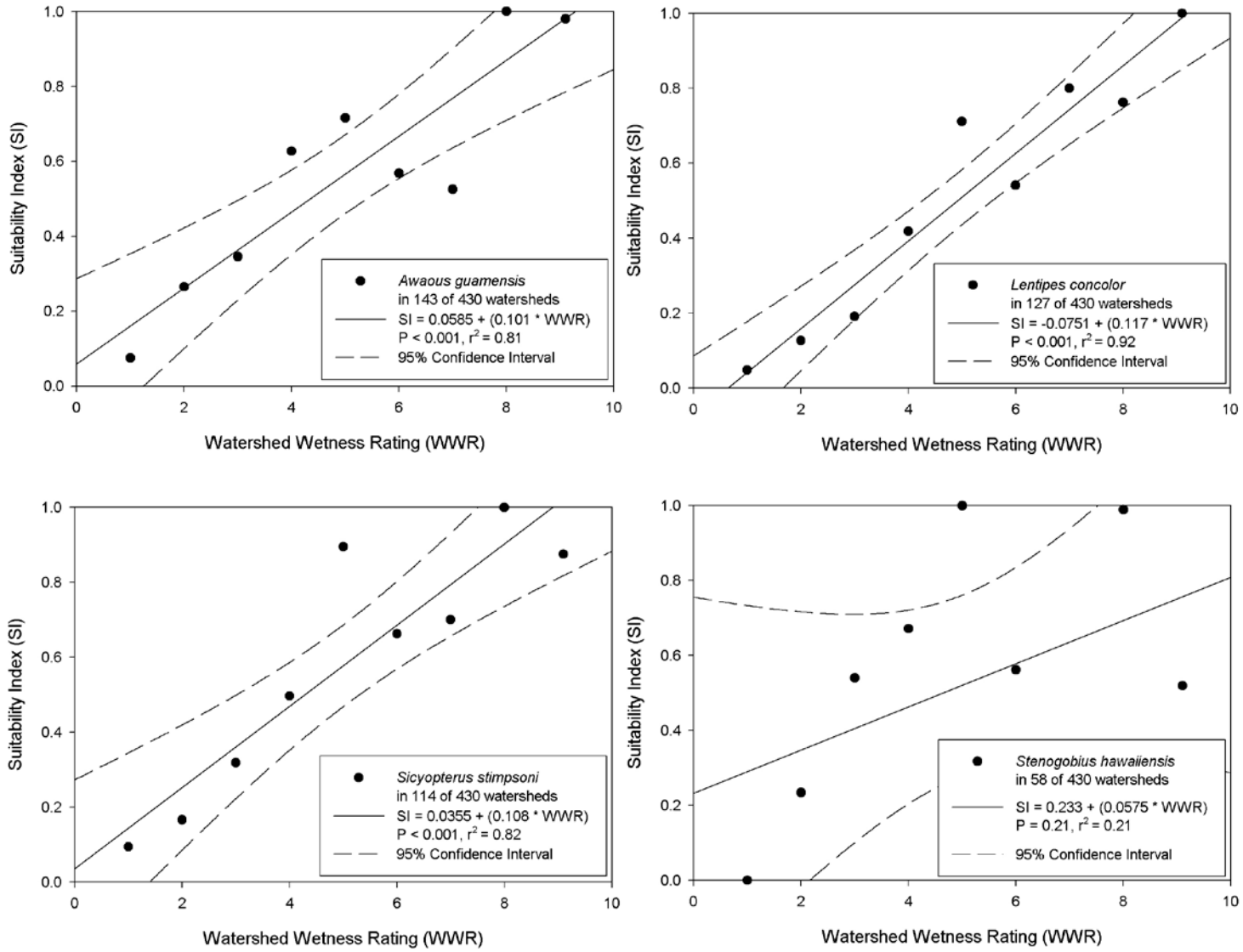

Figure 24: Suitability Indices for Watershed Wetness Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

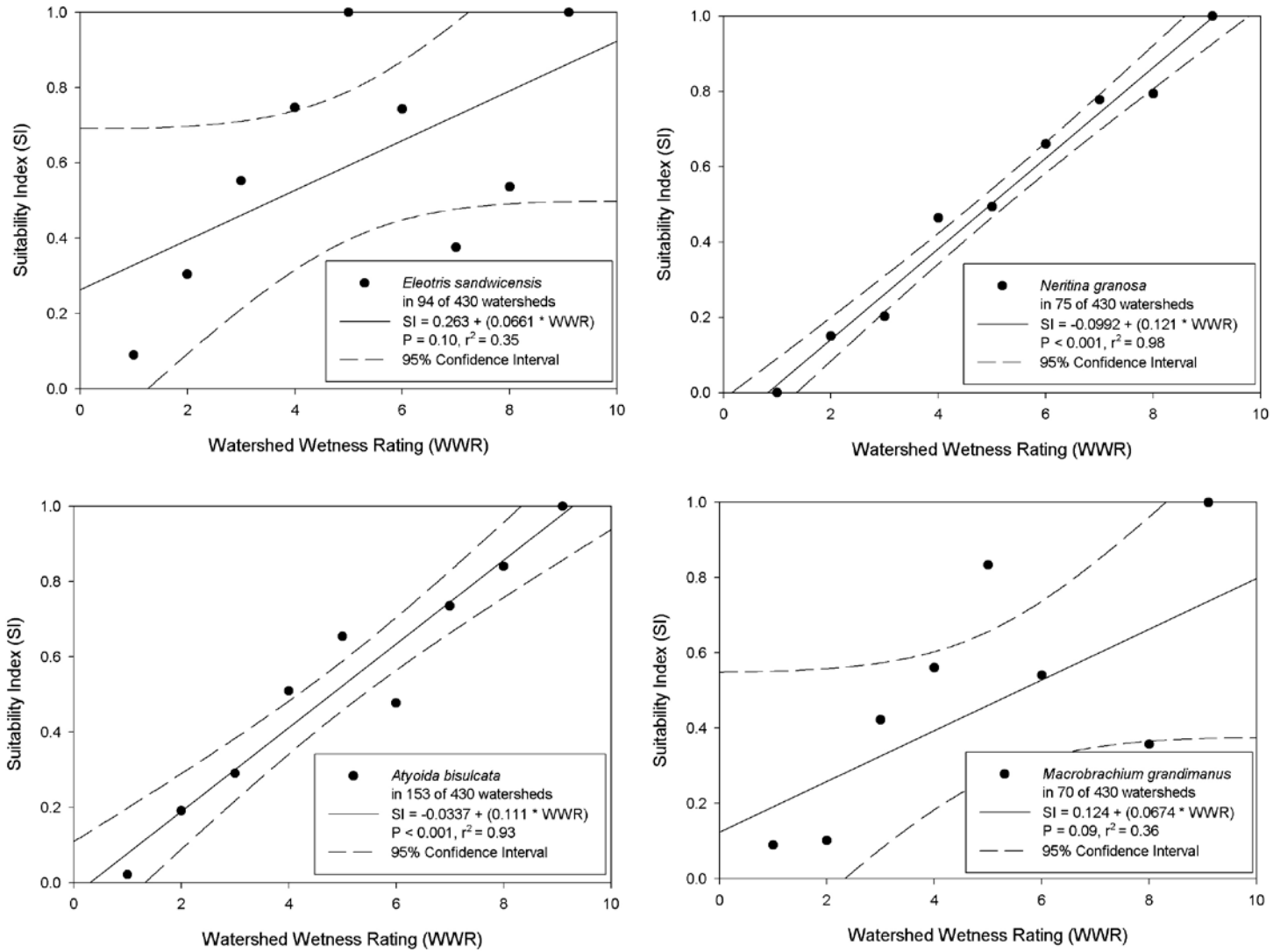

Figure 25: Suitability Indices for Watershed Wetness Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

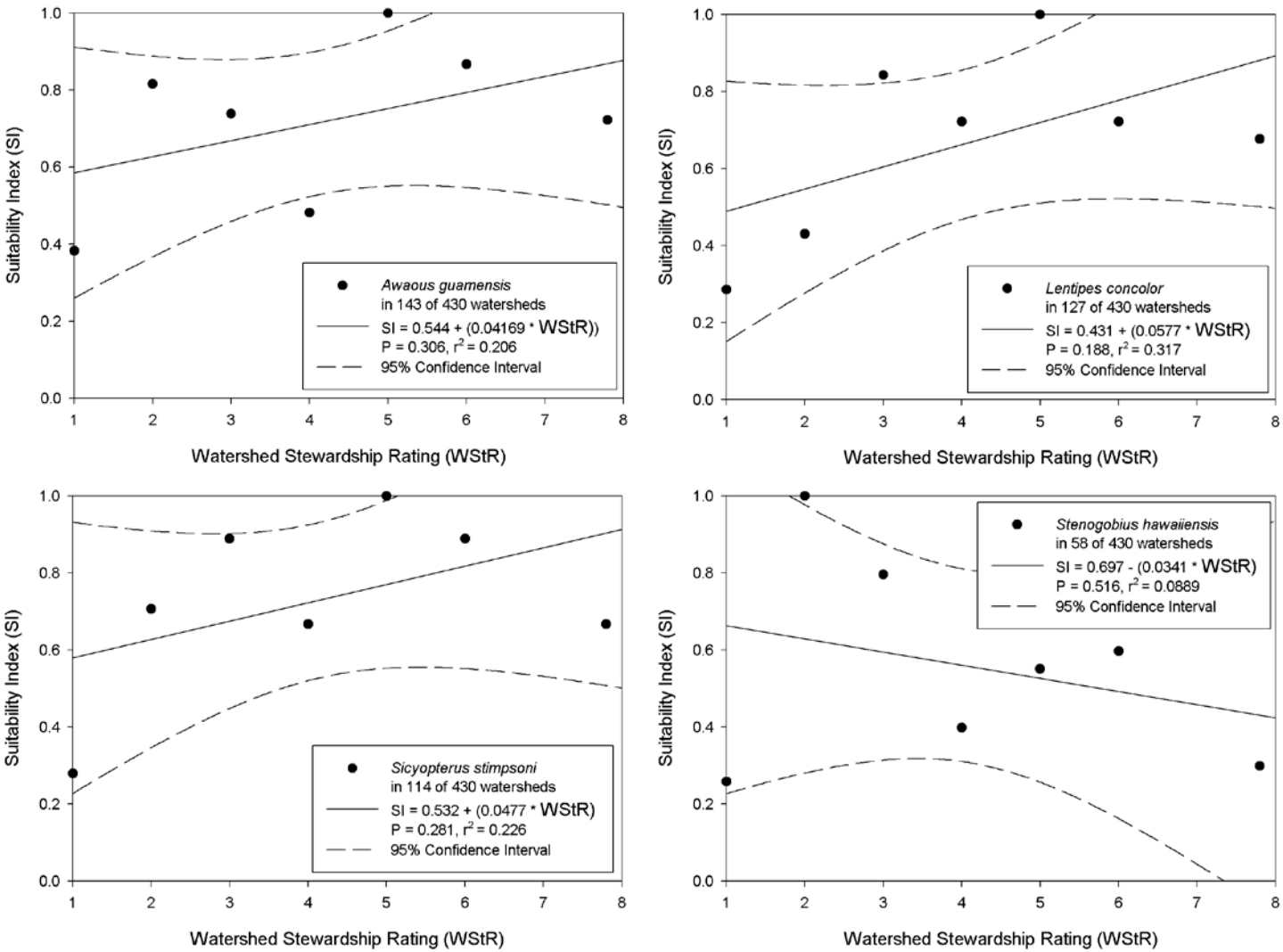

Figure 26: Suitability Indices for Watershed Stewardship Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

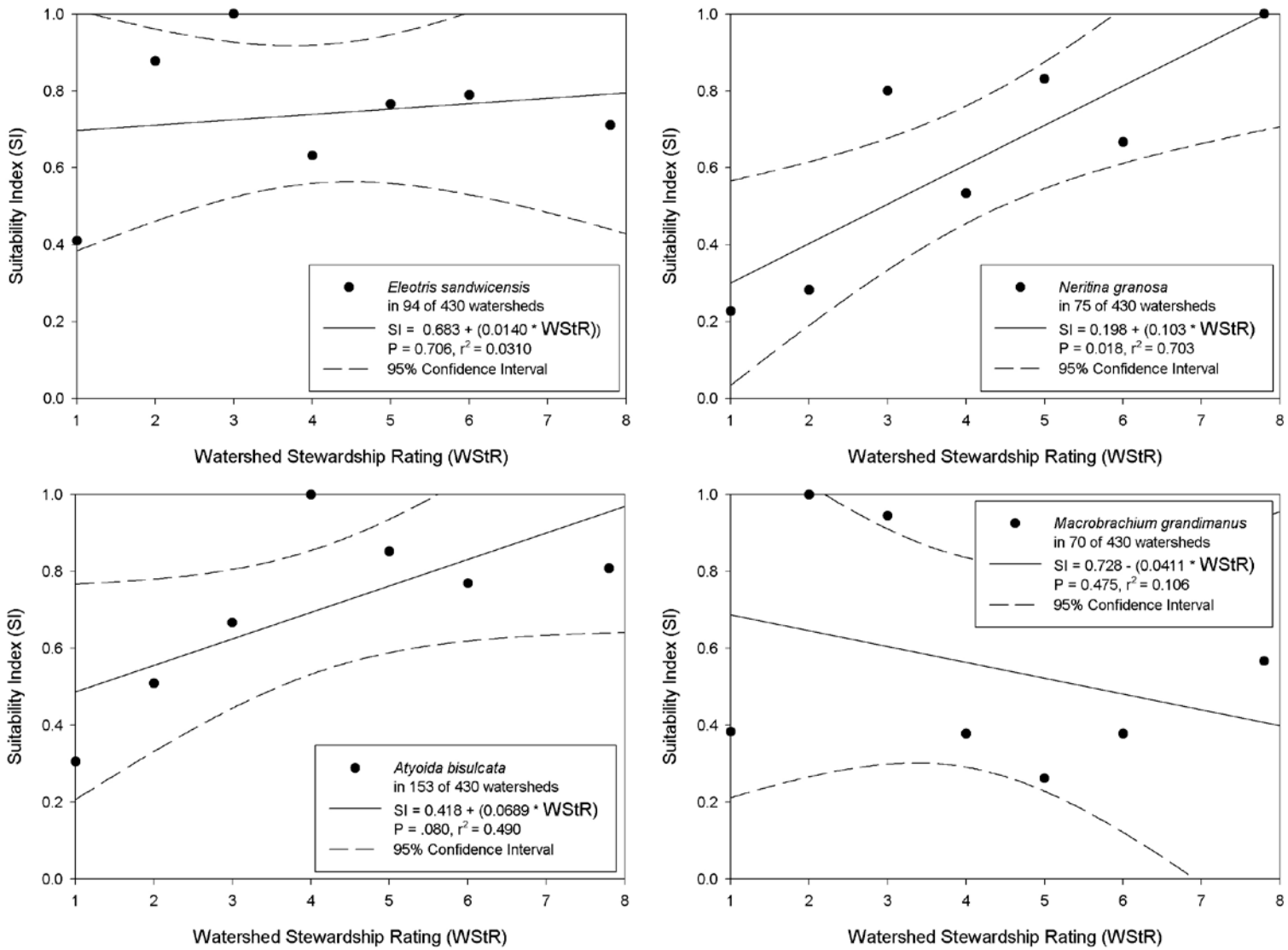

Figure 27: Suitability Indices for Watershed Stewardship Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

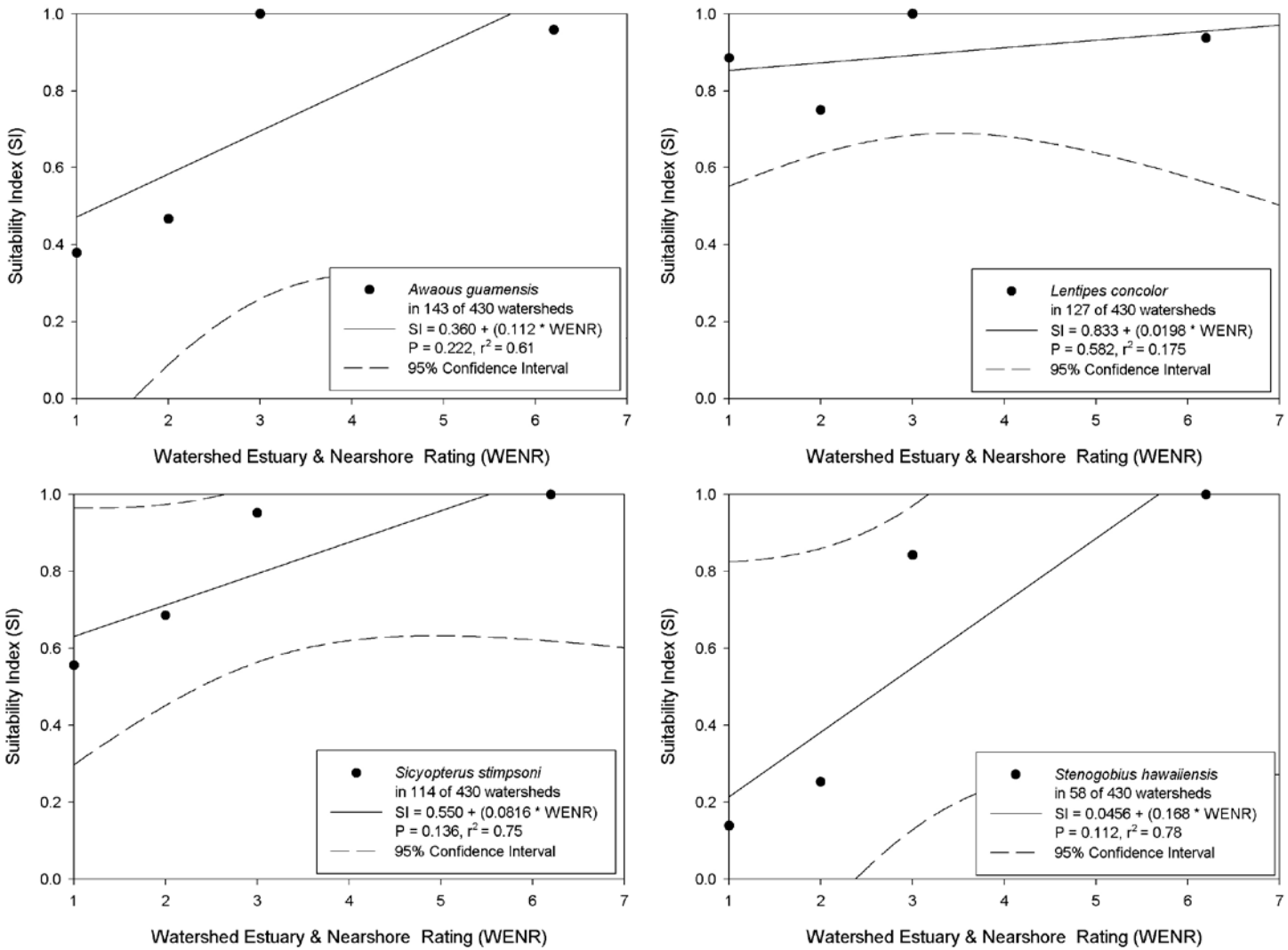

Figure 28: Suitability Indices for Watershed Estuary and Nearshore Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

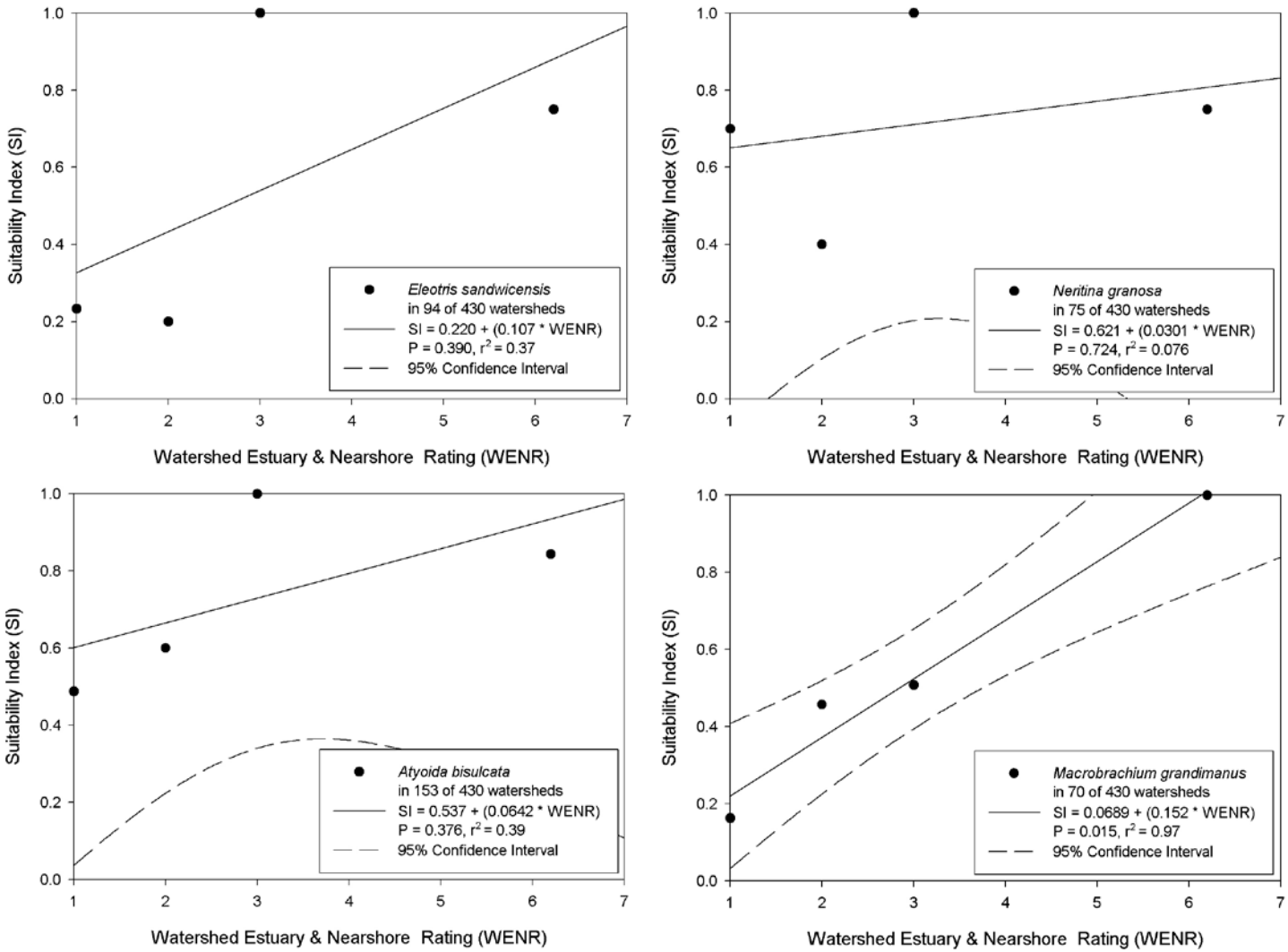

Figure 29: Suitability Indices for Watershed Estuary and Nearshore Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

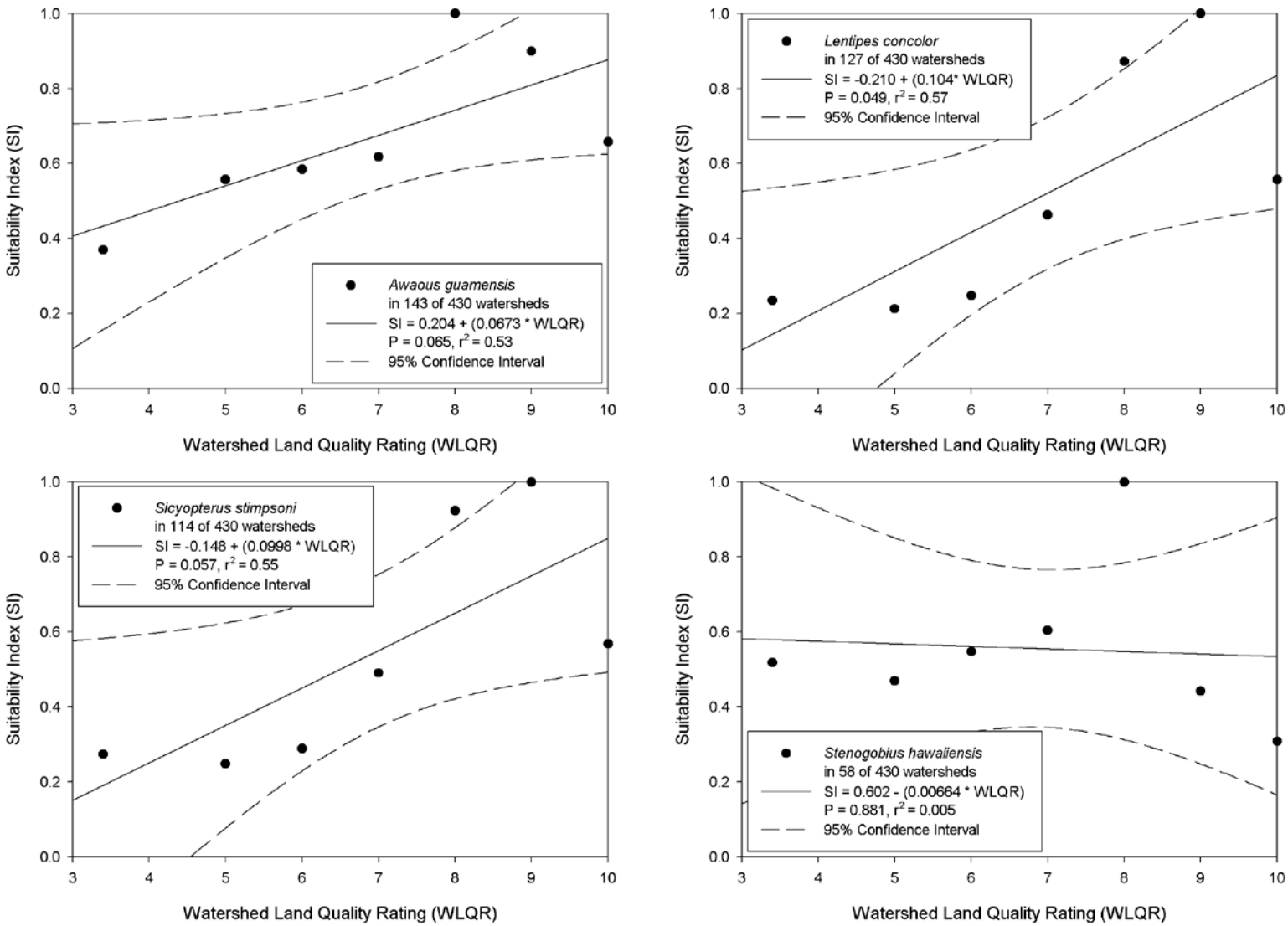

Figure 30: Suitability Indices for Watershed Land Quality Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

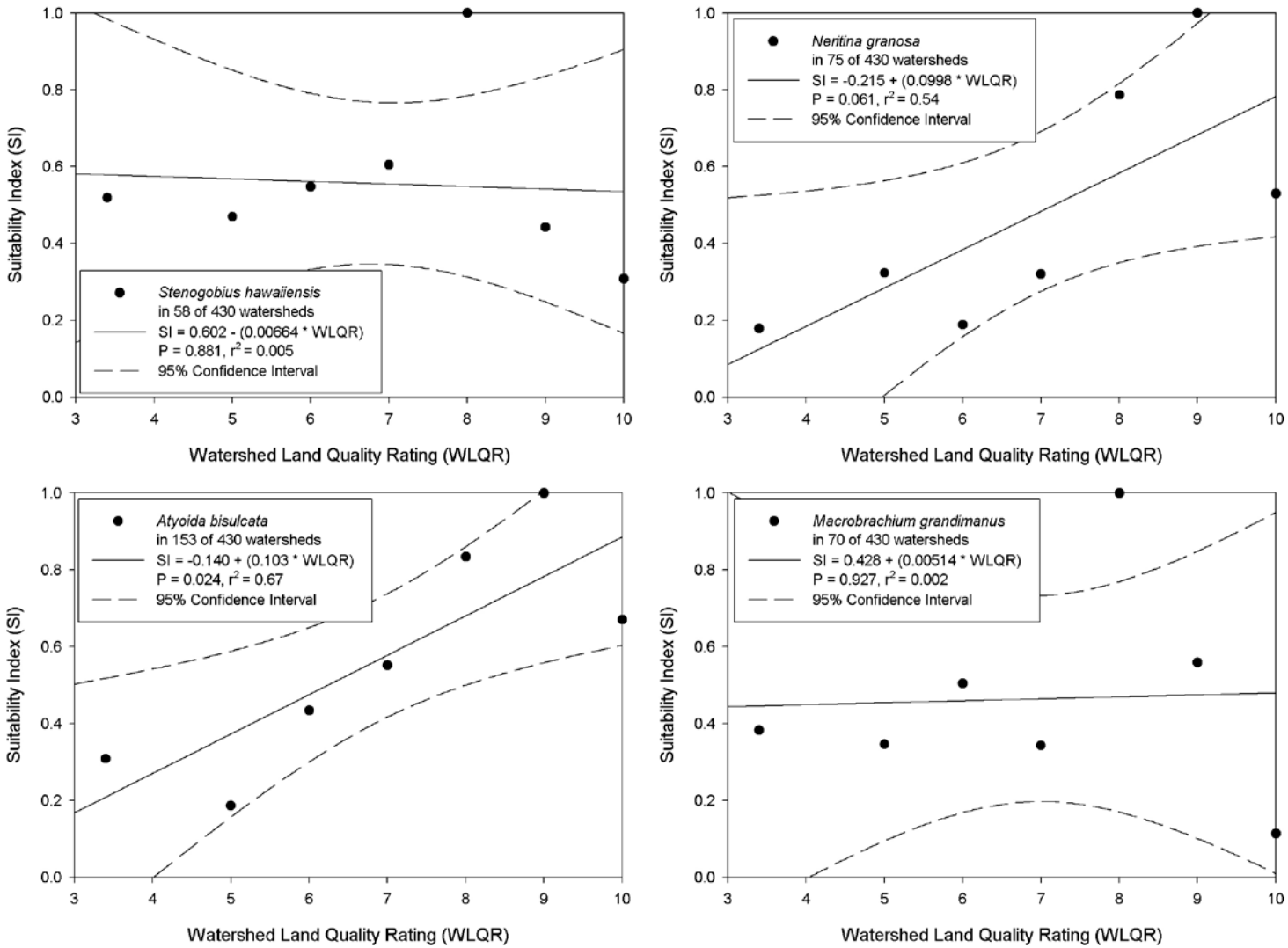

Figure 31: Suitability Indices for Watershed Land Quality Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

Watershed Suitability Models for each species

Awaous guamensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.043 + (0.425 * \mathrm{WWR}) + (0.543 * \mathrm{WSR}) + (0.280 * \mathrm{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 120.7 (P = <0.001), and correctly predicted the presence or absence of *Awaous guamensis* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Awaous guamensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Awaous guamensis* occurred (Figure 32).

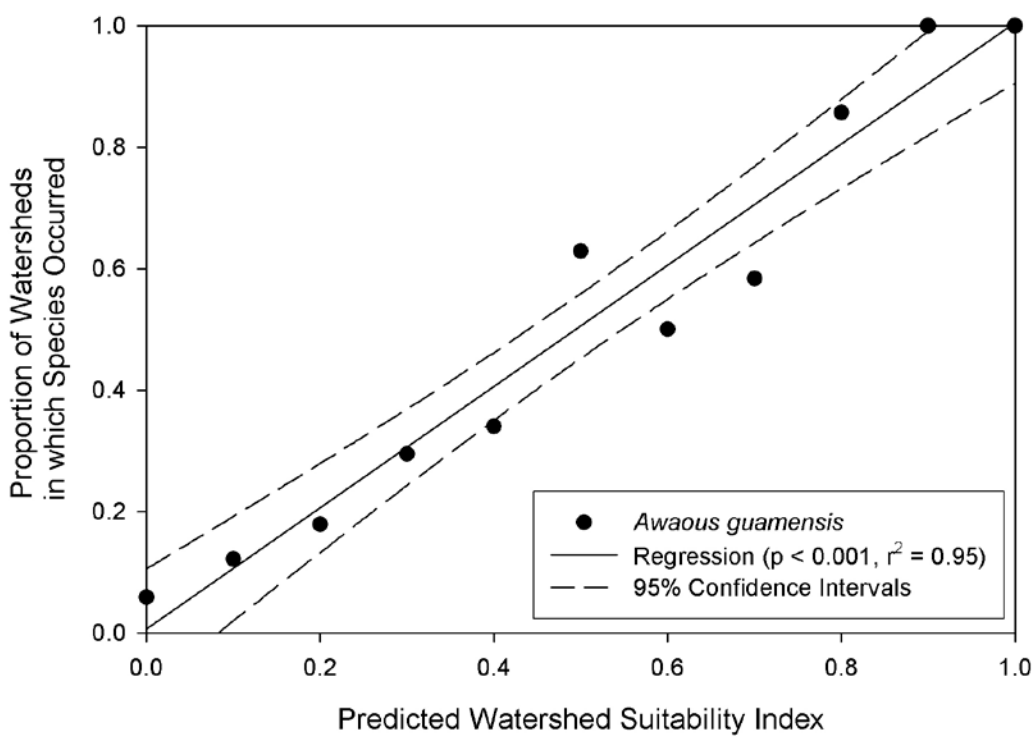

Figure 32: Proportion of the total watersheds where *Awaous guamensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.164 + (0.493 * \mathrm{WWR}) + (0.362 * \mathrm{WSR}) + (0.121 * \mathrm{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WStR = Watershed Stewardship Rating, ($p = 0.025$).

This equation had a Likelihood Ratio Test Statistic of 117.8 (P = <0.001), and correctly predicted the presence or absence of *Lentipes concolor* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Lentipes concolor*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Lentipes concolor* occurred (Figure 33).

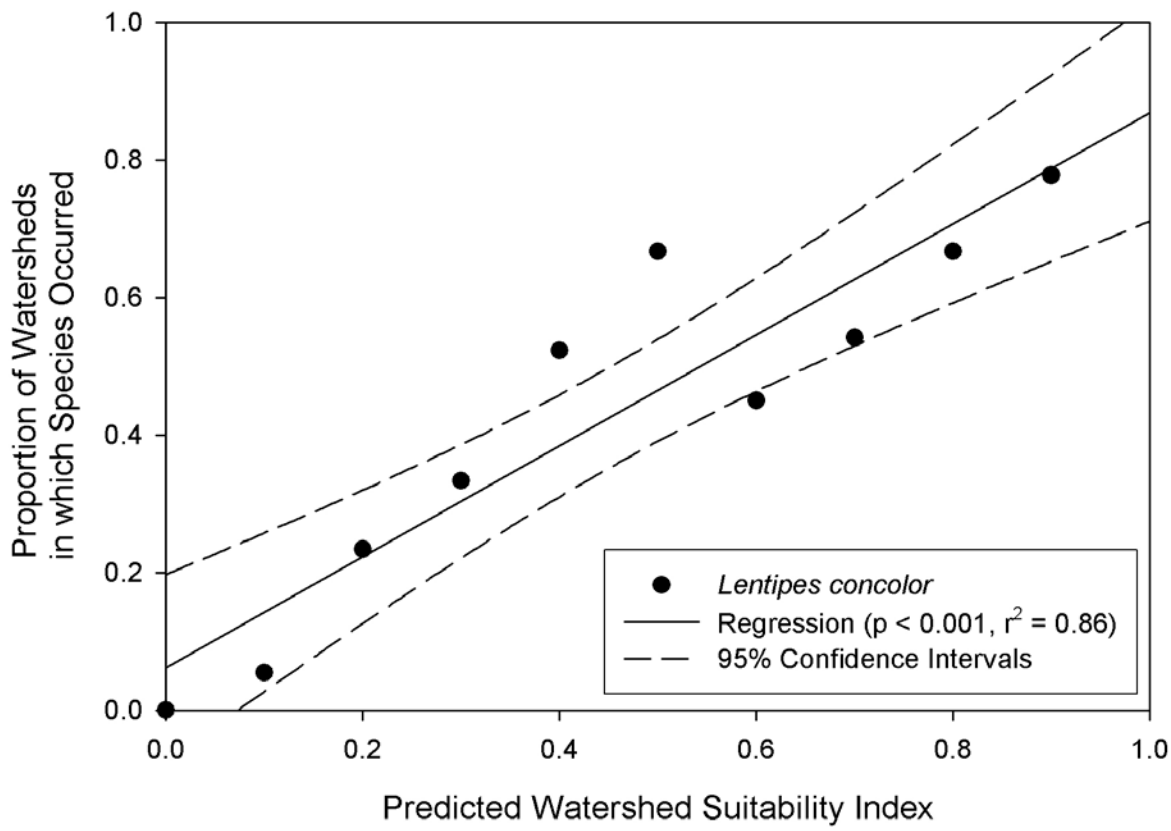

Figure 33: Proportion of the total watersheds where *Lentipes concolor* was observed within each 0.1 group of the Watershed Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.195 + (0.358 * \mathrm{WWR}) + (0.539 * \mathrm{WSR}) + (0.135 * \mathrm{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Stewardship Rating, ($p = 0.012$).

This equation had a Likelihood Ratio Test Statistic of 97.1 ($P = <0.001$), and correctly predicted the presence or absence of *Sicyopterus stimpsoni* in 340 of 430 watersheds (79.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Sicyopterus stimpsoni*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Sicyopterus stimpsoni* occurred (Figure 34).

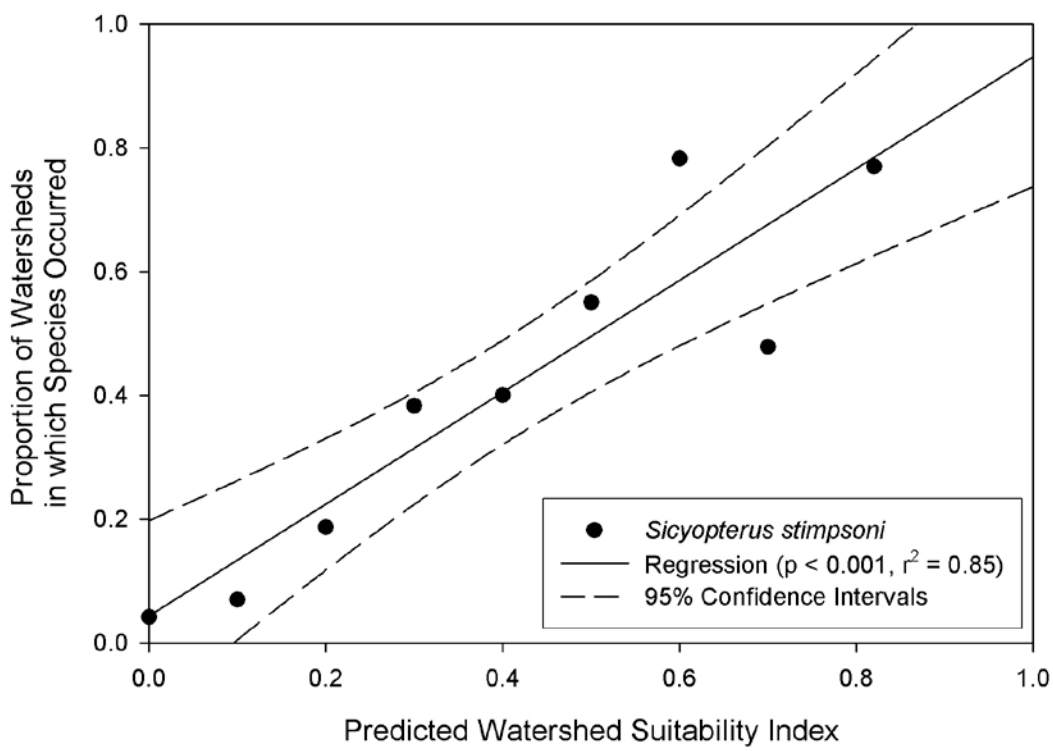

Figure 34: Proportion of the total watersheds where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Watershed Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.923 + (0.206 * \mathrm{WWR}) + (0.796 * \mathrm{WSR}))}}$$

where: WWR = Watershed Wetness Rating, (p = 0.003)

WSR = Watershed Size Rating, (p < 0.001).

This equation had a Likelihood Ratio Test Statistic of 73.4 (P = <0.001), and correctly predicted the presence or absence of *Stenogobius hawaiiensis* in 375 of 430 watersheds (87.2% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Stenogobius hawaiiensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Stenogobius hawaiiensis* occurred (Figure 35).

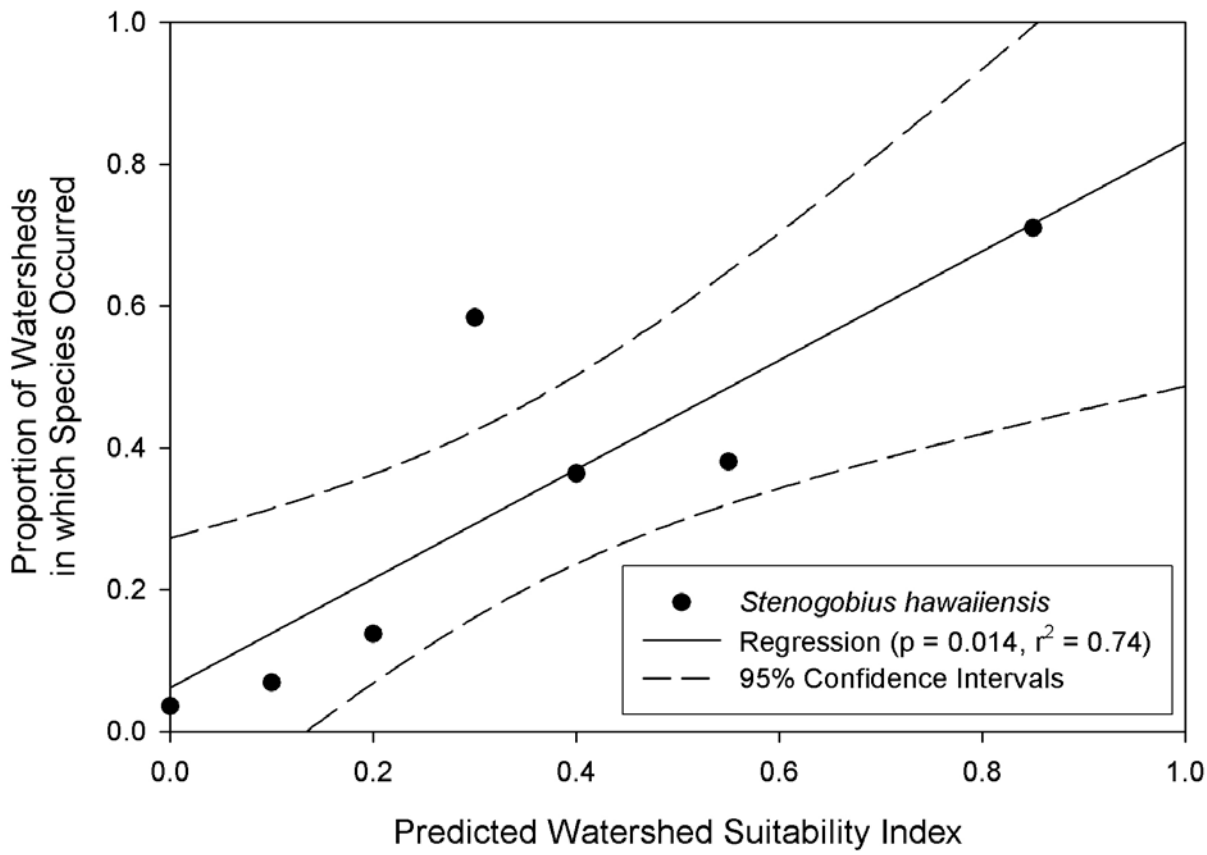

Figure 35: Proportion of the total watersheds where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-3.552 + (0.245 * \mathrm{WWR}) + (0.376 * \mathrm{WSR}) + (0.278 * \mathrm{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 65.4 ($P = <0.001$), and correctly predicted the presence or absence of *Eleotris sandwicensis* in 343 of 430 watersheds (79.8% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Eleotris sandwicensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Eleotris sandwicensis* occurred (Figure 36).

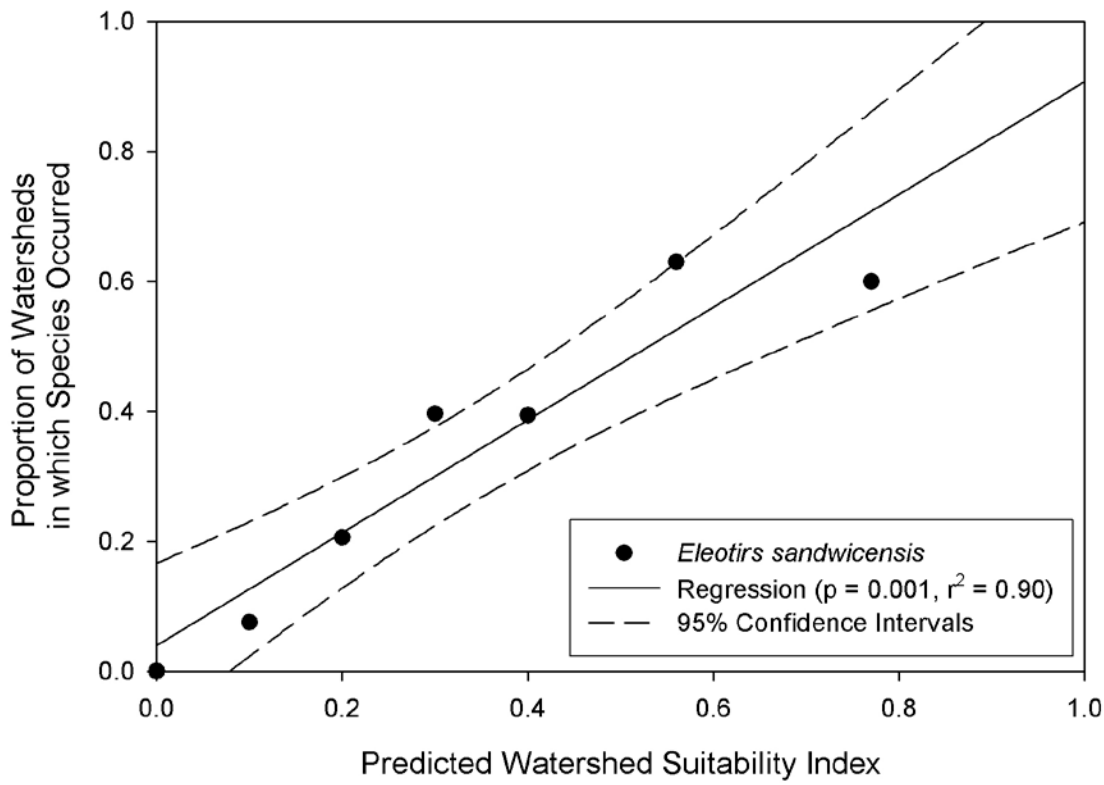

Figure 36: Proportion of the total watersheds where *Eleotris sandwicensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.806 + (0.375 * \mathrm{WWR}) + (0.435 * \mathrm{WSR}) + (0.177 * \mathrm{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Stewardship Rating, ($p = 0.003$).

This equation had a Likelihood Ratio Test Statistic of 77.5 ($P = <0.001$), and correctly predicted the presence or absence of *Neritina granosa* in 357 of 430 watersheds (83.0% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Neritina granosa*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Neritina granosa* occurred (Figure 37).

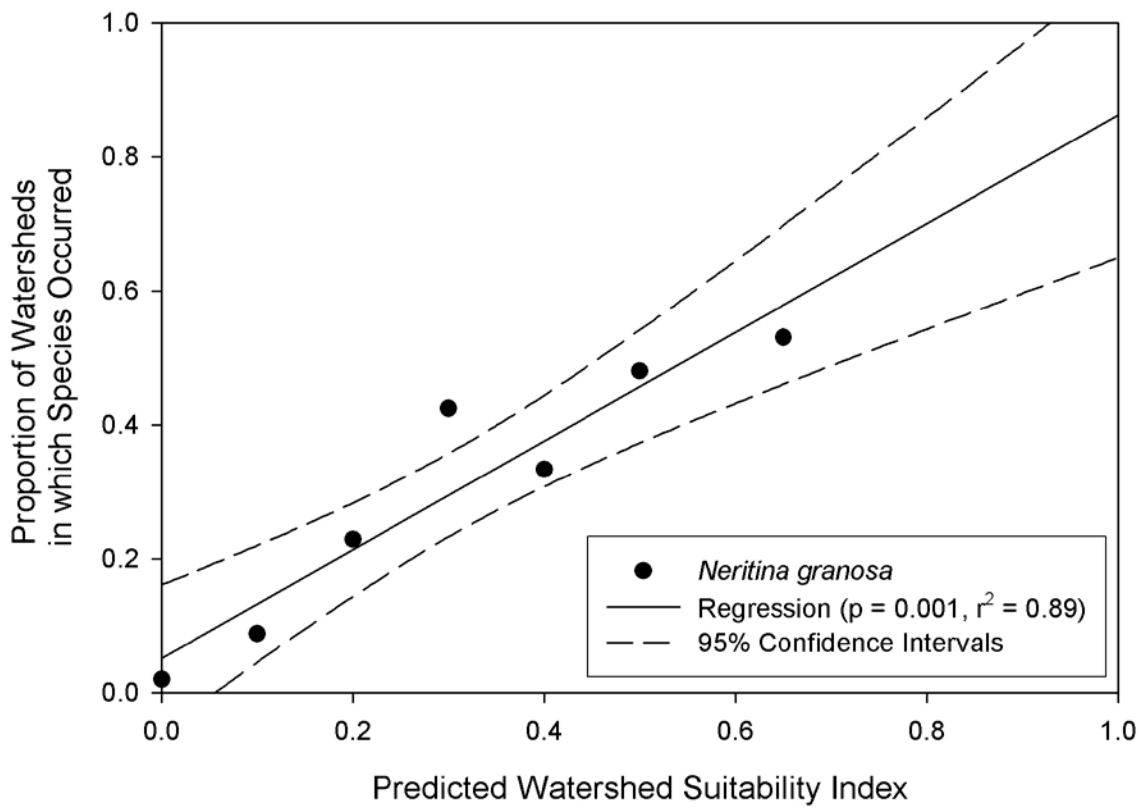

Figure 37: Proportion of the total watersheds where *Neritina granosa* was observed within each 0.1 group of the Watershed Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.458 + (0.508 * \mathrm{WWR}) + (0.497 * \mathrm{WSR}) + (0.179 * \mathrm{WStR}) + (0.165 * \mathrm{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WStR = Watershed Stewardship Rating, ($p = 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p = 0.04$).

This equation had a Likelihood Ratio Test Statistic of 153.3 (P = <0.001), and correctly predicted the presence or absence of *Atyoida bisulcata* in 336 of 430 watersheds (78.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Atyoida bisulcata*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Atyoida bisulcata* occurred (Figure 38).

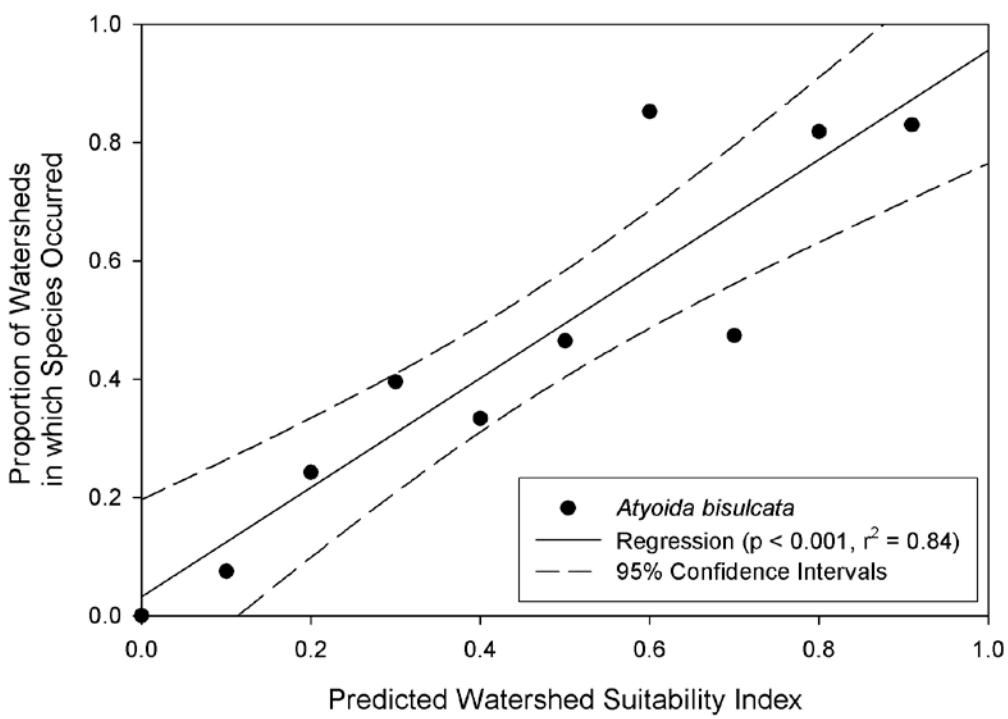

Figure 38: Proportion of the total watersheds where *Atyoida bisulcata* was observed within each 0.1 group of the Watershed Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.942 + (0.286 * \mathrm{WWR}) + (0.775 * \mathrm{WSR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 82.4 ($P = <0.001$), and correctly predicted the presence or absence of *Macrobrachium grandimanus* in 366 of 430 watersheds (85.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Macrobrachium grandimanus*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Macrobrachium grandimanus* occurred (Figure 39).

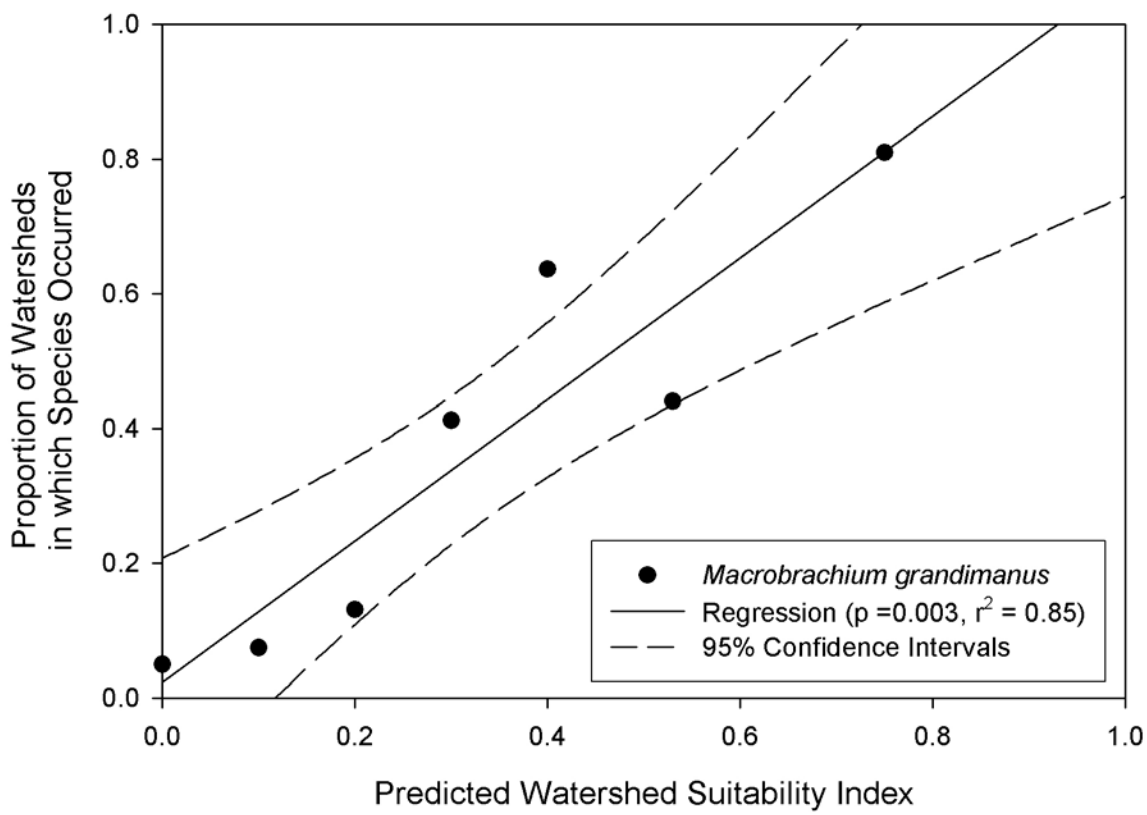

Figure 39: Proportion of the total watersheds where *Macrobrachium grandimanus* was observed within each 0.1 group of the Watershed Suitability Index equation for *Macrobrachium grandimanus*.

Appendix 2: Instream Distribution Scale:

Unlike the watershed and stream metric relationships, the instream distribution model is more of a GIS construct than a statistical construct. The data that underlies the prediction of instream distribution for the native amphidromous species comes primarily from DARs point quadrat surveys. In general, these standardized surveys have been conducted by state biologists and technicians in a wide variety of locations in many different streams across all of the lower Hawaiian Islands. The point quadrat survey is a visual survey in which both habitat and species information are recorded within a defined point in a stream. As a result, at a defined location we have a record of species occurrence. This survey location can be mapped and the co-occurring elevation, distance inland, and maximum downstream slope can be extracted from gridded GIS data. This results in a data set in which all survey points have a location, the values for the instream distribution variables, and the presence or absence of each species.

To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977) and as reported for Hawaiian stream animals (Parham 2008). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution.

The decision on the bin sizes for the various continuous variables was set subjectively to balance several factors. First, the number of samples in each bin attempted to have at least 200 observations from the total number of samples. Next, the bin sizes were adjusted to make the number of samples in each bin as consistent as possible, and finally, the bins were distributed to cover a range of biologically meaningful values. For example, the native amphidromous animals migrate upstream from the ocean. As the elevation increases different species are less likely to be observed, therefore, the elevation bins are more closely spaced at lower elevations and more widely spaced at higher elevations to see changes that occur as the animals move upstream.

The selection of animals included in this analysis was based on the overall number of sites in which the animals were observed. In most cases, at least 50 independent site observations were needed to include the animal in development of specific suitability criteria, although in some cases smaller sample sizes were accepted if the species had consistently been observed in other suitability criteria variables. In a perfect database, all observations of the animals would have all of the information included, but in many cases, the information for certain variables were not recorded so sample size varies among criteria. The database and spreadsheets are designed to allow changes in bin distribution or species to allow user adjustment to account for specific project needs.

GIS Suitability Modeling

The use of table based suitability criteria was in part based on the desire to allow rapid integration of the results with the GIS map-based analyses. The spreadsheet results were multiplied by 100 and then converted to integer values to fit the GIS reclassification requirements. The bins were split into a “from value” and “to value” with the integer suitability for each species in the subsequent columns. For example using elevation, the “from value” may be 0 and the “to value” was 2, the next “from value” would be 3 to 5, etc. No overlap of subsequent “from” and “to” values are allowed, although the “from” and “to” value on an individual line can be the same value.

After converting the suitability table to the reclassification format, the spreadsheet was converted to a database table (dbf). Next, the dbf table was imported into ArcGIS. In ArcGIS, the distributional layers were added to the map. Each layer was developed in previous work from the

USGS 10 meter digital elevation model. The distribution layers of elevation, distance inland, and maximum downstream slope were used to predict instream distribution of the native amphidromous animals. Prediction of the instream distribution of introduced animals is difficult as most of their locations are based on proximity to the place of introduction in the stream and not migration.

The instream distributional variables were combined by using map algebra where the results of each of the suitability criteria layers were multiplied together to describe a range of conditions from most to least suitable in a stream. Within the stream sections that a species is expected to occur, the habitat suitability criteria describe the suitable habitat for the species. To determine the appropriate combination method within the ArcGIS map algebra, two of the most commonly used methods were tried. These combination methods were an additive model and a multiplicative model.

- Instream Distribution Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)
  where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0
- Instream Distribution Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

To determine which of these combination methods were more appropriate for an individual species, the variables for elevation, distance inland, and downstream barrier height were combined using two different relationships. Next, each relationship was range standardized with a minimum value of 0 and a maximum value of 1. Then, the results of each relationship for all sites with all data for each variable in the database were calculated. The sites were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 100 of the 8300 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples. The results of the comparison of predicted suitability with the proportion of samples containing a species were plotted on a graph and analyzed using linear regression.

To select the more appropriate relationship, two criteria were used. First, the distribution of predicted results to observed proportions was visually compared. If predicted values between 0 and 1 resulted in a range of proportions between 0 and 1, the relationship was considered acceptable. If both relationships were acceptable to the first criteria, then the relationship with the higher r^2 value for the linear regression was chosen.

Figure 40 to Figure 45 graphically show the suitability for the native amphidromous stream animals. While Table 2 to Table 25 show the bins, frequency, utilization, suitability, and smooth suitability for the species. Finally, Figure 46 to Figure 53 show the selected combination method and its associated linear regression with statistics for each species.

Elevation Suitability Indices

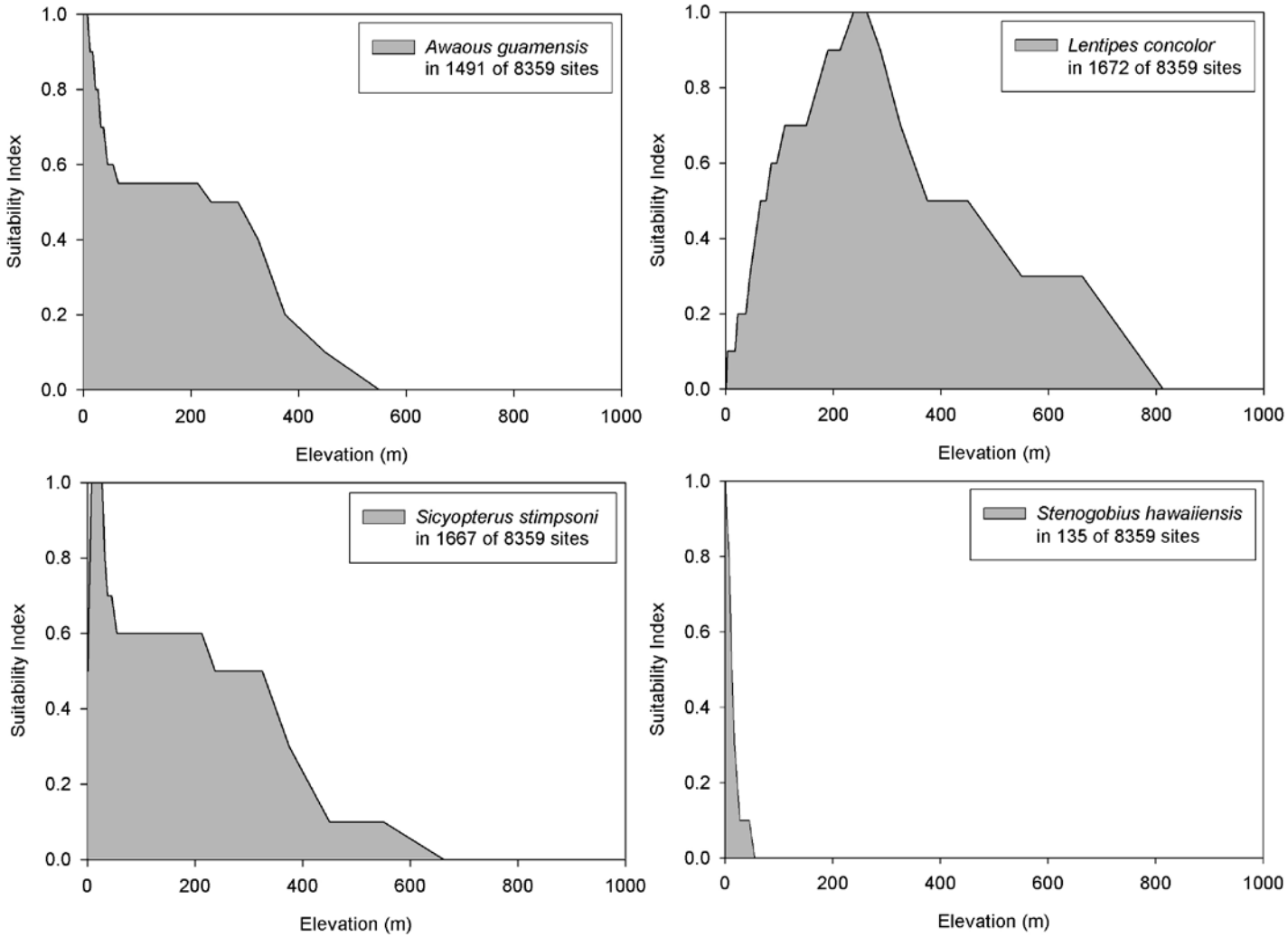

Figure 40: Suitability Indices for Elevation for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

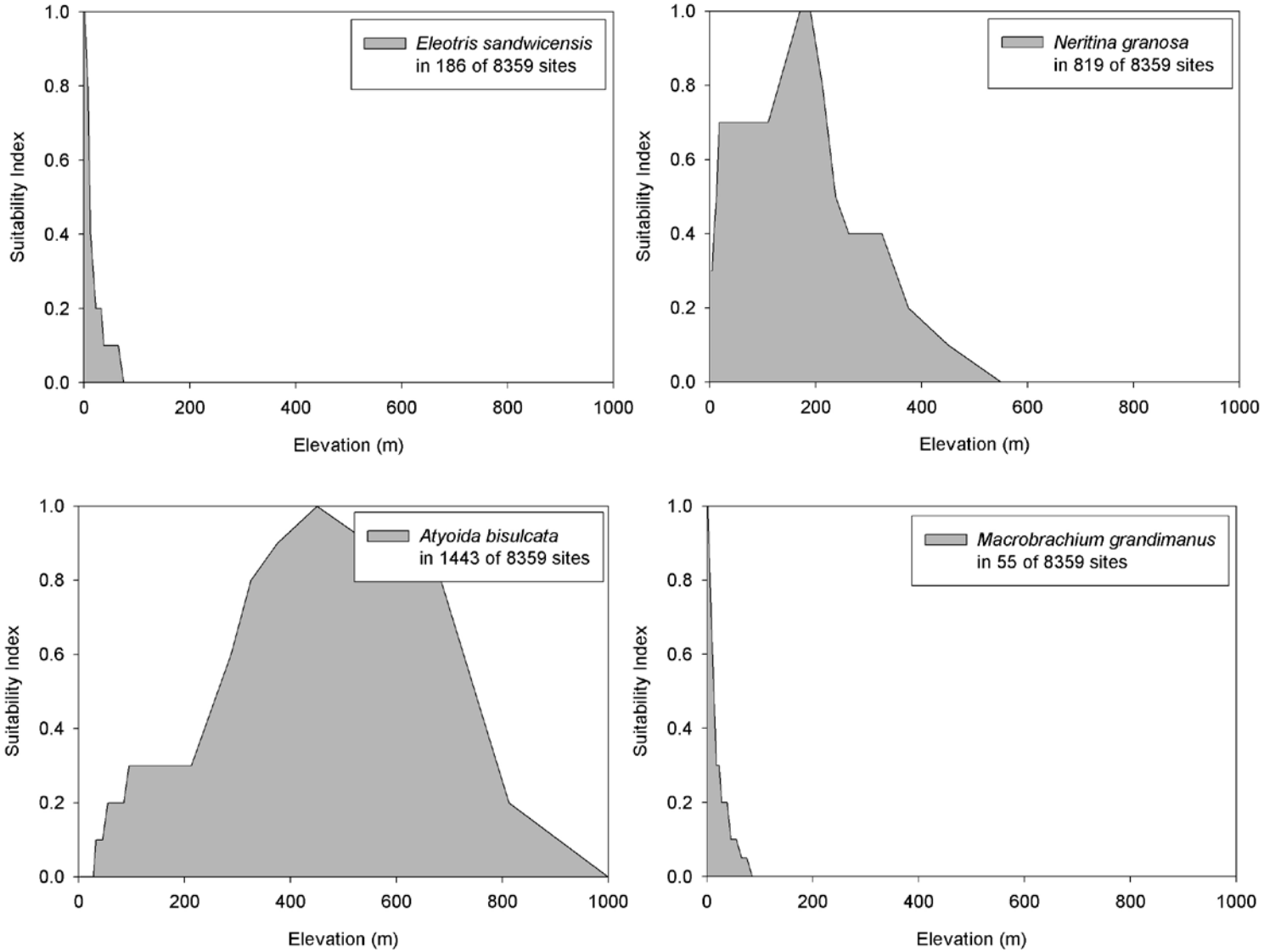

Figure 41: Suitability Indices for Elevation for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

Distance Inland Suitability Indices

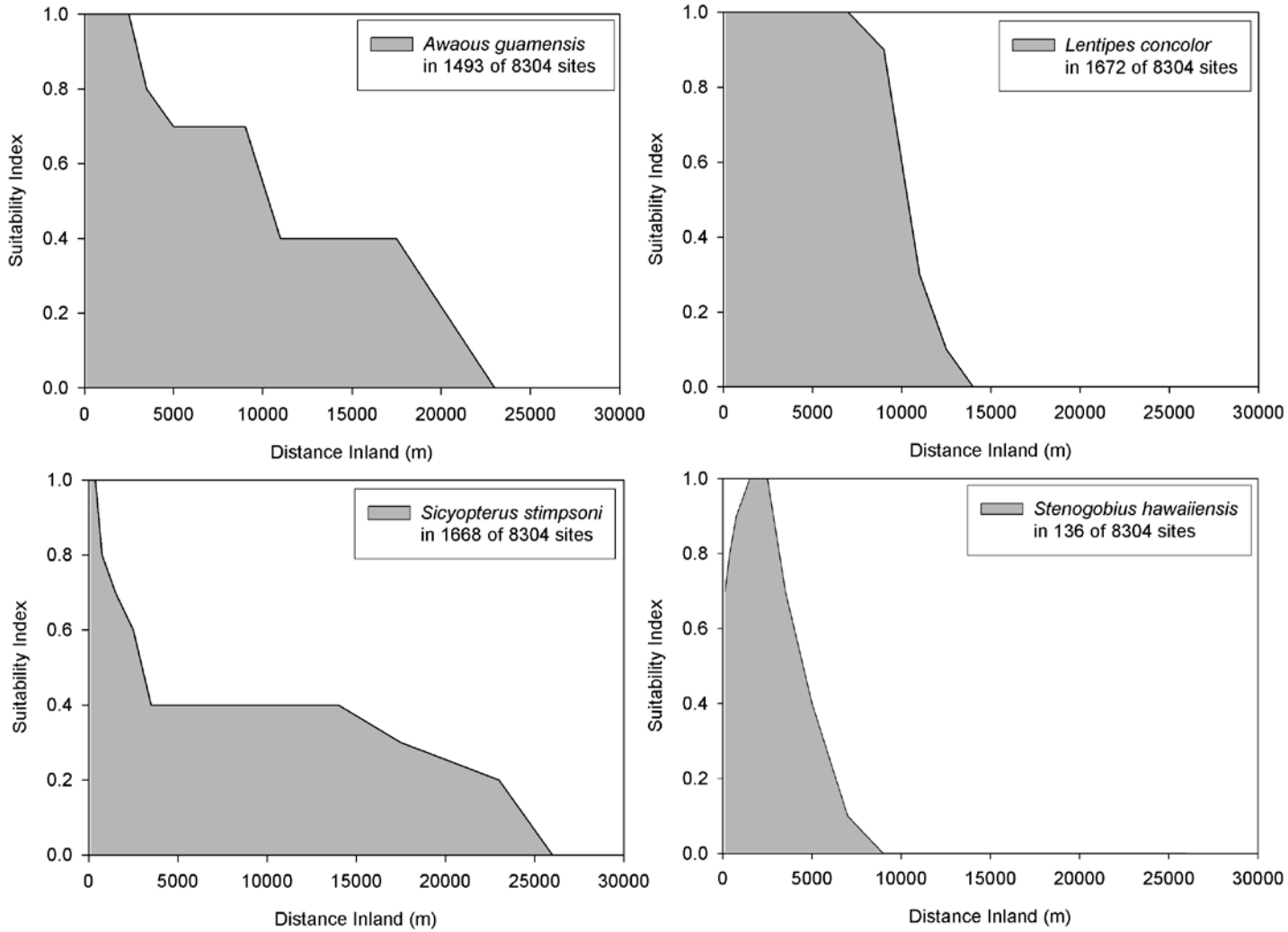

Figure 42: Suitability Indices for Distance Inland for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

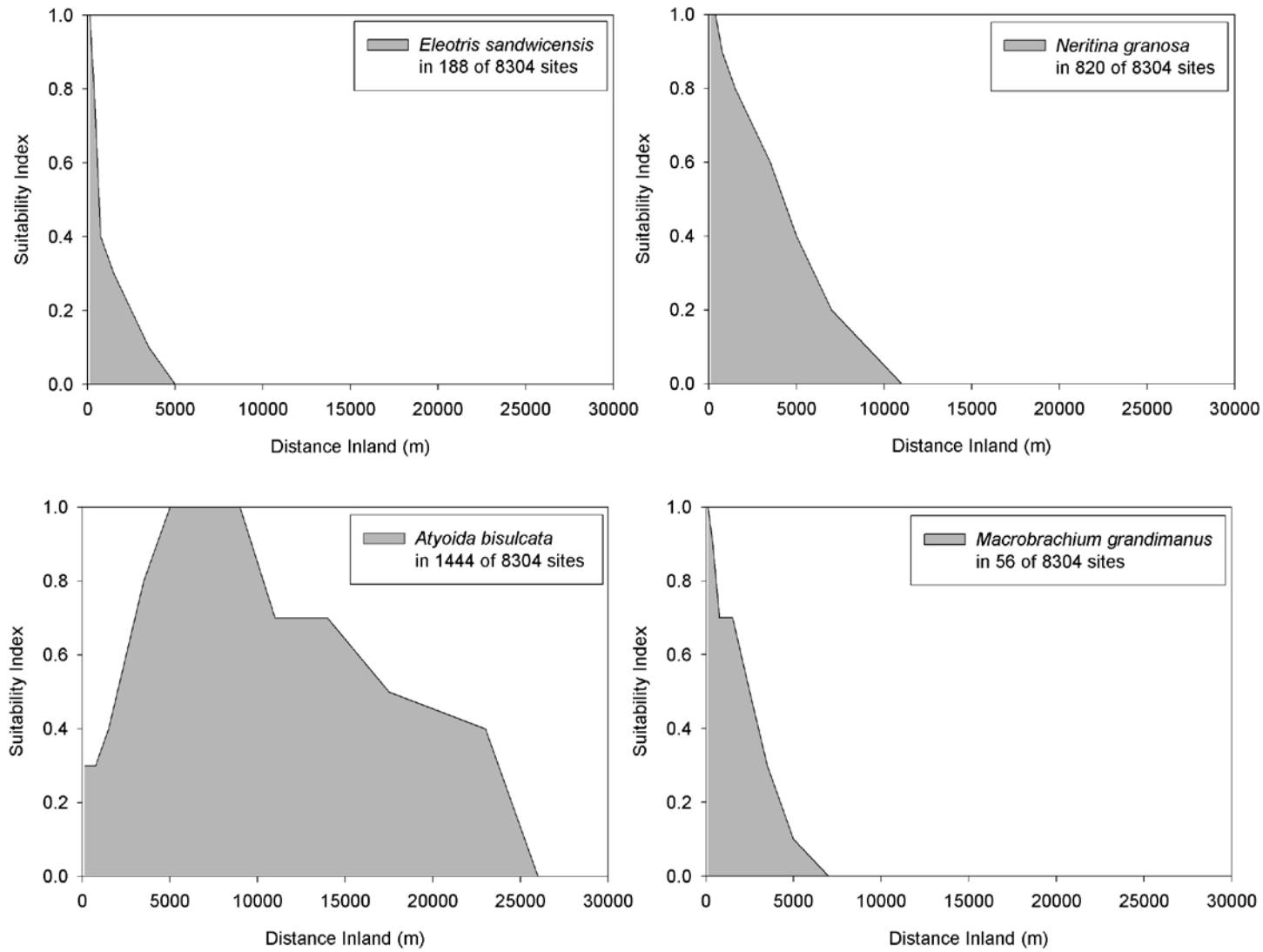

Figure 43: Suitability Indices for Distance Inland for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

Barrier Height Suitability Indices

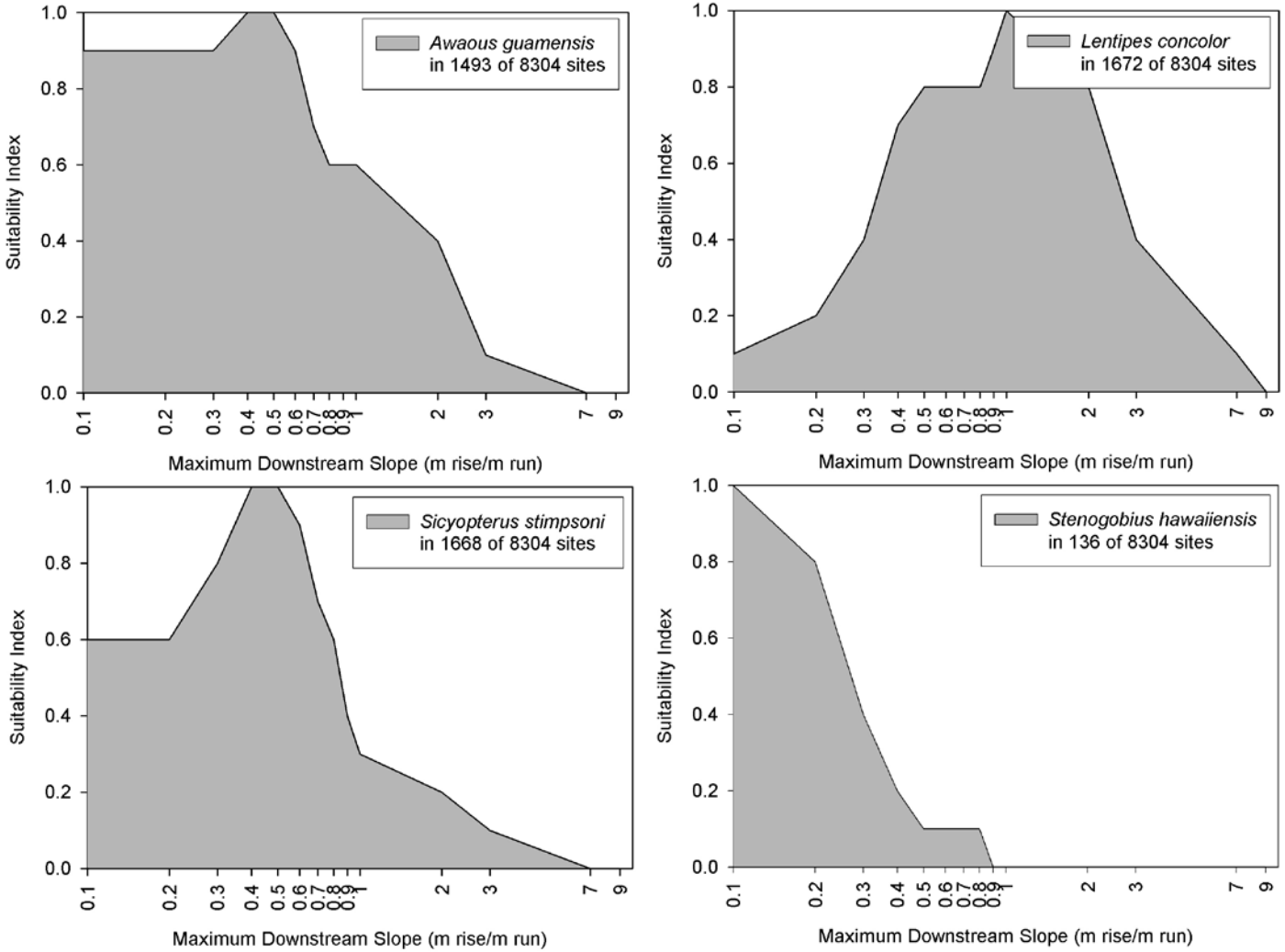

Figure 44: Suitability Indices for Barriers (maximum downstream slope over 10m distance) for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

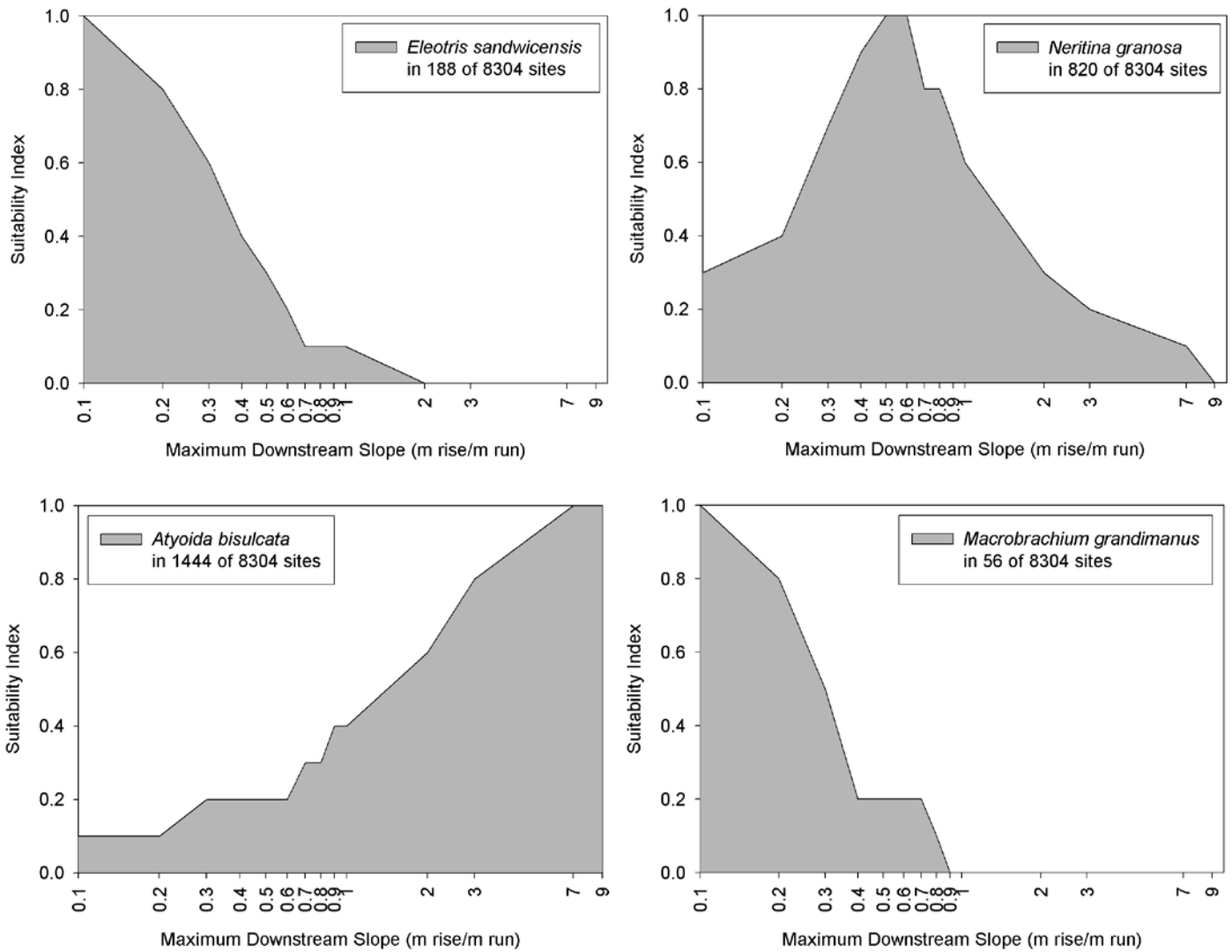

Figure 45: Suitability Indices for Barriers (maximum downstream slope over 10m distance) for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

Table 2: Frequency of occurrence for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	111	1	29	12	1	27	1	5	9	2	33	3	4	6	12	5	8
5	331	5	109	56	2	71	11	11	47	35	70	1	2	87	38	4	7
10	470	12	136	46	12	63	15	14	105	31	100	13	3	162	36	6	33
15	333	5	93	18	9	20	12	7	61	20	89	12	9	111	20	8	20
20	274	9	73	5	6	10	14	3	51	41	77	9	3	78	8	6	23
25	315	4	76	14	3	29	18	2	60	53	84	11	2	100	6	6	27
30	243	7	55	9	3	6	34	3	60	34	74	7	1	83	6	2	17
35	306	10	78	5	2	9	22	3	81	40	84	15	3	79	1	4	37
40	186	10	34	8	2	2	18	0	53	26	57	7	1	40	2	3	22
50	355	23	71	1	6	2	41	3	66	28	130	25	4	70	1	6	45
60	414	44	71	6	4	4	82	0	85	50	144	11	15	91	3	9	31
70	284	38	53	2	2	1	58	1	76	19	90	4	5	55	1	2	23
80	393	46	51	1	1	5	94	0	81	31	151	3	7	59	0	4	8
90	245	30	24	0	1	0	47	1	51	15	111	5	4	34	0	8	6
100	174	30	26	0	0	2	47	0	36	16	62	5	2	40	0	3	5
120	319	59	68	1	2	1	106	2	74	43	86	11	7	57	1	17	8
140	324	53	46	0	2	0	101	0	81	51	87	9	5	53	0	14	4
160	296	42	70	0	2	0	88	0	69	46	87	16	5	68	0	3	13
180	311	41	55	1	2	0	102	0	56	60	86	13	5	89	0	4	4
200	220	41	52	0	3	0	83	0	27	45	60	10	2	48	0	4	8
225	288	43	49	0	1	0	110	0	42	46	88	9	2	48	0	9	4
250	287	50	44	1	3	0	102	0	28	19	100	8	3	43	0	7	3
275	215	55	24	0	1	1	114	0	21	10	46	1	1	29	0	4	4
300	189	64	41	0	0	0	71	0	2	22	47	0	1	41	0	0	1
350	298	122	37	0	2	0	69	0	15	17	81	4	1	52	0	6	2
400	278	147	17	0	2	0	71	0	2	8	99	1	6	16	0	2	1
500	406	192	5	0	2	0	77	0	2	10	173	0	1	21	0	0	2
600	320	209	0	0	6	0	50	0	1	1	76	0	26	5	0	0	41
700	126	45	4	0	1	0	8	0	0	0	69	2	5	2	0	0	7
1000	44	6	0	0	0	0	6	0	0	0	31	0	0	0	0	0	0
1000+	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Total	8359	1443	1491	186	83	253	1672	55	1342	819	2576	215	135	1667	135	146	414

Table 3: Percent Utilization for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1.3	0.1	1.9	6.5	1.2	10.7	0.1	9.1	0.7	0.2	1.3	1.4	3.0	0.4	8.9	3.4	1.9
5	4.0	0.3	7.3	30.1	2.4	28.1	0.7	20.0	3.5	4.3	2.7	0.5	1.5	5.2	28.1	2.7	1.7
10	5.6	0.8	9.1	24.7	14.5	24.9	0.9	25.5	7.8	3.8	3.9	6.0	2.2	9.7	26.7	4.1	8.0
15	4.0	0.3	6.2	9.7	10.8	7.9	0.7	12.7	4.5	2.4	3.5	5.6	6.7	6.7	14.8	5.5	4.8
20	3.3	0.6	4.9	2.7	7.2	4.0	0.8	5.5	3.8	5.0	3.0	4.2	2.2	4.7	5.9	4.1	5.6
25	3.8	0.3	5.1	7.5	3.6	11.5	1.1	3.6	4.5	6.5	3.3	5.1	1.5	6.0	4.4	4.1	6.5
30	2.9	0.5	3.7	4.8	3.6	2.4	2.0	5.5	4.5	4.2	2.9	3.3	0.7	5.0	4.4	1.4	4.1
35	3.7	0.7	5.2	2.7	2.4	3.6	1.3	5.5	6.0	4.9	3.3	7.0	2.2	4.7	0.7	2.7	8.9
40	2.2	0.7	2.3	4.3	2.4	0.8	1.1	0.0	3.9	3.2	2.2	3.3	0.7	2.4	1.5	2.1	5.3
50	4.2	1.6	4.8	0.5	7.2	0.8	2.5	5.5	4.9	3.4	5.0	11.6	3.0	4.2	0.7	4.1	10.9
60	5.0	3.0	4.8	3.2	4.8	1.6	4.9	0.0	6.3	6.1	5.6	5.1	11.1	5.5	2.2	6.2	7.5
70	3.4	2.6	3.6	1.1	2.4	0.4	3.5	1.8	5.7	2.3	3.5	1.9	3.7	3.3	0.7	1.4	5.6
80	4.7	3.2	3.4	0.5	1.2	2.0	5.6	0.0	6.0	3.8	5.9	1.4	5.2	3.5	0.0	2.7	1.9
90	2.9	2.1	1.6	0.0	1.2	0.0	2.8	1.8	3.8	1.8	4.3	2.3	3.0	2.0	0.0	5.5	1.4
100	2.1	2.1	1.7	0.0	0.0	0.8	2.8	0.0	2.7	2.0	2.4	2.3	1.5	2.4	0.0	2.1	1.2
120	3.8	4.1	4.6	0.5	2.4	0.4	6.3	3.6	5.5	5.3	3.3	5.1	5.2	3.4	0.7	11.6	1.9
140	3.9	3.7	3.1	0.0	2.4	0.0	6.0	0.0	6.0	6.2	3.4	4.2	3.7	3.2	0.0	9.6	1.0
160	3.5	2.9	4.7	0.0	2.4	0.0	5.3	0.0	5.1	5.6	3.4	7.4	3.7	4.1	0.0	2.1	3.1
180	3.7	2.8	3.7	0.5	2.4	0.0	6.1	0.0	4.2	7.3	3.3	6.0	3.7	5.3	0.0	2.7	1.0
200	2.6	2.8	3.5	0.0	3.6	0.0	5.0	0.0	2.0	5.5	2.3	4.7	1.5	2.9	0.0	2.7	1.9
225	3.4	3.0	3.3	0.0	1.2	0.0	6.6	0.0	3.1	5.6	3.4	4.2	1.5	2.9	0.0	6.2	1.0
250	3.4	3.5	3.0	0.5	3.6	0.0	6.1	0.0	2.1	2.3	3.9	3.7	2.2	2.6	0.0	4.8	0.7
275	2.6	3.8	1.6	0.0	1.2	0.4	6.8	0.0	1.6	1.2	1.8	0.5	0.7	1.7	0.0	2.7	1.0
300	2.3	4.4	2.7	0.0	0.0	0.0	4.2	0.0	0.1	2.7	1.8	0.0	0.7	2.5	0.0	0.0	0.2
350	3.6	8.5	2.5	0.0	2.4	0.0	4.1	0.0	1.1	2.1	3.1	1.9	0.7	3.1	0.0	4.1	0.5
400	3.3	10.2	1.1	0.0	2.4	0.0	4.2	0.0	0.1	1.0	3.8	0.5	4.4	1.0	0.0	1.4	0.2
500	4.9	13.3	0.3	0.0	2.4	0.0	4.6	0.0	0.1	1.2	6.7	0.0	0.7	1.3	0.0	0.0	0.5
600	3.8	14.5	0.0	0.0	7.2	0.0	3.0	0.0	0.1	0.1	3.0	0.0	19.3	0.3	0.0	0.0	9.9
700	1.5	3.1	0.3	0.0	1.2	0.0	0.5	0.0	0.0	0.0	2.7	0.9	3.7	0.1	0.0	0.0	1.7
1000	0.5	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
1000+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0

Table 4: Standardized suitability for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1	0.01	0.79	0.64	0.33	1.00	0.02	1.00	0.28	0.09	0.30	0.38	0.44	0.16	0.94	0.85	0.56
5	1	0.02	1.00	1.00	0.22	0.88	0.06	0.74	0.50	0.52	0.21	0.04	0.07	0.76	1.00	0.23	0.17
10	1	0.04	0.88	0.58	0.94	0.55	0.06	0.66	0.78	0.32	0.21	0.39	0.08	1.00	0.67	0.24	0.55
15	1	0.02	0.85	0.32	1.00	0.25	0.07	0.47	0.64	0.29	0.27	0.51	0.33	0.97	0.52	0.45	0.47
20	1	0.05	0.81	0.11	0.81	0.15	0.10	0.24	0.65	0.73	0.28	0.47	0.13	0.83	0.25	0.41	0.66
25	1	0.02	0.73	0.26	0.35	0.38	0.11	0.14	0.67	0.82	0.27	0.50	0.08	0.92	0.17	0.36	0.67
30	1	0.04	0.69	0.22	0.46	0.10	0.26	0.27	0.87	0.68	0.30	0.41	0.05	0.99	0.22	0.15	0.55
35	1	0.05	0.77	0.10	0.24	0.12	0.14	0.22	0.93	0.64	0.27	0.70	0.12	0.75	0.03	0.25	0.94
40	1	0.08	0.56	0.25	0.40	0.04	0.18	0.00	1.00	0.68	0.31	0.53	0.07	0.62	0.09	0.30	0.92
50	1	0.10	0.61	0.02	0.63	0.02	0.22	0.19	0.65	0.39	0.37	1.00	0.14	0.57	0.02	0.32	0.99
60	1	0.16	0.52	0.09	0.36	0.04	0.37	0.00	0.72	0.59	0.35	0.38	0.45	0.64	0.06	0.41	0.58
70	1	0.20	0.57	0.04	0.26	0.01	0.39	0.08	0.94	0.33	0.32	0.20	0.22	0.56	0.03	0.13	0.63
80	1	0.18	0.39	0.02	0.09	0.05	0.45	0.00	0.72	0.39	0.38	0.11	0.22	0.44	0.00	0.19	0.16
90	1	0.19	0.30	0.00	0.15	0.00	0.36	0.09	0.73	0.30	0.45	0.29	0.20	0.40	0.00	0.61	0.19
100	1	0.26	0.45	0.00	0.00	0.05	0.51	0.00	0.73	0.45	0.36	0.41	0.14	0.67	0.00	0.32	0.22
120	1	0.28	0.65	0.02	0.23	0.01	0.63	0.14	0.81	0.66	0.27	0.49	0.27	0.52	0.03	1.00	0.20
140	1	0.25	0.43	0.00	0.23	0.00	0.59	0.00	0.88	0.77	0.27	0.39	0.19	0.47	0.00	0.81	0.10
160	1	0.22	0.72	0.00	0.25	0.00	0.56	0.00	0.82	0.76	0.29	0.77	0.21	0.67	0.00	0.19	0.34
180	1	0.20	0.54	0.02	0.24	0.00	0.62	0.00	0.63	0.94	0.28	0.59	0.20	0.83	0.00	0.24	0.10
200	1	0.29	0.72	0.00	0.50	0.00	0.71	0.00	0.43	1.00	0.27	0.65	0.11	0.63	0.00	0.34	0.28
225	1	0.23	0.52	0.00	0.13	0.00	0.72	0.00	0.51	0.78	0.31	0.44	0.09	0.48	0.00	0.59	0.11
250	1	0.27	0.47	0.02	0.39	0.00	0.67	0.00	0.34	0.32	0.35	0.40	0.13	0.43	0.00	0.46	0.08
275	1	0.39	0.34	0.00	0.17	0.02	1.00	0.00	0.34	0.23	0.21	0.07	0.06	0.39	0.00	0.35	0.15
300	1	0.52	0.66	0.00	0.00	0.00	0.71	0.00	0.04	0.57	0.25	0.00	0.07	0.63	0.00	0.00	0.04
350	1	0.63	0.38	0.00	0.25	0.00	0.44	0.00	0.18	0.28	0.27	0.19	0.04	0.51	0.00	0.38	0.05
400	1	0.81	0.19	0.00	0.27	0.00	0.48	0.00	0.03	0.14	0.36	0.05	0.27	0.17	0.00	0.13	0.03
500	1	0.72	0.04	0.00	0.18	0.00	0.36	0.00	0.02	0.12	0.43	0.00	0.03	0.15	0.00	0.00	0.04
600	1	1.00	0.00	0.00	0.69	0.00	0.29	0.00	0.01	0.02	0.24	0.00	1.00	0.05	0.00	0.00	1.00
700	1	0.55	0.10	0.00	0.29	0.00	0.12	0.00	0.00	0.00	0.55	0.23	0.49	0.05	0.00	0.00	0.43
1000	1	0.21	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
1000+	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: Smoothed standardized suitability for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1	0.02	0.90	0.82	0.28	0.94	0.04	0.87	0.39	0.30	0.25	0.21	0.26	0.46	0.97	0.54	0.36
5	1	0.03	0.89	0.74	0.50	0.81	0.05	0.80	0.52	0.31	0.24	0.27	0.20	0.64	0.87	0.44	0.43
10	1	0.03	0.91	0.63	0.72	0.56	0.06	0.62	0.64	0.38	0.23	0.32	0.16	0.91	0.73	0.31	0.39
15	1	0.04	0.85	0.34	0.92	0.32	0.07	0.46	0.69	0.45	0.25	0.46	0.18	0.93	0.48	0.37	0.56
20	1	0.03	0.80	0.23	0.72	0.26	0.09	0.28	0.65	0.62	0.27	0.49	0.18	0.90	0.31	0.41	0.60
25	1	0.04	0.74	0.20	0.54	0.21	0.16	0.22	0.73	0.75	0.28	0.46	0.09	0.91	0.21	0.31	0.62
30	1	0.04	0.73	0.19	0.35	0.20	0.17	0.21	0.82	0.72	0.28	0.53	0.08	0.89	0.14	0.25	0.72
35	1	0.06	0.67	0.19	0.37	0.09	0.19	0.16	0.93	0.67	0.30	0.55	0.08	0.79	0.11	0.23	0.80
40	1	0.08	0.65	0.12	0.42	0.06	0.18	0.14	0.86	0.57	0.32	0.74	0.11	0.65	0.05	0.29	0.95
50	1	0.11	0.56	0.12	0.46	0.04	0.26	0.06	0.79	0.55	0.34	0.64	0.22	0.61	0.06	0.34	0.83
60	1	0.16	0.56	0.05	0.41	0.03	0.33	0.09	0.77	0.43	0.34	0.53	0.27	0.59	0.04	0.29	0.74
70	1	0.18	0.49	0.05	0.24	0.04	0.40	0.03	0.79	0.43	0.35	0.23	0.29	0.55	0.03	0.24	0.46
80	1	0.19	0.42	0.02	0.17	0.02	0.40	0.06	0.80	0.34	0.38	0.20	0.21	0.47	0.01	0.31	0.33
90	1	0.21	0.38	0.01	0.08	0.03	0.44	0.03	0.73	0.38	0.40	0.27	0.19	0.50	0.00	0.38	0.19
100	1	0.24	0.47	0.01	0.13	0.02	0.50	0.08	0.76	0.47	0.36	0.40	0.20	0.53	0.01	0.65	0.20
120	1	0.27	0.51	0.01	0.15	0.02	0.57	0.05	0.81	0.63	0.30	0.43	0.20	0.55	0.01	0.71	0.17
140	1	0.25	0.60	0.01	0.24	0.00	0.59	0.05	0.84	0.73	0.28	0.55	0.22	0.55	0.01	0.67	0.21
160	1	0.22	0.56	0.01	0.24	0.00	0.59	0.00	0.78	0.82	0.28	0.59	0.20	0.66	0.00	0.41	0.18
180	1	0.23	0.66	0.01	0.33	0.00	0.63	0.00	0.63	0.90	0.28	0.67	0.17	0.71	0.00	0.26	0.24
200	1	0.24	0.59	0.01	0.29	0.00	0.68	0.00	0.52	0.91	0.28	0.56	0.13	0.65	0.00	0.39	0.16
225	1	0.26	0.57	0.01	0.34	0.00	0.70	0.00	0.43	0.70	0.31	0.50	0.11	0.52	0.00	0.46	0.16
250	1	0.30	0.44	0.01	0.23	0.01	0.80	0.00	0.40	0.44	0.29	0.30	0.09	0.44	0.00	0.46	0.11
275	1	0.39	0.49	0.01	0.19	0.01	0.79	0.00	0.24	0.37	0.27	0.15	0.08	0.49	0.00	0.27	0.09
300	1	0.51	0.46	0.00	0.14	0.01	0.72	0.00	0.19	0.36	0.24	0.09	0.05	0.51	0.00	0.24	0.08
350	1	0.65	0.41	0.00	0.17	0.00	0.54	0.00	0.08	0.33	0.29	0.08	0.12	0.43	0.00	0.17	0.04
400	1	0.72	0.20	0.00	0.23	0.00	0.43	0.00	0.07	0.18	0.35	0.08	0.11	0.27	0.00	0.17	0.04
500	1	0.84	0.07	0.00	0.38	0.00	0.38	0.00	0.02	0.09	0.34	0.02	0.43	0.12	0.00	0.04	0.36
600	1	0.76	0.04	0.00	0.39	0.00	0.26	0.00	0.01	0.05	0.40	0.08	0.51	0.08	0.00	0.00	0.49
700	1	0.59	0.03	0.00	0.33	0.00	0.22	0.00	0.00	0.01	0.50	0.08	0.50	0.03	0.00	0.00	0.48
1000	1	0.25	0.03	0.00	0.10	0.00	0.13	0.00	0.00	0.00	0.75	0.08	0.16	0.02	0.00	0.00	0.14
1000+	1	0.10	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00

Table 6: Frequency of occurrence for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	763	53	182	86	9	115	134	18	193	100	10	110	16	7	270	15	2	8
500	653	55	105	24	9	40	154	1	150	115	0	167	9	7	184	9	1	13
1,000	1050	101	191	24	13	34	250	10	220	150	1	267	24	12	301	24	6	42
2,000	1256	112	283	37	15	37	195	15	252	116	2	389	28	14	290	33	31	62
3,000	1136	183	217	10	7	18	158	8	223	140	0	378	50	21	187	22	25	104
4,000	1190	309	198	6	4	6	250	2	181	110	0	377	15	38	170	24	19	93
6,000	1116	319	132	0	12	2	339	2	86	59	0	362	34	14	135	8	31	48
8,000	528	161	48	1	5	1	141	0	30	28	0	218	14	7	65	1	18	18
12,000	396	112	55	0	6	1	48	0	6	2	0	170	13	6	44	0	12	11
17,000	136	23	42	0	3	0	3	0	2	0	0	63	8	5	16	0	1	7
17,000+	80	16	40	0	0	0	0	0	0	0	0	18	4	4	6	0	0	8
Total	8304	1444	1493	188	83	254	1672	56	1343	820	13	2519	215	135	1668	136	146	414

Table 7: Percent Utilization for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	9.2	3.7	12.2	45.7	10.8	45.3	8.0	32.1	14.4	12.2	76.9	4.4	7.4	5.2	16.2	11.0	1.4	1.9
500	7.9	3.8	7.0	12.8	10.8	15.7	9.2	1.8	11.2	14.0	0.0	6.6	4.2	5.2	11.0	6.6	0.7	3.1
1,000	12.6	7.0	12.8	12.8	15.7	13.4	15.0	17.9	16.4	18.3	7.7	10.6	11.2	8.9	18.0	17.6	4.1	10.1
2,000	15.1	7.8	19.0	19.7	18.1	14.6	11.7	26.8	18.8	14.1	15.4	15.4	13.0	10.4	17.4	24.3	21.2	15.0
3,000	13.7	12.7	14.5	5.3	8.4	7.1	9.4	14.3	16.6	17.1	0.0	15.0	23.3	15.6	11.2	16.2	17.1	25.1
4,000	14.3	21.4	13.3	3.2	4.8	2.4	15.0	3.6	13.5	13.4	0.0	15.0	7.0	28.1	10.2	17.6	13.0	22.5
6,000	13.4	22.1	8.8	0.0	14.5	0.8	20.3	3.6	6.4	7.2	0.0	14.4	15.8	10.4	8.1	5.9	21.2	11.6
8,000	6.4	11.1	3.2	0.5	6.0	0.4	8.4	0.0	2.2	3.4	0.0	8.7	6.5	5.2	3.9	0.7	12.3	4.3
12,000	4.8	7.8	3.7	0.0	7.2	0.4	2.9	0.0	0.4	0.2	0.0	6.7	6.0	4.4	2.6	0.0	8.2	2.7
17,000	1.6	1.6	2.8	0.0	3.6	0.0	0.2	0.0	0.1	0.0	0.0	2.5	3.7	3.7	1.0	0.0	0.7	1.7
17,000+	1.0	1.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.9	3.0	0.4	0.0	0.0	1.9

Table 8: Standardized suitability for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	1	0.23	0.48	1.00	0.53	1.00	0.58	1.00	1.00	0.74	1.00	0.31	0.36	0.18	1.00	0.75	0.08	0.10
500	1	0.28	0.32	0.33	0.62	0.41	0.78	0.06	0.91	1.00	0.00	0.55	0.23	0.21	0.80	0.52	0.04	0.20
1,000	1	0.32	0.36	0.20	0.56	0.21	0.78	0.40	0.83	0.81	0.07	0.55	0.39	0.23	0.81	0.87	0.17	0.40
2,000	1	0.29	0.45	0.26	0.54	0.20	0.51	0.51	0.79	0.52	0.12	0.67	0.38	0.22	0.65	1.00	0.72	0.49
3,000	1	0.53	0.38	0.08	0.28	0.11	0.46	0.30	0.78	0.70	0.00	0.72	0.75	0.37	0.47	0.74	0.65	0.92
4,000	1	0.85	0.33	0.04	0.15	0.03	0.69	0.07	0.60	0.52	0.00	0.68	0.21	0.64	0.40	0.77	0.47	0.78
6,000	1	0.94	0.24	0.00	0.49	0.01	1.00	0.08	0.30	0.30	0.00	0.70	0.52	0.25	0.34	0.27	0.81	0.43
8,000	1	1.00	0.18	0.02	0.43	0.01	0.88	0.00	0.22	0.30	0.00	0.89	0.45	0.27	0.35	0.07	1.00	0.34
12,000	1	0.93	0.28	0.00	0.69	0.02	0.40	0.00	0.06	0.03	0.00	0.93	0.56	0.30	0.31	0.00	0.89	0.28
17,000	1	0.55	0.62	0.00	1.00	0.00	0.07	0.00	0.06	0.00	0.00	1.00	1.00	0.74	0.33	0.00	0.22	0.51
17,000+	1	0.66	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.85	1.00	0.21	0.00	0.00	1.00

Table 9: Smoothed standardized suitability for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	1	0.25	0.40	0.66	0.58	0.70	0.68	0.53	0.95	0.87	0.50	0.43	0.30	0.20	0.90	0.64	0.06	0.15
500	1	0.27	0.39	0.51	0.57	0.54	0.71	0.49	0.91	0.85	0.36	0.47	0.33	0.21	0.87	0.71	0.10	0.23
1,000	1	0.29	0.38	0.26	0.58	0.27	0.69	0.32	0.84	0.78	0.06	0.59	0.33	0.22	0.75	0.80	0.31	0.36
2,000	1	0.38	0.40	0.18	0.46	0.17	0.58	0.40	0.80	0.68	0.06	0.65	0.51	0.27	0.64	0.87	0.51	0.60
3,000	1	0.56	0.39	0.13	0.32	0.11	0.55	0.29	0.72	0.58	0.04	0.69	0.45	0.41	0.51	0.83	0.61	0.73
4,000	1	0.77	0.32	0.04	0.31	0.05	0.72	0.15	0.56	0.51	0.00	0.70	0.49	0.42	0.40	0.59	0.64	0.71
6,000	1	0.93	0.25	0.02	0.36	0.02	0.86	0.05	0.38	0.38	0.00	0.76	0.39	0.38	0.36	0.37	0.76	0.52
8,000	1	0.95	0.23	0.01	0.53	0.01	0.76	0.03	0.20	0.21	0.00	0.84	0.51	0.27	0.33	0.11	0.90	0.35
12,000	1	0.83	0.36	0.01	0.71	0.01	0.45	0.00	0.11	0.11	0.00	0.94	0.67	0.43	0.33	0.02	0.70	0.38
17,000	1	0.71	0.63	0.00	0.56	0.01	0.16	0.00	0.04	0.01	0.00	0.80	0.80	0.68	0.29	0.00	0.37	0.60
17,000+	1	0.61	0.81	0.00	0.50	0.00	0.04	0.00	0.03	0.00	0.00	0.74	0.93	0.87	0.27	0.00	0.11	0.76

Table 10: Frequency of occurrence for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1177	44	237	59	21	99	15	24	205	37	459	55	25	140	75	35	142
0.2	1189	81	263	63	15	83	50	17	195	78	399	38	16	293	25	32	103
0.3	941	175	200	20	6	29	140	6	168	102	265	29	8	173	21	29	28
0.4	728	98	145	13	12	13	119	2	130	99	249	26	6	197	2	15	28
0.5	1160	96	298	22	16	15	447	2	201	230	263	15	7	490	6	13	16
0.6	442	79	93	3	2	7	110	2	58	59	170	14	8	89	3	1	17
0.7	259	32	40	3	1	5	58	1	46	33	91	3	3	57	3	3	10
0.8	283	69	21	1	0	1	75	0	48	27	81	20	9	47	0	9	3
0.9	254	46	34	2	0	1	68	0	75	44	76	3	2	28	0	3	0
1	421	148	75	2	1	1	157	0	30	23	98	3	1	31	1	3	3
2	1171	379	85	0	3	0	425	2	166	86	301	5	15	121	0	2	10
3	242	170	2	0	3	0	7	0	7	1	60	4	35	2	0	1	54
3+	37	27	0	0	3	0	1	0	14	1	7	0	0	0	0	0	0
Total	8304	1444	1493	188	83	254	1672	56	1343	820	2519	215	135	1668	136	146	414

Table 11: Percent Utilization for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	14.2	3.0	15.9	31.4	25.3	39.0	0.9	42.9	15.3	4.5	18.2	25.6	18.5	8.4	55.1	24.0	34.3
0.2	14.3	5.6	17.6	33.5	18.1	32.7	3.0	30.4	14.5	9.5	15.8	17.7	11.9	17.6	18.4	21.9	24.9
0.3	11.3	12.1	13.4	10.6	7.2	11.4	8.4	10.7	12.5	12.4	10.5	13.5	5.9	10.4	15.4	19.9	6.8
0.4	8.8	6.8	9.7	6.9	14.5	5.1	7.1	3.6	9.7	12.1	9.9	12.1	4.4	11.8	1.5	10.3	6.8
0.5	14.0	6.6	20.0	11.7	19.3	5.9	26.7	3.6	15.0	28.0	10.4	7.0	5.2	29.4	4.4	8.9	3.9
0.6	5.3	5.5	6.2	1.6	2.4	2.8	6.6	3.6	4.3	7.2	6.7	6.5	5.9	5.3	2.2	0.7	4.1
0.7	3.1	2.2	2.7	1.6	1.2	2.0	3.5	1.8	3.4	4.0	3.6	1.4	2.2	3.4	2.2	2.1	2.4
0.8	3.4	4.8	1.4	0.5	0.0	0.4	4.5	0.0	3.6	3.3	3.2	9.3	6.7	2.8	0.0	6.2	0.7
0.9	3.1	3.2	2.3	1.1	0.0	0.4	4.1	0.0	5.6	5.4	3.0	1.4	1.5	1.7	0.0	2.1	0.0
1	5.1	10.2	5.0	1.1	1.2	0.4	9.4	0.0	2.2	2.8	3.9	1.4	0.7	1.9	0.7	2.1	0.7
2	14.1	26.2	5.7	0.0	3.6	0.0	25.4	3.6	12.4	10.5	11.9	2.3	11.1	7.3	0.0	1.4	2.4
3	2.9	11.8	0.1	0.0	3.6	0.0	0.4	0.0	0.5	0.1	2.4	1.9	25.9	0.1	0.0	0.7	13.0
3+	0.4	1.9	0.0	0.0	3.6	0.0	0.1	0.0	1.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Table 12: Standardized suitability for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1.00	0.05	0.78	0.95	0.22	1.00	0.03	1.00	0.46	0.16	1.00	0.66	0.15	0.28	1.00	0.94	0.54
0.2	1.00	0.09	0.86	1.00	0.16	0.83	0.11	0.70	0.43	0.33	0.86	0.45	0.09	0.58	0.33	0.85	0.39
0.3	1.00	0.25	0.83	0.40	0.08	0.37	0.39	0.31	0.47	0.55	0.72	0.44	0.06	0.44	0.35	0.97	0.13
0.4	1.00	0.18	0.78	0.34	0.20	0.21	0.42	0.13	0.47	0.69	0.88	0.51	0.06	0.64	0.04	0.65	0.17
0.5	1.00	0.11	1.00	0.36	0.17	0.15	1.00	0.08	0.46	1.00	0.58	0.18	0.04	1.00	0.08	0.35	0.06
0.6	1.00	0.24	0.82	0.13	0.06	0.19	0.65	0.22	0.35	0.67	0.99	0.45	0.13	0.48	0.11	0.07	0.17
0.7	1.00	0.17	0.60	0.22	0.05	0.23	0.58	0.19	0.47	0.64	0.90	0.16	0.08	0.52	0.18	0.36	0.17
0.8	1.00	0.33	0.29	0.07	0.00	0.04	0.69	0.00	0.45	0.48	0.73	1.00	0.22	0.39	0.00	1.00	0.05
0.9	1.00	0.25	0.52	0.15	0.00	0.05	0.69	0.00	0.78	0.87	0.77	0.17	0.05	0.26	0.00	0.37	0.00
1	1.00	0.48	0.69	0.09	0.03	0.03	0.97	0.00	0.19	0.28	0.60	0.10	0.02	0.17	0.04	0.22	0.03
2	1.00	0.44	0.28	0.00	0.03	0.00	0.94	0.08	0.37	0.37	0.66	0.06	0.09	0.24	0.00	0.05	0.04
3	1.00	0.96	0.03	0.00	0.15	0.00	0.08	0.00	0.08	0.02	0.64	0.23	1.00	0.02	0.00	0.13	1.00
3+	1.00	1.00	0.00	0.00	1.00	0.00	0.07	0.00	1.00	0.14	0.49	0.00	0.00	0.00	0.00	0.00	0.00

Table 13: Smoothed standardized suitability for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1.00	0.07	0.82	0.97	0.19	0.91	0.07	0.85	0.45	0.24	0.93	0.56	0.12	0.43	0.66	0.89	0.46
0.2	1.00	0.13	0.82	0.78	0.15	0.73	0.18	0.67	0.46	0.35	0.86	0.52	0.10	0.43	0.56	0.92	0.35
0.3	1.00	0.18	0.82	0.58	0.15	0.47	0.31	0.38	0.46	0.52	0.82	0.46	0.07	0.55	0.24	0.82	0.23
0.4	1.00	0.18	0.87	0.37	0.15	0.24	0.60	0.18	0.47	0.74	0.73	0.37	0.05	0.69	0.16	0.66	0.12
0.5	1.00	0.18	0.86	0.27	0.14	0.18	0.69	0.15	0.43	0.79	0.81	0.38	0.07	0.71	0.08	0.36	0.14
0.6	1.00	0.18	0.81	0.23	0.09	0.19	0.74	0.17	0.42	0.77	0.82	0.27	0.08	0.67	0.12	0.26	0.14
0.7	1.00	0.25	0.57	0.14	0.03	0.15	0.64	0.14	0.42	0.60	0.87	0.54	0.14	0.46	0.10	0.48	0.13
0.8	1.00	0.25	0.47	0.14	0.02	0.11	0.65	0.06	0.57	0.67	0.80	0.44	0.12	0.39	0.06	0.58	0.07
0.9	1.00	0.35	0.50	0.10	0.01	0.04	0.78	0.00	0.47	0.54	0.70	0.42	0.10	0.28	0.01	0.53	0.03
1	1.00	0.39	0.50	0.08	0.02	0.03	0.87	0.03	0.45	0.51	0.67	0.11	0.05	0.23	0.01	0.22	0.02
2	1.00	0.63	0.34	0.03	0.07	0.01	0.66	0.03	0.21	0.22	0.63	0.13	0.37	0.15	0.01	0.14	0.36
3	1.00	0.80	0.10	0.00	0.39	0.00	0.36	0.03	0.48	0.18	0.59	0.10	0.36	0.09	0.00	0.06	0.35
3+	1.00	0.98	0.02	0.00	0.58	0.00	0.07	0.00	0.54	0.08	0.56	0.12	0.50	0.01	0.00	0.06	0.50

Awaous guamensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

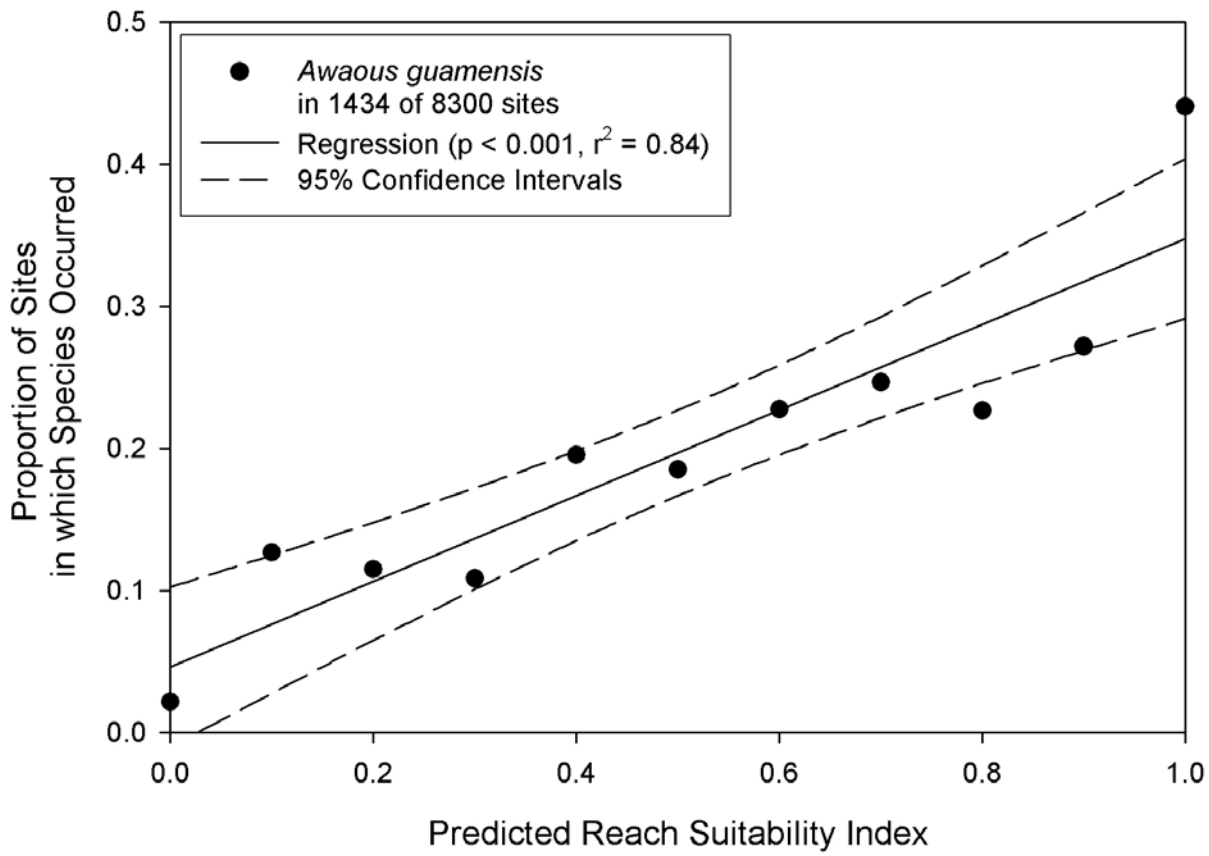

Figure 46: Proportion of the total sites where *Awaous guamensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

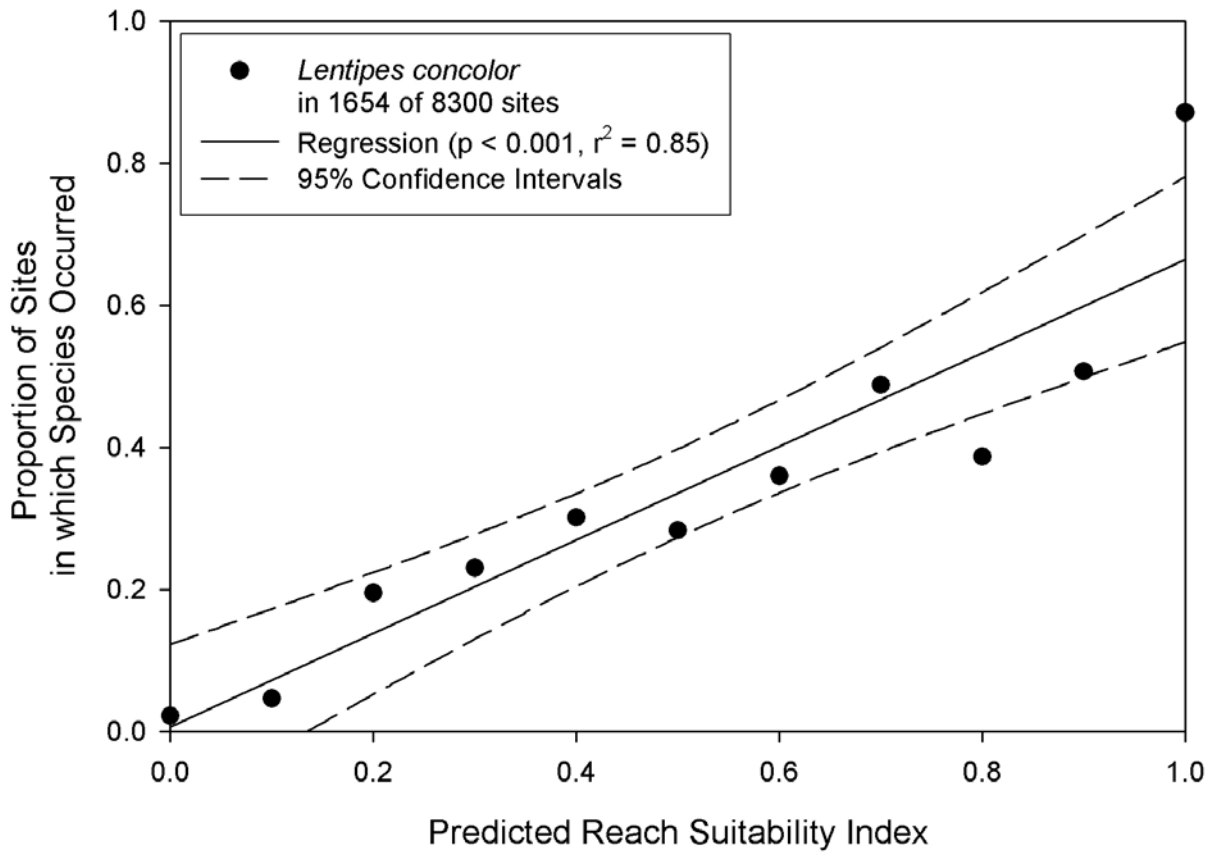

Figure 47: Proportion of the total sites where *Lentipes concolor* was observed within each 0.1 group of the Reach Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

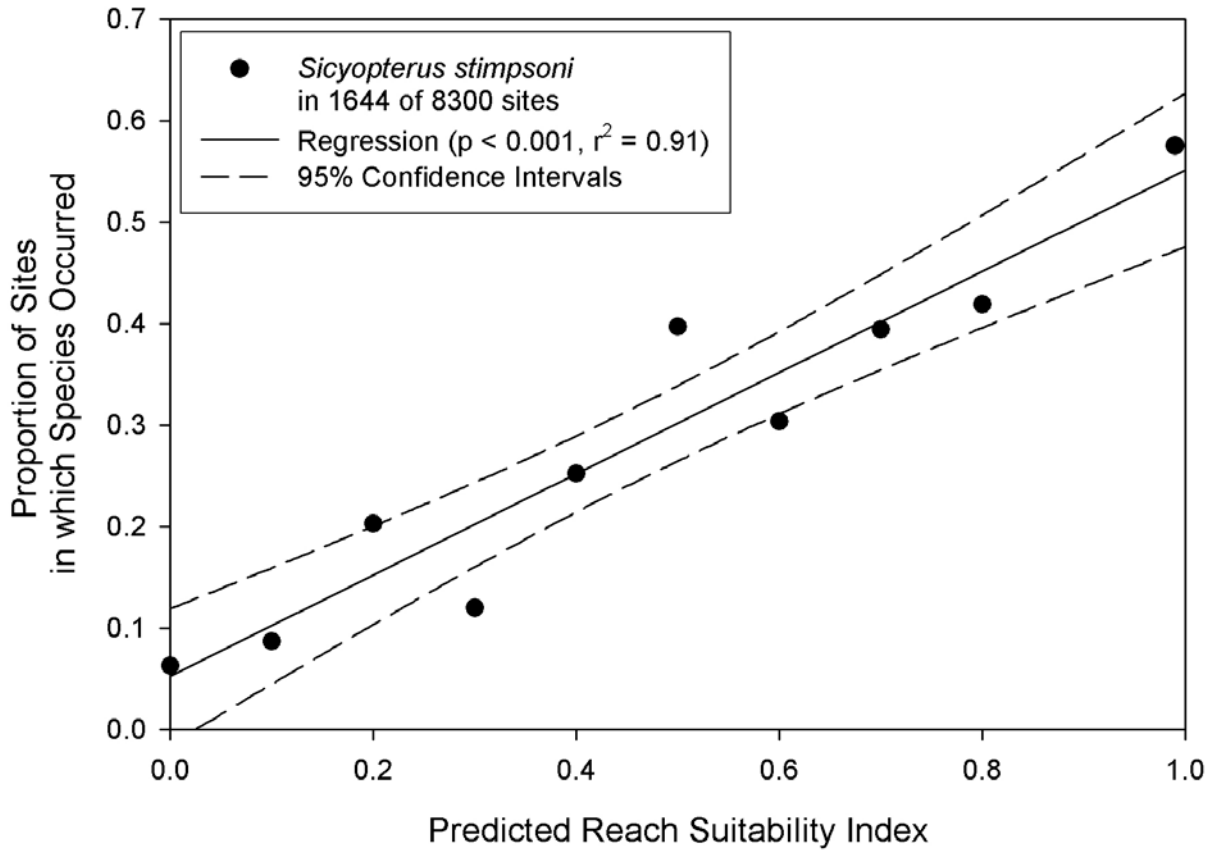

Figure 48: Proportion of the total sites where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Reach Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

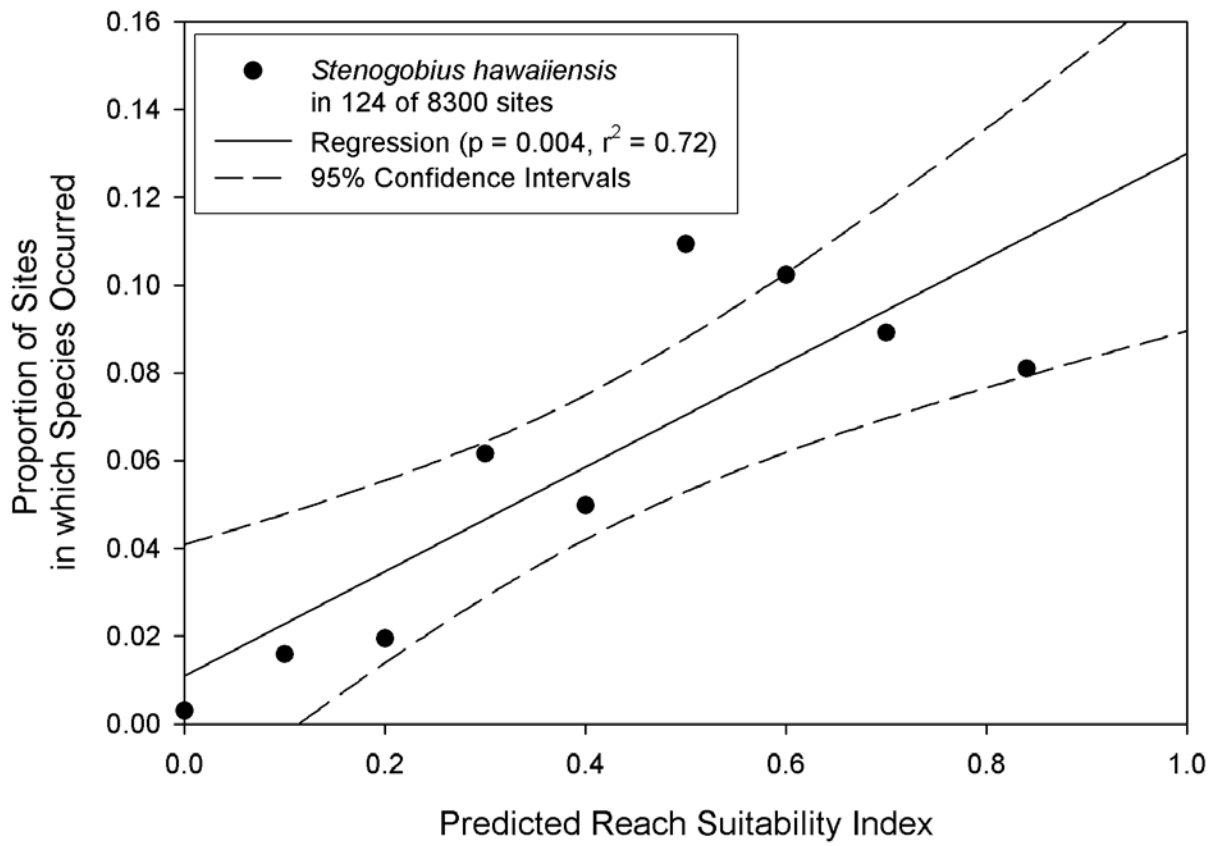

Figure 49: Proportion of the total sites where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

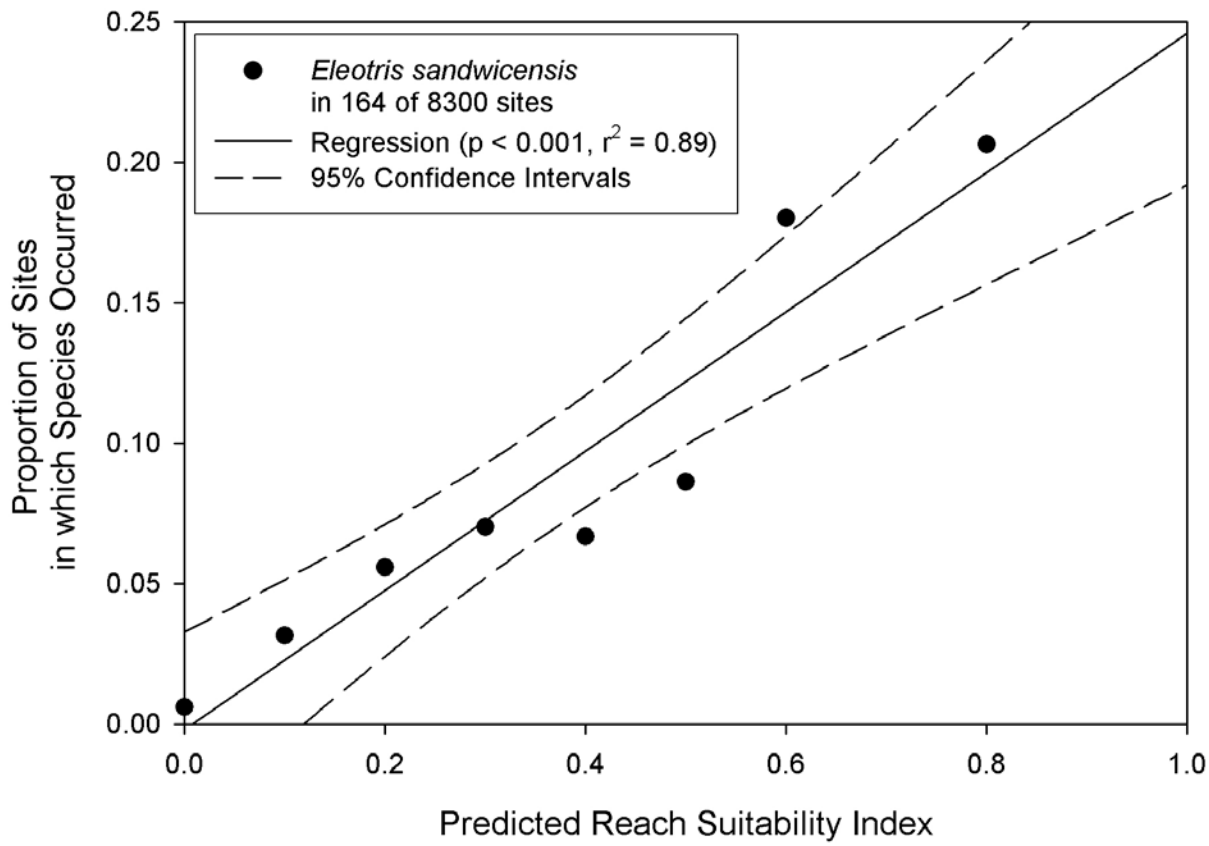

Figure 50: Proportion of the total sites where *Eleotris sandwicensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

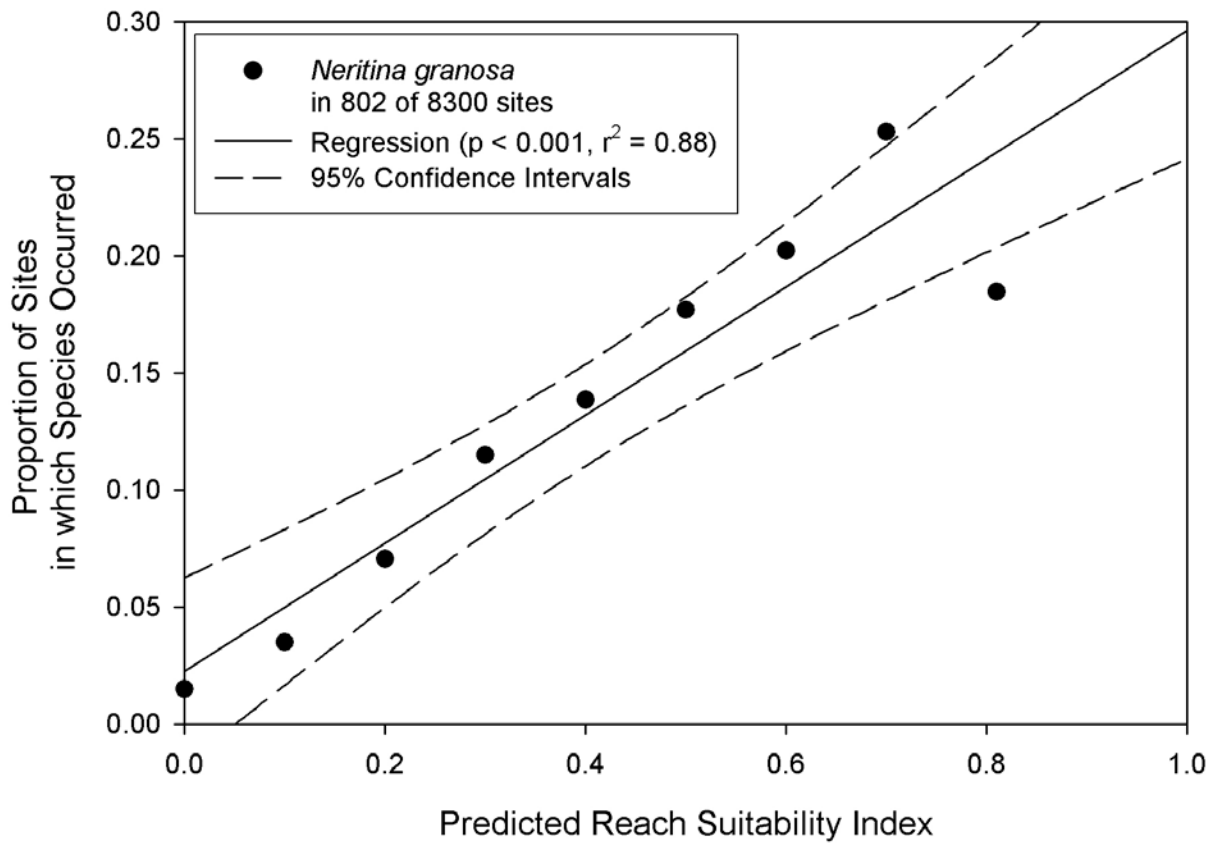

Figure 51: Proportion of the total sites where *Neritina granosa* was observed within each 0.1 group of the Reach Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability)

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

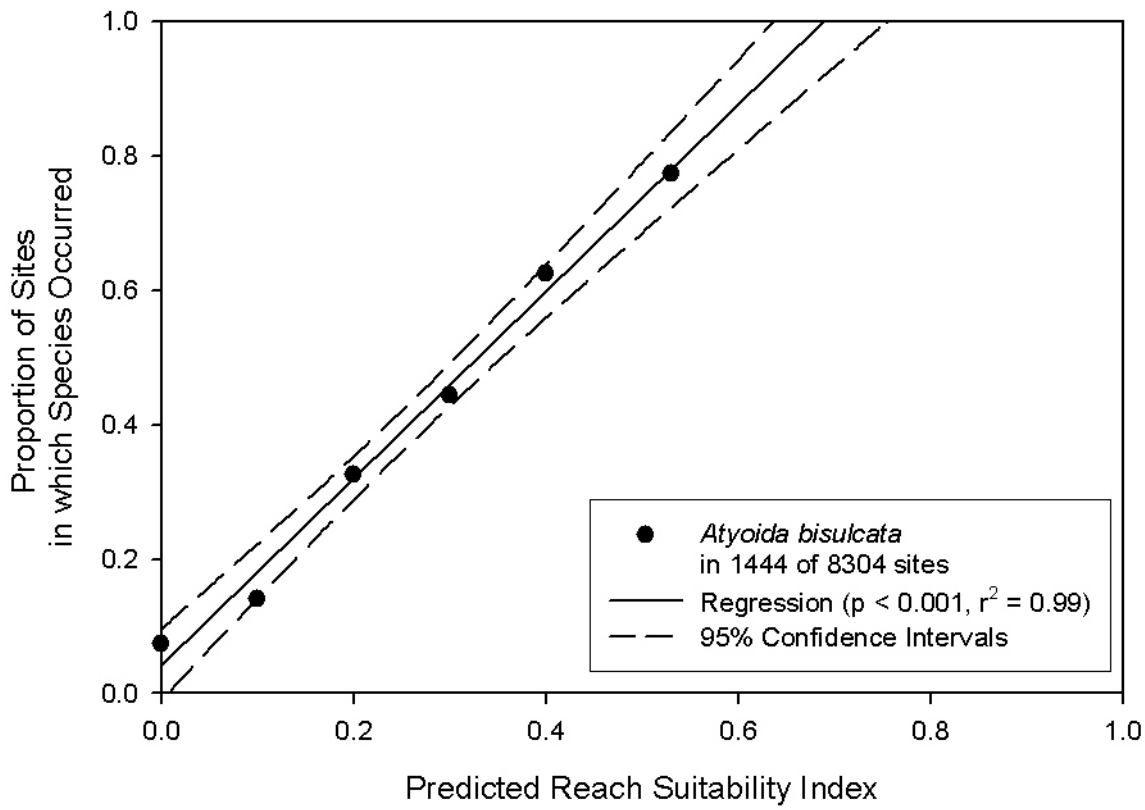

Figure 52: Proportion of the total sites where *Atyoida bisulcata* was observed within each 0.1 group of the Reach Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)

where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

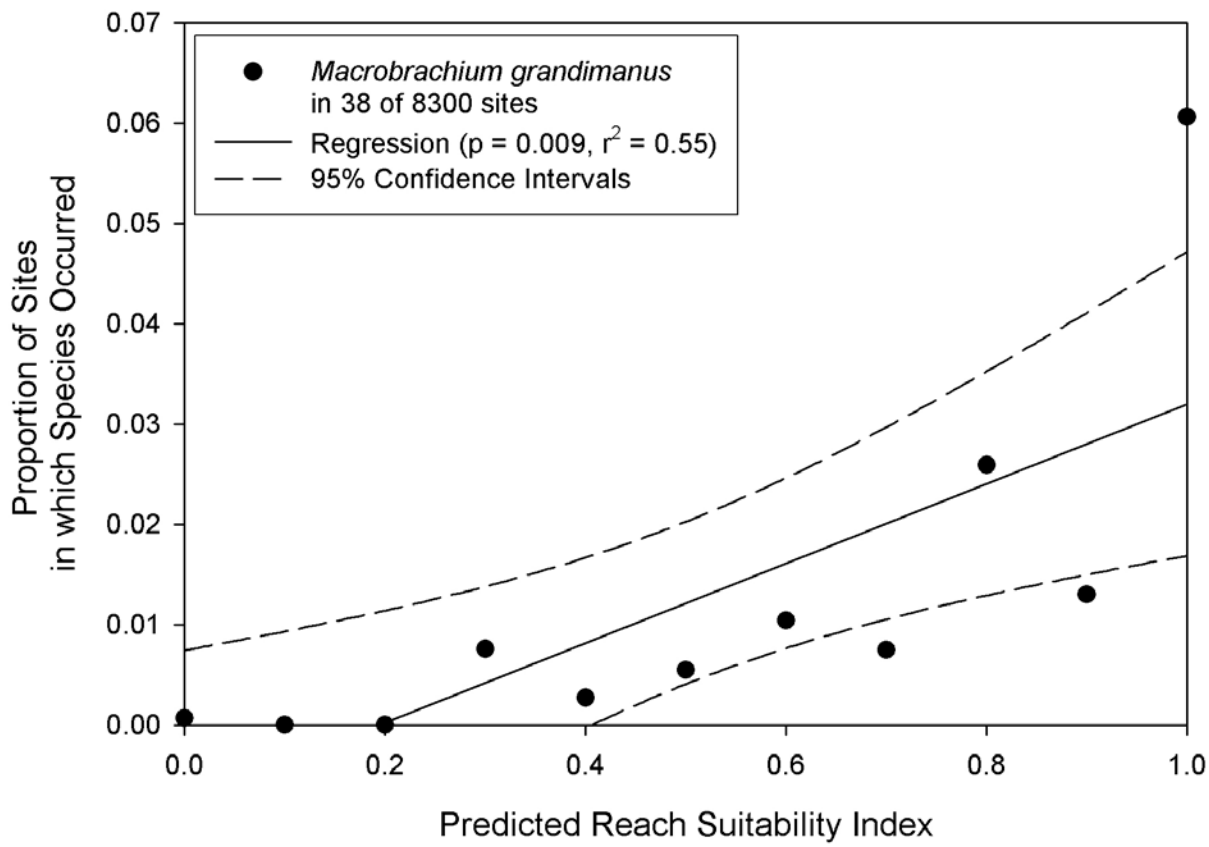

Figure 53: Proportion of the total sites where *Macrobrachium grandimanus* was observed within each 0.1 group of the Reach Suitability Index equation for *Macrobrachium grandimanus*.

Appendix 3: Site Scale Metrics

All data reflected in this report came from the DAR Aquatic Surveys Database. The data for the habitat level variables of habitat type, depth, substrate, and temperature were gathered from DAR point quadrat survey data within the DAR Aquatic Surveys Database as these surveys consistently used the same methodology to collect these habitat variables.

Following an identical process to developing suitability criteria for the instream distribution variables, suitability was determined for site scale metrics. To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution. Non-ordinal categorical suitability criteria (e.g., habitat types) were not smoothed.

The decision on the bin sizes for the various continuous variables was set subjectively to balance several factors. First, the number of samples in each bin attempted to have at least 200 observations from the total number of samples. Next, the bin sizes were adjusted to make the number of samples in each bin as consistent as possible, and finally, the bins were distributed to fit the field survey data. For example, the HDSS technique classified depth into specific depth

categories. In this case, the field depth categories were used to most closely match survey information.

To combine the various site scale variables into an overall suitability score for the site the following process is followed. Data from field surveys are used to characterize local habitat. Typical data collected during field surveys can be divided into two broad categories. First are those descriptive variables that differentiate natural habitat into more or less suitable units. For example, habitat type classifications into riffle runs or pools or depth classification from shallow to deep are good examples of differentiation of natural habitat into different units. The second type of descriptive variables is those variables that describe some level of human modification to natural habitats. For example, the extent of channelization or presence of flood control structures occurring at a site modifies what natural habitat would be normally expected to be found at the location. So in general, first we calculate the natural conditions at a site and then score for the natural condition is modified by downward by extent of human modification at the site.

For native amphidromous animals found in Hawaiian streams, we typically describe habitat with respect to variables associated with habitat type, depth, substrate, water velocity, water quality, bank and riparian condition to describe the natural stream habitats. Not all surveys of stream habitat record all of these variables. Habitat type, depth, substrate, water quality, bank and riparian conditions form the core descriptors stream animal habitat using the HDSS techniques. At a single location a linear combination of the suitability for each of the five variables is used to provide an overall suitability score. The combination would be the suitability for each score added together and divided by the total number of variables. This approach allows some flexibility to utilize the variables are collected during field sampling.

The next set of variables are associated with human modification of the environment include channel type, substrate embeddedness, or other human modifications of the environment that may be recorded during surveys. These variables modify the natural habitat variables described above. For example, cobble may be the primary substrate, but if it is highly embedded with fine sediment than it is less suitable than non-embedded cobble substrate. Not all variables will have a modifier variable.

The overall site impact score calculation is defined in advance and is applied identically to all sites within the HSHEP model. So while some variables may or may not occur in a specific application of an HSHEP model, within a specific application of the model all variables will be consistently applied.

For the application of the HSHEP model within the Ala Wai watershed streams, the variable combination calculations are as follows:

Site Suitability Equation for each species is –

$$(HV_1 * MV_1 + HV_2 * MV_2 + \cdots HV_n * MV_n)/n$$

where habitat variables (HV) and associated Modifier Variables (MV) are shown below:

Area	**Habitat Variable**	**Modifier Variable**
Habitat Type	Habitat Type	Channel Condition
Substrate	Substrate	Embeddedness
Depth	Depth	
Water Quality	Threshold limits for Temperature, Dissolved Oxygen, pH, Conductivity	
Bank & Riparian Condition	(Bank Height + Bank Angle + Surface Protection + Riparian Condition)/4	

Change as a result of an instream alteration (either negative or positive) in physical habitat, water quantity or water quality that will need to be able to be measured by one of the habitat or modifier variables to be able to quantify habitat changes in a HSHEP model.

Note to reviewer: The data for the site variables shown below are being updated to reflect the latest information within the DAR Aquatic Surveys Database but provide a good example of the data and the approach.

Table 14: Frequency, percent utilization, and standardized suitability for the use of habitat types by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Colors in the standardized suitability reflect three groups to aid in interpreting the data. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green. No smoothed standardized suitability values are presented as the habitat types are categorical variables.

	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
Frequency															
Cascade	84	11	7	0	0	0	17	12	18	35	0	0	13	0	1
Riffle	1076	162	138	13	1	18	223	131	170	354	10	2	307	7	14
Run	3216	505	587	66	15	134	734	486	359	863	57	23	780	75	158
Pool	1605	279	320	28	28	43	374	358	127	429	55	23	209	21	105
Plunge Pool	213	67	33	6	1	1	64	40	42	37	0	5	44	0	6
Side Pool	649	97	111	14	10	20	101	132	43	217	21	2	99	9	33
Total	6843	1121	1196	127	55	216	1513	1159	759	1935	143	55	1452	112	317
Percent Utilization															
Cascade	1.2	1.0	0.6	0.0	0.0	0.0	1.1	1.0	2.4	1.8	0.0	0.0	0.9	0.0	0.3
Riffle	15.7	14.5	11.5	10.2	1.8	8.3	14.7	11.3	22.4	18.3	7.0	3.6	21.1	6.3	4.4
Run	47.0	45.0	49.1	52.0	27.3	62.0	48.5	41.9	47.3	44.6	39.9	41.8	53.7	67.0	49.8
Pool	23.5	24.9	26.8	22.0	50.9	19.9	24.7	30.9	16.7	22.2	38.5	41.8	14.4	18.8	33.1
Plunge Pool	3.1	6.0	2.8	4.7	1.8	0.5	4.2	3.5	5.5	1.9	0.0	9.1	3.0	0.0	1.9
Side Pool	9.5	8.7	9.3	11.0	18.2	9.3	6.7	11.4	5.7	11.2	14.7	3.6	6.8	8.0	10.4
Standardized Suitability															
Cascade	1	0.42	0.42	0.00	0.00	0.00	0.67	0.64	1.00	1.00	0.00	0.00	0.54	0.00	0.18
Riffle	1	0.48	0.64	0.43	0.05	0.40	0.69	0.55	0.74	0.79	0.27	0.08	1.00	0.28	0.20
Run	1	0.50	0.92	0.73	0.27	1.00	0.76	0.68	0.52	0.64	0.52	0.30	0.85	1.00	0.75
Pool	1	0.55	1.00	0.62	1.00	0.64	0.78	1.00	0.37	0.64	1.00	0.61	0.46	0.56	1.00
Plunge Pool	1	1.00	0.78	1.00	0.27	0.11	1.00	0.84	0.92	0.42	0.00	1.00	0.72	0.00	0.43
Side Pool	1	0.48	0.86	0.77	0.88	0.74	0.52	0.91	0.31	0.80	0.94	0.13	0.53	0.59	0.78

Table 15: Frequency of occurrence, percent utilization, standardized suitability, and adjusted smoothed standardized suitability for site depth (in.) for native amphidromous animals in different survey sites within the DAR Point Quadrat Surveys. The *values were adjusted to further smooth the results with unadjusted smoothed results in parentheses.

Depth Bin (in)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Neritina granosa*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*
Frequency									
0	27	0	0	0	0	0	0	0	0
3	210	9	9	1	11	0	3	6	4
6	500	50	32	4	20	3	8	16	9
12	1742	273	216	19	275	5	152	296	29
24	2503	442	500	46	584	13	295	629	48
36	786	123	191	27	226	2	85	203	10
>36	315	51	71	14	74	3	33	46	11
Total	6083	948	1019	111	1190	26	576	1196	111
Percent Utilization									
0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.5	0.9	0.9	0.9	0.9	0.0	0.5	0.5	3.6
6	8.2	5.3	3.1	3.6	1.7	11.5	1.4	1.3	8.1
12	28.6	28.8	21.2	17.1	23.1	19.2	26.4	24.7	26.1
24	41.1	46.6	49.1	41.4	49.1	50.0	51.2	52.6	43.2
36	12.9	13.0	18.7	24.3	19.0	7.7	14.8	17.0	9.0
>36	5.2	5.4	7.0	12.6	6.2	11.5	5.7	3.8	9.9
Total	100	100	100	100	100	100	100	100	100
Standardized Suitability									
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0.3	0.3	0.3	0.3	0.0	0.2	0.1	1.0
6	1	0.6	0.4	0.4	0.2	1.4	0.2	0.2	1.0
12	1	1.0	0.7	0.6	0.8	0.7	0.9	0.9	0.9
24	1	1.1	1.2	1.0	1.2	1.2	1.2	1.3	1.1
36	1	1.0	1.5	1.9	1.5	0.6	1.1	1.3	0.7
>36	1	1.0	1.3	2.4	1.2	2.2	1.1	0.7	1.9
Max	1	1.1	1.5	2.4	1.5	2.2	1.2	1.3	1.9
Adjusted Smoothed Standardized Suitability									
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0.2	0.2	0.1	0.2	0.0	0.1	0.1	0.5
6	1	0.6	0.3	0.2	0.1	0.5*(0.6)	0.1	0.1	0.5
12	1	0.9	0.5	0.2	0.5	0.5*(0.3)	0.7	0.7	0.5
24	1	1.0	0.8	0.4	0.8	0.5	1.0	1.0	0.5
36	1	0.9	1.0	0.8	1.0	0.5*(0.3)	0.9	1.0	0.5*(0.4)
>36	1	0.9	0.9	1.0	0.8	1.0	0.9	0.6	1.0

Table 16: Percent Utilization for site substrate and total samples by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1.2	1.5	0.2	0.2	1.8	0.6	0.5	0.3	2.7	1.4	3.6	2.8	2.6	2.5	1.9
Fine Sediment	6.5	5.8	8.4	7.2	7.4	9.3	4.3	4.4	5.1	6.2	11.5	6.4	7.6	6.0	2.9
Sand	3.5	3.5	1.1	2.0	3.8	5.7	0.9	1.7	6.4	6.0	6.0	6.1	23.6	8.4	3.6
Gravel	12.2	14.8	7.0	7.8	12.8	12.3	7.4	8.0	23.7	13.8	19.3	13.9	14.9	12.2	20.5
Cobble	29.5	29.0	30.7	35.5	28.1	30.2	29.4	28.6	29.3	33.4	18.5	35.7	31.4	30.0	32.7
Boulder	32.8	29.6	35.5	39.1	34.8	34.3	33.9	42.6	28.0	36.5	29.0	31.0	19.9	19.1	32.3
Bedrock	14.3	15.9	17.0	8.1	11.3	7.7	23.5	14.4	4.9	2.7	12.1	4.1	0.0	21.8	6.2
Total Samples	6999	2156	1445	1438	1156	1156	1087	757	315	187	146	123	111	56	52

Table 17: Standardized suitability for site substrate by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1	1.00	0.13	0.13	1.00	0.30	0.27	0.22	1.00	0.70	1.00	1.00	0.32	0.88	0.97
Fine Sediment	1	0.69	1.00	0.92	0.75	0.87	0.40	0.51	0.34	0.55	0.58	0.42	0.17	0.38	0.26
Sand	1	0.80	0.25	0.48	0.73	1.00	0.16	0.38	0.80	1.00	0.57	0.74	1.00	1.00	0.61
Gravel	1	0.95	0.45	0.53	0.69	0.61	0.37	0.50	0.84	0.65	0.53	0.48	0.18	0.41	1.00
Cobble	1	0.77	0.81	1.00	0.63	0.63	0.61	0.74	0.43	0.66	0.21	0.51	0.16	0.42	0.66
Boulder	1	0.71	0.84	0.99	0.71	0.64	0.63	1.00	0.37	0.65	0.29	0.40	0.09	0.24	0.59
Bedrock	1	0.87	0.92	0.47	0.53	0.33	1.00	0.78	0.15	0.11	0.28	0.12	0.00	0.63	0.26

Table 18: Smoothed standardized suitability for site substrate by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1	0.85	0.56	0.52	0.88	0.59	0.34	0.37	0.67	0.62	0.79	0.71	0.25	0.63	0.62
Fine Sediment	1	0.83	0.46	0.51	0.83	0.72	0.28	0.37	0.71	0.75	0.72	0.72	0.50	0.75	0.62
Sand	1	0.81	0.57	0.64	0.73	0.83	0.31	0.46	0.66	0.74	0.56	0.54	0.45	0.60	0.63
Gravel	1	0.84	0.50	0.67	0.69	0.75	0.38	0.54	0.69	0.77	0.44	0.57	0.45	0.61	0.76
Cobble	1	0.81	0.70	0.84	0.68	0.63	0.54	0.75	0.55	0.65	0.34	0.46	0.14	0.36	0.75
Boulder	1	0.78	0.86	0.82	0.62	0.53	0.75	0.84	0.32	0.47	0.26	0.34	0.08	0.43	0.50
Bedrock	1	0.79	0.88	0.73	0.62	0.48	0.82	0.89	0.26	0.38	0.29	0.26	0.04	0.44	0.42

Table 19: Frequency of occurrence for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	57	39	0	0	0	2	1	1	16	0	0	1	0	0
17	66	19	7	0	0	23	15	23	11	0	1	19	0	1
18	99	27	11	0	0	12	6	9	46	0	4	5	0	9
19	391	105	53	10	15	18	29	8	159	2	16	37	4	33
20	521	49	40	7	10	33	41	18	253	19	1	37	1	57
21	737	101	73	13	28	104	159	94	278	19	6	66	3	51
22	850	73	121	11	31	81	177	91	299	17	6	146	23	71
23	380	15	59	8	23	56	102	45	114	25	1	39	15	23
24	206	4	32	6	11	18	48	31	52	16	1	38	16	10
25	169	0	44	6	7	28	39	18	43	7	0	48	12	5
26	114	0	35	1	3	23	25	17	29	3	0	46	6	1
26+	81	0	35	10	6	13	15	9	10	1	0	26	10	0
Total	3671	432	510	72	134	411	657	364	1310	109	36	508	90	261

Table 20: Percent Utilization for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1.6	9.0	0.0	0.0	0.0	0.5	0.2	0.3	1.2	0.0	0.0	0.2	0.0	0.0
17	1.8	4.4	1.4	0.0	0.0	5.6	2.3	6.3	0.8	0.0	2.8	3.7	0.0	0.4
18	2.7	6.3	2.2	0.0	0.0	2.9	0.9	2.5	3.5	0.0	11.1	1.0	0.0	3.4
19	10.7	24.3	10.4	13.9	11.2	4.4	4.4	2.2	12.1	1.8	44.4	7.3	4.4	12.6
20	14.2	11.3	7.8	9.7	7.5	8.0	6.2	4.9	19.3	17.4	2.8	7.3	1.1	21.8
21	20.1	23.4	14.3	18.1	20.9	25.3	24.2	25.8	21.2	17.4	16.7	13.0	3.3	19.5
22	23.2	16.9	23.7	15.3	23.1	19.7	26.9	25.0	22.8	15.6	16.7	28.7	25.6	27.2
23	10.4	3.5	11.6	11.1	17.2	13.6	15.5	12.4	8.7	22.9	2.8	7.7	16.7	8.8
24	5.6	0.9	6.3	8.3	8.2	4.4	7.3	8.5	4.0	14.7	2.8	7.5	17.8	3.8
25	4.6	0.0	8.6	8.3	5.2	6.8	5.9	4.9	3.3	6.4	0.0	9.4	13.3	1.9
26	3.1	0.0	6.9	1.4	2.2	5.6	3.8	4.7	2.2	2.8	0.0	9.1	6.7	0.4
26+	2.2	0.0	6.9	13.9	4.5	3.2	2.3	2.5	0.8	0.9	0.0	5.1	11.1	0.0

Table 21: Standardized suitability for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1	1.00	0.00	0.00	0.00	0.10	0.07	0.05	0.58	0.00	0.00	0.04	0.00	0.00
17	1	0.42	0.25	0.00	0.00	1.00	0.85	1.00	0.34	0.00	0.37	0.71	0.00	0.14
18	1	0.40	0.26	0.00	0.00	0.35	0.23	0.26	0.96	0.00	0.99	0.13	0.00	0.83
19	1	0.39	0.31	0.21	0.52	0.13	0.28	0.06	0.84	0.07	1.00	0.23	0.08	0.77
20	1	0.14	0.18	0.11	0.26	0.18	0.29	0.10	1.00	0.47	0.05	0.18	0.02	1.00
21	1	0.20	0.23	0.14	0.51	0.40	0.80	0.37	0.78	0.33	0.20	0.22	0.03	0.63
22	1	0.13	0.33	0.10	0.49	0.27	0.78	0.31	0.72	0.26	0.17	0.43	0.22	0.76
23	1	0.06	0.36	0.17	0.82	0.42	1.00	0.34	0.62	0.85	0.06	0.25	0.32	0.55
24	1	0.03	0.36	0.24	0.72	0.25	0.87	0.43	0.52	1.00	0.12	0.46	0.63	0.44
25	1	0.00	0.60	0.29	0.56	0.48	0.86	0.31	0.52	0.53	0.00	0.70	0.58	0.27
26	1	0.00	0.71	0.07	0.36	0.58	0.82	0.43	0.52	0.34	0.00	1.00	0.43	0.08
26+	1	0.00	1.00	1.00	1.00	0.46	0.69	0.32	0.25	0.16	0.00	0.80	1.00	0.00

Table 22: Smoothed standardized suitability for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1	0.71	0.12	0.00	0.00	0.55	0.46	0.53	0.46	0.00	0.19	0.38	0.00	0.07
17	1	0.61	0.17	0.00	0.00	0.48	0.38	0.44	0.63	0.00	0.45	0.29	0.00	0.32
18	1	0.40	0.27	0.07	0.17	0.49	0.45	0.44	0.71	0.02	0.79	0.36	0.03	0.58
19	1	0.31	0.25	0.11	0.26	0.22	0.27	0.14	0.93	0.18	0.68	0.18	0.03	0.87
20	1	0.24	0.24	0.15	0.43	0.24	0.46	0.17	0.87	0.29	0.42	0.21	0.04	0.80
21	1	0.15	0.25	0.12	0.42	0.29	0.62	0.26	0.83	0.35	0.14	0.27	0.09	0.80
22	1	0.13	0.31	0.14	0.61	0.37	0.86	0.34	0.71	0.48	0.15	0.30	0.19	0.65
23	1	0.07	0.35	0.17	0.68	0.32	0.88	0.36	0.62	0.70	0.12	0.38	0.39	0.59
24	1	0.03	0.44	0.23	0.70	0.38	0.91	0.36	0.55	0.79	0.06	0.47	0.51	0.42
25	1	0.01	0.56	0.20	0.55	0.44	0.85	0.39	0.52	0.62	0.04	0.72	0.54	0.26
26	1	0.00	0.77	0.45	0.64	0.50	0.79	0.35	0.43	0.34	0.00	0.83	0.67	0.12
26+	1	0.00	0.86	0.54	0.68	0.52	0.75	0.37	0.39	0.25	0.00	0.90	0.71	0.04

Appendix 4: HDSS data collection

Introduction:

This report documents the results of the High Definition Stream Surveys (HDSS) data collection on Manoa Stream, Oahu. The Department of Land and Natural Resources, Engineering Division requested Parham & Associates Environmental Consulting, LLC to collect data on Manoa Stream. The request for these data was to better understand the environmental impact of flood control structures proposed within Manoa Stream. Specifically, the Engineering Division is planning to construct the Woodlawn Chute Flood Control Structure. The Woodlawn Chute project focuses on channel improvements under and downstream of the bridge on Woodlawn Drive. In general, the channel improvements can be described as: (1) widening and stabilizing the stream banks and (2) grading the stream channel to allow water to flow more swiftly through this channel segment, thus lowering the overall flood risk at the site. In addition to the Woodlawn Chute structure, the U.S. Army Corps of Engineers are planned to add nine additional flood control structures within the Ala Wai Watershed (Manoa Stream) and this data will be used to support this effort as well.

This HDSS data collection effort is part of a larger project. The data collected in this project is to be incorporated into a Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model to assess three different conditions: the current conditions within the site, the conditions with the flood control project, and the mitigation burden as a result of the project. This larger project includes fish surveys collected by the Department of Land and Natural Resources, Division of Aquatic Resources (DAR) and the overall model integration by researchers at Bishop Museum. This report will focus on the results of the HDSS effort within Manoa Stream and not on the larger results of the HSHEP model or overall mitigation effort.

In general, the HDSS approach is a multi-attribute, high resolution sampling technique that collects data of both streambanks and the stream channel bottom at approximately 1 m intervals. This approach is an improvement over traditional transect methods because the data collection is

continuous over the survey area as opposed to being limited to small survey areas. For this project we collected data throughout Manoa Stream, including all of the Palolo and Makiki tributaries, to better understand conditions within and outside all of the project footprints. The HDSS technique integrates GPS, video, depth, and water quality sensors in a single pass. These results can be easily mapped to better understand conditions at the survey site. The following is a description of the HDSS methodology.

Methods:

Field Data Collection:

During the HDSS data collection process, two primary methods were used. A backpack-mounted HDSS system accounted for the majority of the data collected. A bodyboard-mounted HDSS system was used in deeper sections of the stream. The two systems shared many features. All video collected was geo-referenced to a GPS data stream so that an X,Y locational coordinate was associated with each second of video collected. Water quality was collected using a YSI EXO1 sonde will at point locations throughout the stream. When using the backpack HDSS system, depth was classified from the video collected, while when using the bodyboard-mounted HDSS system, depth was collected from a hull-mounted transducer.

The backpack-mounted HDSS system featured four different high definition video cameras with image stabilization (Figure 1). One camera was faced forward, one camera was faced downward, and a single camera was faced at the right and left banks. When using the backpack-mounted HDSS system, the surveyor moved in an upstream direction attempting to follow the thalweg of the stream. The bodyboard-mounted HDSS system included two additional cameras (Figure 2). These cameras were faced at a 45° angle downward towards the stream bottom. When using the bodyboard-mounted HDSS system, the bodyboard was drifted downstream under control of a long extension pole.

The GPS signal was collected using a Garmin 64C handheld GPS and a Garmin 19X GPS receiver. In both of these cases, the GPS NMEA data string was recorded at 1 Hz (approximately 1 sec interval). All data including the video and GPS track logs were saved to multiple external hard drives at the end of each day in the field. The track log for the GPS signal was exported in GPX format and the data was stored in a Microsoft Access database. The video was further post-processed in Adobe Premiere software to create a single view that encompassed all four video streams.

Figure 54: The author wearing the backpack-mounted HDSS system.

Figure 55: The bodyboard-mounted HDSS system.

Video Classification:

The HDSS video was classified by applying a standard classification system for each variable under consideration. The individual classes within each category are described below, but in general the process for each classification pass was similar. Prior to classification, the technician was trained on a subset of the videos under supervision of the principal investigator. Each video was watched by a technician and the category under consideration was scored. The HDSS Video Coder software version 2 (Parham 2014) was used to facilitate the classification process (Figure X). This software allows the human classifier to select the appropriate class and have it tied to the second it occurs in the video. In addition to the appropriate category classes, several additional classes were included in most categories. Unknown class was reserved for areas where the appropriate category was not visible to or otherwise noted by the surveyors. Other 1 and Other 2 classes were reserved for classes not accounted for in the above classification or for areas where the classifier had trouble determining class membership. These areas were then revisited with the field surveyors to decide on the appropriate class.

Once the classification was completed for the entire group of videos, an overall spreadsheet containing the video file name, the second at which the category occurred, the class name, and the class code was created. Given the unique combination of video name and second, we were able to link the classified spreadsheet with the GPS coordinates contained within the database.

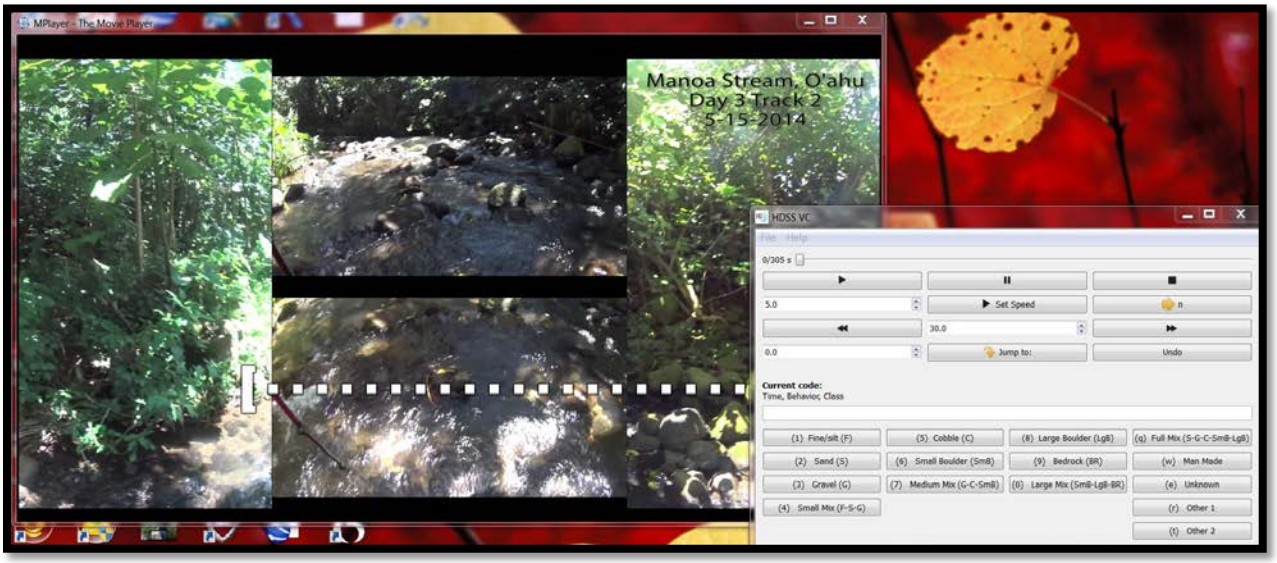

Figure 56: A computer screen image of the HDSS Video Coder Version 2 software and associated HDSS video of Manoa stream. In actual application, multiple computer monitors are used so that the HDSS video is displayed at high resolution on one monitor and the HDSS Video Coder software is displayed on a different monitor.

<u>Classification Categories:</u>

At each point, data for the following variables were estimated from the HDSS video:

- Habitat Type
- Depth
- Substrate
- Embeddedness
- Channel Condition
- Channel Width
- Percent Wetted Width
- Right and Left Streambank Height
- Right and Left Streambank Angle

- Right and Left Streambank Surface Protection
- Right and Left Riparian Zone Condition

The following describe each classification category.

Habitat Type

1. Pool
2. Run
3. Riffle
4. Cascade
5. Falls
6. Pocket Water
7. Sheet Flow
8. Unknown

Habitat type is one of the primary measures in describing instream habitat. Habitat types represent the classic riffle-run-pool combinations found in most streams. In general, the habitat types classified from the HDSS videos are compatible with those habitat types used by DAR in their habitat and fish surveys. Two additional classes were added. Pocket water represents a mix of riffle, run, and small pool habitat commonly found in the mid to upper reaches of the stream. Sheet flow is characteristic of the habitat found in man-made channelized stream sections. Transitions from one habitat type to the other were visually determined from experience by the primary investigator.

The following are examples of some of the more common habitat types found in the stream:

Figure 57: Habitat Types of Pool and Falls are shown in the image.

Figure 58: Run Habitat Type. The water is moving, but not broken on the surface.

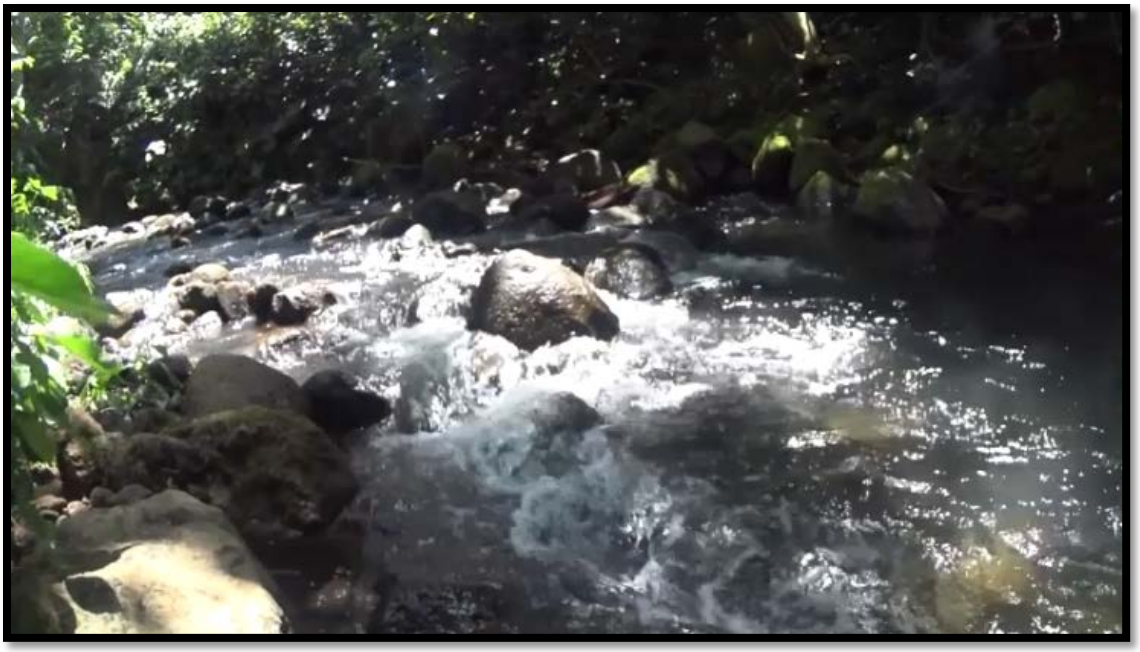

Figure 59: Riffle Habitat Type. Swiftly flowing water with broken surface.

Figure 60: Cascade Habitat Type. Note the high velocity, highly mixed flow in center of the image.

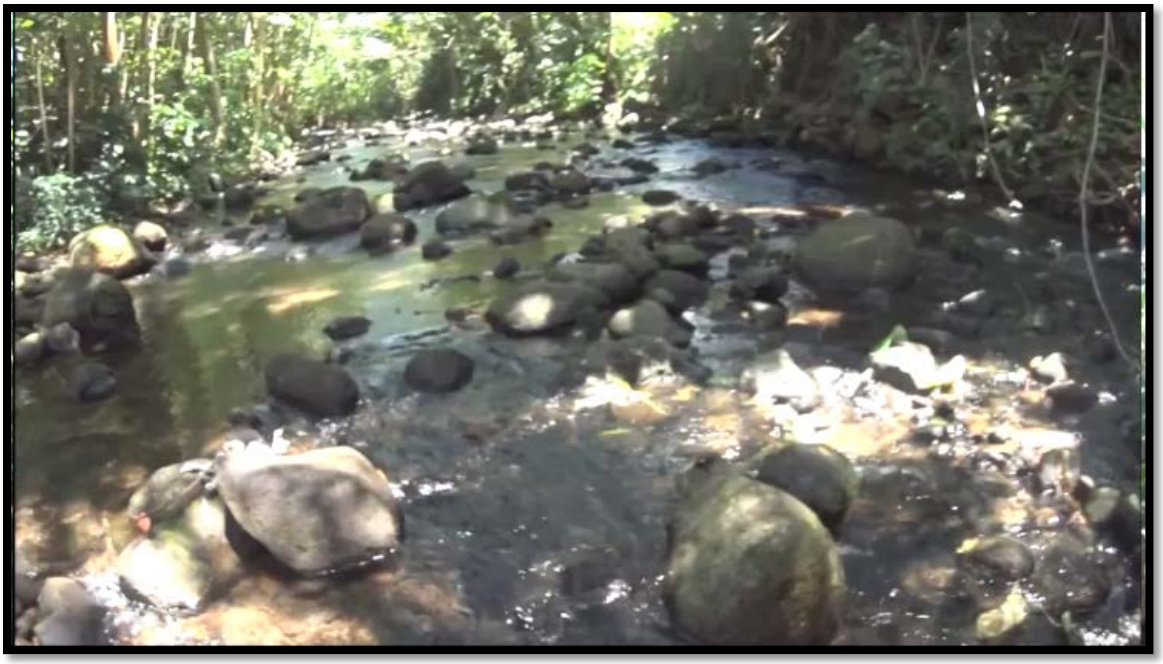

Figure 61: Pocket Water Habitat Type. Note the mixture of riffles, runs and small pools intermixed across the channel.

Figure 62: Sheet Flow Habitat Type is swift, shallow and uniform and is characteristic of fully channelized stream sections.

Depth:

1. Dry
2. 1-3 inches
3. 3-6 inches
4. 6-12 inches
5. 12-24 inches (1-2 ft deep)
6. 24-36 inches (2-3 ft deep)
7. 36+ inches (>3ft deep)
8. Unknown

The Depth category was intended to capture the thalweg depth for the main flow of the stream channel. The thalweg can be considered the center of the main flow and usually the deepest depth across the stream channel. The wading poles (as seen in the down-looking video) are set at 1 ft at the first black joint and 2 ft at the second joint for reference. In deeper sections, verbal documentation of depths by the surveyors may have been noted for reference.

The following are some example of depth classes observed in the surveys:

Figure 63: Depth class of 1 to 3 inches deep. This class was common in the fully channelized stream sections.

Figure 64: Depth class of 3 to 6 inches.

Figure 65: Depth class of 6 to 12 inches. Note the first clasp of the wading staff is above the water surface.

Figure 66: Depth class of 1 to 2 feet deep. Note second black clasp on wading staff denoting 2 ft deep is just above the water surface.

Figure 67: Depth class of 2 to 3 ft deep. Note the second clasp on the wading staff is fully underwater.

Figure 68: Depth class of greater than 3 ft deep. Note the right wading staff fully underwater.

Substrate:

1. Detritus (D): Dead particulate organic matter. Typically woody or leafy plant debris.
2. Fine/silt (F): All sediments finer than sand. Covers the Mud and Silt categories in the Wentworth Particle Classification Scale. Visually it is difficult to see individual grains of the sediment and if disturbed it easily clouds the water.
3. Sand (S): Observable small grains of sand ranging up to 2 mm in diameter. The covers all of the Sand category in the Wentworth Particle Classification Scale.
4. Gravel (G): From 2 mm to 64 mm in diameter. Visually this can be observed as small pebbles to rocks a little larger than a golf ball.
5. Small Mix (F-S-G)
6. Cobble (C): From 64 mm to 256 mm in diameter. Visually these can be observed as rocks from little larger than a golf ball to a volley ball size.
7. Small Boulder (SmB): From 256 to 610 mm or large rocks from 1 to 2 ft in diameter.
8. Medium Mix (G-C-SmB)
9. Large Boulder (LgB): Boulder greater than 610 mm (approximately 2 ft) in diameter
10. Bedrock (BR): Large areas of unbroken rock. Bedrock is typically smooth with some small cracks.
11. Large Mix (SmB-LgB-BR)
12. Full Mix (S-G-C-SmB-LgB)
13. Man-made: Any man-made substrate. Typically concrete.
14. Unknown

The classification is primarily based on the center (down-looking) video track where possible. The side-looking video was used for substrate classification when surveyor was not following the thalweg of the channel. Basing the substrate classification on the primary substrate in the channel thalweg is intended to achieve two things: (1) substrate type will vary with the thalweg depth criteria and thus will be more consistent among stream segments, and (2) may allow us to classify left and right channel substrate if necessary. For this habitat classification project, only the center (thalweg) channel substrate was scored.

Substrate classification is based on the substrate classification commonly applied by DAR in stream habitat surveys and can be considered a modification of the Wentworth particle scale (Higashi and Nishimoto 2007). The standard classes used in DAR surveys were modified to include several substrate mix classes as the visual assessment averages substrate type across several meters of the channel bottom. Man-made bottom type was generally concrete and found in channelized sections, but could include any non-natural bottom type.

The rules for determining specific substrate classes were as follows: if approximately 75% or more of the bottom is in a single class (i.e. gravel or cobble) then place it in the single substrate class. If it is mixed, pick the majority as small, medium, or large mix. Only use the full mix if the site contains a mix of everything small to large. In general, the mixes will be considered 33%, 33%, 33% of each substrate class. If it is 50/50% in two classes use the appropriate mix class as opposed to one or the other class. If you have a 50/50 mix of gravel and large boulder, go with the larger substrate class.

The following are examples of some of the more common substrate classes:

Figure 69: Small Mix substrate class. This is a mix of fine, sand, and gravel substrate classes.

Figure 70: Medium Mix substrate class. This is a mix of gravel, cobble and small boulder substrates classes.

Figure 71: Cobble substrate class. A few small boulders and some gravel were present, but the majority of the substrate is in the cobble class.

Figure 72: Large Boulder substrate class.

Figure 73: Full Mix substrate class. A wide range of substrate classes are visible from gravel to large boulder.

Figure 74: Bedrock substrate class

Figure 75: Man-made substrate class.

Embeddedness:

1. Optimal (0-25%)
2. Suboptimal (25-50%)
3. Marginal (50-75%)
4. Poor (75-100%)

The Embeddedness category refers to the extent at which rocks gravel cobble are covered or sunken in fine or sand substrates. We followed the EPA classification for high gradient streams with embeddedness ranging from optimal to poor depending on the extent that the large substrate is surrounded by fine substrate. Embeddedness is rated as the average of the most common condition and not reflective of a single boulder or cobble within the video frame. As with substrate, the embeddedness classification focused on the down-looking video where possible associated with the thalweg of the stream.

The following are examples of some of the more common embeddedness classes:

Figure 76: Optimal Embeddedness class. While some of the larger boulders are surrounded by smaller gravel or cobble, there is almost no fine or sand substrate surrounding the gravel and small cobbles.

Figure 77: Sub-optimal Embeddedness class. The larger cobbles are surrounded between 25% and 50% by fine or sand substrates.

Figure 78: Marginal Embeddness class. Note how the boulder and larger cobble are surrounded between 50% and 75% by fine or sand substrate.

Figure 79: Poor Embeddedness class. Most boulders are surrounded by greater than 75% by fine substrate.

Channel Condition:

1. Natural Channel
2. Natural Bottom – Walls far back
3. Natural Bottom – Left wall close
4. Natural Bottom – Right wall close
5. Natural Bottom – Both walls close
6. Fully channelized – low flow channel
7. Fully channelized – flat bottom
8. Unknown

The channel condition category is intended to capture the extent of channel modification at an individual location. In general, this category differentiates a natural stream channel from a channel with hardened walls from a fully channelized segment. The location of a man-made wall on either right or left bank and its proximity to the stream channel (close or far) was documented to aid in understanding available habitat and stream function within an area. The difference between close or far wall positions is if the wall is closer or further than 10 feet of the active

channel. A low flow channel in a fully channelized segment was defined as an area of confined flow that constrains the majority of the low flow.

The following are examples of some of the more common channel condition classes:

Figure 80: Natural Channel class.

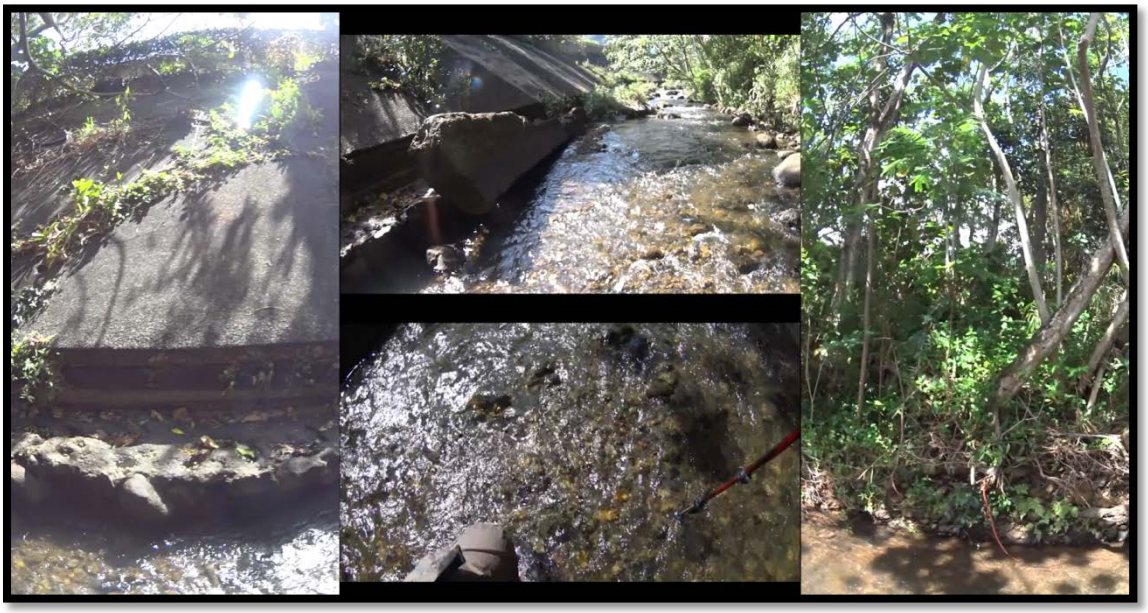

Figure 81: Natural Bottom: Left Wall Close class.

Figure 82: Natural Bottom - Both Walls Close class.

Figure 83: Fully Channelized - Flat Bottom

Channel Width:

1. Less than 10 ft. wide
2. Between 10 and 20 ft. wide
3. Between 20 and 30 ft. wide
4. Between 30 and 40 ft. wide
5. Greater than 40 ft. wide

The channel width metric categorically describes the stream's active channel. This category is intended to help determine the potential habitat area of a stream segment. The longitudinal HDSS approach can determine channel length effectively. The combination of length and width provides a measure of total habitat area within the active channel. When channel width is used in combination with percent wetted width, a measure of wetted habitat area can be determined.

The following examples are some of the channel width classes:

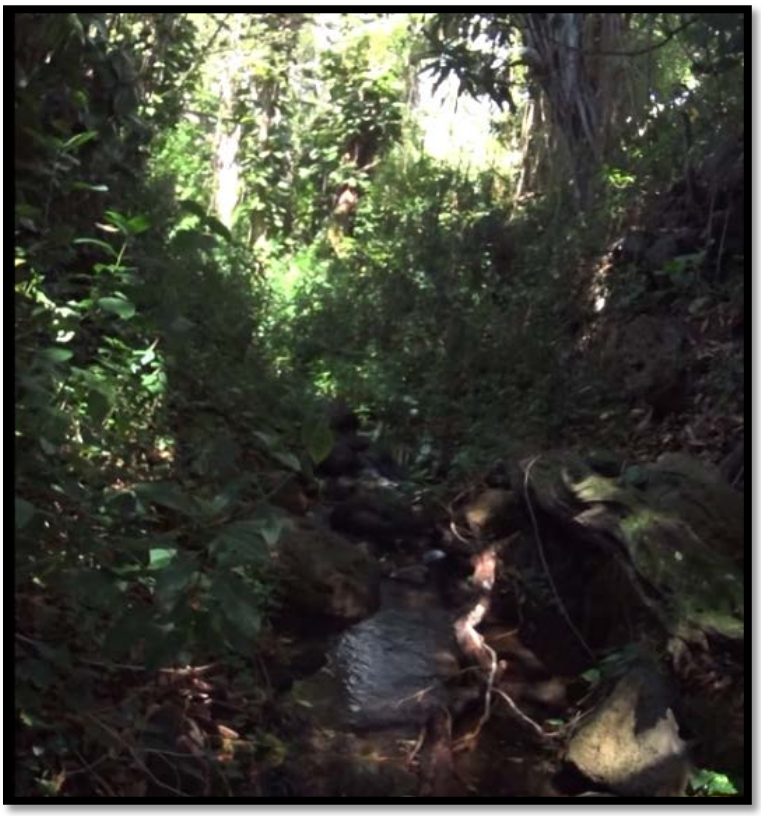

Figure 84: Channel width less than 10 ft wide.

Figure 85: Channel width between 10 and 20 ft wide.

Figure 86: Channel width between 20 to 30 ft wide.

Figure 87: Channel width between 30 and 40 ft wide.

Figure 88: Channel width greater than 40 ft wide.

Percent Wetted Width:

1. Dry
2. 1 -10%
3. 10-20%
4. 20-40%
5. 40-60%
6. 60-80%
7. 80-100%
8. Unknown

The category Percent Wetted Width is a descriptor of the extent at which the active channel is filled with water during the survey. Longitudinal changes in Percent Wetted Width can reflect changes in the base flow in the stream due to stream diversion, a losing or gaining reach, differences in channel morphology, or sections of unstable streams (i.e., incising or aggrading streams). There are more classes in the lower range of this category due to the critical nature of the amount of water found in the stream at very low flows.

The following are examples of some classes within the Percent Wetted Width category:

Figure 89: Percent Wetted Width class of 20 to 40%.

Figure 90: Percent Wetted Width class of 40 to 60%. Note that the active channel width includes the exposed rocks to the left of the image.

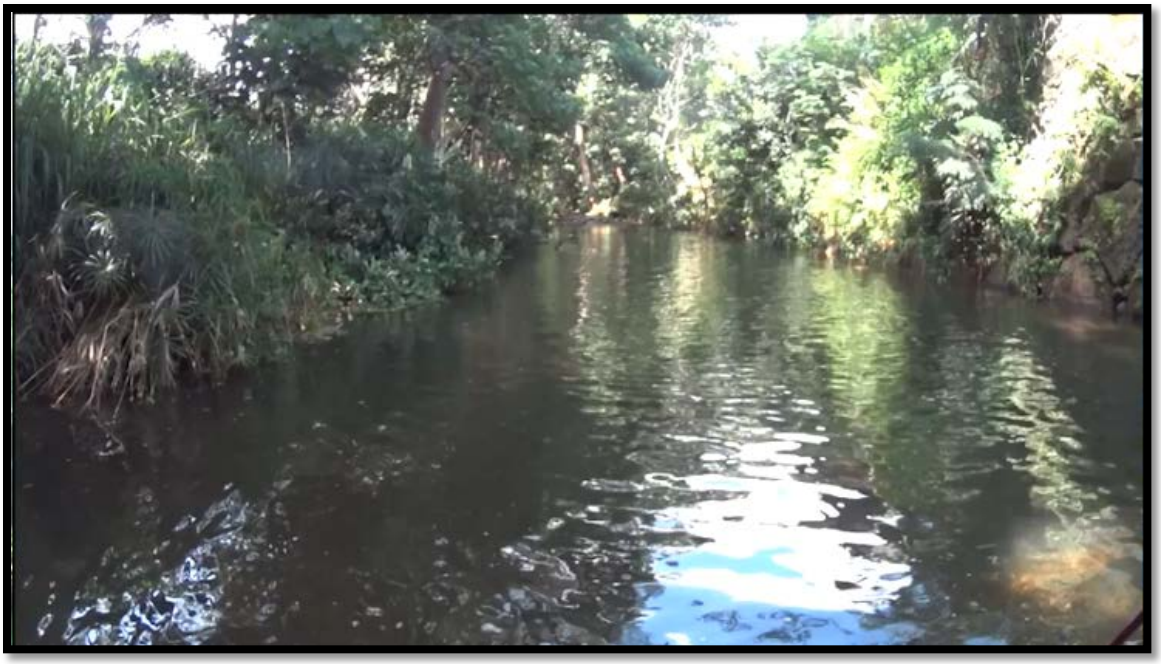

Figure 91: Percent Wetted Width class 80 to 100%.

Right and Left Streambank Height:

1. 0 to 1 ft
2. 1 to 3 ft
3. 3 to 6 ft
4. 6 to 9 ft
5. 9 to 12 ft
6. 12 to 18 ft
7. Greater than 18 ft
8. Unknown

Streambank height is relatively self-explanatory as it is the height of either the left or right streambank. The confusion comes and in determining where the streambank ends and the floodplain begins. This is further compounded in Manoa Stream as much of the stream is channelized or has setback flood control walls. For Manoa Stream, we define streambank height as the height of the wall if the walls were close to the active channel. At locations where there was no flood wall or the flood wall was far back from the active channel, streambank height was considered the height to the first bench.

Documenting streambank height is important in understanding channel volume, flow characteristics, and the stability of the streambank. Streambank height and bank angle may also indicate areas of channel incision or aggradation.

The following are examples of some classes within the Streambank Height category:

Figure 92: Streambank Height class for 3 - 6 ft.

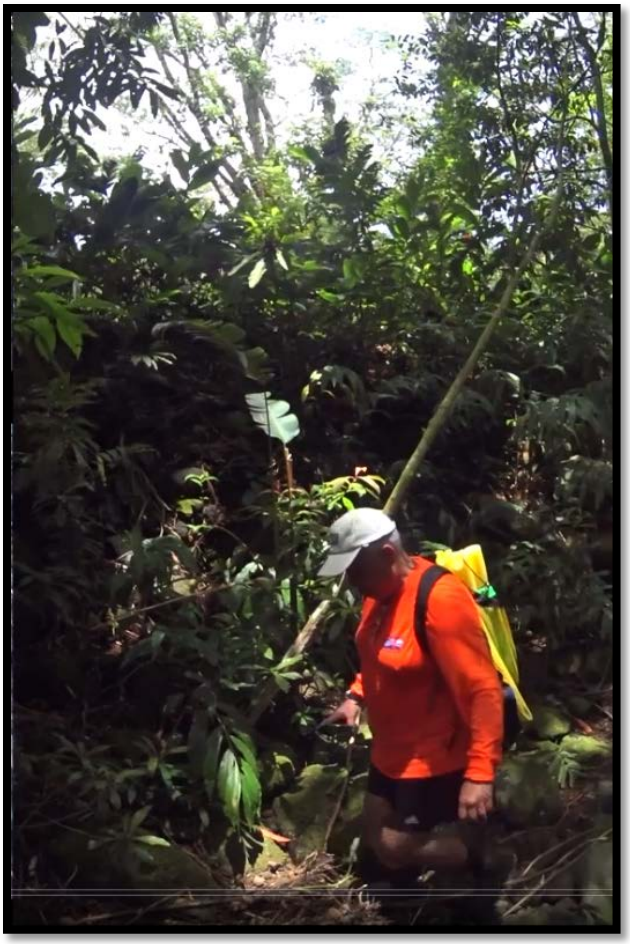

Figure 93: Streambank Height class for 6 - 9 ft.

Figure 94: Streambank Height class for greater than 18 ft. This image highlights the scoring when a flood wall is close to the streambank. Where the wall is close, the bank height equals the height of the wall. If the wall had been set further back, then height would equal the first bench in the front.

Right and Left Streambank Angle:

1. Low (0 - 60°)
2. Medium (61 - 80°)
3. High (81 - 90°)
4. Extreme (>90°)
5. Unknown

Streambank angle documents how steep or shallow the bank is where it enters the water. Streambank angle must be considered in combination with streambank height as the overall angle should be determined from the water level to the top of the streambank. In locations with near vertical or overhung bank angles there is greater potential for bank failure or streambank erosion.

The following are examples of some classes within the Streambank Angle category:

Figure 95: Low streambank angle (<60°).

Figure 96: High streambank angle (near 90°).

Figure 97: Extreme streambank angle (>90°, or undercut).

Right and Left Streambank Surface Protection:

1. Optimal (greater than 56% protected)
2. Sub-optimal (30 to 55% protected)
3. Marginal (15 to 29% protected)
4. Poor (less than 15% protected)
5. Unknown

Surface protection class is related to the percentage of the stream bank covered and protected from erosion by plant roots, downed logs and branches, and rocks. This metric is scored independently for both the left and right streambank. These classes follow the classes described by Connell (2012) as a modification of those of Rosgen (2001). Surface protection can be an important variable in and of itself, yet is more commonly combined with other variables to aid in determining overall streambank erosion potential.

The following are examples of streambank surface protection classes:

Figure 98: Optimal streambank surface protection. The banks are fully covered by vegetation minimizing possible surface erosion.

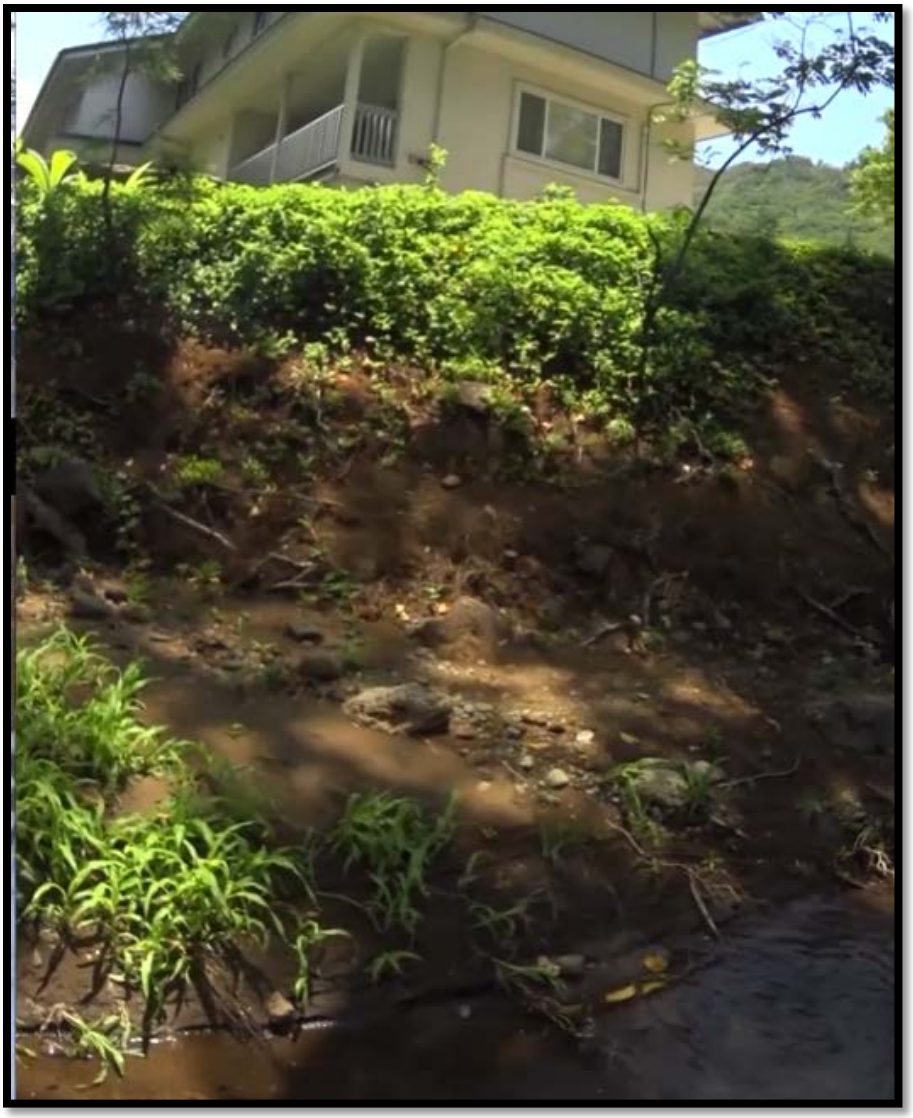

Figure 99: Poor and Marginal streambank surface protection. Here the bank is transitioning from an area of poor surface protection (right) to marginal surface protection (left). Note the high potential for surface erosion at this location.

Right and Left Riparian Zone Condition:

1. Optimal (presence of large trees or a wide variety of plant diameters)
2. Sub-optimal (mostly small trees or shrubs)
3. Marginal (mostly tall grasses)
4. Poor (lawn grass, pavement, or bare soil)
5. Unknown

For the purposes of this study, riparian zone condition refers to the extent at which the streambank or floodplain is vegetated by various sized trees. At one extreme there may be no riparian zone vegetation and at the other large trees can dominate the area near the banks of the stream. Where large trees exist, the stream is more likely to be shaded and thus have lower average stream temperatures. The root structures on the trees also stabilize the bank and prevent lateral in-cutting during flooding events. Much of Manoa Stream lacks a true riparian area thus this measure was adjusted to consider any vegetation within the stream channel corridor.

The following are a few examples of the Riparian Zone Condition classes:

Figure 100: Poor Riparian Zone Condition. No trees, shrubs or tall grasses to provide shading.

Figure 101: Marginal Riparian Zone Condition. Here large grasses are the primary cover and the trees are relatively far off the stream channel.

Figure 102: Optimal Riparian Zone Condition. There is a dense stand of moderate sized trees. If the trees were all small it would likely fall into the sub-optimal class.

Figure 103: Optimal Riparian Zone Condition. This location has very large tree that provide bank stability as well as stream shading.

Streambank Erosion Potential:

Streambank Erosion Potential is a derived metric that is formed from a combination of bank height, bank angle, and bank surface protection. Streambank erosion potential was modified from the calculation and scoring system described in Connell (2012). The modification involved the removal of the riparian zone condition score from the overall metric. This change was made to better represent the majority of the conditions observed in Manoa Stream. The streambanks of Manoa Stream are highly modified. In most places the stream channel is constrained by flood control walls and the riparian zone is highly urbanized. As a result the riparian metric represents

the extent at which trees grow inside the flood walls and is used to represent the extent of stream shading not root depth as the riparian metric is traditionally used for. A further modification involved scoring where flood walls occurred near the stream. In this case, the concrete or grouted-rock walls had low erosion potential under any flow condition, therefore, where flood walls existed close to the stream channel, streambank erosion potential was low.

After determining the final streambank erosion potential score, the values were range standardized between 0 and 1. The range standardized value was inverted so that high bank erosion potential scores were near zero and low bank erosion potential scores were near one. This was done to allow this metric to be combined with other habitat modification metrics in an appropriate scale. Additionally, a combined metric for right and left bank scores was created by selecting the maximum value of the two scores. This single score represents the estimated likelihood of sediment entering into the adjacent instream habitat.

The Streambank Erosion Potential metric is calculated independently for each bank as follows:

$$Streambank\ Erosion\ Potential\ (for\ each\ bank) = Bank\ Height\ score + Bank\ Angle\ Score + Surface\ Protection\ Score$$

$$where: if\ [channel\ condition] indicates\ presence\ of\ flood\ wall\ close\ to\ channel,$$

$$then\ Streambank\ Erosion\ Potential\ is\ low$$

The following are a few examples of the component and overall Streambank Erosion Potential scores:

Figure 104: Low Potential for Bank Erosion. Bank Angle is just under vertical and the Bank Surface Protection is highly protected due to gabion baskets. There is no riparian diversity which means no root structure to hold together the rocks, but this has been functionally replaced by the braided wire fence.

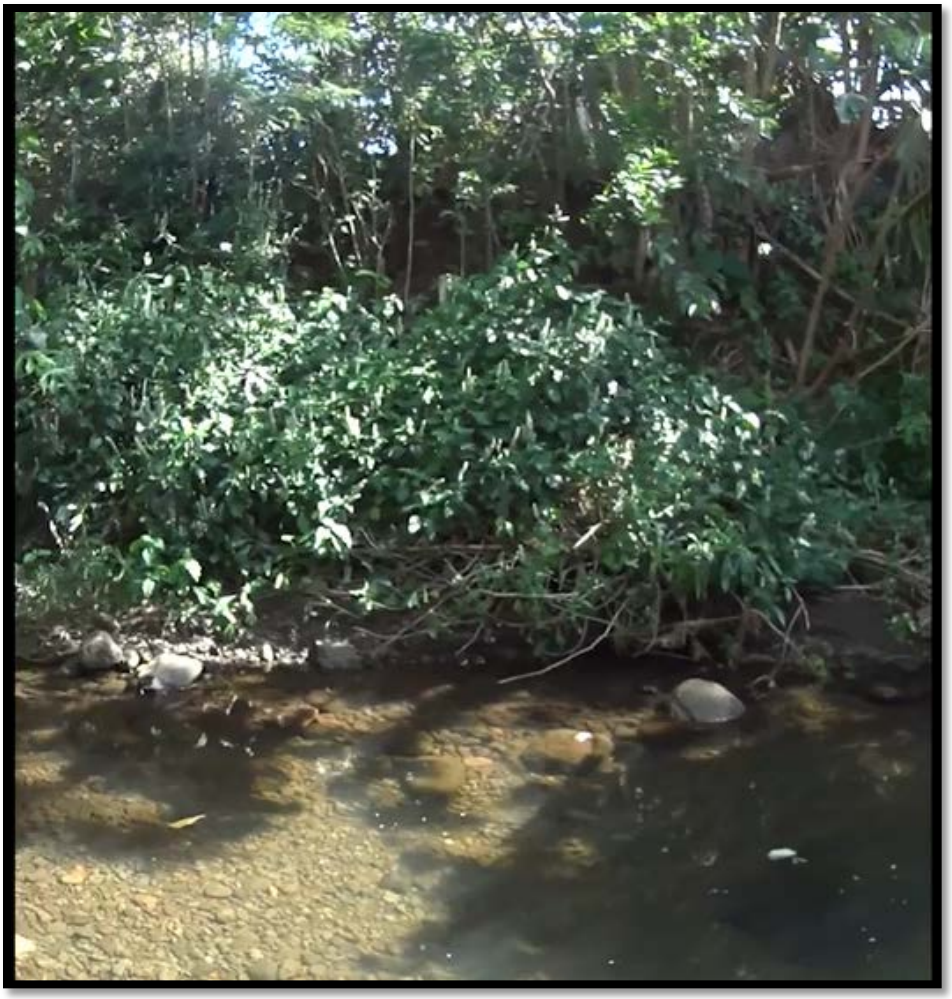

Figure 105: Moderate Potential for Bank Erosion. Bank angle is relatively steep (between 60-80°), Surface Protection is good, but there is some exposed bank. The Bank Height is rather tall (9 to 12 ft) and the Riparian Zone displays a lack of larger diameter vegetation.

Figure 106: High potential for Bank Erosion. The bank shows an almost undercut bank angle with marginal surface protection due to limited vegetation on the top part of bank and poor riparian diversity due to the complete lack of roots. Bank erosion is likely during high water events.

Fish Classification:

Native Fishes: O'opu nakea (*Awaous stamenius*), O'opu naniha (*Stenogobious hawaiiensis*), O'opu nopili (*Sicyotperus stimponi*), O'opu alamo'o (*Lentipes concolor*) O'opu akupa (*Eleotris sandvicensis*), Aholehole (*Kuhlia zenura*), Mullet (*Mugil cephalus)*

Native Crustaceans and Mollusks: Opae oeha'a (*Macrobrachium grandimanus*), Opae kala'ole (*Atyoida bisulcata*), Hihiwai *(Neritina granosa*), Hapawai (*Neritina vespertina*)

Introduced Fishes: Armored Catfish (*Hypostomus c.f. watawata)*, Bristlenose Catfish (*Ancistrus c.f. temmincki*), Bronze Corydoras (*Corydoras aeneus)*, Liberty Molly (*Poecilia sp. hybrid complex)*, Green Swordtail (*Xiphophorus hellerii)*, Guppy (*Poecilia reticulata)*, Mosquitofish (*Gambusia affinis*), Blackchin Tilapia (*Sarotherodon melanotheron)*, Convict Cichlid (*Amatitlania nigrofasciata)*, Smallmouth Bass (*Micropterus dolomieu)*, Carp (*Cyprinus carpio)*, Goldfish *(Carassius auratus)*

Introduced Crustaceans, Mollusks, and Amphibians: Tahitian prawn (*Macrobrachium lar*), Grass Shrimp (*Neocaridina denticulata sinensis*), Crayfish (*Procambarus clarkii*), Cane Toad (*Bufo marinus*)

Fish and other stream animal surveys were accomplished using two methods. The first method was visual surveys completed as the HDSS habitat surveys were underway. The visual surveys were further confirmed with net samples conducted by DAR biologists and technicians. While the visual surveys were widespread and covered all the habitat areas, these surveys likely missed some small or cryptic animals.

Figure 107: An example of a large Koi (Cyprinus carpio) captured during the net surveys.

Figure 108: Native mollusk, *Neritina vespertina*, on rock from in the lower reach of a stream.

The second and more extensive fish and aquatic animal survey involved the use of the High Definition Fish Survey (HDFS) approach. The HDFS approach utilized pole-mounted, high-definition, underwater video cameras to capture images of fish or other aquatic animals at a specific location. The underwater cameras were also geo-referenced so that specific time and place information was recorded for all video observations. By logging GPS data with underwater video, the HDFS results can easily be integrated with the HDSS habitat information gathered at the same location.

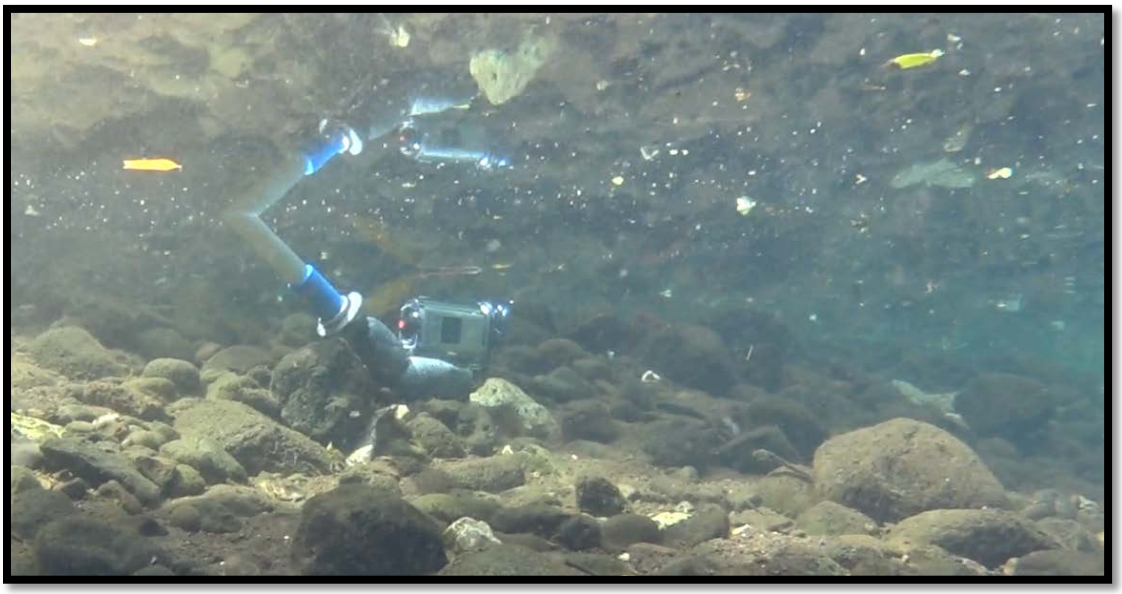

Figure 109: Underwater geo-referenced video camera used during the HDFS observations.

In general, the HDFS sample could be considered a point sample. The cameras are moved into position, slowly lowered to the bottom, and then remain in position for approximately 15 seconds to capture a sample of animals at that location. This process is repeated at sites distributed evenly throughout the available habitat. To document the animals observed in the videos, the HDSS video coder software with a list of potential animal species was used. During classification, a start code was inserted when the camera was in position. Next, all species were recorded, and then a stop code was recorded. This process allowed only high-quality underwater video samples to be used and to link the appropriate GPS data for that location. Habitat data associated with the fish samples was linked from the HDSS data collection.

The following are some examples of stream animals observed during the HDFS sample collection from various Hawaiian streams:

Figure 110: Native fish, *Awaous steminus*, in a stream pool.

Figure 111: Native fish, *Sicyopterus stimpsoni*, on boulder substrate.

Figure 112: Native species, *Kuhlia zenura*, in the lower reach of a stream.

Figure 113: Introduced swordtails, *Xiphophorus hellerii*, observed at high density.

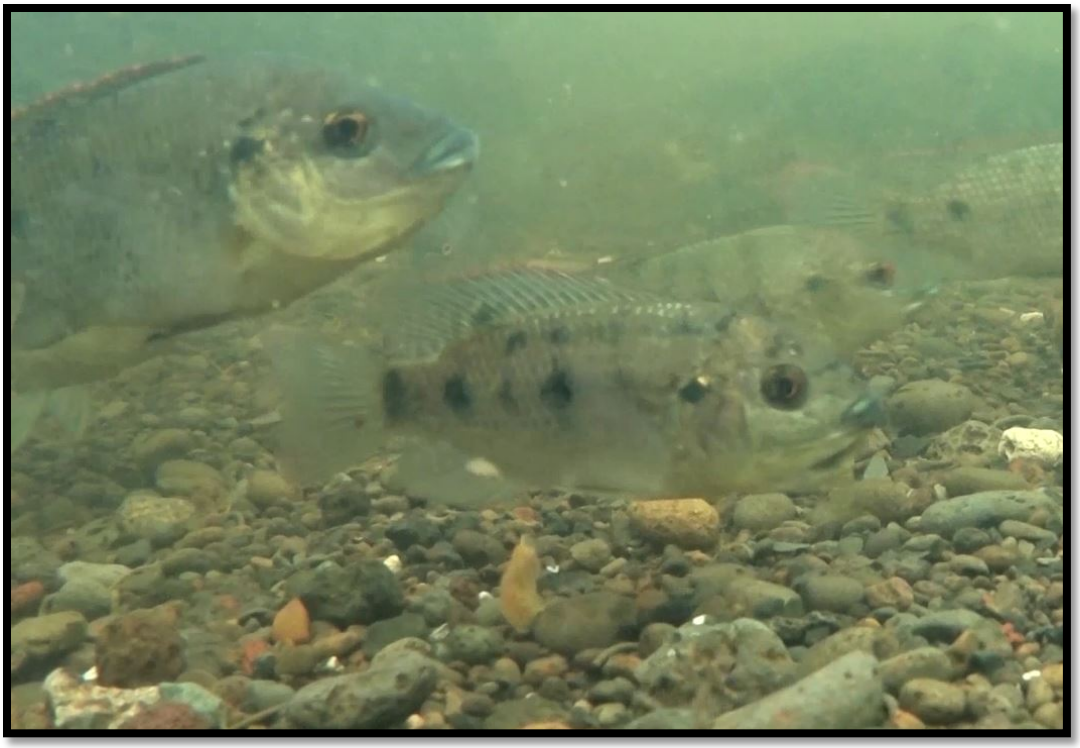

Figure 114: Introduced Blackchin tilapia, *Sarotherodon melanotheron*, over gravel substrate.

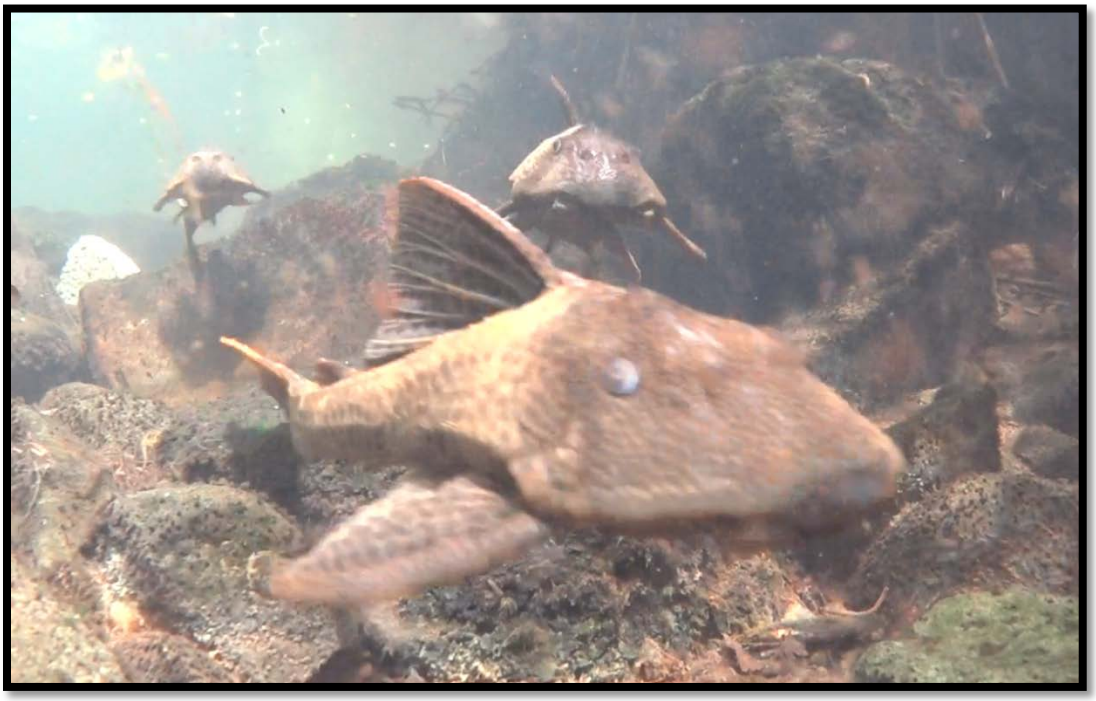

Figure 115: Introduced armored catfish, *Hypostomus c.f. watawata*, were found in large aggregations.

Attachment 2. Single-Use Approval of the Hawaiian Stream Habitat Evaluation Procedure for the Ala Wai Canal Flood Risk Management Project

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P 28 May 2015

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: Single-Use Approval of the Hawaiian Stream Habitat Evaluation Procedure for the Ala Wai Canal Flood Risk Management Project, Hawaii

1. The HQUSACE Model Certification Panel has reviewed the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) in accordance with EC 1105-2-412 and has determined that the model and its accompanying documentation are sufficient to approve its use for the Ala Wai Canal flood risk managament study, Oahu, Hawaii. Adequate technical reviews have been accomplished and the Panel considered the assessments of the ECO-PCX and the Agency Technical Review in making this determination.

2. The HSHEP model was developed through collaboration between the Hawaii Division of Aquatic Resources and researchers at universities, state agencies, museums, and private entities. The model follows the Habitat Evaluation Procedure concepts and methodology to capture the major aspects of native stream animal ecology, geomorphology of Hawaiian streams, and common modifications to the environment. The intent of the model is to be useful in assessing the potential impacts of stream channel modification, flow alteration, land use change, climate change, stream restoration, and barrier modifications on native stream animal habitat quality and quantity. The HSHEP is designed to be used at site, stream segment, and stream and watershed scales depending on the scenario and level of detail required. Variables at the watershed scale include stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. Variables in the model describe instream habitat and animal distributions include factors such as elevation, distance from the ocean, and the presence of instream barriers. Finally, at the site level, more specific characteristics are included as suitability indices for six instream flow assessment (e.g., depth, velocity, and substrate) or habitat assessment (e.g., habitat type, depth, substrate, and temperature for habitat assessment) depending on the project objectives. Habitat suitability for eight species of native stream animals (i.e., five fish, two crustaceans, and one mollusk) was determined using presence/absence data as the basis for habitat utilization. Habitat utilization is the frequency of occurrence for an individual species in each habitat category. Suitability is developed by dividing the percent utilization for each habitat category with the percent available. The resulting suitability curve ranges from 0 (unsuitable) to 1.0 (highly suitable). By combining HSHEP results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable.

3. The HSHEP model has been reviewed by the Hawaii Division of Aquatic Resources, the USFWS and private consultants utilizing the model for hydroelectric licensing applications. Additionally, the ECO-PCX managed a review of the HSHEP model. The review was conducted by an ecologist with expertise in tropical island flora and fauna, associated habitat requirements, and extensive ecological modeling expertise, Dr. Kyle McKay, ERDC Environmental Laboratory. Comments received pursuant to this review recommended actions to clarify and improve model documentation and improve the overall usability of the model. The model documentation and inherent user's guide was

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updated to more explicitly describe the intended use and appropriate documentation for variables, use of scales, and addition of variables. Documentation was improved to further detail application methodology, assumptions and limitations of the model, and address statistical model development issues.

4. The HSHEP has sufficient technical quality, is computationally correct, meets usability criteria and is policy compliant.

APPLICABILITY: The HSHEP is approved for single use on the Ala Wai Canal flood risk management study, Oahu, Hawaii.

BRUCE D. CARLSON
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

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Attachment 3. Ala Wai Flood Control Project Impact to Native Stream Animal Habitat and Possible Habitat Mitigation Options

Ala Wai Flood Risk Management Project Impact to Native Stream Animal Habitat and Possible Habitat Mitigation Options

August 5, 2015

Submitted to:

CH2MHill
1132 Bishop Street, Suite 1100
Honolulu, Hawaii 96813

Submitted by:

James E. Parham, Ph.D.
Bishop Museum

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Introduction:

The purpose of the Ala Wai Canal Project is to reduce the risk of flooding within the Ala Wai watershed. In general, the flood risk management project is focused on holding back or diverting peak flood flows to lessen the impact of a flooding event. The infrastructure needed to do this is expected to have an impact on aquatic habitat and native Hawaiian stream animals. This report is an accounting of the impacts of the flood risk management project on aquatic habitat and native Hawaiian stream animals, and potential mitigation plans to offset these impacts. The Hawaiian Stream Habitat Assessment Procedure (HSHEP) model was used to determine the impact and quantify mitigation scenarios. In addition to supporting the HSHEP model, long stretches of Manoa, Palolo and Makiki streams were surveyed to better understand instream conditions both at the impact sites and throughout the stream in general.

Data Collection and HSHEP Methodology:

The overall HSHEP approach and methodology was reviewed by the USACE and approved for use on the Ala Wai Flood Risk Management Project. The HSHEP for the Ala Wai Flood Risk Management Project followed the accepted approach and methods can be found in the document:

Parham, J.E. 2015. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat. Submitted to Civil and Public Works Branch, U.S. Army Corps of Engineers, Honolulu District, HI. 178 pages.

Associated Data:

Also provided with this report are associated data tables and field videos. An Excel spreadsheet of the information associated with the stream segment results from the HSHEP model is named:

Parham, J.E. 2015. Ala Wai HSHEP Impact and Mitigation Worksheet: Spreadsheet of model outputs. Final Output.

There are also a number of video files from the High Definition Stream Surveys (HDSS) for the Ala Wai watershed streams (Table 1). The video files may be referred to as:

Parham J.E. and G.R. Higashi. 2015. High Definition Stream Surveys Video for the Ala Wai Watershed Streams: Video Name: *insert_name_here*.

The video names are as follows:

Table 1: HDSS Video Names for Ala Wai Watershed Streams.

HDSS_Video_Name
02_LowerManoa1
03_LowerManoa2
06_MaonaF2UH_final
07_UHupstreamT11_final
08_UHupstreamT12_final
09_UHupstreamT2_final
11_Track23_combined_final
13_ManoaDVpark_Up1Final
14_Manoa_D3T1a
15_Manoa_D3T2a
16_Manoa_D3T3a
17_Manoa_D3T3ba
18_Manoa_D3T4a
20_Upper_Trib
51_lowerPalolo1
54_PaloloMid1
55_PaloloMid2
58_UpperPaloloHDSS
80_Makiki1

Not all of the data could be presented effectively in this report. There were approximately 23,000 lines of data generated for the sites in the HSHEP model. This report summarizes the results in a segment by segment approach. All data will be made available with this report.

Geographic Area of Concern:

The overall HSHEP Model included Manoa Stream and its tributary Palolo Stream as well as Makiki Stream and Hausten Ditch which also flow into the Ala Wai Canal (Figure 1). These streams are all within the Ala Wai Watershed. The Ala Wai Flood Risk Management Project impacts various locations within Ala Wai Watershed streams. The stream segments are broadly numbered with lower numbers closer to the stream mouth and higher numbers toward the headwaters. Manoa Stream is numbered from 1 to 120, Palolo Stream 200 to 225, Makiki Stream 300 to 306, Hausten Ditch from 500 to 502. Table 1 shows the Segment IDs, Stream Name, and Flood Risk Management Site (Table 2).

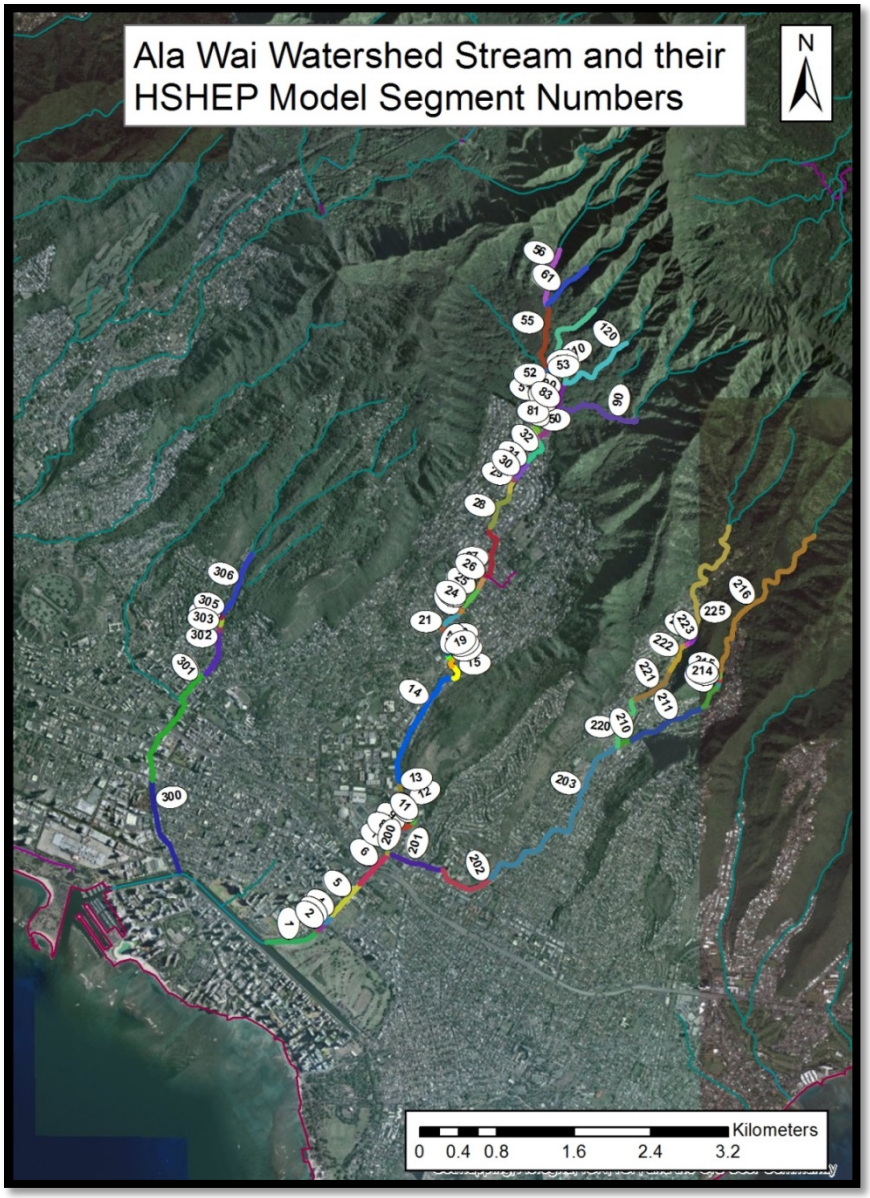


Figure 1: The Ala Wai Watershed Streams and the segment numbering used in the HSHEP model. Manoa Stream numbering goes from 1 at the stream mouth upstream to 120 in the upper reaches, Palolo Stream from 200 to 225, and Makiki Stream from 300 to 306.

Table 2: HSHEP Stream Segment ID, Name, and other information.

Segment ID	Stream Name	Tributary Name[1]	Key Site Description	Barriers: Falls Number (at start of segment)	Length[3] (m)	Width Class (ft)	Wetted Width (%)	Width (m)	Area (m^2)
1	Manoa	Manoa			520	80	90%	22	11,410
2	Manoa	Manoa	Ala Wai Golf Course Basin		22	80	90%	22	476
3	Manoa	Manoa			96	80	90%	22	2,115
4	Manoa	Manoa	Channel Maintenance Area		99	60	90%	16	1,638
5	Manoa	Manoa	Channel Maintenance Area		394	49	90%	13	5,304
6	Manoa	Manoa	Channel Maintenance Area		404	49	90%	13	5,407
7	Manoa	Manoa			108	36	90%	10	1,066
8	Manoa	Manoa			69	30	90%	8	569
9	Manoa	Manoa		Lower Falls	111	33	90%	9	1,004
10	Manoa	Manoa			96	33	90%	9	882
11	Manoa	Manoa	Kanewai Detention Basin		19	40	90%	11	212
12	Manoa	Manoa			320	35	90%	10	3,057
13	Manoa	Manoa			122	35	90%	10	1,171
14	Manoa	Manoa			1208	39	89%	11	12,714
15	Manoa	Manoa	State Woodlawn Chute Project		170	39	56%	7	1,132
16	Manoa	Manoa	State Woodlawn Chute Project		106	32	90%	9	942
17	Manoa	Manoa	State Woodlawn Chute Project		11	40	86%	10	116
18	Manoa	Manoa	State Woodlawn Chute Project		19	40	48%	6	111
19	Manoa	Manoa	State Woodlawn Chute Project		10	40	30%	4	36
20	Manoa	Manoa			228	33	30%	3	684
21	Manoa	Manoa	Channelized	Chan Barrier	74	50	30%	5	338
22	Manoa	Manoa	Channelized	Chan Barrier	199	50	30%	5	912
23	Manoa	Manoa	Channelized	Chan Barrier	55	50	30%	5	253
24	Manoa	Manoa	Manoa Instream Debris Catchment		13	44	68%	9	120
25	Manoa	Manoa			234	32	90%	9	2,078
26	Manoa	Manoa	Streambank Restoration Area		124	40	90%	11	1,362
27	Manoa	Manoa			564	35	89%	9	5,298

28	Manoa	Manoa		Barrier: Falls 6[4]	428	39	90%	11	4,567
29	Manoa	Manoa		Barrier: Falls 7	116	50	90%	14	1,597
30	Manoa	Manoa		Barrier: Falls 8	36	50	90%	14	498
31	Manoa	Manoa			197	50	90%	14	2,704
32	Manoa	Manoa			318	43	90%	12	3,784
50	Manoa	Waiahi			190	34	90%	9	1,759
51	Manoa	Waiahi		Barrier: Falls 11	366	30	75%	7	2,518
52	Manoa	Waiahi			73	30	75%	7	503
53	Manoa	Waiahi	Waiahi Detention Basin		37	30	75%	7	255
54	Manoa	Waiahi			60	30	75%	7	415
55	Manoa	Waiahi			617	20	90%	5	3,383
56	Manoa	Waiahi			567	15	90%	4	2,333
61	Manoa	Unnamed			531	15	90%	4	2,184
80	Manoa	Luaalaea			191	34	90%	9	1,768
81	Manoa	Luaalaea		Barrier: Falls 12	58	24	90%	7	387
82	Manoa	Luaalaea	Waiakeakua Detention Basin		63	27	90%	8	474
83	Manoa	Luaalaea			36	25	90%	7	247
90	Manoa	Waiakeakua			864	15	90%	4	3,557
100	Manoa	Luaalaea			257	20	90%	5	1,413
110	Manoa	Luaalaea			960	15	90%	4	3,949
120	Manoa	Naniuapo			815	15	90%	4	3,354
200	Palolo	Palolo			44	30	85%	8	344
201	Palolo	Palolo	Channelized	Chan Barrier	528	40	33%	4	2,086
202	Palolo	Palolo			570	30	86%	8	4,522
203	Palolo	Palolo	Channelized	Chan Barrier	2003	38	45%	5	10,451
210	Palolo	Waiomao	Channelized	Chan Barrier	154	35	45%	5	739
211	Palolo	Waiomao			789	35	45%	5	3,788
212	Palolo	Waiomao			275	22	83%	6	1,522
213	Palolo	Waiomao			40	25	90%	7	279
214	Palolo	Waiomao	Waiomao Detention Basin		34	20	90%	5	185
215	Palolo	Waiomao	Waiomao Detention Basin Excavation	Barrier: P_Falls 5	66	35	89%	9	620

216	Palolo	Waiomao			1852	15	90%	4	7,623
220	Palolo	Pukele	Channelized	Chan Barrier	566	40	50%	6	3,447
221	Palolo	Pukele			459	30	90%	8	3,777
222	Palolo	Pukele			308	30	90%	8	2,535
223	Palolo	Pukele	Pukele Detention Basin		54	30	90%	8	443
224	Palolo	Pukele			114	25	90%	7	785
225	Palolo	Pukele			1373	15	90%	4	5,648
300	Makiki	Makiki			940	40	90%	11	10,312
301	Makiki	Makiki	Channelized	Chan Barrier	1272	30	50%	5	5,814
302	Makiki	Makiki			454	18	84%	5	2,126
303	Makiki	Makiki			56	14	90%	4	220
304	Makiki	Makiki	Makiki Detention Basin		74	20	90%	5	404
305	Makiki	Makiki			57	16	90%	4	255
306	Makiki	Makiki			634	15	90%	4	2,607
500	Hausten	Hausten	Hausten Detention Intake		10	66	90%	18	181
501	Hausten	Hausten			150	66	90%	18	2,716
502	Hausten	Hausten	above Marco Polo Apts		560	44	90%	12	6,759

Description of Flood Risk Management Impact Areas:

<u>Site 1, Manoa Stream: Ala Wai Golf Course Basin Intake</u>

Segment ID: 2

Area Map:

Figure 2: HSHEP segment numbers associated with the Ala Wai Golf Course Detention Basin

Site Description: Manoa Stream is relatively wide at this location and the banks are covered with mangrove trees. The channel is constrained by man-made streambanks. The water is relatively

slow moving and deep with fine substrates most common. This area is tidally influenced and what hard substrates do exist appear to be highly embedded with fine sediment.

The detention basin intake would be on the right hand shore looking upstream and would be a concrete structure that would fully harden a small section of the streambank. Instream habitat is unlikely to be greatly affected, as no plans for modification of the stream bottom are in the designs. The Expected Condition based on best professional judgment was a reduction in 20% of the habitat at the location due to the armoring of the streambank. The Worst-Case Condition reflected the maximum impact and was modeled at 100% loss of habitat as a result of the intake construction. The Worst-Case Condition likely far overstates the potential changes to instream habitat and its effects on native stream animals.

Figure 3: Looking upstream toward the Date Street Bridge. The golf course basin intake would be on the right.

Figure 4: Left bank looking upstream of lower Manoa Stream near the Date Street Bridge.

Figure 5: Right bank looking upstream of lower Manoa Stream near the Date Street Bridge. This is typical of the streambank condition at the basin intake site.

Site 2, Manoa Stream: Kanewai Field Multi-Purpose Detention Basin Intake

Segment ID: 11

Area Map:

Figure 6: HSHEP segment numbers associated with the Kanewai Field Detention Basin

Site Description: Manoa Stream is moderately wide and varies between riffles, runs, and pools in this area. The right bank looking upstream is already hardened with the majority of the riparian vegetation being found on the left-hand side. The site is a mix of substrates ranging from gravel to small boulders with cobble being the most common substrate type. The stream in this area has

relatively decent instream habitat typical of mid-reaches in Hawaiian streams. There is some embeddedness from fine substrates due to upstream erosion.

Similar to the Ala Wai golf course basin intake, the detention basin intake at the Kanewai Field would be on the right hand shore looking upstream and would be a concrete structure that would fully harden a small section of the streambank. Instream habitat is unlikely to be greatly affected as no plans for modification of the stream bottom are in the designs. In the Expected Condition, our best professional judgment was a reduction in 20% of the habitat at the location due to the armoring of the streambank. The Worst-Case Condition was 100% loss of habitat as a result of the intake construction. The Worst-Case Condition likely far overstates the potential changes to instream habitat and its effects on native stream animals.

Figure 7: Below the Kanewai Field Intake Site looking upstream. This image shows instream conditions typical downstream of the impact site. Note the USGS gage site on the right bank.

Figure 8: Immediately below the Kanewai Field Intake Site. The large box culvert in upper center image is a reference to the site location.

Figure 9: Streambank and in-channel conditions at the Kanewai Field Intake site.

Figure 10: Looking upstream of the Kanewai Field Intake site.

<u>Site 3, Manoa Stream: Manoa Instream Debris Catchment Site near Manoa Valley District Park</u>

Segment ID: 24

Area Map:

Figure 11: HSHEP segment numbers associated with the Manoa In-Stream Debris Catchment Site.

Site Description: The site for the instream debris catchment is just upstream of a long channelized segment of Manoa Stream. This site is adjacent to the Manoa Valley District Park in the channel appears to have been straightened and widened in the past. Cobble and gravel are the primary substrates available with a small amount of fine sediment embedding of larger substrate types. The area is primarily a run habitat type mostly a foot or less in depth.

The impact at this location is expected to remove all instream habitat for native stream animals as the bottom will be entirely made of cement with the debris catchers rising up from it. Thus, the Expected Condition is in line with the Worst-Case Condition modeled as a total removal of the habitat.

Figure 12: Downstream of Debris Catchment site. Note that the stream is fully channelized here.

Figure 13: At the end of the channelized section immediately downstream of the Debris Catchment site.

Figure 14: Debris Catchment site. Manoa Valley District Park is on the left side of the image.

Figure 15: Upstream of the Debris Catchment Site. Instream habitat is similar from the end of the channelized segment to the bridge above.

Site 4, Manoa Stream: Woodlawn Ditch Detention Basin

Segment ID: no ID number (not perennial stream at Detention Basin site)

Area Map:

Figure 16: Map of the Woodlawn Ditch stream segments downstream of detention basin site.

Site Description: The Woodlawn Ditch was surveyed by state biologists and technicians. The ditch appears to have perennial flow in the lower end and becomes intermittent in the area of the planned detention basin. The stream was not surveyed directly in the impact area, but it was dry above it and was very small below it. Under best of conditions, the amount and quality of

instream habitat for native amphidromous stream animals would be limited, but with its designation as an intermittent stream, we did not include it in the model as by definition it would not support the stream animals of concern.

Figure 17: Mouth of the Woodlawn Ditch entering Manoa Stream. Ditch is entering on the right side of stream.

Figure 18: Downstream view of Woodlawn Ditch from East Manoa Road Bridge. (G. Higashi, DAR photo)

Figure 19: View straight down from East Manoa Road Bridge into Woodlawn Ditch. (G. Higashi, DAR photo)

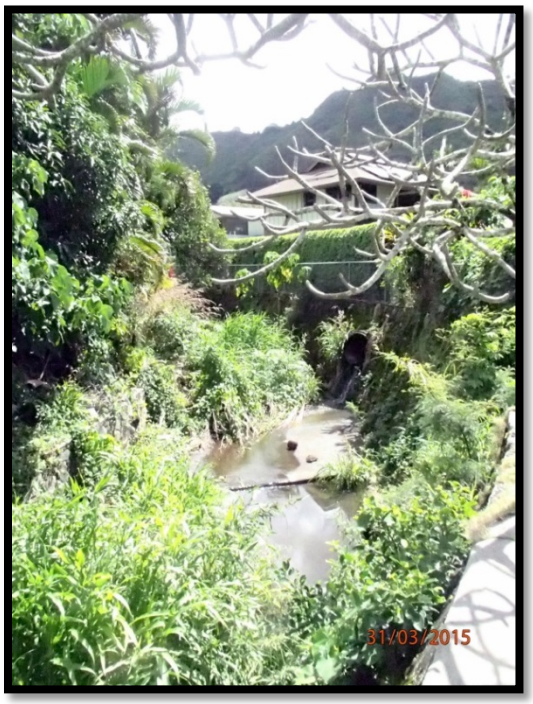


Figure 20: Looking upstream on Woodlawn Ditch from end of Kahiwa Place. Channelized section begins here. (G. Higashi, DAR photo)

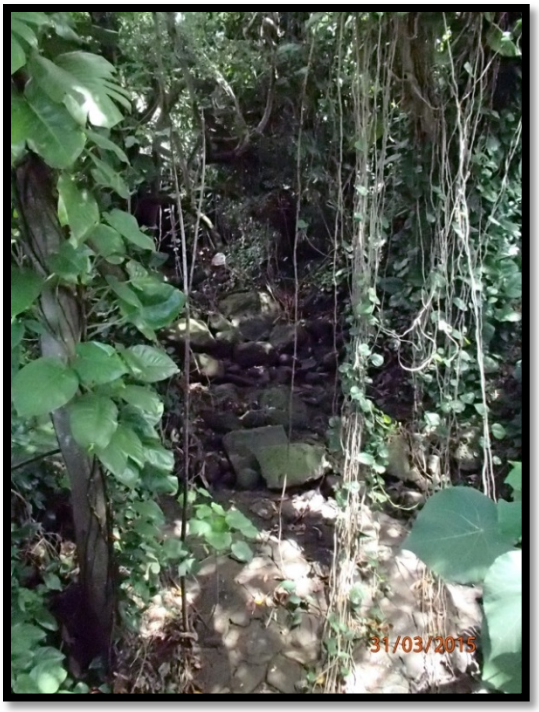


Figure 21: Looking upstream from the East Manoa Road and Akaka Place intersection. Stream is dry here. This is just above the Detention Basin site. (G. Higashi, DAR photo)

Figure 22: Looking upstream from the East Manoa Road and Akaka Place intersection. Stream is dry here. This is just above the Detention Basin site. (G. Higashi, DAR photo)

Site 5, Manoa Stream: Waihi Debris and Detention Basin

Segment ID: 53

Area Map:

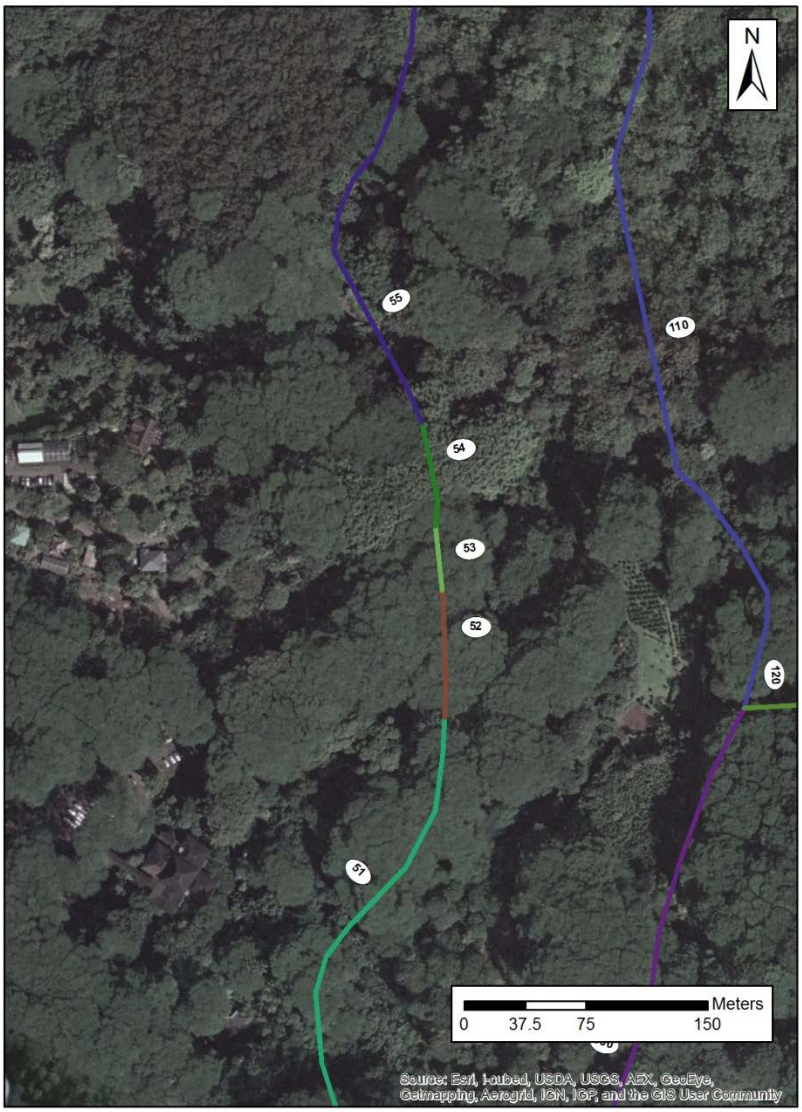


Figure 23: HSHEP segment numbers associated with the Waihi Debris and Detention Basin Site.

Site Description: Manoa Stream, in the vicinity of the Waihi Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site is above the majority of the development found lower in the watershed and has large trees throughout its riparian zone. There is evidence of erosion scars from past flooding events and numerous large logs are found in the stream channel but in general the instream habitat would be considered good in comparison to much of the rest of Manoa Stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and the Worst-Case Condition scenarios.

Figure 24: Downstream of the Waihi Detention Basin Site.

Figure 25: A plunge pool in the area of the Waihi Detention Basin Site.

Figure 26: Looking upstream toward Waihi Detention Basin Site. Much of the area ahead was impassable due to flood debris, with many logs across the stream.

Site 6, Manoa Stream: Waiakeakua Debris and Detention Basin

Segment ID: 82

Area Map:

Figure 27: HSHEP segment numbers associated with Waiakeakua Debris and Detention Basin Site.

Site Description: The tributary of Manoa Stream, in the vicinity of the Waiakeakua Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site is above the majority of the development found lower in the watershed and has large trees throughout its riparian zone.

There is evidence of erosion scars from past flooding events and hau and bamboo are growing in the stream channel, but in general the instream habitat would be considered good in comparison to much of the rest of Manoa Stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and the Worst-Case Condition scenarios.

Figure 28: Lower end of Waiakeakua Debris Basin. Note that much of the area is overgrown by Hau trees.

Figure 29: Upper end of Waiakeakua Debris basin.

Site 7, Palolo Stream: Waiomao Debris and Detention Basin

Segment ID: 214 and 215

Area Map:

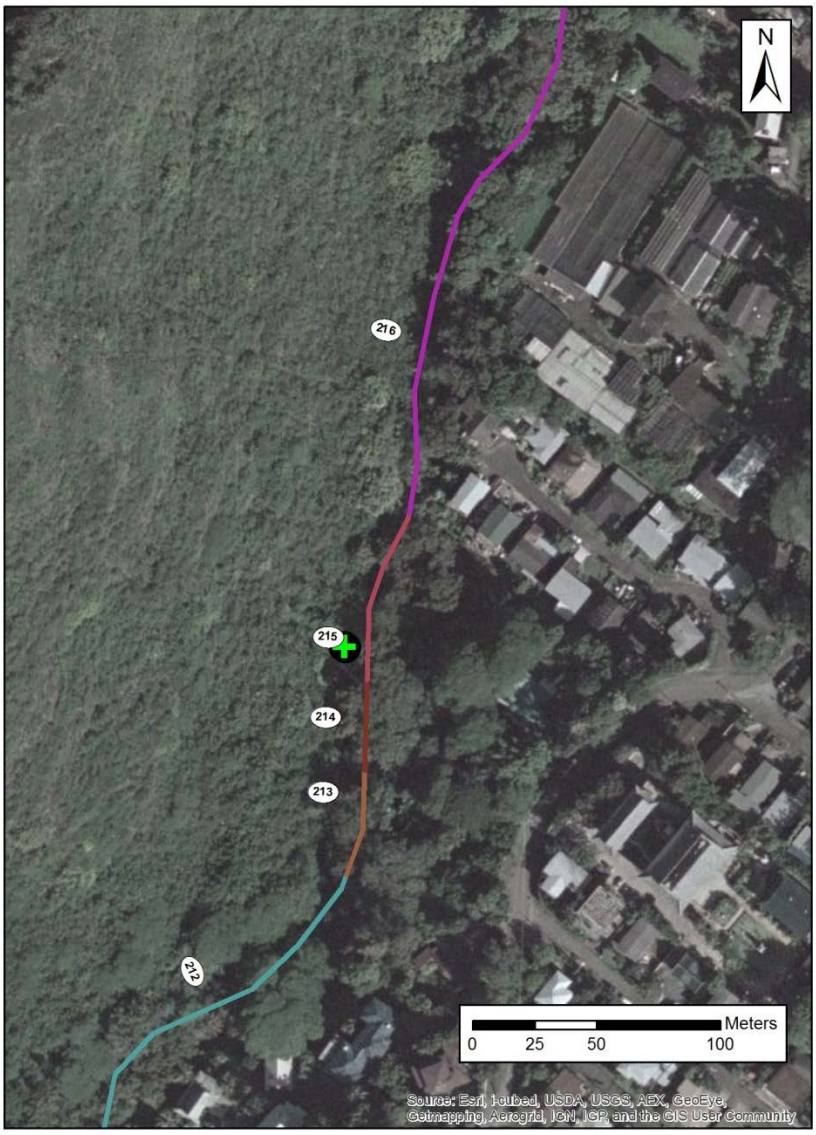


Figure 30: HSHEP segment numbers associated with Waiomao Debris and Detention Basin Site.

Site Description: The Waiomao tributary of Palolo stream, in the vicinity of the Waiomao Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site has housing developments on its right bank looking upstream but still has large trees and bushes in much of its riparian zone. There is evidence of erosion scars from past flooding events and an old USGS

gage is located in the stream channel at the site. Overall, the instream habitat would be considered good in comparison to much of the rest of Palolo stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the best professional judgment and the maximum impact scenarios. At this location, the area above the berm will be excavated to increase the detention volume of the basin and thus some habitat will be lost in this area also. Expected Condition expected a loss of approximately 50% of the habitat with the Worst-Case Condition scenario at 100% loss of habitat in the excavation area.

The old USGS gage will be removed during the construction of this project and as a result upstream passage will be improved for native migratory stream animals. Thus, there are both positive and negative impacts associated with the flood risk management project at this location.

Figure 31: Downstream of the Waiomao Tributary Detention Basin site.

Figure 32: Looking upstream into the Waiomao Tributary Detention Basin site.

Figure 33: The USGS gage in the Waiomao Tributary Detention Basin site. This old gage will be removed with the project and will no longer be a barrier to upstream animal passage.

Site 8, Palolo Stream: Pukele Debris and Detention Basin

Segment ID: 223

Area Map:

Figure 34: HSHEP segment numbers associated with Pukele Debris and Detention Basin Site.

No pictures available as we were unable to gain access to this site. It is modeled to be similar to the Waiomao Tributary site.

Site 9, Makiki Stream: Makiki Debris and Detention Basin

Segment ID: 304

Area Map:

Figure 35: HSHEP segment numbers associated with Makiki Debris and Detention Basin Site.

Site Description: Makiki stream, in the vicinity of the Makiki Debris and Detention basin, is a relatively natural stream. It is narrow with steep walls and we observed a range of substrate types from gravel to large boulder, with run, riffle and pool habitats all present. This site has large trees and bushes in much of its riparian zone. There is evidence of erosion scars from past flooding events. Overall, the instream habitat would be considered good in comparison to much of the rest of Makiki stream. We began our survey after the stream reemerged from being underground for a

long section under Honolulu. Interestingly, we observed amphidromous animals as well as numerous introduced fishes in the area. This confirms that some native animals are able to travel underneath the city to reach the upper reaches of the stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and Worst-Case Condition scenarios.

Figure 36: Downstream of Makiki Detention Basin Site.

Figure 37: Near downstream end of Makiki Detention Basin Site.

Figure 38: Makiki Stream in the area of Makiki Detention Basin Site.

<u>Site 10, Hausten Ditch: Hausten Ditch Detention Basin Intake</u>

Segment ID: 500

Area Map:

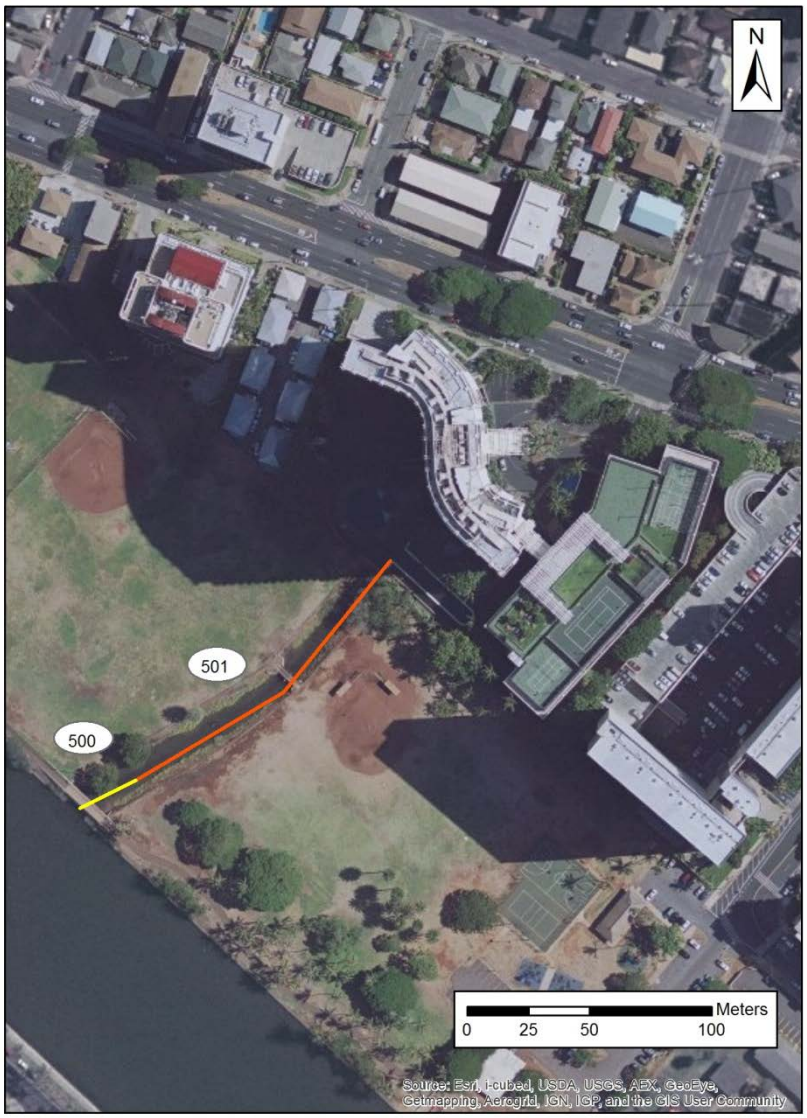


Figure 39: HSHEP segment numbers associated with Hausten Ditch Detention Basin Intake Site.

Site Description: Hausten Ditch is moderately wide at this location and the banks are covered with mangrove trees. The channel is constrained by man-made streambanks. The water is relatively slow moving and deep with mostly fine substrates. This area is tidally influenced and what hard substrates do exist appear to be highly embedded with fine sediment.

The Hausten Ditch detention basin intake would cross the entire channel and would likely eliminate instream habitat within its footprint. As a result, the Expected Condition and the Worst-Case Condition were modeled with a 100% loss of habitat as a result of the intake construction. The detention basin intake would not affect passage for stream animals and flow impacts would only be at very high flood flows.

Figure 40: Looking downstream toward the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch.

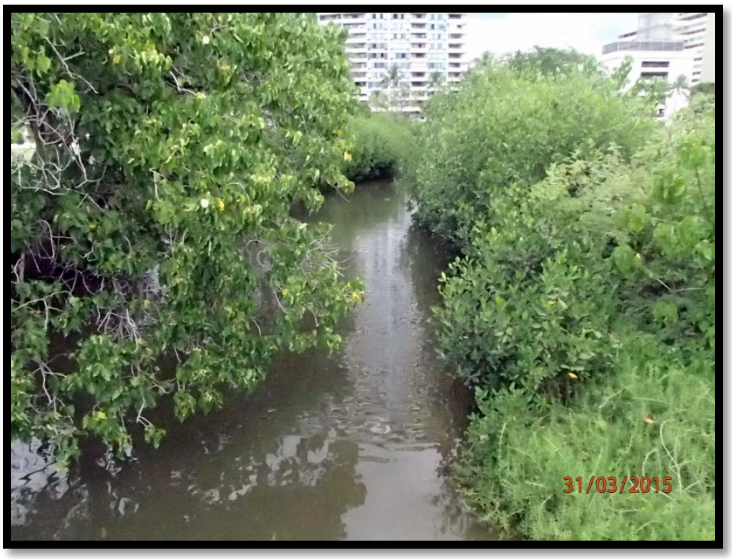


Figure 41: Looking upstream away from the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch. The intake will be on the right bank in this area.

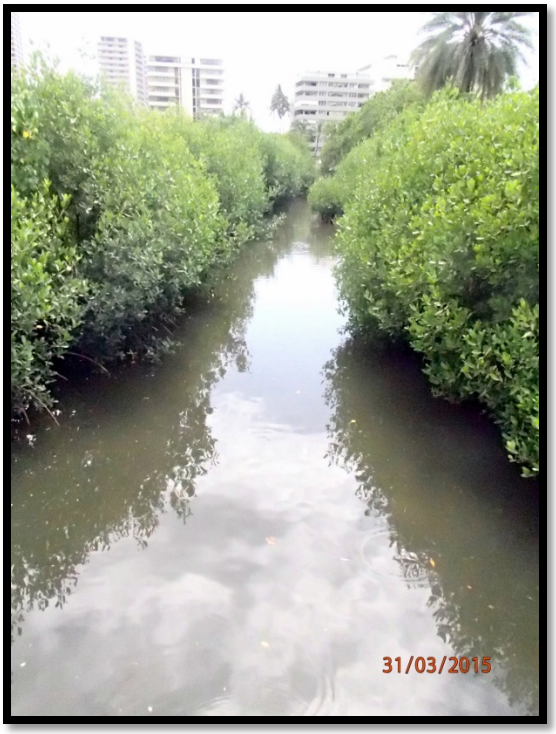


Figure 42: Downstream view from the second pedestrian bridge upstream of the intake site on Hausten Ditch.

Figure 43: The boundary fence for the Marco Polo Apartments on Hausten Ditch.

Figure 44: Looking upstream from Kapiolani Blvd. across from Marco Polo by bus stop.

Figure 45: Upstream view from Date St. Bridge into Hausten Ditch.

Mitigation Scenario 1, Manoa Stream: Mitigation of Channelized segment in Manoa Stream

Segment ID: 22 and 23

Area Map:

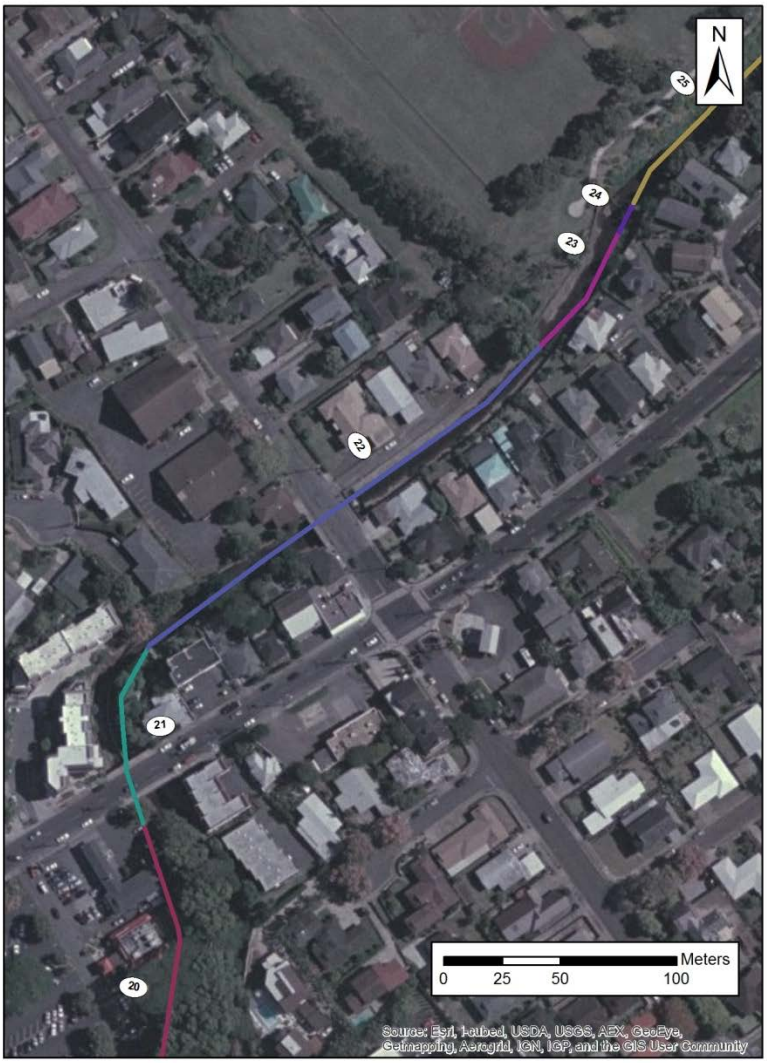


Figure 46: HSHEP segment numbers associated with Channelized section of Manoa Stream.

Mitigation Description: Improvements to the channelized section are intended to accomplish two separate goals. First, the improvements will allow easier passage across the long flat concrete bottom for migratory animals. The improvements will add some roughness and increase water depth to provide holding pools during passage. Second, the habitat pool and low flow channel designs would also provide suitable instream habitat within the channelized section. The plans would place the channel improvements starting above the curve in segment 21 and going

upstream to the end of the channelized section. The drop found in the middle of this section is not currently a barrier to native stream species that could reach this location so improvements are not focused on this particular instream feature.

The three instream improvements are:

1. Resting riffles - these are small speedbump-like features that provide shallow pools on the upstream side and concentrate flow on the downstream side. This is intended to allow migratory animals places to rest as they move through the channelized segment. It is not primarily for the improvement of instream habitat with the intent of animals living within the shallow features.
2. Habitat Pools - these are small pools cut into the existing bottom of the channel. These would be deep enough to provide some instream habitat under all flow conditions. The pools would be disconnected by the otherwise flat channel bottom. They would also improve passage by providing resting pools during migratory events.
3. Low-Flow Channel - the low-flow channel would be cut into the existing bottom of the channel. The low-flow channel would constrain flow to a much narrower channel with rocks embedded in the channel to provide complex flow, a variety of depths, and more natural substrate. This feature would be continuous through the channelized segment. The low-flow channel would provide instream habitat and improve passage.

From a modeling perspective, channelized sections of the stream are a barrier to passage, affecting the availability of habitat in all upstream segments. The longer the channelized section, the more difficult it will be for fish to pass without ending up in unsuitable habitat conditions (for example overly hot water due to its shallow and fully exposed channel shape). For short distances the majority of fish would likely pass, but if distances reach more than a kilometer or two, it is likely to cause some problems for passage. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 10% of the animals for each 100 m of channelized stream and the greater impact was modeled at a barrier to passage 15% of the animals for each 100 m of channelized stream. These provided a range of impacts to address passage uncertainty at the site.

For improvements to fish habitat, the estimates change in suitable habitat for the two instream habitat improvement is based on the designs of the structures and reflect the area of the new structure with respect to the overall channel dimension. The habitat pools were thought to add approximately 8% more suitable habitat area to the channel than without the features and the low-flow channel would add about 62% more suitable habitat area to the channel. The habitat pools are much smaller features than the continuous low flow channel. Both of these actions are improvements over the flat concrete bottom currently found in the channelized section, but neither option is a return to a natural stream bottom with complex instream habitat, therefore neither option returns 100% of potential habitat.

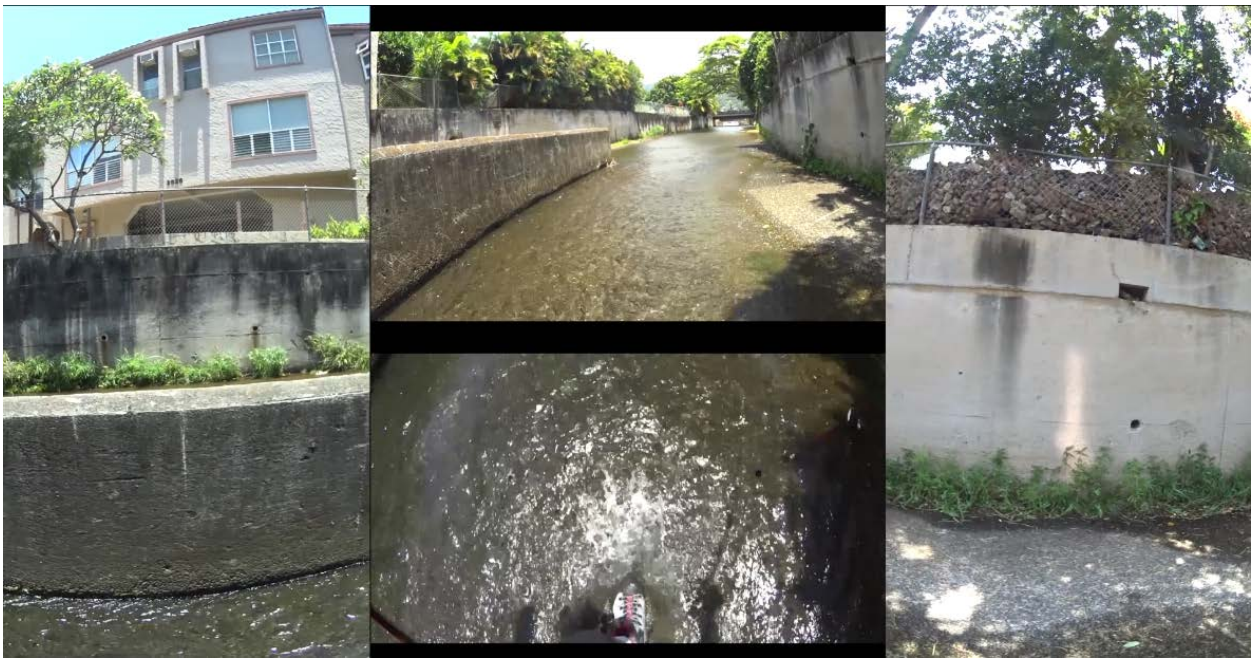


Figure 47: Channelized segment in Manoa Stream. Low-flow channel would begin just above wall in middle of stream.

Figure 48: Channelized segment of Manoa Stream

Figure 49: Drop in the channelized segment of Manoa Stream.

Figure 50: Above the drop in the Channelized segment of Manoa Stream.

<u>Mitigation Scenario 2, Mitigation of overhanging barriers</u>

Segment ID: multiple segments depending on barriers selected

Area Map:

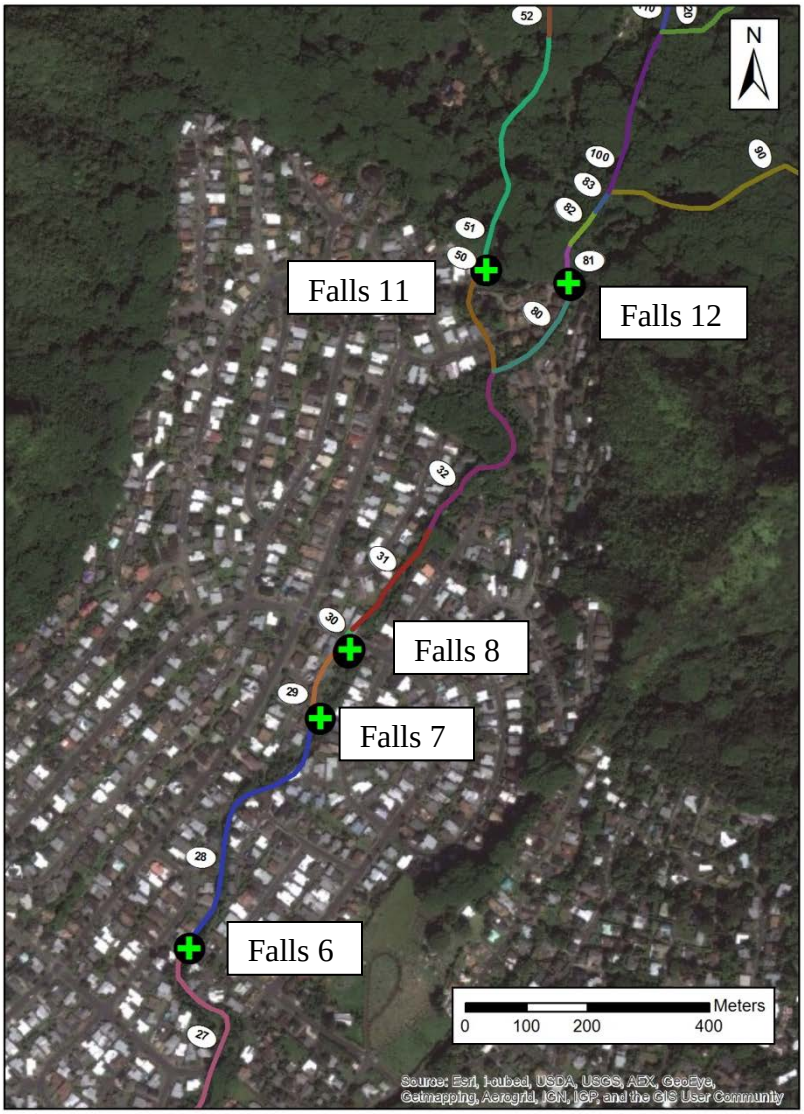


Figure 51: HSHEP segment numbers associated with overhanging falls on Manoa Stream. Falls are represented by the green cross in the black circle.

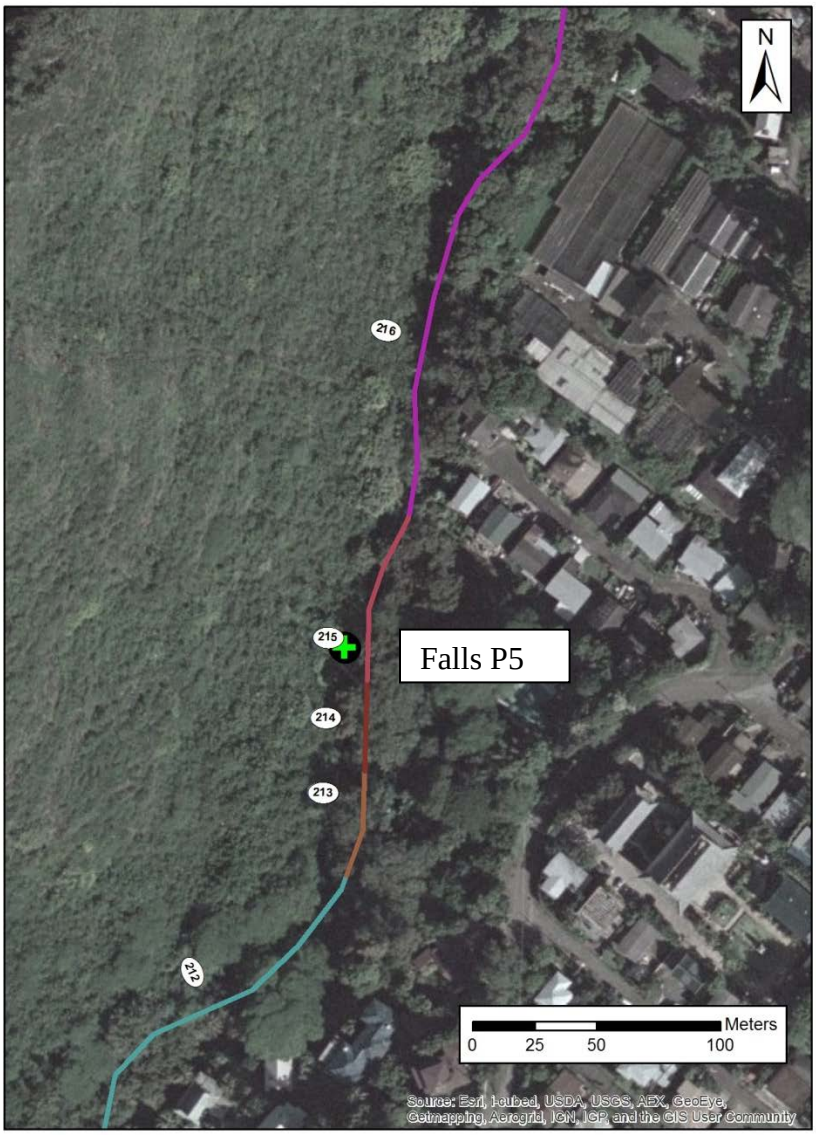


Figure 52: HSHEP segment numbers associated with overhanging falls on Palolo Stream. Falls are represented by the green cross in the black circle.

Mitigation Description: Waterfalls, either natural or man-made, which feature an overhanging lip that does not allow water to flow down the face of the waterfall with continuous contact, have been found to limit the ability of migratory animals to pass. During the surveys in the Ala Wai watershed streams, we observed a number of man-made structures that had the overhanging feature. In most cases, the overhanging feature was the result of erosion and undermining of the structure by the stream flow. These overhanging features were unlikely to be complete barriers to passage as at higher flows they may be completely underwater. At lower flows, migratory stream animals would need to wait below the feature until suitable flows aloud upstream passage. As a

result each barrier would increase the time that it would take for an animal to reach suitable upstream habitats and decrease the temporal window in which passage would be available.

The mitigation action proposed to improve the structures would be to fill in the area under the structure with grouted riprap to provide a continuous wetted surface at all discharges to allow fish passage. As a secondary benefit, these improvements would also extend the life of the features and decrease the probability of their failure in the stream.

From a modeling perspective, these barriers to passage affect the suitability of habitat in all upstream segments above the barrier. Additionally, the cumulative effect of multiple barriers can greatly reduce the suitability of upstream habitats by limiting the probability that fish could reach these locations. In the Ala Wai watershed streams, this is a problem because high-quality habitat can be found in the forested upstream reaches and these barriers decrease the availability of these habitats to native stream animals. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 50% of the time and the greater impact was modeled at a barrier to passage 65% of the time. These provided a range of impacts to address passage uncertainty at the site.

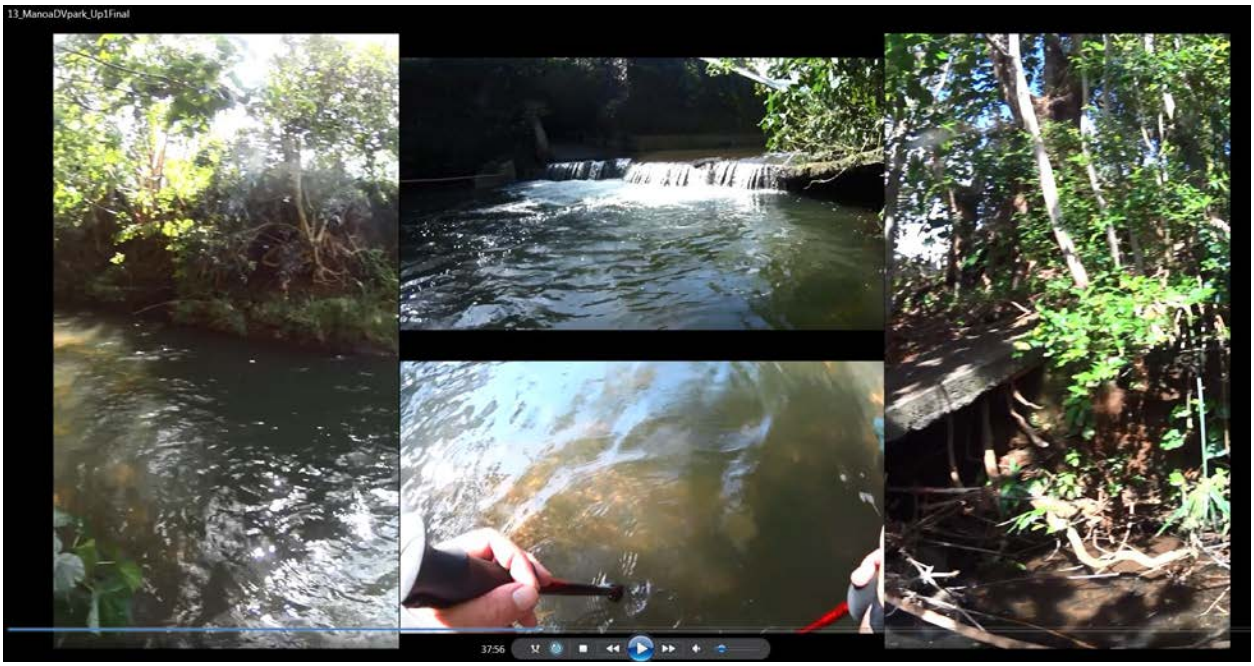


Figure 53: Overhanging barrier on the main channel of Manoa Stream (named as Falls 6).

Figure 54: Overhanging barrier on the main channel of Manoa Stream (named as Falls 7).

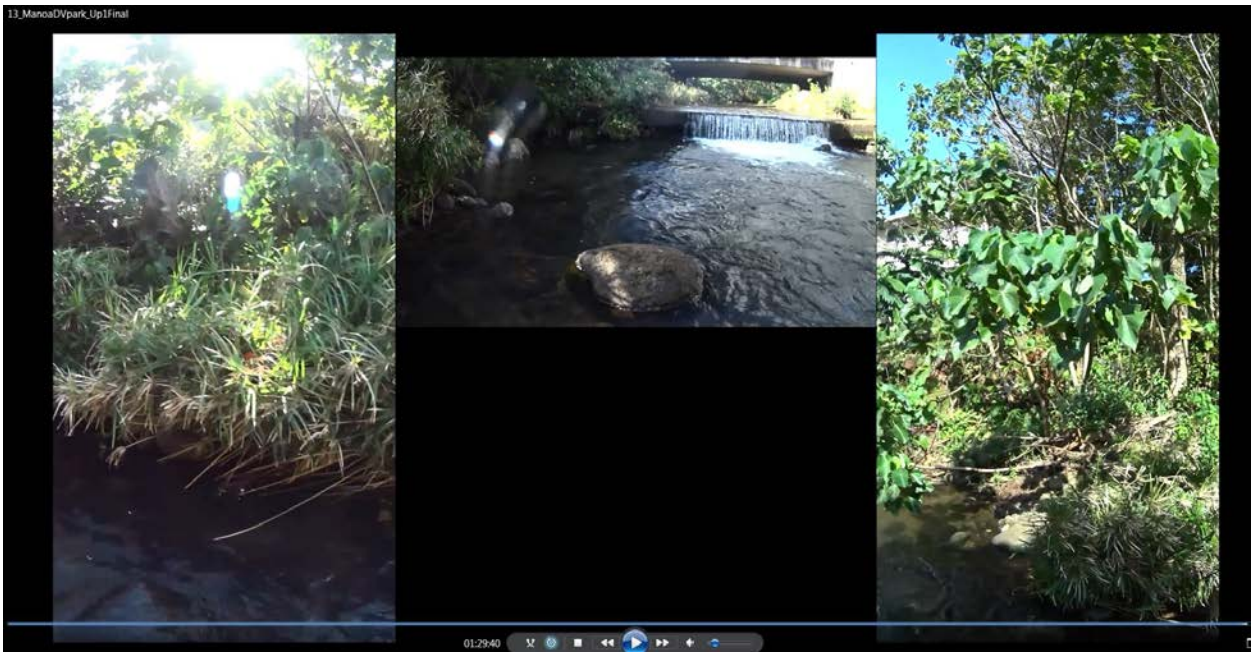


Figure 55: Overhanging barrier on the main channel of Manoa Stream (named as Falls 9).

Figure 56: Overhanging barrier on Manoa Stream tributary Waihi (named as Falls 11). This is a USGS gage that is failing.

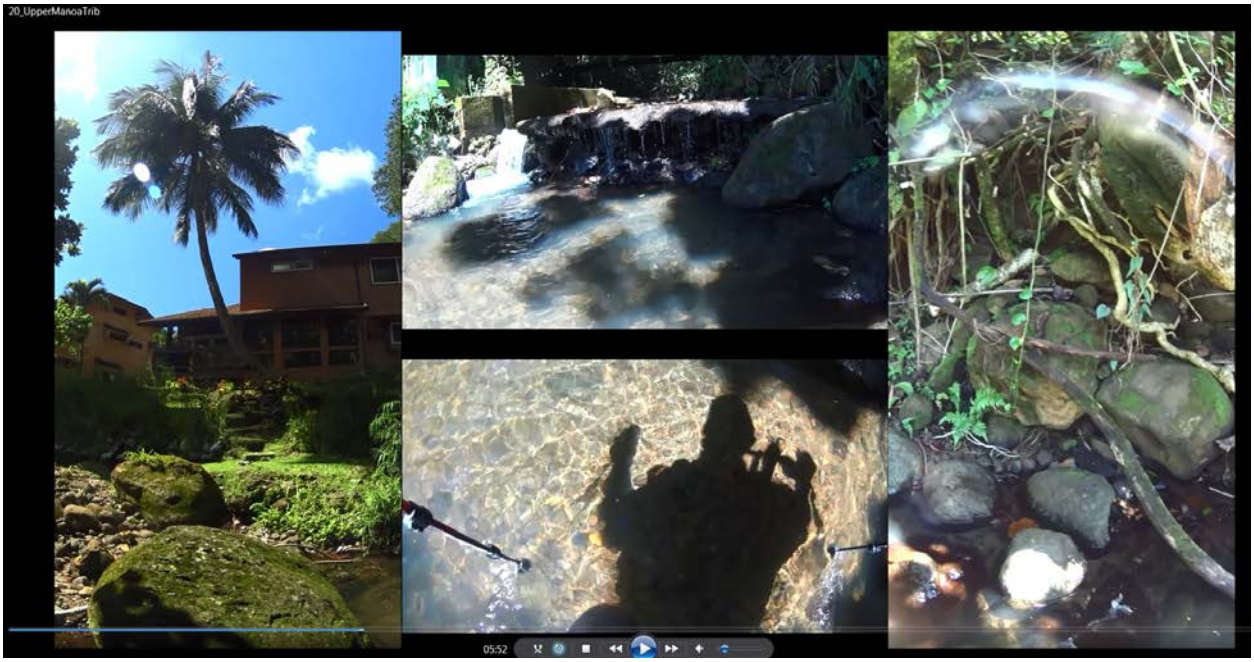


Figure 57: Overhanging barrier on Manoa Stream (named as Falls 12). This is another USGS gage that is being undermined. This is on the Waiakeakua tributary of Manoa Stream just below the Waiakeakua Debris and Detention Basin site.

Figure 58: Overhanging barrier on Palolo Stream tributary Waiomao. (named as Falls P5). This is a USGS gage that is in the footprint of the Waiomao Debris and Detention Basin.

Determination of current instream habitat availability:

Selection of Evaluation Species:

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Hawaiian streams (Table 2). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 3: Species habitat evaluated within the Hawaiian Streams using the HSHEP model. *Identified as "Species of Greatest Conservation Need" in the Hawaii Statewide Aquatic Wildlife Conservation Strategy.

Organism Type and Family	**Scientific name**	**Hawaiian name**	**Climbing Species**
Freshwater fish (family Gobiidae)	*Awaous guamensis**	‘O‘opu nākea	Yes
	*Lentipes concolor**	‘O‘opu alamo‘o	Yes
	*Stenogobius hawaiiensis**	‘O‘opu naniha	No
	*Sicyopterus stimpsoni**	‘O‘opu nōpili	Yes
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	‘O‘opu akupa	No
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	‘Ōpae kala‘'ole	Yes
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	‘Ōpae ‘oeha‘a	No
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai	Yes

Determination of Habitat Availability, Impact, and Mitigation:

Following the HSHEP methods approved by the USACE, the habitat suitability was determined for approximately each meter of the project area and then the average suitability within the segment was applied to each segment. A combination of habitat suitability and the length and width of the segment were used to determine the habitat units (HU) within the segment. The HU were calculated for each species and also the combination of all native species within the segment.

The current (or without project conditions) are based on the observed field conditions within the stream segments. The project impact (or with project conditions) was determined for loss of habitat and potential for restriction of passage for the native species. As discussed earlier, two impact possibilities were considered: (1) the Expect Condition based on best professional judgement (BPJ) of the impact, and (2) Worst-Case Condition with the complete elimination of habitat in the segment. The Expected Condition was based on discussions with state biologists, consulting hydrologic engineers and my professional opinion. We had a number of meetings and phone discussions to determine the extent of impacts and the potential mitigation benefits. The Worst-Case Condition provides an estimate of the upper bounds of the impact to habitat in the project area.

Table 4: Expected Condition results in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	36713	36,522	36,522	0
Palolo Stream	1377	1,484	1,366	118
Makiki Stream	7800	7,777	7,777	0
Hausten Ditch	8681	8,597	8,597	0
Total	**54572**	**54,380**	54,262	118
Overall HU Change		**-192**	-310	118
Net HU Change				

Table 5: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	35,391	34,584	34,584	0
Palolo Stream	834	863	831	32
Makiki Stream	7,495	7,484	7,484	0
Hausten Ditch	8,681	8,261	8,261	0
Total	**52,401**	**51,192**	**51,160**	**32**
Overall HU Change		**-1,210**	**-1,242**	**32**

The mitigation potential was determined for different potential mitigation efforts: (1) the improvement of passage barriers in the upstream reaches, and (2) the installation of a low-flow channel with various levels of instream habitat. Each of these mitigation efforts had different design applications and results are shown for the options below.

Table 6: Expected Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options in the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	37,875	40,392	41,978	42,604	44,190	37,814	37,736	37,729
Palolo Stream	1,484	1,484	1,484	1,484	1,484	1,484	1,484	1,484
Makiki Stream	7,777	7,777	7,777	7,777	7,777	7,777	7,777	7,777
Hausten Ditch	8,597	8,597	8,597	8,597	8,597	8,597	8,597	8,597
Total	**55,733**	**58,250**	**59,836**	**60,462**	**62,048**	**55,672**	**55,594**	**55,587**
Overall HU Change	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
Net HU Change	**1,161**	**3,678**	**5,264**	**5,891**	**7,477**	**1,100**	**1,022**	**1,016**

Table 7: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options for the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	35,386	37,401	39,041	39,689	41,329	35,882	35,809	35,803
Palolo Stream	863	863	863	863	863	863	863	863
Makiki Stream	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484
Hausten Ditch	8,261	8,261	8,261	8,261	8,261	8,261	8,261	8,261
Total	**51,994**	**54,009**	**55,649**	**56,297**	**57,937**	**52,490**	**52,417**	**52,411**
Overall HU Change	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**
Net HU Change	**-407**	**1,607**	**3,248**	**3,895**	**5,536**	**89**	**16**	**9**

It is important to remember that these summary tables provide the results for all of the native amphidromous species combined and are summarized at the stream level. The results of the model are far more specific than this but it is difficult to present very large spreadsheets in document form. The underlying data were collected at approximately 1 m resolution for both streambanks and the stream channel and then was summarized for the segments of concern throughout the watersheds. Next, changes for uncertainty in impact (Expected Condition and Worst-Case Condition), mitigation options, and species-specific distribution and habitat were all calculated. Changes to any one of these variables affects all the other results, and while this is an effective way to view the results in an active spreadsheet, it is difficult to reproduce in printed form.

Conclusion:

The application of the HSHEP model and High Definition Stream Surveys (HDSS) approach to habitat quantification for the assessment of current conditions with project impacts, and mitigation scenarios for the Ala Wai watershed streams in response to the USACE flood risk management project proved very successful. HDSS habitat availability data were collected broadly throughout the streams. This allowed very detailed understanding of where and what type of habitat was present in different stream segments. Prior to the HDSS fieldwork, the presence of over-hanging drops within Manoa and Palolo Streams were unknown. Covering extensive stream reaches also allowed us to see that the upper reaches of all of the streams still have suitable habitat for native amphidromous species and in many locations in the highly developed lower and middle reaches suitable habitat still exists.

The HSHEP model provides a standardized approach to assess both instream distribution and habitat suitability for the native amphidromous stream animals. It was able to address issues of fish passage as well as changes to local instream habitat. For all of the streams in the system, allowing migratory animals a pathway to reach their favorite habitats should allow for more native species to be found in the streams. Local improvement of habitat will also improve instream conditions. In many places, decent habitat existed but few native species were observed at the sites. Instead of native species, numerous introduced species were observed suggesting that habitat and water quality conditions were acceptable to stream fish.

To assess project impacts, the available habitat was multiplied by the percent of habitat likely left after the construction of the project given its design. Some loss of habitat was expected given the design criteria of the various Ala Wai Flood risk management structures. Determining exactly how habitat for native amphidromous species is changed by these construction activities is not always well understood. As a result, we combined our best professional judgment (Expected Condition) with a maximum impact (Worst-Case Condition) to provide a range of possibilities. The effect of the construction activities combined with variability instream conditions, as well as differences in species habitat use, result in a complicated matrix of outputs.

In general, Manoa Stream had the majority of the habitat units for native amphidromous species within the streams of concern. Palolo Stream had small amounts of habitat as a result of the long channelized segments of its downstream reaches. Makiki Stream had habitat for native species in both the upper and lower reaches even though it is a highly developed and impacted stream. We did observe native species in areas the model predicted they would occur although their densities were very low in comparison to introduced animals. Hausten Ditch, somewhat surprisingly, was predicted to have relatively large amounts of native stream animal habitat even though it is also highly developed. The majority of the habitat for the lower reach species was found in the lower end just upstream from the Ala Wai canal.

When viewing the with-project conditions, it is apparent that many of these flood risk management measures will not have a large impact on the overall native species habitat within the streams. The footprint of these measures is relatively small in comparison to the total length streams and the overall impacts to water quality, flow patterns, sediment movement, and fish passage are limited. There are also some positive benefits from the location of the flood risk management measures. In the Waiomao detention basin, a legacy barrier in the form of an old USGS gage will be removed during construction and will improve this passage as a result. The native fish, *Awaous stamineus*, was observed below the USGS gage and improved passage will provide more habitat for this and other native species. The use of the Expected and Worst-Case Conditions allowed a range of potential impacts to be assessed for the flood risk management measures and in both cases we expect an overall loss of habitat as a result of the construction activities.

When viewing the mitigation options, the effect of barriers to upstream movement for native species is clearly of primary concern. The majority of the gains to habitat units as result of the mitigation measures can be attributed to improving the availability of the high quality habitat in the upper ends of the streams to native species. In contrast, the impacts are high in the lower end of the streams as the streams are large and multiple native species use the available habitat. When improving fish passage, it is most beneficial to do so in a downstream-to-upstream order. The native Hawaiian stream animals are migratory and require a pathway from the ocean to instream habitats. In other words, fish and other animals need to surmount the first barrier prior to reaching any others upstream. This pattern is also true when looking at the benefits associated with habitat improvements in the channelized section of Manoa Stream. The majority of the benefits come from the improvement in fish passage and not from the construction of suitable habitat within the channelized section. This does not suggest that improving habitat is not an important goal, but it does suggest that allowing the native species to access currently suitable habitat may result in large increases in habitat units in the streams.

By design, the focus of the HSHEP model was to look at physical habitat remediation efforts (either building habitat or allowing passage primarily) as opposed to management of introduced species or water quality gains with off-channel improvements. In these urban streams, flood runoff and the potential pollutions contained in it may pose a significant threat to native stream

animals. While this is surely possible, there are high densities of fish throughout the streams suggesting water quality conditions are at least marginal.

The issue of introduced species is more difficult to address. We observed large numbers of introduced species many of which may be competitive with or predatory on native amphidromous stream animals. Where native species were observed we did see many other introduced species with the exception of smallmouth bass. Throughout much of the best habitat in the middle reaches of Manoa stream smallmouth bass were common and we did not see native fishes at all in these areas. Further surveys by DAR may clarify this relationship but for now it appears that smallmouth bass limit the presence of native stream animals. Limiting the spread of introduced species should be a priority when improving fish passage for native species. The native amphidromous species observed at these upper barriers can all climb near vertical surfaces and thus fixing of these barriers can still include quite steep faces to help prevent the upstream movement of introduced species. With that said we observed introduce species throughout the streams all the way to the upper waterfalls.

When attempting to understand how the potential mitigation options will improve instream conditions over time, both adding habitat and improving fish passage will likely see benefits for years to come. From an accounting perspective the habitat opened by improving fish passage should be available at all times into the future. The actual presence of native species in these habitats may take some time to be realized as new recruits need to make it to the stream and moved to these newly opened habitats. A similar accounting could be done for the improvements to instream habitat within the channelized section. These habitats will be available as soon as they are completed and should be suitable long into the future.

Overall the combination of the HSHEP model and HDSS data collection proved very useful in determining instream habitat and passage barriers in the Ala Wai watershed streams. Improvements to this passage may be very beneficial to increasing populations of native amphidromous stream fish while continued protection of water quality and management of introduced species may also be necessary.

Attachment 4. Results of Mitigation Measure Screening

Ala Wai Canal Project, Screening of Mitigation Measures

Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
Remove Existing Passage Barriers	**Manoa**	**Falls 6**	Approximately 0.3 miles above Manoa District Park	Yes; except that passage barrier is expected to be addressed by City & County	Yes, Waihee Stream	**Box culvert to be stabilized by the City & County; assumes fish passage will be addressed as part of this effort**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	**Eliminate measure, as structure improvements are planned by City & County**
		Falls 7	Approximately 0.6 miles above Manoa District Park	Yes	Yes, Waihee Stream	No, assumes downstream barriers (Falls 6) to be addressed by City & County	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 8	Approximately 0.7 miles above Manoa District Park (just below Pawaina St. Bridge)	Yes	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 11	USGS gaging station on Waihi Stream	Yes; can either riprap undercutting portion of structure, or remove/replace entire structure	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Privately owned	Yes; assumes real estate rights can be reasonably obtained with easement	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	Native damselfly population located upstream; measure not expected to affect this species.	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
		Falls 12	USGS gaging station on Waiakeakua Stream	Yes; existing structure needs to stay in place (to support bridge), but grouted riprap can be added to eliminate undercutting	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Primarily BWS, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
	Palolo	**Falls P5**	USGS gaging station on Waiomao Stream	Yes; except structure to be removed for construction of Waiomao Detention Basin	Yes, Waihee Stream	**Structure is expected to be removed as part of construction for Waiomao Detention Basin**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be obtained for detention basin	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measures supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur)	No archaeological/historic structures identified to date	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as structure will be removed as part of construction of the detention basin**
Improve Passage Corridor and/or Habitat in Channelized Reach	**Manoa**	**Install low-flow channel (with embedded habitat pools)**	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Excavate habitat pools	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	Med-High	Possibly, may be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Install resting pockets	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
	Palolo	**Install low-flow channel (with embedded habitat pools)**	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**

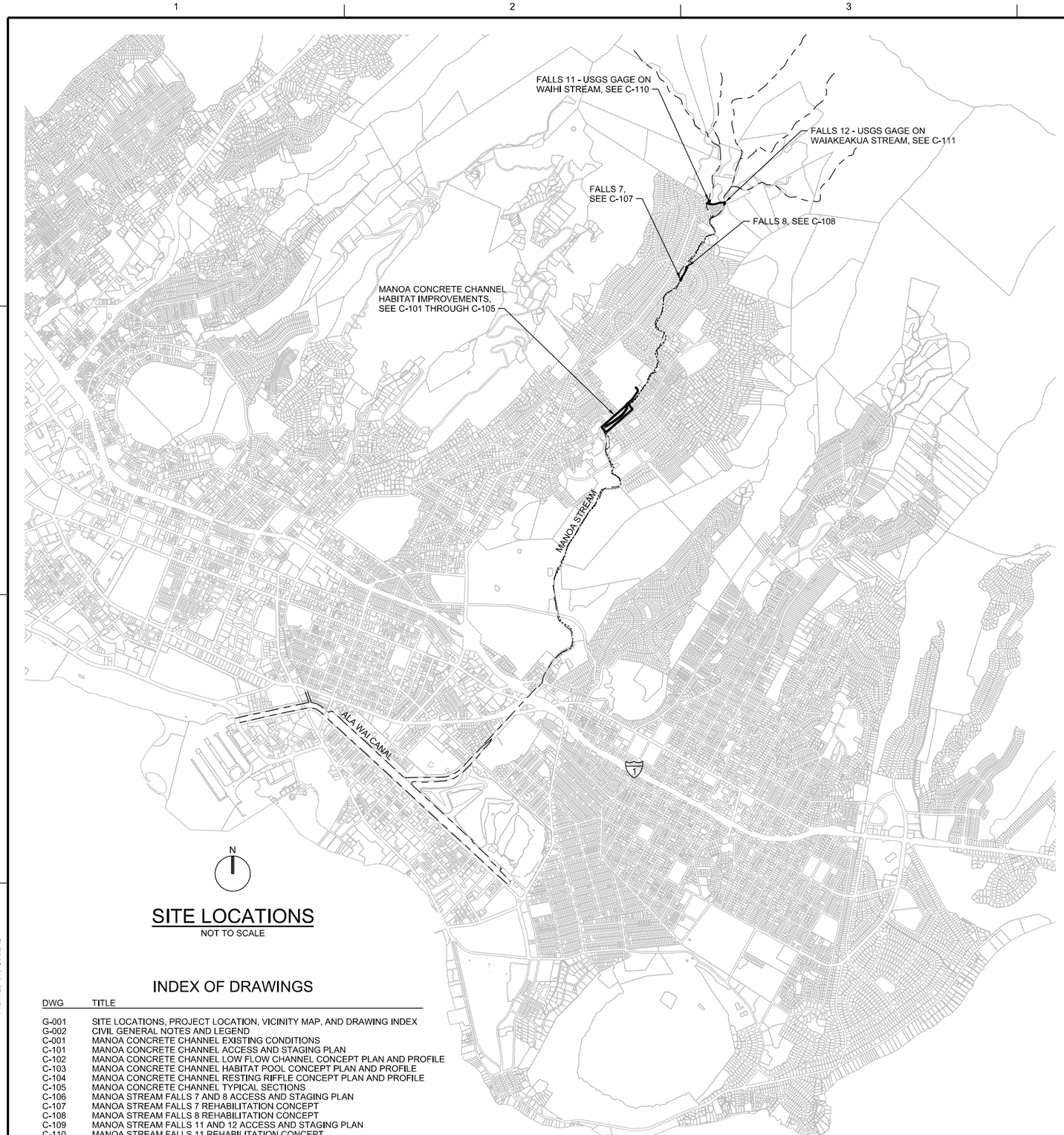
Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
		Excavate habitat pools	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
		Install resting pockets	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Med	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
	Makiki	**Add passage/ habitat improvements**	Extending through most of urbanized Makiki (including 0.75-mile of underground channel)	**Channel modifications to improve passage/habitat are not feasible in underground section of stream**	None known	No	Channel modifications could increase roughness, trap debris and/or change sediment transport	**Extremely high**	**No; channel improvements in above-ground section would not provide much benefit without improvements to underground section; improvements to underground section would be extremely expensive relative to habitat gain**	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Patchwork of public and private land	Unknown; specific requirements not investigated as measure was eliminated	Low; possibly some sediment/debris removal	Unknown; not investigated as measure was eliminated	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Makiki Stream	Makiki Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Makiki Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure as improvements would be needed to underground section, which would be extremely expensive relative to habitat gain**
Bank Stabilization	**Manoa**	**Stabilize Eroding Banks**	Above Kahaloa Bridge (Manoa Gardens Retirement Community)	Yes	Yes, successful bank replanting downstream of Kahaloa Bridge (but previous bank condition unknown)	No	No; assume little to no effect on channel capacity	**High**	**No; channel bank improvements would be extremely expensive, with only very minimal improvements to aquatic species habitat**	Yes, staging and access available via Manoa District Park	City & County land (but they are considering selling property)	Yes; assumes real estate rights can be reasonably obtained with ROE (or quit-claim deed to State if C&C sells property)	Low; temporary vegetation maintenance during plant establishment	Not expected	Could affect use of property (views; pedestrian walkway)	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	None identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would primarily involve the stream bank, with minimal movement of streambed sediments	**Eliminate measure as improvements would be extremely expensive relative to very minimal habitat gain**
Other	**Palolo**	**Waiomao Excavation Area**	Adjacent to residences on Waiomao Road	Yes; assumes channel form and substrate would be replaced within area excavated for detention basin	None known	**Dependent on Waiomao Detention Basin; construction of detention basin will include replacement of channel form and substrate**	Assumes these factors were considered in modeling for detention basin; not further addressed for mitigation as measure was eliminated	Med	Possibly	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be addressed as part of detention basin	Low; assumes debris removal and already being conducted for detention basin	No	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	USGS gaging station may be within excavation area, but assumes it will be removed as part of project construction	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as channel form and substrate will be replaced as part of detention basin measure (therefore, minimal habitat improvements available for mitigation)**

Attachment 5. Conceptual Designs for Potential Mitigation Measures

ALA WAI CANAL PROJECT

MITIGATION MEASURES
HONOLULU, OAHU, HI

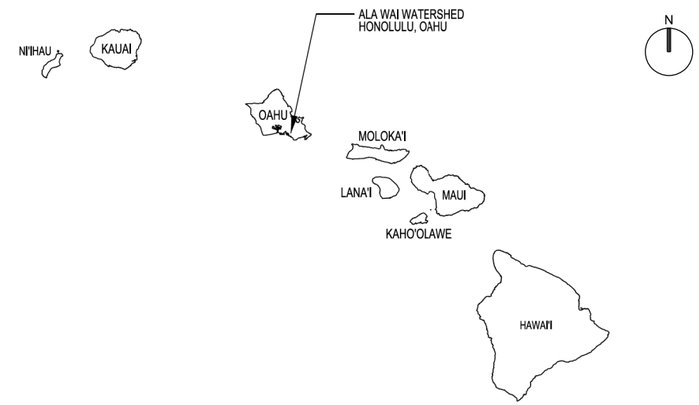
PROJECT TITLE



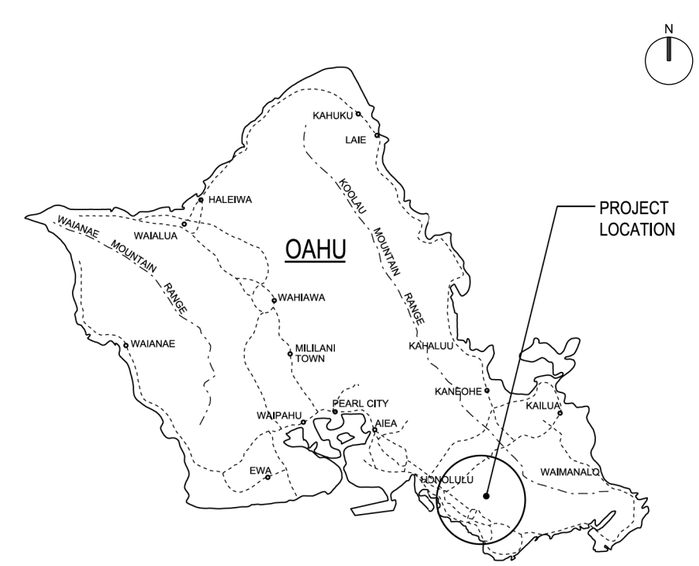
SITE LOCATIONS
NOT TO SCALE

INDEX OF DRAWINGS

DWG	TITLE
G-001	SITE LOCATIONS, PROJECT LOCATION, VICINITY MAP, AND DRAWING INDEX
G-002	CIVIL GENERAL NOTES AND LEGEND
C-001	MANOA CONCRETE CHANNEL EXISTING CONDITIONS
C-101	MANOA CONCRETE CHANNEL ACCESS AND STAGING PLAN
C-102	MANOA CONCRETE CHANNEL LOW FLOW CHANNEL CONCEPT PLAN AND PROFILE
C-103	MANOA CONCRETE CHANNEL HABITAT POOL CONCEPT PLAN AND PROFILE
C-104	MANOA CONCRETE CHANNEL RESTING RIFFLE CONCEPT PLAN AND PROFILE
C-105	MANOA CONCRETE CHANNEL TYPICAL SECTIONS
C-106	MANOA STREAM FALLS 7 AND 8 ACCESS AND STAGING PLAN
C-107	MANOA STREAM FALLS 7 REHABILITATION CONCEPT
C-108	MANOA STREAM FALLS 8 REHABILITATION CONCEPT
C-109	MANOA STREAM FALLS 11 AND 12 ACCESS AND STAGING PLAN
C-110	MANOA STREAM FALLS 11 REHABILITATION CONCEPT
C-111	MANOA STREAM FALLS 12 REHABILITATION CONCEPT



VICINITY MAP — NOT TO SCALE



PROJECT LOCATION — NOT TO SCALE

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: YYYY/MM/DD
SIZE: ANSI D
FILE NAME: FILENAME
DATE: 5/XX/2015
REVISION:
SOLICIT. / CONTRACT NO.:
481684
LOCATION CODE
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES

SITE LOCATIONS, PROJECT LOCATIONS, VICINITY MAP, AND DRAWING INDEX

SHEET IDENTIFICATION
G-001
SHEET 01 OF 14

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PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

GENERAL SITE NOTES:

1. SOURCE OF TOPOGRAPHY SHOWN ON THE CIVIL PLANS ARE BASE MAPS PROVIDED BY THE US ARMY CORP OF ENGINEERS HONOLULU DISTRICT. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. EXISTING TOPOGRAPHY, STRUCTURES, AND SITE FEATURES ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW FINISH GRADE, STRUCTURES, AND SITE FEATURES ARE SHOWN HEAVY-LINED.

   HORIZONTAL DATUM: NAD 1983, HAWAII STATE PLANE ZONE 3, US SURVEY FEET
   VERTICAL DATUM: NAVD 1988, US SURVEY FEET
3. MAINTAIN, RELOCATE, OR REPLACE EXISTING SURVEY MONUMENTS, CONTROL POINTS, AND STAKES WHICH ARE DISTURBED OR DESTROYED. PERFORM THE WORK TO PRODUCE THE SAME LEVEL OF ACCURACY AS THE ORIGINAL MONUMENT(S) IN A TIMELY MANNER, AND AT THE CONTRACTOR'S EXPENSE.
4. STAGING AREA SHALL BE FOR CONTRACTOR'S EMPLOYEE OVERFLOW PARKING AND ON-SITE STORAGE OF MATERIALS.
5. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
6. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
7. CONTRACTOR SHALL PREPARE AND SUBMIT DEWATERING AND CREEK BYPASS PLAN FOR CONTRACTING OFFICER APPROVAL.
8. IN-WATER CONSTRUCTION WORK IS EXPECTED TO BE CONDUCTED DURING DRY SEASON FROM APPROXIMATELY MAY TO SEPTEMBER.

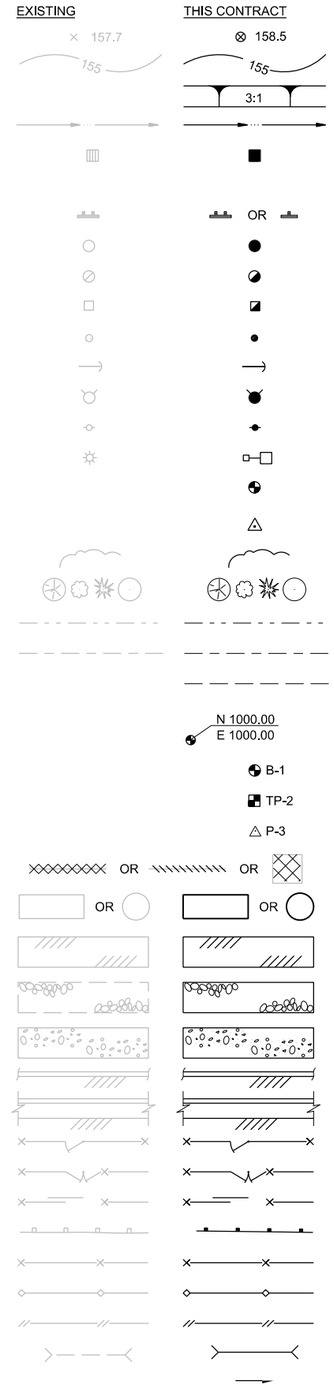
GENERAL YARD PIPING AND UTILITIES NOTES:

1. EXISTING UNDERGROUND UTILITIES HAVE NOT BEEN IDENTIFIED BUT IS EXPECTED TO OCCUR IN A FUTURE DESIGN PHASE. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION. PROTECT ALL EXISTING UTILITIES TO REMAIN DURING CONSTRUCTION.
2. EXISTING PIPING AND EQUIPMENT ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW PIPING AND EQUIPMENT ARE SHOWN HEAVY-LINED.
3. UNLESS OTHERWISE SHOWN ALL PIPING SHALL HAVE A MINIMUM OF 3' COVER.
4. ALL PIPES SHALL HAVE A CONSTANT SLOPE BETWEEN INVERT ELEVATIONS UNLESS A FITTING IS SHOWN.
5. FOR SURFACE RESTORATION OF ASPHALT CONCRETE MATCH EXISTING PAVEMENT.
6. MINIMUM ALLOWABLE CLEARANCE BETWEEN PIPES AT CROSSINGS SHALL BE 3".

GENERAL NOTE:

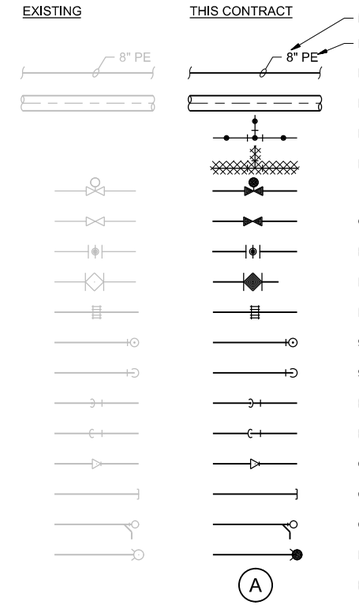
1. THIS IS A STANDARD LEGEND SHEET. THEREFORE, NOT ALL OF THE INFORMATION SHOWN MAY BE USED ON THIS PROJECT.

CIVIL LEGEND



SPOT ELEVATION	
CONTOUR LINE	
EMBANKMENT AND SLOPE	
DRAINAGEWAY OR DITCH	
CATCH BASIN OR INLET	
TRENCH DRAIN	
SIGN	
MANHOLE	
ELECTRICAL MANHOLE	
ELECTRIC HANDHOLE	
POST OR GUARD POST	
GUY ANCHOR	
FIRE HYDRANT	
UTILITY POLE	
LIGHT POLE	
BENCH MARK	
SURVEY CONTROL POINT OR POINT OF INTERSECTION	
BRUSH/TREE LINE	
TREE	
PROPERTY LINE	
CENTER LINE, BUILDING, ROAD, ETC.	
FEATURE LINES AND AVERAGE SEASONAL WATER LEVELS	
STRUCTURE, BUILDING OR FACILITY LOCATION POINT - COORDINATES	
BORING LOCATION AND NUMBER	
TEST PIT LOCATION AND NUMBER	
PIEZOMETER LOCATION AND NUMBER	
DEMOLITION	
STRUCTURE, BUILDING OR FACILITY	
ASPHALT CONCRETE PAVEMENT	
GRAVEL SURFACING	
CONCRETE PAVEMENT	
CURB	
CURB AND GUTTER	
SINGLE SWING GATE	
DOUBLE SWING GATE	
SLIDING GATE	
GUARD RAIL	
CHAIN LINK FENCE	
ARCHITECTURAL FENCE	
WIRE FENCE	
CULVERT	
FLOW DIRECTION	

YARD PIPING LEGEND



NOMINAL PIPE DIAMETER	
PIPE USE IDENTIFICATION	
PIPING < 30" DIAMETER	
PIPING ≧ 30" DIAMETER	
EXISTING PIPE TO BE ABANDONED	
EXISTING PIPE TO BE REMOVED	
INDICATOR POST VALVE	
GATE VALVE AND VALVE BOX	
BUTTERFLY VALVE AND VALVE BOX	
PLUG VALVE AND VALVE BOX	
FLEXIBLE COUPLING	
90° ELBOW UP	
90° ELBOW DOWN	
BEND < 90° UP	
BEND < 90° DOWN	
CONCENTRIC REDUCER	
CAP OR PLUG	
CLEANOUT	
FIRE HYDRANT	
BACKFILL CLASS	

ABBREVIATIONS

APPROX	APPROXIMATE
AVG	AVERAGE
B.F.	BUTTERFLY
°	DIAMETER
DIA	DIAMETER
EL	ELEVATION
ELEV	ELEVATION
EXST	EXISTING
FT	FOOT / FEET
GAL	GALLON
HDPE	HIGH DENSITY POLYETHYLENE
HP	HORSE POWER
N	NORTH
NTS	NOT TO SCALE
O.C.	ON-CENTER
PE	POLYETHYLENE
PVC	POLYVINL CHLORIDE
SQ FT	SQUARE FOOT
TYP	TYPICAL
W/	WITH

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T SIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 5/XX/XXXX
DRAWING NUMBER:
REVISION:
SIZE: ANSI D
FILE NAME:

ALA WAI CANAL PROJECT
MITIGATION MEASURES

CIVIL GENERAL NOTES AND LEGEND

SHEET IDENTIFICATION
G-002
SHEET 02 OF 14

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:
PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$

N

PLAN
1"=40'

0 40 80 120
Scale In Feet

PHOTO 1
NTS

PHOTO 2
NTS

PHOTO 3
NTS

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: 2/20/2013
DATE: 5/XX/2015
REVISION:
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
EXISTING CONDITIONS

SHEET IDENTIFICATION
C-001
SHEET 03 OF 14

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

US Army Corps of Engineers®

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: L HAYS
DATE: 5/XX/2015
REVISION:
DRAWN BY: T STMPSON
CHECKED BY: J YOUNG
SOLICIT./ CONTRACT NO.: 481684
SUBMITTED BY: J YOUNG
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 5/XX/15
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
ACCESS AND STAGING PLAN

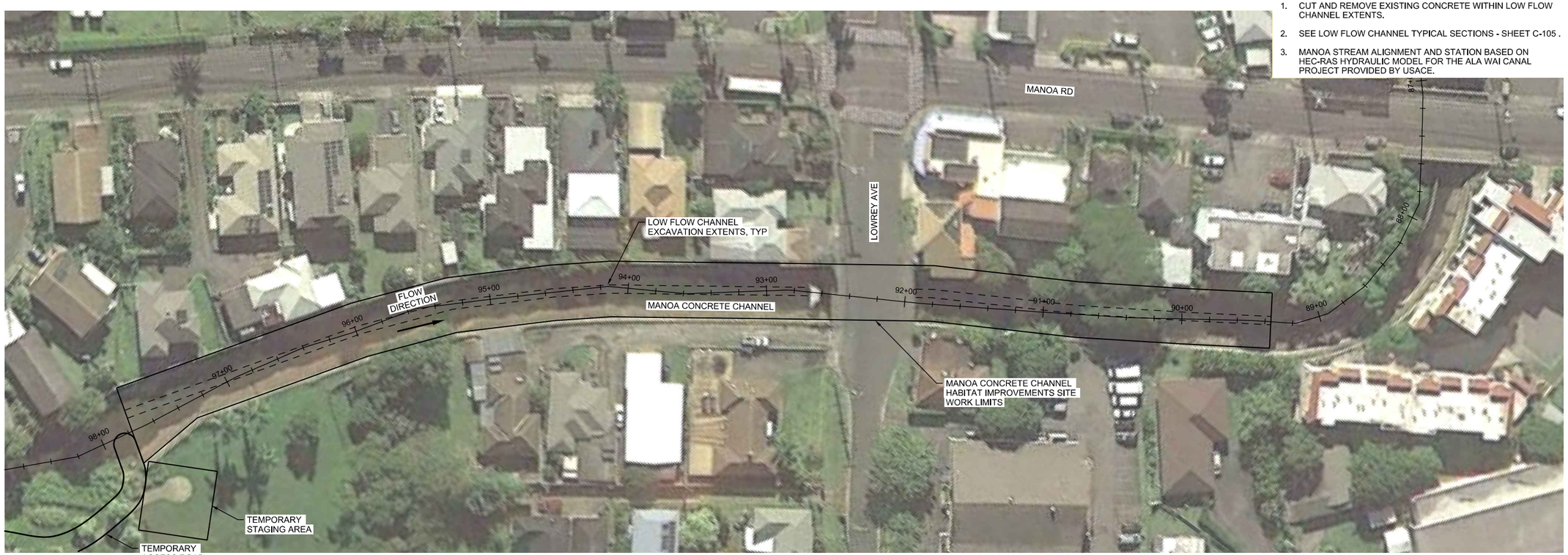
SHEET IDENTIFICATION
C-101
SHEET 04 OF 14

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$

NOTES:

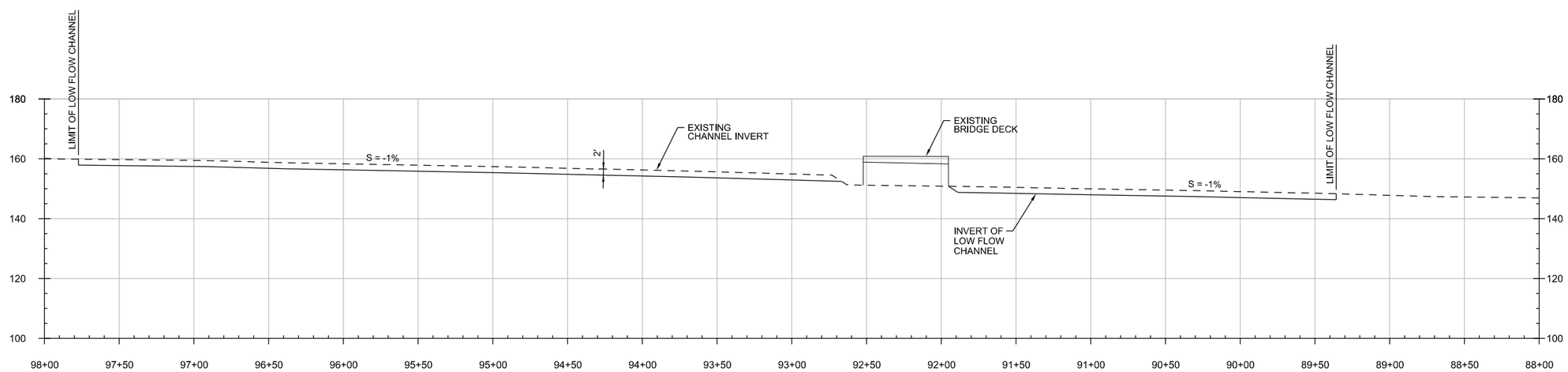
1. CUT AND REMOVE EXISTING CONCRETE WITHIN LOW FLOW CHANNEL EXTENTS.
2. SEE LOW FLOW CHANNEL TYPICAL SECTIONS - SHEET C-105 .
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



PLAN

1"=40'

0 40 80 120
Scale In Feet



PROFILE

HORZ: 1"=40'
VERT: 1"=20'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
REVISION:
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 2/20/2015
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET - SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
LOW FLOW CHANNEL CONCEPT
PLAN AND PROFILE

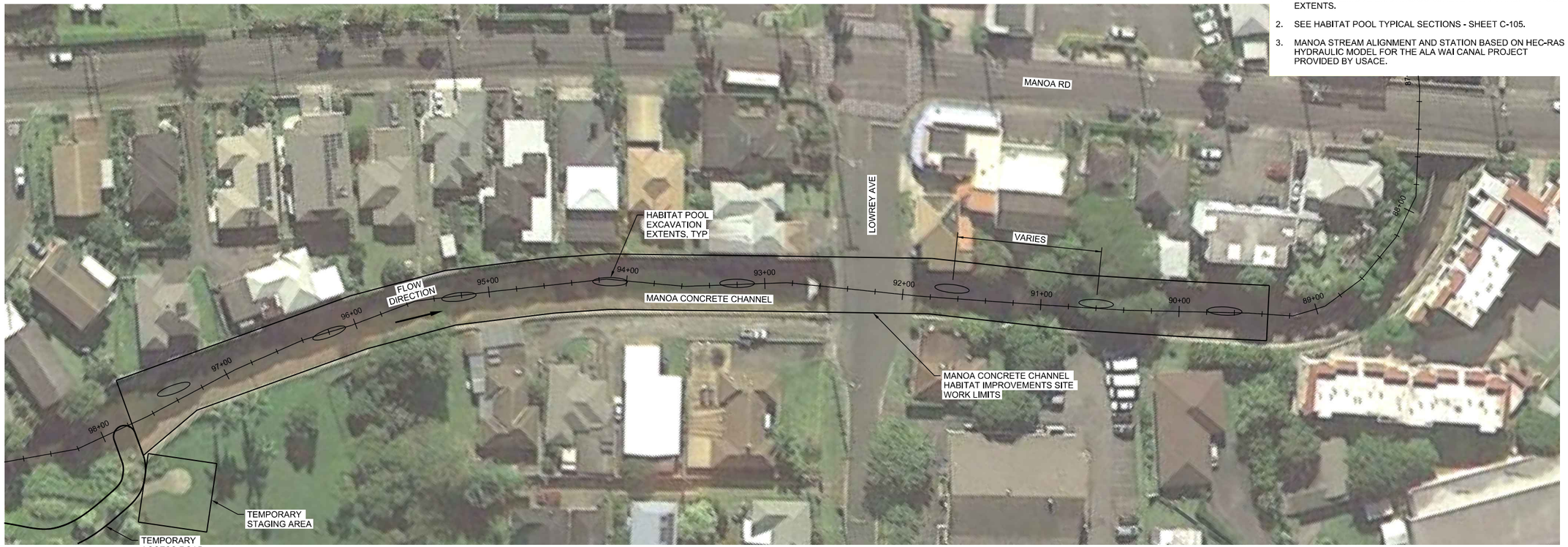
SHEET IDENTIFICATION
C-102
SHEET 05 OF 14

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

NOTES:

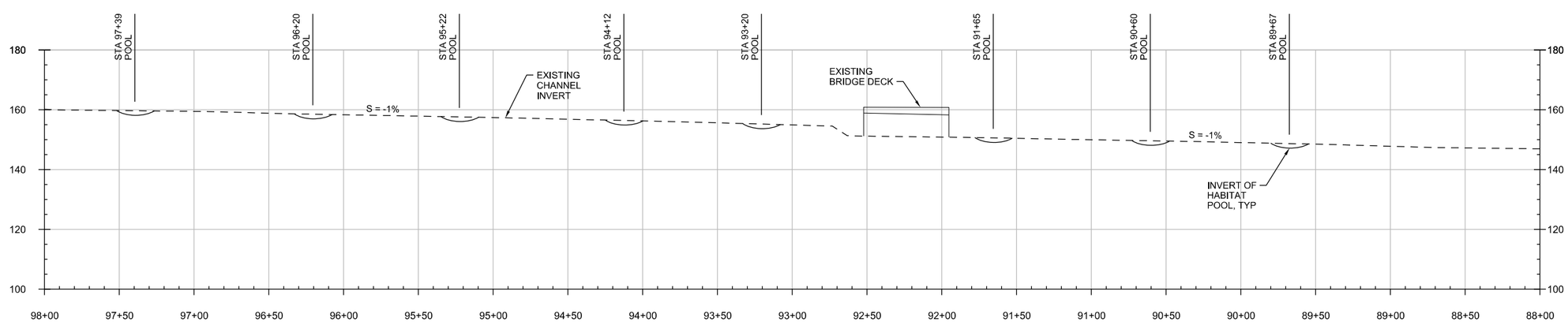
1. CUT AND REMOVE EXISTING CONCRETE WITHIN HABITAT POOL EXTENTS.
2. SEE HABITAT POOL TYPICAL SECTIONS - SHEET C-105.
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



PLAN

1"=40'

0 40 80 120
Scale In Feet



PROFILE

HORZ: 1"=40'
VERT: 1"=20'

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

DESIGNED BY: L HAYS
DATE: 5/XX/2015
REVISION:
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SOLICIT / CONTRACT NO.: 481684
SUBMITTED BY: J YOUNG
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: XX/XX/XX
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET - SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
HABITAT POOL CONCEPT
PLAN AND PROFILE

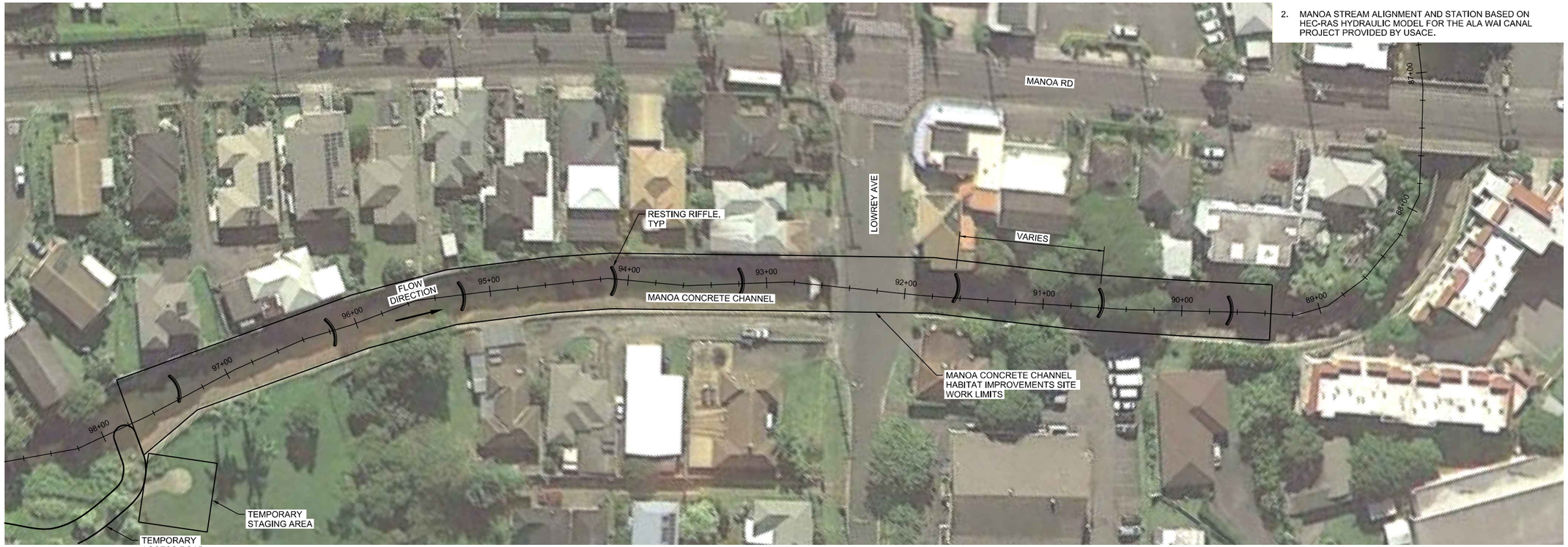
SHEET IDENTIFICATION
C-103
SHEET 06 OF 14

PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

NOTES:

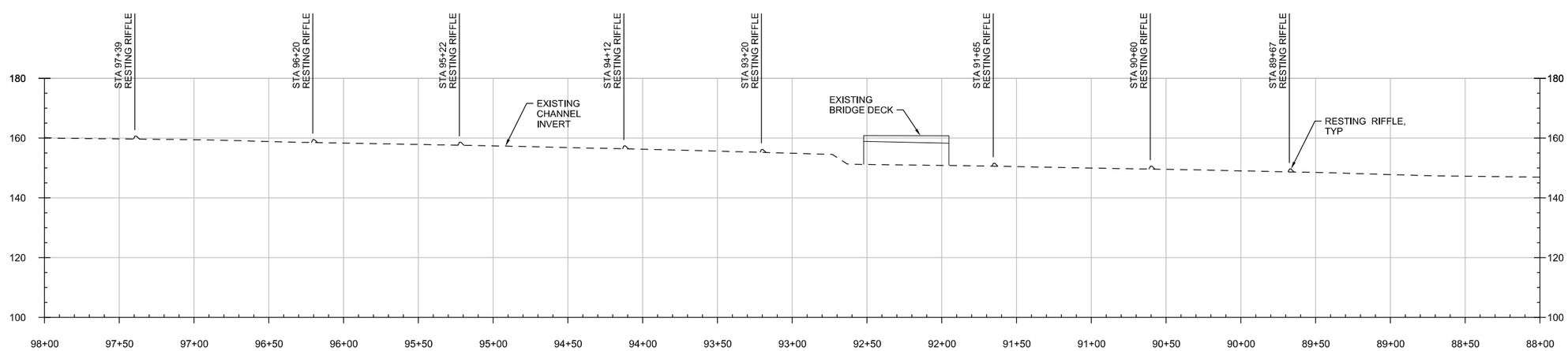
1. SEE RESTING RIFFLE TYPICAL SECTIONS - SHEET C-105.
2. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



PLAN

1"=40'

0 40 80 120
Scale In Feet



PROFILE

HORZ: 1"=40'
VERT: 1"=20'

US Army Corps of Engineers®

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET - SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
REVISION:
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 20YRMODA
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

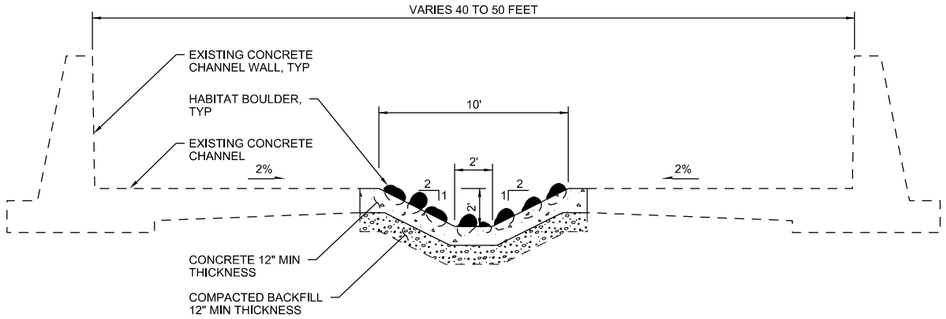
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
RESTING RIFFLE CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-104
SHEET 07 OF 14

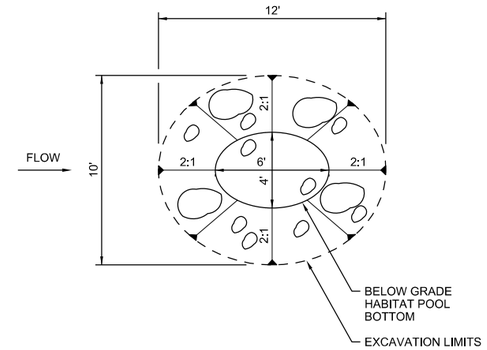
PLOTDRIVER: $PLTDRV$
PEN TABLE: $PENTBL$
PRINTED BY: $USER$

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:



LOW FLOW CHANNEL TYPICAL SECTION

1"=4'

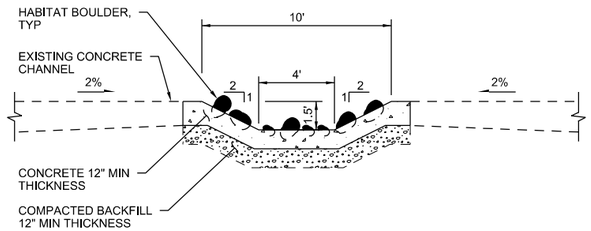


HABITAT POOL PARTIAL PLAN

1"=4'

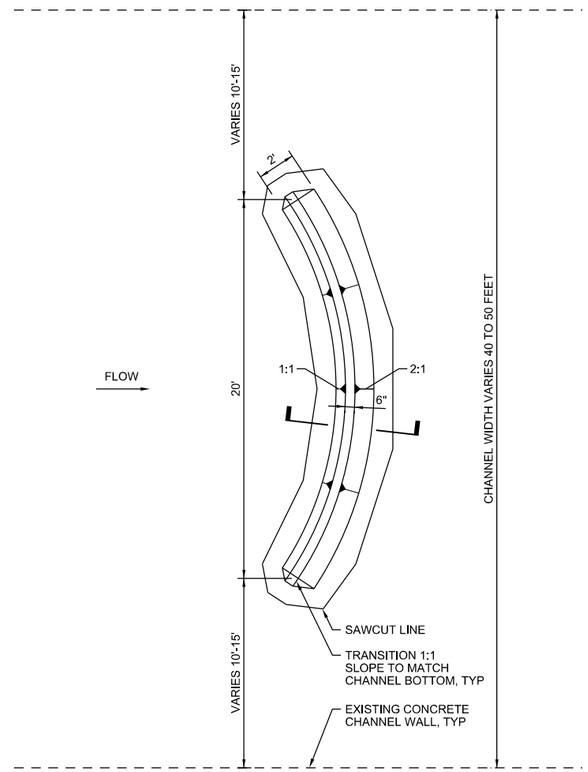
GENERAL SHEET NOTES:

1. ALL DIMENSIONS APPROXIMATE
2. REINFORCING STEEL DOWELS MAY BE INCORPORATED IN A FUTURE DESIGN PHASE.



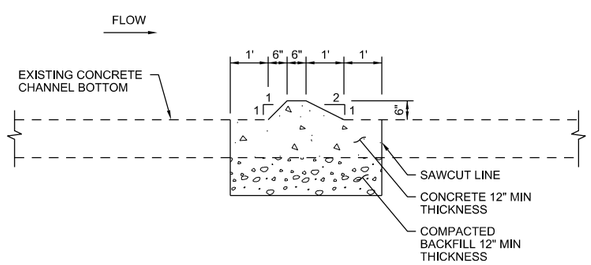
HABITAT POOL TYPICAL SECTION

1"=4'



RESTING RIFFLE PARTIAL PLAN

NTS



RESTING RIFFLE CROSS SECTION

1"=2'

US Army Corps of Engineers®

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US ARMY CORPS OF ENGINEERS
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1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
SIZE: ANSI D
DATE: 50X/2015
CHECKED BY: J YOUNG
PLOT DATE: $DATE$
FILE NAME: $FILENAME
REVISION:
SOLICIT./ CONTRACT NO.: 481684
LOCATION CODE
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
TYPICAL SECTIONS

SHEET IDENTIFICATION
C-105
SHEET 08 OF 14

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

NOTES:

1. LOCATION OF A STAGING AREA WILL BE DETERMINED, IF NEEDED.
2. IF EQUIPMENT, MATERIALS AND/OR ACCESS IS PROVIDED VIA THE BRIDGE, THEN A PARTIAL LANE CLOSURE AND TRAFFIC CONTRL MAY BE REQUIRED.

N

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: AS NOTED
SIZE: ANSI D
FILE NAME: FILENAME
DATE: 5/XX/2015
REVISION:
CHECKED BY: SOLICIT / CONTRACT NO.:
48168A
LOCATION CODE
DRAWING NUMBER:

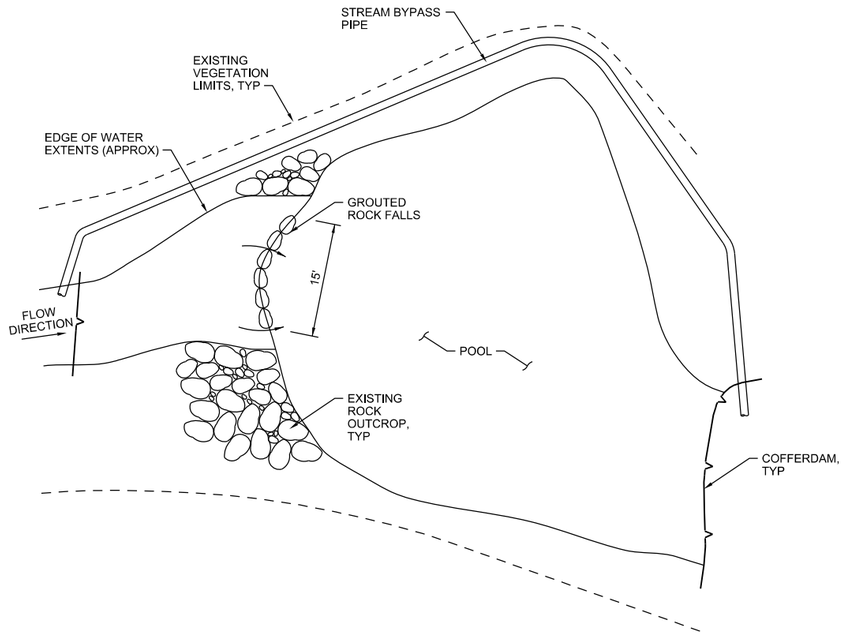
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 7 AND 8
ACCESS AND STAGING PLAN

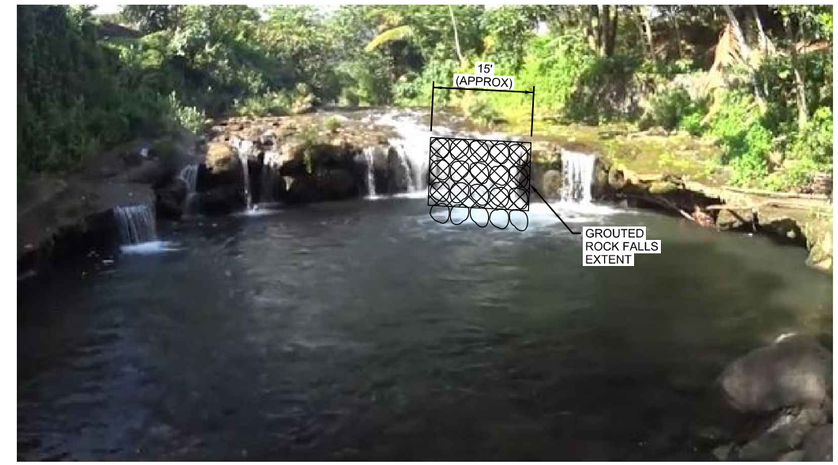
SHEET IDENTIFICATION
C-106
SHEET 09 OF 14

PLOTTDRIVER: $PLTDRIV$S
PEN TABLE: $PENTBLS$
PRINTED BY: $USER$

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:



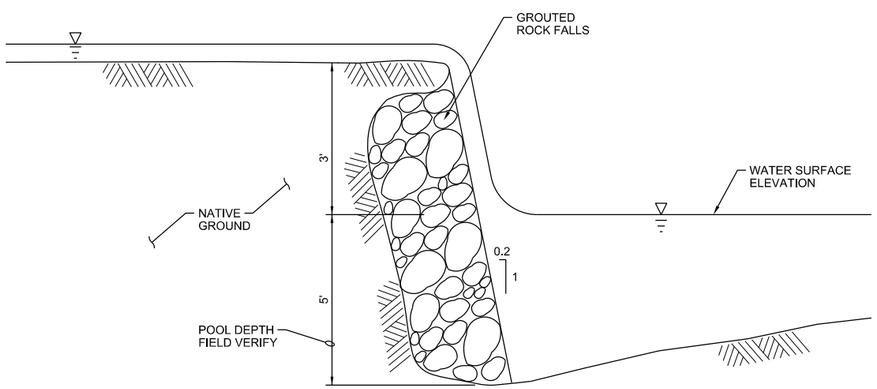
PLAN
NTS



NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

SITE PHOTO
NTS



NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

SECTION
NTS

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
DATE: 5/XX/2015
SOLICIT./ CONTRACT NO.: 481684
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 7/XX/2015
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME
REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

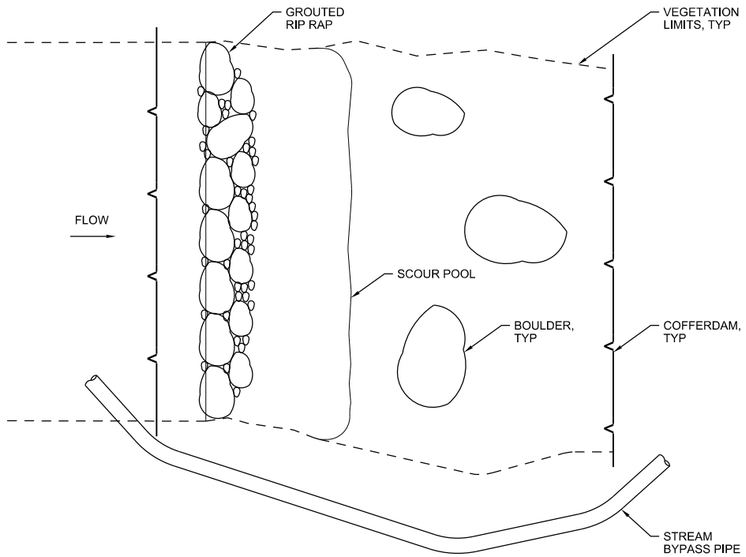
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 7
REHABILITATION CONCEPT

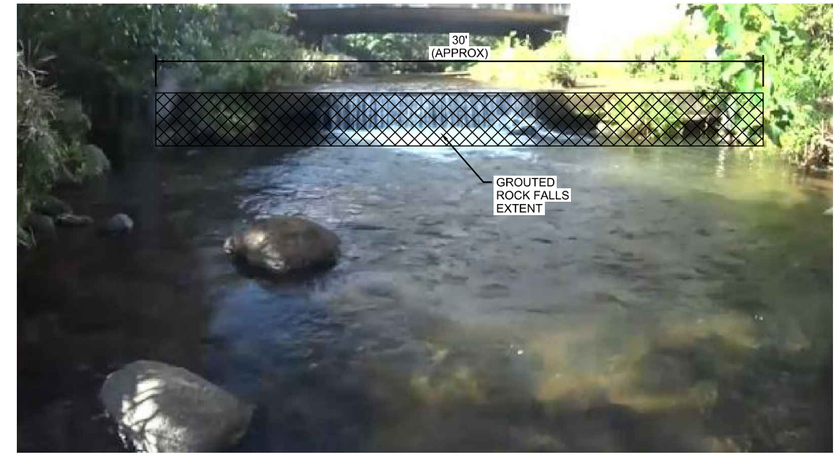
SHEET IDENTIFICATION
C-107
SHEET 10 OF 14

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$



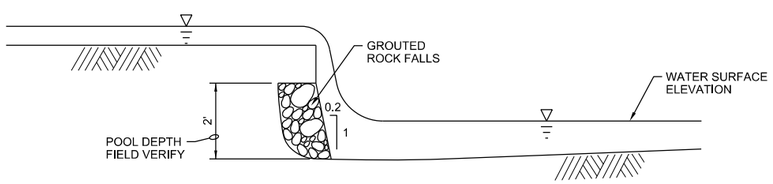
PLAN
1"=5'



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SITE PHOTO
NTS



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SECTION
1"=2'

PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILE$$
MODEL NAME: $MODELNAME$$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

US Army Corps of Engineers®

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L.HAYS
DATE: 5/XX/2015
REVISION:
DRAWN BY: T.STIMPSON
CHECKED BY: J.YOUNG
SOLICIT./ CONTRACT NO.: 481684
SUBMITTED BY: J.YOUNG
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 7/XX/15
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME:

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 8
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-108
SHEET 11 OF 14

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

PLOTTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.
					10% DESIGN		

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

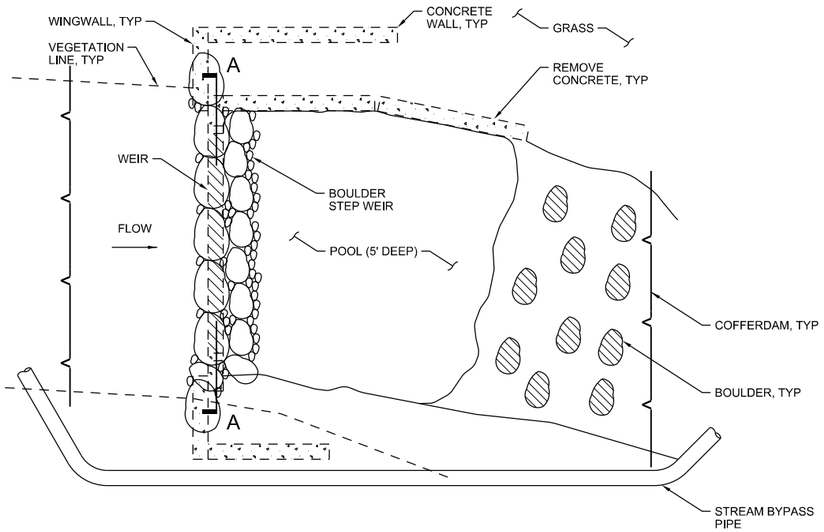
DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT SIZE: ANSI D
DATE: 5/XX/2015
CHECKED BY: J YOUNG
REVISION:
SOLICIT./ CONTRACT NO.:
481684
LOCATION CODE
PLOT DATE:
DRAWING NUMBER:
FILE NAME: FILENAME

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 11 AND 12
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-109
SHEET 12 OF 14



PLAN

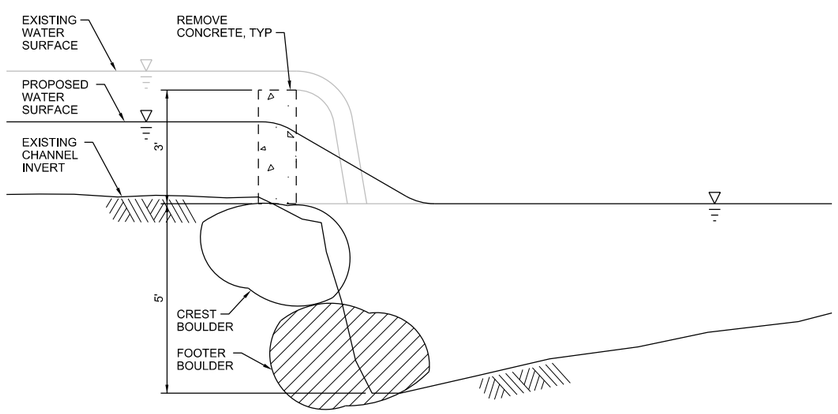
1"=5'

NOTES:

1. REMOVE ALL EXISTING CONCRETE FROM CHANNEL.
2. DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.
3. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

SITE PHOTO

NTS

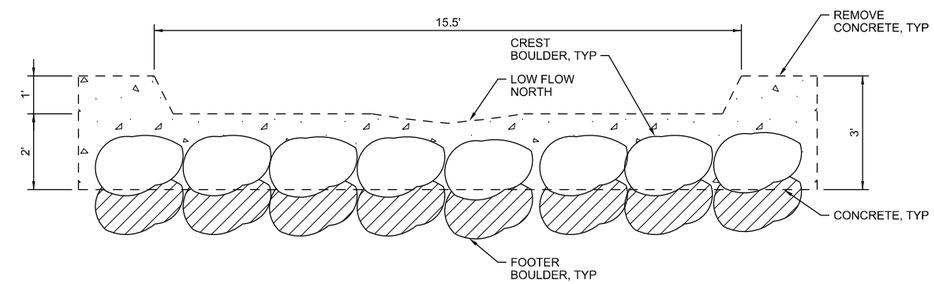


NOTES:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

PROFILE

1"=2'



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

SECTION A-A

1"=2'

US Army Corps of Engineers®

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: L HAYS | DATE: 5/XX/2015 | REVISION:
DRAWN BY: T STIMPSON | CHECKED BY: J YOUNG | SOLICIT. / CONTRACT NO.: 481984
SUBMITTED BY: J YOUNG | LOCATION CODE
PLOT SCALE: AS NOTED | PLOT DATE: 2015/05/13 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET SUITE 1100
HONOLULU, HI 96813

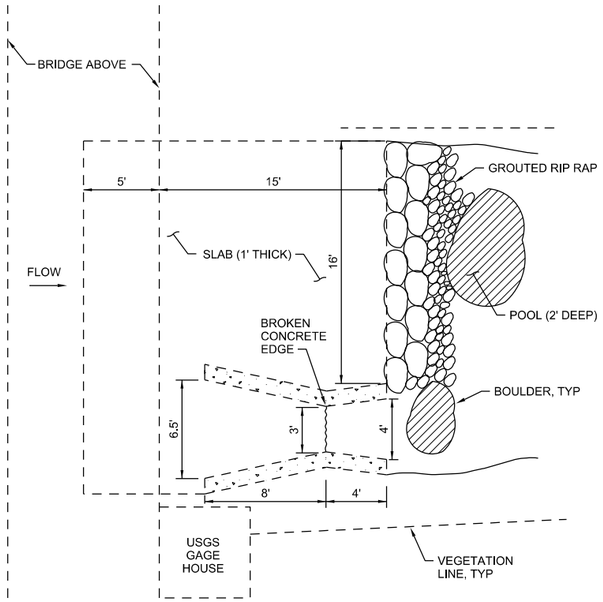
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 11
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-110
SHEET 13 OF 14

PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

FILE: $FILE$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

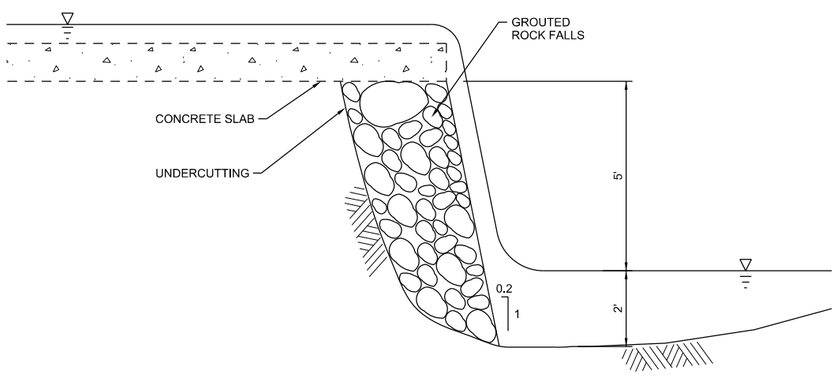


PLAN
1"=5'

NOTES:

1. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

SITE PHOTO
NTS



PROFILE
1"=2'

US Army Corps of Engineers®

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L.HAYS | DATE: 5/XX/2015 | REVISION:
DRAWN BY: T.STIMPSON | CHECKED BY: J.YOUNG | SOLICIT./CONTRACT NO.: 481984
SUBMITTED BY: J.YOUNG | LOCATION CODE
PLOT SCALE: AS NOTED | PLOT DATE: 2015/05/13 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: FILENAME

ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA STREAM FALLS 12
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-111
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Attachment 6. Cost Effectiveness and Incremental Cost Analysis

Cost Effectiveness and Incremental Cost Analysis
Ala Wai Canal Project

July 2015

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1.0 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii[1] (hereafter referred to as "the project"). As project implementation is expected to result in impacts to aquatic habitat, compensatory mitigation will be required to offset these impacts. The USACE planning process requires that compensatory mitigation plans be developed, evaluated and selected consistent with the requirements of their overall planning process. A detailed discussion of the mitigation development process for the project is provided in the Mitigation and Monitoring Plan; this document presents the economic analysis used to support evaluation and selection of the compensatory mitigation plan.

As outlined in Engineering Regulation (ER) 1105-2-100 "USACE Planning Guidance Notebook" (USACE, 2000), alternative plans should be evaluated based on four primary criteria: completeness, effectiveness, efficiency, and acceptability. Economic analyses are important primarily in the evaluation of efficiency. Economic analyses also play a role in the evaluation of the acceptability of an alternative, based on its estimated implementation cost, and the completeness of an alternative, based on identifying all potential costs that could result from implementation.

The USACE Institute for Water Resources (IWR) Planning Suite tool was developed in response to the intricacies of ecosystem restoration planning studies (including mitigation) and performs cost-effectiveness and incremental cost analyses (CE/ICA) on combinations of water resources alternatives. The CE analysis is employed to eliminate "production inefficient" solutions, or alternatives plans with the same level of output that can be provided at a lesser cost than another plan, and "production ineffective" solutions, or alternative plans with less output than a plan that has a lesser or equal cost. The ICA evaluates the incremental cost of cost-effective alternatives to determine which are "best buy" plans, or plans which provide the greatest increase in output for the least increase in cost.

To identify the mitigation alternative(s) that would provide the greatest benefit compared to cost for the project, CE/ICA were conducted to compare predicted future benefits (quantified by average annual habitat units) to estimated average annual costs for each of the mitigation alternatives identified for the project. This analysis is based on and follows guidance from the USACE IWR publication, *Evaluation of Environmental Investment Procedures Manual, Interim: Cost Effectiveness and Incremental Analyses*, May 1995, IWR Report #95-R-1 and *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps*, October 1994, IWR Report 94-PS-2. The organization of this appendix follows the steps outlined in IWR Report #95-R-1k:

Plan Formulation Steps

- **Step 1:** Display Outputs and Costs of Management Measures
- **Step 2:** Identify Management Measure Relationships
- **Step 3:** Add Costs and Outputs of Combinations

Cost Effectiveness Analysis Steps

- **Step 4:** Identify "Production Inefficient" Solutions
- **Step 5:** Identify "Production Ineffective" Solutions

Incremental Cost Analysis Step

- **Step 6:** Calculate and Display Incremental Costs

Additional Analytical Steps to Assist in Scale Selection

- **Step 7:** Calculate Change in Unit Cost from No-Action Plan to All Other Plans
- **Step 8:** Recalculate Change in Unit Cost from Last Selected Plan
- **Step 9:** Tabulate and Display Incremental Costs of Selected Plans

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[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

2.0 Plan Formulation

Steps 1 through 3 are related to plan formulation and, in the case of this project, include an analysis of the possible management measures identified for compensatory mitigation. In the context of the USACE planning process, management measures are defined as actions that can be implemented to cause a desirable change relative to the planning objective; they are individual features or activities that serve as the building blocks of alternative plans. Formulation of mitigation measures is detailed in Section 3 of the Mitigation and Monitoring Plan and is summarized below.

2.1 Step 1: Display Outputs and Costs of Management Measures

The first step of plan formulation, as it relates to analysis of cost-effectiveness and incremental cost, is to identify the mitigation measures and their output and cost. The mitigation measures that were considered as part of the evaluation, based on the results of the mitigation development process (as described in the Mitigation and Monitoring Plan) are summarized in Table 1. Given that the mitigation effort is focused on restoring passage or habitat to stream channels based on the conditions known to favor native species, it was determined that different scales or increments of each measure would not meet the objectives of the mitigation effort, and therefore were not considered. Additional detail on the mitigation identification and screening process is provided in the Mitigation and Monitoring Plan.

TABLE 1
Conceptual Mitigation Measures

Mitigation Measure/Alternative	Description
Falls 7	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.6 mile above Manoa District Park
Falls 8	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.7 mile above Manoa District Park
Falls 11	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waihi Stream
Falls 12	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waiakeakua Stream
Manoa Low-Flow Channel	Notch low-flow channel into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Habitat Pools	Notch habitat pools (<18” of water depth) into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Resting Riffles	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat (>6” of water depth) along approximately 1,100 feet of concrete channel below Manoa District Park

2.2 Step 2: Identify Management Measure Relationships

Step 2 of plan formulation and evaluation is to identify potential groupings of management measures, based on their dependency to each other. In the case of this project, each of the mitigation measures considered as part of the CE/ICA are mutually exclusive (meaning, they could be implemented as stand-alone actions). However, recognizing that there are many possible measure combinations, it was determined that a focused set of

alternatives should be defined based on estimated habitat benefits and functionality, according to the rationale summarized below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. The barrier removal measures were not considered in combination with the concrete channel improvements, because individually, they are expected to provide adequate benefits to offset the habitat impacts associated with the flood risk management project.

2.3 Step 3: Derive Combinations and Calculate Costs and Outputs

Based on the concepts described above, a total of eight mitigation alternatives were identified, as follows:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

The costs and outputs were then developed, as detailed below.

2.3.1 Estimate Alternative Costs

Planning level cost estimates are used in CE/ICA, and are comprised of two main cost elements: (1) implementation costs (explicit costs) and (2) opportunity costs of foregone National Economic Development (NED) benefits (implicit costs). For the purposes of this project, it is assumed that there are no implicit costs (as no NED benefits would be foregone), such that the total project cost is equal to the implementation cost. An estimate of the implementation costs was developed by the USACE as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. The cost estimate for each mitigation alternative is summarized in Table 2.

As part of CE/ICA, environmental outputs and cost estimates should be annualized across the period of analysis. To annualize the project costs, an implementation timeline must be developed to identify initial costs, investment costs, and future costs. So that project costs can be evaluated in present value, the implementation timeline is used to categorize cost components as investment costs or future costs. For each alternative, the total project cost is equal to the investment cost plus future costs, in present value terms.

In the case of this project, all costs with the exception of those for monitoring and operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) are assumed to be incurred in Year 0. The IWR Planning Suite Annualizer was used to calculate the average annual cost of each alternative. The average annual cost assumes a 50-year period of analysis and a federal discount rate of 3.5%, which is the federal discount rate established for the evaluation of water resources development projects in fiscal year (FY) 2014. Table 2 shows the total

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

estimated cost and the average annual cost of the mitigation alternatives. A detailed breakdown of the present value cost for each of the 50 years of analysis is provided as an attachment to this document.

TABLE 2
Summary of Estimated Costs (FY2014 Price Level)

Implementation Cost Component	Falls 7	Falls 7 and 8	Falls 7, 8, 11	Falls 7, 8, 12	Falls 7, 8, 11, 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
LERRDs[1]	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre-construction Monitoring	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250
Post-construction Monitoring[2]	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250
OMRR&R[3]	$29,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction[4]	$1,491	$2,918	$3,729	$3,746	$4,557	$17,526	$3,786	$3,916
Contingency[5]	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Estimated Cost for CE/ICA	$240,526	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,264
Average Annual Cost[6]	$9,014	$13,362	$16,101	$16,000	$18,440	$49,564	$14,753	$15,105

[1] Lands, Easements, Rights-of-way, Relocations, and Dredge Disposal areas
[2] Includes 5 monitoring events during Years 1, 2, 3, 4, and 5
[3] Includes 50 years of OMRR&R
[4] Assumes a 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS
[5] Assumes contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, and OMRR&R costs
[6] Calculated using IWR Planning Suite annualizer: discount rate = 3.5% and period of analysis = 50 years

2.3.2 Estimate Alternative Outputs

The benefits of ecosystem mitigation are non-monetary, and therefore outputs must be quantified based on a unit of habitat improvement (that is, habitat units). In the case of this project, the Hawaii Stream Habitat Evaluation Procedure (HSHEP) was used to quantify the habitat benefits associated with each of the mitigation alternatives. A detailed discussion of the HSHEP model and its application to the project is provided in the Mitigation and Monitoring Plan (specifically including Attachments 1 and 2).

In order for proper comparison of costs and benefits, habitat units must be annualized over the period of analysis. Average annual habitat units were calculated using the IWR Planning Suite annualizer. It is expected that all habitat benefits would be realized in Year 1 and remain stable over the 50-year planning period, as shown in Figure 1. The total habitat units and average annual habitat units for the mitigation alternatives are listed in Table 3.

TABLE 3
Total Habitat Units and Average Annual Habitat Units for Mitigation Alternatives

Metric	No Action	Falls 7	Falls 7 and 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11 and 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Total Habitat Units	0	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Average Annual Habitat Units[a]	0	1,340	3,831	5,401	6,021	7,591	1,279	1,202	1,195

[a] Assumes that all benefits would be realized in Year 1 and remain stable over the 50-year planning period; calculated using the IWR Planning Suite annualizer.

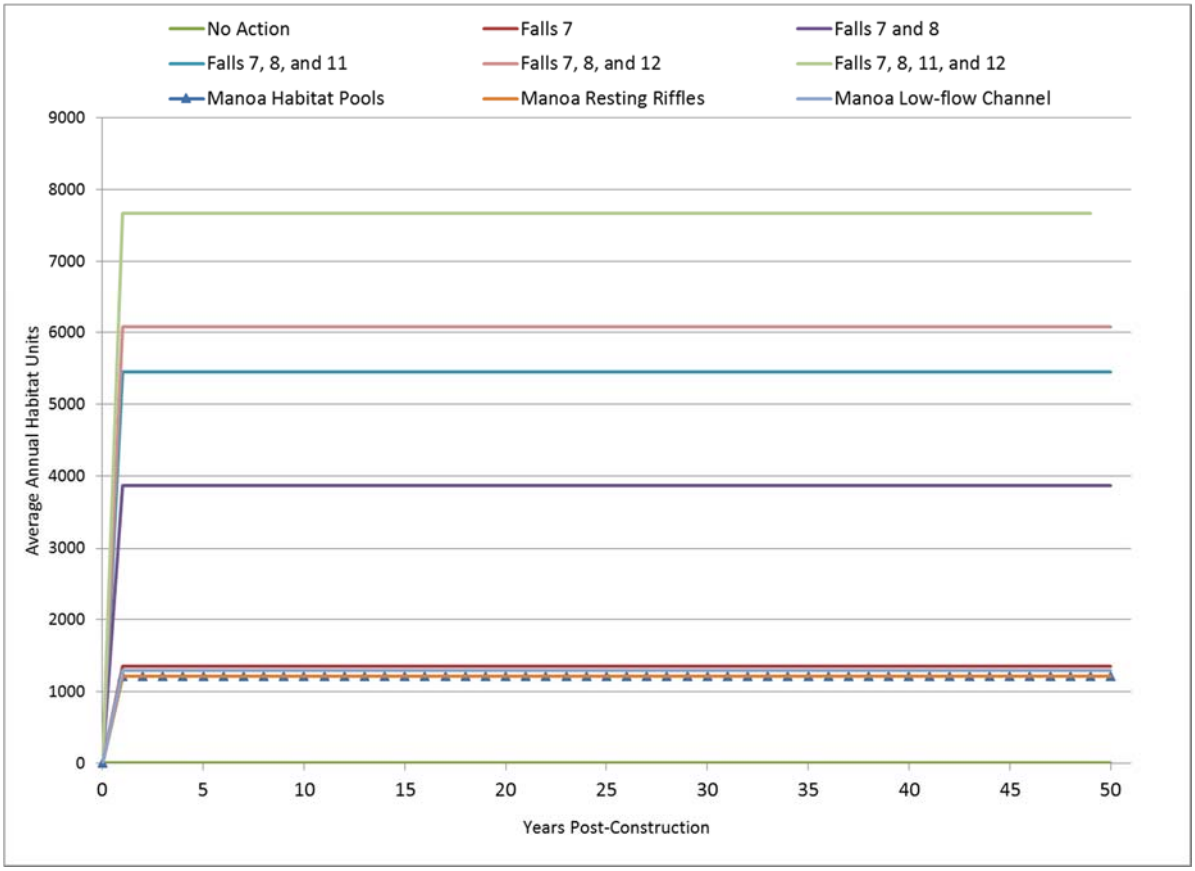

FIGURE 1
Projected Habitat Units over Period of Analysis

2.3.3 Summary of Alternative Outputs and Costs

Table 4 and Figure 2 summarize the outputs and costs of the alternatives. Costs are displayed in average annual costs, and outputs are displayed in average annual habitat units. These values are used in CE/ICA, as detailed in the remainder of this document.

TABLE 4
Summary of Alternative Outputs and Costs

Alternative	Output (Average Annual Habitat Units)	Cost (Average Annual Cost)
No Action	0	$ -
Falls 7	1,340	$ 9,014
Falls 7 and 8	3,831	$ 13,362
Falls 7, 8, 11	5,401	$ 16,101
Falls 7, 8, 12	6,021	$ 16,000
Falls 7, 8, 11, and 12	7,591	$ 18,440
Manoa Habitat Pools	1,202	$ 14,753
Manoa Resting Riffles	1,195	$ 15,105
Manoa Low-Flow Channel	1,279	$ 49,564

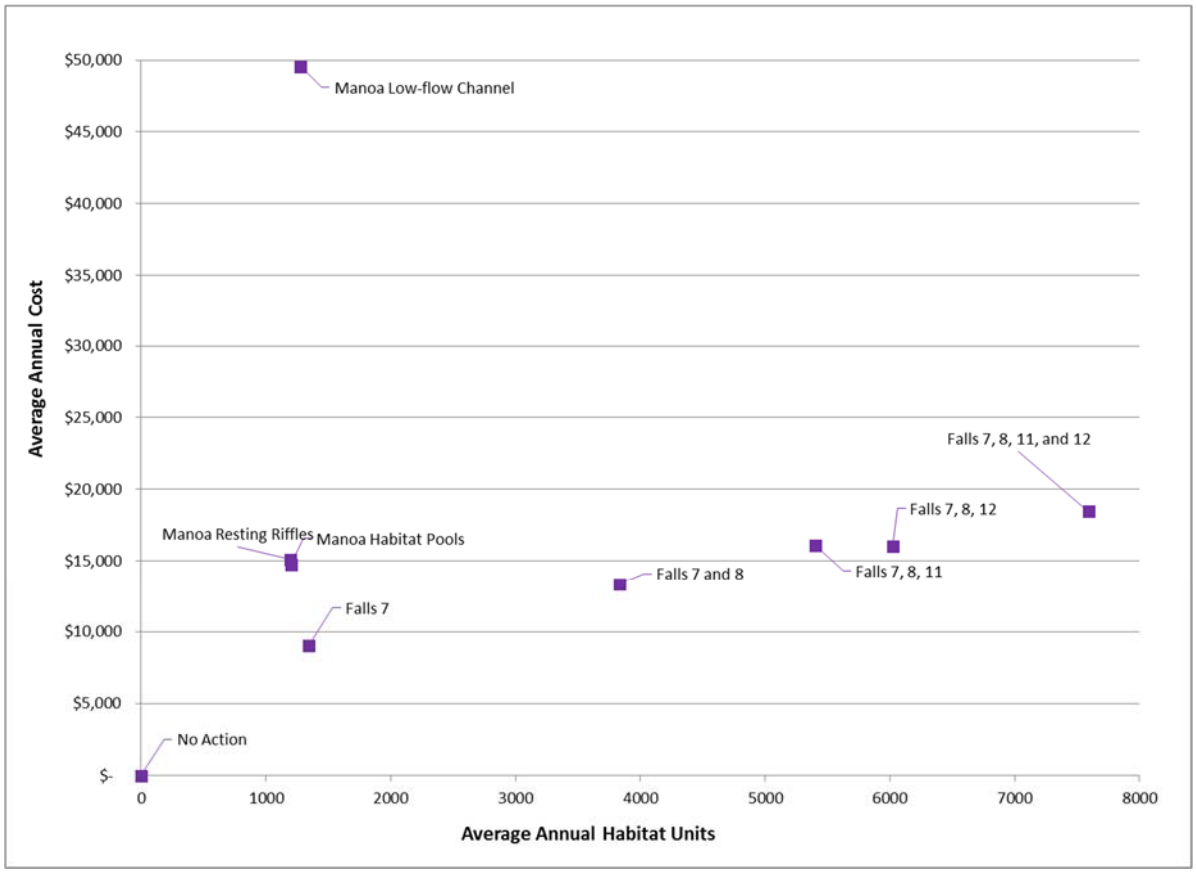

FIGURE 2
Cost and Output of Alternative Plans

3.0 Cost Effectiveness Analysis

The following section details the CE analysis, which is conducted to eliminate the least economically effective restoration alternatives. The inputs to the IWR Planning Suite include the predicted average annual habitat units (output) and the average annual cost for each alternative, each based on a 50-year period of analysis. For each level of output, only the least expensive alternative is cost-effective. As demonstrated in the following section, five of the nine alternatives were considered cost-effective and were carried forward to the ICA.

3.1 Step 4: Identify "Production Inefficient" Solutions

In Step 4, "production inefficient" solutions are identified. Production inefficient solutions are defined as alternative plans with the same level of output that can be provided at a lesser cost than another plan. Since none of the alternatives have the exact same level of output (or, average annual habitat units), there are no production inefficient solutions. These results are shown in Table 5.

TABLE 5
Identification of Production Inefficient Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of Alternative with Same Output?
No Action	0	$ -	N/A
Manoa Resting Riffles	1,195	$ 15,105	N/A
Manoa Habitat Pools	1,202	$ 14,753	N/A
Manoa Low-flow Channel	1,279	$ 49,564	N/A
Falls 7	1,340	$ 9,014	N/A
Falls 7 and 8	3,831	$ 13,362	N/A
Falls 7, 8, 11	5,401	$ 16,101	N/A
Falls 7, 8, 12	6,021	$ 16,000	N/A
Falls 7, 8, 11, and 12	7,591	$ 18,440	N/A

3.2 Step 5: Identify "Production Ineffective" Solutions

In Step 5, "production ineffective" solutions are identified. Production ineffective solutions are defined as plans with less output than a plan that has a lesser or equal cost. To demonstrate analysis conducted to identify these plans, the alternatives are ordered by increasing output, and a plan is removed from further consideration if its cost is more than a plan with greater output. As shown in Table 6, there are four plans (Manoa Resting Riffles, Manoa Habitat Pools, and Manoa Low-flow Channel, and Falls 7, 8, and 11) that have a lesser output but greater cost than at least one other plan, and are therefore production ineffective solutions. Figure 3 demonstrates the results of the CE analysis (Steps 4 and 5). Five alternatives are considered cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8, and 12; and Falls 7, 8, 11 and 12.

TABLE 6
Identification of Production Ineffective Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of all Alternatives in Subsequent Rows?
No Action	0	$ 0	Yes
Manoa Resting Riffles	1,195	$ 15,105	No
Manoa Habitat Pools	1,202	$ 14,753	No
Manoa Low-flow Channel	1,279	$ 49,564	No
Falls 7	1,340	$ 9,014	Yes
Falls 7 and 8	3,831	$ 13,362	Yes
Falls 7, 8, 11	5,401	$ 16,101	No
Falls 7, 8, 12	6,021	$ 16,000	Yes
Falls 7, 8, 11, and 12	7,591	$ 18,440	Yes

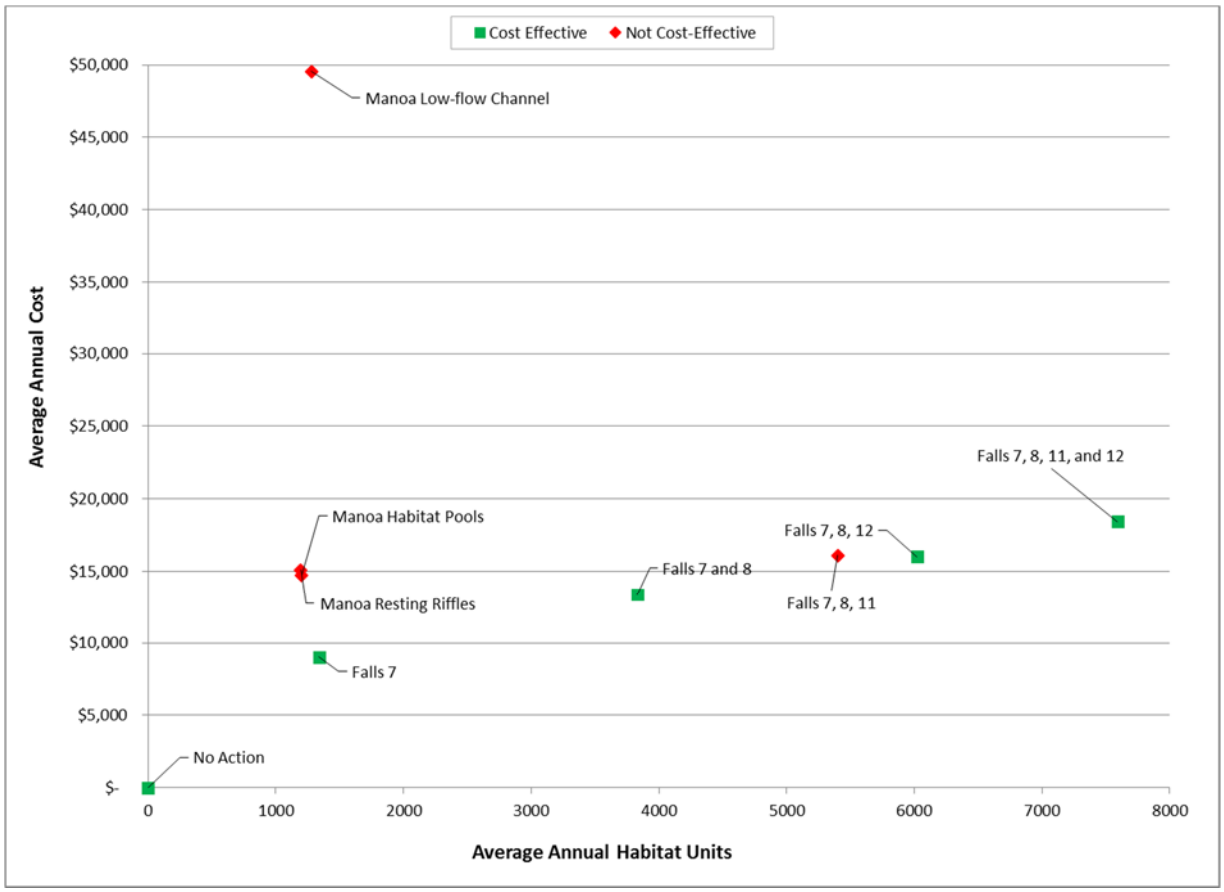

FIGURE 3
Costs and Outputs of Cost Effective Plans

4.0 Incremental Cost Analysis

The following section outlines the ICA conducted for the project. ICA is conducted on the cost-effective alternatives to determine which alternatives provide the greatest increase in output for the least increase in average annual cost. ICA serves to eliminate less economically effective solutions and determine which are best buy alternatives, or which provide the greatest increase in output for the least increase in cost. ICA is used to compare increases in average annual cost to increases in benefits, which are quantified in habitat units, among the alternatives being considered. The No Action Alternative does not have an associated cost and is therefore always considered a best buy plan. As demonstrated in the following section, of the five cost-effective alternatives, two were considered best buy plans.

4.1 Step 6: Calculate and Display Incremental Costs for Cost-Effective Plans

As previously mentioned, ICA is conducted on only the cost-effective plans identified in Steps 4 and 5. In Step 6, the incremental cost of implementing each successive cost-effective plan is calculated. While this step is not conducted to remove any alternatives, it identifies whether Steps 7 through 9 need to be completed. If the results of Step 6 show that the incremental cost per unit increases as the level of output increases, for all alternatives, the remainder of the steps do not need to be completed. However, this ideal situation is often not the case in planning studies. For the cost-effective alternatives identified in Section 3, the incremental cost per unit does not increase with increasing output (Table 7); therefore, Steps 7 through 9 must be employed.

TABLE 7
Summary of Incremental Costs per Unit (Step 6)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	2,491	$4,348	$1.75	No
Falls 7, 8, 12	6,021	$16,000	2,190	$2,638	$1.20	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	1,570	$2,440	$1.55	Yes

4.2 Step 7: Calculate and Display Incremental Costs per Unit from No Action Plan

In Step 7, alternative plans that have a higher incremental cost of implementation over the No Action Plan than an alternative with a higher output level are removed. For example, Falls 7 and 8 has a higher incremental cost per unit over the No Action Plan than does an alternative with a greater output (e.g, Falls 7, 8, and 12); therefore, Falls 7 and 8 is not considered a best buy plan (Table 8). After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 8). In Step 7, three alternatives were removed: Falls 7; Falls 7 and 8; and Falls 7, 8, 11, and 12.

TABLE 8
Summary of Incremental Costs per Unit (Step 7)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from No Action	Incremental Cost from No Action	Incremental Cost Per Unit Output from No Action	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	3,831	$13,362	$3.49	No
Falls 7, 8, 12	6,021	$16,000	6,021	$16,000	$2.66	No
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

Note: Shaded alternatives were removed as potential best buy plan.

4.3 Step 8: Recalculate Incremental Cost from Last Selected Plan

In Step 8, the two remaining alternatives (No Action and Falls 7, 8, 11, and 12) are evaluated. The incremental cost of implementing each plan over the plan with the next lower output is calculated (Table 9). Any alternative plan that has higher incremental cost of implementation over the previous plan than an alternative with a higher output level is removed. After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 9). In Step 8, no alternatives were removed. Therefore, the No Action Plan and Falls 7, 8, 11, and 12 are both considered best buy plans.

TABLE 9
Summary of Incremental Costs per Unit (Step 8)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

4.4 Step 9: Tabulate and Graph Incremental Costs

In Step 9, the incremental costs of implementing each alternative over the No Action Plan are tabulated and graphed. The purpose of Step 9 is to clearly display the CE/ICA results to be used for alternative selection. Since no alternatives were removed in Step 8, the incremental costs do not change (Table 10). Table 10 also provides the average cost per habitat unit, which is often an additional consideration in the decision-making process.

TABLE 10
Summary of Incremental Costs per Unit (Step 9)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Average Cost per Output	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan
No Action	0	$0	$ 0	0	$0	$0
Falls 7, 8, 11, and 12	7,591	$18,440	$2.43	7,591	$18,440	$2.43

Figure 4 displays the average annual cost and average annual habitat units of the alternatives. Figure 5 shows the incremental cost of implementing each successive best buy alternative (in this case only one alternative, Falls 7, 8, 11, and 12, is a successive best buy alternative), and the average annual cost of each best buy alternative. As shown, the average annual cost of Falls 7, 8, 11, and 12 is $18,440, and the incremental cost of implementing Falls 7, 8, 11, and 12 over the No Action Alternative is $2.43 per unit output. This information provides one decision factor for selection of mitigation alternative for the project.

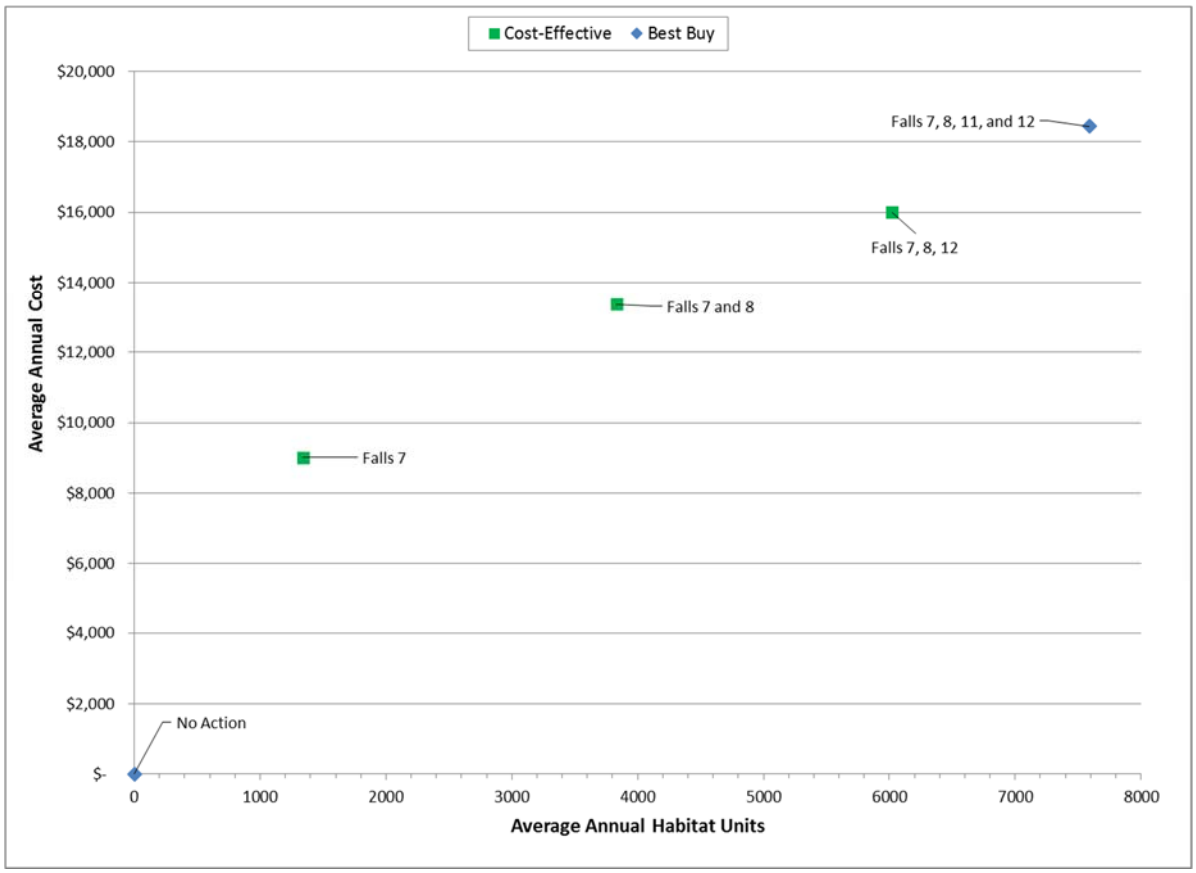

FIGURE 4
Costs and Outputs of Cost Effective and Best Buy Plans

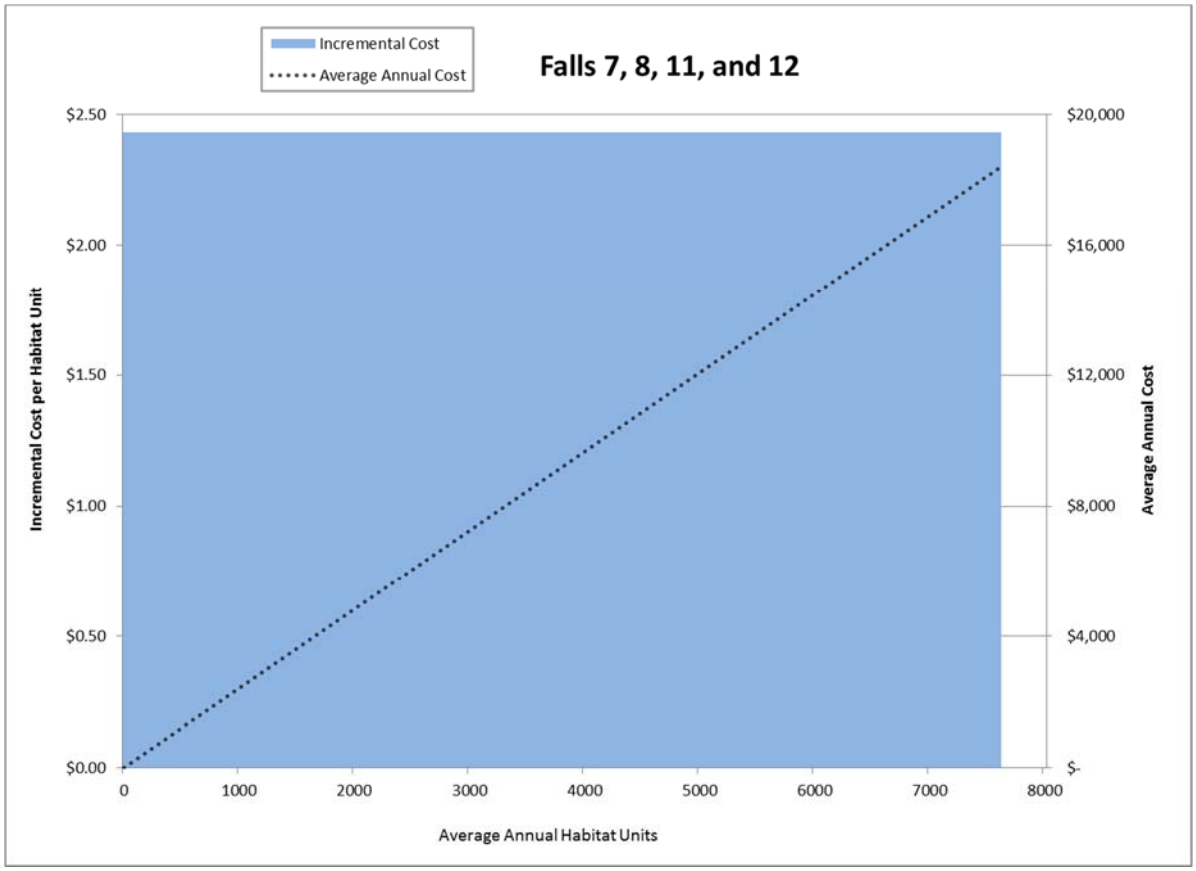

FIGURE 5
Incremental Cost of Best Buy Plans

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Attachment 1

IWR Planning Suite Detailed Cost Output

Annualized Cost for Falls 7, 8, 11, and 12

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Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $18,439.89

Total initial cost:

Construction $260,409.00 + Real Estate $34,900.00 + Monitoring $11,100.00 + Other $0.00 = $306,409.00

Total Investment cost:

Total Initial Cost $306,409.00 + PED $0.00 + IDC $4,557.16 = $310,966.16

Initial investment:

Total Investment Cost $310,966.16 PV Factor 1.000000 Present Value = $310,966.16

Year	Cost	PV Factor	Present Value
0	$310,966.16	1.0000	$310,966.16
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$13,050.00	0.7089	$9,251.39
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$13,050.00	0.5026	$6,558.48
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$13,050.00	0.3563	$4,649.43
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$13,050.00	0.2526	$3,296.07
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$13,050.00	0.1791	$2,336.65

Net Totals: Cost: $494,716.16 Present Value: $432,518.94 Avg Annual Cost: $18,439.89

Annualized Cost for Falls 7, 8, and 11

7/30/2015 8:54:34AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $16,101.07

Total initial cost:

Construction $213,101.00 + Real Estate $32,700.00 + Monitoring $11,100.00 + Other $0.00 = $256,901.00

Total Investment cost:

Total Initial Cost $256,901.00 + PED $0.00 + IDC $3,729.27 = $260,630.27

Initial investment:

Total Investment Cost $260,630.27 PV Factor 1.000000 Present Value = $260,630.27

Year	Cost	PV Factor	Present Value
0	$260,630.27	1.0000	$260,630.27
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,788.00	0.7089	$7,647.82
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,788.00	0.5026	$5,421.68
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,788.00	0.3563	$3,843.53
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,788.00	0.2526	$2,724.75
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,788.00	0.1791	$1,931.63

Net Totals: Cost: $433,070.27 Present Value: $377,660.43 Avg Annual Cost: $16,101.07

Annualized Cost for Falls 7, 8, and 12

7/30/2015 9:00:46AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $16,000.38

Total initial cost:

Construction $214,033.00 + Real Estate $29,300.00 + Monitoring $11,100.00 + Other $0.00 = $254,433.00

Total Investment cost:

Total Initial Cost $254,433.00 + PED $0.00 + IDC $3,745.58 = $258,178.58

Initial investment:

Total Investment Cost $258,178.58 PV Factor 1.000000 Present Value = $258,178.58

Year	Cost	PV Factor	Present Value
0	$258,178.58	1.0000	$258,178.58
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,833.00	0.7089	$7,679.72
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,833.00	0.5026	$5,444.30
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,833.00	0.3563	$3,859.56
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,833.00	0.2526	$2,736.12
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,833.00	0.1791	$1,939.69

Net Totals: Cost: $430,843.58 Present Value: $375,298.71 Avg Annual Cost: $16,000.38

Annualized Cost for Falls 7 and 8

7/30/2015 8:50:19AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $13,361.51

Total initial cost:

Construction $166,724.00 + Real Estate $27,100.00 + Monitoring $11,100.00 + Other $0.00 = $204,924.00

Total Investment cost:

Total Initial Cost $204,924.00 + PED $0.00 + IDC $2,917.67 = $207,841.67

Initial investment:

Total Investment Cost $207,841.67 PV Factor 1.000000 Present Value = $207,841.67

Year	Cost	PV Factor	Present Value
0	$207,841.67	1.0000	$207,841.67
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$8,271.00	0.7089	$5,863.47
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$8,271.00	0.5026	$4,156.72
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$8,271.00	0.3563	$2,946.78
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$8,271.00	0.2526	$2,089.03
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$8,271.00	0.1791	$1,480.95

Net Totals: Cost: $354,196.67 Present Value: $313,402.50 Avg Annual Cost: $13,361.51

Annualized Cost for Falls 7

7/30/2015 8:44:15AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $9,014.08

Total initial cost:

Construction $85,175.00 + Real Estate $15,900.00 + Monitoring $11,100.00 + Other $0.00 = $112,175.00

Total Investment cost:

Total Initial Cost $112,175.00 + PED $ 0.00 + IDC $1,490.56 = $113,665.56

Initial investment:

Total Investment Cost $113,665.56 PV Factor 1.000000 Present Value = $113,665.56

Year	Cost	PV Factor	Present Value
0	$113,665.56	1.0000	$113,665.56
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$4,372.00	0.7089	$3,099.39
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$4,372.00	0.5026	$2,197.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$4,372.00	0.3563	$1,557.65
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$4,372.00	0.2526	$1,104.25
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$4,372.00	0.1791	$782.82

Net Totals: Cost: $240,525.56 Present Value: $211,430.78 Avg Annual Cost: $9,014.08

Annualized Cost for Manoa Habitat Pools

7/30/2015 9:11:30AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $14,753.16

Total initial cost:

Construction $216,353.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $231,953.00

Total Investment cost:

Total Initial Cost $231,953.00 + PED $0.00 + IDC $3,786.18 = $235,739.18

Initial investment:

Total Investment Cost $235,739.18 PV Factor 1.000000 Present Value = $235,739.18

Year	Cost	PV Factor	Present Value
0	$235,739.18	1.0000	$235,739.18
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,644.00	0.7089	$7,545.73
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,644.00	0.5026	$5,349.31
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,644.00	0.3563	$3,792.23
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,644.00	0.2526	$2,688.38
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,644.00	0.1791	$1,905.84

Net Totals: Cost: $393,959.18 Present Value: $346,044.56 Avg Annual Cost: $14,753.16

Annualized Cost for Manoa Low-Flow Channel

7/30/2015 9:15:05AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $49,564.05

Total initial cost:

Construction $1,001,513.0 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $1,017,113.00

Total Investment cost:

Total Initial Cost $1,017,113.00 + PED $0.00 + IDC $17,526.48 = $1,034,639.48

Initial investment:

Total Investment Cost $1,034,639.4 PV Factor 1.000000 Present Value = $1,034,639.48

Year	Cost	PV Factor	Present Value
0	$1,034,639.48	1.0000	$1,034,639.48
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$19,452.00	0.7089	$13,789.89
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$19,452.00	0.5026	$9,775.91
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$19,452.00	0.3563	$6,930.33
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$19,452.00	0.2526	$4,913.04
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$19,452.00	0.1791	$3,482.95

Net Totals: Cost: $1,236,899.48 Present Value: $1,162,555.48 Avg Annual Cost: $49,564.05

Annualized Cost for Manoa Resting Riffles

7/30/2015 9:08:36AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $15,104.61

Total initial cost:

Construction $223,759.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $239,359.00

Total Investment cost:

Total Initial Cost $239,359.00 + PED $0.00 + IDC $3,915.78 = $243,274.78

Initial investment:

Total Investment Cost $243,274.78 PV Factor 1.000000 Present Value = $243,274.78

Year	Cost	PV Factor	Present Value
0	$243,274.78	1.0000	$243,274.78
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,998.00	0.7089	$7,796.69
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,998.00	0.5026	$5,527.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,998.00	0.3563	$3,918.35
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,998.00	0.2526	$2,777.79
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,998.00	0.1791	$1,969.23

Net Totals: Cost: $403,264.78 Present Value: $354,287.95 Avg Annual Cost: $15,104.61

Appendix E3
Clean Water Act Section 404(b)(1) Evaluation

Clean Water Act, Section 404(b)(1) Evaluation
Ala Wai Canal Project
Honolulu, Hawaii

I. PROJECT DESCRIPTION

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project[1] (hereafter referred to as "the project").

The Ala Wai watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (mi^2) (12,064 acres) and extends from the ridge of the Koolau Mountains to the nearshore waters of Mamala Bay. It includes Maikiki, Manoa, and Palolo streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki district. A map of the Ala Wai watershed is provided in the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS).

A. Authority

The project is authorized under Section 209 of the Flood Control Act of 1962. Section 209 is a general authority that authorizes surveys in harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

B. Project Purpose and Need

The purpose of the project is to reduce the risk of flood hazards within the Ala Wai watershed. A high risk of flooding exists within the watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[2] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85 million in damages (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within this area, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in

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[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

[2] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318 million in structural damages alone (2013 price levels).

C. Background and History

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act of 1974) to determine the potential flood risk to the Waikiki area, in response to a request by the Land Division of DLNR. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several mitigative measures and conceptual alternatives that could potentially minimize flood damages to Waikiki and surrounding area. The results of this technical study were used to establish that the USACE could be involved in the investigation of flood damage reduction in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The FCSA was executed between USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and a scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Manoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study, such that the project could be expanded to include the upstream portions of the Ala Wai watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received federal funds to identify specific actions to address flooding in Manoa Valley. The Manoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems.[3] However, because of insufficient federal funding to complete the project, the Manoa Watershed Project was terminated before implementation.

Information developed through the Manoa Watershed Project was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Manoa under the Manoa Watershed Project.

In October 2012, a charette was held to re-scope the project as part of the USACE Civil Works Planning Modernization process.[4] The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division and Headquarters staff, with the non-federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the array of alternatives, and a framework for identification of the tentatively selected plan (TSP). Based on the project review at the charette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify

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[3] This work was conducted by the USACE on behalf of NRCS via a Support Agreement in compliance with a Memorandum of Agreement between USACE and USDA, pursuant to the Economy in Government Act (31 USC S. 1535.).

[4] The charrette was held on October 16-19, 2012 with the purpose of reaching consensus on the actions needed to complete the project on budget and schedule, including a clear path for identification of the TSP (USACE, 2012). Participants included the project delivery team, non-federal sponsors, USACE Division and Headquarters staff, and cooperating agency representatives.

ecosystem restoration as an objective. However, the ecosystem-related information previously identified as part of the study is being incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

D. Planning Process

General investigations, such as those carried out under Section 209 of the Flood Control Act of 1962, are funded by specific appropriations and are conducted through a feasibility planning process. The USACE feasibility planning process is comprised of six steps, as specified by USACE planning regulations and guidance, including Engineer Regulation (ER) 1105-2-100 "Planning Guidance Notebook" (USACE, 2000). These steps include: (1) specification of water and related land resources problems and opportunities; (2) inventory, forecast, and analysis of water and related land resources conditions within the study area; (3) formulation of alternative plans; (4) evaluation of the effects of the alternative plans; (5) comparison of the alternative plans; and (6) identification of a TSP based upon the comparison of the alternative plans.

Recognizing the need to modernize their planning process with an emphasis on delivering high-quality feasibility studies within shorter timeframes and at lower costs, the USACE has recently applied a SMART [Specific, Measurable, Attainable, Risk Informed, Timely] planning approach to the six-step process (USACE, 2012). The SMART planning approach emphasizes risk-based decision making and focuses on three primary requirements for feasibility studies (referred to as the "3x3x3 Rule"): completion within 3 years, at a cost of no more than $3 million, and with 3 levels of vertical team alignment (including USACE District, Major Subordinate Command (MSC), and Headquarters staff). Other key components include (1) focusing the detailed analysis and design on the tentatively selected plan, and (2) identification of the appropriate level of detail, data collection, and modeling based only on what is necessary to complete the feasibility study.

E. Project Description

Over the course of the planning process, a variety of structural and non-structural flood risk management measures were identified, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The measures are generally based on the concepts originally developed in support of the Ala Wai Flood Study (USACE, 2006) and the Manoa Watershed Project (Oceanit, 2008). The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, flood risk reduction, and life safety risks. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the Tentatively Selected Plan [TSP]); this alternative plan constitutes the proposed action. The measures included in the TSP are based on the following concepts:

- **Detention basin**: Detention basins involve construction of an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function

to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.

  - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin via a spillway along the stream bank, then would flow back into the stream as flood conditions subside.

- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, debris catchment structures were also considered as stand-alone measures; these structures would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. They would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.
- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height (with an average height of 4 feet), and would be constructed with a minimal set back distance from the existing stream or canal walls. Local drainage patterns would be maintained to the extent possible, with flap gates and/or slide gates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). The only non-structural measure that was found to be feasible for this project is improvement of the existing flood warning system.

Consistent with USACE regulations (Engineering Regulation [ER] 1105-2-100), compensatory mitigation measures were incorporated into the TSP to compensate for unavoidable impacts to aquatic habitat. As further described in the Mitigation and Monitoring Plan for this project, the Hawaii Stream Habitat Evaluation Procedure (HSHEP) was used to quantify the potential impacts to aquatic habitat, thus establishing the basis for mitigation. Based on the known problems relating to the existing aquatic habitat quality, a suite of potential mitigation measures were developed and evaluated. This process resulted in the selection of a mitigation alternative comprised of two measures, each of which involves removal of a passage barrier to improve access to high quality upstream habitat for native aquatic species.

Each of the flood risk management measures and associated compensatory mitigation measures included in the TSP is summarized in Table 1. Locational maps and engineering drawings of each measure are included as part of the Draft Feasibility Report/EIS.

TABLE 1
Flood Risk Management Measures and Associated Compensatory Mitigation Measures in the TSP

Measure	Description of Measure
Waihi debris and detention basin	Earthen dam, approximately 24 feet high and 225 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.
Waiakeakua debris and detention basin	Earthen dam, approximately 20 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.
Woodlawn Ditch detention basin	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side.
Manoa in-stream debris catchment	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.

TABLE 1
Flood Risk Management Measures and Associated Compensatory Mitigation Measures in the TSP

Measure	Description of Measure
Kanewai Field multi-purpose detention basin	Earthen berm, approximately 7 feet high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.
Waiomao debris and detention basin	Earthen dam, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. Excavation of approx. 2,000 yd3 to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.
Pukele debris and detention basin	Earthen dam, approximately 24 feet high and 120 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.
Makiki debris and detention basin	Earthen berm, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm
Ala Wai Canal floodwalls	Concrete floodwalls ranging up to 4 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.
Hausten Ditch detention basin	Concrete floodwalls and an earthen berm (approximately 4.3 feet high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, up to approximately 7 feet high, around the north and east perimeter of the golf course; grouted rip-rap inflow spillway along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.
Flood warning system	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed.
Compensatory mitigation measures (Falls 7 and 8)	Removal of passage barrier at two separate in-stream structures. Each of the structures currently has an overhanging lip, such that the stream flow over these structures is free-falling and does not maintain contact with the surface of the structure, creating a barrier to upstream passage for native species. The proposed mitigation involves installation of grouted stones as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat.

Following construction, each of the measures will be operated and maintained by the non-federal sponsor. The operations and maintenance (O&M) requirements for each measure type are summarized in Table 2.

TABLE 2
Proposed Operations and Maintenance (O&M) Activities

Measure Type	Summary of O&M Activities
Debris and Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Clear accumulated debris following flood event or annually (whichever is greater)
Multi-Purpose Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Assumes minimal sediment or debris removal would be required
Debris Catchment	Clear accumulated debris twice per year
Floodwalls	Inspect and maintain gates (e.g., greased) annually; Inspect, test, and maintain pump system annually; Inspect floodwalls and repair as needed (e.g., patching)
Flood Warning System	Inspect and test annually (includes annual operating cost)
Mitigation Measures	Inspect for erosion annually

NOTES:
[1] Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

E. General Description of Dredged or Fill Material

1. General Characteristics of Material

The materials to be used would vary by measure; these are generally described in Table 3. The exact specifications of the materials have not yet been determined. In general, the materials would be obtained from existing sources. Stone for the rip-rap would be durable material free from cracks, seams and other defects that would tend to increase deterioration from natural causes. Fill material would consist of soil and stones less than 3-inches in diameter; concrete would be a 4000 psi standard mix. Base course material would consist of clean gravel. The arch culverts would consist of corrugated aluminum, and the debris catchment posts would be 8-inch-diameter steel poles. Slide gates would be comprised of cast iron, and flap gates would be comprised of cast iron and steel.

2. Quantity of Material

For the purpose of this analysis, quantities were calculated based on the conservative assumption that the ordinary high water mark (OHWM) is approximately at the level of the 50-percent ACE event.[5] Based on this assumption, the quantity of material to be placed below the OHWM includes approximately 202 cubic yards of concrete, approximately 853 cubic yards of compacted fill, approximately 109 cubic yards of grouted rip-rap or stone, and approximately 70 cubic yards of base course material (gravel). Table 3 lists the type and quantity of fill material specific to each measure location. These quantities are based on the 35% level of design, and will be revisited and modified as needed during the detailed design phase.

Specific to O&M, no placement of fill material is anticipated. O&M activities would require work within the OHWM; however, these activities would generally be limited to trimming/clearing vegetation around the perimeter of the in-stream detention berms. Accumulated sediment and debris would also be removed from the debris catchment features and in-stream detention basins, as listed in Table 4.

3. Source of Material

The exact source of the material has yet to be determined. However, all fill material would be obtained from a certified pit/quarry or other approved source, and will be free of contaminants. All stone and rock would be clean and reasonably free from soil, quarry fines, and would contain no refuse.

[5] The exact location of OHWM will be verified as part of a formal jurisdictional delineation to be conducted during the detailed design phase; this analysis will be updated based on the delineation, as well as any refinements to the project design.

TABLE 3
General Description of Construction-Related Excavation and Placement of Fill Within Waters of the U.S.

Measure	Component of Measure	Excavated Material			Fill Material		
		Description	Quantity	Unit	Description	Quantity	Unit
Waihi debris and detention basin	Culvert				Concrete footing	9	yds^3
	Detention berm				Compacted fill Grouted rip-rap	140 3	yds^3 yds^3
	Debris catchment feature				Concrete footing	19	yds^3
					Steel posts (8” dia.)	7	posts
	Access road				Base course (gravel)	2	yds^3
Waiakeakua debris and detention basin	Culvert				Concrete footing	7	yds^3
	Detention berm				Compacted fill Grouted rip-rap	290 12	yds^3 yds^3
	Debris catchment feature				Concrete footing	19	yds^3
					Steel posts (8” dia.)	7	posts
	Energy dissipator				Concrete blocks (3’ wide)	8	yds^3
Woodlawn Ditch detention basin	Culvert				Concrete footing	6	yds^3
	Detention berm				Compacted fill Grouted rip-rap	3 1	yds^3 yds^3
Manoa in-stream debris catchment	Debris catchment feature				Concrete footing	36	yds^3
					Steel posts (8” dia.)	14	posts
Kanewai Field multi-purpose detention basin	Spillway				Grouted rip-rap	41	yds^3
Waiomao debris and detention basin	Culvert				Concrete footing	9	yds^3
	Detention berm				Compacted fill Grouted rip-rap	140 3	yds^3 yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8” dia.)	5	posts
	Access road				Base course (gravel)	60	yds^3
	Detention Basin	Excavation	2,000	yds^3	none	-	-

Measure	Component of Measure	Excavated Material			Fill Material		
		Description	Quantity	Unit	Description	Quantity	Unit
Pukele debris and detention basin	Culvert				Concrete footing	9	yds^3
	Detention berm				Compacted fill Grouted rip-rap	140 6	yds^3 yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8” dia.)	5	posts
	Access road				Base course (gravel)	4	yds^3
Makiki debris and detention basin	Culvert				Concrete footing	9	yds^3
	Detention berm				Compacted fill Grouted rip-rap	140 6	yds^3- yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8” dia.)	5	posts
	Access road				Base course (gravel)	4	yds^3
Ala Wai Canal floodwalls	Floodwalls				None	-	-
	Access stairs				None	-	-
	Slide/flap gates				Metal slide/flap gates	47	gates
Hausten Ditch detention basin	Concrete wall				Concrete	26	yds^3
	Slide gates				Metal slide gates	4	gates
Ala Wai Golf Course multi-purpose detention basin	Spillway				Grouted rip-rap	30	yds^3
Flood warning system	Sensors				Prefabricated hoses	1	hoses
Mitigation– Falls 7	Species passage				Grouted stone	4	yds^3
Mitigation– Falls 8	Species passage				Grouted stone	3	yds^3
TOTAL		**Excavation**	**2,000**	**yds^3**	**Concrete**	**202**	**yds^3**
					Compacted fill	**853**	**yds^3**
					Grouted rip-rap / stone	**109**	**yds^3**
					Base course (gravel)	**70**	**yds^3**

NOTES:

1. The quantities reflect excavation and placement of fill material as part of construction (assumes no discharge associated with general clearing and grubbing). Quantities were calculated based on the conservative assumption that the ordinary high water mark (OHWM) is approximately at the level of the 50-percent ACE event. The exact location of OHWM will be verified as part of a formal jurisdictional determination to be conducted during the next phase of the project; this analysis will be updated based on the delineation, as well as any refinements to the project design.

TABLE 4
General Description of Excavation and Placement of Fill Within Waters of the U.S. for Operations and Maintenance

Measure	Description	Excavated Material		Fill Material	
		Quantity[1]	Unit	Quantity	Unit
Waihi debris and detention basin	Sediment/debris removal	300	yds^3	-	-
Waiakeakua debris and detention basin	Sediment/debris removal	400	yds^3	-	-
Woodlawn Ditch detention basin	None	-	-	-	-
Manoa in-stream debris catchment	Sediment/debris removal	25	yds^3	-	-
Kanewai Field multi-purpose detention basin	None	-	-	-	-
Waiomao debris and detention basin	Sediment removal	300	yds^3	-	-
Pukele debris and detention basin	Sediment removal	100	yds^3	-	-
Makiki debris and detention basin	Sediment removal	250	yds^3	-	-
Ala Wai Canal floodwalls	None	-	-	-	-
Hausten Ditch detention	None	-	-	-	-
Ala Wai Golf Course multi-purpose detention basin	Sediment removal	200	yds^3	-	-
Flood warning system	None	-	-	-	-
Mitigation measures (Falls 7 and 8)	None	-	-	-	-

NOTES:
[1] Quantities are an estimate of the amount of sediment and debris to be removed annually; assumes no discharge of dredged or fill material associated with other O&M activities (e.g., trimming/clearing vegetation around the perimeter of the in-stream detention berms and clearing debris within the debris catchment features and in-stream detention basins).

F. Description of Proposed Discharge Sites

1. Location

The proposed measures would be located within and along the various waterways within the Ala Wai watershed; these include Makiki, Manoa and Palolo Streams and the Ala Wai Canal. Each measure is briefly described in Table 1; maps showing their location are contained in the Draft Feasibility Report/EIS.

2. Size

The amount of area within which fill material would be discharged varies by measure. The length of channel that would be within the footprint of each permanent structure (i.e. the areas that would be subject to placement of fill), as well as the length of channel within the overall construction limits for each measure is summarized in Table 5.

3. Type of Habitat

Streams in the Ala Wai watershed arise on the southern slopes of the Koʻolau range. Manoa and Palolo valleys contain the two major streams draining to the Ala Wai Canal, with Manoa Stream consisting of a complex radial set of six tributaries in its upper reaches. Makiki Stream also flows to the Ala Wai Canal, but drains a much smaller area, with at least one of its four tributaries (Kanaha Stream) flowing only intermittently (Englund and Arakaki, 2004). A formal jurisdictional determination of Waters of the U.S. has not yet been completed for the project area; however, all of the streams and Canals in the watershed are assumed to be Waters of the U.S. (AECOS, 2014).[6] Jurisdictional wetlands are not expected to be present outside the defined channel limits. This information will be verified during the next phase of the project

[6] The Ala Wai Canal is a navigable Waters of the U.S., and therefore also subject to Section 10 of the Rivers and Harbors Act.

through a formal jurisdictional determination in accordance with the new Clean Water Rule: Definition of "Waters of the United States" (33 CFR Part 328).

Each stream generally consists of an upper, middle, and lower reach that flow to an estuarine reach and then to the Ala Wai Canal, before discharging to the ocean. In this context, upper reaches are the tributary streams with youthful profiles (steep, relatively straight courses in down-cutting channels). Middle reaches have more mature profiles, slightly meandering and eroding mostly laterally. Lower reaches flow across the coastal plain and are typified by sediment accumulation. The estuarine reaches are those in which sea water and freshwater mix, typically along a gradient of increasing salinity seaward.

Riparian vegetation is present along all of the upper stream reaches, and is generally dominated by non-native species (many of which are considered invasive), including large trees such as Chinese banyan, *kukui* (*Aleurites moluccana*), mango, octopus tree, *hau* (*Hibiscus tiliaceus*), fiddlewood (*Citharexylum spinosum*), mountain apple (*Syzygium malaccense*), gunpowder tree (*Trema orientalis*), and gum (*Eucalyptus* sp.), as well as smaller herbaceous species such as exotic ginger (*Hedychium* sp.) and Job's tears (*Coix lachryma-jobi*) (Kido, 2006; Kido, 2007; Kido, 2008; Oceanit, 2004).

Within the urbanized portion of the watershed, riparian vegetation is generally limited to unchannelized stream reaches, such as along portions of Manoa Stream (for example, near the Dole Street Bridge). A majority of Palolo and Makiki streams are channelized and lack a riparian zone (Oceanit, 2004; Englund and Arakaki, 2004; Kido, 2008). Mangrove trees (*Rhizophora mangle*) are present in some areas in the lower estuarine reaches of the Manoa–Palolo Drainage Canal and the Ala Wai Canal, although concrete and concrete masonry (CRM) walls constructed as banks have eliminated much of the riparian vegetation.

A description of the habitat at each measure location is provided in Table 5.

4. Timing and Duration of Discharge

Subject to approvals and appropriation of funds, construction would begin in the year 2021. In total, construction is expected to last approximately 3 years; it is expected that construction of individual measures will require on the order of 6 to 12 months each.

G. Description of Disposal Method

In general, all material would be moved and placed mechanically.[7] Cranes, backhoes, scrapers, dump trucks and other appropriate heavy machinery would be used to deliver and place fill materials during construction. Materials would be placed in a manner that minimizes disturbance of the aquatic environment. Rip-rap would generally be placed in a systematic manner to ensure a continuous uniform layer of well-graded stone. Concrete for footings would be placed using pumps into wooden formwork. Concrete for rip-rap may be placed using pumps or by hand.

[7] Due to access limitations, it is anticipated that the mitigation measures would be constructed by hand.

TABLE 5
Description of Proposed Discharge Sites

Measure[1]	Location	Description of Habitat	Length of Stream Within Construction Limits (linear feet)	Length of Stream Subject to Placement of Fill (linear feet)	Length of Stream Within O&M Area (linear feet)
Waihi debris and detention basin	Waihi Stream, ~1,200 feet above the upper extent of development in Manoa Valley (~380' in elevation).	Site is characterized by forested habitat, with dominant species including monkeypod (*Albizia saman*), Chinese banyan, gunpowder, *kukui*, swamp mahogany (*Eucalyptus robusta*), mango, Java plum, and Christmas berry; pothos vine (*Epipremnum pinnatum*) is prominent climbing the trees. Site is located on the lower edge of a prominent belt of albizia trees.	160	130	40
Waiakeakua debris and detention basin	Waiakeakua Stream, ~200 feet above the upper extent of development in Manoa Valley (~300' in elevation).	Site (including the staging area) is characterized by forested habitat, with species including guarumo (*Cecropia obtusifolia*), macaranga (*Macaranga tanarius*), hau (*Hibiscus tiliaceus*), bamboo, and the shrub *Odontonema strictum*. Other species include red ginger (*Alpinia purpurata*), shoebutton ardesia (*Ardisia elliptica*), and white shrimp plant (*Justicia betonica*); pothos vine is prominent climbing the trees; site is located on the lower edge of a prominent belt of albizia trees.	190	110	40
Woodlawn Ditch detention basin	Woodlawn Ditch (manmade tributary to Manoa Stream), adjacent to E. Manoa Road (~200' in elevation)	Site is characterized by mixed secondary forest and tended farm/garden areas; forest is nearly monotypic stand of macaranga (*Macaranga tanarius*), with a limited number of tropical almond (*Terminalia catappa*), shoebutton ardisia, Chinese hibiscus (*Hibiscus rosa-sinensis*), coconut (*Cocos nucifera*), African tulip (*Spathodea campanulata*), and small albizia.	120	60	40
Manoa in-stream debris catchment	Middle reach of Manoa Stream, directly adjacent to lower edge of Manoa District Park (~160' in elevation)	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties); the staging areas within Manoa District Park is dominated by lawn, with some planted trees including Formosan *koa* (*Acacia confusa*), *kukui*, coconut, and royal palms (*Roystonia regia*).	48	8	40
Kanewai Field multi-purpose detention basin	Lower reach of Manoa Stream, just below Dole Street	Site is comprised of maintained field for park; predominantly a mowed lawn with two large mango trees near the west corner site; adjacent stream includes a riparian corridor with various mature trees of Java plum, *hau*, mango, macaranga, and monkeypod.	70	70	0
Waiomao debris and detention basin	Pukele Stream, adjacent to residences on Waiomao Rd. (~380' in elevation)	Site is comprised of a heavily forested riparian zone adjacent to residential properties; dominated by non-native species including octopus tree, gunpowder, monkeypod, macaranga (Macaranga tanarius), mango, and fiddlewood; pothos vine is prominent climbing the trees.	455	130	40

TABLE 5
Description of Proposed Discharge Sites

Measure[1]	Location	Description of Habitat	Length of Stream Within Construction Limits (linear feet)	Length of Stream Subject to Placement of Fill (linear feet)	Length of Stream Within O&M Area (linear feet)
Pukele debris and detention basin	Pukele Stream, adjacent to residences on Ipulei Place (~400' in elevation)	Site includes the maintained lawns of two residential homes; right bank of the stream is dominated by weedy species including Guinea grass (*Panicum maximum*) and castor bean (*Ricinus communis*); left bank is forested with non-native species including Chinese banyan, swamp mahogany, and Java plum	170	130	40
Makiki debris and detention basin	Makiki Stream, directly adjacent to Makiki Heights Drive (~160' in elevation).	Site is characterized by dense riparian forest; dominant species include Chinese banyan, African tulip (*Spathodea campanulata*), gunpowder tree, she oak (*Grevillea robusta*), and mango. The understory is as well dominated by a variety of nonnative shrubs and vines, notably pothos (*Epipremnum pinnatum*), shrimp plant (Justicia betonica), and Madeira vine (*Anredera cordifolia*). Staging area includes open *kukui* copse, with open floor.	175	130	40
Ala Wai Canal floodwalls	Perimeter of Ala Wai Canal	Vegetation along the Canal is generally limited to landscaping, with a single row of trees lining most of both sides of Canal, including *niu* (*Cocos nucifera*), with some milo (*Thespesia populnea*) and monkeypod.	0	0	0
Hausten Ditch detention basin	Hausten Ditch (drainage input to Ala Wai Canal)	Hausten Ditch is dominated by non-native species, including mangroves; native species that occur along ditch (including *'akulikuli* [*Sesuvium portulacastrum*]; *kou* [*Cordia subcordata*], and *kīpūkai* [*Heliotropium Curassavicum*]) are common species. The remainder of the site is a maintained lawn, with scattered *niu*, milo and monkeypod trees.	70	35	35
Ala Wai Golf Course multi-purpose detention basin	Ala Wai Canal	Landscaped vegetation for golf course greens and fairways; site also includes two shallow basins and a ditch that are identified as seasonally flooded wetland features on the National Wetlands Inventory (USFWS, 2006a)	70	70	0
Flood warning system	Specific locations to be determined	Assumed to be located in upper reaches of the watershed	0	0	0
Mitigation - Falls 7	Manoa Stream, approximately 400 feet downstream of Pawaina St. Bridge	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties)	50	5	0
Mitigation - Falls 8	Manoa Stream, immediately downstream of Pawaina St. Bridge	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties)	60	5	0

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

1. Substrate Elevation and Slope

In general, the proposed measures are designed to conform to the existing elevation and slope of the stream channel, as further described below.

- **In-stream detention basins:** Overall, the elevation and slope of the existing channel bottom would be maintained throughout the various in-stream detention basins. Specifically, the designs incorporate a natural-bottom arch culvert that would maintain the natural channel for the length of the detention berm. Energy dissipation structures and other features have been incorporated as needed to maintain channel stability.

  Although the detention berms would not substantially affect the channel form, these features would function to temporarily detain stream flows that exceed the approximately 20-percent ACE level. One of the basins (Waiomao debris and detention basin) would require excavation in the area behind the detention berm (including the stream) to provide adequate storage capacity. This work would result in localized changes in the elevation and slope of the area adjacent the stream, but the general channel form would be maintained and the excavation would be designed to blend with the existing topography to the extent possible. Inundation associated with each of the in-stream detention basins is expected to be infrequent and of short duration (e.g., less than 12 hours for the 1% ACE event), such that significant loss of environmental characteristics and values is not anticipated.

- **Multi-purpose detention basins:** These measures would primarily be located in upland areas adjacent to a stream channel, and would not involve modification of the stream bottom. To create an inflow spillway for each basin, a minimal amount of grading may be required along approximately 70 feet of the stream bank, prior to placement of rip-rap. No significant changes in the elevation or slope is expected.

- **Debris catchment features:** The debris catchment features involve installation of a small concrete pad with inset steel poles across the stream bottom. The concrete pad would be installed at existing grade, such that no changes in elevation or slope of the stream channel are anticipated. The steel poles would function to capture debris, which will be removed as part of routine O&M activities.

- **Flood warning systems:** This measure would not affect the elevation or slope of channel.

- **Mitigation measures:** The mitigation measures involve the installation of grouted stone to eliminate an overhanging lip associated with erosion at two existing in-stream structures. The measures would not affect the elevation of the stream bed.

Based on the minimal degree of change in channel substrate elevation and slope, there are not expected to be significant changes in water circulation, depth or temperature during periods of normal flow.

2. Sediment Type

The existing substrate in stream channel within the Ala Wai watershed includes a gradation of materials, with a mixed size of rock and varying levels of sediment. The substrate in the upper reaches of the watershed is typically comprised of large boulders and cobbles, and the middle reaches incorporate a mixed substrate, with a larger percentage of medium-sized substrate. The lower reaches of the watershed, including the Ala Wai Canal and Hausten Ditch include a large component of sediment and other fine particulates.

Construction of the flood management measures would modify the existing substrate within portions of the measure footprint, as described below.

- **In-stream detention basins:** These measures would involve placement of compacted fill and grouted rip-rap for construction of the detention berm. To minimize the loss of natural substrate, an arch culvert would be incorporated into the detention berm to allow for maintenance of a natural-bottom channel. The substrate within the channel would likely be affected during construction, with an increased amount of sediment and fine particulates. Following construction, the natural substrate is expected to return to pre-construction conditions. However, some amount of sediment and debris is expected to accumulate in the area behind the detention berm, and would be routinely removed as part of O&M.
- **Multi-purpose detention basins:** The multi-purpose detention basins would involve placement of rip-rap along a short section of channel bank, which would function as the inflow spillway for the detention basin. The rip-rap would replace the existing earthen stream bank.
- **Debris catchment features:** The debris catchment features would involve installation of a concrete pad, which would displace the existing substrate. However, these features would be at existing grade, and given their relatively small size, are not expected to result in a substantial loss of environmental characteristics and values.
- **Flood warning system:** The flood warning system would not displace or otherwise affect the natural substrate.
- **Mitigation measures:** The mitigation measures would involve placement of grouted stone to address erosion and undercutting associated with existing in-stream structures. The grouted stone would be sized and installed in a manner that mimics the natural channel substrate.

3. Dredged/Fill Material Movement

Fill material would be placed directly into the stream channels, which would be diverted/dewatered to accommodate construction activities. In addition, best management practices (BMPs) would also be implemented to reduce the potential for erosion and sedimentation during construction. The proposed fill material would be sufficiently sized and/or protected (e.g., with rip-rap, vegetative covering or other stabilization measures) so as to preclude downstream movement of the fill materials following construction. The stabilization methods that would be applied to specific areas will be determined during final design. With proper diversion/dewatering and implementation of BMPs, the proposed discharge is expected to be stable, such that the substrate surrounding the discharge site is not expected to be affected by erosion, slumping or lateral displacement of materials.

4. Physical Effects on Benthos

Placement of fill material would smother and/or displace benthic organisms located within the footprint of the flood risk management structures. Excavation activities (i.e. for Waiomao debris and detention basin) could also result in mortality of benthic organisms within these areas. However, it is expected that the newly placed substrate would be rapidly colonized, with little to no long-term effects on benthic communities.

5. Actions Taken to Minimize Impacts

Efforts to minimize stream-related impacts on the physical substrate include the use of approved construction procedures, in compliance with Federal and State requirements, as well as implementation of BMPs. These include:

- Work within the stream channels would be limited to periods of low flow, with proper diversion/ dewatering techniques, as appropriate.
- Construction activities would be sequenced to limit the extent of exposed soil at any given time.
- Erosion prevention and sedimentation control measures would be implemented and maintained for the duration of construction.
- Dirt stockpile areas containing more than 100 cubic yards of material would be covered or kept wet.
- All fill materials would be acquired from approved sources and will be free of contaminants.
- Appropriate vehicles and equipment would be utilized for all stages of construction, and construction crews would be adequately trained to avoid and minimize impacts to the aquatic environment.

B. Water Circulation, Fluctuation, and Salinity Determinations

1. Water Chemistry

The use of clean fill material would preclude any significant impacts on water chemistry as a result of the proposed fill activities. Minor, short-term decreases in water clarity would likely occur during construction, but are not expected to occur long-term. No significant impacts on water color, odor, taste, dissolved oxygen levels, temperature or nutrient levels are anticipated.

2. Current Patterns and Circulation

None of the measures involve placement of fill materials that would substantially modify the existing flow patterns under normal flow conditions. Some aspects of the proposed measures could affect water circulation and/or temporarily alter flow patterns during high flow events, as further described below.

- **In-stream detention basins:** The in-stream detention basins include a natural-bottom arch culvert, which is sized to maintain passage of stream flows up to the 20-percent ACE level. During periods when flows exceed this level, water would be temporarily detained in the detention basins. This would result in areas with reduced flow velocity and circulation behind the detention berm (which could increase deposition of suspended particulates), and a concentration of flows with increased velocity within the culvert (which could result in increased erosion). However, design features (such as energy dissipators) would be incorporated to regulate flow velocities and reduce the potential for erosion. In addition, these flow conditions are only expected to occur on an infrequent basis and for a short duration (less than 12 hours for the 1-percent ACE event), such that significant impacts are not anticipated.
- **Multi-purpose detention basins:** As previously described, the multi-purpose detention basins would be located in an upland area adjacent to a stream, and would include an inflow spillway on the stream bank, as needed to divert stream flows during flood conditions. The spillway would not affect flow patterns or circulation during normal stream flows. During flood flows, the detention basin would temporarily fill with stream flows, which would then be returned to the stream. As these features are located off-channel, and would serve to reduce peak flow volumes on an infrequent basis, they are not expected to affect flow patterns or circulations in a manner that would substantially affect stream characteristics or values.

- **Debris catchment features:** The debris catchment features would function to capture debris that would otherwise flow downstream and increase the potential for stream blockages. If excessive amounts of debris accumulate in the debris catchment features, stream flow circulation could be affected. However, the debris that is caught by these features would be removed as part of routine O&M, such that substantial changes in flow and circulation are not anticipated.
- **Flood warning system:** The flood warning system would not affect flow patterns or water circulation.
- **Mitigation measures:** The mitigation measures are intended to eliminate an overhanging lip associated with undercutting and erosion of in-stream structures. Grouted stone would be installed in a manner that restores water contact with the surface of the structure. This work is not expected to result in a substantial change to flow or circulation.

3. Normal Water Level Fluctuations

In general, the proposed measures are designed to maintain the normal flow regime, such that typical water level fluctuations would not be affected. However, during flood flows, both the in-stream and multi-purpose detention basins are intended to detain water, resulting in areas of inundation behind (or within) the detention berms. However, these conditions would only occur on an infrequent basis and for a short duration (e.g., less than 12 hours for a 1-percent ACE event), such that no substantial changes are anticipated relative to the stream characteristics and values.

4. Salinity Gradients

The vast majority of the proposed measures would be located in areas that are not tidally influenced. The only measures that would be located in areas subject to salinity gradients are the Hausten Ditch Detention Basin and the Ala Wai Golf Course Detention Basin. However, implementation of these measures would not divert or restrict flows in a manner that would substantially affect the salinity gradients. The Ala Wai Golf Course Detention Basin would only divert flood flows that exceed the 20-percent ACE level, and flows would return to the Ala Wai Canal as the flood waters subside (estimated to occur within less than 10 hours). Similarly, the Hausten Ditch Detention Basin would also be used only during flood flows, in which case slide gates would be activated until the flood waters subside. In both cases, modification of the flows would occur infrequently and for a short duration, such that the salinity gradient in the Ala Wai Canal is not expected to be significantly affected.

5. Actions Taken to Minimize Impact

As previously described, design features (such as energy dissipators) would be incorporated into the in-stream debris and detention basins to regulate flow velocities and reduce the potential for erosion. In addition, standard BMPs would be implemented, including those listed above (Section II(A)(5)).

C. Suspended Particulate/Turbidity Determination

1. Suspended Particulates and Turbidity Levels

As previously described, the fill materials to be placed include a combination of earthen fill, rip-rap, concrete and base course, all of which would be adequately stabilized during construction. In general, the size and characteristics of these materials would not substantially contribute to increased turbidity or suspended particulate levels over the long term. However, some degree of increased turbidity and increased concentration of suspended solids is likely to occur during construction of project features. Proper diversion/dewatering techniques and other BMPs would be implemented to avoid and minimize the potential for erosion and sedimentation to the extent possible. As such, these are expected to be temporary impacts, and would be relatively minor and restricted to a localized area. No long-term adverse effects on water quality are expected.

2. Effects on Chemical and Physical Properties of the Water Column

Temporary increases in suspended particulates and turbidity could result in minor impacts on the physical properties of the water column, including reduced light penetration and habitat quality for aquatic species. However, these changes would be short-term and localized, and it is expected that the potential effects would rapidly dissipate upon completion of construction. All discharge material would be clean and free of contaminants, such that no effects relative to toxic metal concentrations, pathogens, or viruses are anticipated.

3. Actions Taken to Minimize Impact

As previously described in Section II(A)(5), BMPs would be implemented during construction, and would help to avoid and minimize impacts associated with suspended particulates and turbidity to the extent possible.

D. Contaminant Determinations

As previously specified, all materials used for construction would be from approved sources, and would be clean and free of contaminants. Previous studies have investigated the extent of pollution in the water column and sediments within the Ala Wai Canal, with a few studies also sampling the main streams in the watershed. In general, these studies have identified the presence of contaminants including bacteria, trace metals, nutrients, pesticides, and toxic organics (Edward K. Noda and Associates, 1992a, 1992b, and 1992d; Laws et al., 1993; DOH, 1997a; DOH, 2002; Anthony et al., 2004; De Carlo et al., 2004). As previously described, the detention basins would function to temporarily hold stream flows, slowly releasing them within the streams and Canal. To the extent that contaminants are present in the detention areas (particularly within the multi-purpose detention areas, which may be subject to herbicide applications), detained water could flush contaminants into the streams, thus contributing to degraded water quality conditions. However, the multi-purpose detention features are located within areas that are already subject to flooding, such that the project is not expected to substantially increase delivery of contaminants to the streams beyond that which already occurs. Similarly, in-stream detention in the upper reaches of the watershed is not expected to substantially increase mobilization of any contaminants beyond the existing condition. As such, the proposed work is not expected to introduce or increase the presence of contaminants into the streams.

E. Aquatic Ecosystem and Organism Determinations

1. Effects on Plankton

During construction, an increase in turbidity and suspended solids in the areas associated with the proposed fill activities might have a short-term localized effect on phytoplankton productivity. It is expected that any potential impacts would be temporary, such that the plankton populations would recover quickly following construction.

2. Effects on Benthos

Placement of fill material would cover and smother benthic communities located within the footprint of each measure. In-stream excavation activities (e.g., at Waiomao debris and detention basin) also could result in mortality of macroinvertebrates. However, it is expected that the affected areas would be rapidly colonized, with little to no long-term effects on benthic organisms.

3. Effects on Nekton

Construction activities are expected to temporarily increase turbidity and suspended solids, as well as noise and overall level of habitat disturbance, which could affect the various species present in the streams, including the assemblage of native aquatic species. However, the work area for each measure would be dewatered prior to construction, such that fish and other free-moving organisms would be precluded from

the temporarily impacted areas. Once stream flows are returned to the work areas, construction-related impacts are expected to rapidly dissipate such that significant effects on nekton are not anticipated.

All of the measures have been designed to minimize the potential impacts to aquatic habitat. In particular, they have all been design to maintain passage for native species. For example, the in-stream detention basins incorporate a natural-bottom arch culvert that is expected to accommodate continued passage for native migratory species under all flow conditions. Passage through the culvert may be limited during peak storm flows when the detention basins are inundated, but these conditions would only occur on an infrequent basis and for short duration, such that impacts are expected to be minor. In addition, the mitigation measures focus on removal of existing passage barriers and improved access to high-quality upstream habitat, and would serve to mitigate for potential impacts associated with the flood management measures.

4. Effects on Aquatic Food Web

The proposed fill activities would temporarily disrupt aquatic biota during project construction, but are not expected to affect overall productivity of the stream ecosystem within the watershed.

5. Effects on Special Aquatic Sites

As previously described, the streams in the Ala Wai watershed occur along a natural gradient, with steep upper reaches, more meandering middle reaches, and lower reaches entering the estuarine environment. Sections of these streams include a range of riffle-pool complexes, to the extent that they exhibit habitat complexity with a combination of higher-gradient riffles of fast-moving water and lower-gradient pools of slow-moving water. The riffle-pool complexes range along a spectrum, generally based on the underlying gradient, where the habitat in the upper reaches tends toward steeper plunge pool features, while the middle reaches tend toward a lower-gradient combination of riffles and pools. However, to the extent that these areas display high complexity with a combination of substrates and velocities that are typical of the underlying gradient (thus providing high quality habitat for the native aquatic species), they have been identified as riffle and pool complexes for the purposes of this evaluation. This includes the habitat within the proposed in-stream debris and detention basis on Waihi, Waiakeakua, Makiki, Pukele and Waiomao Streams.[8] Discharge of fill in these reaches would displace and/or otherwise reduce habitat quality for native aquatic species.

6. Threatened and Endangered Species

As assessment of the federally listed threatened and endangered species that could potentially be affected by the project was conducted, in consultation with the U.S. Fish and Wildlife Service (USFWS). The results of this analysis indicate there are several listed species that the project may affect, but is not likely to adversely affect; these are summarized below. Additional detail, including a discussion of the species that are not expected to be affected by the project is provided in the Biological Assessment, which is included as an appendix to the Draft Feasibility Report/EIS.

- **Hawaiian hoary bat (*Lasiurus cinereus semotus*):** This species roosts in a wide variety of both native and non-native trees, typically at heights more than 20 feet off the ground. Little is known about the species' occurrence across the island of Oahu, including the Ala Wai watershed. However, based on the habitat preferences, it is possible that it could occur within the action area. In particular, all of the detention basins in the mid to upper portions of the watershed include forested habitat with tall trees that may be used for roosting. Although species occurrence within the measure locations is relatively unlikely, should they occur, Hawaiian hoary bats could be impacted by the project. To avoid and minimize the potential for impacts, vegetation clearing would be performed during times

[8] The reach of Manoa Stream adjacent to the Kanewai Field multi-purpose detention basin also exhibits riffle-pool complex characteristics; however, this measure would only affect a short stretch of stream bank, and is not expected to alter any characteristics of the stream bed that may contribute to riffle-pool complex habitat.

of the year when Hawaiian hoary bats are not expected to be breeding to avoid potential for harm or disruption to non-volant juvenile bats; specifically, trees greater than 15 feet in height would not be cleared between July 1 and August 1. In addition, all construction activities would be scheduled to occur during daytime hours, thus avoiding potential bat foraging activities, which typically occur in the evening hours.

- **Oahu elepaio (*Chasiempis sandwichensis ibidis*):** Oahu elepaio nest and forage in a variety of native and non-native forest types across a range of elevations, but are most common in riparian vegetation along streambeds and in mesic forest habitats with continuous tree canopy and dense understory. Based on recent surveys, approximately 12 birds (5 pairs and 2 single males) are known from upper portions of Palolo valley (well above the proposed Waiomao and Pukele debris and detention basin); the species is no longer believed to occur in other portions of the watershed (VanderWerf et al., 2013). Although species occurrence within the measure locations is unlikely, should they occur, Oahu elepaio could be impacted by the project. To minimize the potential for these impacts, trimming or clearing of vegetation in areas of suitable habitat would be restricted during the elepaio nesting season (January through June).
- **Hawaiian waterbirds species (including Hawaiian coot [*Fulica alai*], Hawaiian stilt [*Himantopus mexicanus knudseni*], and Hawaiian moorhen [*Gallinula chloropus sandvicensis*]):** Hawaiian waterbird species typically use a range of low-elevation ponds and wetlands. In general, the only suitable habitat that is expected to support these species within the project site are limited to areas within the Ala Wai golf course and possibly along Hausten Ditch and/or the upper edges of the Ala Wai Canal. These areas provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. In the unlikely event that Hawaiian waterbird species are present within the project site, it is expected that they would readily disperse to nearby areas with higher quality habitat in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise).

The Biological Assessment was transmitted to the USFWS with a request for concurrence with the USACE's determination that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, O'ahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen); the USACE has determined there would be no effect on all other federally listed/candidate species and/or designated critical habitat. The proposed project has been discussed with the resource agencies, and the Biological Assessment incorporates their input provided to date. Written concurrence with USACE's effects determination is pending, and will be included as part of the Final Feasibility Report/EIS.

7. Other Wildlife

Overall, the project is not expected to substantially affect the diversity or productivity of the project area, but the proposed fill activities would result in loss of habitat for terrestrial and aquatic species, as outlined in Section 5.7 of the Draft Feasibility Report/EIS. Consistent with USACE requirements, the loss of aquatic habitat was quantified using the Hawaii Stream Habitat Evaluation Procedure (HSHEP) and mitigation measures to offset those impacts have been incorporated into the Tentatively Selected Plan. The mitigation measures are briefly described in Table 1 of this evaluation, with additional detail provided in the Mitigation and Monitoring Plan (Appendix E) of the Draft Feasibility Report/EIS.

8. Actions Taken to Minimize Impacts

The flood risk management measures have been designed to minimize impacts to the aquatic environment, to the extent practicable, both by reducing the overall measure footprint and by incorporating specific features to maintain native species passage (i.e. natural-bottom arch culvert). As previously described, habitat improvements will be implemented as part of the proposed action to compensate for unavoidable

impacts to aquatic habitat, as described in Table 1 (and further described in the Mitigation and Monitoring Plan (Appendix E) of the Draft Feasibility Report/EIS).

F. Proposed Disposal Site Determinations

1. Mixing Zone Determination

Discharge of the proposed fill materials at each measure location would be conducted within an area subject to dewatering, and would involve minimal mixing zones. In general, the fill material used for the project would either consist of large components, or would be adequately stabilized, such that very little exposed material could be suspended in the water column.

2. Determination of Compliance with Applicable Water Quality Standards

Specific water quality criteria have been promulgated in the Hawaii Administrative Rules [HAR] §11-54, which, if met, are designed to allow water bodies to achieve designated beneficial uses. Water bodies that do not achieve the criteria are designated as "impaired" and are placed on the CWA §303(d) List of Impaired Waters. Based on the data presented in the 2014 State of Hawai'i Water Quality Monitoring and Assessment Report (DOH, 2014), several locations within the Ala Wai watershed are not in attainment of the designated water quality standards.

Locations with impairment listings in the watershed include the three major streams and the Ala Wai Canal. Manoa Stream is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, dieldrin, and chlordane. Palolo Stream is listed for trash, and Makiki Stream is listed for total nitrogen and total phosphorus. The Ala Wai Canal is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, enterococci, pathogens, metals, suspended solids, and organochlorine pesticides.

For each water body on the §303(d) list, a pollution budget or Total Maximum Daily Load (TMDL) must be developed to bring that water body into compliance with water quality standards. To date, the only TMDLs that have been developed are for nitrogen and phosphorus in the Ala Wai Canal. Development of the remaining TMDLs has been designated by DOH as a low priority (DOH, 2014).

As described throughout this evaluation, the project would involve discharge of a combination of compacted fill, rip-rap, concrete and base course (gravel), all of which will be adequately stabilized during construction. In general, the size and characteristics of these materials will not substantially contribute to increased turbidity or suspended particulate levels, or other constituents which impair water quality. Some degree of increased turbidity and increased concentration of suspended solids would likely occur during construction of project features. Proper dewatering techniques and other BMPs would be implemented to avoid and minimize the potential for erosion and sedimentation to the degree possible. As such, these are expected to be temporary impacts, and would be relatively minor and restricted to a localized area. No long-term adverse effects on water quality are expected, such that the project is expected to be in compliance with applicable water quality standards. Water quality certification will be obtained from the State of Hawaii Department of Health prior to project construction.

3. Potential Effects on Human Use Characteristics

The proposed project would provide flood protection throughout most of the Ala Wai watershed without significantly affecting human use characteristics such as municipal and private water supplies, and recreational or commercial fisheries.

The project would result in some impacts to recreation, as several of the measures are sited in designated recreational areas. Facilities that would be affected (at least in part) include Manoa District Park, Kanewai Park, Ala Wai Promenade, Ala Wai Community Park, Ala Wai Golf Course, and Ala Wai Canal. In addition, areas within the Honolulu Forest Reserve and Makiki Tantalus Recreation Area would be affected during construction. In general, the measures would displace some areas that are currently used for recreation. However, to the maximum extent possible, they have been designed with the smallest footprint possible, and to minimize impacts to recreational activities during non-flood conditions. For example, the Kanewai

and Hausten Ditch detention basins are designed to be multi-purpose facilities, such that the baseball/ softball fields may still be used during non-flood conditions. During a flood event, the measures would function to temporarily detain water and debris, thereby precluding recreational use; however, these sites are expected to have minimal recreational value under flood conditions. Additional detail on potential impacts to recreation is provided in Section 5.10 of the Draft Feasibility Report/EIS.

Other potential impacts on human use characteristics include those associated with aesthetics. In general, the measures would introduce a large-scale built element to the natural environment, which would impact views from and toward the site. In general, the detention features in the upper portions of the watershed will either be screened by dense vegetation or otherwise fit into the natural topography, such that they are not expected to be prominently visible from any readily accessible public locations. The proposed measures along the Ala Wai Canal, including the flood walls, would diminish views along and toward the Ala Wai Canal. In addition to these views being an important resource for the Waikiki District in general, they are also significant in terms of the Ala Wai Canal's listing on the National and State Register of Historic Places (as well as a component of the Kauhale O Hookipa Scenic Byway). In spite of the visual impact of the flood walls, the analysis conducted for this project determined that they are a necessary feature to provide adequate flood protection for Waikiki, such that the impacts are unavoidable. Efforts were made throughout the planning process, to minimize the impacts to the extent possible, particularly through reduction of the overall flood wall heights. Refinements to the measure design will be made during as part of the detailed design phase, and will consider opportunities to further reduce the height of the flood walls, as well as incorporate design details that may otherwise minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment. Additional detail on potential impacts to visual resources is provided in Section 5.11 of the Draft Feasibility Report/EIS.

G. Determination of Cumulative Effects on the Aquatic Ecosystem

Although there are multiple measures throughout the watershed, they are generally located in geographically distinct areas. BMPs would be implemented for each of the measures to minimize the potential for impacts to the aquatic environment, such that they are not expected to significantly contribute to cumulative impacts. A detailed discussion of cumulative impacts is provided in Section 5.19 of the Draft Feasibility Report/EIS.

H. Determination of Secondary Effects on the Aquatic Ecosystem

No secondary impacts to the aquatic environment are anticipated to occur. Additional detail in provided in the Draft Feasibility Report/EIS.

III. FINDING OF COMPLIANCE WITH RESTRICTIONS ON DISCHARGE

The proposed fill activities would comply with Section 404(b)(1) guidelines of the Clean Water Act, as amended. No significant adaptations of the guidelines were made for this evaluation. As discussed in the Draft Feasibility Report/EIS, other alternatives considered to reduce the flood risk within the Ala Wai Watershed include no action; a large-scale dam; debris and detention basins throughout the urbanized watershed; floodwalls alone; and non-structural solutions. However, it was determined that these alternatives were prohibitively more costly, were significantly less effective in reducing flood risk, had extensive impacts that would have been difficult to mitigate, and/or did not meet the overall project purpose of reducing flood risk throughout the watershed. Although the tentatively selected plan would involve work in areas that support riffle and pool complexes, this type of habitat occurs throughout the mid to upper reaches of the streams where peak flows are greatest. Detention of water along stream reaches without these special aquatic sites (such as in lower reaches of the watershed, as considered for Alternative 2A) is less effective at achieving the overall purpose of reducing flood risk. No other practicable alternative with less environmental impact has been identified, such that the tentatively selected plan has been identified as the least environmentally damaging practicable alternative. A detailed discussion of the potential effects of the project is presented in the Draft Feasibility Report/EIS.

The proposed fill activities would comply with all State water quality standards, Section 307 of the Clean Water Act, and the Endangered Species Act of 1973, as amended. The proposed fill activities would not have significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife and special aquatic sites. The life stages of aquatic life and other wildlife would not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability, and on recreational, and economic values would not occur. To avoid and minimize the potential for adverse impacts, the project areas would be properly dewatered and standard BMPs would be implemented. Habitat improvements would be implemented to mitigate for loss of aquatic habitat.

A public meeting will be held for the project as part of the public review process for the Draft Feasibility Report/EIS. This draft evaluation will be included as an attachment to the Draft Feasibility Report/EIS and relevant comments will be received as part of the public review process. Comments received at the public meeting and during the following comment period will be considered and this evaluation will be updated as needed.

On the basis of this evaluation, I have determined that the proposed action complies with the requirements of the 404(b)(1) guidelines for the discharge of fill material.

_____
Date

_____
Christopher W. Crary
Lieutenant Colonel, U.S. Army
District Engineer

References

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Appendix E4
Coastal Zone Management Federal Consistency Review

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

August 5, 2015

Civil and Public Works Branch
Programs and Project Management Division

SUBJECT: Ala Wai Canal Project Consistency with Coastal Zone Management Act

Mr. John Nakagawa
Federal Consistency Program
Hawaii State Office of Planning
Department of Business,
Economic Development & Tourism
P.O. Box 2359
Honolulu, Hawaii 96804

Dear Mr. Nakagawa:

We are requesting your concurrence that the Ala Wai Canal Project described below is consistent with the Coastal Zone Management Act (CZMA).

At the request of the State of Hawaii Department of Land and Natural Resources, the Honolulu District, U.S. Army Corps of Engineers (Corps), is conducting a feasibility planning study for the proposed Ala Wai Canal Project in Honolulu, Hawaii. The Ala Wai Watershed is located on the southeastern side of the island of Oahu and includes Makiki, Manoa, and Palolo streams, all of which drain into the Ala Wai Canal. Flooding associated with a 1-percent annual chance exceedance rainfall event would affect approximately 1,358 acres within the Ala Wai Watershed, including over 3,000 properties with an estimated $318M in structural damages alone (at 2013 price levels). As such, the purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding.

In response to identified flood-related problems and opportunities, potential flood risk management measures were identified and formulated into alternatives, which were evaluated through an iterative screening and evaluation process, resulting in tentative selection of a plan for implementation. The tentatively selected plan would reduce flood risks by improving the flood warning system, and constructing six in-stream debris and detention basins in the upper reaches of Makiki, Manoa and Palolo Streams, one standalone debris catchment feature, three multi-purpose detention areas in open spaces through the developed watershed, and concrete floodwalls ranging up to 4 feet high, along one or both sides of approximately 1.9 miles of the Ala Wai Canal (including three pump stations). Additional detail, including a more detailed description of the tentatively selected plan and associated maps are enclosed for your consideration. We

will also provide a copy of the Draft Integrated Feasibility Report and Environmental Impact Statement when it is published for public review, which is anticipated to occur in late August 2015.

Section 307(c)(1)(A) of the CZMA requires Federal actions that affect any land or water use or natural resources of the coastal zone will be conducted in a manner that is consistent to the maximum extent practicable with the enforceable policies of an approved state management program. As the proposed project is being undertaken by the Corps, it represents a Federal action that is understood to require compliance under the "Federal consistency" provision of the CZMA. Based on a review relative to the policies and objectives of Hawaii's Coastal Zone Management Program, we have determined that the proposed project is consistent to the maximum extent practicable. We are submitting the attached application (Enclosure 1) and assessment forms (Enclosure 2), with this request for your concurrence with our determination. Additional information on the project can be found in the enclosed Project Summary (Enclosure 3).

If you have any questions, please contact Mr. Derek Chow, Chief of our Civil and Public Works Branch, at (808) 835-4026 or e-mail derek.j.chow@usace.army.mil.

Sincerely,

for Anthony J. Paresa, P.E.
Deputy District Engineer for
Programs and Project Management

Enclosures

Hawaii CZM Program
Coastal Zone Management

HAWAII CZM PROGRAM
APPLICATION FOR CZM FEDERAL CONSISTENCY REVIEW

Project/Activity Title or Description: Ala Wai Canal Project

Location: Ala Wai Watershed

Island: Oahu

Tax Map Keys: 2-9-054:019, 029, 034, 004, 002; 2-9-055:009, 001; 2-5-020:005, 008, 001; 2-9-036:003; 2-9-029:053; 2-7-036:001; 2-9-043:002; 3-4-016:059; 3-4-034:001, 008, 009; 3-4-019:003 through 010, 052; 2-8-029:011, 004; 2-7-036:002; 2-9-067:008 through 012, 015 through 017

Applicant and Agent Information

1. U.S. Army Corps of Engineers
Name of Applicant
Building 230
Address
Fort Shafter,HI 96858
City & State Zip Code
835-4026
Daytime Phone Fax Number
derek.j.chow@usace.army.mil
E-mail Address

2.
Name of Agent
Address
City & State Zip Code
Daytime Phone Fax Number
E-mail Address

CZM Consistency Determination or Certification

x Check the type of application below and sign.

☒ I. Federal Agency Activity

CZM Consistency Determination: "The proposed activity will be undertaken in a manner consistent to the maximum extent practicable with the enforceable policies of the Hawaii Coastal Zone Management Program."

Signature _____ Date 8/5/15
(Applicant or responsible party)

☐ II. Federal Permit or License (Please sign below)

CZM Consistency Certification: "The proposed activity complies with the enforceable policies of Hawaii's approved management program and will be conducted in a manner consistent with such program."

Signature _____ Date _____
(Applicant or responsible party)

☐ III. Federal Grants and Assistance (Please sign below)

CZM Consistency Certification: "The proposed activity complies with the enforceable policies of Hawaii's approved management program and will be conducted in a manner consistent with such program."

Signature _____ Date _____
(Applicant or responsible party)

Send To: Office of Planning, P.O. Box 2359, Honolulu, Hawaii 96804

Print Form

HAWAII CZM PROGRAM
FEDERAL CONSISTENCY ASSESSMENT FORM

RECREATIONAL RESOURCES

Objective: Provide coastal recreational opportunities accessible to the public.

Policies:

1) Improve coordination and funding of coastal recreation planning and management.

2) Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:

   a) Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;

   b) Requiring replacement of coastal resources having significant recreational value, including but not limited to surfing sites and sandy beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;

   c) Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;

   d) Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;

   e) Encouraging expanded public recreational use of county, State, and Federally owned or controlled shoreline lands and waters having recreational value;

   f) Adopting water quality standards and regulating point and non-point sources of pollution to protect and where feasible, restore the recreational value of coastal waters;

   g) Developing new shoreline recreational opportunities, where appropriate, such as artificial reefs for surfing and fishing; and

   h) Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, County planning commissions; and crediting such dedication against the requirements of section 46-6.

RECREATIONAL RESOURCES (continued)

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Will the proposed action involve or be near a dedicated public right-of-way?	☐	☒
2. Does the project site abut the shoreline?	☐	☒
3. Is the project site near a State or County park?	☒	☐
4. Is the project site near a perennial stream?	☒	☐
5. Will the proposed action occur in or affect a surf site?	☐	☒
6. Will the proposed action occur in or affect a popular fishing area?	☐	☒
7. Will the proposed action occur in or affect a recreational or boating area?	☒	☐
8. Is the project site near a sandy beach?	☐	☒
9. Are there swimming or other recreational uses in the area?	☒	☐

Discussion:

See next page.

RECREATIONAL RESOURCES

Given the project objective of reducing the risk of riverine flooding in the Ala Wai Watershed, the flood risk management features would generally be located within or adjacent to a stream (or the Ala Wai Canal). Several of the features would also be located within or near areas used for recreational purposes. Recreational areas that could be affected (at least in part) include Honolulu Forest Reserve, Kanewai Community Park, Makiki Tantalus Recreation Area, Ala Wai Golf Course, Ala Wai Community Park, and Ala Wai Promenade. In addition, portions of Manoa District Park and Archie Baker Park would be used for staging and access. During construction, recreational activities would be restricted within the construction limits for each feature, thus limiting the range and/or accessibility of recreational opportunities temporarily. Construction activities at Honolulu Forest Reserve and Makiki Tantalus Recreation Area, as well staging at Manoa District Park and Archie Baker Park would involve a very small portion of each facility, and would not significantly impact recreational activities. Construction of the floodwalls would not preclude recreational use of the Ala Wai Canal, but certain access points may be temporarily unavailable during the construction phase.

Over the long-term, berms for the multi-purpose debris and detention basins would occupy a portion of Kanewai Community Park, Ala Wai Community Park and Ala Wai Golf Course. To the extent practicable, the flood risk management feature designs have the smallest footprint possible, and minimize impacts to recreational activities during non-flood conditions. For example, the berm for the Ala Wai Golf Course detention basin design would accommodate the existing golf cart path, such that the layout and use of the golf course would not be significantly affected over the long-term. The berms at Kanewai Community Park and Ala Wai Community Park would be located around the outer perimeter of the parks. The Waiakeakua and Makiki debris and detention basins, which are planned in the Honolulu Forest Reserve and Makiki Tantalus Recreation Area (respectively), would also displace potential recreational area (less than one acre each). These feature designs are not multi-purpose; however, no established recreational activities are known to occur there, and sufficient area surrounding the feature would still be available for use.

In the event of a flood, when the various debris and detention structures would detain floodwaters and capture debris/sediment, the area would be temporarily unavailable for recreation. In the case of a 1 percent ACE flood event, the projected inundation period would be less than 10 hours. Following the flood event, post-flood maintenance would remove accumulated debris/sediment; this could require several days. Potential recreational impacts associated with post-flood maintenance could occur at those sites with multi-purpose detention basins, where established recreational activities regularly occur (e.g., Kanewai Community Park, Ala Wai Community Park, and Ala Wai Golf Course). However, project analyses indicate that these sites already flood (thereby impacting recreational uses) under without-project conditions. Furthermore, project operation and maintenance (O&M) activities would be programmed as part of the standard flood responses activities to minimize post-flood maintenance response time.

Overall, these impacts are not expected to significantly decrease the long-term availability and accessibility to recreational opportunities in the coastal zone management area. Although some limited areas would be affected, the project would also provide flood risk management benefits throughout much of the watershed, including recreational areas such as Kapiolani Park. Additional detail is provided in Section 5.10 of the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as “Draft Feasibility Report/EIS.”

HISTORIC RESOURCES

Objective: Protect, preserve, and where desirable, restore those natural and man-made historic and pre-historic resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

Policies:

1) Identify and analyze significant archaeological resources;

2) Maximize information retention through preservation of remains and artifacts or salvage operations; and

3) Support State goals for protection, restoration, interpretation, and display of historic resources.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Is the project site within a historic/cultural district?	☐	☒
2. Is the project site listed on or nominated to the Hawaii or National register of historic places?	☒	☐
3. Does the project site include undeveloped land which has not been surveyed by an archaeologist?	☒	☐
4. Has a site survey revealed any information on historic or archaeological resources?	☒	☐
5. Is the project site within or near a Hawaiian fishpond or historic settlement area?	☒	☐

Discussion:

See next page.

HISTORIC RESOURCES

As detailed in the Draft Feasibility Report/EIS, the project development effort to date has included an assessment of archaeological resources and a historic structure inventory for portions of the project area. The results of these studies indicate that multiple historic properties are located within the project area and could be affected by the project, including the Ala Wai Canal which is listed on the Hawaii Register of Historic Places; a detailed listing of historic properties is provided in Section 5.8 of the Draft Feasibility Report/EIS.

Potential impacts to historic properties include modifications that may affect the integrity and/or characteristics of historic properties as a result of construction and operation of the project. As detailed in Section 5.8 of the Draft Feasibility Report/EIS, treatment recommendations have been identified for properties that are expected to be adversely affected, with the intention of identifying conditions that can be placed on the design and construction to mitigate impacts to the resource. Historic buildings, bridges, and walls affected by construction would undergo appropriate historic documentation, and design input will be solicited from the State Historic Preservation Officer (SHPO); input would be incorporated into the final design where feasible. Where possible, impacts to archaeological resources would be avoided. Where avoidance is not possible, data recovery would be performed. Where practicable, community assistance would be solicited for re-use of materials, and possible reconstruction of features of Native Hawaiian cultural significance that would be disturbed by project actions. During this feasibility phase, a number of variables remain unknown that may result in adverse effects through the future planning, design, and construction phases. A Programmatic Agreement is being developed to establish a process for resolving adverse effects, and expand upon the treatment recommendations. Coordination of this Programmatic Agreement is ongoing with the Advisory Council on Historic Preservation (ACHP), SHPO, and others as appropriate.

SCENIC AND OPEN SPACE RESOURCES

Objective: Protect, preserve and where desirable, restore or improve the quality of coastal scenic and open space resources.

Policies:

1) Identify valued scenic resources in the coastal zone management area;

2) Insure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;

3) Preserve, maintain and where desirable, improve and restore shoreline open space and scenic resources; and

4) Encourage those developments that are not coastal dependent to locate in inland areas.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Does the project site abut a scenic landmark?	☒	☐
2. Does the proposed action involve the construction of a multi-story structure or structures?	☒	☐
3. Is the project site adjacent to undeveloped parcels?	☒	☐
4. Does the proposed action involve the construction of structures visible between the nearest coastal roadway and the shoreline?	☐	☒
5. Will the proposed action involve construction in or on waters seaward of the shoreline? On or near a beach?	☐	☒

Discussion:

See next page.

SCENIC AND OPEN SPACE RESOURCES

The visual landscape of the proposed project area is generally comprised of natural stream corridor and forested habitat in the upper watershed, and open spaces within the heavily developed middle to lower watershed. The General Plan for the City and County of Honolulu has identified specific views that should be preserved within the watershed, including panoramic views from the Ala Wai Canal promenade and Ala Moana Beach Park toward the Koʻolau Mountains, as well as *mauka-makai* view corridors along major roadways. In addition to these viewplanes, other important scenic resources that have been identified include those in the Waikiki District, including the Ala Wai Canal itself, which is listed as a historic property on the Hawai`i Register of Historic Places. Two scenic byways have also been established in this area under the Hawai'i Scenic Byways Program: the Diamond Head Scenic Byway and the Waikīkī - Kauhale O Hookipa Scenic Byway. The Diamond Head Scenic Byway spans from Kapiʻolani Park to Diamond Head Crater. The Waikiki - Kauhale O Hookipa Scenic Byway includes the major thoroughfares through Waikiki, including Ala Wai Boulevard.

Construction of the debris and detention basins would introduce built elements to the natural environment; however, these features have been sited and designed to blend with the natural characteristics of each site to the extent possible. None of the features are expected to substantially diminish important environmental or landscape views from readily accessible viewing locations, nor are they expected to affect significant view corridors, including those identified in the General Plan.

As planned, the floodwalls along the Ala Wai Canal would be approximately 4 feet high (on average), extending from Kapahulu Avenue to Ala Moana Blvd on the *makai* side, and from the confluence with the Mānoa Pālolo Drainage Canal to Ala Moana Blvd on the *mauka* side. The floodwalls would also include a several pump stations (which could be several stories tall): (1) at the Kapahulu Avenue end of the Canal, (2) on the Ala Wai Golf Course near the Kapahulu storm drain, and (3) at Ala Wai Community Park, near the *makai* end of University Avenue. Neither the floodwalls nor the associated pump stations are expected to substantially obstruct broad landscape views (including those of the Koʻolau Mountains), but could diminish localized views, including those along the Ala Wai Canal. Specifically, the floodwalls are expected to partially obstruct views of the Canal from cars along Ala Wai Boulevard and from pedestrians along both sides of Canal, and will also partially obstruct views from within the Canal (e.g., paddlers and others using the Canal for recreation). In addition to these views being an important resource for the Waikiki District in general, they are also significant in terms of the Ala Wai Canal as a historic property on the Hawai`i Register of Historic Places as well as the Kauhale O Hookipa Scenic Byway (which includes Ala Wai Boulevard). However, the feasibility analysis determined that the floodwalls (and associated pump stations) would be a necessary feature to provide adequate flood protection for this area. Efforts throughout the planning process would minimize the impacts to the extent possible, particularly as related to the overall structure heights. Further refinements would be made during the design phases, and would further evaluate opportunities to reduce the dimensions of the floodwalls and pump stations, as well as incorporate design details to further minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment.

COASTAL ECOSYSTEMS

Objective: Protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems.

Policies:

1) Improve the technical basis for natural resources management;
2) Preserve valuable coastal ecosystems of significant biological or economic importance;
3) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land water uses, recognizing competing water needs; and
4) Promote water quantity and quality planning and management practices, which reflect the tolerance of fresh water and marine ecosystems and prohibit land and water uses, which violate State, water quality standards.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Does the proposed action involve dredge or fill activities?	☒	☐
2. Is the project site within the Shoreline Setback Area (20 to 40 feet inland of the shoreline)?	☐	☒
3. Will the proposed action require some form of effluent discharge into a body of water?	☐	☒
4. Will the proposed action require earthwork beyond clearing and grubbing?	☒	☐
5. Will the proposed action include the construction of special waste treatment facilities, such as injection wells, discharge pipes, or cesspools?	☐	☒
6. Is an intermittent or perennial stream located on or near the project site?	☒	☐
7. Does the project site provide habitat for endangered species of plants, birds, or mammals?	☒	☐
8. Is any such habitat located nearby?	☒	☐
9. Is there a wetland on the project site?	☒	☐
10. Is the project site situated in or abutting a Natural Area Reserve?	☐	☒
11. Is the project site situated in or abutting a Marine Life Conservation District?	☐	☒
12. Is the project site situated in or abutting an estuary?	☒	☐

Discussion:

See next page.

COASTAL ECOSYSTEMS

Given the project objective to reduce riverine flooding, all of the proposed flood risk management features would involve work within or adjacent to a stream or the Ala Wai Canal. The only feature that does not involve work directly within a waterway is the Ala Wai Canal floodwalls (and associated pump stations), as the walls would be set back from the existing edge of the Canal. None of the remaining features will permanently obstruct or change the course of a waterway; however, they would involve placement of fill material within the stream channels. Specifically, construction of the features would require placement of materials including compacted fill, concrete, grouted rip-rap, as well as steel poles for the debris catchment feature. Construction of the Waiomao debris and detention basin would also involve excavation to provide adequate detention capacity. In addition, most of the features would require periodic removal of sediment/debris from the debris catchment features. These activities would impact aquatic habitat, which could indirectly affect native aquatic species. Small pockets of wetland habitat occur along the streams and Canals in a few locations (e.g., along Hausten Ditch), but these are generally within the limits of the defined channel.

Impacts to aquatic habitat would primarily be expected to occur as a result of the in-stream detention basins, as these would involve the greatest extent of in-stream work. The debris catchment structures and multi-purpose detention basins would also displace a small amount of stream habitat. The design process incorporated efforts to avoid and minimize potential impacts to the extent practicable. Project designs reduce the project footprint to the extent practicable, and include design features to minimize habitat impacts and maintain passage for native species (e.g., use of natural-bottom arch culverts). However, even with avoidance and minimization efforts, the proposed project would still result in some impacts to aquatic habitat. As such, the project incorporates compensatory mitigation to offset the anticipated loss of aquatic habitat function. Specifically, the compensatory mitigation measures would improve passage for native aquatic species at two adjacent in-stream barriers in Manoa Stream, as described in Section 5.7.2.2 of the Draft Feasibility Report/EIS.

In general, the terrestrial habitat within the project area is comprised of non-native species, many of which are considered invasive. Federally listed threatened or endangered species that have the potential to occur within the measure locations are Hawaiian hoary bat, Oʻahu elepaio, Hawaiian stilt, Hawaiian coot, Hawaiian moorhen, and the blackline Hawaiian damselfly. Pursuant to Section 7 of the ESA, the USACE has been informally consulting with the USFWS and NMFS regarding potential impacts to threatened and endangered species. Based on this ongoing consultation, the USACE evaluated the potential impacts of the proposed project and has determined that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, Oʻahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen). Although previously thought to be restricted to higher elevations of the watershed (and therefore not having the potential to occur within the project area), on July 28, 2015, the USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin. Although the detailed species occurrence information has not yet been provided by USFWS, based on the verbal description provided to date, the proposed action is likely to adversely affect the blackline Hawaiian damselfly and USACE intends to initiate formal Section 7 consultation upon receipt of the species information.

Additional detail regarding potential impacts to these resources is provided in Section 5.7 of the Draft Feasibility Report/EIS.

ECONOMIC USES

Objective: Provide public or private facilities and improvements important to the State's economy in suitable locations.

Policies:

1) Concentrate in appropriate areas the location of coastal dependent development necessary to the State's economy;

2) Insure that coastal dependent development such as harbors and ports, visitor industry facilities, and energy generating facilities are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and

3) Direct the location and expansion of coastal dependent developments to areas presently designated and used for such development and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:

   a) Utilization of presently designated locations is not feasible;

   b) Adverse environmental effects are minimized; and

   c) Important to the State's economy.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Does the project involve a harbor or port?	☐	☒
2. Is the project site within a designated tourist destination area?	☒	☐
3. Does the project site include agricultural lands or lands designated for such use?	☐	☒
4. Does the proposed activity relate to commercial fishing or seafood production?	☐	☒
5. Does the proposed activity related to energy production?	☐	☒
6. Does the proposed activity relate to seabed mining?	☐	☒

Discussion:

Several of the flood risk management features would be located within the Waikiki District, a prime tourist destination that attracts more than 79,000 visitors per day. In combination with the other flood risk management features included in the proposed project, these would function to reduce flood risk within the watershed (including the Waikiki District), thus providing significant economic benefits. A detailed discussion of the economic benefits is provided in Section 8.2 of the Draft Feasibility Report/EIS.

COASTAL HAZARDS

Objective: Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, and subsidence.

Policies:

1) Develop and communicate adequate information on storm wave, tsunami, flood erosion, and subsidence hazard;

2) Control development in areas subject to storm wave, tsunami, flood, erosion, and subsidence hazard;

3) Ensure that developments comply with requirements of the Federal Flood Insurance Program; and

4) Prevent coastal flooding from inland projects.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Is the project site on or abutting a sandy beach?	☐	☒
2. Is the project site within a potential tsunami inundation area as depicted on the National Flood Insurance Program flood hazard map?	☐	☒
3. Is the project site within a potential flood inundation area according to a flood hazard map?	☒	☐
4. Is the project site within a potential subsidence hazard areas according to a subsidence hazard map?	☐	☒
5. Has the project site or nearby shoreline areas experienced shoreline erosion?	☐	☒

Discussion:

The objective of the proposed project is to reduce existing riverine flood risk; as such, the proposed flood risk features are generally located within potential flood inundation areas, as shown on the current Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) flood hazard maps for Hawaii. These features would function to detain floodwaters and/or improve conveyance, so as to reduce the overall risk of flooding within the watershed. In addition, the project would include improvements to the existing flood warning system, which would help to increase life safety during flood events. Additional detail on the potential flood risk reduction is provided in Section 8.3 of the Draft Feasibility Report/EIS.

MANAGING DEVELOPMENT

Objective: Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

Policies:

1) Effectively utilize and implement existing law to the maximum extent possible in managing present and future coastal zone development;

2) Facilitate timely processing of application for development permits and resolve overlapping or conflicting permit requirements; and

3) Communicate the potential short- and long-term impacts of proposed significant coastal developments early in their life cycle and in terms understandable to the general public to facilitate public participation in the planning and review process.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Will the proposed activity require more than two (2) permits or approval? (Provide the status of each.)	☒	☐
2. Does the proposed activity conform with the State and County land use designations for the site?	☒	☐
3. Has or will the public be notified of the proposed activity?	☒	☐
4. Has a draft or final environmental impact statement or an environmental assessment been prepared?	☒	☐

Discussion:

The potential impacts of the proposed project are detailed in the Draft Feasibility Report/EIS (Section 5), which is being published for public review. A discussion of the stakeholder involved efforts to date and a detailed list of the permits and approvals that will be required for the proposed project are contained in Sections 6 and 7 of the Draft Feasibility Report/EIS, respectively.

PUBLIC PARTICIPATION

Objective: Stimulate public awareness, education, and participation in coastal management.

Policies:

1) Maintain a public advisory body to identify coastal management problems and to provide policy advice and assistance to the coastal zone management program;

2) Disseminate information on coastal management issues by means of educational materials, published reports, staff contact, and public workshops for persons and organizations concerned with coastal-related issues, developments, and government activities; and

3) Organize workshops, policy dialogues, and site-specific mediations to respond to coastal issues and conflicts.

Discussion. Please provide information about the proposal relevant to the Objective and Policies No. 2 and No. 3 above:

The planning process for the proposed project has included an extensive public involvement effort, as needed to disseminate information and obtain stakeholder input relative to the potential impacts and other aspects of the proposed project. A discussion of the public involvement efforts that have been conducted to date is contained in Section 6 of the Draft Feasibility Report/EIS.

BEACH PROTECTION

Objective: Protect beaches for public use and recreation.

Policies:

1) Locate new structures inland from the shoreline setback to conserve open space and to minimize loss of improvements due to erosion;

2) Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and

3) Minimize the construction of public erosion-protection structures seaward of the shoreline.

Discussion. Please provide information about the proposal relevant to the Objective and Policies above:

The proposed project would not affect any shoreline or beach areas.

MARINE RESOURCES

Objective: Implement the State's ocean resources management plan.

Policies:

1) Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;

2) Assure that the use and development of marine and coastal resources are ecologically and environmentally sound and economically beneficial;

3) Coordinate the management of marine and coastal resources and activities management to improve effectiveness and efficiency;

4) Assert and articulate the interests of the State as a partner with federal agencies in the sound management of ocean resources within the United States exclusive economic zone;

5) Promote research, study, and understanding of ocean processes, marine life, and other ocean resources in order to acquire and inventory information necessary to understand how ocean development activities relate to and impact upon ocean and coastal resources; and

6) Encourage research and development of new, innovative technologies for exploring, using, or protecting marine and coastal resources.

Discussion. Please provide information about the proposal relevant to the Objective and Policies above:

The proposed project would not affect any marine resources. As listed in Section 6 of the Draft Feasibility Report/EIS, coordination with NOAA and other resource agencies has been conducted as part of the planning process.

Print Form

PROJECT SUMMARY

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the Honolulu District, U.S. Army Corps of Engineers (USACE) is conducting a feasibility planning study for the proposed Ala Wai Canal Project in Honolulu, Hawaii. The study is authorized under Section 209 of the Flood Control Act of 1962 (Public Law 87-874), which is a general authority that authorizes surveys in harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

The Ala Wai Watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (12,064 acres) and extends from the ridge of the Ko`olau Mountains to the nearshore waters of Mamala Bay. It includes Makiki, Manoa, and Palolo streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands (see Figure 1). This construction and subsequent draining allowed the development of the Waikiki district.

Purpose and Need

The purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding. A high risk of flooding exists within the Ala Wai watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[1] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85M in damages (at 2004 price levels) (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within the floodplain, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the

[1] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318M in structural damages alone (2013 price levels), not accounting for loss in business income or other similar economic losses.

Project Description

In response to the flood-related problems and opportunities identified for the Ala Wai watershed, a variety of structural and non-structural flood risk management measures were considered, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, and flood risk reduction. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the tentatively selected plan. The measures included in this plan are based on the following concepts:

- **Detention basin**: The detention basins are comprised of an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.
    - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin (via a spillway along the stream bank), then would drain back into the stream.
- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, the TSP also includes a stand-alone debris catchment structure, which would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. This

structure would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.

- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height (with an average height of 4 feet), and would be constructed with a minimal set back distance from the existing canal walls. Local drainage patterns would be maintained to the extent possible, with flapgates/slidegates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). The only non-structural measure that has been identified as feasible for this project is improvement to the existing flood warning system.

Consistent with the requirements of the Clean Water Act and USACE planning regulations, and after consideration of avoidance and minimization measures, it was determined that compensatory mitigation would be required for unavoidable impacts to aquatic habitat resulting from implementation of the flood risk management measures. Based on a detailed mitigation development process (which included the use of a habitat-based ecosystem output model to quantify habitat loss), the mitigation measures incorporated into the tentatively selected plan include removal of two existing passage barriers for native aquatic species in Manoa Stream. The flood risk management features and compensatory mitigation measures included in the tentatively selected plan are summarized in Table 1. The location of each measure is shown in Figures 2 and 3; detailed design drawings of the measures will be included in the Draft Feasibility Report with integrated Environmental Impact Statement, which will be available for public review after August 23, 2015.

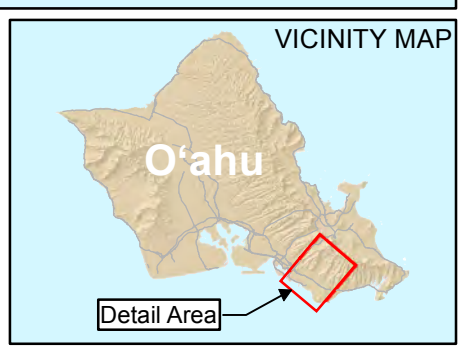
TABLE 1
Description of the Tentatively Selected Plan

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements
Waihi Debris and Detention Basin	Earthen dam, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Waiakeakua Debris and Detention Basin	Earthen dam, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area.
Manoa In-stream Debris Catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Kanewai Field Multi-Purpose Detention Basin	Earthen berm, approximately 7' high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Manoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.
Waiomao Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip rap on upstream and downstream side debris catchment feature located on upstream end of culvert. Excavation of approx. 2,015 cubic yards to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam and excavation area) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Pukele Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements
Makiki Debris and Detention Basin	Earthen dam, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 5 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area. Periodically inspect drainage pipes and gates, and remove any impediments to movement. Paint and/or grease metal parts, as needed.
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (4.3' high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm and floodwalls) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for recreational use during non-flood conditions. Periodically inspect slide gates and actuators and remove any impediments to movement. Paint and/or grease metal parts, as needed.
Ala Wai Golf Course Multi-Purpose Detention Basin	Earthen berm, up to approximately 7' high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Manoa Palolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a golf course (with no woody vegetation in sediment basin) for recreational use during non-flood conditions. Periodically inspect floodgate and remove any impediments to movement. Paint and/or grease metal parts, as needed. Inspect, test, and maintain pump system annually. Paint and/or grease metal parts, as needed.
Floodwarning System	Installation of 3 real-time rain gages (Manoa, Makiki and Palolo Streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai watershed	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection.
Falls 7 and 8 (Mitigation Measures)	Installation of grouted stones to eliminate passage barrier by providing a suitable surface for migration of native species at 2 in-stream structures on Manoa Stream	Periodically inspect in-stream structure for potential erosion or undercutting; reinforce as needed.

LEGEND

- Stream
- Major Road
- Watershed Boundary



0 0.5 1 Mile

Projection: State Plane Hawaiʻi Zone 3 feet NAD83 HARN

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 1
Overview of the
Ala Wai Watershed
Ala Wai Canal Project
Oʻahu, Hawaiʻi

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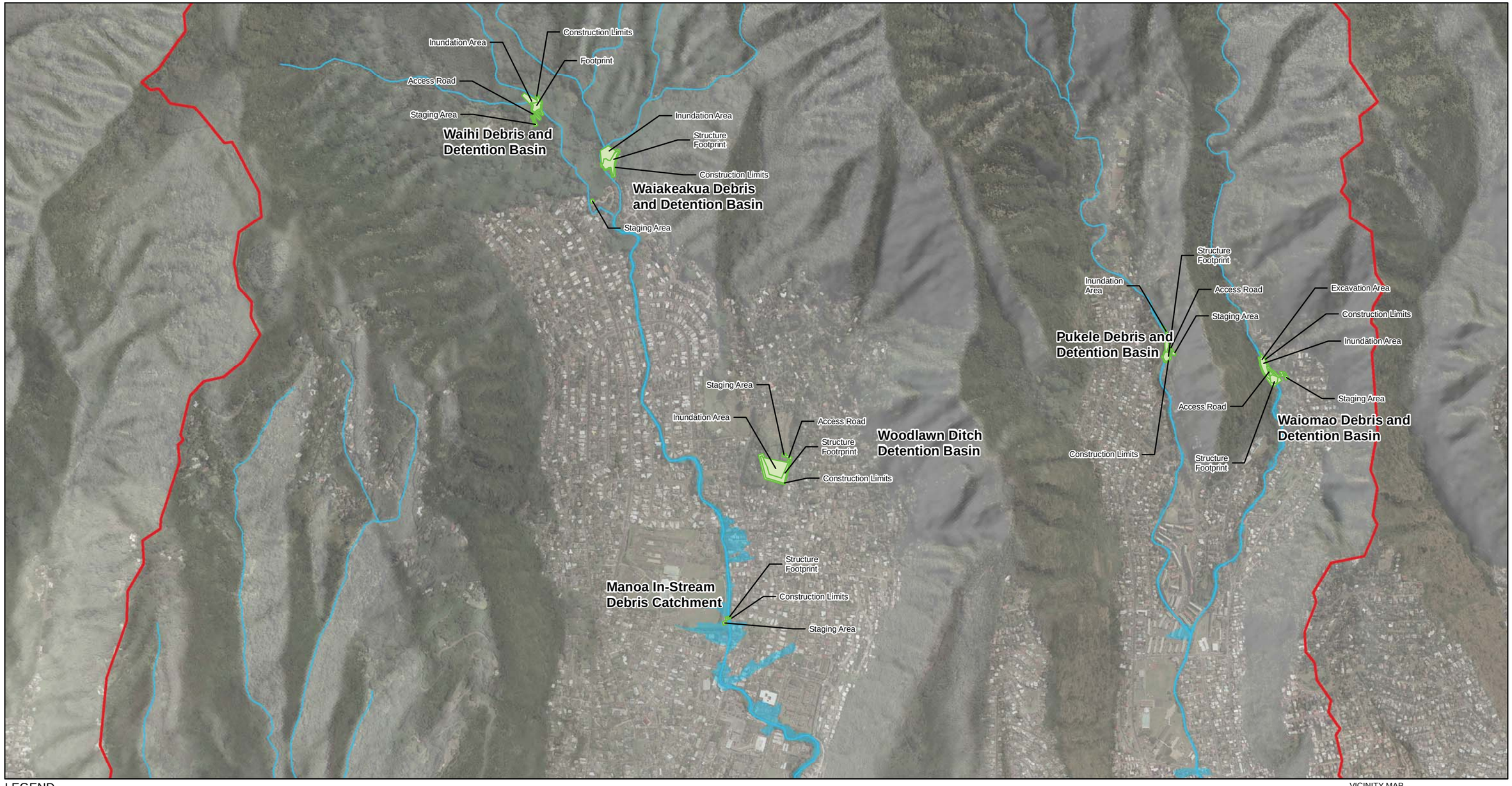
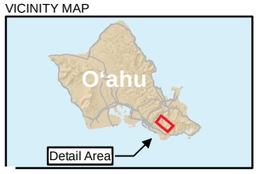


LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)
- Flood Risk Management Measure

VICINITY MAP



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Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 2a
Tentatively Selected Plan
(Alternative 3A-2.2) - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)
- Flood Risk Management Measure

VICINITY MAP

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

FIGURE 2b
Tentatively Selected Plan
(Alternative 3A-2.2) - Lower Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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LEGEND

Stream

Compensatory Mitigation Measure

N

0 100 200

Feet

VICINITY MAP

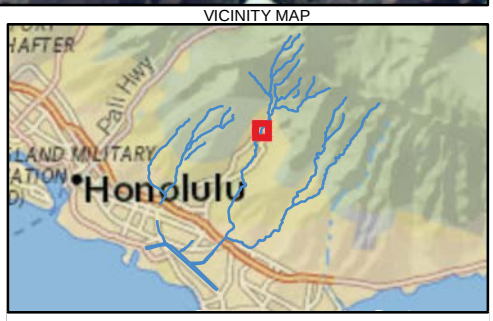

FIGURE 3

Compensatory Mitigation Measures

Ala Wai Canal Project

O'ahu, Hawai'i

DISCLAIMER: This map was created by USACE using the best available data at the time (July 2015). It may or may not accurately reflect existing conditions.

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Appendix E5
Endangered Species Act Section 7 Consultation Documentation

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

In Reply Refer To:
12200-2008-SL-0187

MAY 16 2008

RECEIVED 5/19/08

Mr. Anthony Paresa, P.E.
Deputy District Engineer
Programs and Project Management
Department of the Army
U.S. Army Engineer District, Honolulu
Fort Shafter, Hawaii 96858-5440

Subject: Species List and Critical Habitat for Ala Wai Canal Project Watershed Plan, Island of Oahu

Dear Mr. Paresa:

Thank you for your letter dated April 9, 2008, received on April 18, 2008, requesting information regarding threatened and endangered species and designated critical habitat that may occur within the proposed project location. The proposed project is the development of the Ala Wai Canal Project (AWCP) Watershed Plan with the U.S. Army Corps of Engineers, Honolulu District, in partnership with the State of Hawaii, Department of Land and Natural Resources. The AWCP encompasses the watersheds of Makiki, Manoa, and Palolo streams on the Island of Oahu.

We have reviewed the information you provided and pertinent information in our files, including data compiled by the Hawaii Biodiversity and Mapping Program and the Hawaii GAP. Enclosure 1 lists the federally listed species and Enclosure 2 identifies federally designated critical habitat known to occur within the proposed project area.

We hope this information assists you in your planning effort and aides in conservation of listed species. If you have questions, please contact Aaron Nadig, Fish and Wildlife Biologist (phone: 808-792-9466; fax: 808-792-9581).

Sincerely,

for Patrick Leonard
Field Supervisor

Enclosures

TAKE PRIDE® IN AMERICA

Enclosure 1. Species List for Ala Wai Canal Project.

Common Name	Scientific Name	Status
Mammals		
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Endangered
Hawaiian monk seal	*Monachus schauinslandi*	Endangered
Birds		
Oahu elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Hawaiian coot	*Fulica alai*	Endangered
Hawaiian stilt	*Himantopus mexicanus knudseni*	Endangered
Hawaiian duck	*Anas wyvilliana*	Endangered
Hawaiian moorhen	*Gallinula chloropus sandvicensis*	Endangered
Invertebrates		
Oahu tree snail	*Achatinella* sp.	Endangered
Plants		
Haha	*Cyanea acuminate*	Endangered
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea koolauensis*	Endangered
No Common Name	*Diellia erecta*	Endangered
Nanu	*Gardenia mannii*	Endangered
No Common Name	*Gouania meyenii*	Endangered
Wawae iole	*Huperzia nutans*	Endangered
No Common Name	*Lobelia oahuensis*	Endangered
Ihi ihi	*Marsilea villosa*	Endangered
No Common Name	*Pteris lidgatei*	Endangered
No Common Name	*Schiedea nuttallii*	Endangered
No Common Name	*Spermolepis hawaiiensis*	Endangered

Enclosure 2. Critical Habitat for Ala Wai Canal Project.

Common Name	**Scientific Name**	**Status**
Birds		
Oahu elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Plants		
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea humboldtiana*	Endangered
No Common Name	*Delissea subcordata*	Endangered
No Common Name	*Gouania meyenii*	Endangered
No Common Name	*Lobelia monostachya*	Endangered

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, Hawaii 96814-4700
(808) 944-2200 • Fax (808) 973-2941

April 25, 2008

RECEIVED 4-28-08

Mr. Anthony Paresa, P.E.
Deputy District Engineer
Department of the Army
U.S. Army Engineer District, Honolulu
Ft. Shafter, Hawaii 96858-5440

Dear Mr. Paresa:

This letter responds to your April 9, 2008, letter received by our office on April 21, 2008, concerning the Ala Wai Canal Project (AWCP) Watershed Plan, located Honolulu County on the Island of Oahu. Your letter requested information on listed species and their critical habitats that may occur within the project area. Under our statutory authorities under the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. §1531 *et seq.*), the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) Pacific Islands Regional Office Protected Resources Division provides the following ESA-listed marine protected species information.

As described in your letter, the purpose of the project is to identify and implement measures to address overall watershed health including flood risk management and ecosystem restoration. Based on the map that you provided, the proposed action occurs inland, but is closely linked to the nearshore waters of Malama Bay through down stream transport of potential effects from the proposed project area. Therefore, the ESA-listed marine species that are reasonably likely to occur within the action area are green and hawksbill sea turtles, as well as the Hawaiian monk seals. A complete list of ESA-listed species under NMFS's jurisdiction in the Hawaiian Archipelago is enclosed for your review. No additional marine species are proposed or are candidates for listing under the ESA at this time, and no critical habitat has been designated or proposed for any marine protected species around the Island of Oahu, Hawaii.

Thank you for working with NMFS to protect our nation's living marine resources. Should you have any other questions regarding this project or the consultation process, please contact Donald Hubner on my staff at (808) 944-2233, or at the e-mail address Donald.Hubner@noaa.gov. Please refer to consultation #: I-PI-08-677-CY.

Sincerely,

Chris E. Yates
Assistant Regional Administrator
For Protected Resources

MARINE PROTECTED SPECIES of the HAWAIIAN ISLANDS

National Marine Fisheries Service, Pacific Islands Regional Office

MARINE MAMMALS

All marine mammals are protected under the Marine Mammal Protection Act. Those identified under the ESA Listing are also protected under the Endangered Species Act.

Common Name	Scientific Name	ESA Listing
Blue Whale	*Balaenoptera musculus*	Endangered
Blainville's Beaked Whale	*Mesoplodon densirostris*	
Bryde's Whale	*Balaenoptera edeni*	
Cuvier's Beaked Whale	*Ziphius cavirostris*	
Dwarf Sperm Whale	*Kogia simus*	
False Killer Whale	*Pseudorca crassidens*	
Fin Whale	*Balaenoptera physalus*	Endangered
Humpback Whale	*Megaptera novaeangliae*	Endangered
Killer Whale	*Orcinus orca*	
Longman's Beaked Whale	*Indopacetus pacificus*	
Melon-headed Whale	*Peponocephala electra*	
Minke Whale	*Balaenoptera acutorostrata*	
North Pacific Right Whale	*Eubalaena japonica*	Endangered
Pygmy Killer Whale	*Feresa attenuata*	
Pygmy Sperm Whale	*Kogia breviceps*	
Sei Whale	*Balaenoptera borealis*	Endangered
Short-finned Pilot Whale	*Globicephala macrorhynchus*	
Sperm Whale	*Physeter macrocephalus*	Endangered
Bottlenose Dolphin	*Tursiops truncatus*	
Common Dolphin	*Delphinus delphis*	
Fraser's Dolphin	*Lagenodelphis hosei*	
Pantropical Spotted Dolphin	*Stenella attenuata*	
Risso's Dolphin	*Grampus griseus*	
Rough-toothed Dolphin	*Steno bredanensis*	
Spinner Dolphin	*Stenella longirostris*	
Striped Dolphin	*Stenella coeruleoalba*	
Hawaiian Monk Seal	*Monachus schauinslandi*	Endangered
Northern Elephant Seal	*Mirounga angustirostris*	

SEA TURTLES

All sea turtles are protected under the Endangered Species Act.

Common Name	Scientific Name	ESA Listing
Green Turtle	*Chelonia mydas*	Threatened
Hawksbill Turtle	*Eretmochelys imbricata*	Endangered
Loggerhead Turtle	*Caretta caretta*	Threatened
Leatherback Turtle	*Dermochelys coriacea*	Endangered
Olive Ridley Turtle	*Lepidochelys olivacea*	Threatened

Last updated April 2008

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

August 5, 2015

Civil and Public Works Branch
Programs and Project Management

Ms. Kristi Young
Deputy Field Supervisor
Programmatic Division
U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Blvd, Room 3-122
Honolulu, Hawaii 96850-0001

Dear Ms. Young:

For purposes of continuing informal consultation under Section 7 of the Endangered Species Act, the Honolulu District, U.S. Army Corps of Engineers (Corps), transmits the enclosed draft Biological Assessment (BA) for the Ala Wai Canal Project, Oahu, Hawaii. The State of Hawaii Department of Land and Natural Resources (DLNR) is the non-Federal sponsor of this single purpose flood risk management project.

Based on current available documentation, the attached draft BA indicates that the project may affect, but would not likely adversely affect any Federally listed species. However, during a July 29, 2015, Fish and Wildlife Coordination Act meeting, a representative of the U.S. Fish and Wildlife Service (USFWS) verbally informed my staff that USFWS field investigations discovered a population of endangered blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) in the vicinity of a proposed project feature site.

The endangered blackline Hawaiian damselfly is endemic to the island of Oahu, found historically in stream sites at higher altitudes. We anticipate that upon receipt of the detailed species occurrence information from the USFWS, we may determine that the proposed action is likely to adversely affect the blackline Hawaiian damselfly. If that occurs, we would revise the enclosed draft BA accordingly and request initiation of formal consultation between our agencies on this project. Through consultation with the USFWS, we expect to identify appropriate actions to avoid and minimize any potential impacts to this species.

We greatly appreciate your review of our preliminary impact assessment documents, helpful comments, discussion of potential impacts, and policy review provided by your staff, especially Mr. Kevin Foster, Ms. Jiny Kim, and Mr. Dan Polhemus. Their efforts

aided our task preparing this Biological Assessment. We want to continue our cooperation through completion of this work.

If you have questions, please contact Mr. Derek Chow, Chief of my Civil and Public Works Branch, at (808) 835-4026 or e-mail derek.j.chow@usace.army.mil.

Sincerely,

for Anthony J. Paresa, P.E.
Deputy District Engineer for
Programs and Project Management

Enclosure

CC:
Ms. Jiny Kim, USFWS
Mr. Aaron Nadig, USFWS
Mr. Patrick Opay, NOAA Fisheries
Mr. David Nichols, NOAA Fisheries

DRAFT

Biological Assessment of Threatened and Endangered Species for the Ala Wai Canal Project

Under the Endangered Species Act of 1973, As Amended

Submitted by:

U.S. Army Corps of Engineers Honolulu District
Bldg. 230, CEPOH-PP-C
Fort Shafter, HI 96858

Submitted to:

U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, HI 96850

July 2015

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1.0 INTRODUCTION

At the request of the State of Hawai`i Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project[1] (hereafter referred to as "the project"). The purpose of the project is to reduce flood hazards within the watershed, which is comprised of approximately 19 square miles (12,064 acres) on the southeastern side of the island of Oahu in the State of Hawai`i (Figure 1).

In accordance with Section 7 of the Endangered Species Act (ESA) (Title 16, United States Code [USC], Section 1536[c]) and in consultation with the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Services (NMFS), this Biological Assessment (BA) defines and evaluates the potential effects of the proposed project on ESA-listed species and their designated critical habitats.

1.1 Project Authority

The project is authorized under Section 209 of the Flood Control Act of 1962. Section 209 is a general authority that authorizes surveys in harbors and rivers in Hawai`i "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

1.2 Project Purpose and Need

The purpose of the project is to reduce flood hazards within the watershed. A high risk of flooding exists within the Ala Wai watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[2] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85 million in damages (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within this area, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $723 million in structural damages alone (2013 price levels).

1.3 Project History

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and

---

[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

[2] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act of 1974) to determine the potential flood risk to the Waikiki area, in response to a request by the Land Division of DLNR. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several mitigative measures and conceptual alternatives that could potentially minimize flood damages to Waikiki and surrounding area. The results of this technical study were used to establish that the USACE could be involved in the investigation of flood damage reduction in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The FCSA was executed between USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and an EIS scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Manoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study, such that the project could be expanded to include the upstream portions of the Ala Wai watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received federal funds to identify specific actions to address flooding in Manoa Valley. The Manoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems.[3] However, because of insufficient federal funding to complete the project, the Manoa Watershed Project was terminated before implementation.

Information developed through the Manoa Watershed Project was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second EIS scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Manoa under the Manoa Watershed Project.

In October 2012, a charette was held to re-scope the project as part of the USACE Civil Works Planning Modernization process.[4] The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division and Headquarters staff, with the non-federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the array of alternatives, and a framework for identification of the tentatively selected plan. Based on the project review at the charette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify ecosystem restoration as an objective. However, the ecosystem-related information previously identified as part of the study is being incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

[3] This work was conducted by the USACE on behalf of NRCS via a Support Agreement in compliance with a Memorandum of Agreement between USACE and USDA, pursuant to the Economy in Government Act (31 USC S. 1535.).

[4] The charrette was held on October 16-19, 2012 with the purpose of reaching consensus on the actions needed to complete the project on budget and schedule, including a clear path for identification of the TSP (USACE, 2012). Participants included the project delivery team, non-federal sponsors, USACE Division and Headquarters staff, and cooperating agency representatives.

1.4 Consultation History

The ESA is administered by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), and establishes protection and conservation of threatened and endangered species and the ecosystems upon which they depend. Section 7 of the ESA requires that all federal agencies consult with the USFWS before initiating any action that could affect a listed species. Section 7 states that any project authorized, funded, or conducted by any federal agency should not "…jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined to be critical."

In compliance with ESA consultation requirements, USACE requested information from USFWS regarding threated and endangered species and designated critical habitat within the overall Ala Wai watershed in April 2008. The USFWS responded in May 2008, and provided a list of federal listed species and designed critical habitat that could occur within the watershed (see Attachment 1). Follow-up meetings were held with agency staff on October 14, 2014; January 23, 2015; April 14, 2015; May 26, 2015; June 5, 2015; and June 29, 2015. The purpose of these meetings was to update agency staff on the current project status, discuss the project features, and to obtain any additional input on ESA-related issues. As part of the initial meeting on October 14, 2014, USFWS staff indicated that the original species list is still considered valid (such that a new list does not need to be generated), but stated that several species of Hawaiian damselfly (*Megalagrion* spp.) were federally listed in 2012 and should also be considered; in particular, a population of blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) is known from the upper reaches of Manoa Stream.

Consultation was also initiated with NMFS in 2008; in response to USACE's request, NMFS provided a complete list of ESA-listed species under their jurisdiction in the Hawaiian Archipelago on April 25, 2008 (see Attachment 1). At the time of the original consultation, the project scope and objectives were more broadly defined, with the project area extending to include the nearshore marine waters. As the objectives and scope of the project were subsequently narrowed to focus on riverine-based flood risk management, the project is not expected to directly or indirectly affect the nearshore marine waters. Therefore, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

1.5 USACE Planning Process

General investigations, such as those carried out under Section 209 of the Flood Control Act of 1962, are funded by specific appropriations and are conducted through a feasibility planning process. The USACE feasibility planning process is comprised of six steps, as specified by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Principles and Guidelines [P&G]) (U.S. Water Resources Council, 1983) and USACE planning regulations and guidance, including Engineer Regulation (ER) 1105-2-100 "Planning Guidance Notebook" (USACE, 2000). These steps include: (1) specification of water and related land resources problems and opportunities; (2) inventory, forecast, and analysis of water and related land resources conditions within the study area; (3) formulation of alternative plans; (4) evaluation of the effects of the alternative plans; (5) comparison of the alternative plans; and (6) identification of a tentatively selected plan based upon the comparison of the alternative plans.

Recognizing the need to modernize their planning process with an emphasis on delivering high-quality feasibility studies within shorter timeframes and at lower costs, the USACE has recently applied a SMART planning approach to the six-step process (USACE, 2012a). The SMART planning approach emphasizes risk-based decision making and includes three primary requirements for feasibility studies (referred to as the "3x3x3 Rule"): completion within 3 years, at a cost of no more than $3 million, and of a "reasonable" report size (approximately 100-page report, with appendices not exceeding 3 inches). Other key components include: (1) engagement of a coordinated vertical team (comprised of USACE District, Division, and

Headquarters staff) throughout the project development process as needed to identify and resolve policy, technical, and legal issues early in the process, (2) focusing the detailed analysis and design on the tentatively selected plan, and (3) identification of the appropriate level of detail, data collection, and modeling based only on what is necessary to complete the feasibility study.

1.6 Purpose and Scope of Biological Assessment

This BA has been prepared as part of the Section 7 consultation process to provide the necessary information to support the USACE's determination as to whether the proposed project is likely to adversely affect or jeopardize the continued existence of the listed species that may occur in the project area or result in the destruction or adverse modification of critical habitat. All ESA-listed species whose known or potential distribution intersects with the action area are listed in Table 1; these are the species that are addressed by this BA. As previously described, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

TABLE 1
Federally-Listed Species Addressed by the Biological Assessment

Common Name	Scientific Name	ESA Status
MAMMALS		
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Endangered
Hawaiian monk seal	*Monachus schauinslandi*	Endangered
BIRDS		
Oahu `elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Hawaiian coot	*Fulica alai*	Endangered
Hawaiian stilt	*Himantopus mexicanus knudseni*	Endangered
Hawaiian duck	*Anas wyvilliana*	Endangered
Hawaiian common moorhen	*Gallinula chloropus sandvicensis*	Endangered
INVERTEBRATES		
Oahu tree snail	*Achatinella* sp.	Endangered
INSECTS		
Blackline Hawaiian damselfly	*Megalagrion nigrohamatum nigrolineatum*	Endangered
Crimson Hawaiian damselfly	*Megalagrion leptodemas*	Endangered
Oceanic Hawaiian damselfly	*Megalagrion oceanicum*	Endangered
Orangeblack Hawaiian damselfly	*Megalagrion xanthomelas*	Candidate
PLANTS		
Haha	*Cyanea acuminate*	Endangered
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea koolauensis*	Endangered
No Common Name	*Diellia erecta*	Endangered
Nanu	*Gardenia mannii*	Endangered
No Common Name	*Gouania meyenii*	Endangered
Wawae iole	*Huperzia nutans*	Endangered
No Common Name	*Lobelia oahuensis*	Endangered
Ihi ihi	*Marsilea villosa*	Endangered
No Common Name	*Pteris lidgatei*	Endangered
No Common Name	*Schiedea nuttallii*	Endangered
No Common Name	*Spermolepis hawaiiensis*	Endangered

Critical habitat has been designated within the Ala Wai watershed for the Oahu `elepaio and for a variety of federally listed plant species, including several species listed in Table 1. The location of designated critical habitat in the Ala Wai watershed is shown in Figure 2.

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2.0 DESCRIPTION OF PROPOSED ACTION AND ACTION AREA

In response to the flood-related problems and opportunities identified for the Ala Wai watershed, a variety of structural and non-structural flood risk management measures were identified, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The measures are generally based on the concepts originally developed in support of the Ala Wai Flood Study (USACE, 2006) and the Manoa Watershed Project (Oceanit, 2008). The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, and flood risk reduction. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the Tentatively Selected Plan); this alternative plan constitutes the proposed action. The measures included in the Tentatively Selected Plan are based on the following concepts:

- **Detention basin**: This measure is an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.
    - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin (via a spillway along the stream bank), then would drain back into the stream.
- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, the Tentatively Selected Plan also includes a stand-alone debris catchment structure, which would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. This structure would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.
- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height, and would be either constructed with a minimal set back distance from the existing stream or canal walls. Local drainage patterns would be maintained to the extent possible, with flapgates/slidegates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). Non-structural measures

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that have been identified as feasible options for this project include improvements to the flood warning system.

The specific measures included in the Tentatively Selected Plan (and the approximate area of disturbance associated with each) is summarized in Table 2. The location of each measure is shown in Figure 3; detailed design drawings of each measure are included in Attachment 2.

Based on the requirements of the Clean Water Act and USACE planning regulations, and after consideration of avoidance and minimization measures, it was determined that compensatory mitigation would be required for unavoidable impacts to aquatic habitat resulting from implementation of the flood risk management measures. The USACE planning process requires that the mitigation requirement be based on functional habitat loss and quantified using a habitat-based methodology (i.e., ecosystem output model). As such, the Hawai`i Stream Habitat Equivalency Procedure (HSHEP) was used to quantify the loss of habitat function.[5] Detailed stream surveys were conducted, with the resulting data processed according to the variables in the HSHEP model, as needed to quantify the habitat value of the existing and future without-project condition (in terms of habitat units [HUs]). Anticipated changes in the model variables were then defined for the with-project condition, and the modeling results were then compared to quantify the anticipated habitat loss (i.e., the mitigation requirement). Potential mitigation concepts that could be implemented to offset the anticipated loss of habitat quality were then identified, and were refined through an iterative process, in coordination with the resource agencies. The increase in habitat quality associated with each of the mitigation measures was quantified using the HSHEP model, and these results were used to combine the measures into different mitigation alternatives that could be implemented to compensate for the loss of habitat quality associated with the tentatively selected plan. The habitat modeling results and cost estimates for each mitigation alternatives were then used to complete a Cost Effectiveness and Incremental Cost Analysis (CE/ICA), which provided the basis for selection of the mitigation alternative to be included as part of the tentatively selected plan.

Based on this process, the selected mitigation alternative is comprised of two measures, both of which involve removal of a passage barrier for native aquatic species in Manoa Stream (Falls 7 and Falls 8). The location of these measures is shown in Figure 4. In each location, there is currently an in-stream structure where undercutting has resulted in an overhanging lip, which creates a passage barrier for native aquatic species. Specifically, the stream flow over these structures is free-falling and does not maintain contact with the surface of the structure, such that the native species do not have any means to migrate upstream. The proposed mitigation involves installation of grouted riprap as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat. The location of the mitigation measures are shown in Figure 4; conceptual design drawings for all of the measures that were considered (including Falls 7 and 8) are included in Attachment 2.

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[5] The HSHEP model was developed to support management of Hawaii's streams and associated habitat for freshwater flora and fauna through a collaborative effort by biologists at the State of Hawai`i Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. To confirm its applicability to the Ala Wai Canal Project, the model was reviewed by the USACE Ecosystem Planning Center of Expertise (EOC-PCX), and was certified for project use on May 19, 2015.

TABLE 2
Flood Risk Management Measures in the Tentatively Selected Plan

Measure[1]	Description of Measure	Total Area of Disturbance (acres)	Permanent Footprint (acres)	Vegetation Management (acres)	Inundation Area[2] (acres)
Waihi debris and detention basin	Earthen berm, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	1.0	0.5	0.3	0.6
Waiakeakua debris and detention basin	Earthen berm, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	1.2	0.7	0.5	0.9
Woodlawn Ditch detention basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area	1.9	1.1	1.0	1.7
Manoa in-stream debris catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad	0.1	0.01	0.1	0
Kanewai Field multi-purpose detention basin	Earthen berm, approximately 7' high around 3 sides of field; inflow spillway on northwest end that allows high flows to enter basin; existing drainage pipe at south end to allow water to re-enter stream; 20-foot-wide perimeter to be maintained as cleared around the perimeter of the berm and the potential flooded area	6.5	0.9	5.5	5.1
Waiomao debris and detention basin	Earthen berm, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm; excavate behind berm to provide required detention volume	1.6	0.3	1.1	0.7
Pukele debris and detention basin	Earthen berm, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	0.5	0.2	0.1	0.4
Makiki debris and detention basin	Earthen berm, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	0.6	0.3	0.1	0.5
Ala Wai Canal floodwalls	Concrete floodwalls along Ala Wai Canal; ranging up to approximately 5 feet high; three pump stations and gates for existing drainage pipes	11.8	0.3	0	0
Hausten Ditch detention basin	Concrete floodwalls and earthen berm (4.3' high) to provide detention for local drainage; install slide gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal	1.4	0.2	1.1	3.5
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, approximately up to 7' high around outside perimeter of golf course property with floodgate across main entrance road; passive drainage back into Ala Wai Canal	25.6	4.0	8.4	134.3

NOTES:
[1] In addition to these structural measures, the Tentatively Selected Plan would also include improvements to the existing flood warning system.
[2] Inundation area is the area behind the detention basin that is expected to be inundated during a 1-percent annual chance exceedance flood event.

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Following construction, each of the flood risk management measures will be operated and maintained by the non-federal sponsor. The operations and maintenance requirements for each measure type are summarized in Table 3.

TABLE 3
Proposed Operations and Maintenance Activities

Measure Type	Summary of O&M Activities
Debris and Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year Clear accumulated debris following flood event or annually (whichever is greater)
Multi-Purpose Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year Assumes minimal sediment or debris removal would be required
Debris Catchment	Clear accumulated debris twice per year
Floodwalls	Inspect and maintain gates (e.g., greased) annually Inspect, test, and maintain pump system annually Inspect floodwalls and repair as needed (e.g., patching)
Flood Warning System	Inspect and test annually (includes annual operating cost)

NOTES:
[1] Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

Separate from the Ala Wai Canal Project, the State of Hawai`i DLNR is pursuing the Woodlawn Chute Structure. Although it was originally contemplated as part of the Ala Wai Canal Project, it is now being implemented as a stand-alone project (with independent utility). No interdependent or interrelated actions have been identified to date.

2.1 Action Area

The regulations governing consultations under the ESA define action area as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the area." The action area should be determined based on all direct and indirect effects of the proposed action (Federal Register, 1986).

The areas that are expected to be directly affected by project implementation include those areas within which ground-disturbing activities are proposed (including clearing, grading, vegetation trimming, staging, access, construction activities, and operations and maintenance). The areas within which these activities would occur have been delineated as the construction limits, as indicated in Figure 3 (the acreage for which is summarized in Table 2) and Figure 4 (for the compensatory mitigation measures).

Indirect effects (for example, noise-related impacts) could occur both within the construction limits, as well in those areas immediately adjacent the construction limits; for the purposes of this assessment, it is assumed that indirect effects could extend 100 feet beyond the edge of the construction limits (based on the types of potential indirect impacts). As the proposed action would modify the hydraulics within the watershed, indirect effects could also occur along the length of the stream corridors, as well as in those areas that may be inundated as a result of the flood risk reduction measures (which are also shown in Figure 3, with acreages indicated in Table 2).

Based on this rationale, the action area for the proposed project has been defined to consist of the construction limits plus a 100-foot buffer for each measure (including the compensatory mitigation measures), plus the stream corridors (Makiki, Manoa and Palolo Streams) extending downstream from the proposed measures to the mouth of the Ala Wai Canal.

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3.0 EXISTING ENVIRONMENTAL CONDITIONS

In general, the natural environments within the watershed generally vary along a gradient from the ridge of the Koʻolau Mountains down to the coastal plain, with similar distribution of natural and urbanized environments in Makiki, Manoa, and Palolo valleys. Dense urban development covers the coastal plain, extending to the back of each valley floor. Several of the ridges between these major valleys are also developed, in some cases to the same degree as the valley floor (for example, Makiki Heights and St. Louis Heights), at least up to where the ridgelines narrow appreciably. Given this pattern of development, most of the natural environments are concentrated within the undeveloped portions of the upper watershed, and along the stream corridors through the urban district.

A general overview of the existing environmental conditions in the watershed is provided below, followed by a more detailed summary for each measure location in Table 4. This information is based on a series of surveys conducted within the watershed, as summarized in a natural resources assessment for the project (AECOS, 2010 and 2014). A copy of these assessments are provided in Attachment 3.

3.1 Vegetation

Vegetation communities in the upper watershed include shrubland, wet forest, and mesic forest habitats, which generally occur along a decreasing precipitation gradient, ranging from the highest elevations in the watershed down to the interface with the urban areas. The steeper slopes at and below the Koʻolau ridgeline to roughly about the 1500-foot contour are relatively undisturbed and mostly dominated by native vegetation; these windswept ridge areas support what has been classified as "Montane Wet Shrubland" (Gagne and Cuddihy, 1990), or specifically on Oʻahu as "Mixed Fern Shrubland." Below the shrubland is a wet forest, which grades into a mesic forest at lower elevations just above the urban zone. Introduced species dominate these habitats, particularly trees and shrubs such as albizia (*Falcateria moluccana*), eucalyptus (*Eucalyptus globulus* and *E. robusta*), Chinese banyan (*Ficus microcarpa*), octopus tree (*Schefflera actinophylla*), guava, java plum (*Syzygium cumini*), Christmas berry (*Schinus terebinthefolius*), mango (*Mangifera indica*), and shoebutton ardisia (*Ardisia elliptica*). Many of these species are considered to be invasive. All of the flood risk measures that are located in the undeveloped upper watershed (e.g., Waihi, Waiakeakua, Pukele, Waiomao and Makiki debris basins) are generally dominated by these vegetation types.

Riparian vegetation is present along all of the upper stream reaches, and is generally dominated by non-native species (many of which are considered invasive), including large trees such as Chinese banyan, *kukui* (*Aleurites moluccana*), mango, octopus tree, *hau* (*Hibiscus tiliaceus*), fiddlewood (*Citharexylum spinosum*), mountain apple (*Syzygium malaccense*), gunpowder tree (*Trema orientalis*), and gum (*Eucalyptus* sp.), as well as smaller herbaceous species such as exotic ginger (*Hedychium* sp.) and Job's tears (*Coix lachryma-jobi*) (Kido, 2006; Kido, 2007; Kido, 2008a; Oceanit, 2004). Within the urbanized portion of the watershed, riparian vegetation is generally limited to unchannelized stream reaches, such as along portions of Manoa Stream (for example, near the Dole Street Bridge). A majority of Palolo and Makiki streams are channelized and lack a riparian zone (Oceanit, 2004; Englund and Arakaki, 2004; Kido, 2008a). Mangrove trees (*Rhizophora mangle*) are present in some areas in the lower estuarine reaches of the Manoa–Palolo Drainage Canal and the Ala Wai Canal, although most of these reaches are comprised of concrete and

As further described in Section 4, the occurrence of federally-listed plant species is generally restricted to the higher elevations of the upper watershed. These areas, as well as the slopes of Diamond Head, have been designated as critical habitat for the conservation of these species (Figure 2). However, not all of the listed species are presently known to occupy the designated critical habitat; some have not been recorded from the watershed since early in the last century and some are possibly extinct (Federal Register, 2012). No federally-listed plant species (or designated critical habitat) are known to occur in the action area.

A summary of the existing vegetation at each measure location is provided in Table 4.

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3.2 Terrestrial Wildlife

A variety of terrestrial wildlife species occur throughout the watershed, including mammals, birds, invertebrates and insects (Mitchell et al., 2005). The vast majority of these species are non-native, many of which are considered invasive and pose a significant management concern (e.g., feral pig [*Sus scrofa*], mongoose [*Herpestes aruopunctatus*], and various bird species). However, there are several federally listed species that could potentially occur within the watershed.

The forested areas of the watershed provide habitat for native bird populations, including the federally listed Oahu *`elepaio* (*Chasiempis sandwichensis ibidis*); the upper-most portion of the watershed is designated as critical habitat for this species, although it is not believed to be currently occupied. Other federally listed species that are known from the upper watershed include endemic tree snails (*Achatinella* sp.) and the blackline Hawaiian damselfly species (*Megalagrion nigrohamatum nigrolineatum*). In addition, the Hawaiian hoary bat *ʻōpeʻapeʻa* [*Lasiurus cinereus semotus*], the only land mammal native to Hawaii, could potentially occur in the watershed.

In the lower portions of the watershed, federally listed waterbird species could potentially occur; these include the Hawaiian coot (*ʻalae keʼokeʼo*), Hawaiian stilt (*aeʼo*), Hawaiian duck (*Anas wyvilliana*), and Hawaiian moorhen (*ʻalae ʻula*). Although unlikely given their known distribution, these species could possibly use estuarine areas within the watershed as resting habitat.

Federally listed species, including those described above, are further discussed in Section 4.

3.3 Aquatic Species

Native freshwater fish in Hawaiʼi are limited to five gobiid species (*oʼopu*), including one indigenous (*oʼopu nakea* [*Awaous guamensis*]) and three endemic (*oʼopu alamoʻo* [*Lentipes concolor*], *oʼopu nopili* [*Sicyopterus stimpsoni*], and *oʼopu naniha* [*Stenogobius hawaiiensis*]) gobies, and one endemic eleotrid (*oʼopu akupa*, *Eleotris sandwicensis*) (Kinzie, 1990). The native stream macrofauna assemblage also includes several shrimp species (*ʼopae kalaʼole* [*Atyoida bisulcata*] and *ʻopae ʼoehaʻa* [*Macrobrachium grandimanus*]), and mollusk species (*hapawai* [*Neritina vespertina*] and *hihiwai* [*Neritina granosa*]). As part of their lifecycle, the adults of each of these species live and breed in freshwater streams; newly hatched larvae drift to the ocean, remaining there for several months before migrating back to freshwater habitat, cued by freshets (Yamamoto and Tagawa, 2000). None of the native stream species are federally listed under the ESA.

All of these native species have been recently documented in the Ala Wai watershed, with the exception of *oʼopu alamoʻo* and *hihiwai* (Parnham et al., 2008; Kido, 2008a). The presence of native species of stream macrofauna can often be used as an indicator of stream ecosystem health (Kido, 2008b). In this context, portions of the watershed display signs of good stream habitat. However, the overall watershed lacks healthy populations of native fishes and aquatic invertebrates, likely because of degradation and fragmentation of usable habitat in the urban zone (Oceanit, 2004). Recent observations of native species are typically limited to only a few individuals in the higher reaches of the upper watershed and in the estuarine environment. With these notable exceptions, the extant aquatic macrofauna is dominated by non-native species (Englund and Arakaki, 2004; Kido, 2008a).

TABLE 4
Existing Conditions at Flood Risk Management Measure Locations (summarized from AECOS, 2014)

Measure	General Location	Existing Environmental Conditions
Waihi debris and detention basin	Waihi Stream, ~1,200 feet above the upper extent of development in Manoa Valley (~380' in elevation).	Site is characterized by forested habitat, with dominant species including monkeypod (*Albizia saman*), Chinese banyan, gunpowder, *kukui*, swamp mahogany (*Eucalyptus robusta*), mango, Java plum, and Christmas berry; pothos vine (*Epipremnum pinnatum*) is prominent climbing the trees. Site is located on the lower edge of a prominent belt of albizia trees.
Waiakeakua debris and detention basin	Waiakeakua Stream, ~200 feet above the upper extent of	Site (including the staging area) is characterized by forested habitat, with species including guarumo (*Cecropia obtusifolia*), macaranga (*Macaranga tanarius*), hau (*Hibiscus tiliaceus*), bamboo, and the shrub *Odontonema strictum*. Other species

TABLE 4
Existing Conditions at Flood Risk Management Measure Locations (summarized from AECOS, 2014)

Measure	General Location	Existing Environmental Conditions
	development in Manoa Valley (~300' in elevation).	include red ginger (*Alpinia purpurata*), shoebutton ardesia (*Ardisia elliptica*), and white shrimp plant (*Justicia betonica*); pothos vine is prominent climbing the trees; site is located on the lower edge of a prominent belt of albizia trees.
Woodlawn Ditch detention basin	Woodlawn Ditch (manmade tributary to Manoa Stream), adjacent to E. Manoa Road (~200' in elevation)	Site is characterized by mixed secondary forest and tended farm/garden areas; forest is nearly monotypic stand of macaranga (*Macaranga tanarius*), with a limited number of tropical almond (*Terminalia catappa*), shoebutton ardisia, Chinese hibiscus (*Hibiscus rosa-sinensis*), coconut (*Cocos nucifera*), African tulip (*Spathodea campanulata*), and small albizia.
Manoa in-stream debris catchment	Middle reach of Manoa Stream, directly adjacent to lower edge of Manoa District Park (~160' in elevation)	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties); the staging areas within Manoa District Park is dominated by lawn, with some planted trees including Formosan *koa* (*Acacia confusa*), *kukui*, coconut, and royal palms (*Roystonia regia*).
Kanewai Field multi-purpose detention basin	Lower reach of Manoa Stream, just below Dole Street	Site is comprised of maintained field for park; predominantly a mowed lawn with two large mango trees near the west corner site; adjacent stream includes a riparian corridor with various mature trees of Java plum, *hau*, mango, macaranga, and monkeypod.
Waiomao debris and detention basin	Pukele Stream, adjacent to residences on Waiomao Rd. (~380' in elevation)	Site is comprised of a heavily forested riparian zone adjacent to residential properties; dominated by non-native species including octopus tree, gunpowder, monkeypod, macaranga (Macaranga tanarius), mango, and fiddlewood; pothos vine is prominent climbing the trees.
Pukele debris and detention basin	Pukele Stream, adjacent to residences on Ipulei Place (~400' in elevation)	Site includes the maintained lawns of two residential homes; right bank of the stream is dominated by weedy species including Guinea grass (*Panicum maximum*) and castor bean (*Ricinus communis*); left bank is forested with non-native species including Chinese banyan, swamp mahogany, and Java plum
Makiki debris and detention basin	Makiki Stream, directly adjacent to Makiki Heights Drive (~160' in elevation).	Site is characterized by dense riparian forest; dominant species include Chinese banyan, African tulip (*Spathodea campanulata*), gunpowder tree, she oak (*Grevillea robusta*), and mango. The understory is as well dominated by a variety of nonnative shrubs and vines, notably pothos (*Epipremnum pinnatum*), shrimp plant (Justicia betonica), and Madeira vine (*Anredera cordifolia*). Staging area includes open *kukui* copse, with open floor.
Ala Wai Canal floodwalls	Ala Wai Canal	Vegetation along the Canal is generally limited to landscaping, with a single row of trees lining most of both sides of Canal, including *niu* (*Cocos nucifera*), with some milo (*Thespesia populnea*) and monkeypod.
Hausten Ditch detention basin	Hausten Ditch (drainage input to Ala Wai Canal)	Hausten Ditch is dominated by non-native species, including mangroves; native species that occur along ditch (including '*akulikuli* [*Sesuvium portulacastrum*]; *kou* [*Cordia subcordata*], and *kīpūkai* [*Heliotropium Curassavicum*]) are common species. The remainder of the site is a maintained lawn, with scattered *niu*, milo and monkeypod trees.
Ala Wai Golf Course multi-purpose detention basin	Ala Wai Canal	Landscaped vegetation for golf course greens and fairways; site also includes two shallow basins and a ditch that are identified as seasonally flooded wetland features on the National Wetlands Inventory (USFWS, 2006a)

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4.0 POTENTIALLY AFFECTED LISTED SPECIES AND CRITICAL HABITAT

In order to identify whether any of the listed species potentially occurring in the watershed could be affected by the project, the species habitat requirements and known distribution was assessed relative to the action area. In addition, the location of designated critical habitat was mapped to identify any potential overlap with the action area. Following is a summary of the potentially affected species within the watershed, and the effects analysis for each.

4.1 Hawaiian hoary bat (*Lasiurus cinereus semotus*)

The Hawaiian hoary bat (*ope'ape'a*) was listed as an endangered species in October 1970 (Federal Register, 1970). The original recovery plan was approved in May 11, 1998; a five-year review was conducted in September 2011 (USFWS, 2011a). Critical habitat has not been designated for this species.

The species is endemic to Hawaii; it is the only native terrestrial mammal that occurs in the State. It is still believed to be present on all of the main islands, with the largest populations known from Hawai`i and Kauai. Information about the species abundance is currently based on localized survey information, such that there are no reliable current population estimates. There is also limited information relative to species distribution, but the species has been observed year-round across a variety of habitats and elevations, generally ranging from the coast up to elevations of 7,500 feet (but possibly as high as 13,000 feet) (USFWS, 2011b).

The Hawaiian hoary bat is a solitary species that typically leaves its roost shortly before or after sunset and returns before sunrise. Roosting has been documented in a wide variety of both native and non-native trees, including native species (e.g., *ohia lehua* [*Metrosideros polymorpha*], *hala* [*Pandanus tectorius*], *pukiawe* [*Styphelia tameiameiae*], Polynesian-introduced species (e.g., *kukui* [*Aleurites moluccana*], and non-native species (e.g., Java plum [*Syzygium cumini*]) (USFWS, 1998a). Recent data from Hawai`i Island suggest that roosting occurs in trees at heights more than 20 feet off the ground (Bonaccorso, as reported in USFWS, 2011a). Hawaiian hoary bats forage across a range of open areas (e.g., fields, shoreline, and streams/ponds), as well as forest edges and clearings.

Threats to this species include habitat loss, predation, roost disturbance, and disease. The species' decline may have primarily been due to the historic loss of tree cover associated with deforestation in the early 19th century. Current threats may also include barbed wire fences, wind turbines, and pesticides (including contamination of prey) (USFWS, 1998a).

<u>Potential to Occur in the Action Area</u>

Little is known about the species' occurrence across the island of Oahu, including the Ala Wai watershed. However, based on the habitat preferences, it is possible that it could occur within the action area. Specifically, all of the detention basins in the mid to upper portions of the watershed (including those on Waihi, Waiakeakua, Woodlawn Ditch, Pukele, Waiomao, and Makiki Streams) include forested habitat with tall trees that may be used for roosting. Several of the measure locations in the lower watershed, such as the Kanewai Field, Hausten Ditch and Ala Wai golf course detention basins, may also provide suitable foraging habitat; however, the habitat value of these sites is likely diminished by the extensive urbanization in the surrounding areas.

<u>Potential Effects of the Proposed Action</u>

Should they occur, Hawaiian hoary bats could be directly or indirectly impacted by the project. Direct effects could include mortality or other forms of take (e.g., harm or harrassment) to individual bats as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt bats that are present within the action area. To avoid and minimize the potential for these impacts, vegetation clearing for the project would be performed during times of the year when Hawaiian hoary bats are not expected to be breeding to avoid potential for harm or disruption to non-volant juvenile bats; specifically, trees greater than 15 feet in height

would not be cleared between July 1 and August 1. In addition, all construction activities would be scheduled to occur during daytime hours, thus avoiding potential bat foraging activities, which typically occur in the evening hours.

Other effects could include permanent loss or temporary impacts to habitat. However, given the amount of habitat available throughout the upper watershed, tree clearing within the action area is not expected to measurably decrease the amount of forest available to the local population of bats for roosting. In addition, as the total population of bats on Oahu is believed to be small (USFWS, 1998a) and trees are plentiful, roost trees are not expected to be a limiting factor for the species on Oahu. The forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or structure between adjacent patches. For these reasons, it is expected that any bats displaced by the clearing would readily find alternate roost sites in surrounding undisturbed forest.

Effects Determination

As described above, seasonal restrictions for tree trimming/clearing and enforcement of construction hours will be incorporated to avoid and/or minimize the potential for impacts to the Hawaiian hoary bat, should the species be present in the action area. With implementation of these measures, impacts to the Hawaiian hoary bat are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.2 Hawaiian monk seal (*Monachus schauinslandi*)

The Hawaiian monk seal (‘*ilio-holo-i-ka-uaua*) was listed as endangered under the ESA in November 1976 (Federal Register, 1876). The original recovery plan was approved in March 1983; the most recent revision was made in August 2007 (NMFS, 2007). Critical habitat was designated in the northwest Hawaiian Islands for this species in 1986 (NMFS, 2007); no critical habitat occurs within the action area.

The species is endemic to the Hawaiian archipelago; it is one of only two remaining monk seal species, and is considered to be one of the rarest marine mammals in the world. Its range is generally limited to the Hawaiian archipelago, with most of the population occurring in the northwestern Hawaiian Islands, but the population in the main Hawaiian Islands appears to be expanding. Overall, the species has been steadily declining over time, with an estimated total of 1,200 seals remaining throughout the species’ entire range. This population size is considered to be very small, raising concerns about the long-term maintenance of genetic diversity (NMFS, 2007).

Hawaiian monk seals spend approximately two-thirds of their time in marine waters, primarily in areas surrounding atolls, islands, and areas farther offshore on reefs and submerged banks. They forage for food across a range of benthic substrates (generally in waters 60-300 feet deep), feeding on a variety of fish, cephalopods and crustaceans; they may also use deepwater coral beds as foraging habitat. Terrestrial habitats are primarily sandy beaches (and occasionally other shoreline areas), which are used as haul-outs for pupping, nursing, molting and resting.

Threats to Hawaiian monk seals include both natural and human-induced factors, including reduction of habitat and prey (at least in part due to environmental change), predations by sharks, disease, entanglement in marine debris, and human disturbance (NMFS, 2007).

Potential to Occur in the Action Area

The proposed action is focused on stream-related flood risk reduction and the action area does not include any marine or coastal habitat. As such, there is no potential for the Hawaiian monk seal to occur in the action area.

Potential Effects of the Proposed Action

The proposed action will not directly or indirectly affect the Hawaiian monk seal, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on the Hawaiian monk seal.

4.3 Oahu `*Elepaio* (*Chasiempis sandwichensis ibidis*)

The Oahu `elepaio was listed as endangered under the ESA on April 18, 2000; the recovery plan for the species was approved in 2006 (USFWS, 2006b). Critical habitat for the Oahu `elepaio was designated in December 2001. The critical habitat consists of five units, which encompass a total area of approximately 65,879 acres in the Ko`olau and Wai`anae Mountains (Federal Register, 2001). Unit 5 encompasses over 10,000 acres of the southern Ko`olau Mountains and, in the Ala Wai watershed, includes most of the undeveloped upland areas from Tantalus to Mauʻumae Ridge and beyond (Figure 2); the action area does not overlap with any portion of the designated critical habitat.

Historically, the species is believed to have been abundant across the more than 300,000 acres of forest habitat on Oahu. The geographic range of Oahu `elepaio has declined significantly, with the species currently occupying only about 12,811 acres, or approximately 4 percent of its former range (USFWS, 2006; Vander Werf et al., 2013). As of 2001, the population was estimated to include approximately 1,980 birds distributed across fragmented habitat in the Wai`anae Mountains and the Ko`olau Mountains, with three relatively large populations and several smaller remnant populations in each mountain range. Recent surveys indicate continued decline of the species, with a total estimated population size of 1,261 birds that have been fragmented into four large subpopulations and 12 smaller subpopulations (VanderWerf et al., 2013).

Oahu `*elepaio* nest and forage in a variety of native and non-native forest types across a range of elevations, but are most common in riparian vegetation along streambeds and in mesic forest habitats with continuous tree canopy and dense understory. Habitat structure appears to be more important than species composition, and the species has adapted to use introduced species in disturbed forest habitat (VanderWerf et al., 1997). Common native plants in areas where `*elepaio* occur include *alahe`e* (*Psydrax odorata*), *pāpala kēpau* (*Pisonia umbellifera*), *lama* (*Diospyros sandwicensis*), *hame* (*Antidesma platyphyllum*), *māmaki* (*Pipturus albidus*), *kaulu* (*Sapindus oahuensis*), and `*āla`a* (*Pouteria sandwicensis*); common introduced plants include strawberry guava (*Psidium cattleianum*), common guava (*Psidium guajava*), *kukui* (*Aleurites moluccana*), mango (*Mangifera indica*), and Christmas berry (*Schinus terebinthifolius*). The nesting season usually extends from February to May, but active nests have been documented from January to July (VanderWerf, 1998).

Much of the species' historic decline is believed to be attributed to habitat loss, particularly as a result of extensive development and urbanization at lower elevations. In recent years, the greatest threat to the species is associated with predation by alien black rats (*Rattus rattus*) and mosquito-borne diseases (VanderWerf et al., 2013). Other current threats include avian malaria and pox, although there is some evidence that the species is building an immunity to the poxvirus. In addition to these threats, natural processes (e.g., loss of genetic variability, natural disasters, etc.) further threaten the small, remnant populations.

Potential to Occur in the Action Area

A recent survey for Oahu `elepaio indicated that the population in the Ko`olau Mountains is comprised of 545 males and 317 females. The geographic range is approximately 9,749 acres, and is fragmented into 2 larger subpopulations in the central and southeastern Ko`olau Mountain (each with more than 400 birds), a smaller subpopulation in Waikane and Kahana Valleys (25 birds), and three small remnant populations in Nuuanu, Waihee and Waiahole Valleys (less than 4 birds each) (VanderWerf et al., 2013). Previous data indicated populations in both Manoa and Palolo Valleys (with 2 birds and 46 birds, respectively); as of 2012, approximately 12 birds (5 pairs and 2 single males) are known from Palolo valley, and the species is no longer believed to occur in Manoa valley (VanderWerf et al., 2013).

The portions of the action area within Manoa Valley (i.e., Waihi and Waiakeakua detention basins) contain suitable habitat; however, as described above, the species is no longer believed to occupy any portion of Manoa Valley. The portions of the action area within Palolo Valley (i.e., Pukele and Waiomao detention basins) also contain suitable habitat, but these areas are considerably downslope from the lower edge of the species' current geographic range. Given the proximity to the known range, it is possible (although unlikely) that the species could reoccupy portions of the action area.

Critical habitat for this species is located in the upper portions of the watershed, but none is present within the action area.

Potential Effects of the Proposed Action

Although species occurrence within the measure locations is unlikely, should they occur, Oahu `elepaio could be directly or indirectly impacted by the project. Direct effects could include mortality or other forms of take (e.g., harm or harassment) to individual birds or destruction of their nests as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt birds that are present within the action area. To avoid and minimize the potential for these impacts, trimming or clearing of vegetation in areas of suitable habitat would be restricted during the `elepaio nesting season (January through June).

Other effects could include permanent loss or temporary impacts to habitat. However, vegetation clearing within the action area is not expected to measurably decrease the amount of forest available for `elepaio habitat. The total population of `elepaio in this region is small, and forested areas are readily available, such that habitat is not expected to be a limiting factor for the species. In addition, the forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or structure between adjacent patches. Therefore, in the unlikely event that `elepaio were to reoccupy this area, it is expected that they would readily find alternate habitat in the surrounding undisturbed forest.

Effects Determination

As described above, species occurrence within the action area is unlikely, but seasonal restrictions for trimming/clearing of vegetation would be incorporated to avoid and/or minimize the potential for impacts to the Oahu `elepaio, should it occur in the action area. With implementation of these measures, impacts to the Oahu `elepaio are expected to be discountable, such that the proposed action may affect, but is not likely to adversely affect the species.

As no designated critical habitat occurs within the action area, there will be no effect on critical habitat for Oahu `elepaio.

4.4 Hawaiian coot (*Fulica alai*)

The Hawaiian coot (*Fulica alai*) was listed as endangered in 1970. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

The Hawaiian coot is an endemic, non-migratory waterbird species that was historically known to occur on all of the main Hawaiian islands, except Lana`i and Kaho`olawe. No population estimates are available for the early 1900s, but the species' decline and potential threat of extinction was documented in the mid-1900s (Schwartz and Schwartz, 1949); the population was documented at fewer than 1,000 in the 1950 and 1960s (USFWS, 1978). Currently, Hawaiian coots inhabit all of the main Hawaiian islands except Kaho`olawe. Biannual waterbird surveys from 1997 through 2006 indicate the Hawaiian coot population generally averages between approximately 1,500 and 2,800 birds; on Oahu, the population generally fluctuates between 500 and 1000 birds (DOFAW, 1976-2008). Most of these occur in coastal wetlands, including the James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Kuilima wastewater treatment plant, Ka`elepulu Pond in Kailua, Pearl Harbor National Wildlife Refuge, and the Hawai`i Prince Golf Course (USFWS, 2011c).

Coots typically use naturally occurring ponds and wetlands on the coastal plain, in areas with emergent plant growth interspersed with open water (Brisbin et al., 2002). They also use aquatic features actively managed for taro cultivation and fish production, and are known to readily disperse between areas of suitable habitat (USFWS, 2011c; Engilis and Pratt, 1993). Primary food sources include invertebrates and aquatic vegetation, with foraging in mud/sand substrate and diving near the water surface. They nest in open freshwater and brackish ponds, constructing floating or semi-floating nests using aquatic vegetation; false nests are also constructed for use as loafing or brooding platforms (USFWS, 2011c). Habitat suitability is limited in large, deep ponds (USFWS, 2011c). Although coots may prefer freshwater for nesting, they are commonly found in brackish water (Berger, 1981), loafing on rafts of vegetation, mud bars, and false nests, as well as on open water.

Potential to Occur in the Action Area

The only suitable habitat that could support this species within the action area are very small pockets of wetland habitat; these are limited to isolated features within the Ala Wai golf course and possibly along Hausten Ditch and/or the upper edges of the Ala Wai Canal. However, these areas are very small and provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though unlikely), that Hawaiian coots could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that coots are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of coots (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, the detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect coots.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability of species occurrence in the action area. Given this fact, coupled with the nature of activities proposed in these areas, impacts to the Hawaiian coot are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.5 Hawaiian stilt (*Himantopus mexicanus knudseni*)

The Hawaiian stilt (*Himantopus mexicanus knudseni*) was listed as endangered in 1970. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

The Hawaiian stilt is endemic to Hawai`i and was historically known to occur all of the major islands except Lāna`i and Kaho`olawe (but were subsequently documented on Lāna`i starting in 1989) (Engilis and Pratt,

1993). Although there is no estimate of historical numbers, stilts were identified as common in the late 1800s. Population declines were documented as early as 1900, with loss of wetland habitat identified as the primary cause of decline; other contributing factors include predation by introduced species, habitat overgrowth by invasive plant species, and hunting (USFWS, 2011c).

Biannual surveys conducted from 1998 through 2007 suggest that, on average, the population is comprised of approximately 1,500 stilts and is relatively stable (DOFAW, 1976-2008; Reed and Oring, 1993; USFWS, 2011c). Oahu supports the largest number of Hawaiian stilts, with approximately 450 to 700 birds in any given year (Engilis, 1988; DOFAW, 1976-2008). Most of these occur at the James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Pearl Harbor National Wildlife Refuge, and on Nu`upia Ponds in Kaneohe; populations also exist at the Chevron Refinery, the fishponds at Kualoa Beach Park, at Salt Lake District Park, and at scattered locations along the northern and eastern coasts.

The Hawaiian stilt is primarily found in low-elevation wetlands with sparse, low-growing vegetation and water depths less than approximately 9 inches. Stilts forage for a variety of invertebrates in fresh, brackish, or saline waters. Stilts use open or sparsely vegetated flats and pasture lands for loafing, as well as other open areas with good visibility. Nesting predominantly occurs in areas with little to no cover, which most likely allows predators to be easily spotted.

Potential to Occur in the Action Area

A small amount of potentially suitable habitat occurs within the action area; these areas include the aquatic features within the Ala Wai golf course, Hausten Ditch and possibly the upper reaches of the Ala Wai Canal. However, these areas are limited in size and provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though relatively unlikely), that Hawaiian stilts could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that stilts are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of stilts (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, areas within the Hausten Ditch and Ala Wai golf course detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract a larger number of waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect stilts.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability that Hawaiian stilts would occur in the action area. Given this fact, coupled with the nature of the proposed activities, impacts to the Hawaiian stilt are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.6 Hawaiian duck (*Anas wyvilliana*)

The Hawaiian duck (*Anas wyvilliana*) was listed as endangered in 1967. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

Hawaiian ducks were known historically from all of the main Hawaiian Islands except Lāna`i and Kaho`olawe. Although there is no estimate of historical numbers, Hawaiian ducks were identified as common in the 1800s. By the 1960s, Hawaiian ducks were nearly extirpated on all islands, except Kauai and possibly Niihau; Hawaiian ducks were subsequently reintroduces to Oahu, Maui and Hawai`i (USFWS, 2011c).

Although populations of Hawaiian ducks are believed to still exist on each of these islands, the remaining populations are affected by hybridization with feral mallards. Engilis et al. (2002) estimated the statewide population of pure Hawaiian ducks to be 2,200 birds, with 2,000 on Kaua`i and 200 on Hawai`i. Allozyme data indicate there has been extensive hybridization between Hawaiian ducks and feral mallards on O`ahu, with the near disappearance of Hawaiian duck alleles from the population (Browne et al. 1993). Hawaiian ducks are still reported from wetlands on O`ahu's windward coast (Kawainui, Hāmākua, and He`eia Marshes, Ka`elepulu and Nu`upia Ponds, and Ho`omaluhia Botanical Garden), north shore (James Campbell National Wildlife Refuge, Kahuku aquaculture ponds, Punaho`olapa, Hale`iwa), Pearl Harbor area (Pearl Harbor National Wildlife Refuge, Pouhala Marsh), and Lualualei; however, it is not known whether these individuals are actually Hawaiian ducks or hybrids (USFWS, 2011c).

The Hawaiian duck historically used a wide variety of natural habitats for nesting and feeding, including freshwater marshes, flooded grasslands, coastal ponds, and streams at elevations ranging from sea level to 3,000 meters (9,900 feet); other areas that may be utilized as habitat include agricultural and artificial wetlands, sewage treatment ponds, irrigation ditches, and reservoirs. Wetlands that are relatively small, isolated, or close to houses are less likely to be occupied (Uyehara et al., 2008). Nests are established on the ground, which makes them highly vulnerable to predators (e.g., mongoose, cats).

Potential to Occur in the Action Area

The aquatic environments within the action area provide suitable habitat for the Hawaiian duck. However, given the extensive urban development, it is unlikely that these areas would be utilized by the species. Coupled with the very low number of Hawaiian ducks that remain on Oahu (none of which have been reported from this region on Oahu), the species is not expected to occur in the action area.

Potential Effects of the Proposed Action

As the Hawaiian duck is not expected to occur in the action area, the proposed action is not expected to affect this species.

Effects Determination

The proposed action is expected to have no effect on the Hawaiian duck.

4.7 Hawaiian moorhen (*Gallinula chloropus sandvicensis*)

The Hawaiian moorhen (*Gallinula chloropus sandvicensis*) was listed as endangered in 1967. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

Historically, the Hawaiian moorhen was found on all of the main Hawaiian Islands except Lāna`i and possibly Ni`ihau. The population (especially on Oahu, Maui and Molokai) was drastically reduced by the late 1940s; the species was subsequently extirpated on Maui and Molakai and reintroduction efforts failed (presumably due to nest predation). Hawaiian moorhens are currently found only on the islands of Kaua`i and O`ahu. The population is small, but relatively stable, with an average of 287 birds from 1998 to 2007 (DOFAW 1976-2008). Approximately half of the birds are found on Oahu; they are widely distributed on the island, but are most prevalent on the northern and eastern coasts between Hale`iwa and Waimanalo. Small numbers occur

in Pearl Harbor, where they foraging in semi-brackish water. The population on the leeward coast is limited to Lualualei Valley (USFWS, 2011c).

Hawaiian moorhen habitat consists of freshwater marshes, taro patches, reedy margins of water courses (e.g., streams, irrigation ditches), reservoirs, wet pastures, and occasionally saline and brackish water areas. They appear to prefer lowland freshwater habitats. Key habitat features include dense stands of robust emergent vegetation near open water, floating mats of vegetation, water depths less than 1 meter (3.3 feet), and fresh water (as opposed to saline or brackish water). Interspersion of emergent vegetation and open water is also believed to be important.

Potential to Occur in the Action Area

The only suitable habitat that could support this species within the action area are very small pockets of wetland habitat; these are limited to isolated features within the Ala Wai golf course, and possibly Hausten Ditch and the upper reaches of the Ala Wai Canal. However, these areas lack some of the key habitat features, and therefore are expected to provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); these areas are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though unlikely), that Hawaiian moorhens could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that moorhens are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of moorhens (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, the detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect moorhen.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability of species occurrence in the action area. Given this fact, coupled with the nature of activities proposed in these areas, impacts to the Hawaiian moorhen are expected to be insignificant, such that the proposed action is not likely to adversely affect the species.

4.8 Blackline Hawaiian Damselfly (*Megalagrion nigrohamatum nigrolineatum*)

The blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was also designated in 2012; Unit 11 is located within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The blackline Hawaiian damselfly was known historically from the Ko`olau and Wai`anae Mountains, at elevations ranging from sea level to over 2,400 feet (730 m) (Williams, 1936; Polhemus, 1994). There are

currently 17 known populations from lowland wet ecosystem in the headwaters and upper reaches of streams of the Ko`olau Mountains.

This species occurs in the slow sections or pools along mid-reach and headwater sections of perennial upland streams and in seep-fed pools along overflow channels bordering such streams. Colonies are constrained to portions of streams not occupied by non-native predatory fish (for example, stream reaches above geologic or manmade barriers) (Federal Register, 2012).

The blackline Hawaiian damselfly is threatened by habitat loss, as well as competition and predation by non-native fish species. Habitat loss may occur as a result of invasive California grass (*Brachiaria mutica*), which forms dense stands that can eliminate standing water.

Potential to Occur in the Action Area

Based on initial information provided by the USFWS, it is understood that the species occurs in areas along Manoa Stream, but is restricted to elevations higher than 2,000 feet. Based on this information, the species is not expected to not have the potential to occur within the action area. This conclusion is being validated as part of a field investigation by USFWS biologists.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

Based on currently available information, the proposed action is not expected to directly affect the blackline Hawaiian damselfly, or its critical habitat. As previously described, the proposed mitigation measures are intended to improve access for native aquatic species to the upper reaches of Manoa Stream. Recognizing the threat that invasive aquatic species pose to the blackline Hawaiian damselfly, it is possible that increased access or abundance of invasive aquatic species could indirectly affect the blackline Hawaiian damselfly. However, recent stream surveys indicate that invasive aquatic species are already abundant in the reaches above the proposed mitigation measures, such that these features are not expected to measurably increase abundance (G. Higashi, State Division of Aquatic Resources, personal communication, May 26, 2015).

Effects Determination

The proposed action is expected to have **No Effect** on the blackline Hawaiian damselfly.

4.9 Crimson Hawaiian Damselfly (*Megalagrion leptodemas*)

The crimson Hawaiian damselfly (*Megalagrion leptodemas*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was designated in 2012; Unit 11 is within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The crimson Hawaiian damselfly was known historically from the windward side of the Wai`anae Mountains and scattered locations in the Ko`olau Mountains, but is currently only known from 3 locations in the Ko`olau Mountains: Moanalua, north Halawa, and Maakua (Federal Register, 2012). This species is found in lowland wet and wet cliff ecosystems, and breeds in the slow reaches of streams and seep-fed pools (Williams, 1936; Polhemus, 1994). All colonies are constrained to portions of streams not occupied by non-native predatory fish (for example, stream reaches above geologic or manmade barriers) (Federal Register, 2012).

The crimson Hawaiian damselfly is threatened by habitat loss and alteration, as well as competition and predation by non-native fish species. Given the small remaining populations sizes, the species is also threatened by natural events (e.g., drought) that could extirpate the remaining populations.

Potential to Occur in the Action Area

Pockets of suitable habitat for this species occurs in the upper reaches of the action area; however, it is now restricted to three locations in the Ko`olau Range (Federal Register, 2012). Given its current range, this species is not expected to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect the crimson Hawaiian damselfly, or its critical habitat.

Effects Determination

The proposed action is expected to have **No Effect** on the crimson Hawaiian damselfly.

4.10 Oceanic Hawaiian Damselfly (*Megalagrion oceanicum*)

The oceanic Hawaiian damselfly (*Megalagrion oceanicum*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was designated in 2012; Unit 12 is within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The oceanic Hawaiian damselfly is endemic to the island of Oahu, and was known historically from both the Ko`olau and Wai`anae Mountains. It is now believed to be extirpated from the Wai`anae Mountains, and is only known to occupy the upper reaches (above 100 meters [300 feet]) of perennial streams on the windward side of the Ko`olau Range (Polhemus, 1994; Federal Register, 2012).

Immature stages of this species are found in swiftly flowing sections of streams, usually amid rocks and gravel in stream riffles and small cascades (Williams, 1936; USFWS, 2007). The naiads usually crawl among gravel or submerged vegetation; older naiads often forage out of the actual stream channel and have been observed among wet moss on rocks, and wet rock walls and seeps (Williams, 1936). Adults are strong flyers, and when disturbed frequently fly upward into the forest canopy overhanging the stream (Williams, 1936; Polhemus, 1994).

The oceanic Hawaiian damselfly is threatened by habitat loss and alteration (e.g., water diversions), as well as competition and predation by non-native fish and insect species. Habitat loss may occur as a result of invasive California grass, which forms dense stands that can eliminate standing water. Given the small remaining populations sizes, the species is also threatened by natural events (e.g., drought) that could extirpate the remaining populations.

Potential to Occur in the Action Area

Pockets of suitable habitat for this species occurs in the upper reaches of the action area; however, it is now restricted to a handful of locations on the windward side of the Ko`olau Range (Polhemus, 1994; USFWS, 2012b). Given its current range, this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect the oceanic Hawaiian damselfly, or its critical habitat.

Effects Determination

The proposed action is expected to have **No Effect** on the oceanic Hawaiian damselfly.

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4.11 Orangeblack Damselfly (*Megalagrion xanthomelas*)

The orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) is currently a candidate for listing under the ESA (Federal Register, 2014; USFWS, 2014a).

This species was historically the most abundant damselfly species in Hawaii, and occurred on all the major islands except Kahoolawe. It is now restricted to a total of 16 populations distributed across the islands of Oahu, Maui, Molokai, Lanai, and Hawai`i (Perkins, 1913; Polhemus, 1996; USFWS, 2014a). Currently, the only known population on Oahu is located near Tripler Army Medical Facility (Englund, 2001).

Orangeblack Hawaiian damselflies generally occur in lowland aquatic habitats, and prefer standing or very slow moving bodies of water. The most common habitat in which this species was found during surveys across its current distribution include coastal wetlands fed by basal springs, and terminal or lower mid-reaches of perennial streams (Polhemus, 1996).

Threats to this species include predation from nonnative aquatic species (including fish and insects), and habitat loss due to dewatering of streams and invasion by nonnative plants. Invasive plants (e.g., California grass (*Brachiaria mutica*)) also contribute to loss of habitat by forming dense, monotypic stands that completely eliminate open water (Federal Register, 2014).

Potential to Occur in the Action Area

Pockets of suitable habitat for this species occurs within the action area; however, the last report of this species on Oahu was in 1935 (Williams, 1936), with the exception of one remnant population recently discovered near Tripler Army Medical Facility. Given its current range, this species is not expected to not have the potential to occur within the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect the orangeblack Hawaiian damselfly.

Effects Determination

The proposed action is expected to have **No Effect** on the orangeblack Hawaiian damselfly.

4.12 Oahu tree snail (*Achatinella* sp.)

All 41 species of the genus *Achatinella* (Oahu tree snails) were listed as endangered in February 1981. The original recovery plan was approved 1992; a five-year review was most recently conducted in 2011 (USFWS, 2012). Critical habitat has not been designated for this species.

The genus is endemic to Oahu, where it was once common in the native forests of the Ko`olau and Wai`anae Ranges. At the time the recovery plan was written in 1993, approximately half of the species were either extinct or had not been seen for a significant length of time; nearly all of the remaining species have extremely small populations in areas restricted to the high ridges of the mountain ranges. Surveys conducted from 2005 to 2009 indicate *Achatinella mustelina*, a species restricted to the Wai`anae Range, is the most abundant of the Hawaiian tree snails. *Achatinella sowerbyana*, from the northern Ko‘olau Mountains, is the next most abundant species (USFWS, 2012).

Members of the genus Achatinella are currently found in mountainous areas of dry to wet forests and shrublands at elevations of 1300 feet (400 meters). They are arboreal, nocturnal, and feed by grazing fungus from the surface of native plant leaves and trunks. Species that *Achatinella* sp. have been observed inhabiting including *koa* (*Acacia koa*), *kukui* (*Aleurites moluccana*), *hame* (*Antidesma* sp.), *banana* (*musa paradisiaca*), *kookoolau* (*Bidens* spp.), *ahakea* (*Bobea elatior*), *ohia lehua* (*Metrosideros polymorpha*), *kopiko* (*Psychotria* spp.), and *papala kepau* (*Pisonia umbellifera*) (USFWS, 1992).

Historically, the primary causes of reduction in the species' range and abundance were likely destruction of native forest habitat and the introduction of predators, such as rats. More recently, the genus is threatened

by predation by introduced snails and rats, and the spread of non-native vegetation into higher elevation forests (USFWS, 1992).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Achatinella* sp. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect Oahu tree snails, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on Achatinella sp.

4.13 *Haha* (*Cyanea acuminata*)

Cyanea acuminata was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2013 (USFWS, 2013a). Critical habitat was designated for this species in 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Cyanea acuminata is a short-lived perennial shrub that is endemic to the island of Oahu. When listed, there were 15 populations with a total of less than 100 individuals (USFWS, 1998b). The total population has increased over time, with a total of 458 plants documented in 2012; this includes three populations with 50 or more mature individuals (USFWS, 2013a).

This species typically grows on slopes, ridges, or stream banks from 305 to 915 meters (1,000 to 3,000 feet) elevation. The plants are found in mesic to wet *ohia-uluhe*, *koa-ohia,* or *Diospyros sandwicensis* (*lama*)-*ohia* forest (HHP 1997, Lammers 1990 as reported in USFWS, 1998b). The major threats to *Cyanea acuminata* are habitat degradation and/or destruction by feral pigs; predation by rats and slugs; competition with non-native plant species; and climate change (USFWS, 2013a).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea acuminata*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Cyanea acuminata*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Cyanea acuminata*.

4.14 *Haha* (*Cyanea crispa*)

Cyanea crispa was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently completed in 2009 (USFWS, 2009a). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Cyanea crispa is a short-lived perennial shrub that is endemic to the Ko`olau Mountains of Oahu. It was historically known from the upper elevations of the Ko`olau Mountains, from Kaipapau Valley to Waialae Iki Ridge. At the time critical habitat was designated in 2003, there were 11 occurrences with a total of 56 individuals in locations including Hidden Valley, Palolo Valley, Kapakahi Gulch, Moanalua Valley, Wailupe, Ko`olau Summit Trail, Kawaipapa Gulch, Maakua Gulch, Kaipapa Gulch, Maunawili, and Pia Valley. As of 2012, there were 7 occurrences with a total of 56 individuals.

Cyanea crispa occurs in habitats ranging from steep, open mesic forests to gentle slopes or moist gullies of closed wet forests, at elevations between 185 and 730 meters (600 and 2,400 feet). Species that commonly occur in association with *Cyanea crispa* include *Cyrtandra* species (*haiwale*), *papala kepau*, and *Touchardia latifolia* (*olona*). The major threats to *Cyanea cripsa* are habitat alteration; predation by rats, slugs and feral pigs; competition with non-native plant species; and extinction due to naturally occurring events and/or reduced reproductive vigor due to the small number of remaining individuals, their limited gene pool, and restricted distribution (USFWS, 2009a).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea crispa*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Cyanea crispa*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Cyanea crispa*.

4.15 *Haha* (*Cyanea koolauensis*)

Cyanea koolauensis was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013b). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (USFWS, 2012b).

Cyanea koolauensis is a short-lived perennial shrub that is endemic to the Ko`olau Mountains of Oahu. At the time critical habitat was designated in 2003, there were 42 occurrences with a total of less than 80 individuals, known from Waimea-Malaekahana Ridge to Hawai`i Loa Ridge in the Ko`olau Mountains. As of 2012, there were 15 occurrences with approximately 100 individuals (USFWS, 2012b).

Cyanea koolauensis is usually found on slopes, stream banks, and ridge crests in wet *Metrosideros polymorpha-Dicranopteris linearis* forest or shrubland at elevations between 163 and 959 m (535 and 3,146 ft). Associated native plant species include *Acacia koa*, *Antidesma platyphyllum*, *Bidens* sp., *Bobea elatior*, *Broussaisia arguta*, *Cibotium* sp., *Diplopterygium pinnatum*, *Dubautia* sp., *Hedyotis* sp., *Machaerina* sp.,

Melicope sp., *Pittosporum* sp., *Pritchardia martii* (*loulu hiwa*), *Psychotria mariniana*, *Sadleria* sp., *Scaevola* sp. (*naupaka*), *Syzygium sandwicensis*, or *Wikstroemia* sp. (HINHP Database 2001; Lammers 1999; in Federal Register, 2003). The major threats to this species are habitat destruction by feral pigs; pherbivory by rats and slugs, trampling by hikers and military activities; competition with aggressive nonnative plant species; and climate change (USFWS, 2013b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea koolauensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Cyanea koolauensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Cyanea koolauensis*.

4.16 No Common Name (*Diellia erecta*)

Diellia erecta was listed as endangered in October 1994. The original recovery plan was approved in 1999; a five-year review was most recently conducted in 2009 (USFWS, 2009b). Critical habitat was designated for this species in 2003 and 2012. None of the critical habitat is within the Ala Wai watershed (Federal Register, 2012).

Diellia erecta is a short-lived perennial fern that was historically known from the Kokee area of Kauai, the Ko`olau Mountains on Oahu, Molokai, Lanai, Maui, and the island of Hawaii. As the time that critical habitat was designated in 2003, this species was known from Kauai, Molokai, Maui, and Hawaii; there was 1 known occurrence of 20 individuals on Hawai`i Loa Ridge on Oahu (Federal Register, 2012). In 2008, fewer than 100 wild individuals were known, with the remaining Oahu population consisting of four mature and 10 immature individuals (USFWS, 2009b).

Diellia erecta is typically found on moderate to steep gulch slopes or sparsely vegetated rock faces, in lowland mesic forests at elevations between 210 and 1,590 meters (700 and 5,200 feet); most populations occur in remote and highly fragmented native communities. Associated plant species include *pilo* (*Coprosma* sp.), *Dodonaea viscosa* (*aalii*), *Dryopteris unidentata*, *kolea* (*Myrsine* sp.), *kopiko* (*Psychotria* sp.), *halapepe* (*Pleomele auwahiensis*), *ohia ha* (*Syzygium sandwicensis*), and *akia* (*Wikstroemia* sp.) (USFWS, 2009b). The major threats to *Diellia erecta* are habitat degradation by pigs, goats, and cattle; competition with alien plant species; and random naturally occurring events causing extinction due to the small number of existing individuals (USFWS, 2009b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Diellia erecta*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Diellia erecta*.

Effects Determination

The proposed action is expected to have **No Effect** on *Diellia erecta*.

4.17 *Nanu* (*Gardenia mannii*)

Gardenia mannii was listed as endangered in October 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013c). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Gardenia mannii is a tree species that is endemic to Oahu, and was historically known from 7 widely scattered occurrences in the Wai`anae Mountains and 39 occurrences distributed along the length of the Ko`olau Mountains of Oahu (Federal Register, 2003). At the time of listing, there were 27 known populations with a total of 70-100 individuals, with only 3 populations having at least 25 mature individuals (USFWS, 1998b). By 2003, there were 49 occurrences in both the Wai`anae and Ko`olau Mountains, totaling between 69 and 80 individuals (USFWS, 2012b). As of the last 5-review in 2013, a total of 96 individuals are known, a decline from the approximately 110 individuals reported in the previous 5-year review (USFWS, 2013c).

This species is usually found on moderate to moderately steep gulch slopes between 300 and 750 meters (980 and 2,460 feet) in elevation. It typically occurs with other native mesic or wet forest species, with species including ohia, alaa, koa, and uluhe. Other associated plants include *kalia*, *hoio* (*Diplazium sandwichianum*), *alani*, *hoawa*, *ohe mauka* (*Tetraplasandra oahuensis*), *hame*, *kanawao*, *pilo*, *kawau*, *maile* (*Alyxia oliviformia*), and *kopiko* (USFWS, 1998b).

The major threats to *Gardenia mannii* are habitat degradation and/or destruction by feral pigs; potential impacts from military activities; competition with nonnative plant species; fire; and risk of extinction from random environmental events and/or reduced reproductive vigor due to the widely dispersed, small number of remaining individuals.

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Gardenia mannii*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Gardenia mannii*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Gardenia mannii*.

4.18 No Common Name (*Gouania meyenii*)

Gouania meyenii was listed as endangered in October 1991. The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2010 (USFWS, 2010a). Critical habitat was

designated for this species in 2003 and 2012; Lowland Dry Unit 16 is located on the slopes of Diamond Head within the Ala Wai watershed (Federal Register, 2012).

Gouania meyenii is a short-lived perennial shrub that was historically known from the Wai`anae Mountains; it was also recorded from Diamond Head in 1831. Currently, on Oahu, this species is found on Kamaileunu Ridge and Makaha-Wai`anae Kai Ridge; as of 2009, there are believed to be a total of 20-40 individuals (USFWS, 2010a).

This species typically grows on rocky ledges, cliff faces, and ridge tops in dry shrubland or *ohia* lowland mesic forest at an elevation of 580 to 820 meters (1,900 to 2,700 feet). Associated plants include *aalii*, *akoko*, *kopiko*, *manono*, *alani*, *olopua*, *kookoolau*, *Carex meyenii*, *lama*, *kolokolo kuahiwi*, and *Senna gaudichaudii* (*kolomona*) (USFWS, 1998b).

The major threats to *Gouania meyenii* are competition from alien plants, fire, habitat degradation by feral pigs and goats, and the small number of remaining populations (USFWS, 2010a).

Potential to Occur in the Action Area

The only portion of the watershed that has suitable habitat that could support this species occurs on the slopes of Diamond Head; the species was documented in this area in 1831 and critical habitat has since been designated. The proposed project does not involve any work on or near the slopes of Diamond Head, and no portion of the project otherwise supports suitable habitat for *Gouania meyenii*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Gouania meyenii*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Gouania meyenii*.

4.19 *Wawae iole* (*Huperzia nutans*)

Huperzia nutans (formerly *Phlegmariurus nutans*) (*wawae iole*) was listed as endangered in March 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013d). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Huperzia nutans is a short-lived fern ally, historically known from Kauai and Oahu. At the time critical habitat was designated in 2003, there were 3 occurrences containing 7 individuals in the Ko`olau Mountains of Oahu (Kaukonahua Ridge, Kaukonahua Gulch, and along Waikane-Schofield Trail). The most recent survey data found 5 small fragmented populations with a total of 11 individuals (USFWS, 2013d).

This species grows on tree trunks, usually on open ridges and slopes in *ohia*-dominated wet forests and occasionally mesic forests between 600 and 1,070 meters (2,000 and 3,500 feet) in elevation. Commonly occurring native species in these areas typically include *kanawao*, *kopiko*, *uluhe*, *uki*, *kokio*, *keokeo*, and *hame* (USFWS, 1998b).

The primary threat to *Huperzia nutans* is extinction due to naturally-occurring events and/or reduced reproductive vigor due to the limited distribution and small number of remaining individuals. Additional threats to the species are feral pigs and the noxious alien plants.

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Huperzia nutans*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Huperzia nutans*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Huperzia nutans*.

4.20 No Common Name (*Lobelia oahuensis*)

Lobelia oahuensis was listed as endangered in March 1994. The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2011 (USFWS, 2011d). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Lobelia oahuensis is a short-lived shrub that was historically known from Kahana Ridge, Kipapa Gulch, and the southeastern Ko`olau Mountains of Oahu (from Waikane and Halawa to Mount Olympus and the summit ridges above Kuliouou and Waimanalo) (Federal Register, 2012). At the time of listing, there were approximately 100-200 individuals; as of 2011, there were approximately 48 to 68 individuals of *Lobelia oahuensis* known from seven or eight locations.

The species occurs on summit cliffs in cloud-swept wet forests or in areas of low-shrub cover that are frequently exposed to heavy wind and rain. Associated plants include *akia*, *kanawao*, *manono*, *hapuu*, *ohia*, *uluhe*, *pilo*, *uki*, *olapa* (*Cheirodendron trigynum*), *naenae pua melemele* (*Dubautia laxa*), and *Labordia hosakana* (*kamakahala*).

The primary threats to *Lobelia oahuensis* are competition with nonnative plant species, and habitat degradation by feral pigs, predation by rats and slugs, and a risk of extinction from naturally-occurring events and/or reduced reproductive vigor due to the small remaining population size (Federal Register, 2012).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the habitat conditions or native species that are typically associated with *Lobelia oahuensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Lobelia oahuensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Lobelia oahuensis*.

4.21 *Ihi ihi* (*Marsilea villosa*)

Marsilea villosa (*ihihi*) was listed as endangered in June 1992. The original recovery plan was approved in 1996; a five-year review was most recently completed in 2011 (USFWS, 2011e). Critical habitat was designated for this species in 2003 and 2012; Lowland Dry Unit 7 is within the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Lobelia oahuensis is an endemic fern that was historically known from Oahu, Molokai and Niihau; populations on Oahu were reported from Kokohead, Lualualei, Ewa Plains, Nuuanu Valley, Palolo Valley and Makapuu. There were previously 11 populations documented across the islands, but as of 2010, only 6 populations are believed to be remaining. On Oahu, these include naturally occurring populations at Kokohead and Lualualei, and planted populations at Makapuu and Hanauma Bay (USFWS, 1996).

Marsilea villosa typically grows in cinder craters, vernal pools, mud flats, or lowland grasslands. It is found in areas that periodically flood, such as small depressions with clay soils; it requires standing water and drying to complete its life cycle. It can withstand shade, but is most vigorous in open areas.

The main reason for the decline of *Marsilea villosa* on Oahu is habitat degradation and destruction of natural hydrology. The greatest immediate threats to the survival of this species are encroachment and competition from naturalized, nonnative plants; continued development and habitat degradation; fire; small population size; and fragmentation, trampling, and other impacts from humans and introduced mammals (USFWS, 2011e).

Potential to Occur in the Action Area

The action area is generally comprised of either densely vegetated non-native riparian/forest habitat (such as that associated with the upper watershed detention basins), or developed areas (such as that associated with the multi-purpose detention basins and floodwalls). No portion of the action area supports regularly flooded depressional features. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Marsilea villosa*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Marsilea villosa*.

4.22 No Common Name (*Pteris lidgatei*)

Pteris lidgatei was listed as endangered in September 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2014 (USFWS, 2014b). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (USFWS, 2012b).

Lobelia oahuensis is a short-lived terrestrial fern that was historically known from Oahu, Molokai, and Maui. At the time of listing, there were 7 populations with 33 individuals on Oahu and Maui, with Oahu populations located at Kawaliki Stream, North Waimano Gulch (two populations), Kawainui Drainage, and S. Kaukonahua Gulch (USFWS, 1998c). As of 2014, only a total of 18 individuals remain (USFWS, 2014b).

This species is found in lowland wet forest habitats, at elevations ranging from 530 to 910 meters (1,750 to 3,000 feet). It typically occurs on streambanks and near waterfalls with mosses and other species of ferns. Ohia is the dominant native overstory tree species (USFWS, 2014b).

The primary threats to *Pteris lidgatei* are competition with non-native plant species; habitat destruction by feral pigs; slug herbivory; landslides and flooding; and a risk of extinction from naturally occurring events and/ or reduced reproductive vigor due to the small number of remaining individuals (USFWS 1998b; USFWS, 2014b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Pteris lidgatei*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Pteris lidgatei*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Pteris lidgatei*.

4.23 No Common Name (*Schiedea nuttallii*)

Schiedea nuttallii was listed as endangered in October 1996. The original recovery plan was approved in 1999; a five-year review was most recently completed in 2013 (USFWS, 2013e). Critical habitat was designated for this species in 2003 and 2012; no designated critical habitat occurs within the Ala Wai watershed (Federal Register, 2012).

Schiedea nuttallii is a short-lived shrub that was historically known from Kauai, Oahu, Molokai, and Maui. At the time of listing, there were approximately 75 wild individuals. As of 1996, there were a total of 40-100 individuals; locations on Oahu include Kahanahaiki Valley on the Army's Makua Military Reservation, Pahole Natural Area Reserve, and Ekahanui Gulch in the Honouliuli Preserve. Since that time, the total number of wild individuals has decreased to a total of 11, but approximately 225 individuals exist in outplanted populations.

Schiedea nuttallii on Oahu typically grows on steep rock walls and forested slopes in *Acacia koa-Metrosideros polymorpha* lowland mesic forest and *Metrosideros polymorpha-Dodonaea viscosa* forest at elevations between 436 and 1,185 m (1,430 and 3,887 feet). Associated plants include *hame*, *kopiko*, *olomea*, *papala kepau*, and *Hedyotis acuminata* (USFWS, 1999).

Schiedea nuttalii on Oahu is threatened by competition with nonnative plant species; predation by the black twig borer, slugs, and snails; habitat degradation by feral pigs; and a risk of extinction from naturally occurring events (e.g., landslides) and/or reduced reproductive vigor due to the small number of individuals (USFWS, 1999).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Schiedea nuttallii*.

As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

No critical habitat has been designated for this species within the Ala Wai watershed.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Schiedea nuttallii*.

Effects Determination

The proposed action is expected to have **No Effect** on *Schiedea nuttallii*.

4.24 No Common Name (*Spermolepis hawaiiensis*)

Spermolepis hawaiiensis was listed as endangered in November 1994. The original recovery plan was approved in 1999; a five-year review was most recently completed in 2010 (USFWS, 2010b). Critical habitat was designated for this species in 2003 and 2012; Lowland Dry Unit 6 and 7 is within the Ala Wai watershed (Federal Register, 2012).

Spermolepis hawaiiensis is an endemic herb that was historically known from Waimea on Kauai, Kokohead on Oahu, Paomai and Kahinahina on Lanai and Apua on Hawai`i (USFWS, 1999). At the time critical habitat was designated in 2003, there were 6 occurrences totaling between 110 and 910 individuals in the Wai`anae and Ko`olau Mountains (Diamond Head). As of 2012, the number of individuals ranged between several hundred to thousands of individuals, depending on annual weather conditions (Federal Register, 2012).

Spermolepis hawaiiensis on Oahu typically grows on steep to vertical cliffs or at the base of cliffs and ridges in coastal dry cliff vegetation at elevations of 25 to 839 m (82 to 2,752 ft). Associated native plant species include *Artemisia australis*, *Bidens* sp., *Dodonaea viscosa*, *Doryopteris* sp., *Heteropogon contortus*, *Santalum ellipticum*, or *Waltheria indica*.

The primary threats to *Spermolepis hawaiiensis* on Oahu are habitat degradation by feral goats; competition with nonnative plant species; and habitat destruction and death of plants due to erosion, landslides, and rock slides resulting from natural weathering (USFWS, 1999).

Potential to Occur in the Action Area

The only portion of the watershed that has suitable habitat that could support this species occurs on the slopes of Diamond Head. The proposed project does not involve any work on or near the slopes of Diamond Head, and no portion of the project otherwise supports suitable habitat for *Spermolepis hawaiiensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the watershed (surrounding Diamond Head), but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Spermolepis hawaiiensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Spermolepis hawaiiensis*.

5.0 EFFECTS DETERMINATION

Based on the information presented in Section 4.0, the effects determinations for the species addressed in this BA are summarized in Table 5. As no critical habitat occurs within the action area, there will be no effect on any critical habitat. As previously noted, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

TABLE 5
Summary of Effects Determination

Common Name	Scientific Name	Potential to Occur in Action Area	Potential Effects	Effects Determination
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Possibly (though unlikely); bats could roost in the forested portions of the action area	Harm/harassment as a result of clearing and construction, but potential impacts to be minimized with seasonal restrictions on tree clearing	May affect, but not likely to adversely affect
Hawaiian monk seal	*Monachus schauinslandi*	No; no marine or coastal habitat present within action area	None	No Effect
Oahu `elepaio	*Chasiempis sandwichensis ibidis*	Unlikely given the current distribution (although birds could possibly reoccupy habitat)	Harm/harassment as a result of clearing and construction, but potential impacts to be minimized with seasonal restrictions on vegetation clearing	May affect, but not likely to adversely affect
Hawaiian coot	*Fulica alai*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Hawaiian stilt	*Himantopus mexicanus knudseni*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Hawaiian duck	*Anas wyvilliana*	No; not expected given the extent of habitat disturbance and current species distribution	None	No Effect
Hawaiian common moorhen	*Gallinula chloropus sandvicensis*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Blackline Hawaiian damselfly	*Megalagrion nigrohamatum nigrolineatum*	No; outside known range	None	No Effect
Crimson Hawaiian damselfly	*Megalagrion leptodemas*	No; outside known range	None	No Effect
Oceanic Hawaiian damselfly	*Megalagrion oceanicum*	No; outside known range	None	No Effect
Orangeblack Hawaiian damselfly	*Megalagrion xanthomelas*	No; outside known range	None	No Effect
Oahu tree snail	*Achatinella* sp.	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea acuminata*	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea crispa*	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea koolauensis*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Diellia erecta*	No; no suitable habitat, and outside known range	None	No Effect
Nanu	*Gardenia mannii*	No; no suitable habitat, and outside known range	None	No Effect

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Common Name	Scientific Name	Potential to Occur in Action Area	Potential Effects	Effects Determination
No Common Name	*Gouania meyenii*	No; no suitable habitat, and outside known range	None	No Effect
Wawae iole	*Huperzia nutans*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Lobelia oahuensis*	No; no suitable habitat, and outside known range	None	No Effect
Ihi ihi	*Marsilea villosa*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Pteris lidgatei*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Schiedea nuttallii*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Spermolepis hawaiiensis*	No; no suitable habitat, and outside known range	None	No Effect

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Appendix E6
Renderings of Flood Risk Management Measures

Figure E1. Conceptual Rendering of the Waiakeakua Debris and Detention Basin

Figure E2. Conceptual Rendering of the Woodlawn Ditch Detention Basin

Figure E3. Conceptual Rendering of the Pukele Debris and Detention Basin

Figure E4. Conceptual Rendering of the Makiki Debris and Detention Basin

Figure E5. Conceptual Rendering of the Ala Wai Canal Floodwalls (near Ala Wai Boulevard)

Figure E6. Conceptual Rendering of the Ala Wai Canal Floodwalls (near Kalakaua Avenue)

Figure E7. Conceptual Rendering of the Hausten Ditch Detention Basin (with aesthetic improvements)

Figure E8. Conceptual Rendering of the Ala Wai Golf Course Detention Basin

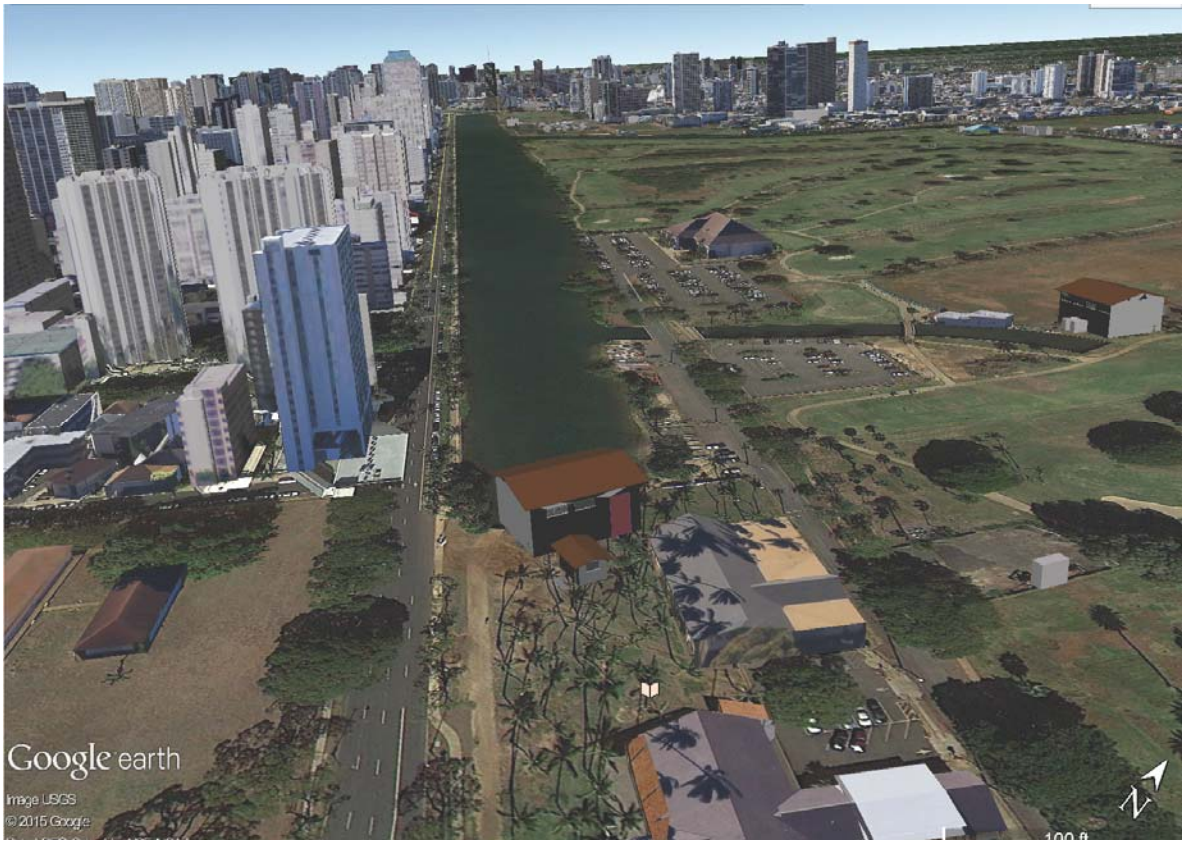

Figure E9. Conceptual Rendering of the Pump Stations at the East End of the Ala Wai Canal

Appendix E7
Draft Record of Decision

DRAFT
RECORD OF DECISION
ALA WAI CANAL PROJECT; HONOLULU, HAWAII

FLOOD RISK MANAGEMENT

The Final Integrated Feasibility Report and Environmental Impact Statement (EIS), dated [DATE], for the Ala Wai Canal Project Feasibility Study addresses flood risk management for the Ala Wai Watershed, located in Honolulu, Hawaii. Based on the report, the reviews of other Federal, State, and local agencies, input from the public, and the review by my staff, I find that the plan recommended by the Chief of Engineers to be technically feasible, economically and environmentally justified, cost effective, in accordance with environmental statutes, and in the public interest.

The Final Feasibility Report/EIS evaluated various structural and non-structural alternative plans to address the flood damage reduction needs of the Ala Wai Watershed. The recommended plan (Alternative 3A-2.2) is the National Economic Development (NED) plan and consists of a series of in-stream and multi-purpose debris and detention basins, as well as floodwalls along the Ala Wai Canal. Specific flood damage reduction features include:

- Construction of six in-stream debris and detention basins in the upper reaches of the watershed;
- Construction of one stand-alone debris catchment feature;
- Construction of three multi-purpose detention basins in open space areas through the developed watershed;
- Construction of floodwalls along the Ala Wai Canal (including three associated pump stations); approximately 1.7 miles along left bank and approximately 0.9 mile along right bank (including gaps for bridges); and
- Improvements to the existing flood warning system (non-structural).

Mitigation features include:

- Improvements to two in-stream structures to eliminate a migratory passage barrier for native aquatic species; and
- Monitoring mitigation performance and corrective action, if needed.

In addition to a “No Action” plan, a range of structural and non-structural alternatives for flood damage reduction were considered through the plan formulation and evaluation process, as described in the Final Integrated Feasibility Report and EIS. In addition to the Recommended Plan, alternatives that were considered included an alternative which maximized attenuation with a dam in the upper watershed, an alternative which maximized detention in the developed watershed, and an alternative which focused the flood risk reduction measures where the majority of the damages occur (i.e. along the Ala Wai Canal). Non-structural solutions were also considered; these included improvements to the flood warning system; raising, relocating and acquiring or buying-out structures; floodproofing; and building individual berms and floodwalls to protect small clusters of buildings. These were considered both as a stand-alone non-structural alternative plan, as well as in combination with structural solutions. Alternative 3A-2.2, which is the NED plan and the environmentally preferable alternative, would protect against a flood event with a 1-percent annual change of exceedance with 95-percent conditional non-exceedance probability.

Consistent with reducing flood damages in an environmentally sustainable manner, the project will be designed, constructed and operated to avoid impacts to native aquatic species by incorporating natural-bottom arch culverts to maintain species passage and by limiting work in the streams to low-flow conditions. All practicable means to avoid or minimize adverse environmental effects have been incorporated into the recommended plan.

The Draft Integrated Feasibility Report and EIS was circulated for public review for 45 days from August 21 to October 7, 2015. A public meeting was held September 30, 2015. A response was provided to all comments submitted within the 45-day public review period, with copies provided in the Final Integrated Feasibility Report and EIS.

All applicable laws, executive orders, regulations and local government plans were considered in the evaluation of alternatives. Based on review of these evaluations, I find that the benefits outweigh the costs and any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

_____
Date

_____
[NAME]
Assistant Secretary of the Army (Civil Works)

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX F
CULTURAL RESOURCES

F1 National Historic Preservation Act (NHPA) Section 106 Consultation Documentation

- Consultation Letter Distributing Technical Reports (dated February 20, 2014)
- Consultation Letter Initiating Consultation (dated August 21, 2014) and Comments from Office of Hawaiian Affairs
- Consultation Letter Redefining the Area of Potential Effects (dated March 10, 2015), and Correspondence with Historic Hawaii Foundation [*Note: maps from this letter have been revised by removing the locations of archaeological sites to protect the resource per 36 CFR 800.11(c)*]
- Consultation Letter Identifying Historic Properties, Providing Significance Evaluations, Presenting Determinations of Effect, and Proposing Conditions to Mitigate Adverse Effects (dates June 29, 2015) [*Note: maps from this letter have been revised by removing the locations of archaeological sites to protect the resource per 36 CFR 800.11(c)*]

F2 Cultural Impact Assessment

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

SECTION 209 OF FLOOD CONTROL ACT OF 1962 (PUBLIC LAW 87-874)

APPENDIX F1

CULTURAL RESOURCES

National Historic Preservation Act Section 106 Consultation Documentation

February 20, 2014 Consultation Letter Distributing Technical Reports

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

REPLY TO
ATTENTION OF:

20 February 2014

Environmental Programs Branch
CEPOH-PP-E

Alan Downer
Administrator
State Historic Preservation Division
Kakuhihewa Building
601 Kamokila Blvd., Suite 555
Kapolei, HI 96707

SUBJECT: Submittal of Technical Reports for Ala Wai Watershed Feasibility Study

Dear Mr. Downer :

The Civil Works and Public Works Branch, Honolulu District, United States Army Corps of Engineers is submitting four technical reports for your review in advance of opening consultation with your office pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended (16 USC 470f), for the Ala Wai Canal Feasibility Study project. The Ala Wai Canal (also known as the Ala Wai Watershed) project is a flood risk management project being investigated under Section 209 of the Flood Control Act of 1962 (Public Law 87-874). The project sponsor is the State Department of Land and Natural Resources (DLNR), Engineering Division. The study area consists of the Ala Wai watershed and its four sub-watersheds of Makiki, Manoa, Palolo, and Ala Wai. Multiple construction and TMK locations for detention basins/small dry reservoirs and in-stream debris catchments are identified in Alternative 3, the current preferred plan of eight alternatives evaluated, and includes conceptual engineering footprints and profiles that are 10% complete (Enclosure 1).

The reports are titled:
Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project: Makiki, Mānoa and Pālolo Ahupuaʻa, Honolulu District, Oʻahu Island, TMK: [1] 2–3, 2–4, 2–5, 2–6, 2–7, 2–8, and 2–9; [1] 3–1, 3–2, 3–3 and 3–4, Volume I:
Cultural Resources of the Makiki, Mānoa and Pālolo Ahupuaʻa (Enclosure 2);

Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project: Makiki, Mānoa and Pālolo Ahupuaʻa, Honolulu District, Oʻahu Island, TMK: [1] 2–3, 2–4, 2–5, 2–6, 2–7, 2–8, and 2–9; [1] 3–1, 3–2, 3–3 and 3–4, Volume II:
Cultural Resources of Kakaʻako and Waikīkī Ahupuaʻa (Enclosure 3);

Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project, Honolulu, Makiki, Mānoa, Pālolo, and Waikīkī Ahupuaʻa, Honolulu District, Oʻahu Island, TMK: [1] 2–3, 2–4, 2–5, 2–6, 2–7, 2–8, and 2–9; [1] 3–1,3–2, 3–3 and 3–4, Volume III: Ethnographic Study (Enclosure 4); and

Historic Structures Inventory Survey of the Ala Wai Watershed (Enclosure 5).

Alternative 3 is still subject to revisions and approval by our local sponsor, DLNR. The Final Feasibility Study report, with the complementing Final Environmental Impact Statement is scheduled for submittal to, and approval by, the Chief of Engineers, United States Army Corps of Engineers by 30 October 2015.

Copies of these technical reports have also been provided to the federal Advisory Council on Historic Preservation, state Office of Hawaiian Affairs, and Oahu Council of Hawaiian Civic Clubs for their review and comments. Electronic copies on CD are also available by request.

The Corps, at your convenience, would like to meet with you during the week of March 17-21, 2014 to discuss measures to advance and ensure compliance with Section 106. Should you have any questions, please contact Mr. Farley Watanabe, Archaeologist and Technical Lead of my Environmental Programs Branch, by telephone at (808) 835-4305 or e-mail Farley.K.Watanabe@usace.army.mil.

DAN NAKAMURA
Chief, Environmental Programs Branch

5 Encls. as

List of Consulting Parties

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Tom McCulloch
Advisory Council on Historic Preservation
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Na Daniel Naho`opii
Pelekikena, Oahu Council
Association of Hawaiian Civic Clubs
PO Box 1135
Honolulu, Hawai`i 96807

August 21, 2014 Consultation Letter Initiating Consultation and Comments from Office of Hawaiian Affairs

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

21 August 2014

Environmental Programs Branch
CEPOH-PP-E

Alan Downer
Administrator
State Historic Preservation Division
Kakuhihewa Building
601 Kamokila Blvd., Suite 555
Kapolei, HI 96707

SUBJECT: Coordination for Determination of Area of Potential Effect, Ala Wai Canal Project

Dear Mr. Downer,

The United States Army Corps of Engineers, Honolulu District (the Corps) has preliminarily determined the Area of Potential Effect (APE) for the Ala Wai Canal Project in accordance with 36 CFR 800.16(d). Based on an evaluation of the final array of alternatives (Alternatives 2A and 3A, as described in our previous correspondence), the Corps has tentatively selected Alternative 3A as the preferred alternative. Both alternatives will be evaluated in a draft combined Feasibility Report and Environmental Impact Statement, which is scheduled to be available for public review in early 2015.

A draft supplemental technical report reporting on additional interviews with Native Hawaiian Organizations, lineal descendants, and knowledgeable individuals of the watersheds is in preparation and will be made available to consulting parties upon request. Three technical reports were previously transmitted to the Advisory Council on Historic Preservation (ACHP), Administrator, State Historic Preservation Division (SHPD), Office of Hawaiian Affairs, and Oahu Council, Association of Hawaiian Civic Clubs and are also available upon request.

The following APE is proposed to delineate resources subject to Section 106 compliance (see Enclosure 1 for listing of Tax Map Keys (TMKs) potentially affected):

For Archaeological Resources, the APE is proposed to be the entire Tax Map Key parcel in which all areas of direct ground disturbance are proposed. These areas include stream debris catchment structures, detention basins, floodwalls, access roads, and storage yards for equipment and construction materials.

For Traditional Cultural Properties (TCPs) the APE is proposed to be the extension of a visual or aesthetic element extending outwards and/or upwards 500 feet from the Tax Map Key parcels in which all areas of direct ground disturbance are proposed and TCPs are reported to be present.

deep when a district or thematic element is listed on the State and National Register of Historic Places. For built structures in, along and over a stream segment where a ground disturbing measure is proposed, the APE is proposed to be the entire Tax Map Key parcel in which all areas of direct ground disturbance are proposed extending to a linear distance 500 feet downstream.

The Corps requests your review, comments and concurrence to the proposed APE within 31 days of your receipt of this letter. Maps depicting the proposed APE are included as Enclosure 2, and a list of parties to whom this letter has been sent is included as Enclosure 3.

The Corps, at your convenience, would like to meet with you during the weeks of September 15-26, 2014 to discuss measures to advance and ensure compliance with Section106. Should you have any questions, please contact Mr. Farley Watanabe, Archaeologist and Technical Lead of my Environmental Programs Branch, by telephone at (808) 835-4305 or e-mail Farley.K.Watanabe@usace.army.mil.

Sincerely,

DAN NAKAMURA, P.E
Chief, Environmental Programs Branch
Programs and Project Management Division

3 Encls. as

Subwatershed	Measure	Location	Drawing Sheet	TMK Parcel	Area in Acres	
					APE by TMK	Direct Ground Disturbance
Structural						
Manoa	Debris and detention basin	Waiakeakua Stream	**C-302**	29054002	3.3	
				29054004	5.1	
				29054006	2.6	
				29054034	1.0	
				subtotal	12.0	1.2
	Debris and detention basin	Waihi Stream	**C-301**	29054019	5.1	
				29054029	1.3	
				29055001	813.0	
				29055009	1.9	
				subtotal	821.3	2.0
	Detention basin	Woodlawn Ditch	**C-305**	29043002	14.6	1.1
				subtotal	14.6	1.1
	In-stream debris catchment	Manoa Stream	**C-318**	29029053	0.2	2.2
				29036003	44.0	
				subtotal	58.7	2.2
	Multi-purpose detention basin	Kanewai Community Park	**C-306**	28029004	2.6	
				28029011	9.3	
				subtotal	11.9	5.1
Palolo	Debris and detention basin	Waiomao Stream	**C-308**	34016059	4.1	
				34034001	4.8	
				34034008	0.1	
				34034009	3.3	
				subtotal	12.3	1.0
	Debris and detention basin	Pukele Stream	**C-313**	34019050	1.3	
				34019008	0.2	
				34019009	0.2	
				34019010	0.2	
				34019052	2.6	
				subtotal	4.7	0.5
Makiki	Debris and Detention basin	Makiki Stream	**C-315**	25020001	2.1	
				25020005	1.3	
				25020008	2.6	
				subtotal	6.1	3.1
Ala Wai	Configuration 1 -Floodwalls (3-4')	Both sides of canal	**C-101**	27036001	84.0	7.0
	Configuration 2-Floodwalls (1-3')	Both sides of canal	**C-106/C-309/ C-401**	27036001	84.0	7.0
				subtotal	84.0	7.0
	Multi-purpose detention basin	Ala Wai Golf course	**C-103/C-317**	27036002	145.6	4.9
				subtotal	145.6	4.9
	Detention basin	Hausten Ditch	**C-102/C-316**	27036001	84.0	0.8
				subtotal	84.0	0.8
				TOTAL	**1228.2**	**28.9**

ENCLOSURE 1. Area of Potential Effect by TMK and Direct Ground Disturbance Acreage

Alternative 3: Detention Basins/ Small Dry Reservoirs

Flood Warning System

Waihi Debris & Detention Basin

Waiakeakua Debris & Detention Basin

Pukele Debris & Detention Basin

Waiomao Debris & Detention Basin

Woodlawn Ditch Detention Basin

Manoa In-stream Debris Catchment

Makiki Debris & Detention Basin

Kanewai Field Multi-Purpose Detention Basin

Hausten Ditch Detention

Ala Wai Golf Course Multi-purpose Detention

Ala Wai Canal Floodwalls

Waihi Stream
Luakaha Stream
Nuuanu Stream
Waiakeakua Stream
Aihualama Stream
Pukele Stream
Waiomao Stream
Kaaha Stream
Manoa Stream
Makiki Stream
Palolo Stream
Ala Wai Stream
Ala Wai Canal

ST. LOUIS HEIGHTS
MANOA VALLEY
PALOLO VALLEY
Punchbowl
Ala Moana Beach Park
Ala Wai Small Boat Harbor
Diamond Head State Monument
PACIFIC OCEAN

Island of Oahu
Project Location

LEGEND
- Future Project Hyperlink Button
- Stream
- Road
- Stream Reach
- Ala Wai Management Area

N E S W

0 750 1,500 3,000 Feet

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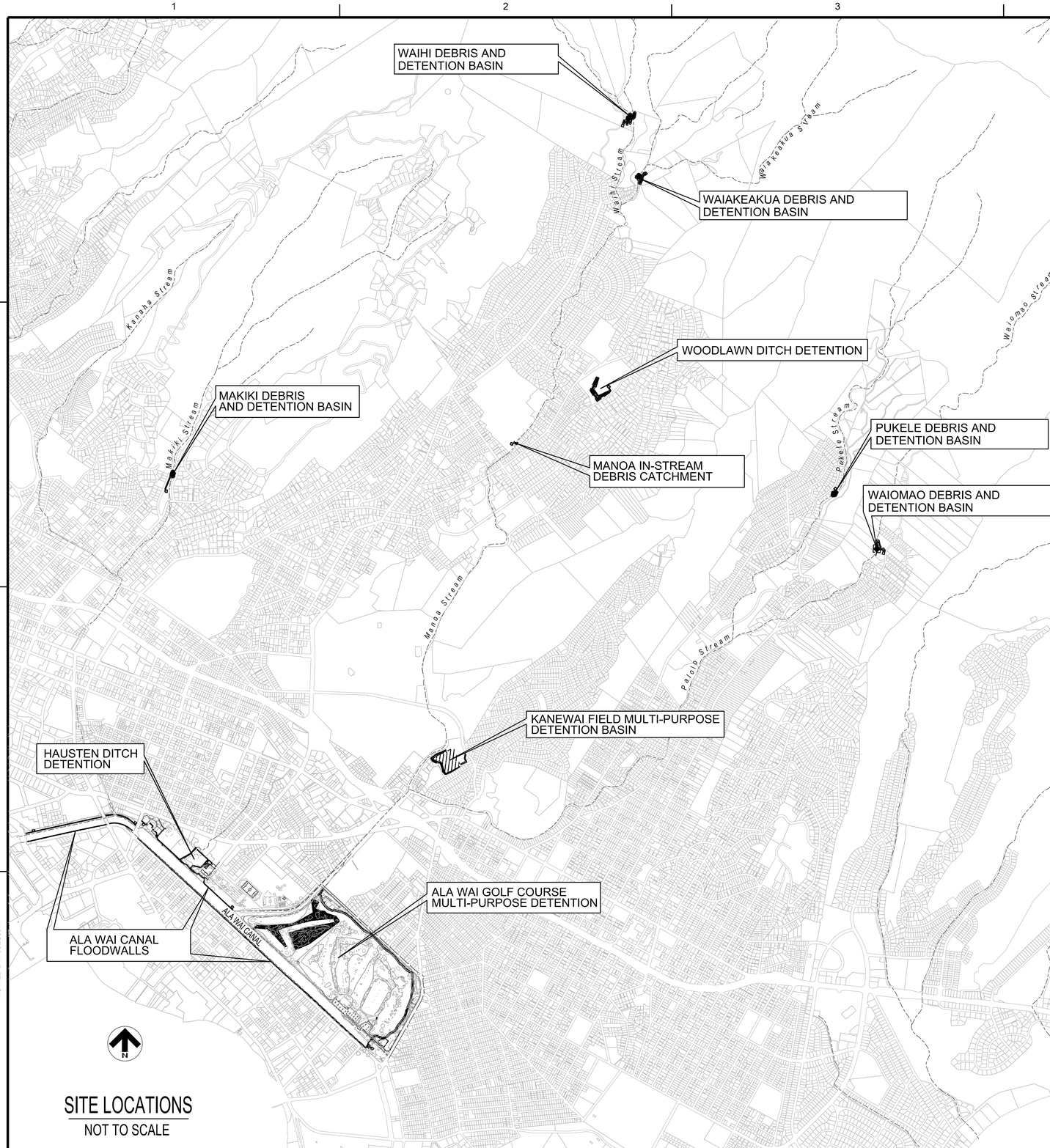


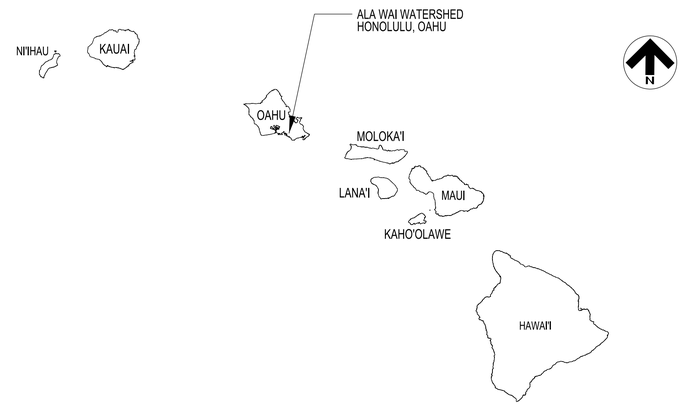
SITE LOCATIONS

NOT TO SCALE

ALA WAI WATERSHED PROJECT

HONOLULU, OAHU, HI

PROJECT TITLE



VICINITY MAP

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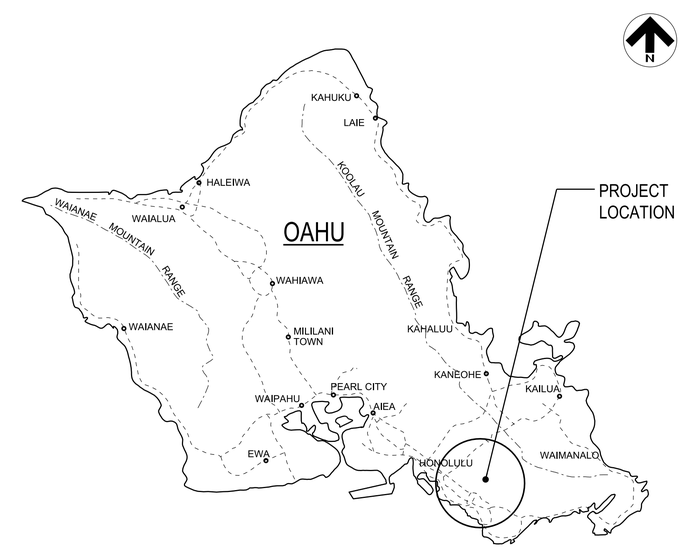

PROJECT LOCATION

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REVISION:

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HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

SITE LOCATIONS
PROJECT LOCATION & VICINITY MAP

SHEET IDENTIFICATION
G-001
SHEET 1 OF 28

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ALA WAI WATERSHED PROJECT
INDEX TO DRAWINGS

SHT. NO	SHT. REF. NO.	DESCRIPTION
1	G-001	SITE LOCATIONS, PROJECT LOCATION AND VICINITY MAP
2	G-002	INDEX TO DRAWINGS
3	C-101	ALA WAI CANAL FLOODWALLS, SITE PLAN
4	C-102	HAUSTEN DITCH DETENTION, SITE PLAN
5	C-103	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PLAN
6	C-104	ALA WAI UPPER LEFT BANK PLAN
7	C-105	ALA WAI UPPER END PLAN
8	C-106	KALAKAUA AVE AND ALA WAI BLVD PLAN
9	C-107	ALA WAI CANAL AND MCCULLY ST PLAN
10	C-301	WAIHI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
11	C-302	WAIAKEAKUA DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
12	C-303	PUMP STATION 1, PLAN AND SECTIONS
13	C-304	PUMP STATION 2, PLAN AND SECTIONS
14	C-305	WOODLAWN DITCH DETENTION BASIN, PLAN AND SECTIONS
15	C-306	KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN, PLAN AND SECTIONS
16	C-307	PUMP STATION 3, PLAN AND SECTIONS
17	C-308	WAIOMAO DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
18	C-309	ALA WAI CANAL MIDDLE AND LOWER RIGHT BANK, PROFILE AND SECTION
19	C-310	ALA WAI CANAL MIDDLE AND LOWER LEFT BANK, PROFILE AND SECTION
20	C-311	ALA WAI CANAL UPPER LEFT BANK, PROFILE
21	C-313	PUKELE DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
22	C-315	MAKIKI DEBRIS AND DETENTION BASIN, PLAN AND SECTIONS
23	C-316	HAUSTEN DITCH DETENTION FLOODWALLS AND BERM, PROFILE AND SECTIONS
24	C-317	ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE AND SECTION
25	C-318	MANOA IN-STREAM DEBRIS CATCHMENT, PLAN AND SECTIONS
26	C-401	HAUSTEN BRIDGE CONCRETE WALL, PLAN, SECTION AND ELEVATION
27	C-501	STRUCTURAL NOTES AND MISCELLANEOUS DETAILS
28	C-601	SCHEDULE OF SLIDE GATES

GENERAL NOTES:

1. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. COORDINATE SYSTEM: NAD 1983 (HARN), HAWAII ZONE 3 (US FEET)
3. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
4. UNLESS SHOWN OTHERWISE, ALL DISTURBED AREAS NOT RECEIVING A HARD SURFACE SHALL BE COVERED WITH GRASS.
5. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
6. EXISTING UNDERGROUND UTILITIES OBTAINED FROM AS-BUILTS AND FROM FIELD SURVEYS. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION AND PROTECT ALL EXISTING UTILITIES DURING CONSTRUCTION.
7. THE CONTRACTOR SHALL VERIFY AND CHECK ALL DIMENSIONS AND DETAILS SHOWN ON THE DRAWINGS PRIOR TO THE START OF CONSTRUCTION. ANY DISCREPANCY SHALL BE IMMEDIATELY BROUGHT TO THE ATTENTION OF THE CONTRACTING OFFICER FOR CLARIFICATION BEFORE PROCEEDING WITH CONSTRUCTION.
8. THERE WILL BE A FLOODWARNING SYSTEM INSTALLED FOR THIS PROJECT.
9. ANY ITEMS OF HISTORICAL OR ARCHEOLOGICAL VALUE OBSERVED DURING CONSTRUCTION ACTIVITIES SHALL BE REPORTED IMMEDIATELY TO THE CONTRACTING OFFICER, AND THE CONTRACTOR SHALL CEASE ALL ACTIVITIES THAT MAY RESULT IN THE DESTRUCTION OF SUCH RESOURCES IN ACCORDANCE WITH THE SPECIAL CONTRACT REQUIREMENTS.

GENERAL ABBREVIATIONS

A.C.	ASHPALT CONCRETE
AVE	AVENUE
BLVD	BOULEVARD
CONC	CONCRETE
DIA	DIAMETER
EL	ELEVATION
EXIST	EXISTING
FT	FOOT, FEET
IN	INCH, INCHES
INV	INVERT
LB	LEFT BANK
MAX	MAXIMUM
MSL	MEAN SEA LEVEL
NTS	NOT TO SCALE
o.c.	ON CENTER
O&M	OPERATIONS AND MAINTENANCE
PL	PLACE
RB	RIGHT BANK
RCP	REINFORCED CONCRETE PIPE
RD	ROAD
SQ	SQUARE
ST	STREET
STA	STATION
THK	THICK
TMK	TAX MAP KEY
TYP	TYPICAL
W.S.	WATER SURFACE
YR	YEAR

SYMBOLS

&	AND
@	AT
℄	CENTER LINE
'	FOOT, FEET
"	INCH, INCHES

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ALA WAI WATERSHED PROJECT

INDEX OF DRAWINGS, GENERAL NOTES
ABBREVIATIONS & SYMBOLS

SHEET IDENTIFICATION
G-002
SHEET 2 OF 28

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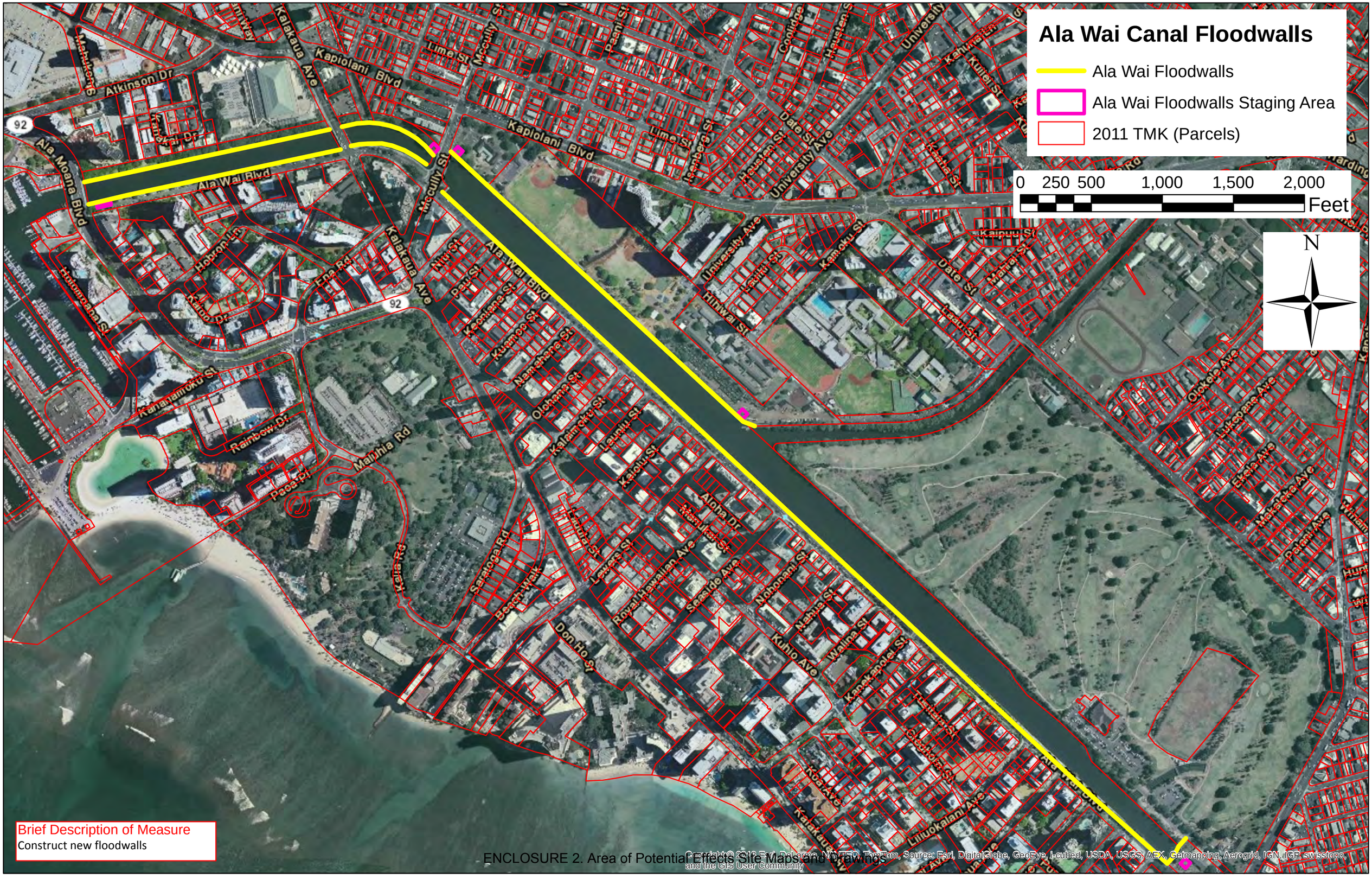
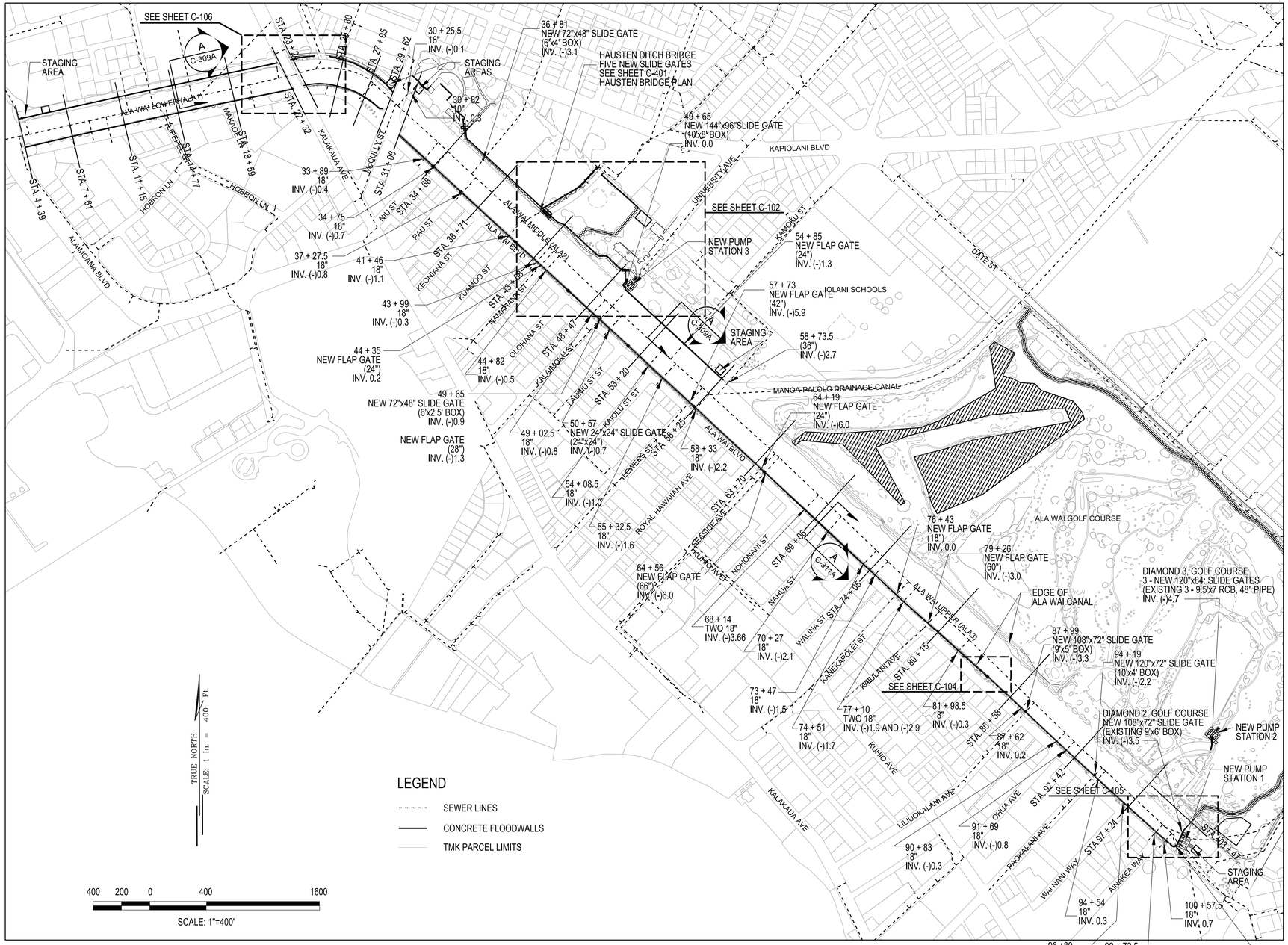


ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings

Conceptual Renderings of Ala Wai Canal Floodwalls

Near Kalakaua Avenue

Near Ala Wai Boulevard



PLAN
ALA WAI CANAL FLOODWALLS

ALA WAI CANAL INTERIOR DRAINAGE TABLE

CULVERT NAME	STATION	SIZE & TYPE	NOTES
DIAMOND 2, GOLF COURSE	102+45.5	108"x72" SLIDE GATE	PUMP STATION 1
DIAMOND 1, ALA WAI BLVD	101+75	144"x96" SLIDE GATES	
DIAMOND 3, GOLF COURSE	96+67	3 - 120"x84" SLIDE GATES	PUMP STATION 2
100+57.5	100+57.5	18" FLAP GATE	INV. 0.7
99+72.5	99+72.5	18" FLAP GATE	INV. 0.6
96+80	96+80	18" FLAP GATE	INV. (-)0.3
94+54	94+54	18" FLAP GATE	INV. 0.3
94+19	94+19	120"x72" SLIDE GATE	INV. (-)2.2
91+69	91+69	18" FLAP GATE	INV. (-)0.8
90+83	90+83	18" FLAP GATE	INV. (-)0.3
87+99	87+99	108"x72" SLIDE GATE	INV. (-)3.3
87+62	87+62	18" FLAP GATE	INV. 0.2
81+98.5	81+98.5	18" FLAP GATE	INV. (-)0.3
79+26	79+26	60" FLAP GATE	INV. (-)3.0
77+10	77+10	TWO 18" FLAP GATES	INV. (-)1.9 AND (-)2.9
76+43	76+43	18" FLAP GATE	INV. 0.0
74+51	74+51	18" FLAP GATE	INV. (-)1.7
73+47	73+47	18" FLAP GATE	INV. (-)1.5
70+27	70+27	18" FLAP GATE	INV. (-)2.1
68+14	68+14	TWO 18" FLAP GATES	INV. (-)3.7
64+56	64+56	66" FLAP GATE	INV. (-)6.0
64+19	64+19	24" FLAP GATE	INV. (-)6.0
58+73.5, RB	58+73.5	36" FLAP GATE	INV. (-)2.7
58+33	58+33	18" FLAP GATE	INV. (-)2.2
57+73	57+73	42" FLAP GATE	INV. (-)5.9
55+32.5	55+32.5	18" FLAP GATE	INV. (-)5.6
54+08.5	54+08.5	18" FLAP GATE	INV. (-)1.0
54+85, RB	54+85	24" FLAP GATE	INV. (-)1.3
50+57	50+57	24"x24" SLIDE GATE	INV. (-)0.7
49+65, RB	49+65	144"x96" SLIDE GATE	INV. 0.0, PUMP STATION 3
49+65	49+65	72"x48" SLIDE GATE & 28" FLAP GATE	INV. (-)1.3 & (-)0.9
49+02.5	49+02.5	18" FLAP GATE	INV. (-)0.8
44+82	44+82	18" FLAP GATE	INV. (-)0.5
44+35	44+35	24" FLAP GATE	INV. 0.2
43+99	43+99	18" FLAP GATE	INV. (-)0.3
HAUSTEN DITCH BRIDGE	42+10	4 - SLIDE GATES	SEE SHEET C-401
41+46	41+46	18" FLAP GATE	INV. (-)1.1
37+27.5	37+27.5	18" FLAP GATE	INV. (-)0.8
36+81, RB	36+81	72"x48" SLIDE GATE	INV. (-)3.1
34+75	34+75	18" FLAP GATE	INV. (-)0.7
33+89	33+89	18" FLAP GATE	INV. (-)0.4
30+82, RB	30+82	10" FLAP GATE	INV. 0.3
30+25.5, RB	30+25.5	18" FLAP GATE	INV. (-)0.1

NOTES:

1. SEE SHEET C-309 FOR THE RIGHT BANK (MOUNTAIN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
2. SEE SHEET C-310 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI MIDDLE (ALA2) AND ALA WAI LOWER (ALA1).
3. SEE SHEET C-311 FOR THE LEFT BANK (OCEAN SIDE) PROFILE OF ALA WAI UPPER (ALA3).
4. PUMP STATIONS WILL BE 50'x50'.

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HONOLULU DISTRICT

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PLOT DATE:
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REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT
ALA WAI LOWER, MIDDLE & UPPER FLOODWALLS
SITE PLAN

SHEET IDENTIFICATION
C-101
SHEET 3 OF 28

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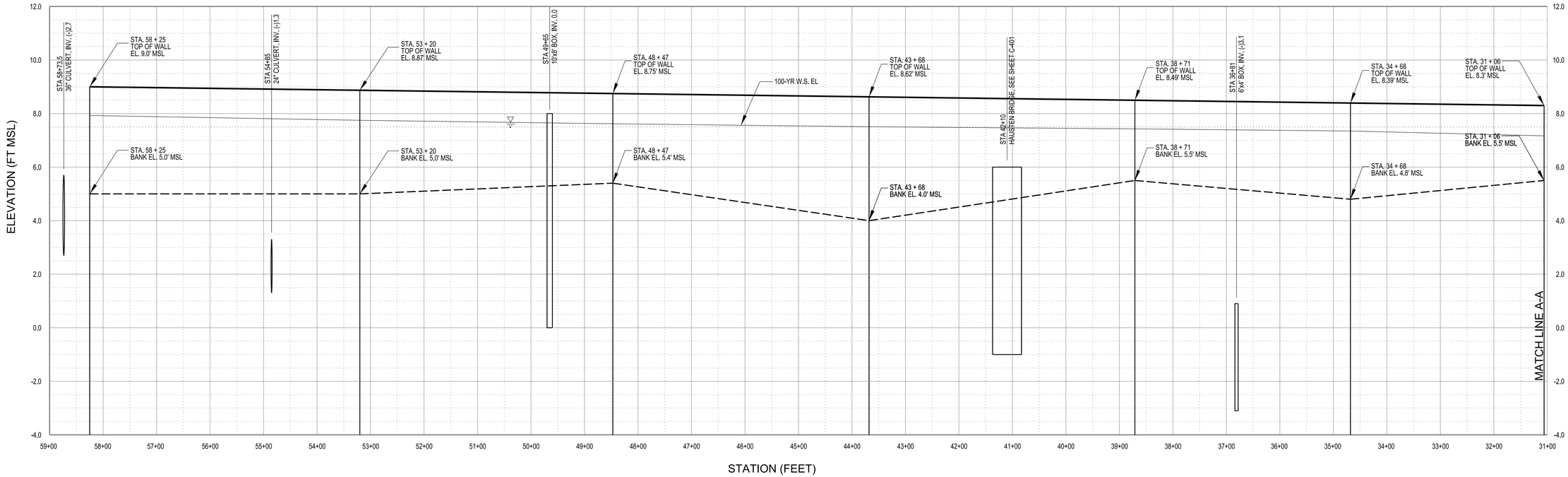

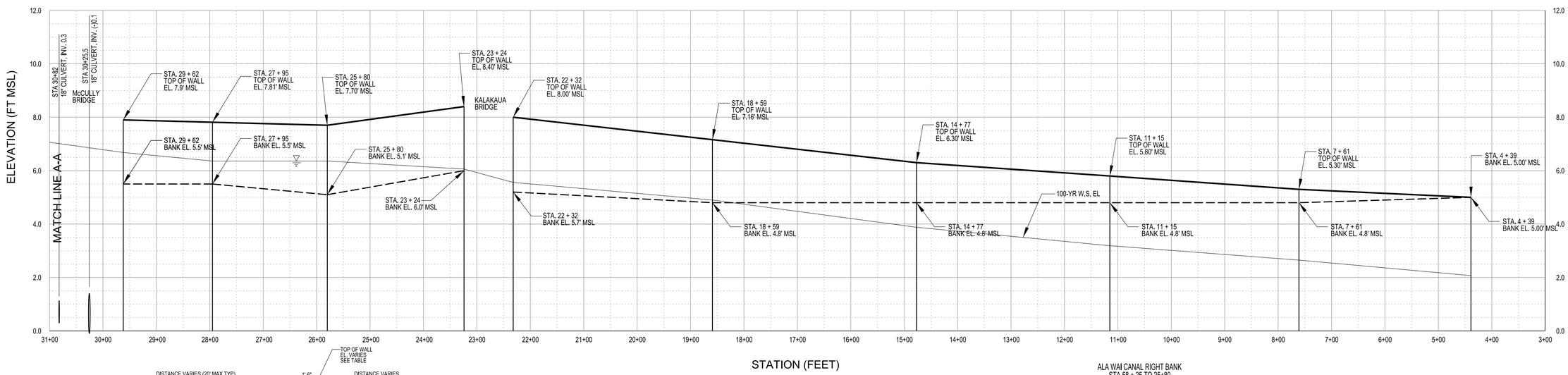

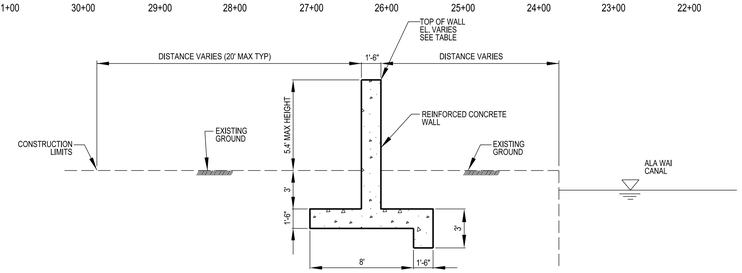

A TYPICAL RIGHT BANK REINFORCED CONCRETE FLOODWALL SECTION

NOT TO SCALE

PROFILE

ALA WAI MIDDLE (ALA2) AND LOWER (ALA1) RIGHT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

ALA WAI CANAL RIGHT BANK
STA 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	4.00	9.00
53 + 20	3.87	8.87
48 + 47	3.35	8.75
43 + 68	4.62	8.62
38 + 71	2.99	8.49
34 + 68	3.59	8.39
31 + 06	2.80	8.30
MCCLULLY BRIDGE		
29 + 62	2.40	7.90
27 + 95	2.31	7.81
25 + 80	2.60	7.70

ALA WAI CANAL RIGHT BANK
STA 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.40	8.40
22 + 32	2.80	8.00
18 + 59	2.36	7.16
14 + 77	1.50	6.30
11 + 15	1.00	5.80
7 + 61	0.50	5.30
4 + 39	0	5.00

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PLOT DATE:
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ALA WAI WATERSHED PROJECT

ALA WAI MIDDLE & LOWER RIGHT BANK FLOODWALLS
PROFILE AND SECTION

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C-309
SHEET 18 OF 28

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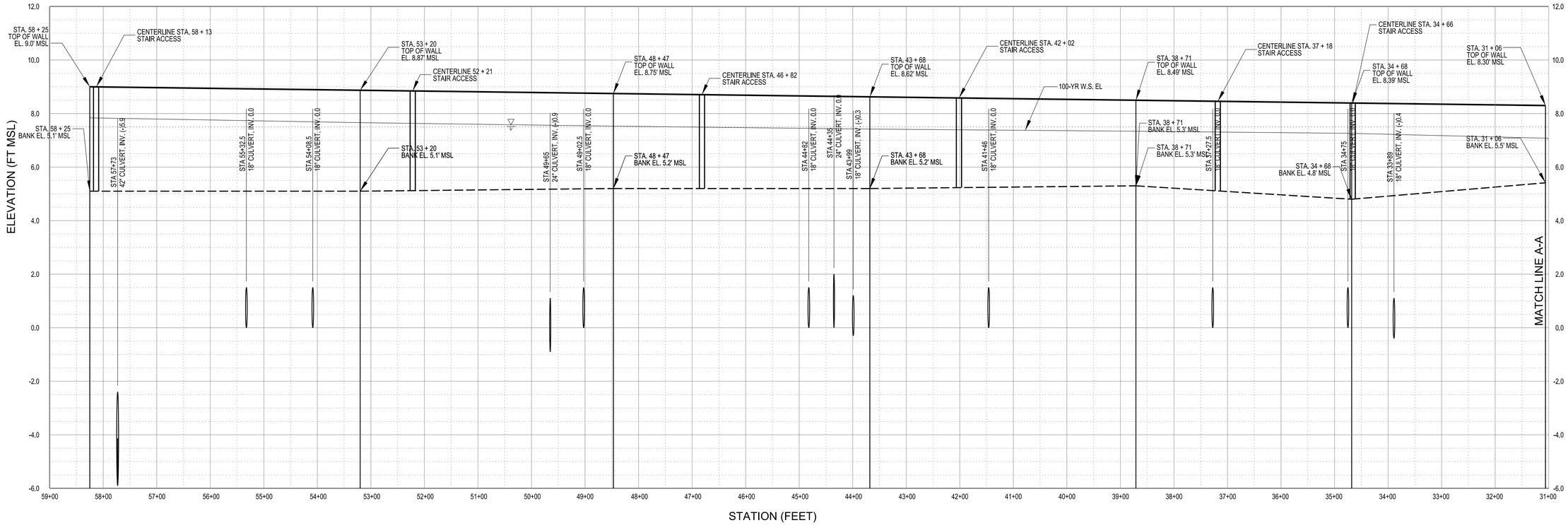
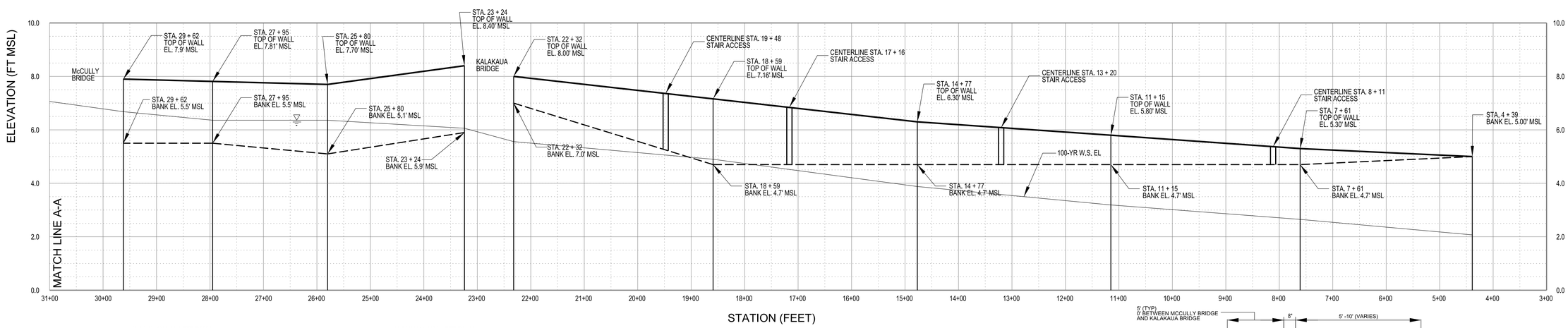




ALA WAI CANAL LEFT BANK
STA TO 58 + 25 TO 25+80

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
58 + 25	3.90	9.00
53 + 20	3.77	8.87
48 + 47	3.55	8.75
43 + 68	3.42	8.62
38 + 71	3.19	8.49
34 + 68	3.59	8.39
31 + 06	2.80	8.30
MCCLULLY BRIDGE		
29 + 62	2.40	7.90
27 + 95	2.31	7.81
25 + 80	2.60	7.70

ALA WAI CANAL LEFT BANK
STA TO 23 + 24 TO 4 + 39

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
23 + 24	2.50	8.40
KALAKAUA BRIDGE		
22 + 32	1.00	8.00
18 + 59	2.46	7.16
14 + 77	1.60	6.30
11 + 15	1.10	5.80
7 + 61	0.60	5.30
4 + 39	0	5.00

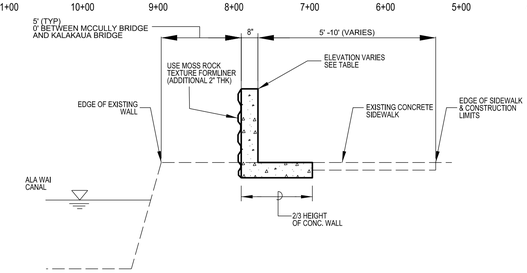
PROFILE

ALA WAI CANAL MIDDLE (ALA2) AND LOWER (ALA1) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

NOTES:

1. SEE DETAIL "C" ON SHEET C-311 FOR ALA WAI CANAL MIDDLE (ALA2) TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION.
2. ALA WAI CANAL LOWER (ALA1) IS FROM STATION 23+24 TO STATION 4+39.



B TYPICAL ALA WAI LOWER (ALA1) LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

US Army Corps of Engineers®
HONOLULU DISTRICT

35% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
DRAWING NUMBER:
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: ALA WAI CANAL MIDDLE & LOWER LEFT BANK PROFILE & SECTION
DATE:
REVISION:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI MIDDLE & LOWER LEFT BANK FLOODWALLS
PROFILE AND SECTION

SHEET IDENTIFICATION
C-310
SHEET 19 OF 28

FILE: c:\pw-work\poh-1\j3ec9jhhd\d1437180\Ala_Wai_C-310xxx.dgn
MODEL NAME: C-310A
DATE & TIME: 8/4/2014 4:54:37 PM
LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
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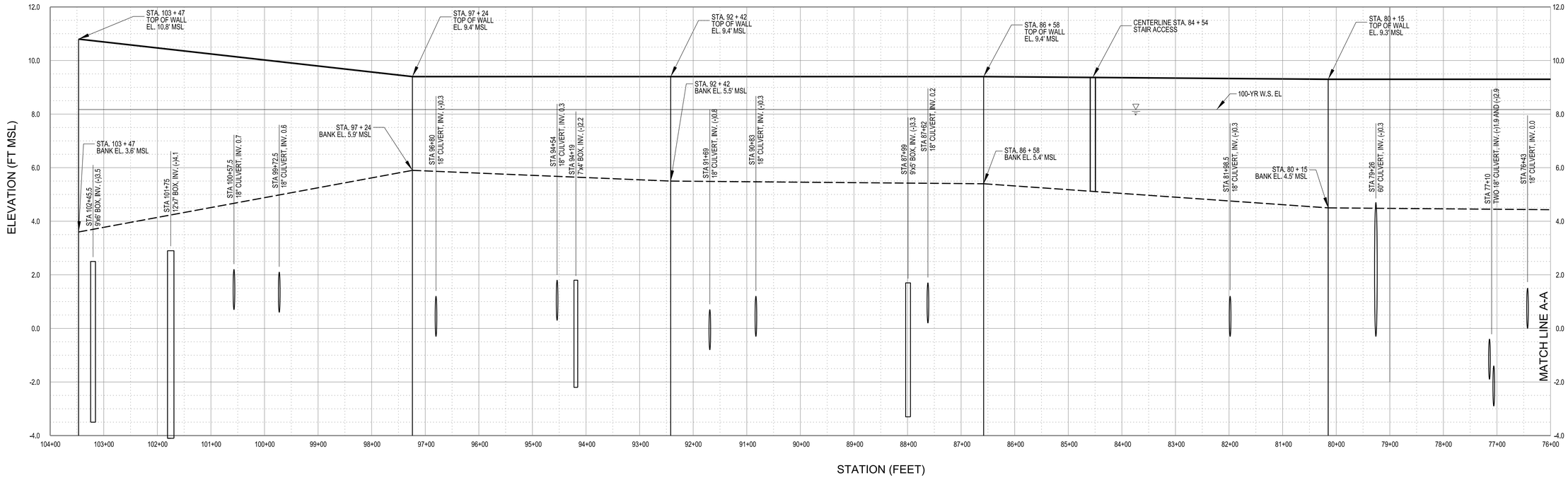

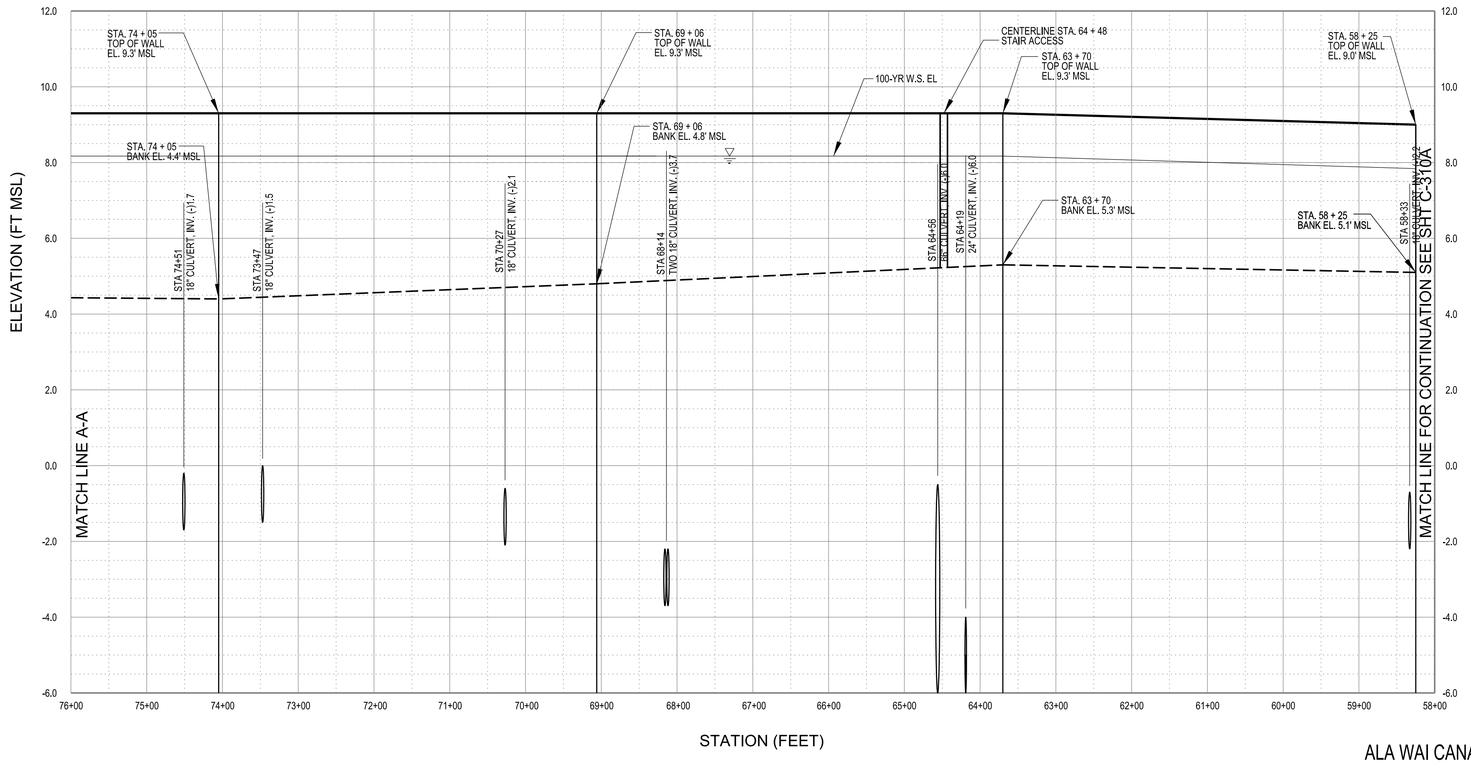

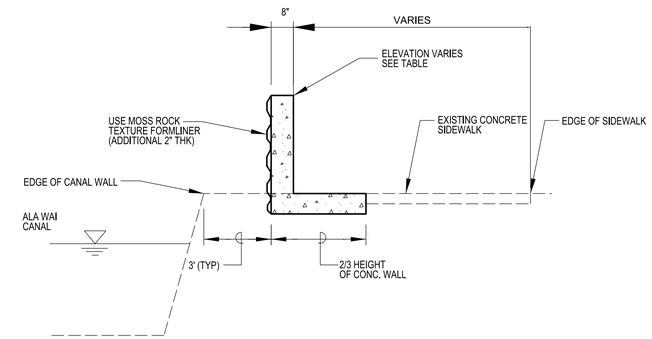

C TYPICAL LEFT BANK CONCRETE FLOODWALL SECTION

NOT TO SCALE

ALA WAI CANAL LEFT BANK
STA 101 + 24 TO 58 + 25

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
101 + 24	7.20	10.80
97 +24	3.50	9.40
92 + 42	3.90	9.40
86 + 58	4.00	9.40
80 + 15	4.70	9.30
74 + 05	4.90	9.30
69 + 06	4.50	9.30
63 + 70	4.00	9.30
58 + 25	3.90	9.00

PROFILE
ALA WAI CANAL UPPER (ALA3) LEFT BANK FLOODWALLS

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'

US Army Corps of Engineers
HONOLULU DISTRICT

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
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SUBMITTED BY:
PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
FILE NAME: ALA WAI CANAL UPPER LEFT BANK, PROFILE & SECTION
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI UPPER LEFT BANK FLOODWALLS
PROFILE AND SECTION

SHEET IDENTIFICATION
C-311
SHEET 20 OF 28

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-311xxx.dgn
MODEL NAME: C-311A
DATE & TIME: 8/4/2014 4:59:27 PM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotdg\printer.pltcfg
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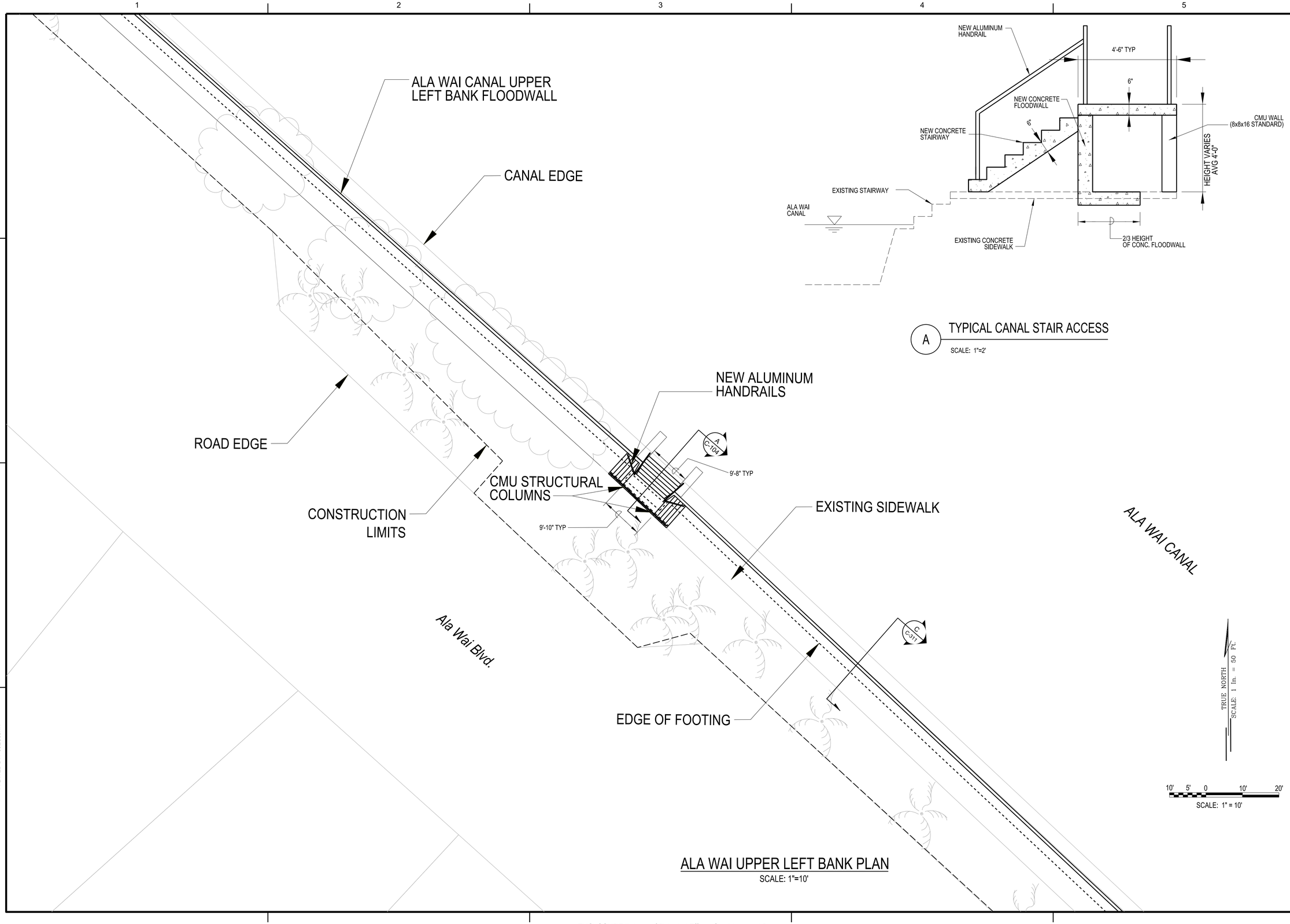
PRINTED BY: J3EC9JHH



ALA WAI UPPER LEFT BANK PLAN

SCALE: 1"=10'

A TYPICAL CANAL STAIR ACCESS

SCALE: 1"=2'

US Army Corps of Engineers®
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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HONOLULU DISTRICT
HONOLULU, HAWAII

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SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: ALA WAI UPPER LEFT BANK PLAN

ALA WAI WATERSHED PROJECT

ALA WAI UPPER LEFT BANK PLAN

SHEET IDENTIFICATION
C-104
SHEET OF 28

FILE: c:\pw-work\pcb-1\j3ec9jhh\d0143718\Ala_Wai_C-104xxx.dgn
MODEL NAME: C-104
DATE & TIME: 8/4/2014 2:33:55 PM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\pltcfg\printer.pltcfg
PEN TABLE: BW_and_Grayscale_Pen.tbl
PRINTED BY: J3EC9JHH

ALA WAI CANAL

EXISTING SIDEWALK

C
C-311

ALA WAI CANAL UPPER
LEFT BANK FLOODWALL

CANAL EDGE

ROAD EDGE

NEW FLOODGATE

A
C-317

CONSTRUCTION
LIMITS

Ala Wai Golf Course Rd.

CONCRETE SLIDE GATE
STRUCTURES

Ala Wai Blvd.

NEW PUMP STATION 1
SEE SHEET C-303 FOR THE
PLAN AND SECTIONS

STAGING AREA

Ainakea Way

TRUE NORTH
SCALE: 1 In. = 50 FL

20' 10' 0 20' 40'
SCALE: 1" = 20'

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.

ALA WAI UPPER END PLAN

SCALE: 1"=20'

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SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
FILE NAME: ALA WAI UPPER END PLAN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI UPPER END PLAN

SHEET IDENTIFICATION
C-105
SHEET OF 28

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MODEL NAME: C-105
DATE & TIME: 8/4/2014 2:50:42 PM
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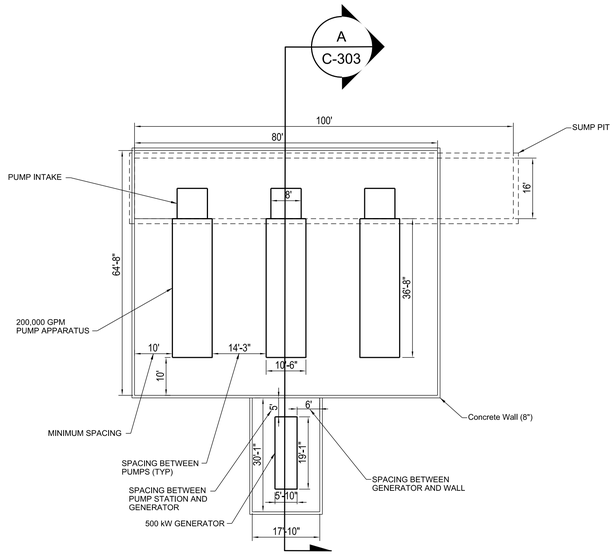
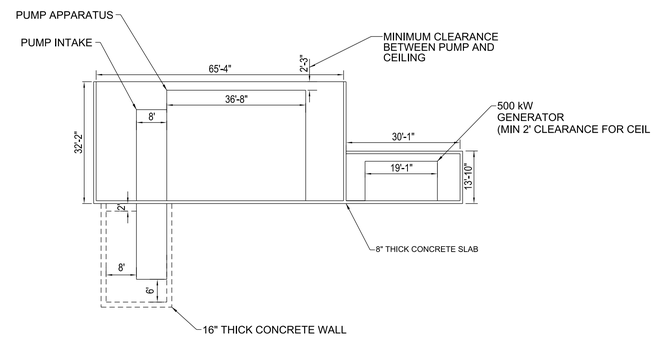


PLAN - PUMP STATION

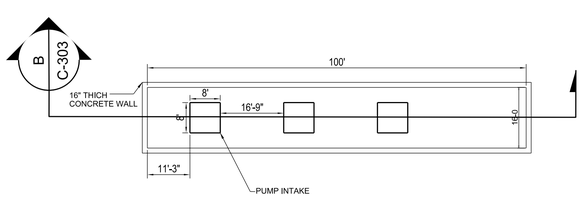
Scale: 1"=20'



A PUMP STATION SECTION

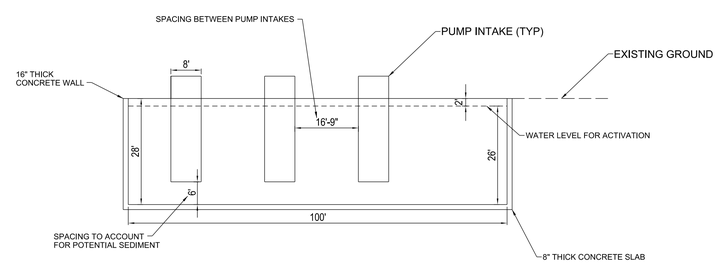
Scale: 1"=20'

ALA WAI CANAL SIDE



PLAN - SUMP PIT

Scale: 1"=20'



B PUMP SUMP PIT SECTION

Scale: 1"=20'

20 10 0 20 60

Scale: 1"=20'

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Honolulu District

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SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 8/7/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: PUMP STATION 1, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

PUMP STATION 1
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-303
SHEET 12 OF 28

FILE: c:\pw-work\pcb-1\j3ec9jhh\d0143718Ala_Wai_C-303xxx.dgn
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DATE & TIME: 8/1/2014 4:16:58 PM
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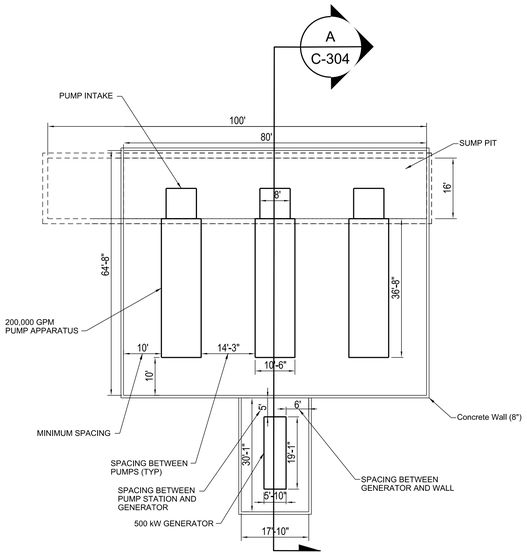
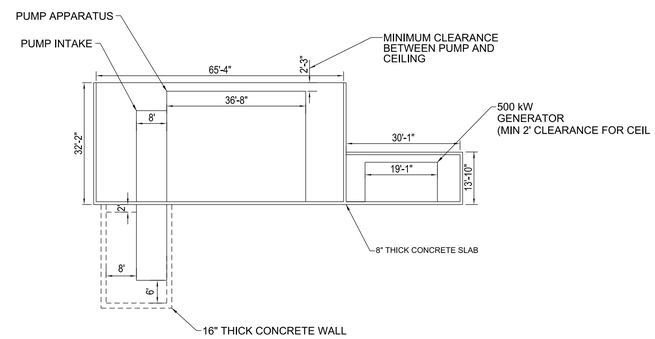


PLAN - PUMP STATION

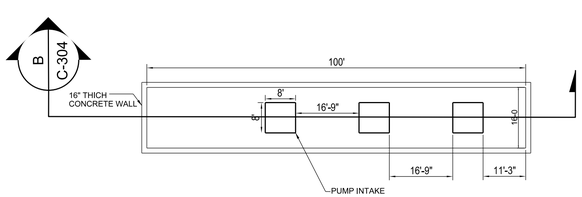
Scale: 1"=20'



A PUMP STATION SECTION

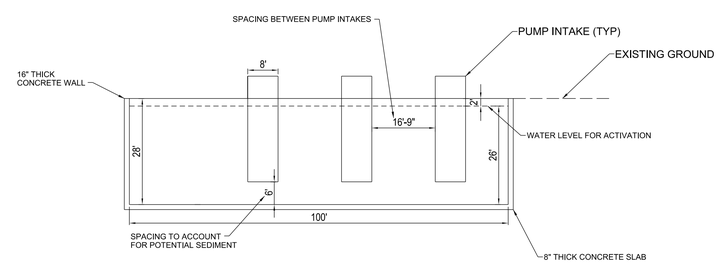
Scale: 1"=20'

ALA WAI CANAL SIDE



PLAN - SUMP PIT

Scale: 1"=20'



B PUMP SUMP PIT SECTION

Scale: 1"=20'

20 10 0 20 60

Scale: 1"=20'

US Army Corps of Engineers®
Honolulu District

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

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LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 8/7/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: PUMP STATION 2, PLAN & SECTIONS

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HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

PUMP STATION 2
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-304
SHEET 13 OF 28

FILE: c:\pw-work\pcb-1\j3ec9jhh\d0143718\Ala_Wai_C-304xxx.dgn
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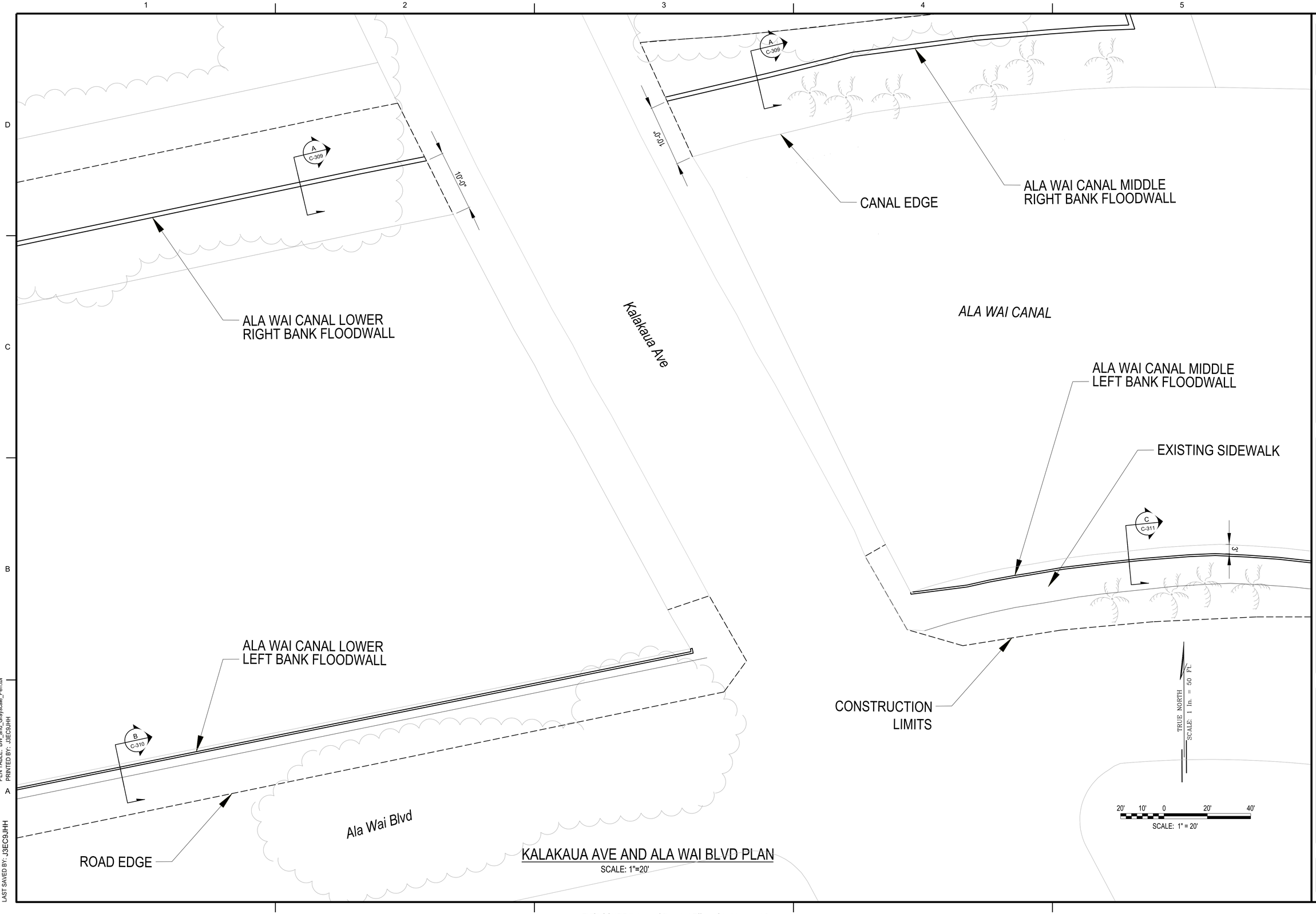

KALAKAUA AVE AND ALA WAI BLVD PLAN

SCALE: 1"=20'

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-106xxx.dgn
MODEL NAME: C-106
DATE & TIME: 8/4/2014 4:13:32 PM
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PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries)\WorkSpace\system\plotd\printer.pltcfg
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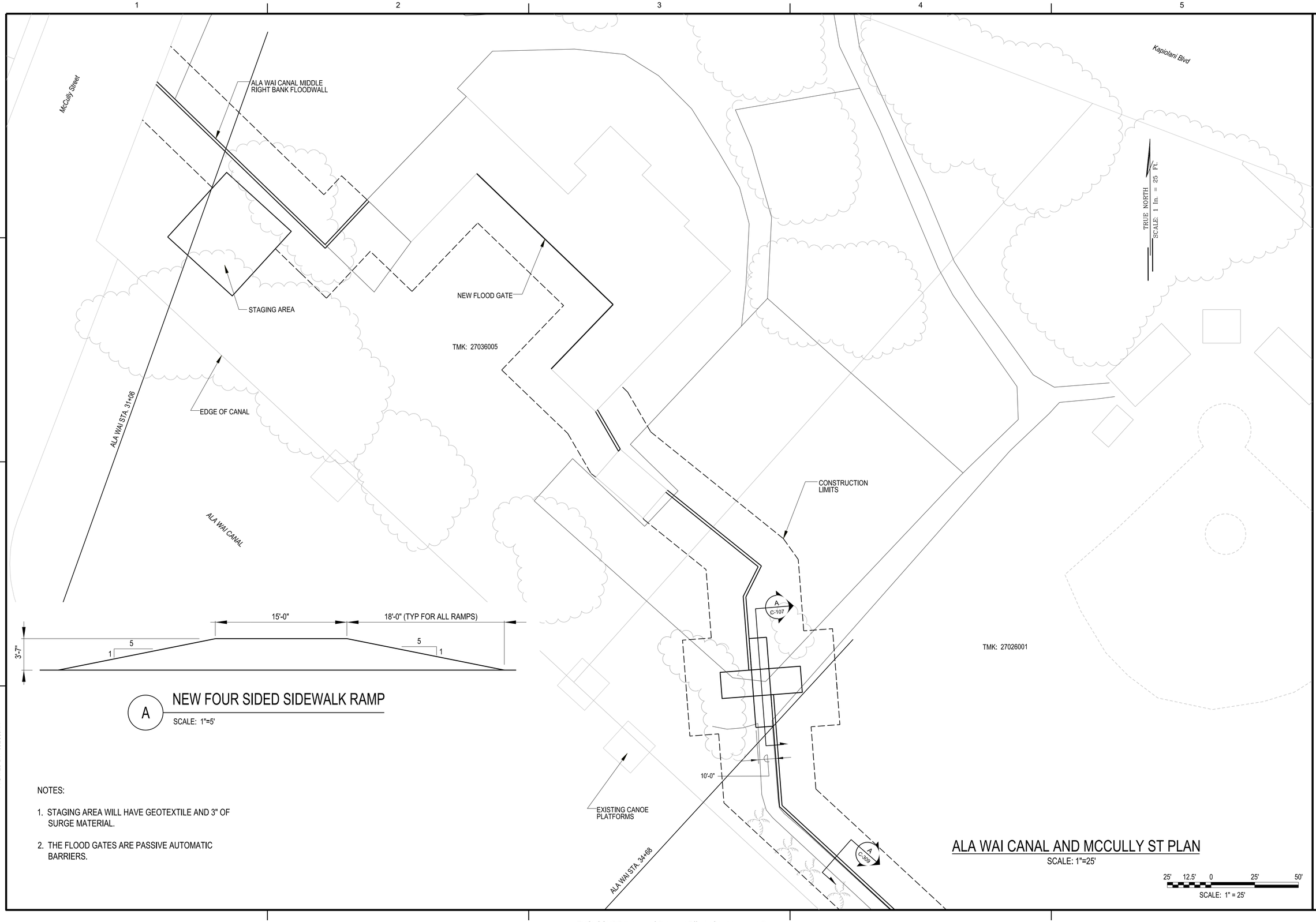
SOLICIT. / CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE: 8/4/2014
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: KALAKAUA AVE AND ALA WAI BLVD PLAN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

KALAKAUA AVE AND ALA WAI BLVD PLAN

SHEET IDENTIFICATION
C-106
SHEET OF 28



NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. THE FLOOD GATES ARE PASSIVE AUTOMATIC BARRIERS.

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HONOLULU DISTRICT

35% DESIGN

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: JHH
DRAWN BY:
CHECKED BY:
SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: ALA WAI CANAL AND MCCULLY ST PLAN
DATE:
REVISION:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI CANAL AND MCCULLY ST SITE PLAN

SHEET IDENTIFICATION
C-107
SHEET 9 OF 28

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-107xxx.dgn
MODEL NAME: C-102
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LAST SAVED BY: J3EC9JHH
PLOTDRIVER: C:\ProgramData\Bentley\MicroStation V8i (SELECTseries1)\WorkSpace\system\plotdrv\printer.pltcfg
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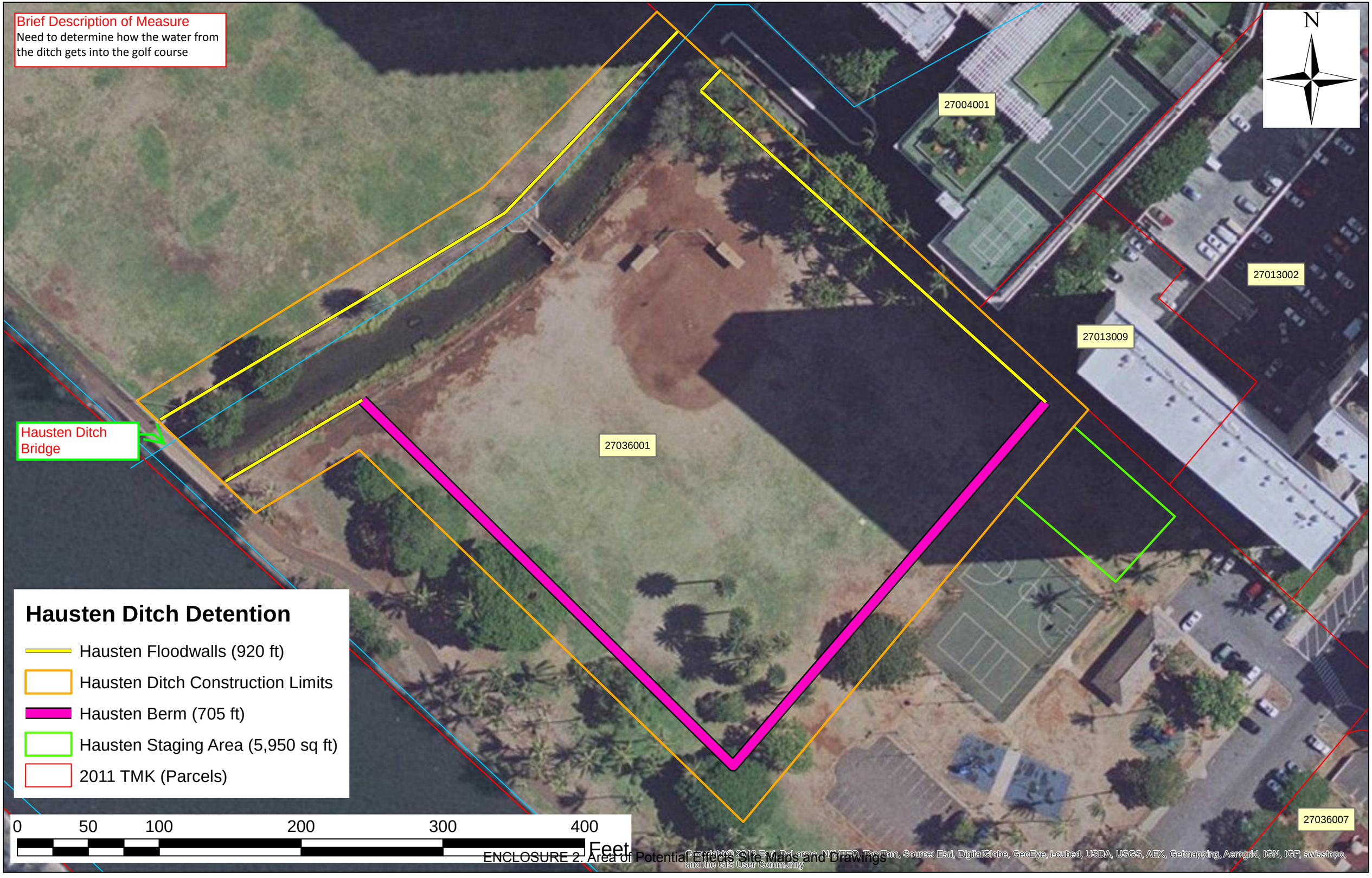
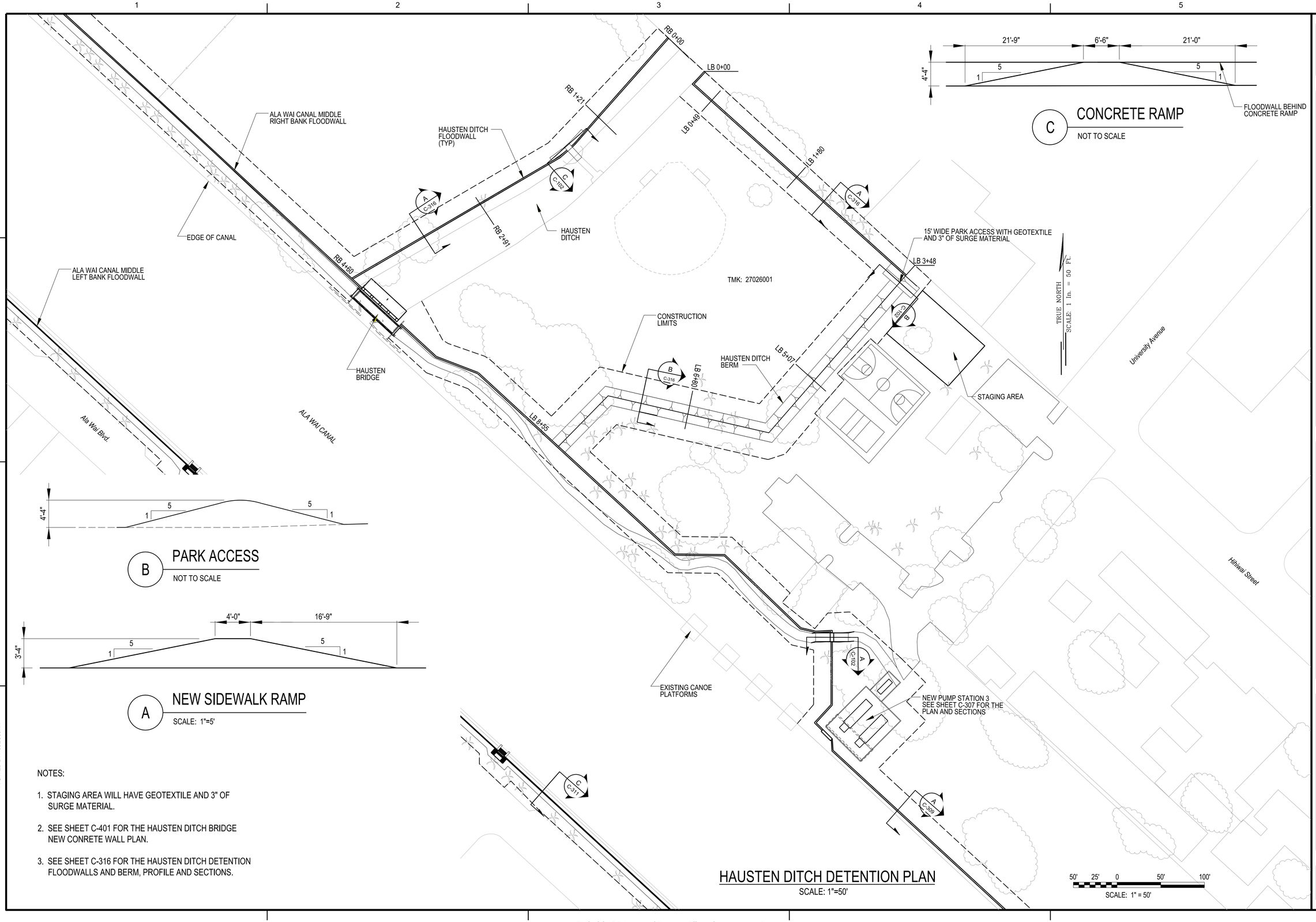


ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings

Conceptual Renderings of Detention Basins

Hausten Ditch

Ala Wai Golf Course



HAUSTEN DITCH DETENTION PLAN

SCALE: 1"=50'

C CONCRETE RAMP

NOT TO SCALE

B PARK ACCESS

NOT TO SCALE

A NEW SIDEWALK RAMP

SCALE: 1"=5'

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-401 FOR THE HAUSTEN DITCH BRIDGE NEW CONRETE WALL PLAN.
3. SEE SHEET C-316 FOR THE HAUSTEN DITCH DETENTION FLOODWALLS AND BERM, PROFILE AND SECTIONS.

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SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT SIZE: ANSI D
DATE:
CHECKED BY:
PLOT DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
FILE NAME: HAUSTEN DITCH DETENTION PLAN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

HAUSTEN DITCH DETENTION SITE PLAN

SHEET IDENTIFICATION
C-102
SHEET 4 OF 28

FILE: c:\pwworking\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-102xxx.dgn
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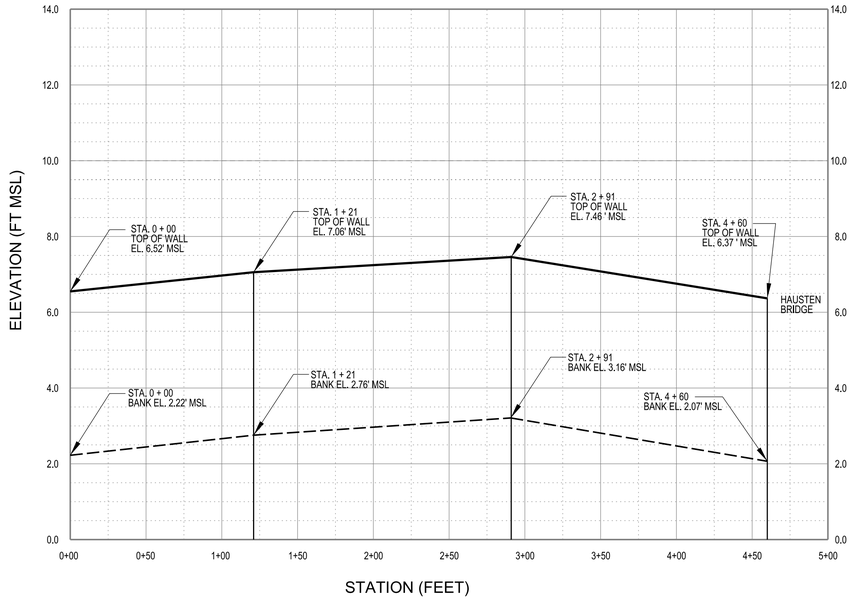
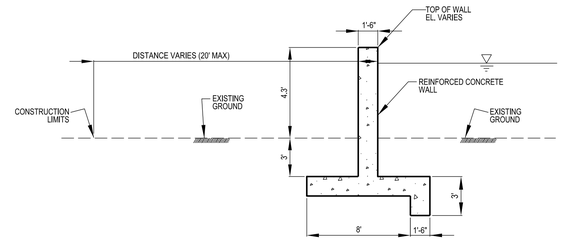
PRINTED BY: J3EC9JHH

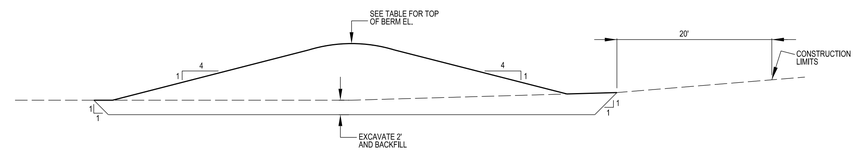


PROFILE
HAUSTEN DITCH RIGHT BANK FLOODWALL

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'



A TYPICAL REINFORCED CONCRETE FLOODWALL SECTION
NOT TO SCALE



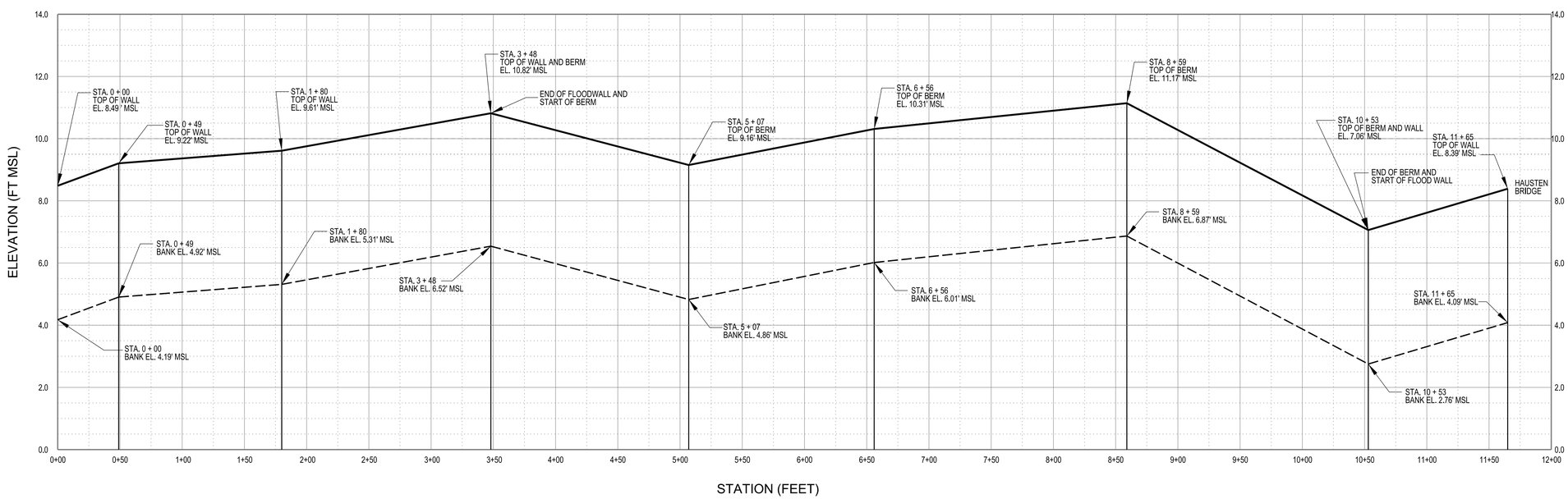
B HAUSTEN TYPICAL EARTHEN BERM SECTION
NOT TO SCALE

HAUSTEN DITCH RIGHT BANK FLOODWALL
STA TO 0 + 00 TO 4 + 60

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	6.52
1 + 21	4.30	7.06
2 + 91	4.30	7.46
4 + 60	4.30	6.37
HAUSTEN BRIDGE		

HAUSTEN DITCH LEFT BANK
FLOODWALL AND BERM
STA TO 0 + 00 TO 11 + 65

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	4.30	8.49
0 + 49	4.30	9.22
1 + 80	4.30	9.61
3 + 48	4.30	10.82
END OF FLOODWALL AND START OF BERM		
3 + 48	4.30	10.82
5 + 07	4.30	9.16
6 + 56	4.30	10.31
8 +59	4.30	11.17
10 + 53	4.30	7.06
END OF BERM AND START OF FLOODWALL		
10 + 53	4.30	7.06
11 + 65	4.30	8.39
HAUSTEN BRIDGE		



PROFILE
HAUSTEN DITCH LEFT BANK FLOODWALL AND BERM

SCALE:
HORIZONTAL: 1" = 50'
VERTICAL: 1" = 2'

US Army Corps of Engineers
HONOLULU DISTRICT

MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

10% DESIGN

DESIGNED BY: JHH
DRAWN BY:
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SIZE: ANSI D
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LOCATION CODE
PLOT DATE:
DRAWING NUMBER:
FILE NAME: C-316 HAUSTEN DITCH PROFILE & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

HAUSTEN DITCH FLOODWALL AND BERM
PROFILE AND SECTIONS
ALTERNATIVE 2

SHEET IDENTIFICATION
C-316
SHEET 19 OF 25

FILE: pw:\\POH-AP07FTS.poh.ds.usace.army.mil:poh-ap07fts/Documents\11 Other Locations\2 - Oahu\Civil Works\Ala Wai Canal\Ala Wai Flood Study\01-Drawings\Civil\Final\Alternative 2\C-316 HAUSTEN DITCH PROFILE & SECTIONS
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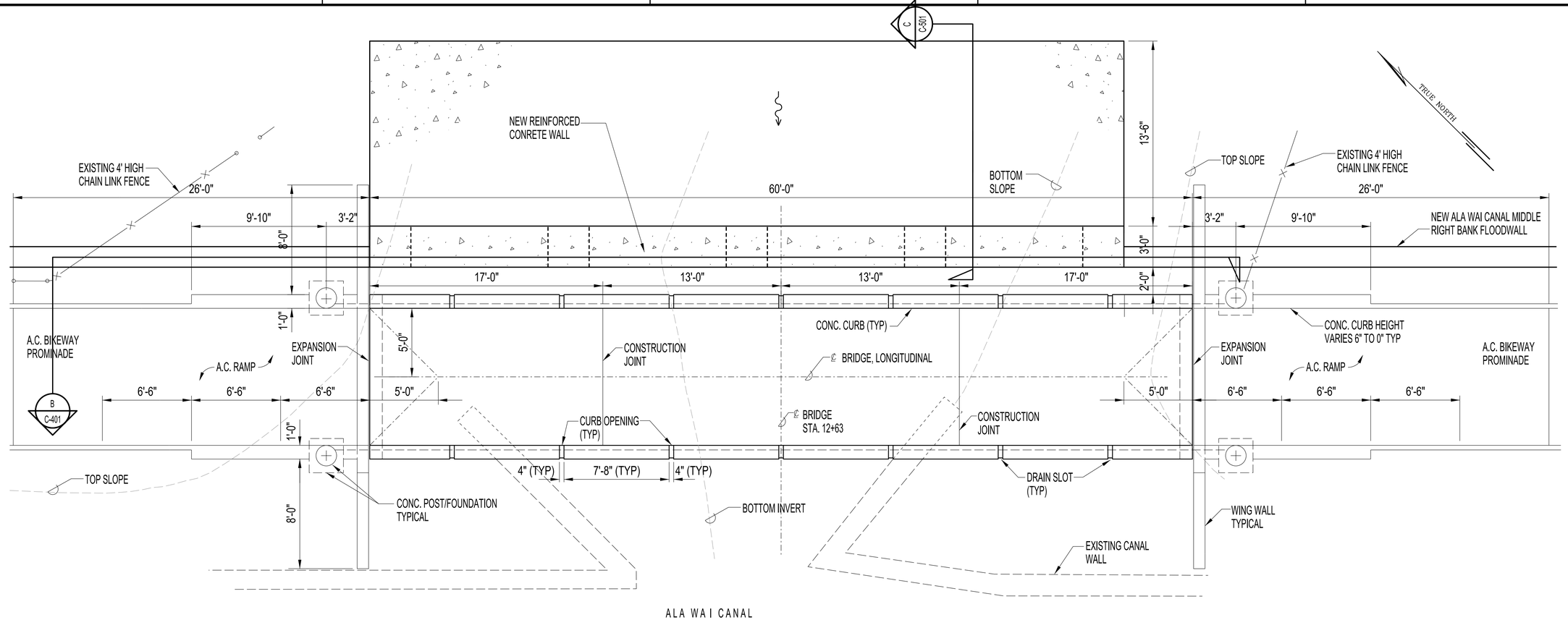
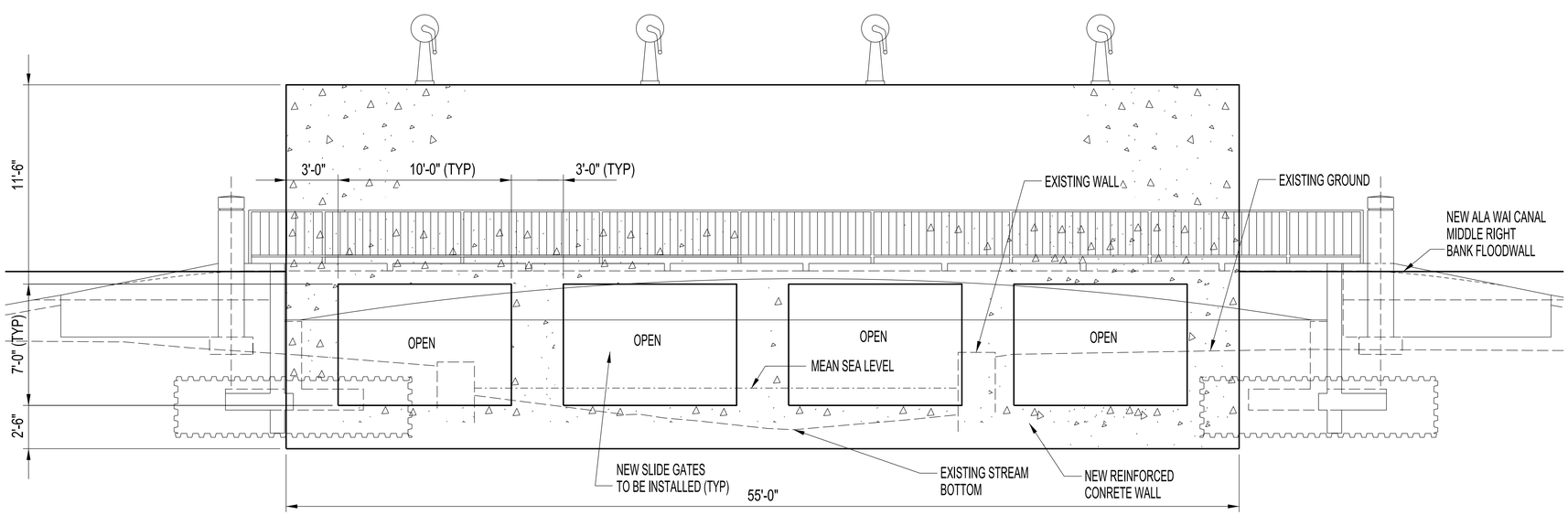


A PLAN
SCALE: 1/4"=1'



B ELEVATION
SCALE: 1/4"=1'

NOTES:

1. SEE SHEET C-501 FOR THE SLIDE GATE DETAIL.

US Army Corps of Engineers
HONOLULU DISTRICT

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SIZE: ANSI D
PLOT DATE:
REVISION:
DATE:
SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
FILE NAME: HAUSTEN BRIDGE PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

HAUSTEN BRIDGE CONCRETE WALL
PLAN, SECTION AND ELEVATION

SHEET IDENTIFICATION
C-401
SHEET 26 OF 28

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PRINTED BY: J3EC9JHH

STRUCTURAL NOTES:

1. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND CONDITIONS AND REPORT ANY DISCREPANCIES IN WRITING TO THE CONTRACTING OFFICER BEFORE COMMENCING WORK.
2. DETAILS SHOWN ON THE DRAWINGS SHALL BE TYPICAL FOR ALL SIMILAR CONDITIONS.

CONSTRUCTION NOTES:

1. THE CONTRACTOR SHALL BE FULLY RESPONSIBLE FOR METHODS OF CONSTRUCTION, WORKMANSHIP, AND JOB SAFETY INCLUDING FALSEWORK, BRACING, AND OTHER TEMPORARY ITEMS USED FOR THE CONSTRUCTION OF THIS PROJECT.
2. THE CONTRACTOR SHALL NOTIFY THE CONTRACTING OFFICER AT LEAST 48 HOURS IN ADVANCE FOR INSPECTION OF EXCAVATIONS AND ALL CONCRETE POURS.
3. CHAMFER ALL EXPOSED EDGES 1/2" UNLESS OTHERWISE NOTED.
4. THE LOCATION OF EMBEDDED ITEMS SHALL BE COORDINATED WITH OTHER TRADES BEFORE CONCRETE POURS.

CONCRETE NOTES:

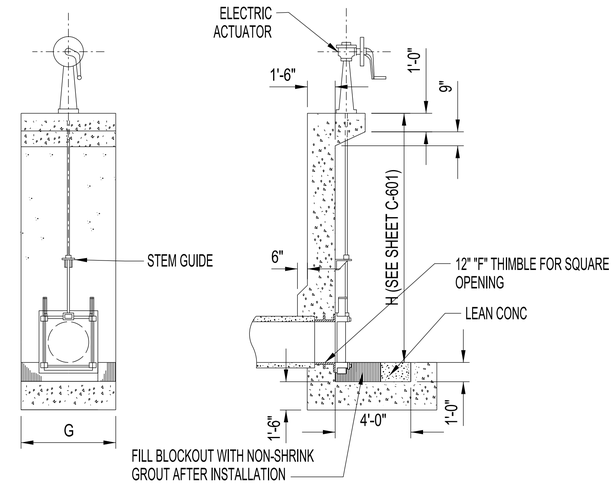
1. UNLESS OTHERWISE SHOWN, CONSTRUCTION JOINTS SHALL BE LOCATED BY THE CONTRACTOR SUBJECT TO APPROVAL BY THE CONTRACTING OFFICER. THEY SHALL BE SO LOCATED AS TO LEAST IMPAIR THE STRENGTH OF THE STRUCTURE AND TO MINIMIZE SHRINKAGE STRESSES. PROVIDE DOWELS AS DIRECTED AND THOROUGHLY CLEAN AND ROUGHEN SURFACES BEFORE PROCEEDING WITH THE NEXT POUR.

REINFORCING STEEL NOTES:

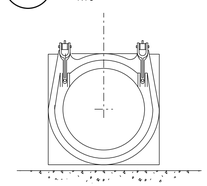
1. DOWELS SHALL BE THE SAME SIZE AND SPACING AND SHALL BE IN THE SAME PLANE AS THE BARS TO WHICH THEY ARE SPLICED UNLESS OTHERWISE SHOWN.
2. MINIMUM CONCRETE COVER:

CONCRETE DEPOSITED ON OR AGAINST EARTH.....3"

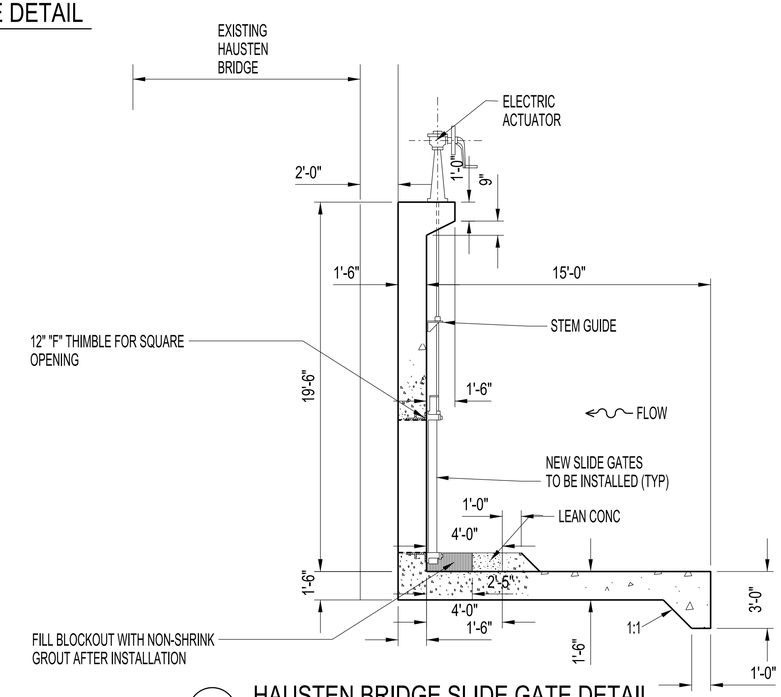
ALL OTHERS.....2"



A TYPICAL SLIDE GATE DETAIL
NTS



B TYPICAL FLAP GATE DETAIL
NTS



C HAUSTEN BRIDGE SLIDE GATE DETAIL
SCALE: 1/4"=1'

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HONOLULU DISTRICT

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DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

STRUCTURAL NOTES AND MISCELLANEOUS DETAILS

SHEET IDENTIFICATION
C-501
SHEET 27 OF 28

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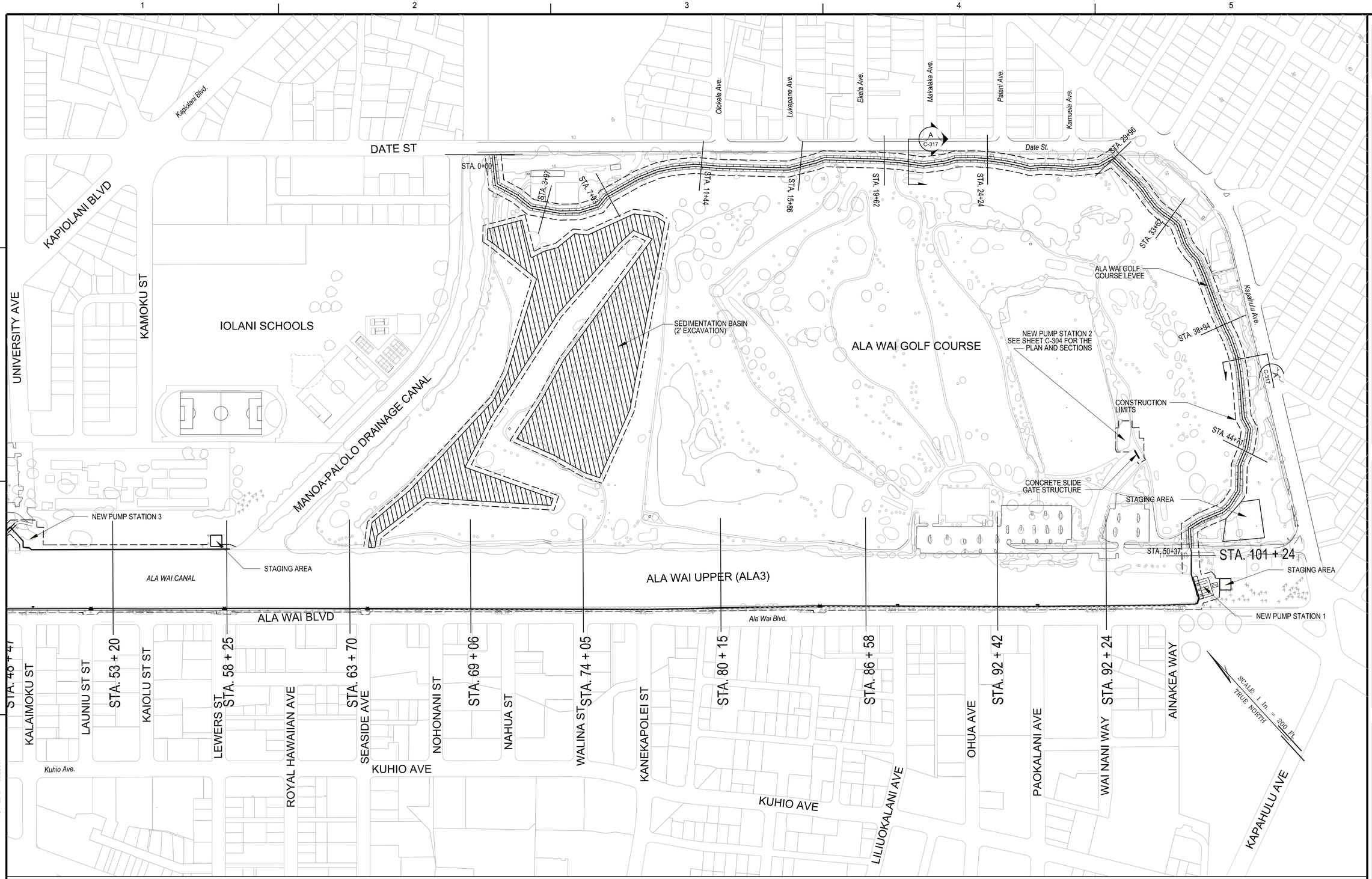

NOTES:

1. STAGING AREA WILL HAVE GEOTEXTILE AND 3" OF SURGE MATERIAL.
2. SEE SHEET C-317 FOR THE ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION, PROFILE AND SECTION.

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN

SCALE: 1"=200'

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PLOT DATE:
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SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION.dgn

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION PLAN

SHEET IDENTIFICATION
C-103
SHEET 5 OF 28

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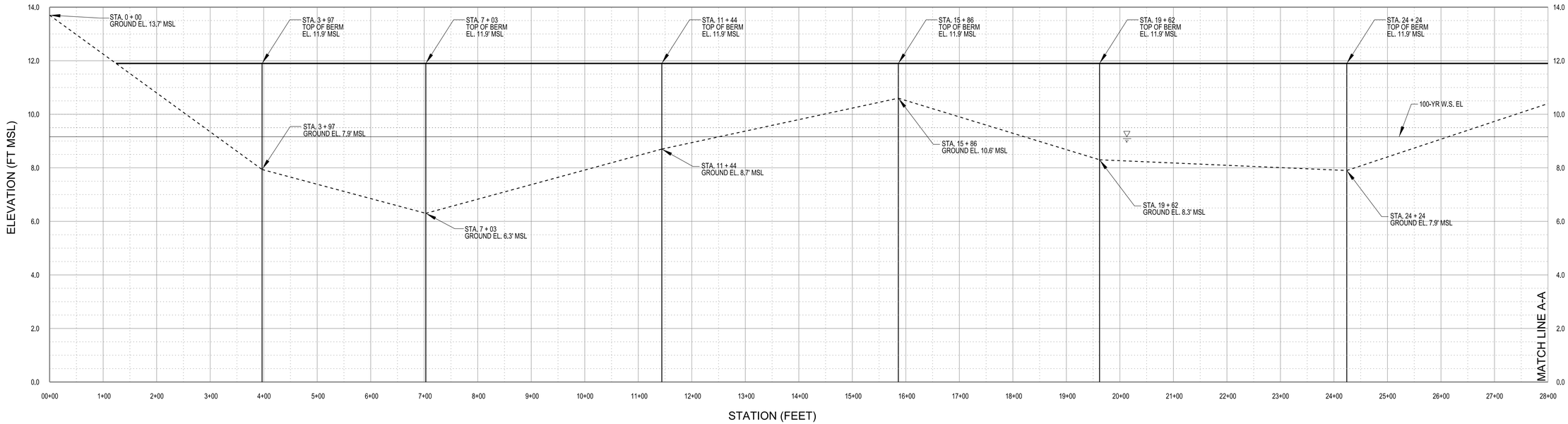
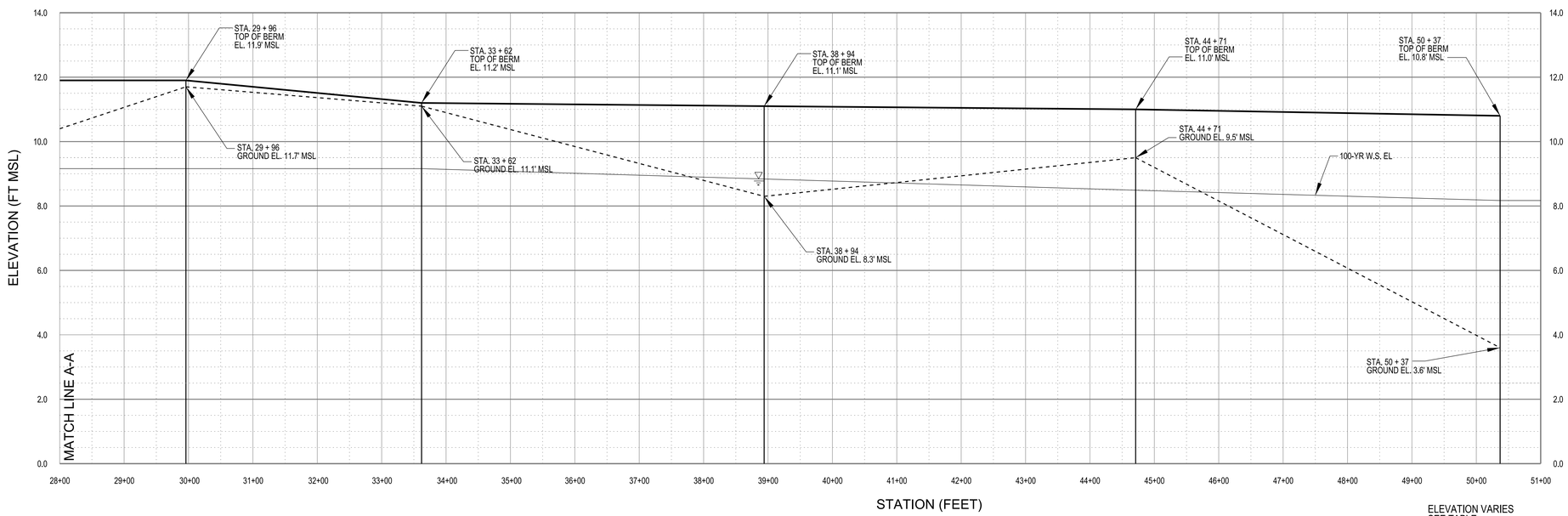


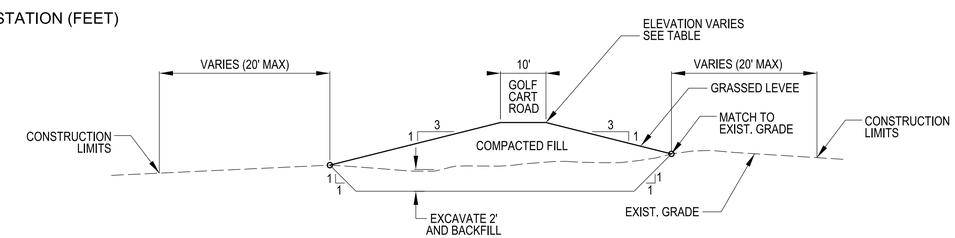


ALA WAI GOLF COURSE LEVEE
STA 0 + 00 TO 50 + 37

STATION	WALL HEIGHT (FT)	FINISHED WALL ELEVATION (FT MSL)
0 + 00	-	-
3 + 97	4.0	11.9
7 + 03	5.6	11.9
11 + 44	3.2	11.9
15 + 86	1.3	11.9
19 + 62	3.6	11.9
24 + 24	4.0	11.9
29 + 96	0.2	11.9
33 + 62	0.1	11.2
38 + 94	2.8	11.1
44 + 71	1.5	11.0
50 + 37	7.2	10.8

ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE PROFILE

SCALE:
HORIZONTAL: 1" = 100'
VERTICAL: 1" = 2'



A TYPICAL LEVEE SECTION
NOT TO SCALE

US Army Corps of Engineers
HONOLULU DISTRICT

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LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: ALA WAI GOLF COURSE MULTI-PURPOSE DETENTION LEVEE

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

ALA WAI GOLF COURSE LEVEE
PROFILE AND SECTION

SHEET IDENTIFICATION
C-317
SHEET 24 OF 28

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ENCLOSURE 2: Area of Potential Effects Site Map and Drawing

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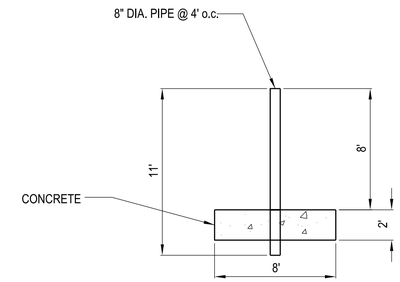
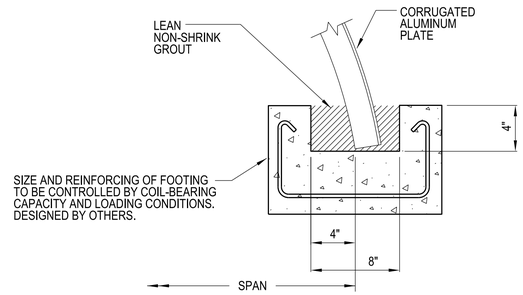
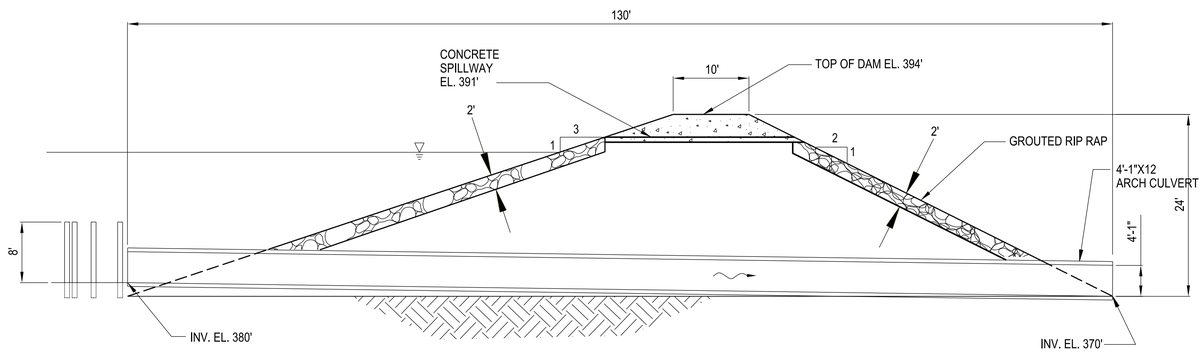


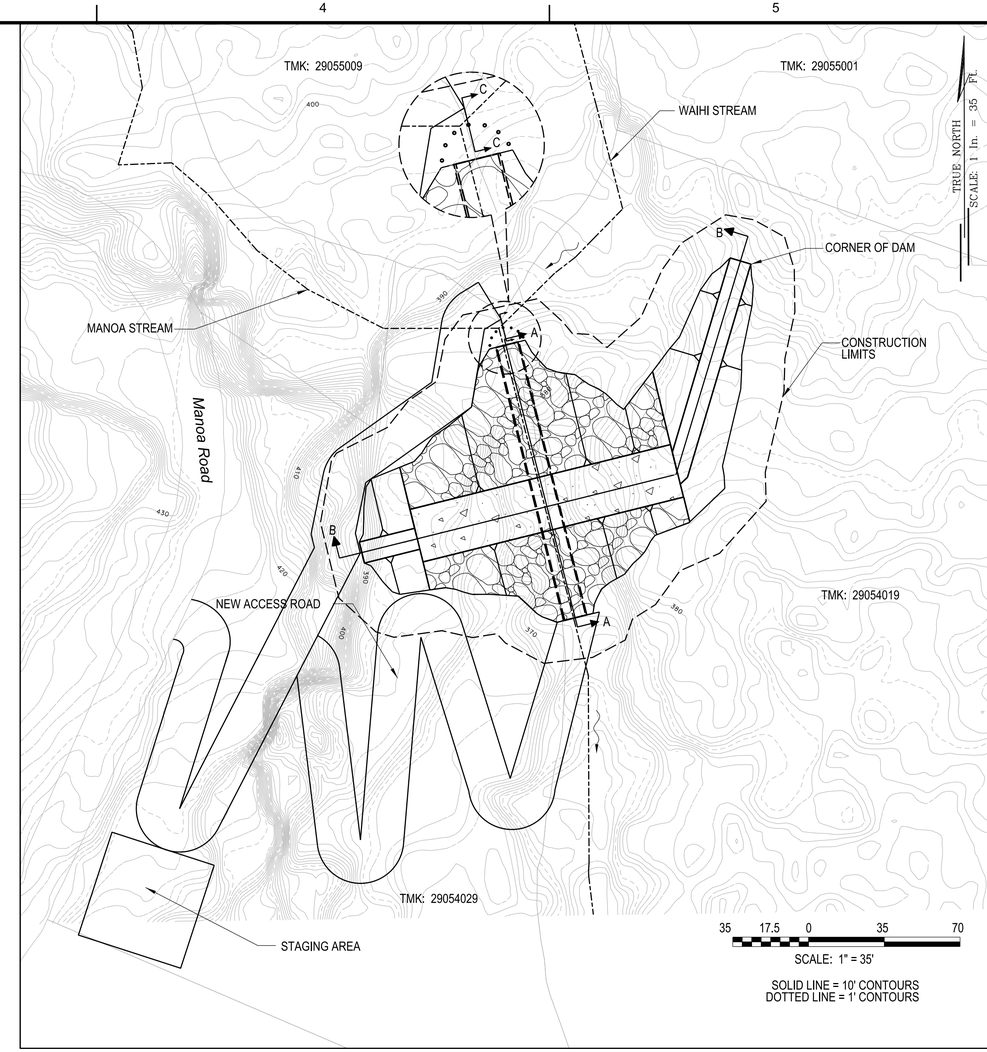
WAIHI DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



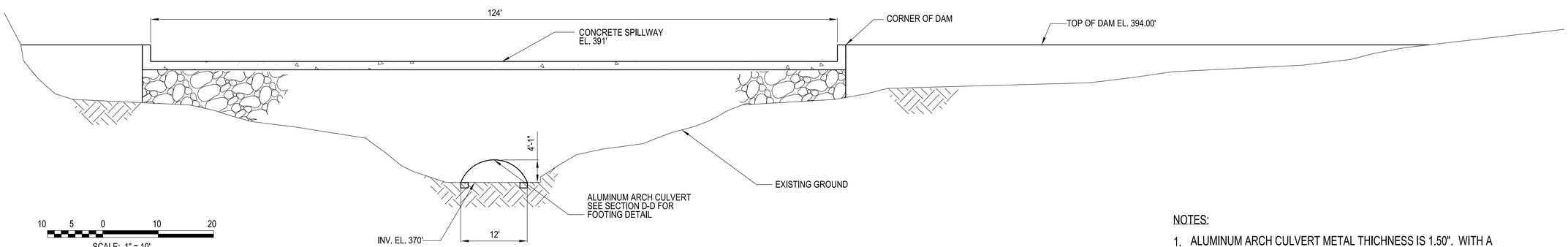
SLOTTED CONCRETE FOOTING
WAIHI DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



WAIHI DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



PLAN
SCALE: 1"=35'



Note: All elevations are feet MSL

WAIHI DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

US Army Corps of Engineers®
HONOLULU DISTRICT

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REVISION:
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LOCATION CODE
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PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: WAIHI DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

WAIHI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-301
SHEET 10 OF 28

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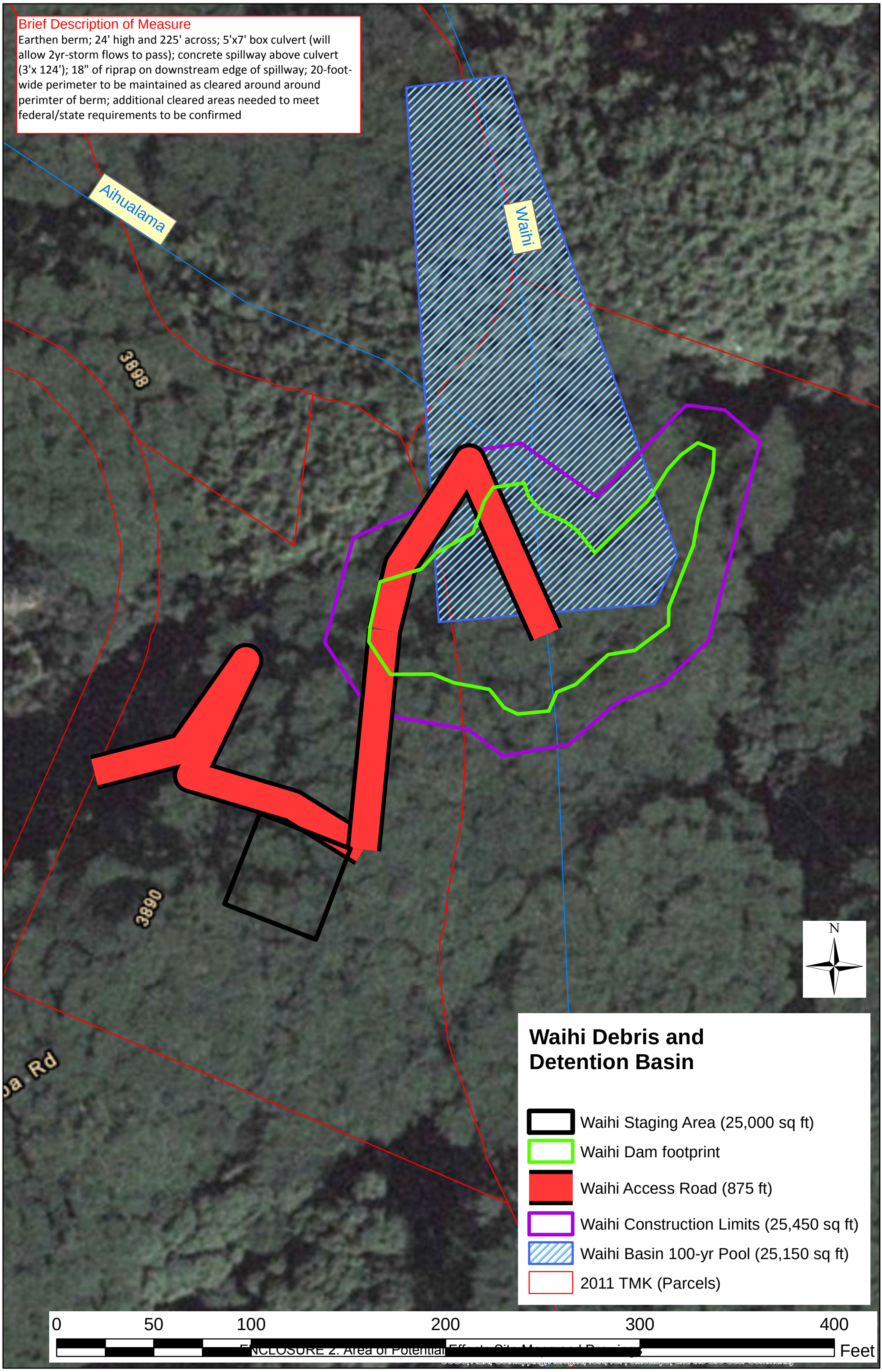
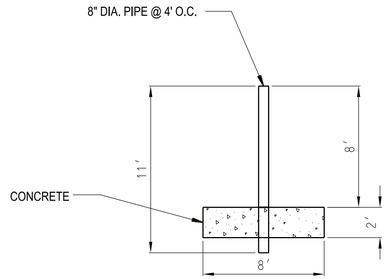
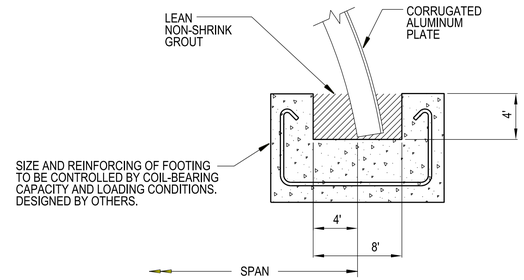


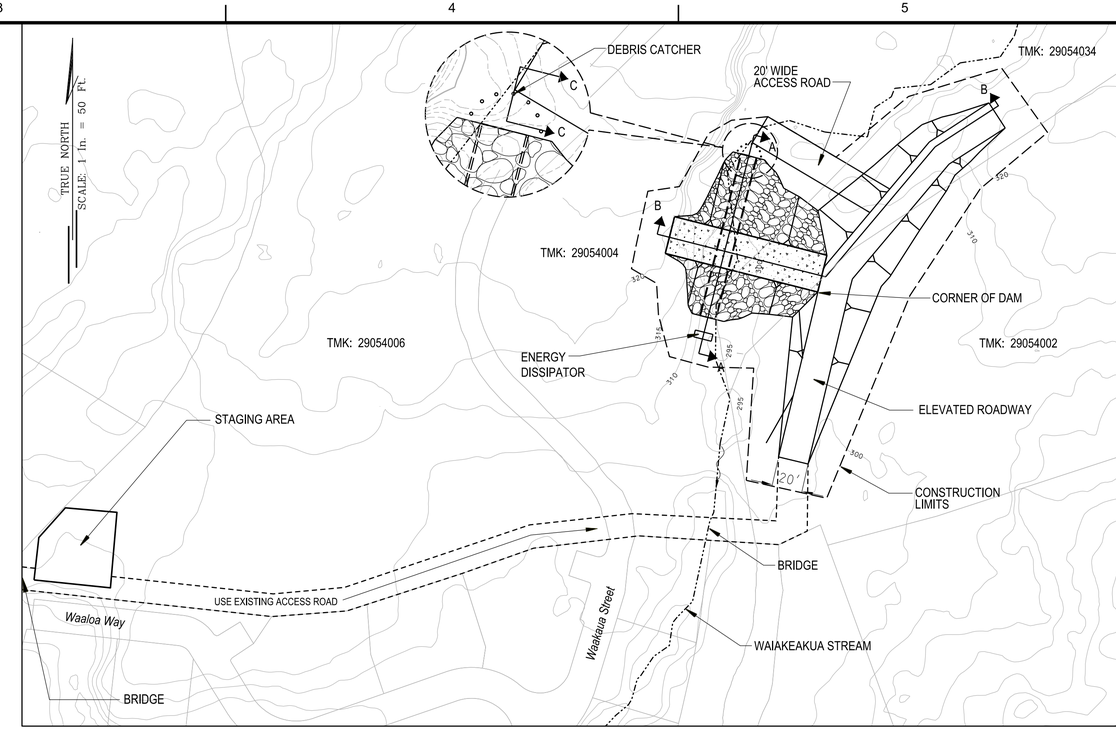
ENCLOSURE 2: Area of Potential [redacted]



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING
WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS

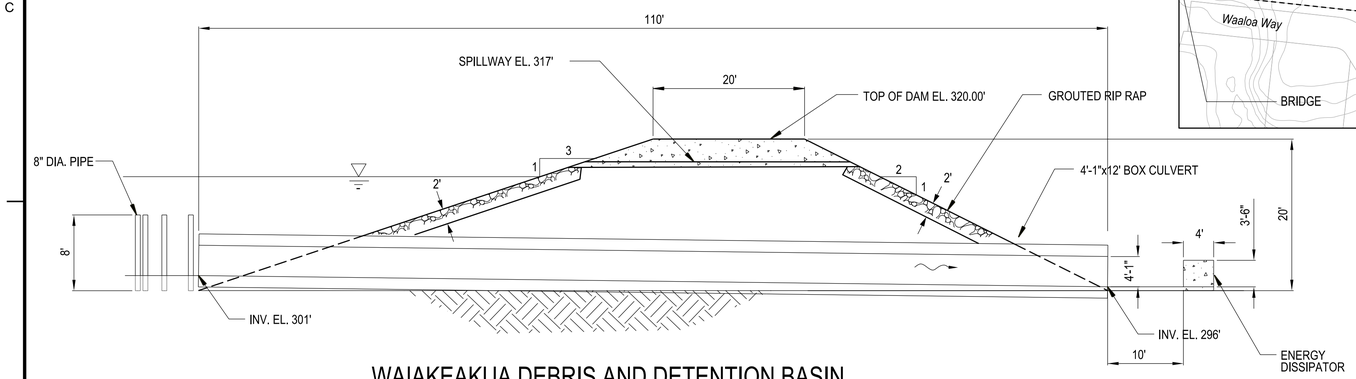


PLAN
SCALE: 1"=50'

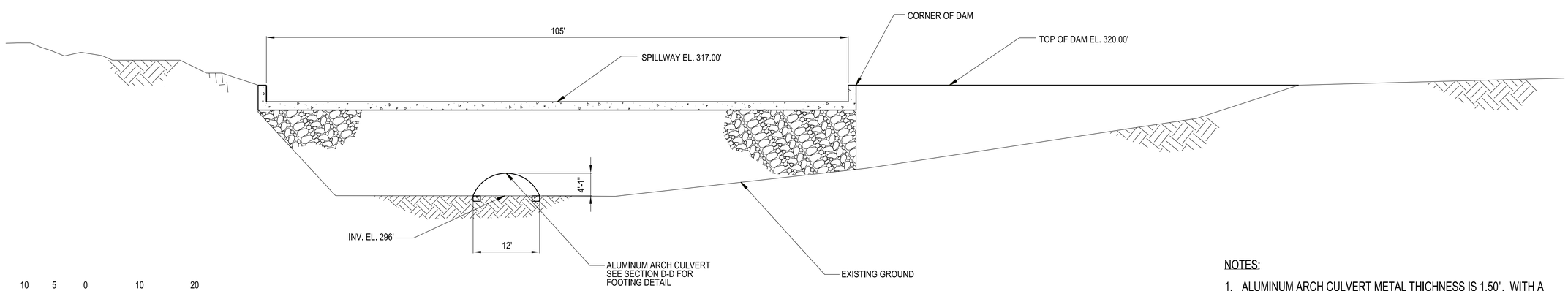
SOLID LINE = 5' CONTOURS

50 25 0 50 100

SCALE: 1" = 50'



WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



10 5 0 10 20

SCALE: 1" = 10'

Note: All elevations are feet MSL

WAIAKEAKUA DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

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PLOT SCALE: AS SHOWN
SIZE: ANSI D
DATE:
REVISION:
CHECKED BY:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: WAIAKEAKUA DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

WAIAKEAKUA DEBRIS AND DETENTION
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-302
SHEET 11 OF 28

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PEN TABLE: BW_and_Greyscale_Pen.tbl
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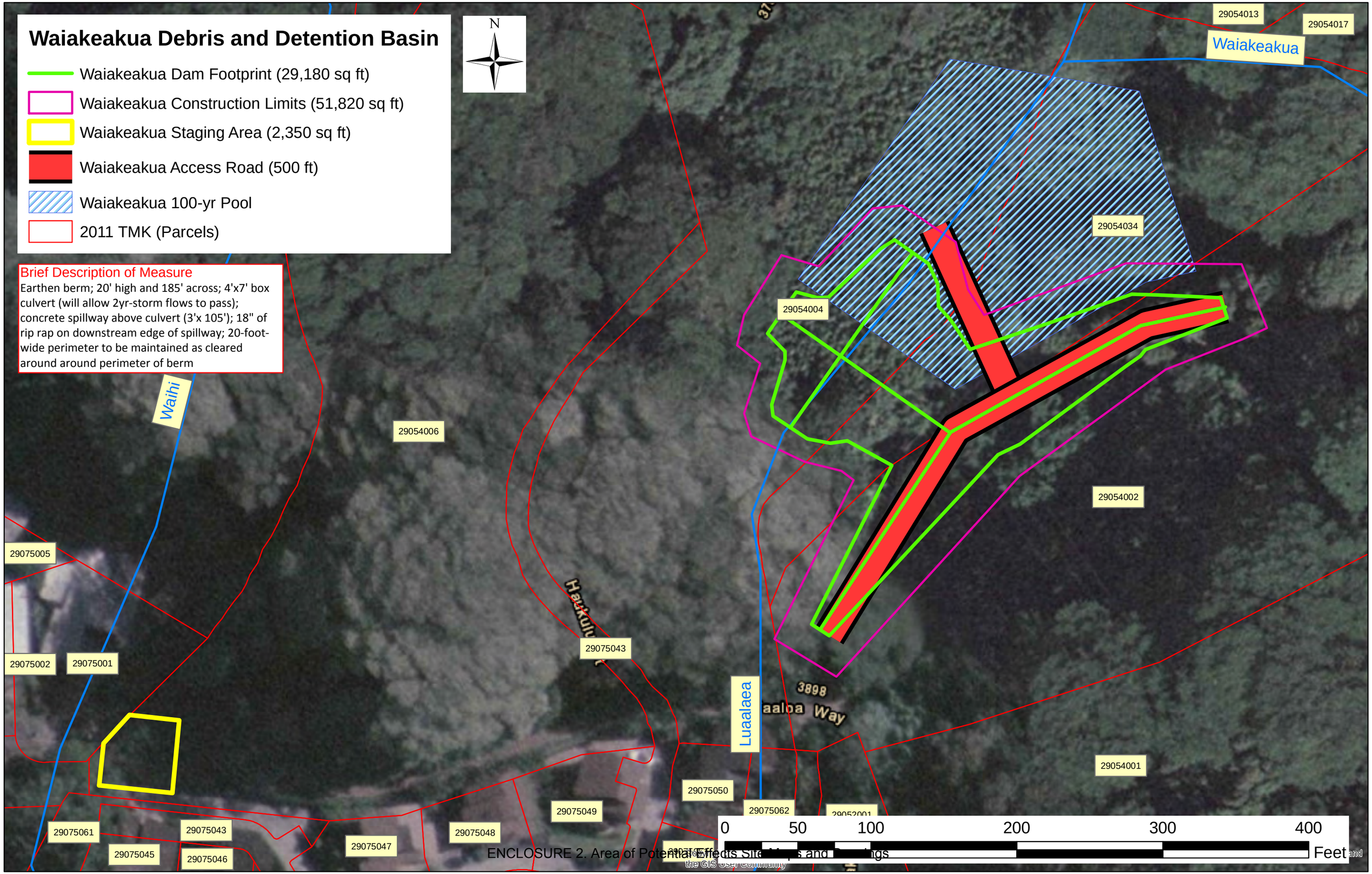
Waiakeakua Debris and Detention Basin

- Waiakeakua Dam Footprint (29,180 sq ft)
- Waiakeakua Construction Limits (51,820 sq ft)
- Waiakeakua Staging Area (2,350 sq ft)
- Waiakeakua Access Road (500 ft)
- Waiakeakua 100-yr Pool
- 2011 TMK (Parcels)

N

Brief Description of Measure

Earthen berm; 20' high and 185' across; 4'x7' box culvert (will allow 2yr-storm flows to pass); concrete spillway above culvert (3'x 105'); 18" of rip rap on downstream edge of spillway; 20-foot-wide perimeter to be maintained as cleared around around perimeter of berm

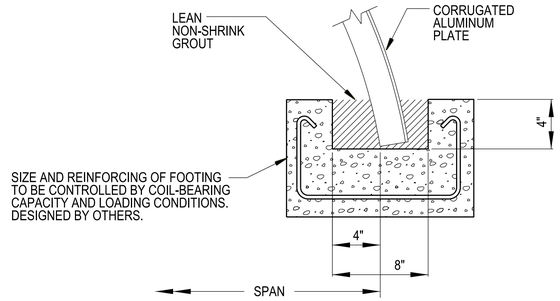


ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings

Conceptual Renderings of Detention Basins

Pukele Stream (Palolo)

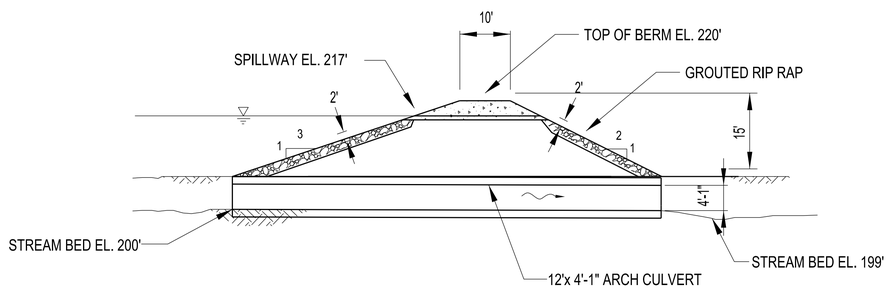
Waiakeakua Stream (Manoa)



SLOTTED CONCRETE FOOTING

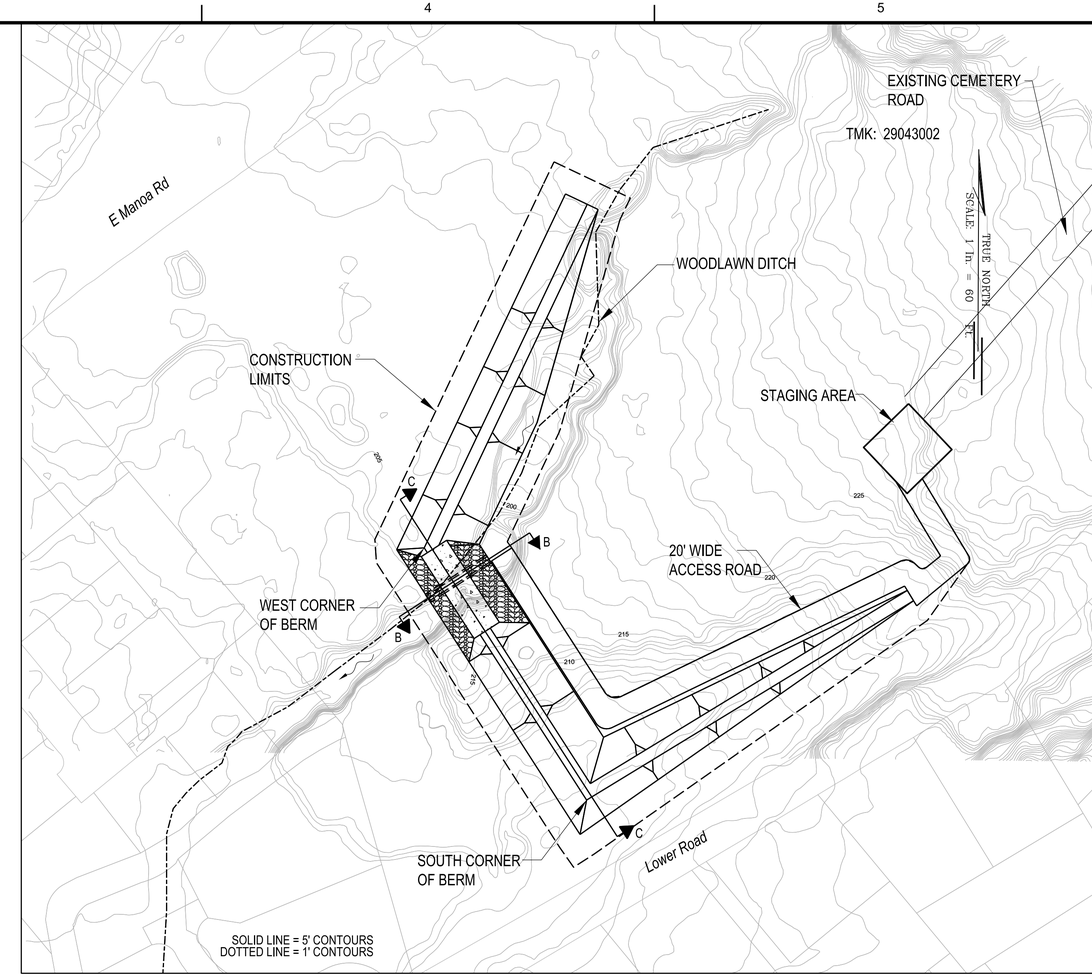
WOODLAWN DITCH DETENTION BASIN SECTION D-D

SCALE: NTS



WOODLAWN DITCH DETENTION BASIN SECTION B-B

SCALE: 1"=15'



PLAN

SCALE: 1"=60'

WOODLAWN DITCH DETENTION BASIN SECTION C-C

SCALE: 1"=15'

15 7.5 0 15 30

SCALE: 1" = 15'

Note: All elevations are feet MSL

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

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SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
PLOT DATE:
FILE NAME: WOODLAWN DITCH DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

WOODLAWN DITCH DETENTION
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-305
SHEET 14 OF 28

FILE: c:\pw\work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-305xxx.dgn
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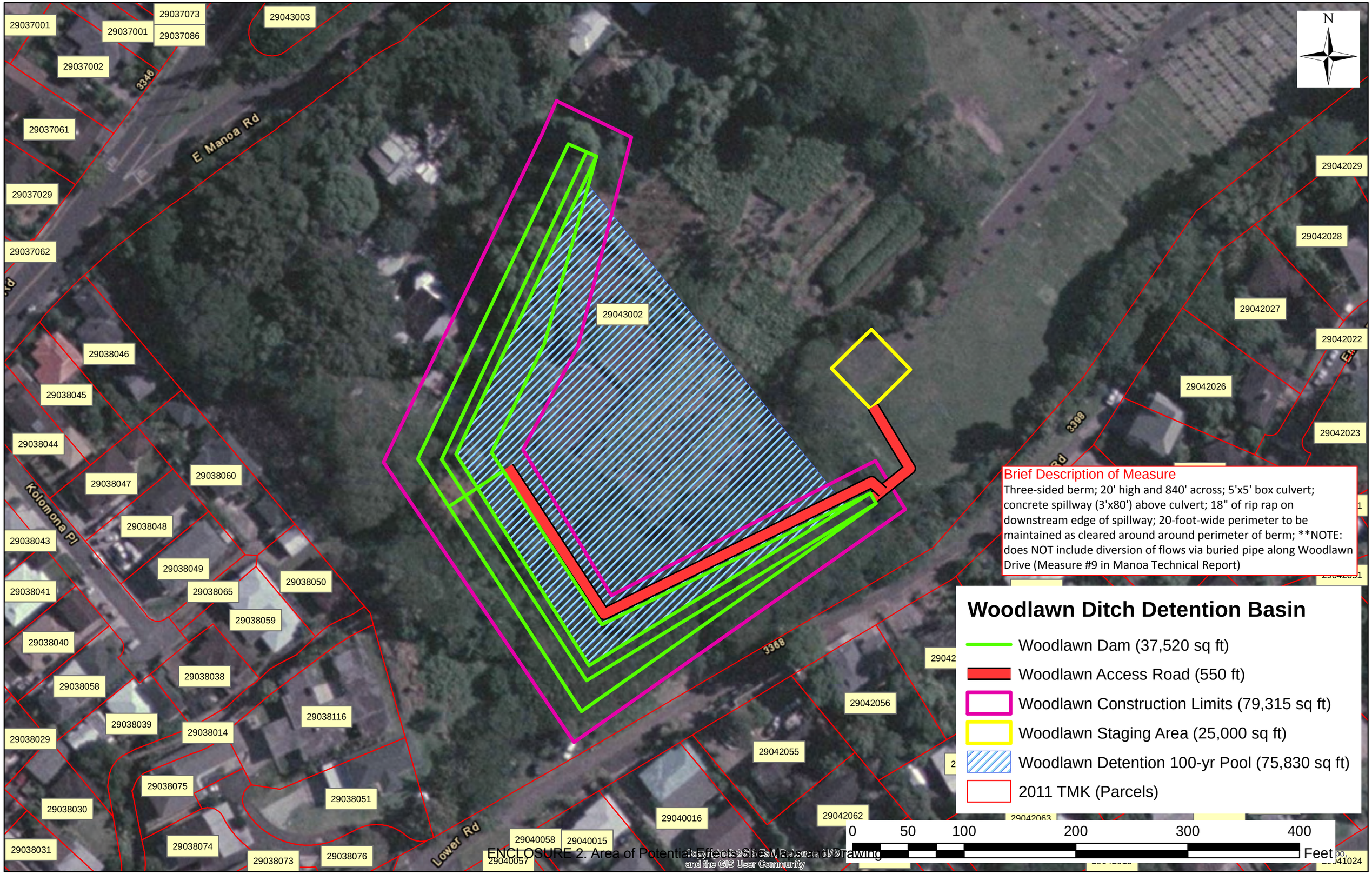
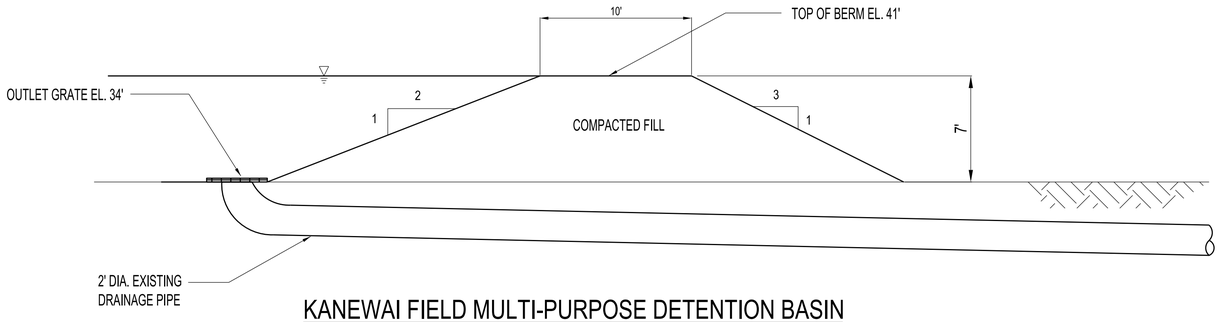


ENCLOSURE 2. Area of Potential Effects (APE) Map, Drawing

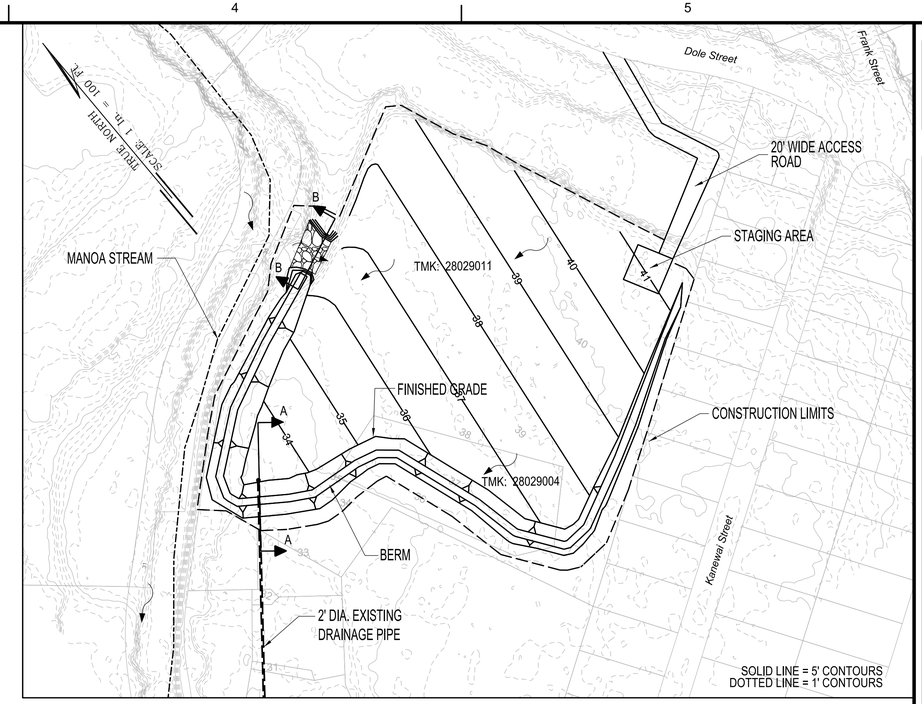
Conceptual Renderings of Detention Basins

Woodlawn Ditch (Manoa)

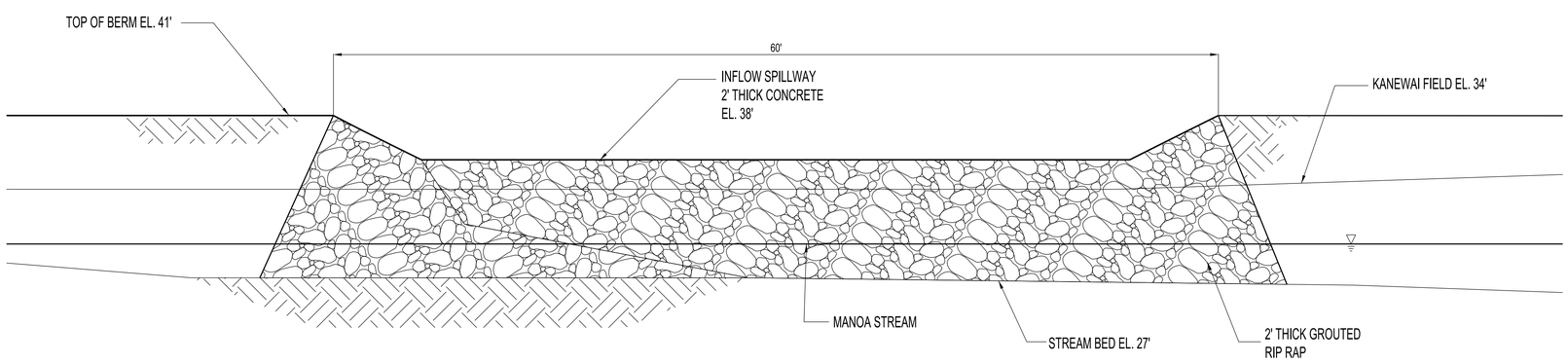
Makiki Stream



KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION A-A
SCALE: 1" = 5'



PLAN
SCALE: 1" = 100'



KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION B-B
SCALE: 1" = 5'

5' 2.5' 0 5' 10'
SCALE: 1" = 5'
Note: All elevations are feet MSL

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SUBMITTED BY: | LOCATION CODE
PLOT SCALE: AS SHOWN | PLOT DATE: AS SHOWN | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN, PLAN AND SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-306
SHEET 15 OF 28

FILE: c:\pw-work\pch-1\j3ec9jhh\d0143718\Alg_Wai_C-306xxx.dgn
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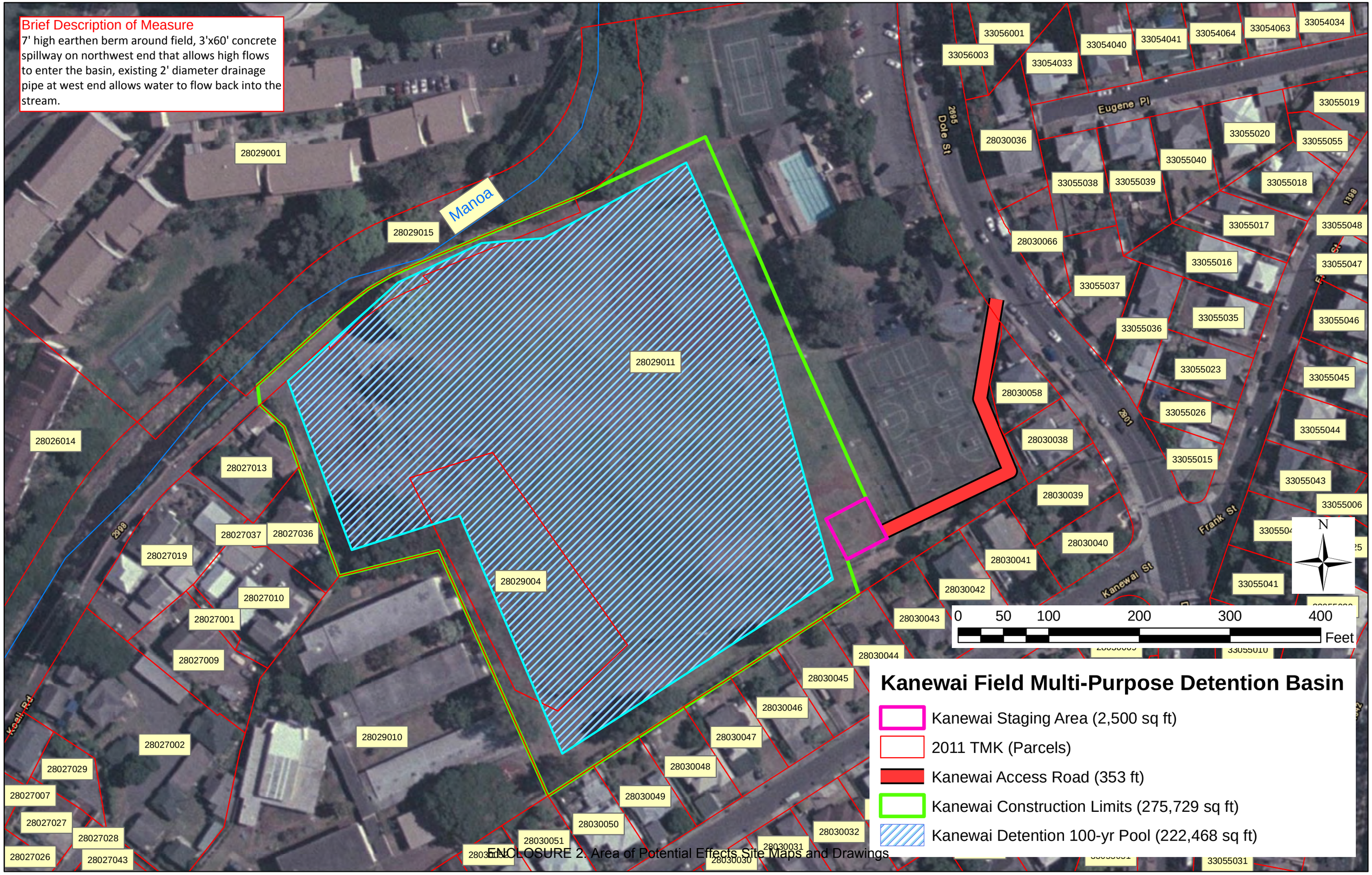
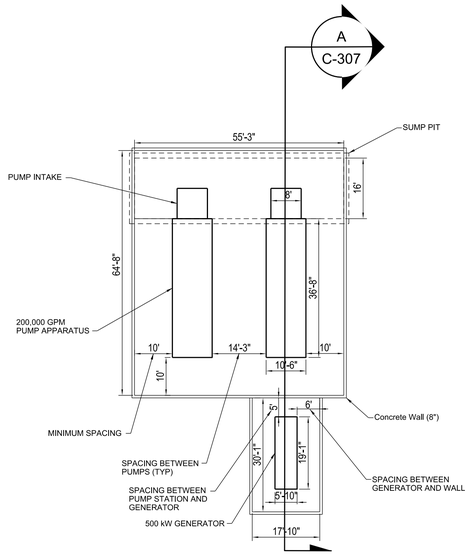
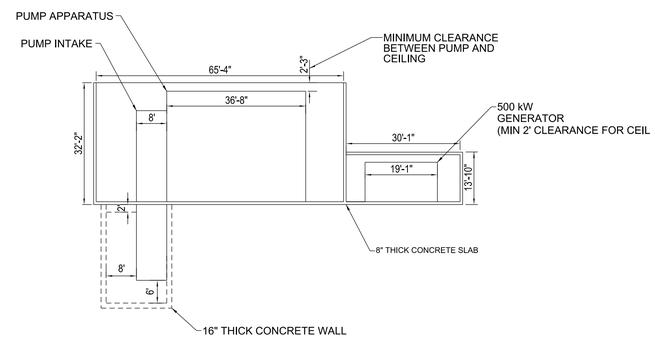


ENCLOSURE 2: Area of Potential Effects Site Maps and Drawings



PLAN - PUMP STATION

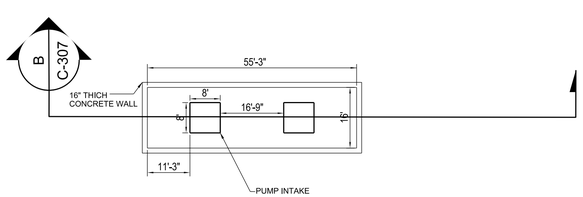
Scale: 1"=20'



A PUMP STATION SECTION

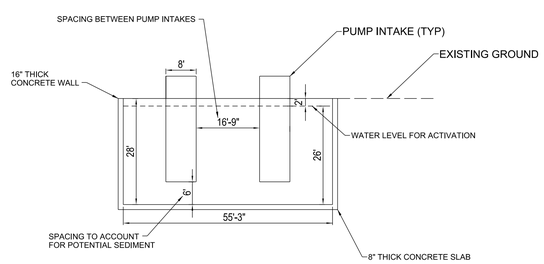
Scale: 1"=20'

ALA WAI CANAL SIDE



PLAN - SUMP PIT

Scale: 1"=20'



B PUMP SUMP PIT SECTION

Scale: 1"=20'

20 10 0 20 60

Scale: 1"=20'

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Honolulu District

35% DESIGN

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DESIGNED BY: JHH
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SUBMITTED BY:
PLOT SCALE: AS SHOWN
PLOT DATE:
SIZE: ANSI D
FILE NAME: PUMP STATION 3, PLAN & SECTIONS
DATE:
REVISION:
SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
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HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

PUMP STATION 3
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-307
SHEET 16 OF 28

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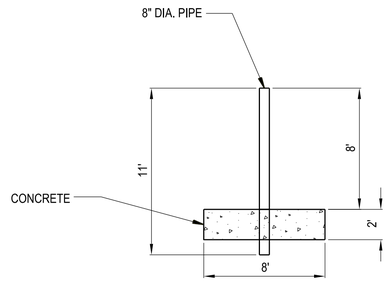
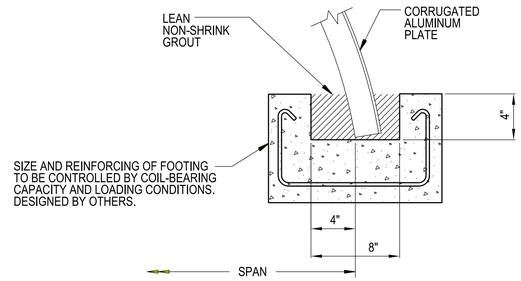
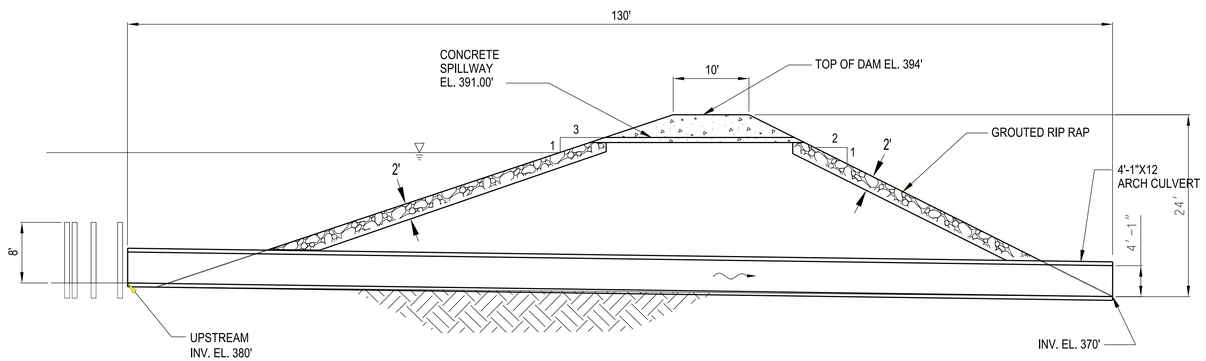


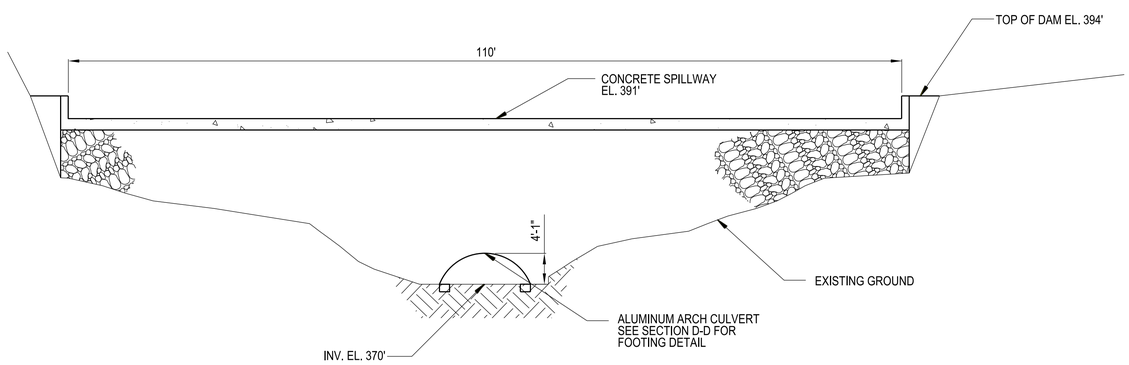
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION D-D
SCALE: NTS



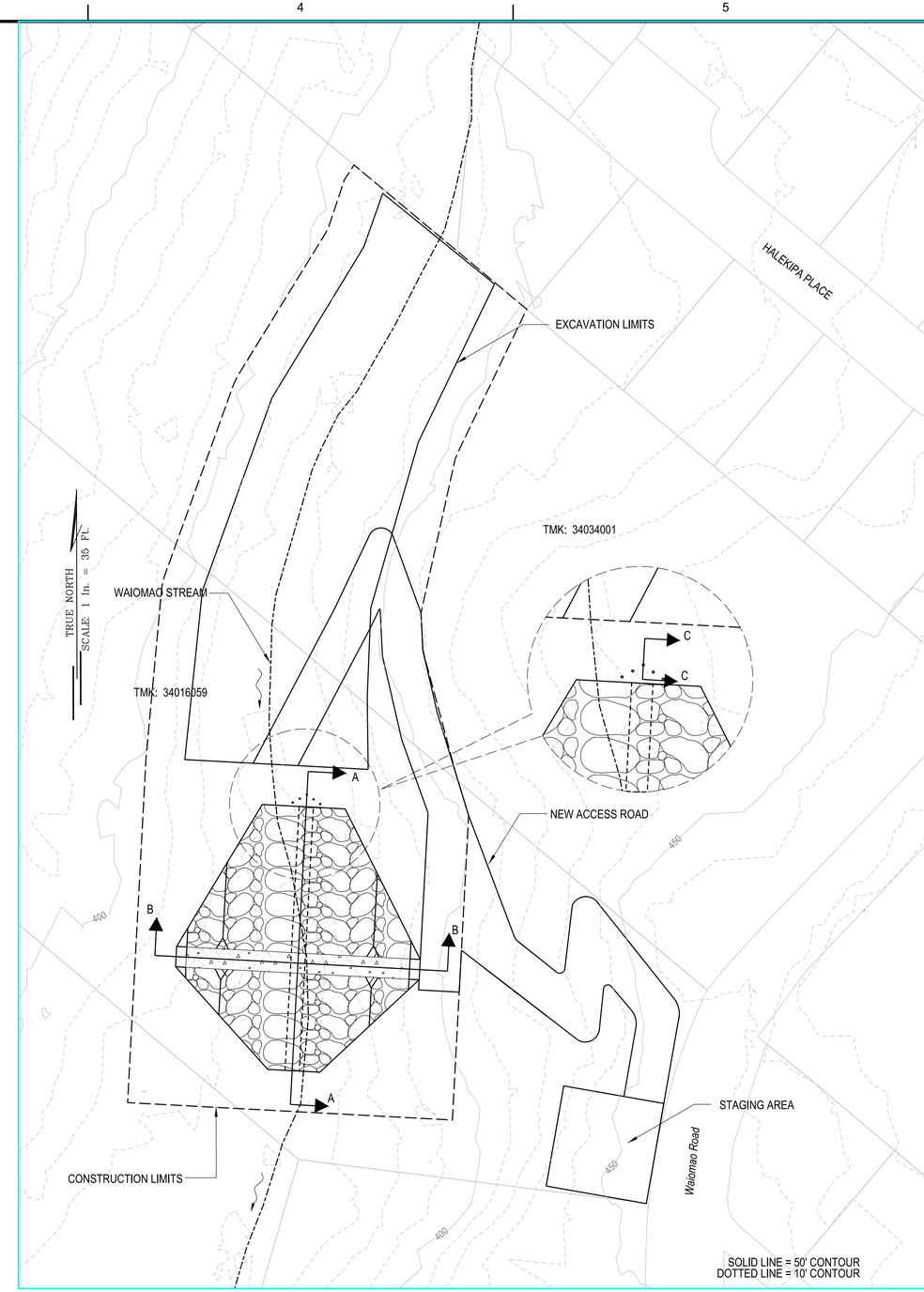
WAIOMAO DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=10'



WAIOMAO DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=10'

10 5 0 10 20
SCALE: 1" = 10'

Note: All elevations are feet MSL



PLAN
SCALE: 1"=35'

35 17.5 0 35 70
SCALE: 1" = 35'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

US Army Corps of Engineers
HONOLULU DISTRICT

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LOCATION CODE
PLOT SCALE: 1:1
PLOT DATE:
DRAWING NUMBER:
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FILE NAME: WAIOMAO DEBRIS & DETENTION BASIN, PLAN & SECTIONS
DATE:
REVISION:

ALA WAI WATERSHED PROJECT

WAIOMAO DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-308
SHEET 17 OF 28

FILE: c:\pw-work\poh-1\j3ec9jhhd\d0143718\Ala_Wai_C-308xxx.dgn
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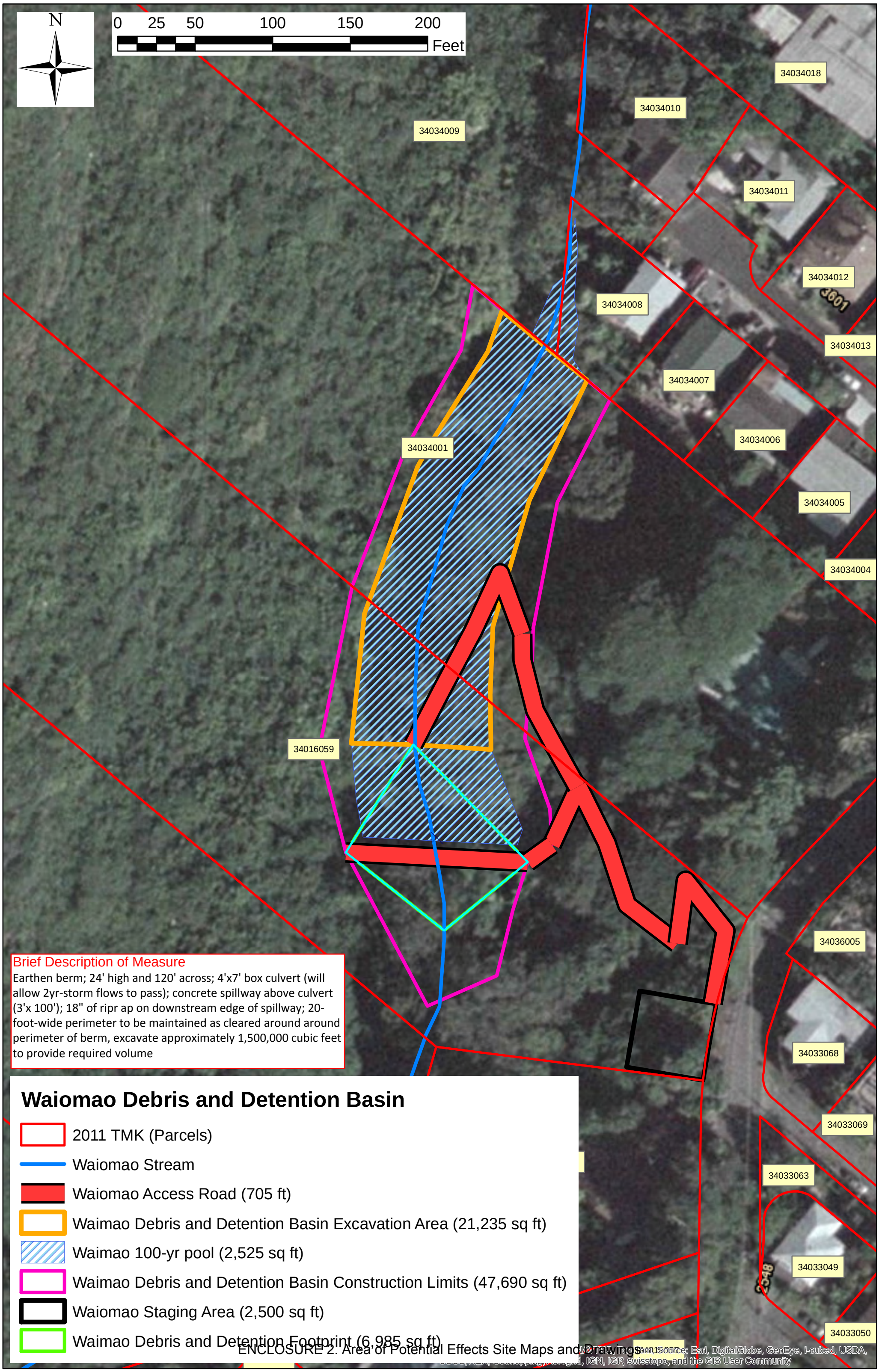
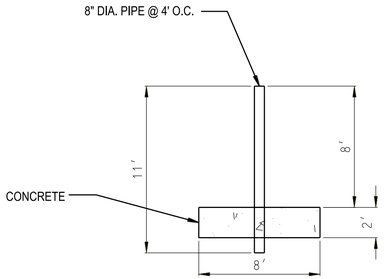
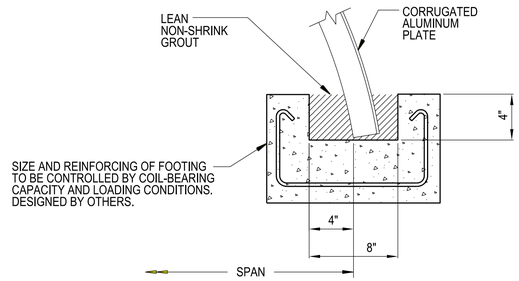


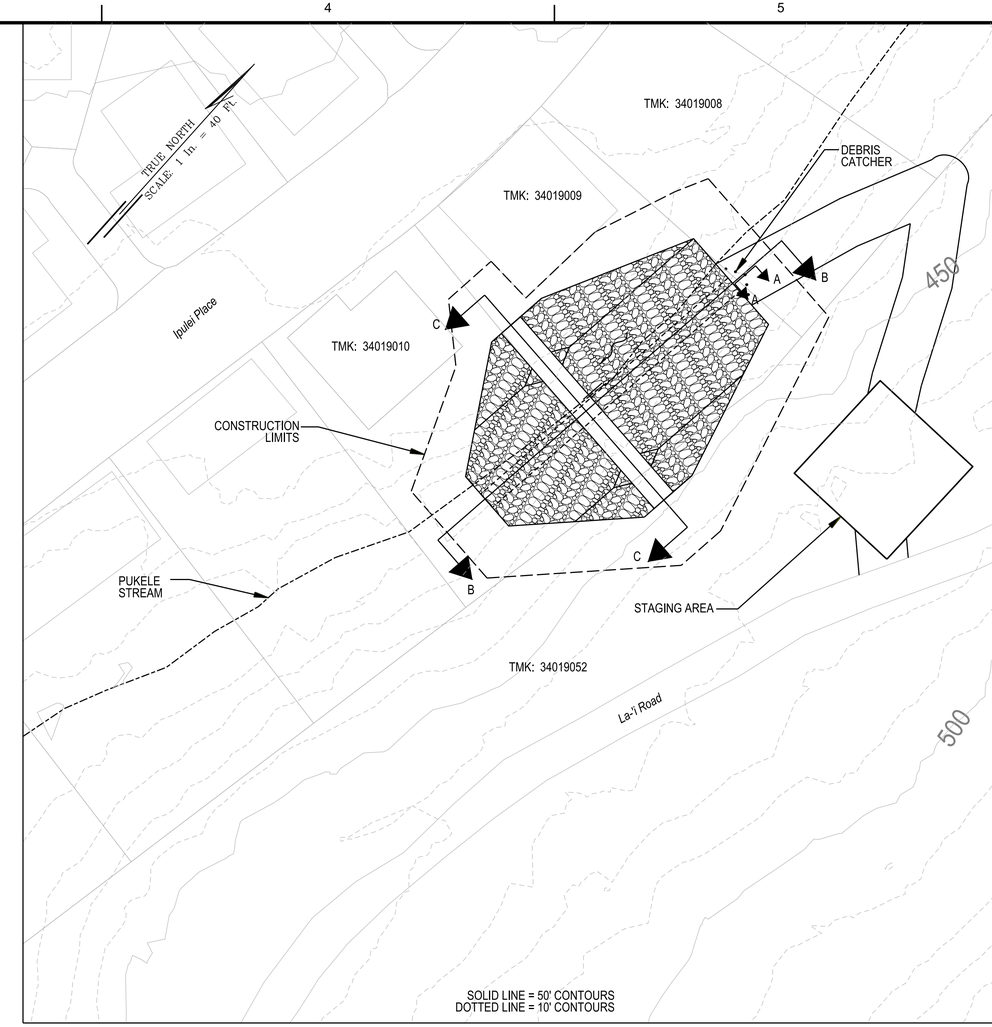
ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings



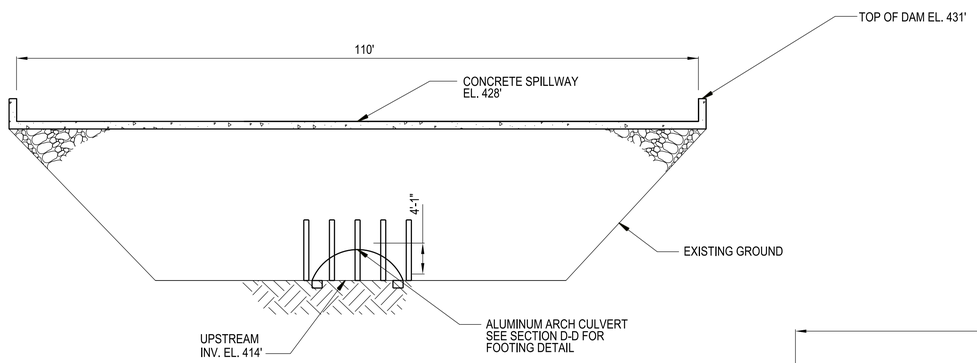
PUKELE DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE: 1"=5'



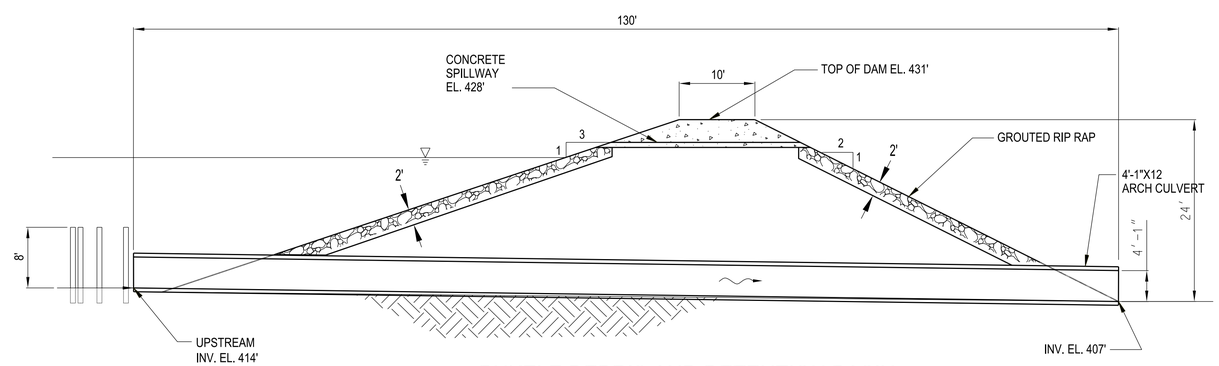
SLOTTED CONCRETE FOOTING
SECTION D-D
SCALE: NTS



PLAN
SCALE: 1"=40'



PUKELE DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=5'



PUKELE DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=5'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

5 2.5' 0 5 10
SCALE: 1" = 5'
Note: All elevations are feet MSL

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PLOT DATE:
DATE:
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SOLICIT./ CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: PUKELE DEBRIS & DETENTION BASIN, PLAN & SECTIONS

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

PUKELE DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-313
SHEET 21 OF 28

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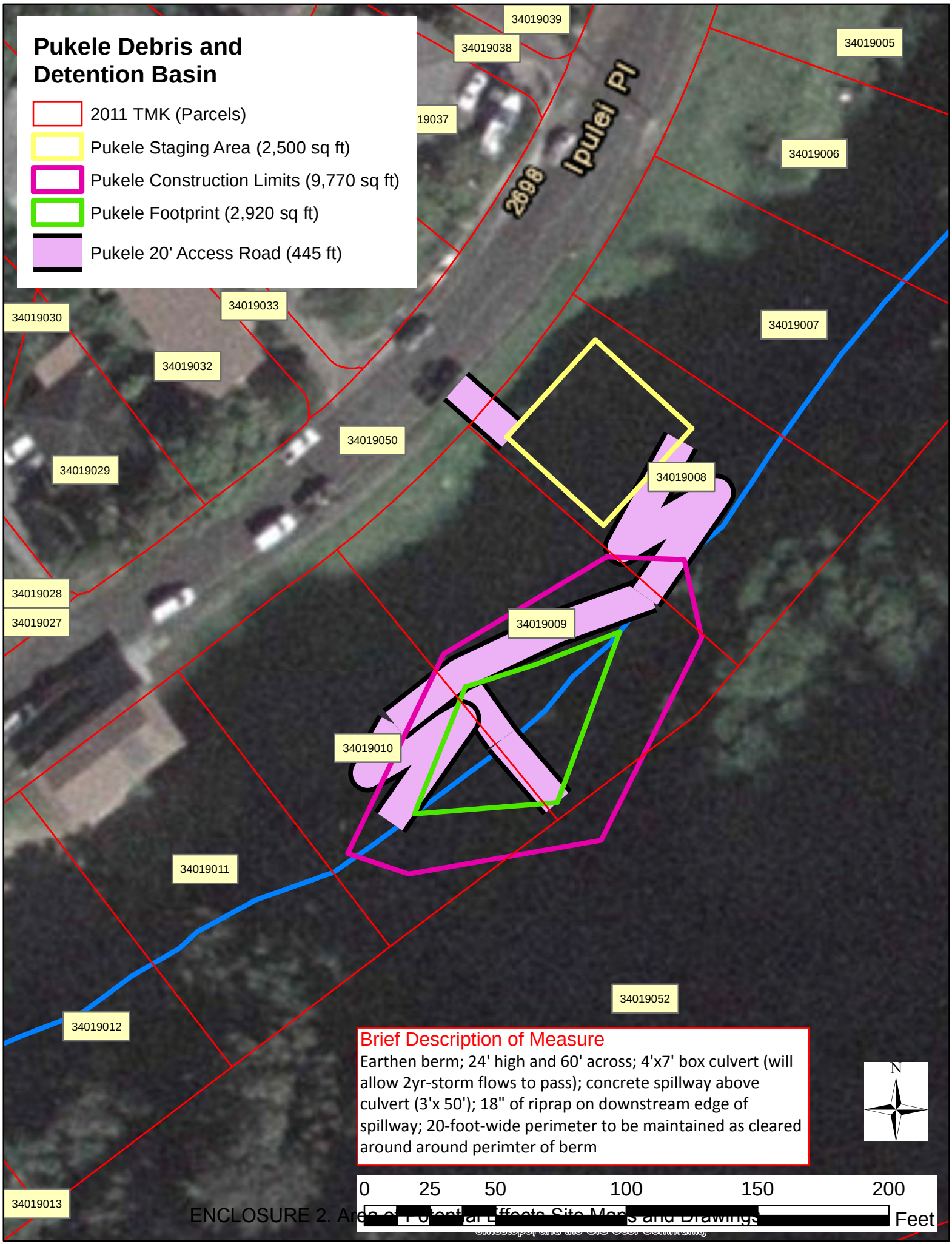
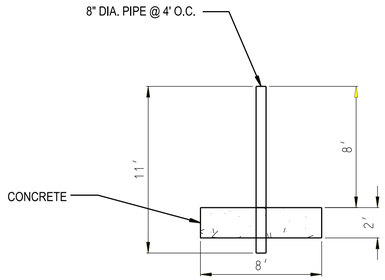
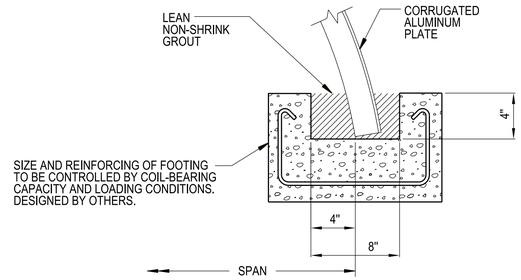


ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings



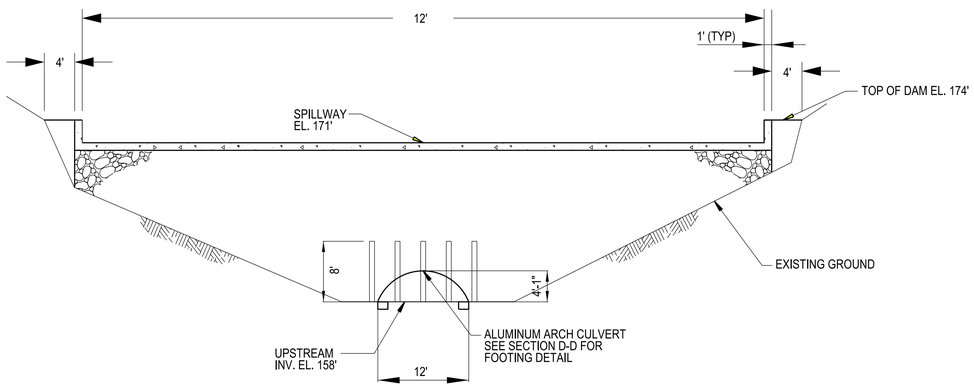
MAKIKI DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



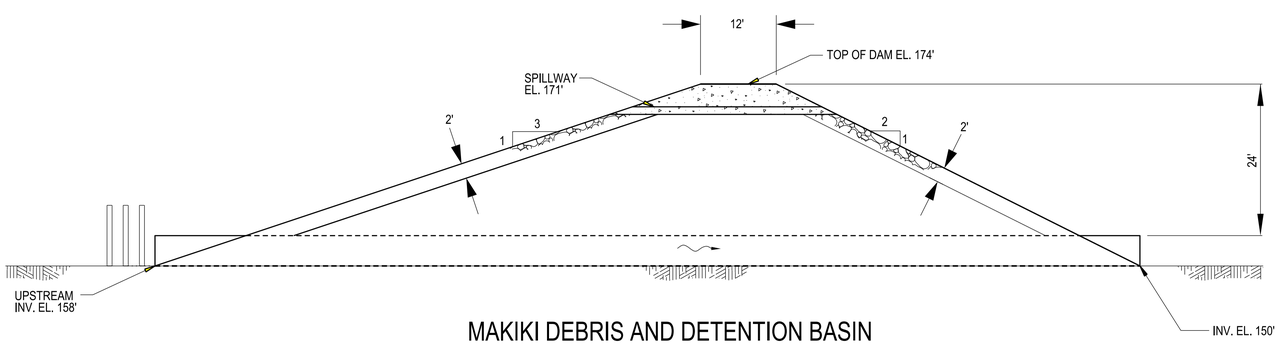
SLOTTED CONCRETE FOOTING MAKIKI DEBRIS AND DETENTION SECTION D-D

SCALE: NTS



MAKIKI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'



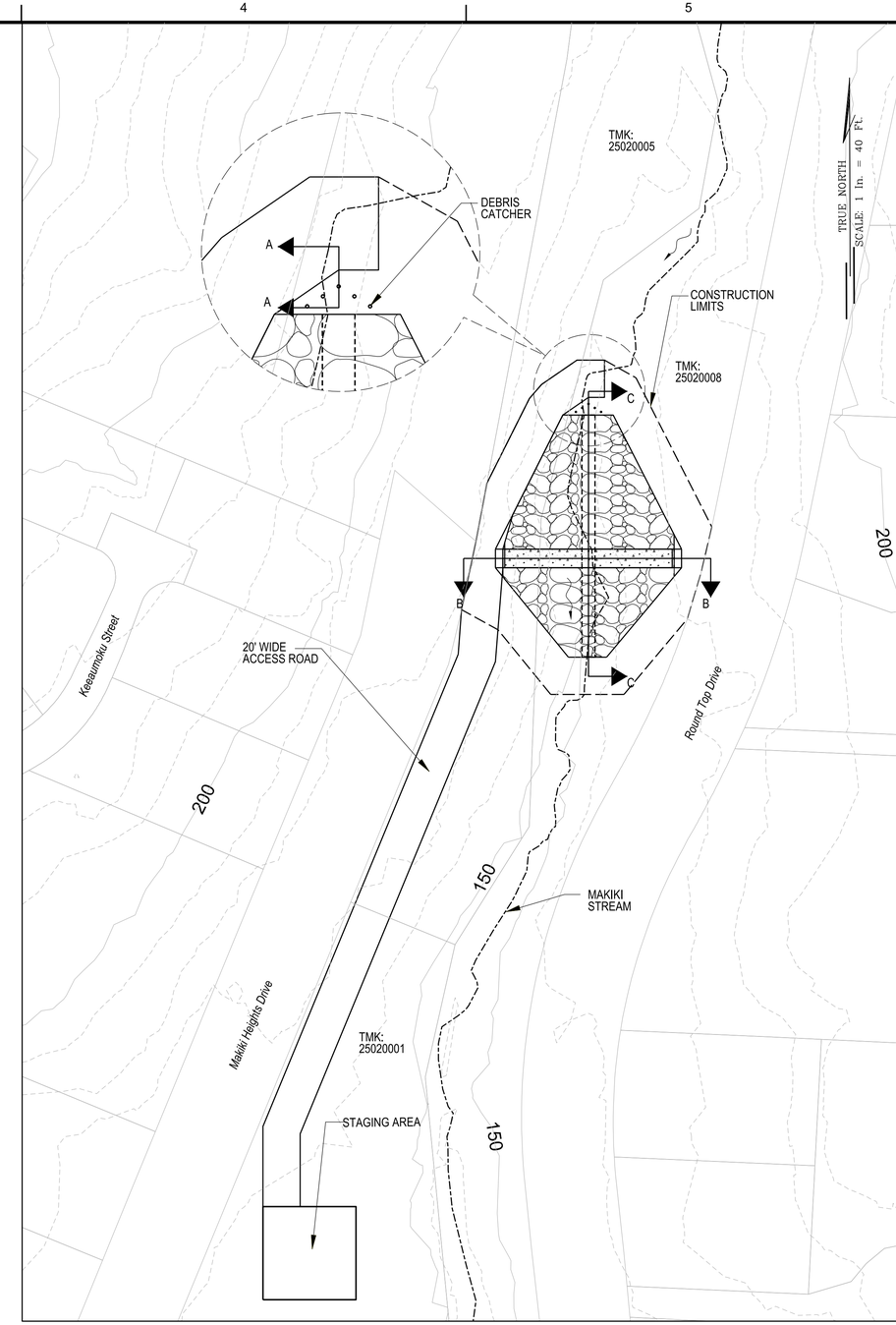
MAKIKI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=10'

10' 5' 0 10' 20'

SCALE: 1" = 10'

Note: All elevations are feet MSL



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

NOTES:

1. ALUMINUM ARCH CULVERT METAL THICHNESS IS 1.50". WITH A NATURAL BOTTOM.
2. THE APPROXIMATE AREA UNDER THE ARCH CULVERT IS 35.3 SQ FT.

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FILE NAME: MAKIKI DEBRIS & DETENTION BASIN, PLAN & SECTIONS
DATE:
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SOLICIT. / CONTRACT NO.:
LOCATION CODE
DRAWING NUMBER:

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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MAKIKI DEBRIS AND DETENTION BASIN PLAN AND SECTIONS

SHEET IDENTIFICATION
C-315
SHEET 22 OF 28

FILE: c:\pw-work\pch-1\j3ec9jhh\d0143718\Ala_Wai_C-315xxx.dgn
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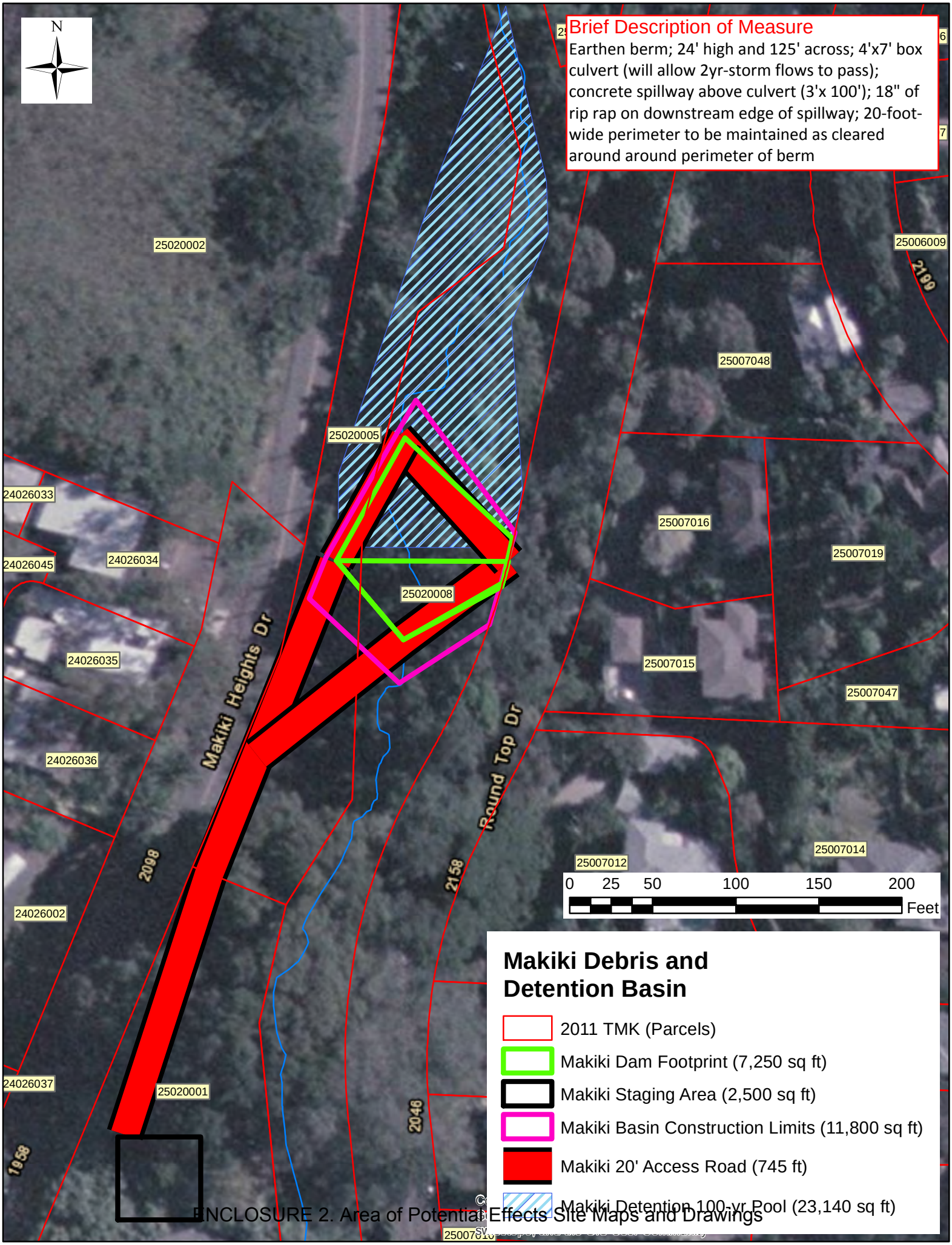
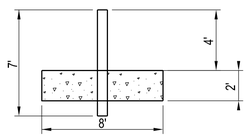
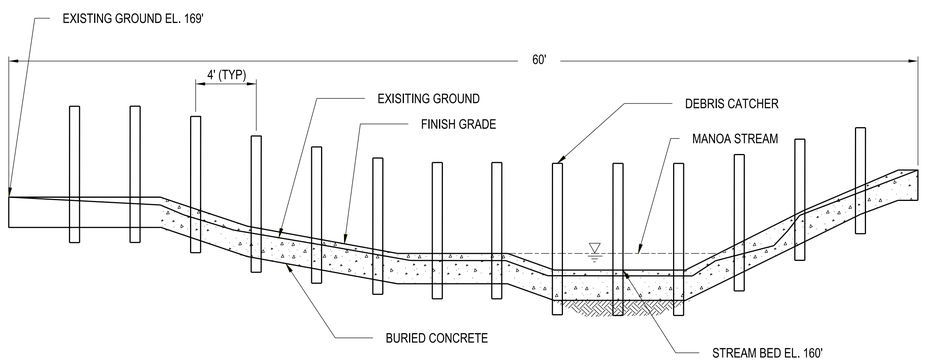


ENCLOSURE 2. Area of Potential Effects Site Maps and Drawings



MANOA IN-STREAM DEBRIS CATHMENT
SECTION A-A

SCALE: 1"=5'



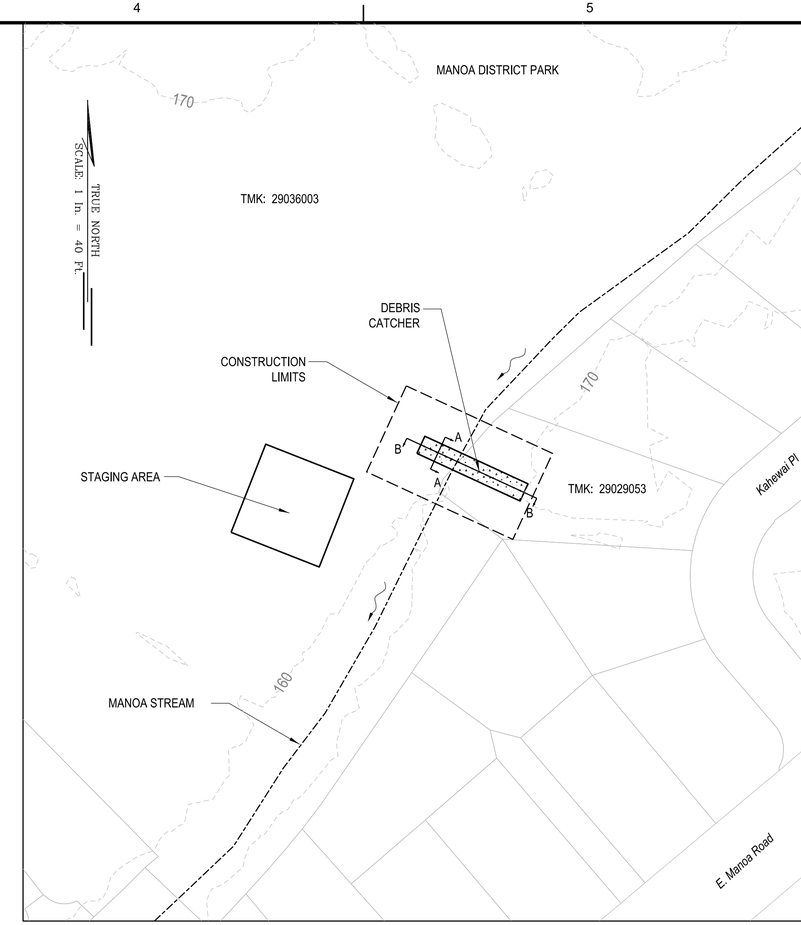
MANOA IN-STREAM DEBRIS CATCHMENT
SECTION B-B

SCALE: 1"=5'

5' 2.5' 0 5' 10'

SCALE: 1" = 5'

Note: All elevations are feet MSL



SOLID LINE = 50' CONTOURS
DOTTED LINE = 10' CONTOURS

PLAN

SCALE: 1"=40'

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MARK	DESCRIPTION	DATE	APPR.	MARK	DESCRIPTION	DATE	APPR.

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

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REVISION:
DRAWN BY:
CHECKED BY:
SOLICIT./ CONTRACT NO.:
SUBMITTED BY:
LOCATION CODE
PLOT SCALE: AS SHOWN
PLOT DATE:
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: MANOA IN-STREAM DEBRIS CATCHMENT, PLAN & SECTIONS

ALA WAI WATERSHED PROJECT

MANOA IN-STREAM DEBRIS CATCHMENT
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-318
SHEET 25 OF 28

FILE: c:\pw-work\poh-1\j3ec9jhh\d0143718\Ala_Wai_C-318xxx.dgn
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PEN TABLE: BW_and_Grayscale_Pen.tbl
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Manoa Park In-Stream Debris Catchment

- Manoa In-stream Debris Catchment footprint (540 sq ft)
- Manoa In-stream Debris Catchment Construction Limits (3,740 sq ft)
- Manoa In-stream Debris Catchement Staging Area (2,500 sq ft)
- HI_OAHU.parcel_area_2011

Brief Description of Measure

Concrete pad; 8' wide, 2' thick, 140' across; steel posts (4' - 7' high), spaced every 4' along concrete pad

N

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29037088
29029057
29029056
29029062
29029061
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29029043
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29074061

E Manoa Rd

0 50 100 200 300 400 Feet

ENCLOSURE 3 – Area of Potential Effects Site Maps and Drawings

USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

William Aila, Jr.
Chairman & State Historic Preservation Officer
DLNR
Kakuhihewa Building
601 Kamokila Blvd., Suite 555
Kapolei, HI 96707

Alan Downer
Administrator
State Historic Preservation Division
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HRD147095

October 22, 2014

Dan Nakamura, P.E.
Chief, Environmental Programs Branch
Programs and Project Management Division
Honolulu District, U.S. Army Corps of Engineers
Fort Shafter, Hawai'i 96858-5440

Re: Coordination for Determination of Area of Potential Effect, Ala Wai Canal Watershed Project Honolulu Ahupua'a Mānoa, Pālolo, and Makiki, Kona Moku, O'ahu Island

Aloha e Mr. Nakamura:

The Office of Hawaiian Affairs (OHA) is in receipt of your August 21, 2014 submission, with enclosures, requesting review, comments, and concurrence to the proposed area of potential effect (APE) for the Ala Wai Canal Watershed Project. The United States Army Corps of Engineers, Honolulu District (the Corps) has preliminarily determined the APE for the Ala Wai Canal Watershed Project in accordance with 36 § CFR Part 800.16(d). Based on your August 21st submission, the Corps has preliminarily selected Alternative 3A as the preferred alternative, however both Alternative 2A and 3A will be evaluated in a draft combined feasibility report and environmental impact statement (EIS), which will be produced in 2015. According to your submission, a draft supplemental technical report, which will include additional interviews with Native Hawaiian Organizations (NHO), lineal descendants, and knowledgeable individuals of the watersheds is being prepared and will be made available upon request.

For archaeological/cultural resources, the APE is described as the entire Tax Map Key (TMK) parcel in which all areas of ground disturbance are proposed. These areas include stream debris catchment structures, detention basins, floodwalls, access roads, and storage yards for equipment and construction materials. For Traditional Cultural Properties (TCPs), the APE is proposed to be an extension of a visual or aesthetic element extending outwards and/or upwards 500 feet from the TMK parcels in which the area of ground disturbance are proposed and TCPs are reported to be present.

We request that once the draft supplemental report, containing interviews with NHO, lineal/cultural descendants, and knowledgeable individuals of the watershed, is completed that OHA be provided a copy for review and comments. At this time, we cannot preliminarily concur with your description and depiction of the proposed APE. While a large number of maps and associated engineering drawing were provided with your submission, a clear description of the proposed project and its desired outcomes was not provided. In addition, your cover letter submission appears to be incomplete with the Page 2 opening paragraph containing what appears to be a cut-off sentence and confusing information. We request that a complete description of the proposed project be provided to our office. If your staff would like to meet with OHA representatives to discuss the project, please contact our offices at the phone or email listed below and we can set up a mutually agreeable date for a meeting. Once a complete description of the proposed project is provided, we will be able to provide comments and recommendations on the project's potential effects. We also look forward to reviewing the draft EIS once it has been prepared.

Thank you for initiating consultation. Should you have any questions or concerns please contact Lauren Morawski of our Kia'i Kānāwai (Compliance Enforcement) division at (808) 594-1997 or laurenm@oha.org.

'O wau iho nō,

Kamana'opono M. Crabbe

Kamana'opono M. Crabbe, Ph.D.
Ka Pouhana, Chief Executive Officer

KC;lm

March 10, 2015 Consultation Letter Redefining the Areas of Potential Effect and Correspondence with Historic Hawaii Foundation

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

March 10, 2015

Environmental Programs Branch
Programs and Project Management

Alan S. Downer, Ph.D.
Administrator & Deputy State Historic Preservation Officer
State Historic Preservation Division
Kakuhihewa Building
601 Kamokila Blvd., Suite 555
Kapolei, HI 96707

Dear Mr. Downer:

We are writing to continue NHPA Section 106 consultation on the Ala Wai Canal Project. The intent of this letter is to redefine the Area of Potential Effect (APE), and clarify the scope of the project. The content of this consultation is also being used for notification and compliance under Chapter 6E of the Hawaii Revised Statutes.

In our letter dated August 21, 2014, we had identified the APE with separate definitions for the Archaeological Resources APE, the Historic Resources APE, and the Traditional Cultural Properties APE. As part of ongoing consultation for this project, we have met with the State Historic Preservation Division and redefined the APE, having now identified a Direct and Indirect APE for each planned construction activity (flood mitigation measure). The Direct APE is the area that will be directly affected by construction, and includes the footprint of the measure to be constructed, the construction footprint with construction buffer, staging area, and access road. The Indirect APE is defined as a one-half mile radius from the outer edge of the Direct APE. The new APEs are defined the same for Archaeological Resources, Historic Resources, and Traditional Cultural Properties.

Maps of both Direct and Indirect APEs, along with a description of each measure are attached (Enclosure 1). Acreages and TMKs are displayed on the maps. The APE maps also display cultural resources identified during cultural resource investigations in support of this project (reference *Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project, Honolulu, Makiki, Mānoa, Pālolo, and Waikīkī Ahupua'a, Honolulu District, O'ahu Island*, Volumes I, II, and III; *Cultural Impact Assessment for the Ala Wai Canal Project, Waikīkī, Pālolo, Makiki, and Mānoa Ahupua'a, Honolulu (Kona) District, O'ahu*; and *Historic Structures Inventory Survey of the Ala Wai Watershed*). Additional details on historic properties identification and effects determinations will be provided in our next consultation letter.

The Tentatively Selected Plan (TSP) for the Ala Wai Canal Project will introduce 13 measures into the Ala Wai Watershed to mitigate potential flooding associated with large storm events. The thirteen measures to be constructed are:

Makiki
1. Makiki Debris and Detention Basin

Manoa Valley
2. Waihi Debris and Detention Basin
3. Waiakeakua Debris and Detention Basin
4. Woodlawn Ditch Detention Basin
5. Manoa In-Stream Debris Catchment
6. Kanewai Field Multi-Purpose Detention Basin

Palolo Valley
7. Pukele Debris and Detention Basin
8. Waiomao Debris and Detention Basin

Ala Wai
9. Hausten Ditch Detention Basin
10. Ala Wai Golf Course Multi-Purpose Detention Basin
11. Ala Wai Canal Floodwalls

Watershed
12. Flood Warning System
13. Aquatic Habitat Mitigation

To assist with clarifying the scope of the project, we are providing the following additional information about the nature of the work at each measure:

a. A description of the measure
b. Why this is the best location for the proposed measure
c. What the area looks like now
d. What will it look like with the measure in place (conceptual rendering)
e. What is the area used for now
f. What can it be used for after the measure is constructed
g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, more frequent storm events
h. Identify measures that have flexibility in their proposed location (can be moved upstream/downstream based on impacts to cultural resources) from those measures whose locations are fixed
i. Provide Direct APE acreage and TMKs for each APE

The Honolulu District, U.S. Army Corps of Engineers (Corps) requests your review and comments on the APEs within 31 days of your receipt of this letter. Our next letter will identify historic properties and assess adverse effects. A list of parties to whom this letter has been sent is included (Enclosure 2). We have added the Historic Hawaii Foundation, Nā Ala Hele, Oahu Island Burial Council, Oahu Hawaiian Canoe Racing Association, and DLNR Division of Forestry and Wildlife (DOFAW) as consulting parties.

The Corps, at your convenience, is available to meet with you to discuss measures to advance consultation and ensure compliance with Section 106 and applicable Hawaii Revised Statutes and Administrative Rules. Should you have any questions, please contact Mr. Loren Zulick, Archaeologist, of my branch, at (808) 835-4305, or e-mail loren.a.zulick@usace.army.mil.

Sincerely,

DAN NAKAMURA
Chief, Environmental Programs Branch

Enclosures

Enclosure 1

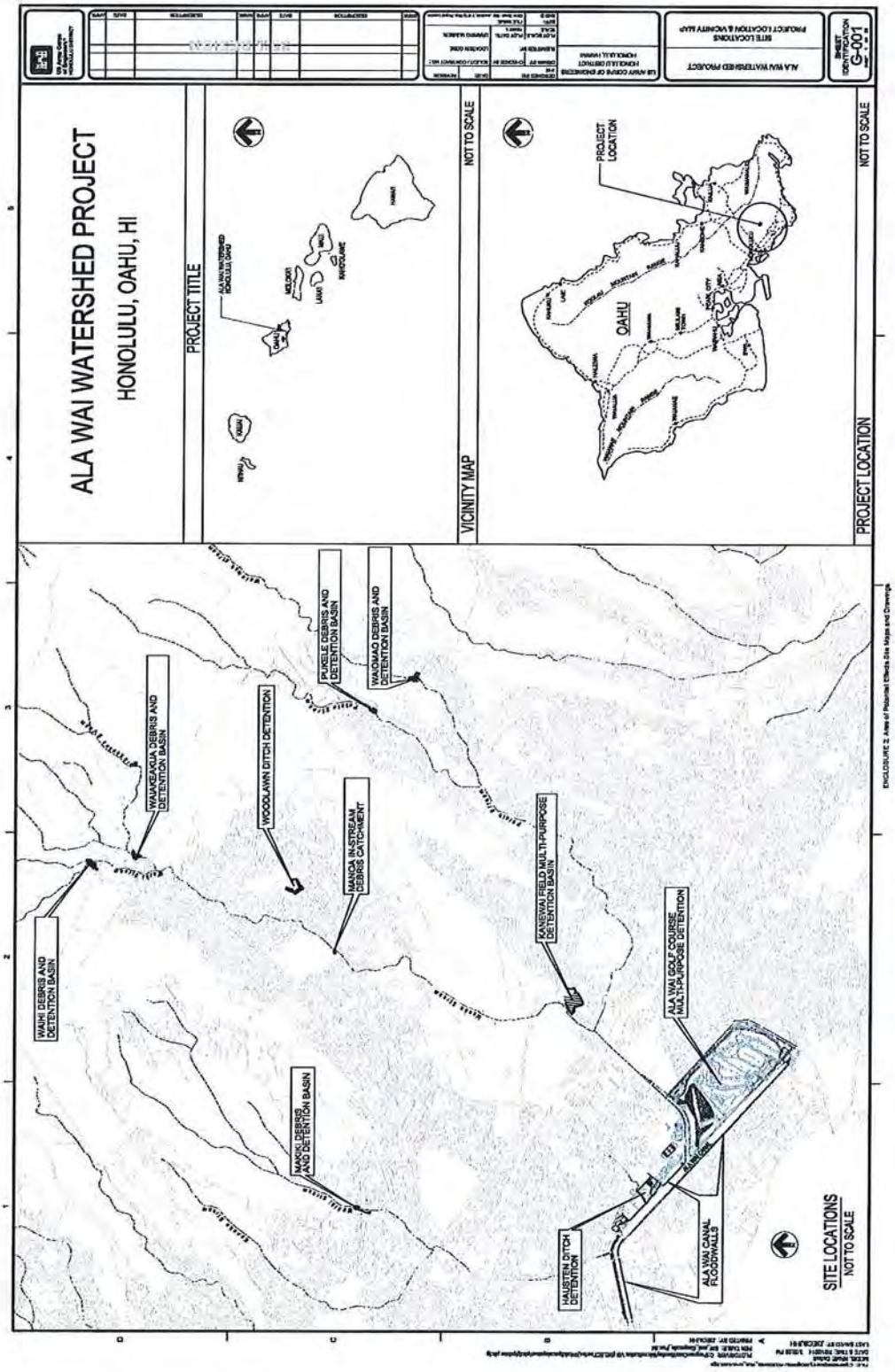

Figure 1 Project Location Map

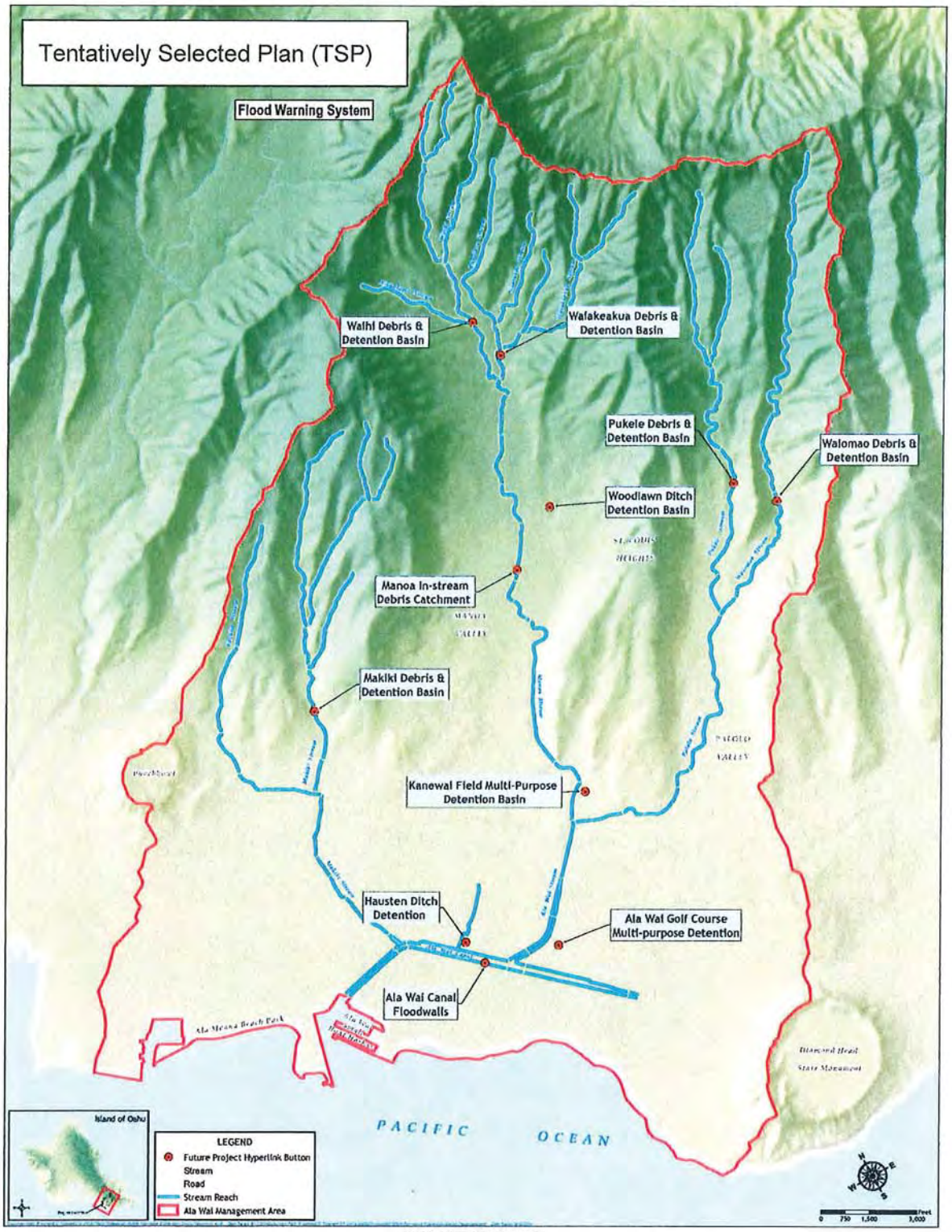

Figure 2 Location of Proposed Flood Protection Measures

Makiki
Measure No. 1: Makiki Debris and Detention Basin

a. Description of the measure
Earthen berm, approximately 24' high and 100' across, with an arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. Why this is the best location for the proposed measure
The Project Delivery Team (PDT) conducted three days of field reconnaissance, and looked at preliminary proposed locations to assess for technical feasibility. Technical feasibility for a measure includes (1) access; (2) topography; (3) land ownership; and (4) presence/absence of natural and cultural resources. (1) The site must be accessible for construction and maintenance. (2) The topography must support a minimal amount of material and construction. (3) Public land ownership is preferred over private land ownership. (4) Avoidance of significant/protected natural and cultural resources in area. Many of the preliminary sitings for the measures were changed as a result of the field reconnaissance effort.

Specifically, for the Makiki Debris and Detention Basin, the following factors contributed to selecting the preferred location:
Macrositing – Could not go higher into watershed because of restricted topographic access.
Micrositing – land ownership (site is on public land); access to public roads; and the topography supports construction with least amount of earthwork.

c. What the area looks like now: See Figure 3

d. What will it look like with the measure in place
See Figure 4 for a conceptual rendering.

NOTE: All renderings provided are conceptual in nature and are intended to present a general visual representation of the proposed measure. Exact layout/look and specific design details will be refined during design phase, and may differ slightly from those shown.

e. What is the area used for now
The proposed location is a forested upper watershed, adjacent to a residential area and park; no known agricultural practices within footprint; adjacent open space areas may be used for recreation and possibly by a charter school.

f. What can it be used for after the measure

Normal stream flow will not be affected; new measure will impound (pool) water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use (including adjacent recreational use of open space areas) will not change; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events

This measure will be used for all flood events, but would only begin to impound water (pool in basin) above a 5-year flood event.

h. Flexibility of proposed measure location

Location of the Makiki Debris and Detention Basin is flexible. Design can microsite (move minimally) upstream/downstream to avoid resources.

i. Direct APE acreage: 0.5 acres

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Figure 3 Location of Makiki Debris and Detention Basin at Present

Conceptual Rendering of the Makiki Detention Basin

Figure 4 Conceptual Rendering of Makiki Debris and Detention Basin with Measure

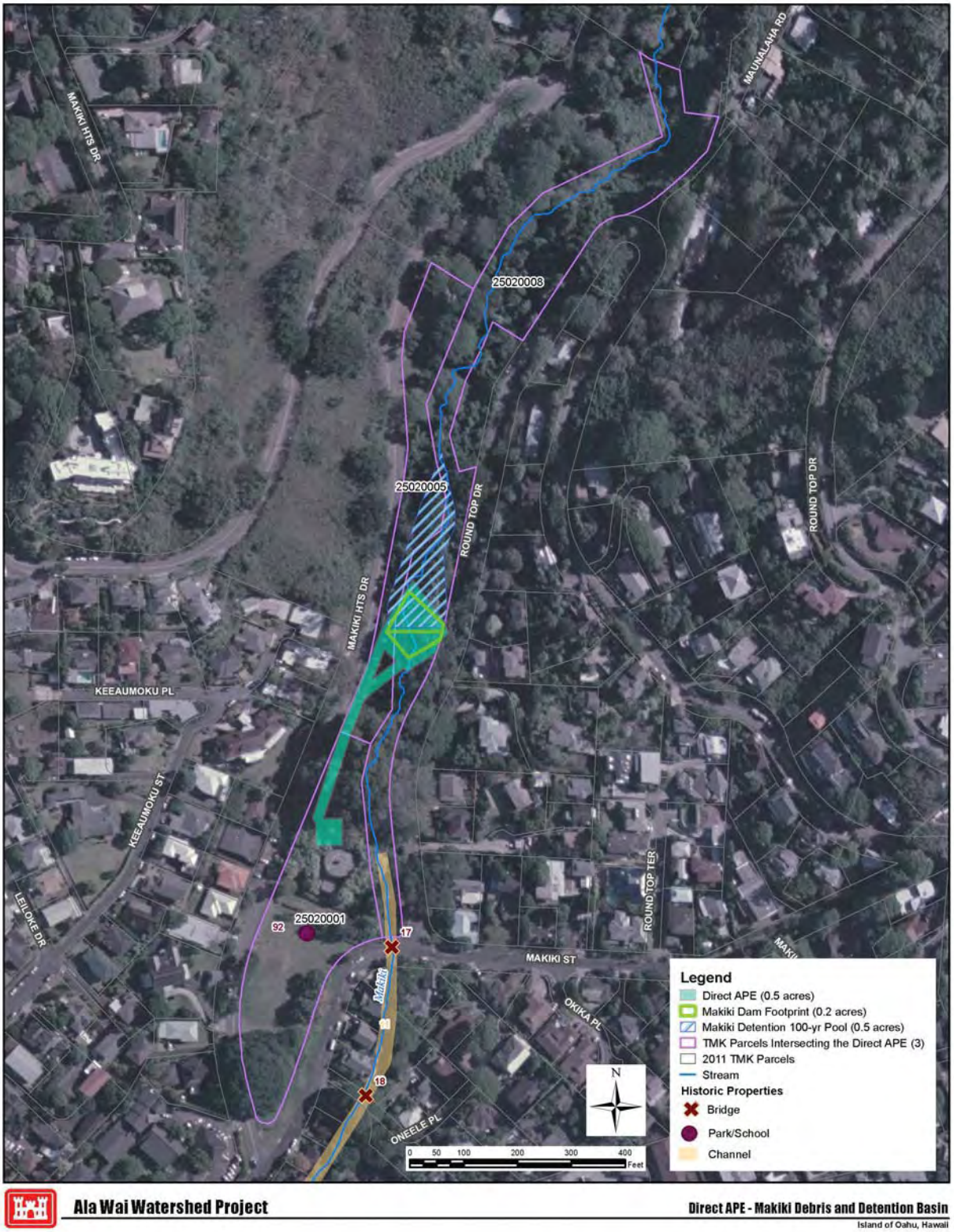
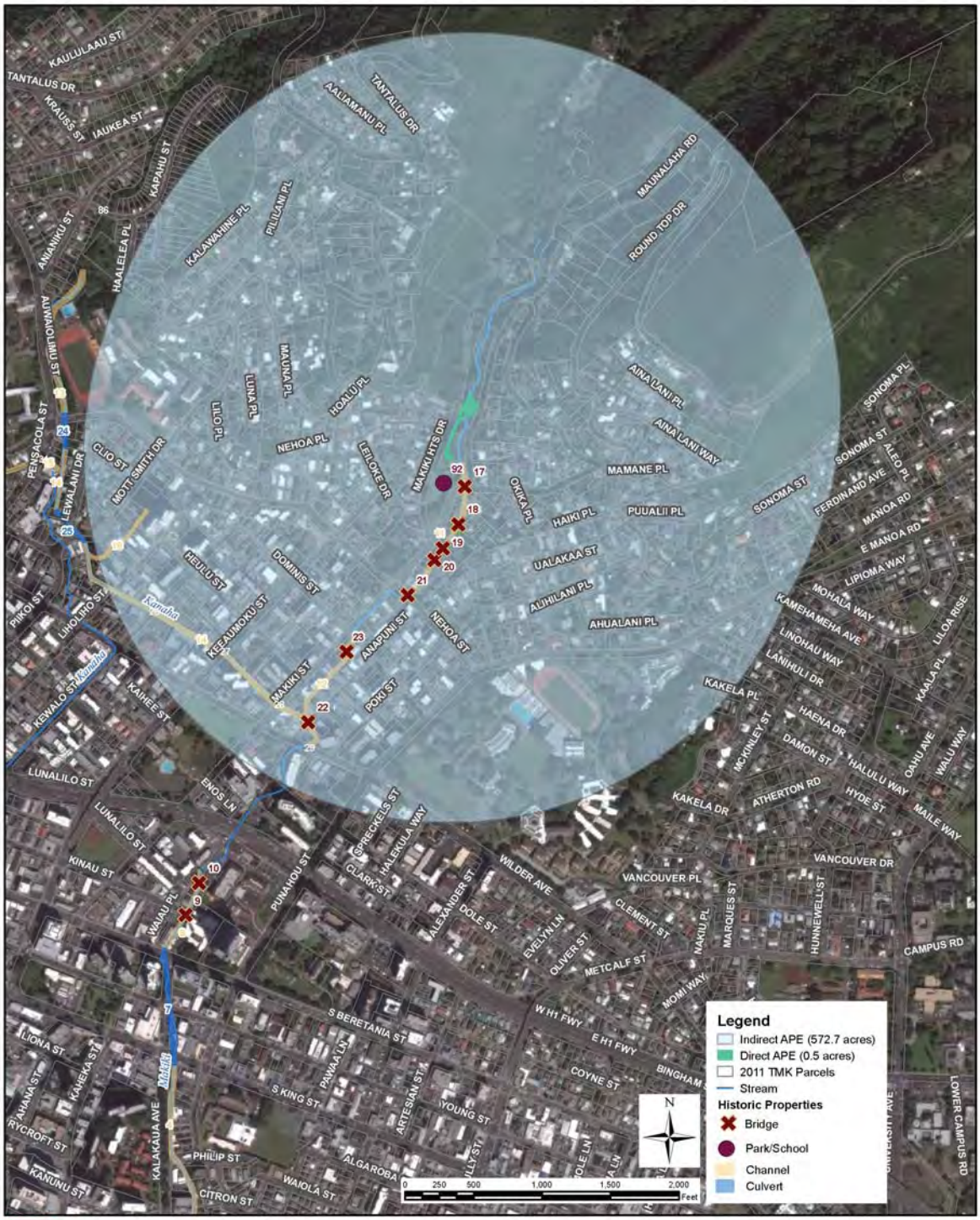


Figure 5 Direct APE for Makiki Debris and Detention Basin



Ala Wai Watershed Project

Indirect APE - Makiki Debris and Detention Basin

Island of Oahu, Hawaii

Figure 6 Indirect APE for Makiki Debris and Detention Basin

Manoa Valley
Measure No. 2: Waihi Debris and Detention Basin

a. Description of the measure
Earthen berm, approximately 24' high and 225' across, with an arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. Why this is the best location for the proposed measure
Macrositing - Needs to be in upper watershed to capture peak flows, but as close to urban area as possible.
Micrositing – land ownership (trying to stay on public land), access to Manoa Road, and the topography supports construction with least amount of earthwork.

c. What the area looks like now: See Figure 7

d. What will it look like with the measure in place: See Figure 8

e. What is the area used for now
The proposed location is a forested upper watershed with no formal recreational access; no agricultural or commercial practices within footprint, but some agriculture/loi located nearby.

f. What can it be used for after the measure
Normal stream flow will not be affected; new measure will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
This measure will be used for all flood events, but would only impound water above five year flood event.

h. Flexibility of proposed measure location
Location of the Waihi Debris and Detention Basin is flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 0.7 acres

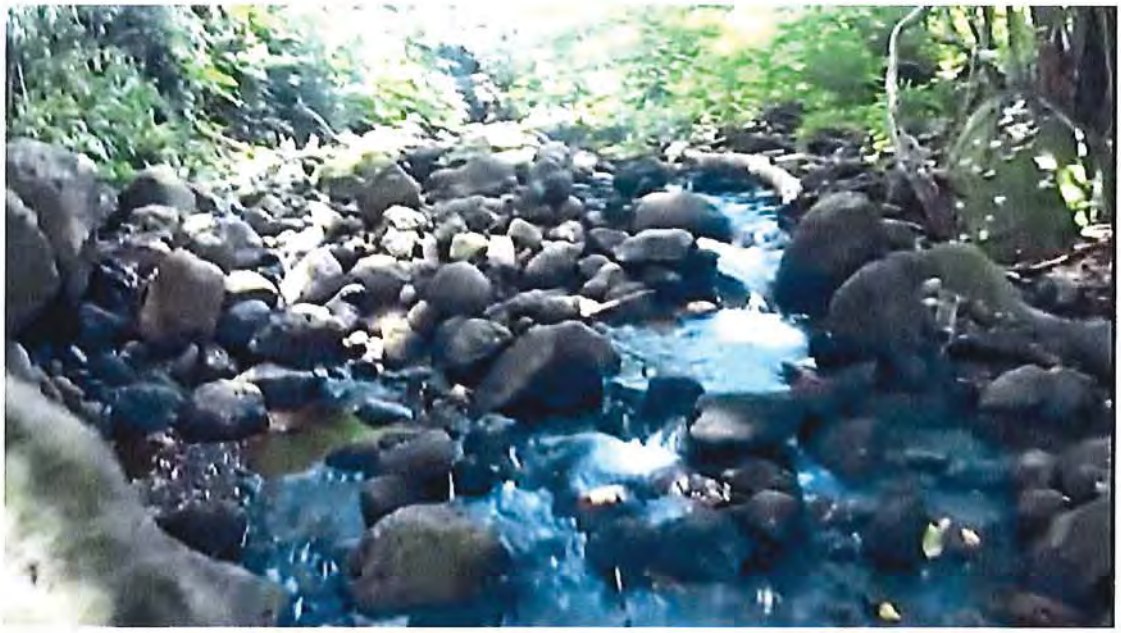


Figure 7 Present Photo of Approximate Location of Waihi Debris and Detention Basin

Figure 8 Conceptual Rendering of Waihi Debris and Detention Basin with Measure (modified from Waiakeakua detention basin measure)

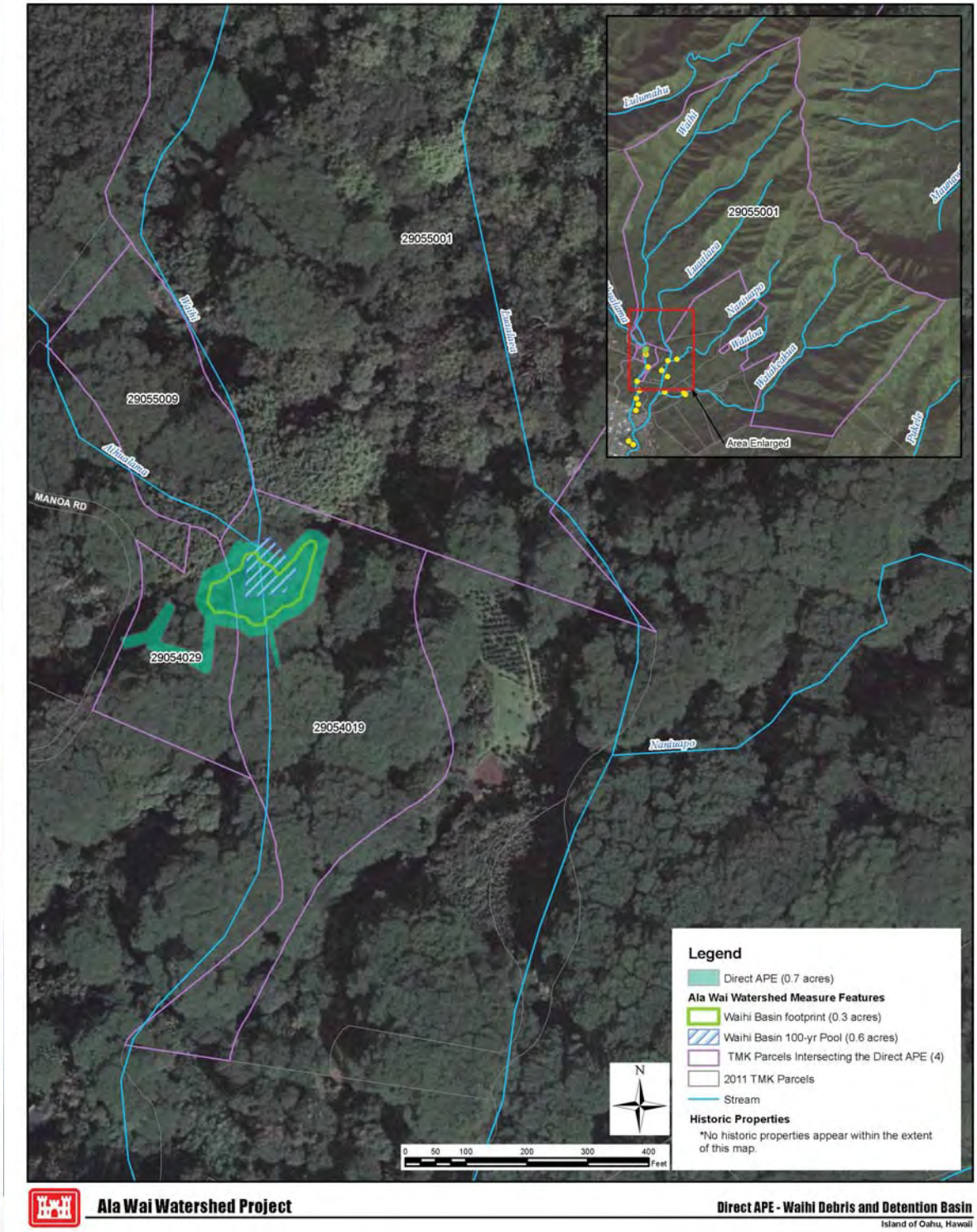
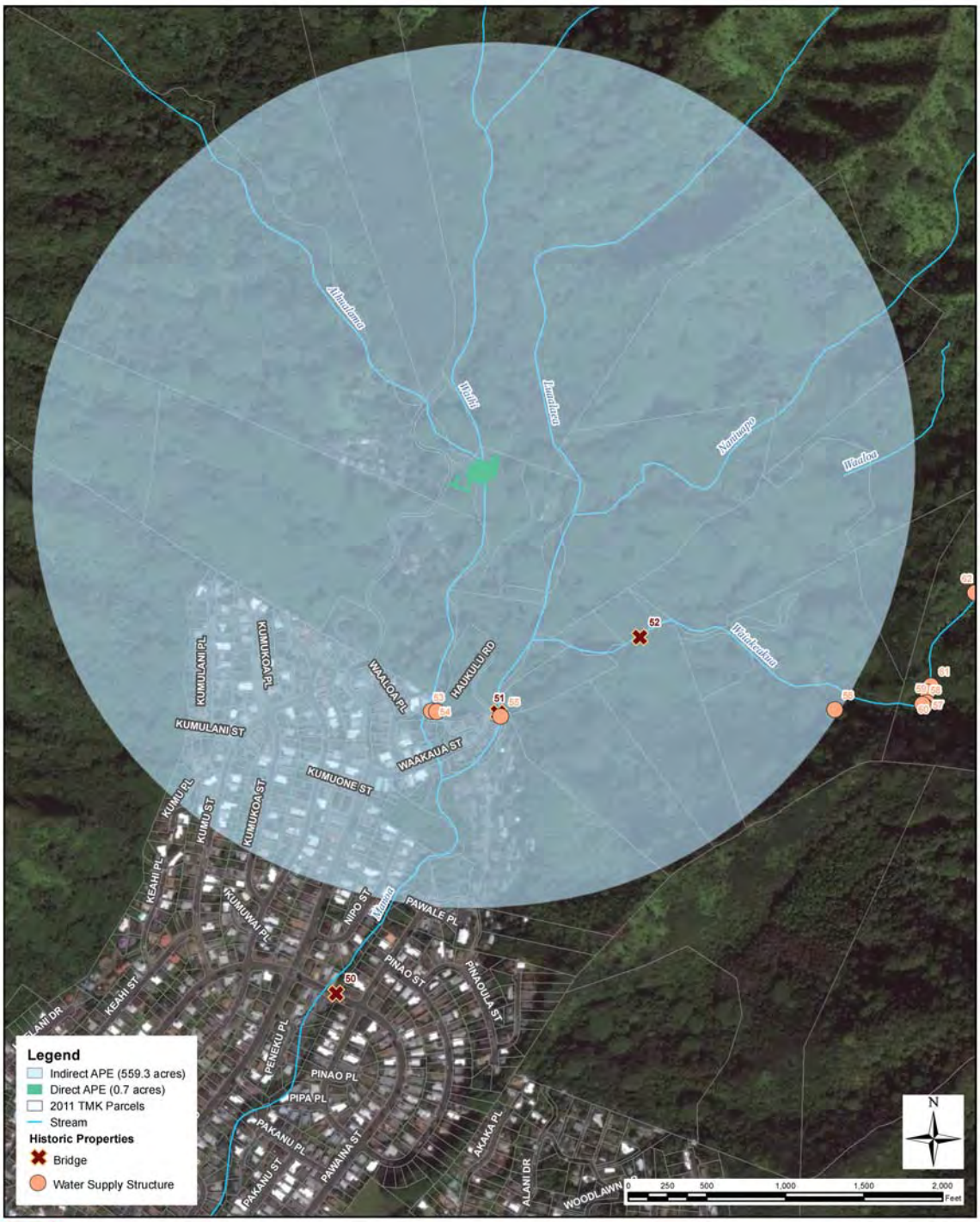


Figure 9 Direct APE for Waihi Debris and Detention Basin



Ala Wai Watershed Project

Indirect APE - Waihi Debris and Detention Basin

Island of Oahu, Hawaii

Figure 10 Indirect APE for Waihi Debris and Detention Basin

Manoa Valley
Measure No. 3: Waiakeakua Debris and Detention Basin

a. Description of the measure
Earthen berm, approximately 20' high and 185' across, with an arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. Why this is the best location for the proposed measure
Macrositing - Needs to be in upper watershed to capture peak flows, but as close to urban area as possible.
Micrositing – land ownership (trying to stay on public land); proximity to Board of Water Supply (BWS) access road; topography supports construction with the least amount of earthwork.

c. What the area looks like now: See Figure 11

d. What will it look like with the measure in place: See Figure 12

e. What is the area used for now
Proposed location is a forested upper watershed; no formal recreational access; no agricultural or commercial practices within footprint, but some agriculture/loi located nearby.

f. What can it be used for after the measure
Normal stream flow will not be affected; new measure will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
This measure will be used for all flood events, but would only impound water (pool in basin) above a 5-year flood event.

h. Flexibility of proposed measure location
Location of the Waiakeakua Debris and Detention basin is flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 1.5 acres

Figure 11 Location of Waiakeakua Debris and Detention Basin at Present

Figure 12 Conceptual Rendering of Waiakeakua Debris and Detention Basin with Measure

Ala Wai Watershed Project

Direct APE - Waiakeakua Debris and Detention Basin

Island of Oahu, Hawaii

Figure 13 Direct APE for Waiakeakua Debris and Detention Basin

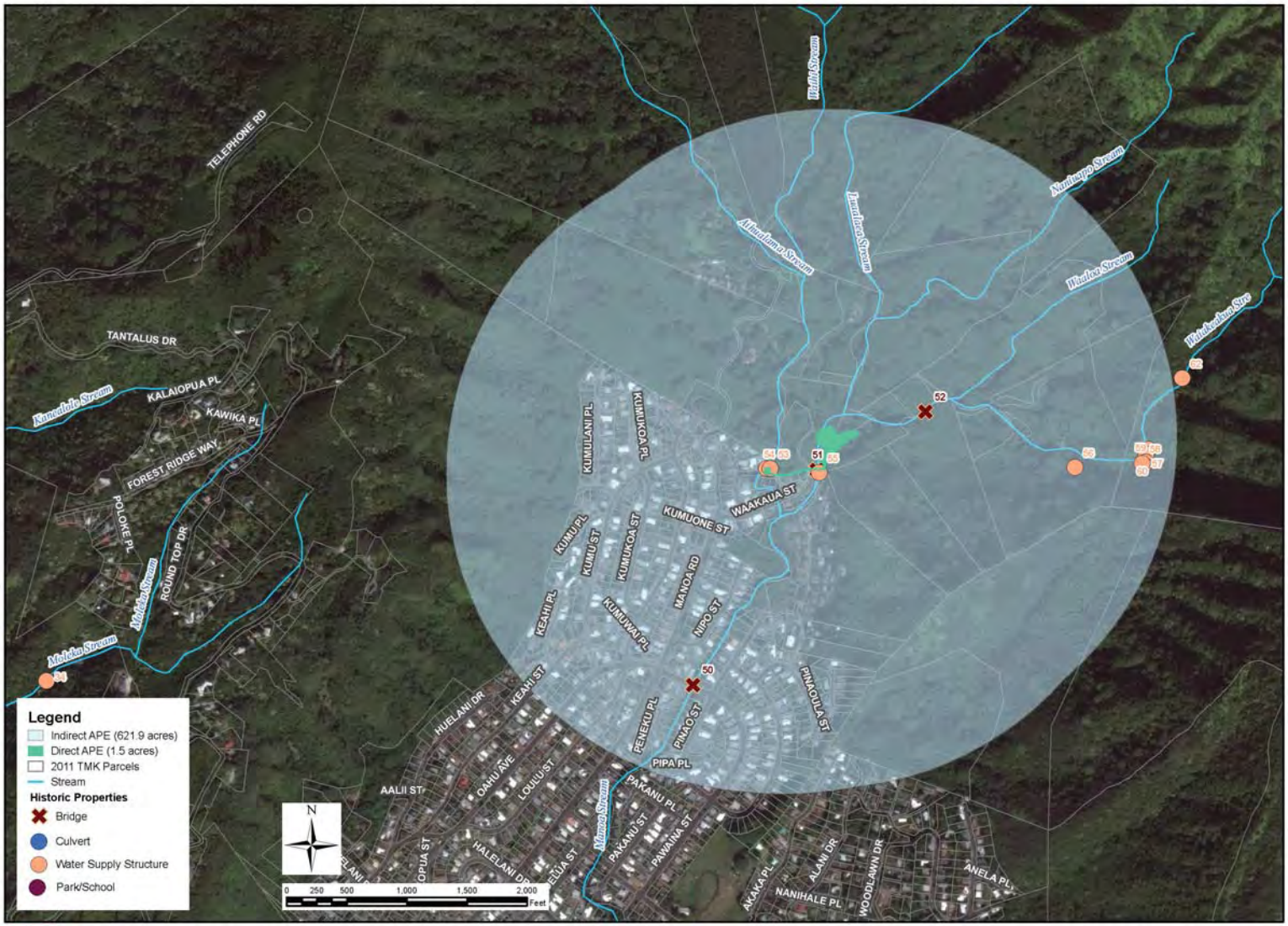


Figure 14 Indirect APE for Waiakeakua Debris and Detention Basin

Manoa Valley
Measure No. 4: Woodlawn Ditch Detention Basin

a. Description of the measure
Three-sided berm, approximately 15' high and 840' across constructed to create the detention basin, with arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.

b. Why this is the best location for the proposed measure
Macrositing: Water detention is needed in an urban area.
Micrositing: This is one of few available open spaces in an urban area, and near the stream, that is large enough to provide detention.

c. What the area looks like now: See Figure 15

d. What will it look like with the measure in place: See Figure 16

e. What is the area used for now
Proposed location is a vegetated area within a residential community; interior portion is an agricultural operation; no formal recreational access; located adjacent to a Chinese cemetery.

f. What can it be used for after the measure
Normal ditch flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; agricultural operations may continue, but would be subject to flooding; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
This measure will be used for all flood events, but would only impound water (pool in basin) above a five-year flood event.

h. Flexibility of proposed measure location
Location of the Woodlawn Ditch Detention Basin is fixed.

i. Direct APE acreage: 1.9 acres

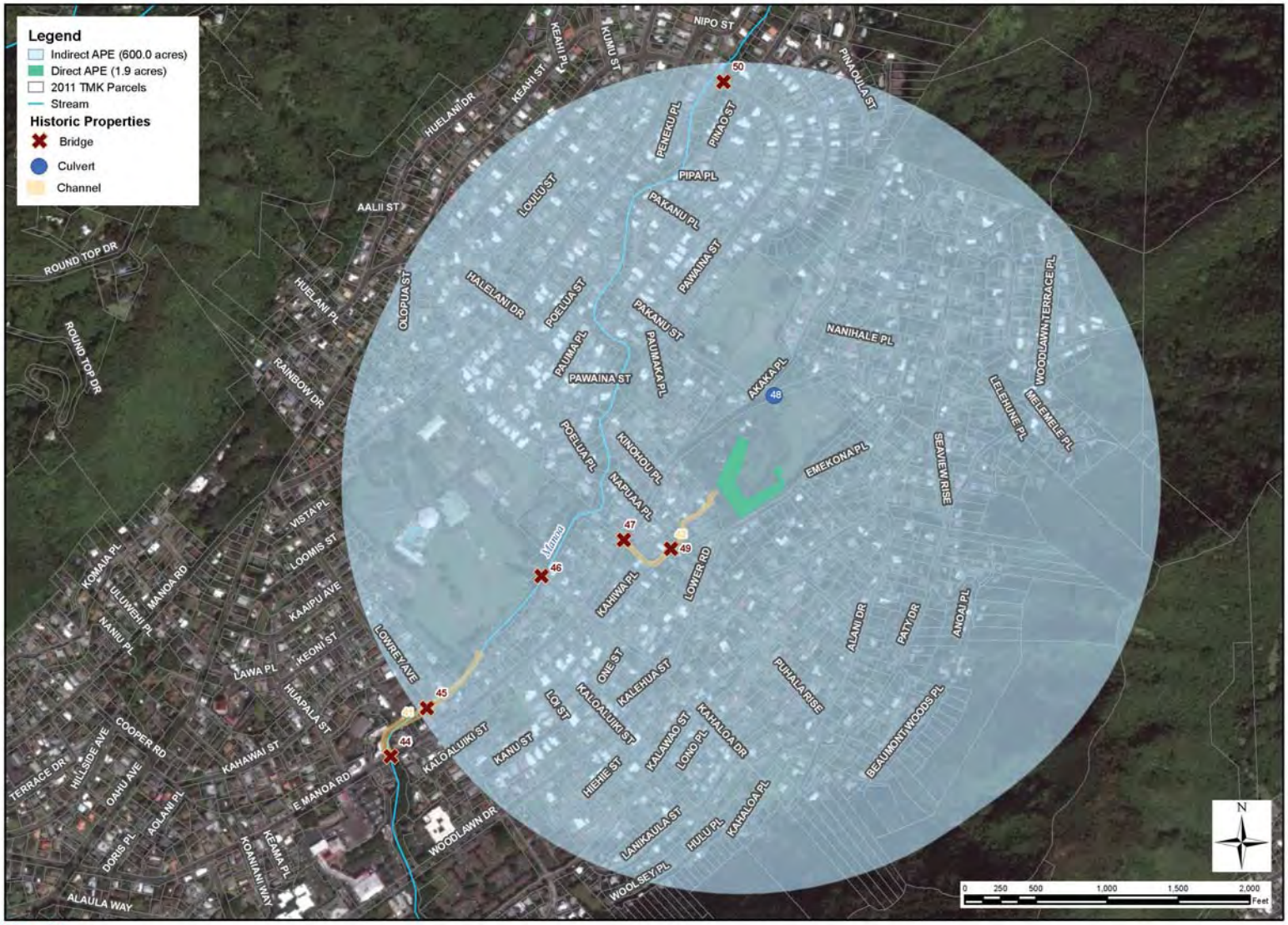
Figure 15 Photo of Woodlawn Ditch Detention Basin at Present

Figure 16 Conceptual Rendering of Woodlawn Ditch Detention Basin with Measure

Ala Wai Watershed Project

Direct APE - Woodlawn Ditch Detention Basin
Island of Oahu, Hawaii

Figure 17 Direct APE for Woodlawn Ditch Detention Basin



Ala Wai Watershed Project

Indirect APE - Woodlawn Ditch Detention Basin
Island of Oahu, Hawaii

Figure 18 Indirect APE for Woodlawn Ditch Detention Basin

Manoa Valley
Measure No. 5: Manoa In-Stream Debris Catchment

a. Description of the measure
Construct concrete pad over stream bed, approximately 8' wide and 60' across, with steel posts up to approximately 7' high, evenly spaced at 4' apart along concrete pad.

b. Why this is the best location for the proposed measure
Macrositing: Debris catchment in urban area is needed.
Micrositing: Site is on public land, and has easy access. Other locations were considered, but are located on private land, are not as accessible, and are more expensive to construct.

c. What the area looks like now: See Figure 19

d. What will it look like with the measure in place: See Figure 20

e. What is the area used for now
Proposed location is within a stream directly adjacent to Manoa District Park and residences.

f. What can it be used for after the measure
Normal stream flow will not be affected; will require occasional maintenance; no changes to land use; no impact on recreation at adjacent park; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
This measure will be used for all flood events.

h. Flexibility of proposed measure location
Location of the Manoa In-Stream Debris Catchment is flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 0.1 acres

Figure 19 Photo of Manoa In-Stream Debris Catchment at Present

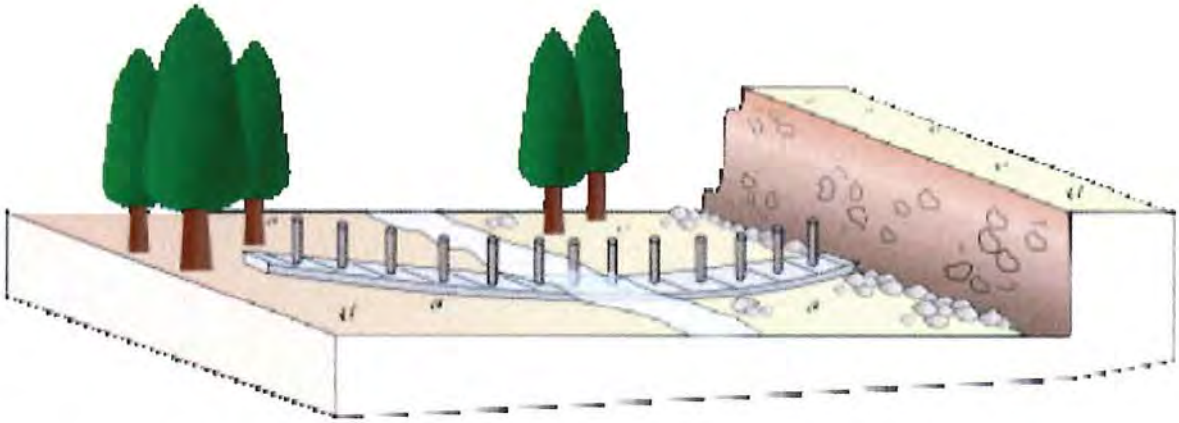
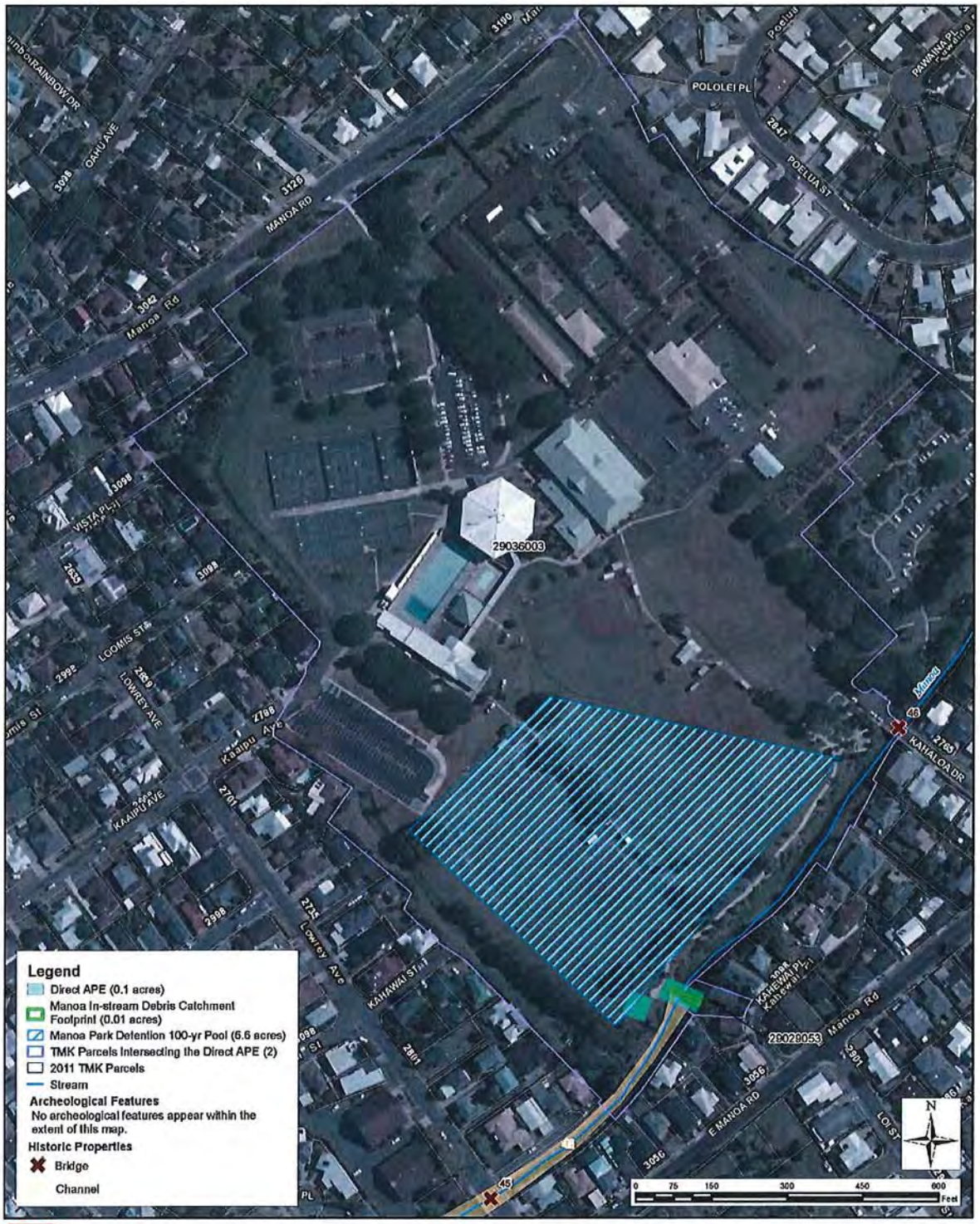


Image from Technical Summary Report, Mānoa Watershed Project, Honolulu, Hawaii
Figure 20 Conceptual Rendering of an in-stream catchment (similar concept to be used for Manoa In-Stream Debris Catchment Measure)



Ala Wai Watershed Project

Direct APE - Manoa Park In-Stream Debris Catchment
Island of Oahu, Hawaii

Figure 21 Direct APE for Manoa In-Stream Debris Catchment

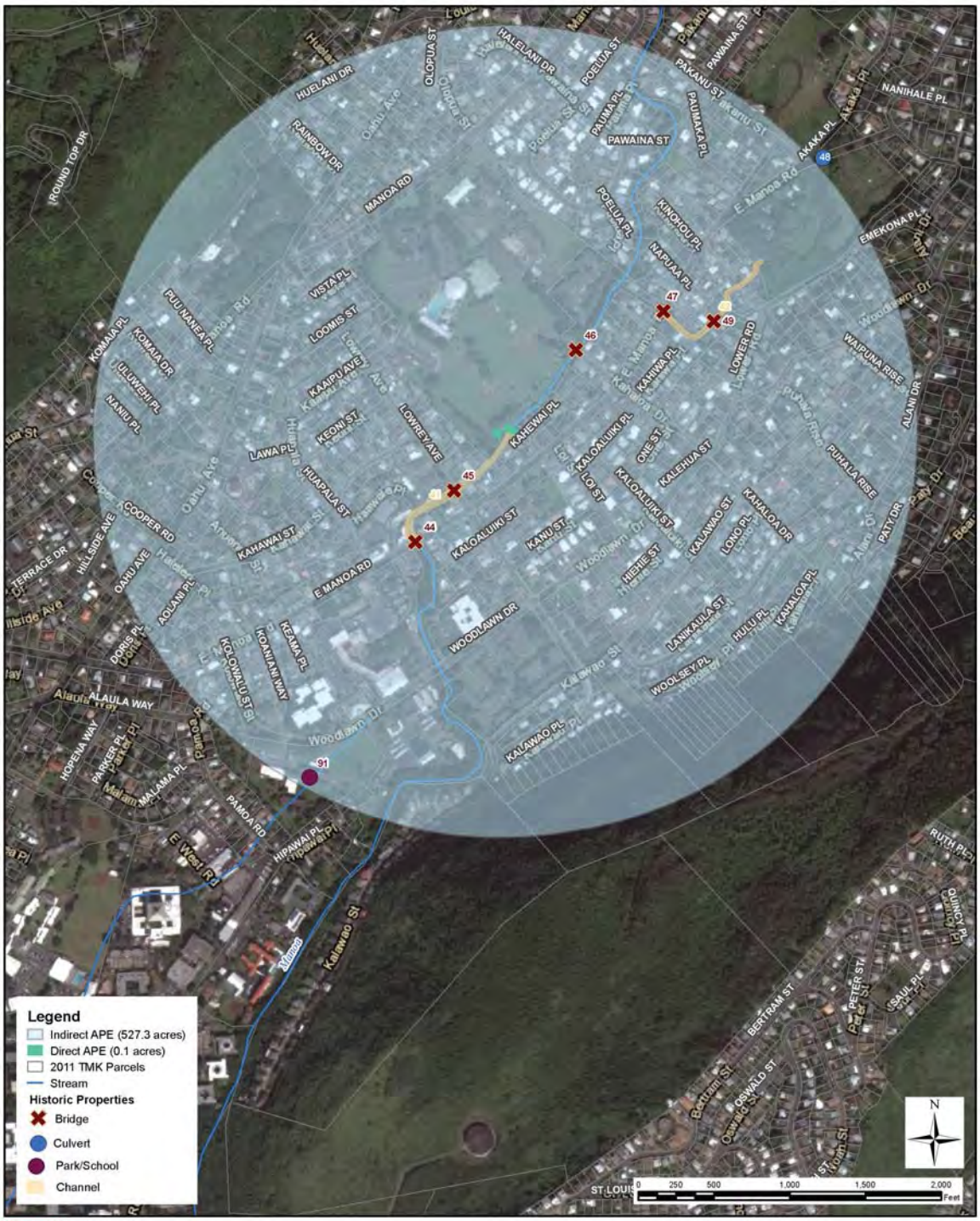


Figure 22 Indirect APE for Manoa In-Stream Debris Catchment

Manoa Valley
Measure No. 6: Kanewai Field Multi-Purpose Detention Basin

a. Description of the measure
Earthen berm, approximately 7' high, around 3 sides of field. Construct spillway on northwest end that allows high flows to enter basin. Existing drainage pipe at south end will allow water to re-enter stream. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.

b. Why this is the best location for the proposed measure
Macrositing: Water detention is needed in an urban area.
Micrositing: This is one of few available open spaces in an urban area, and near the stream, that is large enough to provide detention. Also considered UH athletic field, but Kanewai floods anyway (it is within the floodplain), and this measure is cheaper because it doesn't require pumps. This location will also protect Hokulani School and the community.

c. What the area looks like now: See Figure 23

d. What will it look like with the measure in place: See Figure 24

e. What is the area used for now
The area is a City and County park, located across the stream from UH dorms.

f. What can it be used for after the measure
No work will be conducted in stream; normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access to park would be restricted during flood conditions; will require occasional maintenance; land use will not change during non-flood events; the berm feature is multi-purpose, it can be used for spectating; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
Would start to be impacted at a 10-year flood event.

h. Flexibility of proposed measure location
Location of the Kanewai Field Multi-Purpose Detention Basin is fixed.

i. Direct APE acreage: 6.1 acres

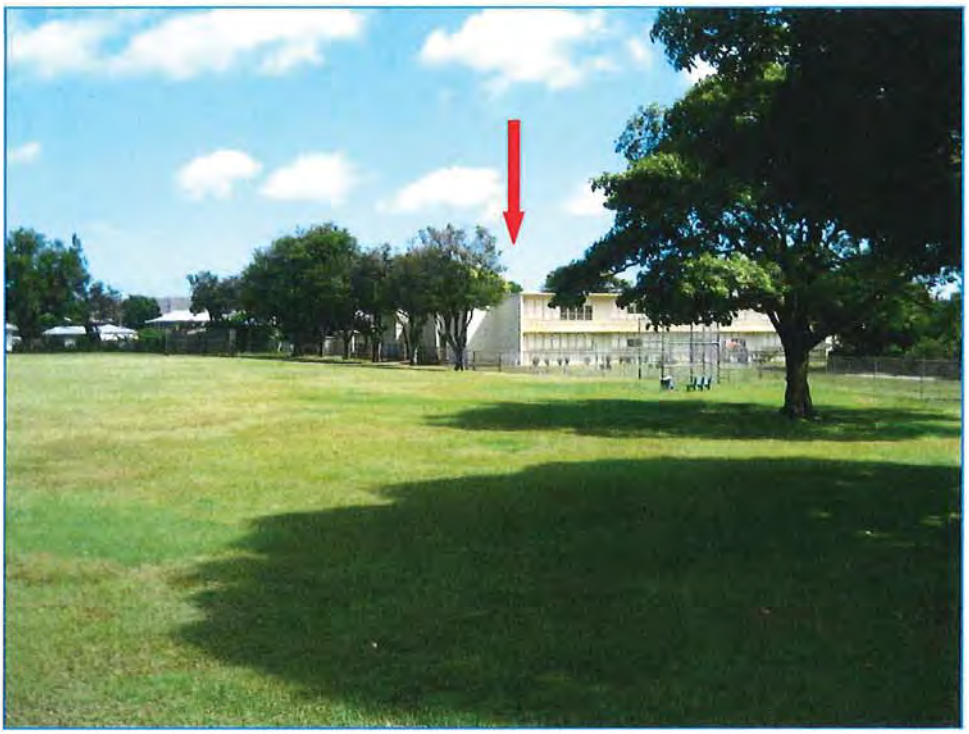
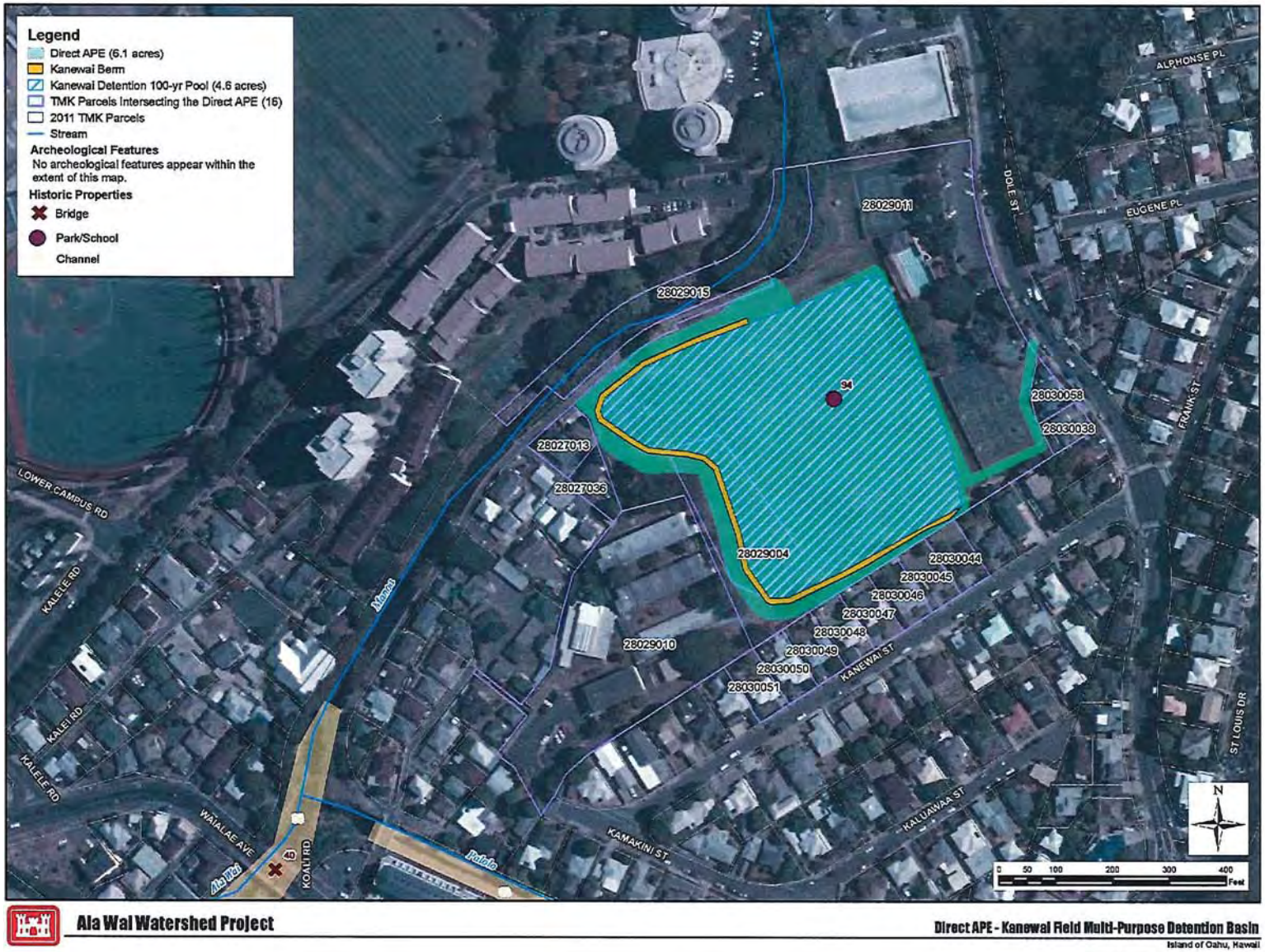


Figure 23 Photo of Kanewai Field Multi-Purpose Detention Basin at Present

Image from Technical Summary Report, Mānoa Watershed Project, Honolulu, Hawaii

Figure 24 Conceptual Rendering of Kanewai Field Multi-Purpose Detention Basin with Measure



Ala Wai Watershed Project

Direct APE - Kanewai Field Multi-Purpose Detention Basin
Island of Oahu, Hawaii

Figure 25 Direct APE for Kanewai Field Multi-Purpose Detention Basin

Ala Wai Watershed Project

Indirect APE - Kanewai Field Multi-Purpose Detention Basin
Island of Oahu, Hawaii

Figure 26 Indirect APE for Kanewai Field Multi-Purpose Detention Basin

Palolo Valley
Measure No. 7: Pukele Debris and Detention Basin

a. Description of the measure

Earthen berm, approximately 24' high and 120' across, with an arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. Why this is the best location for the proposed measure

Macrositing – This measure needs to be in the upper watershed to capture peak flows, but as close to urban area as possible. Could not go higher in watershed because of topographic access, and cultural sensitivity in higher areas.
Micrositing – access to public roads, and topography supports construction with least amount of earthwork.

c. What the area looks like now: See Figure 27

d. What will it look like with the measure in place: See Figure 28

e. What is the area used for now

Proposed location is a forested upper watershed, adjacent to residential area; no formal recreational access; no agricultural or commercial practices within footprint.

f. What can it be used for after the measure

Normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events

This measure will be used for all flood events, but would only begin to impound water (pool in basin) above a 5-year flood event.

h. Flexibility of proposed measure location

Location of the Pukele Debris and Detention Basin is flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 0.3 acres

Figure 27 Photo of Pukele Debris and Detention Basin at Present

Conceptual Rendering of the PukeleDetention Basin

Figure 28 Conceptual Rendering of Pukele Debris and Detention Basin with Measure

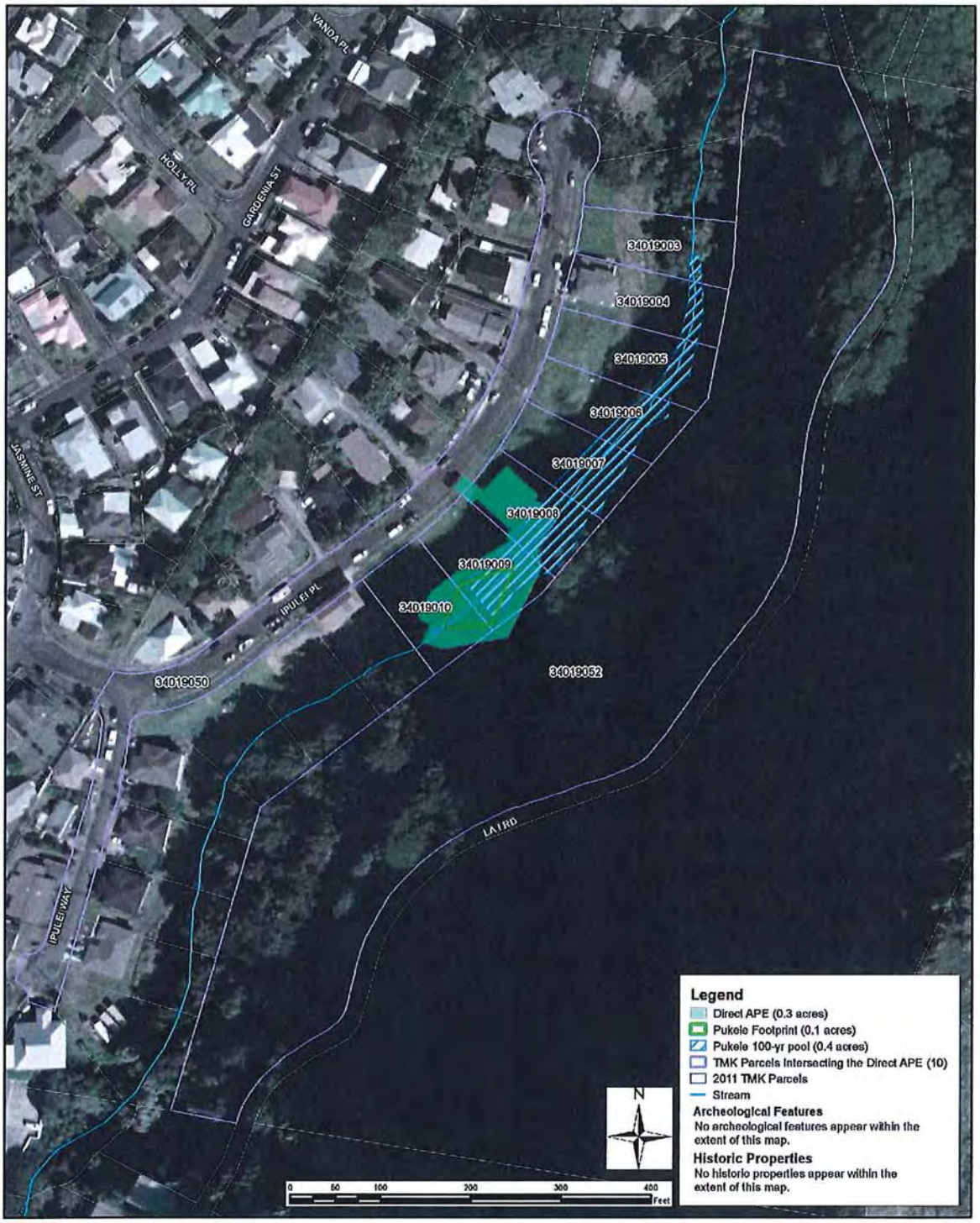


Figure 29 Direct APE for Pukele Debris and Detention Basin

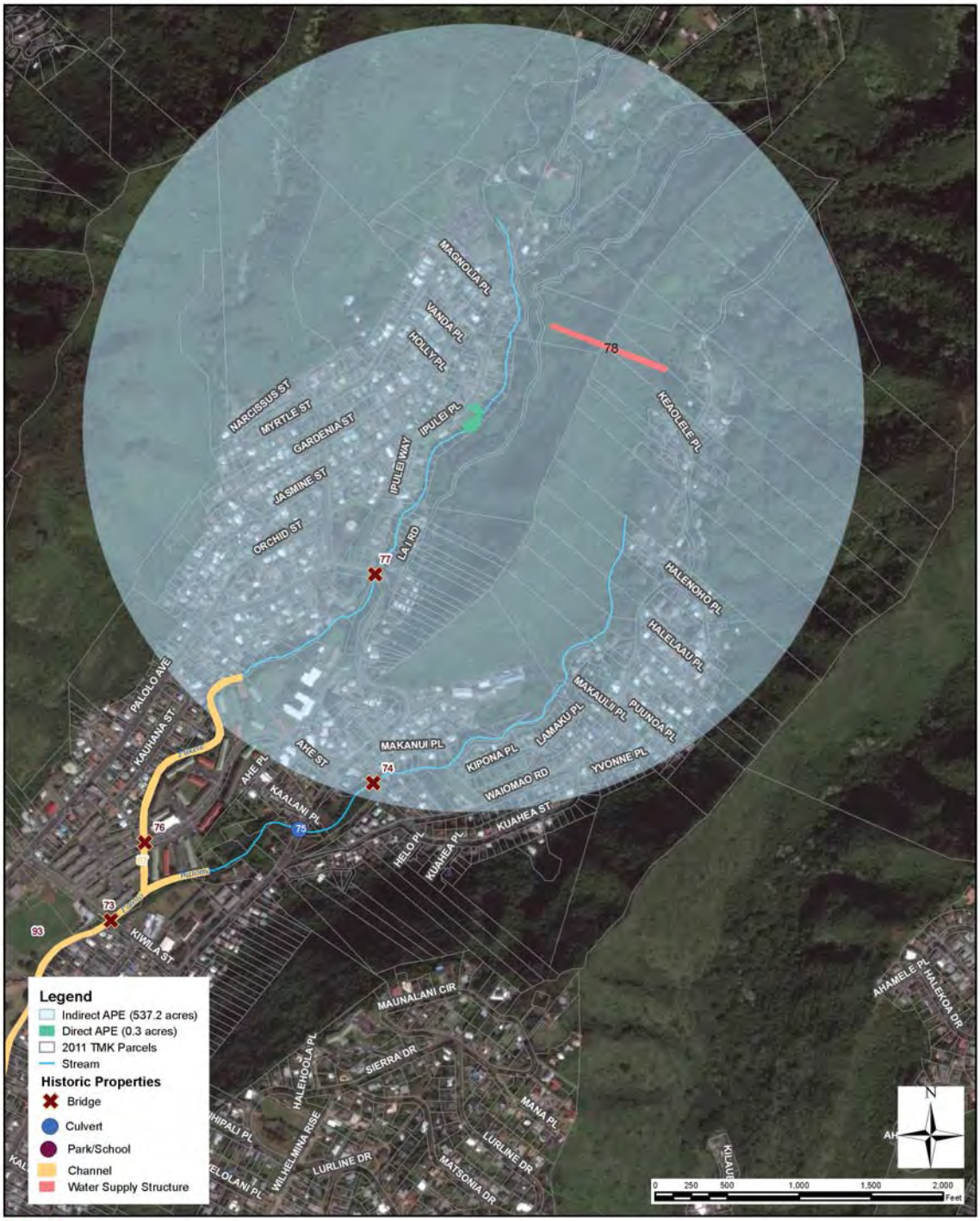


Figure 30 Indirect APE for Pukele Debris and Detention Basin

Palolo Valley
Measure No. 8: Waiomao Debris and Detention Basin

a. Description of the measure
Earthen berm, approximately 24' high and 120' across, with an arch culvert to allow small storm flows to pass. Construct a concrete spillway above culvert, with riprap on upstream and downstream side. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Excavate approximately 2,000 cubic yards of soil to provide required detention volume. Existing Waiomao USGS gauging station will be demolished during construction of this measure.

b. Why this is the best location for the proposed measure
Macrositing - Needs to be in upper watershed to capture peak flows, but as close to urban area as possible. Could not go higher in watershed because of topographic access, and cultural sensitivity in higher areas.

Micrositing – Location provides access to public roads, and will allow feature with least amount of earthwork.

c. What the area looks like now: See Figure 31 (access to preferred location was not granted by landowner)

d. What will it look like with the measure in place: See Figure 32

e. What is the area used for now
Proposed location is a forested upper watershed, adjacent to residential area; no formal recreational access; no agricultural or commercial practices within footprint.

f. What can it be used for after the measure
Normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
This measure will be used for all flood events, but would only impound water (pool in basin) above a five-year flood event.

h. Flexibility of proposed measure location
Location of the Waiomao Debris and Detention Basin is flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 1.3 acres

Figure 31 Photo of Waiomao Debris and Detention Basin at Present

Figure 32 Conceptual Rendering of Waiomao Debris and Detention Basin with Measure (modified from Pukele detention basin measure)

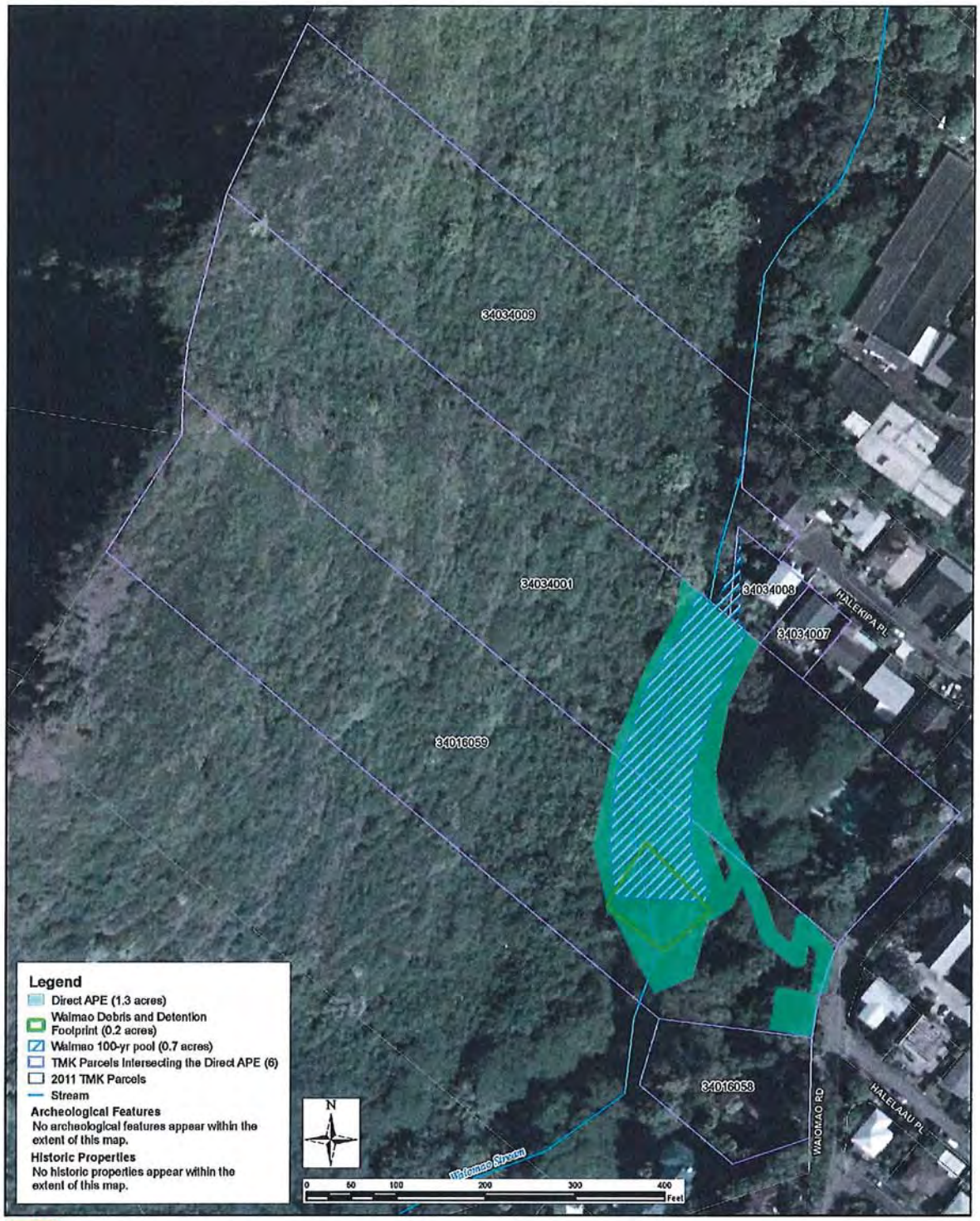
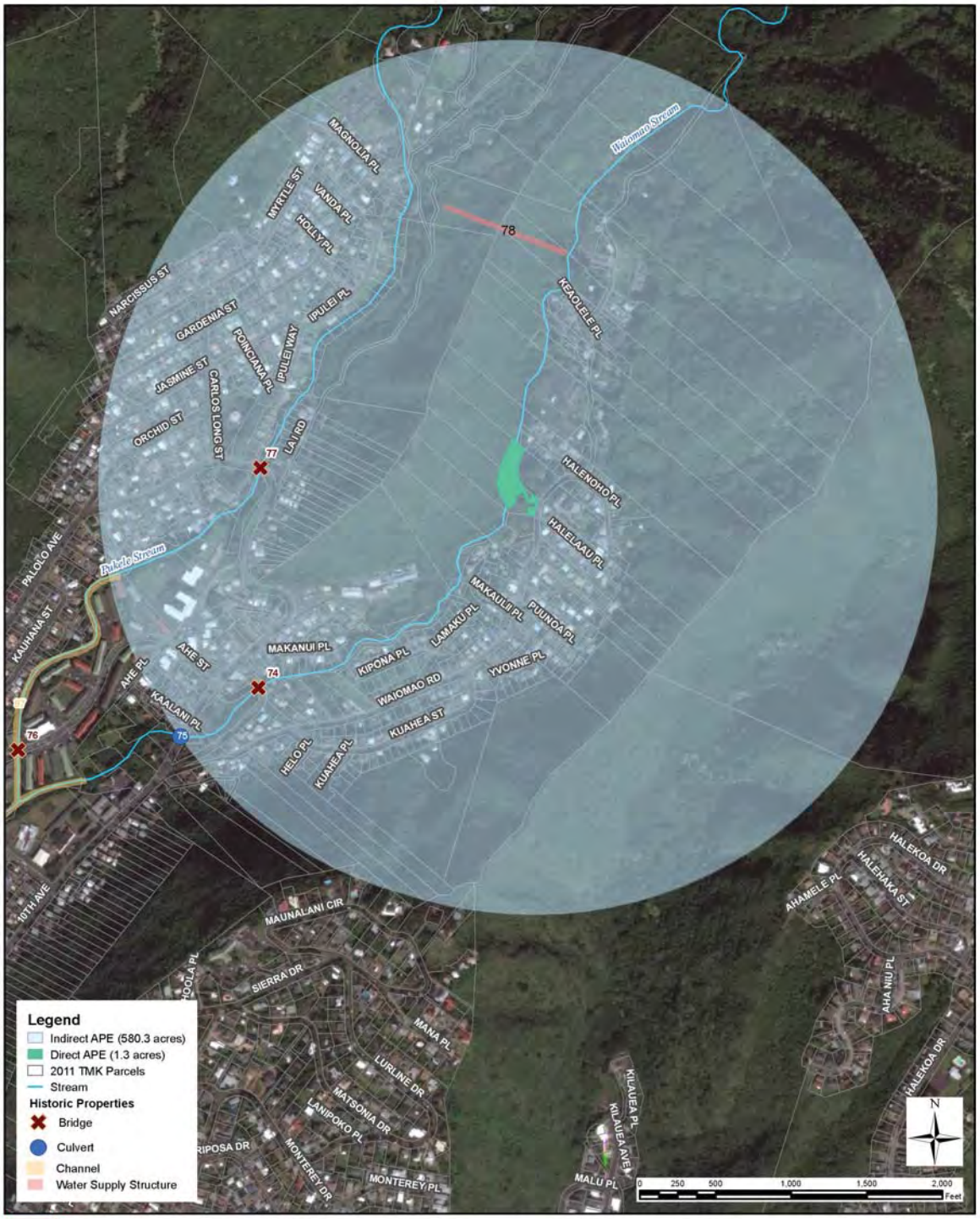


Figure 33 Direct APE for Waiomao Debris and Detention Basin



Ala Wai Watershed Project

Indirect APE - Waiomao Debris and Detention Basin

Island of Oahu, Hawaii

Figure 34 Indirect APE for Waiomao Debris and Detention Basin

Ala Wai
Measure No. 9: Hausten Ditch Detention Basin

a. Description of the measure

Add floodwalls and 4.3' high earthen berm around the City and County park to provide detention for local drainage; install sluice gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal.

b. Why this is the best location for the proposed measure

Macrositing - Measure needed to address interior drainage associated with Hausten Ditch.

Micrositing - land ownership and access are favorable. Also considered other side of Hausten Ditch and at pump station, but both would be more expensive.

c. What the area looks like now: See Figure 35

d. What will it look like with the measure in place: See Figure 36

e. What is the area used for now

Land is a City and County park that is adjacent to condos

f. What can it be used for after the measure

Normal ditch flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access to park would be restricted during flood conditions; will require occasional maintenance; land use will not change during non-flood events. Proposed measure is multi-purpose, berm can be used for spectating; no significant changes to access within project vicinity; no restriction of access for adjacent canoe clubs

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events

Would start to be impacted at a 10-year flood event.

h. Flexibility of proposed measure location

Location of the Hausten Ditch Detention Basin is fixed.

i. Direct APE acreage: 4.1 acres

Figure 35 Photo of Hausten Ditch Detention Basin at Present

Conceptual Rendering of the Hausten Ditch Detention Basin

Figure 36 Conceptual Rendering of Hausten Ditch Detention Basin with Measure

Ala Wai Watershed Project

Direct APE - Hausten Ditch Detention
Island of Oahu, Hawaii

Figure 37 Direct APE for Hausten Ditch Detention Basin

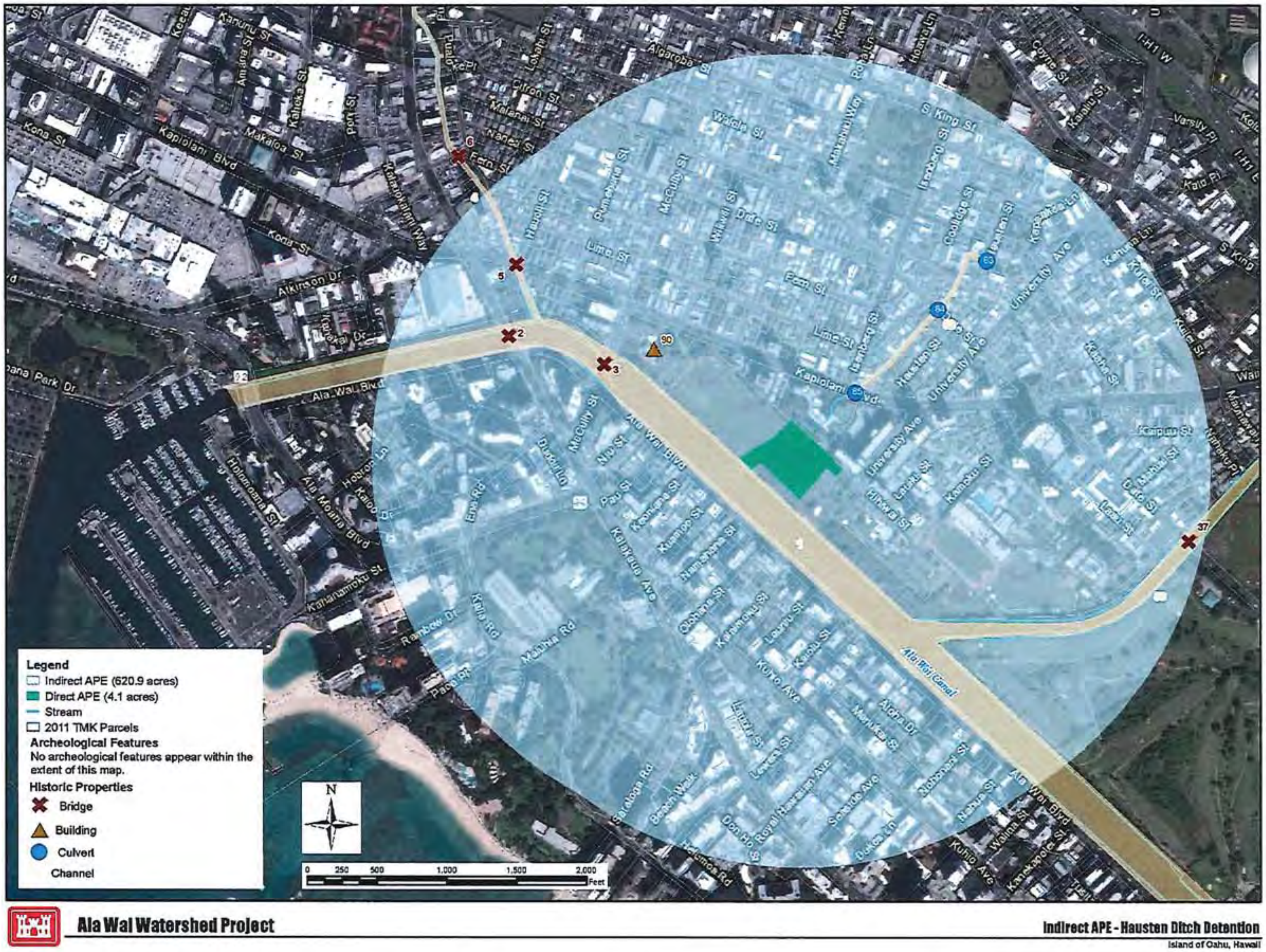


Figure 38 Indirect APE for Hausten Ditch Detention Basin

Ala Wai
Measure No. 10: Ala Wai Golf Course Multi-Purpose Detention Basin

a. Description of the measure
Earthen berm, up to approximately 7' high, around outside perimeter of golf course property with floodgate across main entrance road; passive drainage back into Ala Wai Canal. Excavation within "rough" (out of bounds) areas of the golf course to act as sediment catchment during storm events.

b. Why this is the best location for the proposed measure
Macrositing – Need detention in urban area
Micrositing – One of few available open spaces in urban area near stream that is large enough to provide detention; golf course floods anyway (in floodplain); also protects community behind golf course

c. What the area looks like now: See Figure 39

d. What will it look like with the measure in place: See Figure 40

e. What is the area used for now
City and County of Honolulu golf course

f. What can it be used for after the measure
No change in existing land use (except during flood conditions); will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access would be restricted during flood conditions; will require occasional maintenance.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
Would start to be impacted at a five-year flood event.

h. Flexibility of proposed measure location
The location of the Ala Wai Golf Course Multi-Purpose Detention Basin is fixed, but with limited flexibility to move berm location laterally.

i. Direct APE acreage: 22.2 acres

Figure 39 Photo of Ala Wai Golf Course Multi-Purpose Detention Basin at Present

Conceptual Rendering of the Ala Wai Golf Course Detention Basin

Figure 40 Conceptual Rendering of Ala Wai Golf Course Multi-Purpose Detention Basin with Measure

Ala Wai Watershed Project

Direct APE - Ala Wai Golf Course Multi-purpose Detention
Island of Oahu, Hawaii

Figure 41 Direct APE for Ala Wai Golf Course Multi-Purpose Detention Basin

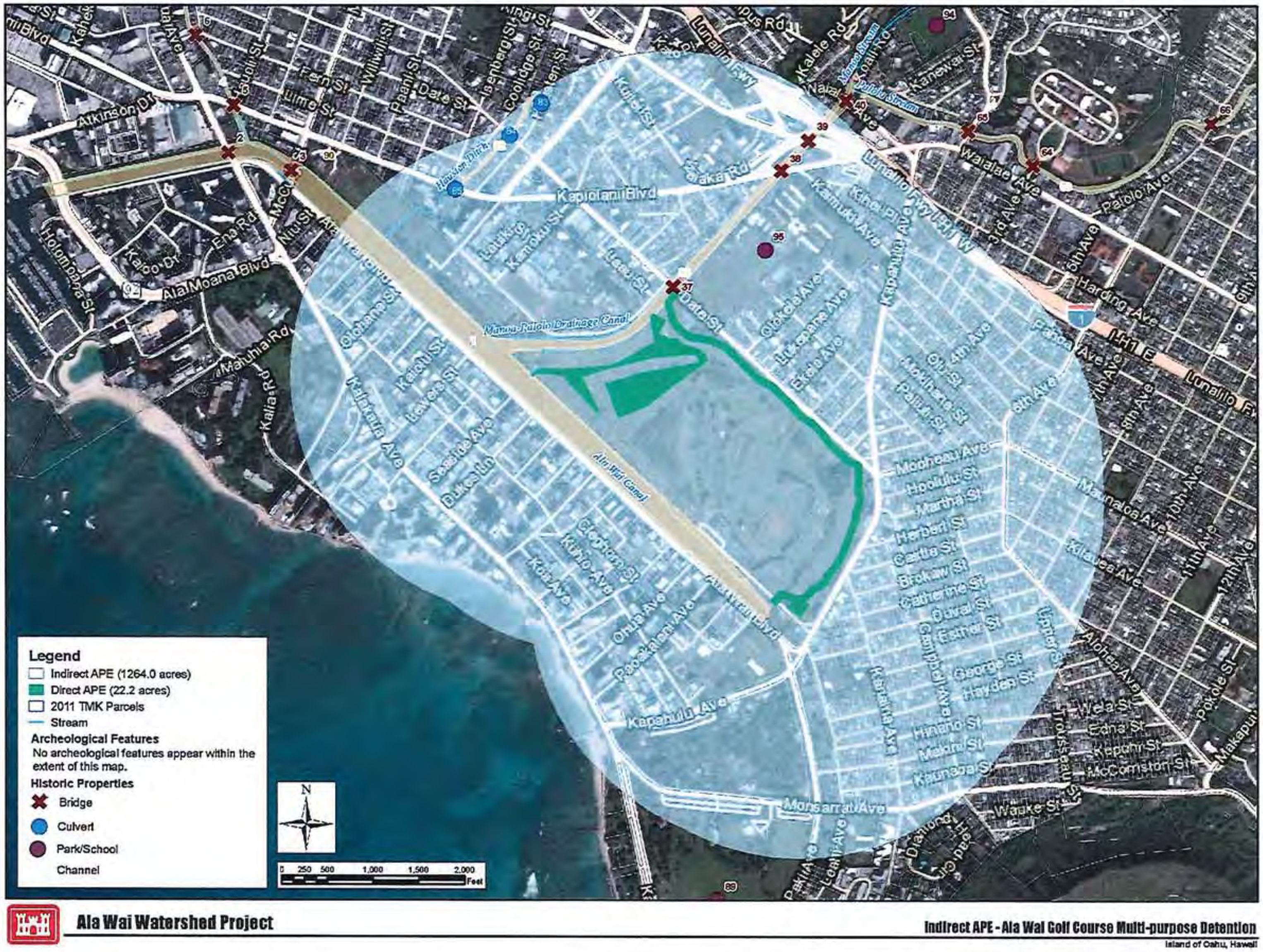


Figure 42 Indirect APE for Ala Wai Golf Course Multi-Purpose Detention Basin

Ala Wai
Measure No. 11: Ala Wai Canal Floodwalls

a. Description of the measure
Add floodwalls along Ala Wai Canal; concrete walls and/or earthen berms, ranging up to approximately 5 feet high; add three pump stations and gates for existing drainage pipes.

b. Why this is the best location for the proposed measure
Macrositing – Make use of existing canal
Micrositing – Floodwalls are required to prevent overtopping of Canal; no alternative placement for floodwalls; Pump stations located at major storm drains; no other alternative placement.

c. What the area looks like now: See Figures 43 and 45

d. What will it look like with the measure in place: See Figures 44 and 46

e. What is the area used for now
Existing canal has sidewalks and promenade for pedestrian recreation, and waterway is used by canoe clubs

f. What can it be used for after the measure
New walls will not restrict pedestrian access, but will limit views along/across/toward, and from Canal; no changes to land use; no restriction of access for adjacent canoe clubs. Pump stations will displace small amounts of open space.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
Would start to be impacted at a five-year flood event.

h. Flexibility of proposed measure location
Location of the Ala Wai Canal Floodwalls on the Ala Wai Blvd side is fixed. There is limited flexibility on *mauka* side to move wall laterally.

i. Direct APE acreage: 9.9 acres

Figure 43 Photo of Ala Wai Canal Floodwalls at Present

Conceptual Rendering of the Ala Wai Canal Floodwalls (near Kalakaua Avenue)

Figure 44 Conceptual Rendering of Ala Wai Canal Floodwalls with Measure (new wall will move closer to existing wall)

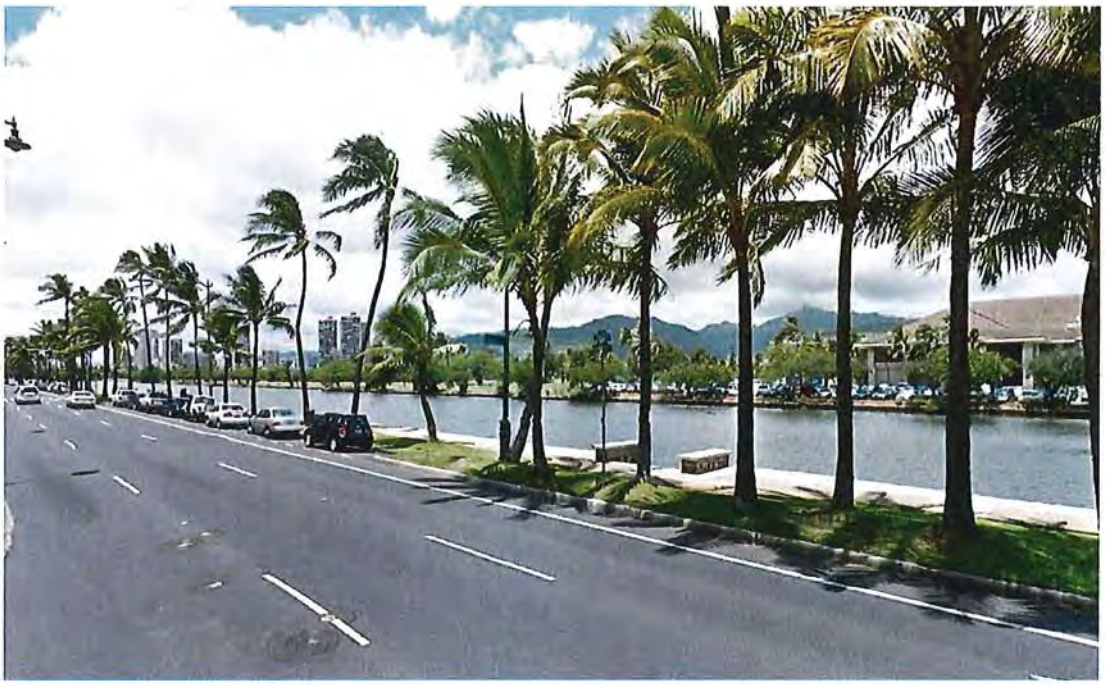
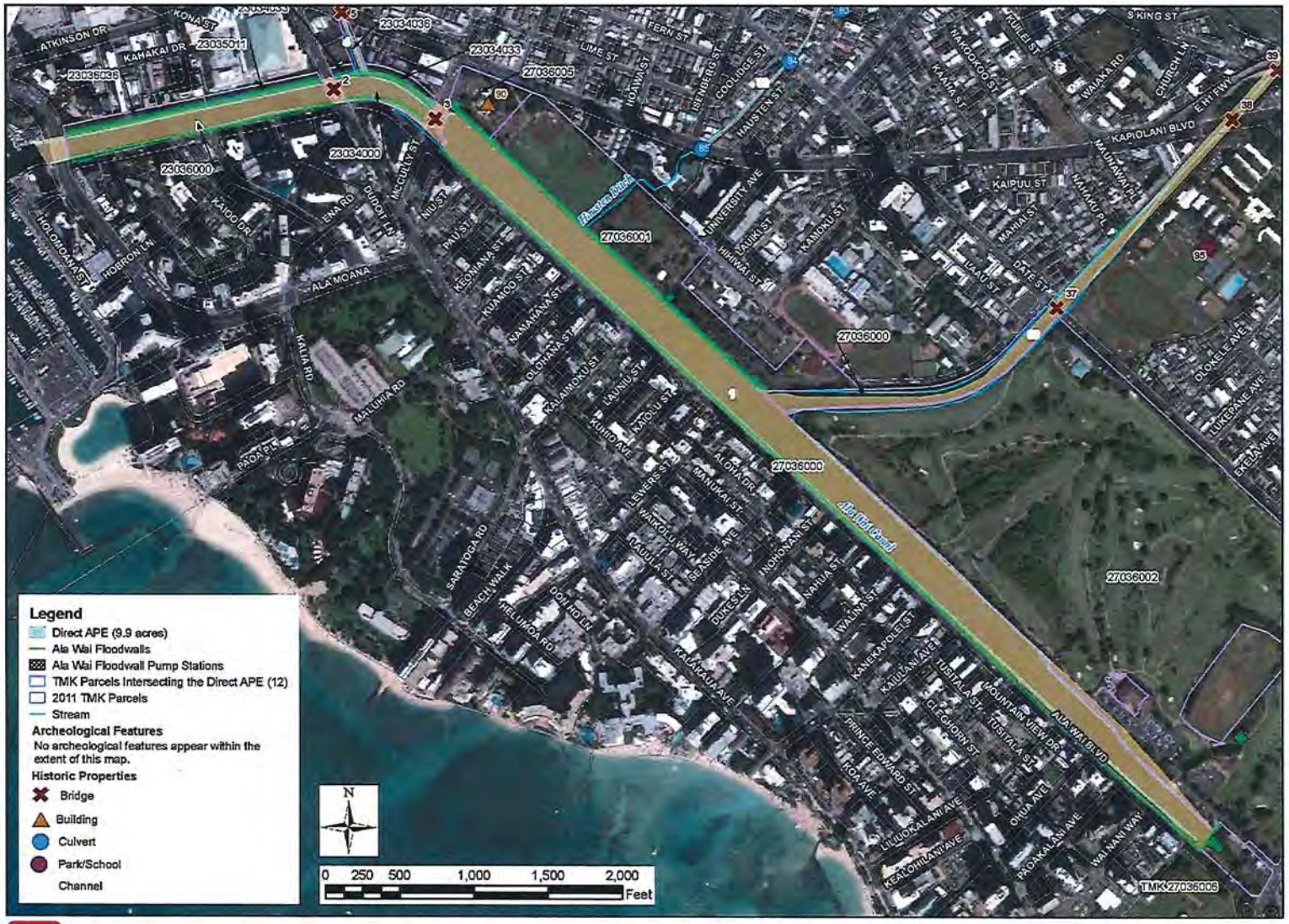


Figure 45 Photo of Ala Wai Canal Floodwalls at Present

Conceptual Rendering of the Ala Wai Canal Floodwalls (near Ala Wai Boulevard)

Figure 46 Conceptual Rendering of Ala Wai Canal Floodwalls with Measure



Ala Wai Watershed Project

Direct APE - Ala Wai Canal Floodwalls
Island of Oahu, Hawaii

Figure 47 Direct APE for Ala Wai Canal Floodwalls

Ala Wai Watershed Project

Indirect APE - Ala Wai Canal Floodwalls
Island of Oahu, Hawaii

Figure 48 Indirect APE for Ala Wai Canal Floodwalls

Watershed
Measure No. 12: Flood Warning System

a. Description of the measure
Installation of three (3) real-time rain gauges and three (3) real-time streamflow or stage gauges to supplement the existing flood warning system in the Ala Wai watershed.

b. Why this is the best location for the proposed measure
Locations of gauging stations to be determined (all in upper watershed), but will be sited based on flood warning need, peak flow locations, and accessibility to site.

c. What the area looks like now
Locations to be determined.

d. What will it look like with the measure in place
See Figures 49 and 50 - example photos of typical USGS gauging station.

e. What is the area used for now
Forested upper watershed.

f. What can it be used for after the measure
No change to use.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
Will be used for all flood events.

h. Flexibility of proposed measure location
Locations for the Flood Warning System are flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: 0.0 acres

Figure 49 Existing out-of-stream components (the house, antenna, etc.) of a stream gauge on Makiki Stream. A rain gauge would be similar to just this "house" component.

Figure 50 Components of a stream gauge that go into the stream (sensors and other gauge apparatus).

Watershed
Measure No. 13: Aquatic Habitat Mitigation

a. Description of the measure
Measures are being considered to mitigate impacts to aquatic habitat. One of the measures being considered to improve fish passage is (1) to rebuild stream channels that have been undercut at in-stream USGS gauging station meters. Another aquatic habitat mitigation measure being considered is (2) adding low-flow channels and/or small habitat pools into the channelized portions of streams. (3) Stream bank stabilization is being considered to reduce erosion and gain habitat (Figure 51).

1) Remove existing passage barriers
   a) Falls 6
   b) Falls 7
   c) Falls 8
   d) Falls 11 (USGS gauging station on Waihi Stream)
   e) Falls 12 (USGS gauging station on Waihi Stream)
   f) Falls P5 (USGS gauging station on Waiomao Stream)

2) Improve passage corridor and/or in-stream habitat in channelized reach
   a) Manoa Stream (improvements will cover a distance of approx. 1,100 ft)
   b) Palolo Stream (improvements will cover a distance of approx. 1.5 miles)

3) Bank stabilization
   a) Manoa Stream, above Kahaloa Bridge near District Park

b. Why this is the best location for the proposed measure
The stream bottom has become undercut where the in-water meters for the gauging stations are located. In some instances, this undercut prevents fish form migrating upstream. The locations for repairs to stream bottoms at gauging stations is wherever the damage is observed. Low-flow channels and small habitat pools are being looked at in portions of Manoa and Palolo Streams based on identified aquatic populations.

c. What the area looks like now
Locations to be determined.

d. What will it look like with the measure in place
Additional information to be provided once measures are determined.

e. What is the area used for now
Most habitat mitigations will occur within exiting stream channels.

f. What can it be used for after the measure
No change to use.

g. Will the measure only be used in the event of a large storm event, or will it also be utilized for smaller, frequent storm events
Will be used for all flood events.

h. Flexibility of proposed measure location
Locations for aquatic habitat mitigations are flexible. Design can microsite upstream/downstream to avoid resources.

i. Direct APE acreage: TBD

Refinement of Mitigation Measures

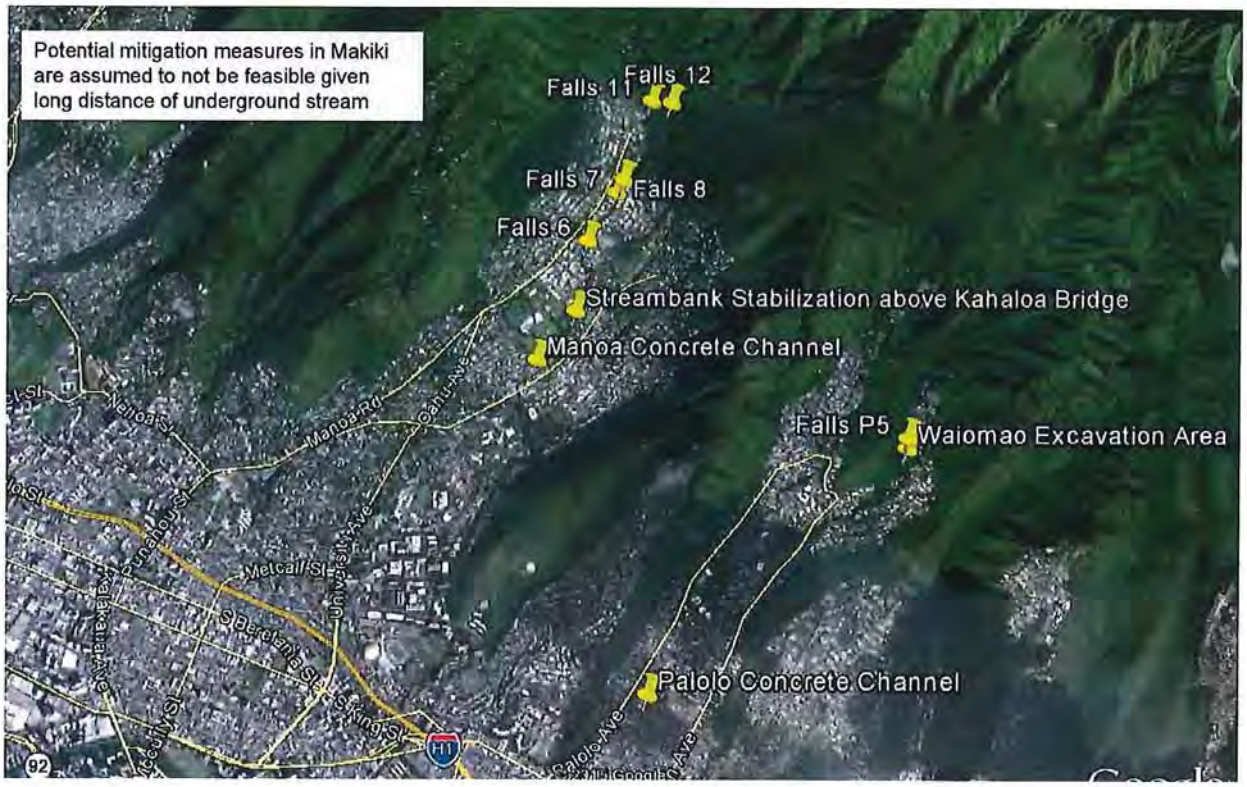


Figure 51 Possible Locations for Aquatic Habitat Mitigation

Enclosure 2

List of Consulting Parties

Chairman, DLNR
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Kapolei, HI 96707

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Kawahapai Ohana
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Hinaleimoana K.K. Wong-Kalu
Chair, Oahu Island Burial Council
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Alan S. Downer, Ph.D. Administrator & Deputy State Historic Preservation Officer
State Historic Preservation Division
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Na Daniel Naho`opii
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Honolulu, HI 96813

Maile Alau
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Honolulu, HI 96807

List of Consulting Parties (continued)

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Honolulu, HI 96817-0916

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Executive Director, Aha Wahine
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Aiea, HI 96701

Stephen Tam Loo
Healani Canoe Club
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Honolulu, HI 96821

Kiersten Faulkner
Executive Director
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Pelekikena
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Pauline Navales
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Kumuola Foundation
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Glenell Choy
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Luana Froiseth
President, Oahu Hawaiian Canoe
Racing Association
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Honolulu, HI 96804

Pelekikena
Papa Ola Lokahi
894 Queen Street
Honolulu, HI 96813

HISTORIC HAWAI'I FOUNDATION

April 8, 2015

Loren Zulick
Environmental Programs
Army Corps of Engineers
Fort Shafter, Hawai'i 96858-5440

RE: National Historic Preservation Act (NHPA) Section 106 Consultation
Ala Wai Canal and Watershed Project

Dear Mr. Zulick,

Thank you for including Historic Hawai'i Foundation in the NHPA Section 106 consultation initiation for the Ala Wai Canal Watershed Project. Since 1974, Historic Hawai'i Foundation has served as a statewide preservation organization encouraging the preservation of Hawai'i's significant historic properties.

The letter dated March 10, 2015 from Department of the Army, Army Corps of Engineers, redefines the Area of Potential Affect (APE) and clarifies the scope of the project. The letter serves as the Section 106 notification. Identification of historic properties and assessment of impacts will be provided in a future letter.

Scope of work includes construction of 13 flood management measures along the Ala Wai Canal in Makiki, Mānoa, Pālolo, Waikīkī, and the watershed. Specific information about each measure includes the location, draft design, and justification. Based on this correspondence, Historic Hawai'i Foundation has some clarification questions:

- What is the impetus for this large scale flood management project?
- Will the Section 106 process be completed as part of the NEPA process?
- As this letter is also addressing HRS 6E compliance, does this project also trigger HRS Chapter 343?
- Have neighborhood boards and neighborhood organizations such as Mālama Mānoa been notified of this project and provided the opportunity to participate in the Section 106 consultation?

Please continue to include Historic Hawai'i Foundation in this Section 106 consultation. Megan Borthwick, Preservation Program Manager will be the point of contact for this project. She can be reached at megan@historichawaii.org or by phone at (808) 523-2900.

Sincerely,

Kiersten Faulkner

Kiersten Faulkner, AICP
Executive Director

680 Iwilei Road, Suite 690 / Honolulu, Hawai'i 96817 / Tel (808) 523-2900 / Fax (808)523-0800
Email preservation@historichawaii.org / Web www.historichawaii.org

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

May 1, 2015

Environmental Programs Branch
Programs and Project Management

Ms. Megan Borthwick
Preservation Program Manager
Historic Hawai'i Foundation
680 Iwilei Road
Dole Office Building Tower, Suite 690
Honolulu, Hawaii 96817

Dear Ms. Borthwick:

We are in receipt of a letter from your organization, dated April 8, 2015, identifying you as the point of contact for this project. We appreciate your interest and participation in the Section 106 process. We offer the following responses to your clarification questions:

Q: What is the impetus for this large scale flood management project?
A: The primary impetus for this project is to improve life safety and reduce property damage associated with flooding events within the watershed. Hawaii streams are prone to flash flooding. With the sudden nature of the flood events and associated high velocities, floods within the watershed have resulted in recorded property damages, and risks to health and safety. Some of the secondary drivers include; reduced flood insurance rates to businesses and homeowners, large scale economic (negative) mitigation for the Waikiki tourist industry, initiation of the eco-restoration of the Ala Wai and connecting waterways, and promulgation of a watershed management program to be used for other Pacific islands.

Q: Will the Section 106 process be completed as part of the National Environmental Policy Act (NEPA) process?
A: We are not substituting the NEPA process for the Section 106 process, as allowed by 36 Code of Federal Regulations (CFR) 800.8(c). We are coordinating and integrating the two processes as specified in the Council on Environmental Quality NEPA regulations at 40 CFR 1502.25.

Q: As this letter is also addressing Hawaii Revised Statutes (HRS) 6E compliance, does this project also trigger HRS Chapter 343?
A: The project is being undertaken in partnership with the State of Hawaii, Department of Land and Natural Resources (DLNR). As the non-federal sponsor, the DLNR is required to comply with all applicable state laws, including HRS Chapter 343.

Q: Have neighborhood boards and neighborhood organizations such as Mālama Mānoa been notified of this project and provided the opportunity to participate in the Section 106 consultation?
A: This project has generated quite a bit of community outreach over the years, including outreach to the neighborhood boards and organizations. This includes multiple scoping meetings and other briefings/updates dating back to 2004. There were a series of open house meetings in May 2014. Invitations to the open house meetings were sent to all of the neighborhood board members that have posted e-mail addresses online, as well as other individuals/organizations identified as project stakeholders. Multiple people (approximately seven) who are affiliated specifically with Mālama Mānoa (as directors or advisors) were invited to the open house meetings.

We appreciate your contributions to the historic preservation process. Please continue to contact Mr. Loren Zulick, Archaeologist of my branch, at (808) 835-4305 or e-mail loren.a.zulick@usace.army.mil with any questions or concerns you may have regarding this project.

Sincerely,

Dan A. Nakamura, P.E.
Chief, Environmental Programs Branch

June 29, 2015 Consultation Letter Identifying Historic Properties, Providing Significance Evaluations, Presenting Determinations of Effect, and Proposing Conditions to Mitigation Adverse Effects

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

June 29, 2015

Environmental Programs Branch
Programs and Project Management

Mr. Alan S. Downer, PhD
Administrator
State Historic Preservation Office
Department of Land and Natural Resources
State of Hawaii
601 Kamokila Boulevard, Suite 555
Kapolei, Hawaii 96707

Dear Dr. Downer:

We are writing to continue NHPA Section 106 consultation on the Ala Wai Canal Project. As mentioned in previous correspondence, the content of this consultation is also being used for notification and compliance under Chapter 6E of the Hawaii Revised Statutes on behalf of the State of Hawaii, Department of Land and Natural Resources. The intent of this letter is to identify historic properties within the Area of Potential Effect (APE), provide significance evaluations, present determinations of effect on historic properties, and propose conditions to mitigate adverse effects.

Through a reasonable and good faith effort utilizing archival research, field investigations, and interviews that have been documented in the following reports; *Cultural Resources and Ethnographic Study for the Ala Wai Watershed Project, Honolulu, Makiki, Mānoa, Pālolo, and Waikīkī Ahupua'a, Honolulu District, O'ahu Island*, Volumes I, II, and III; *Cultural Impact Assessment for the Ala Wai Canal Project, Waikīkī, Pālolo, Makiki, and Mānoa Ahupua'a, Honolulu (Kona) District, O'ahu*; and *Historic Structures Inventory Survey of the Ala Wai Watershed*, the Honolulu District, U.S. Army Corps of Engineers (Corps) has identified forty six historic properties within 100m of the Direct APE that are either listed, or eligible for listing on the National or Hawaii Register of Historic Places (Enclosures 1 and 2). The Direct APE is defined as the area that could be directly affected by construction, and includes the footprint of each proposed measure to be constructed, and the construction footprints with construction buffers, staging areas, and access roads. The resources identified within 100m of the Direct APE include historic buildings and structures, archaeological sites/features, and historic and traditional cultural practices and places.

Historic properties were evaluated for significance in the above mentioned research documentation by applying eligibility criteria from the National Register of Historic Places (36 Code of Federal Regulations (CFR) 60.4), the Hawaii Register of Historic

Places (Hawaii Administrative Rules (HAR) §13-198-8), and site significance under HAR §13-275-6. National/Hawaii Register of Historic Places and site significance determinations are presented in Table 1 (Enclosure 1).

In conducting effects determinations, of those 46 resources within 100m of the Direct APE, 19 will not be directly or indirectly affected by the proposed measures and their cumulative impacts. They are listed with "no effect" determinations in Table 1 (Enclosure 1). We have concluded there will be "no adverse effect" to 7 historic properties, and potential adverse effects on 20 historic resources, all of which are identified in Table 1 (Enclosure 1). For those properties where an adverse effect is projected, conditions have been proposed (Enclosure 2) that would mitigate the adverse effect to "conditional no adverse effect." In accordance with 36 CFR 800.5, we seek your comments and considerations on our assessment of adverse effect.

Treatment recommendations are made for historic properties with an adverse effect determination. The intent is to identify conditions that can be placed on the design and construction that will mitigate impacts to the resource. Investigations and research previously referenced made recommendations for treatment of historic properties. Our first mitigation alternative will be to comply with recommendations made in the reports referenced. Treatment recommendations are attached (Enclosure 2).

Considering that we are at the Feasibility Stage of this project, there are still a number of unknown variables that may result in adverse effects through the remaining planning, design, and construction phases. We are inviting you to assist with the development of a Programmatic Agreement (PA) to establish the process of resolving adverse effects for the proposed undertaking. Our PA will expand upon the proposed treatments of historic properties identified in this letter. We are notifying the Advisory Council on Historic Preservation of the likelihood that the proposed undertaking will have an adverse affect on historic properties consistent with 36 CFR 800.6(a)(1).

We also want to take this opportunity to seek your concurrence on our initial decision under 36 CFR 800.11(c) to withhold from public disclosure information about the location, character, or ownership of the 46 historic properties. Withholding this information will reduce the risk of harm to the resources and reduce the risk of a significant invasion of privacy with respect to others. The information is being provided to you as a consulting party by way of its inclusion in Figures 3 through 19, and 22 through 25 (Enclosure 2) of this letter. However, before those figures are released to the public as part of our compliance with the National Environmental Policy Act, the symbols on maps disclosing information about the specific location, character, or ownership of the 46 historic properties would be removed.

The Corps requests your review, comment, and concurrence with;

1. The Direct and Indirect APEs identified in our consultation letter dated March 10, 2015.

2. Historic Properties identified within the APE.

3. Determinations of eligibility for the National Register and Hawaii Register of Historic Places, and site significance under HAR §13-275-6.

4. Determinations of effect on historic properties.

5. Proposed treatments to mitigate adverse effects on historic properties.

6. Determination under 36 CFR 800.11(c) to withhold from public disclosure, information about the location, character, or ownership of the 46 historic properties.

We ask for your concurrence on the items above within 30 days of your receipt of this letter, and will use that to forge the PA. A list of consulting parties to whom this letter has been sent is included (Enclosure 3).

The Corps is looking forward to continuing our consultation as we work to resolve adverse effects to historic properties. Should you have any questions, please contact Mr. Loren Zulick, Archaeologist of my Environmental Programs Branch, at (808) 835-4305 or e-mail loren.a.zulick@usace.army.mil.

Sincerely,

Christopher W. Crary
Lieutenant Colonel, U.S. Army
District Engineer

Enclosures

Enclosure 1

Historic Property Table

Table 1: Historic Properties

	DESCRIPTION	SITE ID	CRITERIA	TREATMENT RECOMMENDATION	EFFECTS DETERMINATION
	1) Makiki: Makiki D&D Basin				
1	Archie Baker Park	Inventory No. 92	A,C	temporary impacts-no adverse effect	temporary impacts: no adverse effect
2	Makiki Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
3	Makiki Stream Channel	Inventory No. 11	C	no direct impact	no effect
4	Makiki Street Bridge	Inventory No. 17	C	no direct impact	no effect
5	Oneele Place Bridge	Inventory No. 18	A,C	no direct impact	no effect
6	Terrace	50-80-14-6717	D	avoidance during construction	no adverse effect
	2) Manoa: Waihi D&D Basin				
7	Mounds/Platforms/Walls	50-80-14-6734	D,e	avoidance/reuse rocks/community assistance	conditional no adverse effect
8	Waihi Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
9	Aihualama Loi	No SIHP Assigned	A,C	avoidance during construction	no adverse effect
	3) Manoa: Waiakeakua D&D Basin				
10	Waaloa Way Bridge 2	Inventory No. 51	C	historic documentation	conditional no adverse effect
11	Waaloa Way Bridge 1	no inventory number	none	historic documentation	conditional no adverse effect
12	Terraces	50-80-14-6735	D	no direct impact	no effect
13	Waihi Stream Stone/Mortar Dam	50-80-14-6736/No. 54	A	reuse rocks/improve appearance	conditional no adverse effect
14	Historic House	50-80-14-6737	C,D	no direct impact	no effect
15	Historic House	50-80-14-6738	C,D	no direct impact	no effect
16	Waihi Gaging Station	Inventory No. 53	A,C	no direct impact	no effect
17	Waiakeakua Stream	No SIHP Assigned	E	reuse rocks from streambed	conditional no adverse effect

Table 1: Historic Properties

	DESCRIPTION	SITE ID	CRITERIA	TREATMENT RECOMMENDATION	EFFECTS DETERMINATION
18	Waiakeakua Gaging Station	Inventory No. 55	A,C	reuse rocks/improve appearance	conditional no adverse effect
19	Bridge Foundation	50-80-14-6744	C,D	no direct impact	no effect
	4) Manoa: Woodlawn Ditch				
*	Open Space at Park	No SIHP Assigned	none	not historic	not historic
20	Woodlawn Ditch	Inventory No. 42	A,C	no direct impact	no effect
21	East Manoa Road Manoa Park Ditch Bridge	Inventory No. 47	C	no direct impact	no effect
22	East Manoa Road Culvert	Inventory No. 48	C	no direct impact	no effect
23	Kaamamilo Drive Driveway Bridge	Inventory No. 49	C	no direct impact	no effect
	5) Manoa: Manoa In-Stream Debris Catchment				
24	Manoa Stream Channel	Inventory No. 41	A,C	historic documentation	conditional no adverse effect
25	Lowrey Avenue Bridge	Inventory No. 45	C	no direct impact	no effect
26	Kahaloa Drive Bridge	Inventory No. 46	C	no direct impact	no effect
	6) Manoa: Kanewai Field Detention Basin				
27	Kanewai Field	Inventory No. 94	C	avoid architecture/trees/seed berm	conditional no adverse effect
28	Manoa-Palolo Canal	Inventory No. 36	A,C	no direct impact	no effect
29	Old Waialae Road Bridge	Inventory No. 40	C	no direct impact	no effect
30	Palolo Stream Channel	Inventory No. 63	A,C	no direct impact	no effect
31	Kanewai Loi	50-80-14-4498	A,C	avoidance during construction	no adverse effect
	7) Palolo: Pukele Debris/Detention Basin				
32	Pukele Stream	No SIHP Assigned	E	reuse rocks from streambed	conditional no adverse effect

* not identified as an Historic Property

Table 1: Historic Properties

	DESCRIPTION	SITE ID	CRITERIA	TREATMENT RECOMMENDATION	EFFECTS DETERMINATION
	8) Palolo: Waiomao Debris/Detention Basin				
33	Waiomao Stream	No SIHP Assigned	E	reuse rocks from streambed	conditional no adverse effect
*	Waiomao USGS Gaging Station	No SIHP Assigned	None	not historic	not historic
	9) Ala Wai: Hausten Ditch Detention Basin				
*	Ala Wai Park	No SIHP Assigned	None	not historic	not historic
34	Alanaio Stream Channel (Hausten Ditch)	Inventory No. 82	A,C	historic documentation	conditional no adverse effect
35	Ala Wai Canal	50-80-14-9757	A	historic documentation	conditional no adverse effect
36	box culvert at Date Street	Inventory No. 84	C	no direct impact	no effect
37	box culvert at Kapiolani Blvd	Inventory No. 85	C	no direct impact	no effect
	10) Ala Wai: Ala Wai Golf Course MPDB				
38	Ala Wai Golf Course	No SIHP Assigned	none	monitoring during construction	conditional no adverse effect
**	Manoa-Palolo Canal	Inventory No. 36	A,C	historic documentation	conditional no adverse effect
*	Kapahulu Drainage	No SIHP Assigned	none	not historic	not historic
39	Date Street Bridge	Inventory No. 37	A,C	no direct impact	no effect
	11) Ala Wai: Ala Wai Canal Floodwalls/Pump Stations				
**	Ala Wai Canal	50-80-14-9757	A	historic documentation/SHPD design input	conditional no adverse effect
40	Ala Wai Clubhouse (C&C Art Deco Parks)	50-80-14-1388/ No. 90	C	historic documentation/SHPD design input	conditional no adverse effect

* not identified as an Historic Property
** previously identified as part of another Measure

Table 1: Historic Properties

	DESCRIPTION	SITE ID	CRITERIA	TREATMENT RECOMMENDATION	EFFECTS DETERMINATION
41	Paddling Outrigger Canoe	No SIHP Assigned	e	coordination on design with consulting parties	no adverse effect
42	Kalakaua Ave Bridge	Inventory No. 02	A,C	match design with existing walls	no adverse effect
43	McCully St. Bridge	Inventory No. 03	A,C	match design with existing walls	no adverse effect
*	Kapahulu Drainage	No SIHP Assigned	none	not historic	not historic
	12) Watershed: Flood Warning System				
44	Manoa Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
45	Makiki Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
46	Palolo Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
**	Ala Wai Canal	50-80-14-9757	A	historic documentation/SHPD design input	conditional no adverse effect
	13) Watershed: Aquatic Habitat Mitigation				
**	Manoa Stream	No SIHP Assigned	e	reuse rocks from streambed	conditional no adverse effect
**	Waihi Stream Stone/Mortar Dam	50-80-14-6736/No. 54	A	reuse rocks/improve appearance	conditional no adverse effect
**	Waihi Gaging Station	Inventory No. 53	A,C	no direct impact	no effect
**	Waiakeakua Gaging Station	Inventory No. 55	A,C	reuse rocks/improve appearance	conditional no adverse effect
**	Manoa Stream Channel	Inventory No. 41	A,C	historic documentation/SHPD design input	conditional no adverse effect

* not identified as an Historic Property
** previously identified as part of another Measure

Enclosure 2

Historic Property Maps and Descriptions

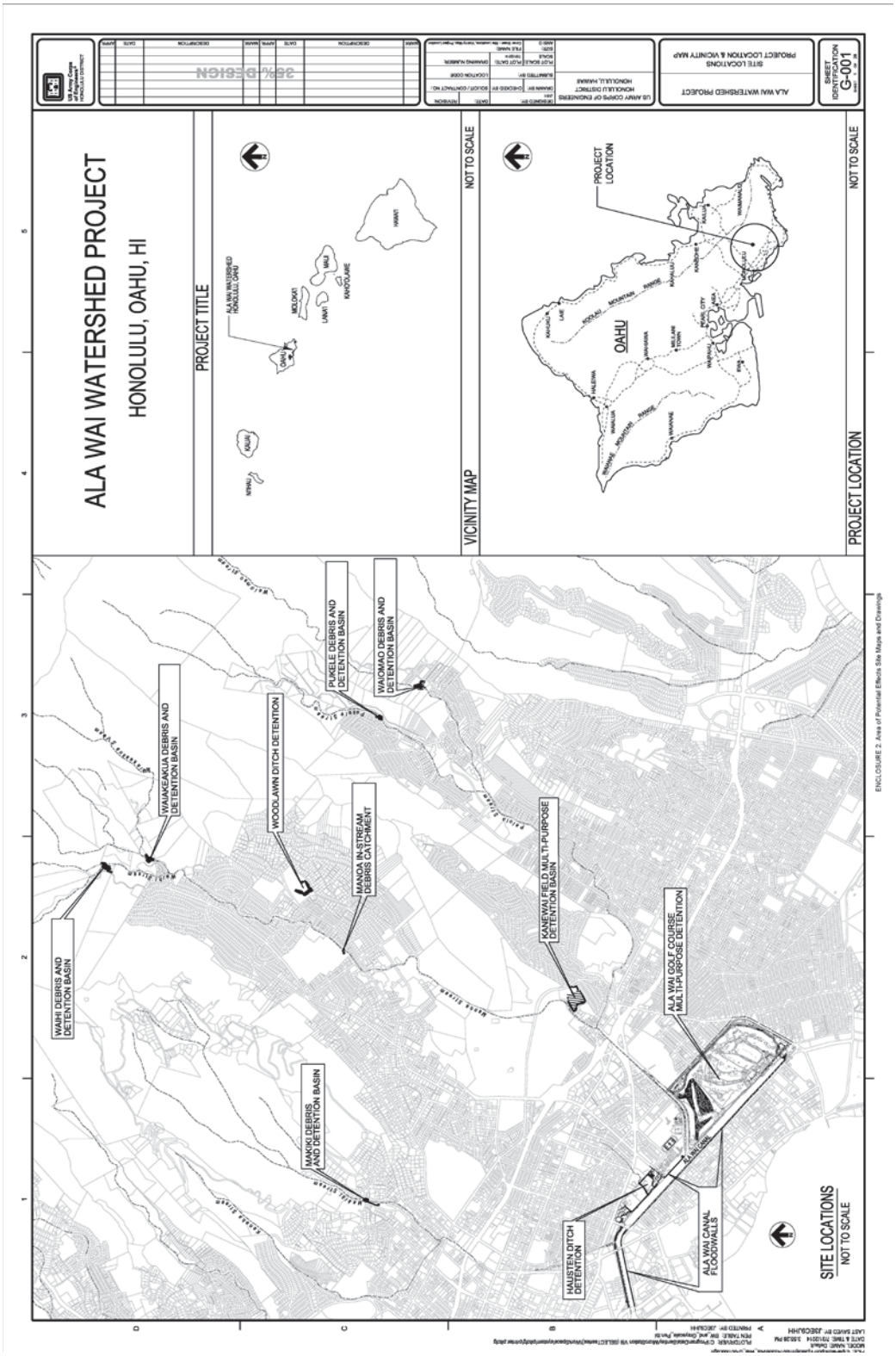


Figure 1 Project Location Map

Figure 2 Location of Proposed Flood Protection Measures

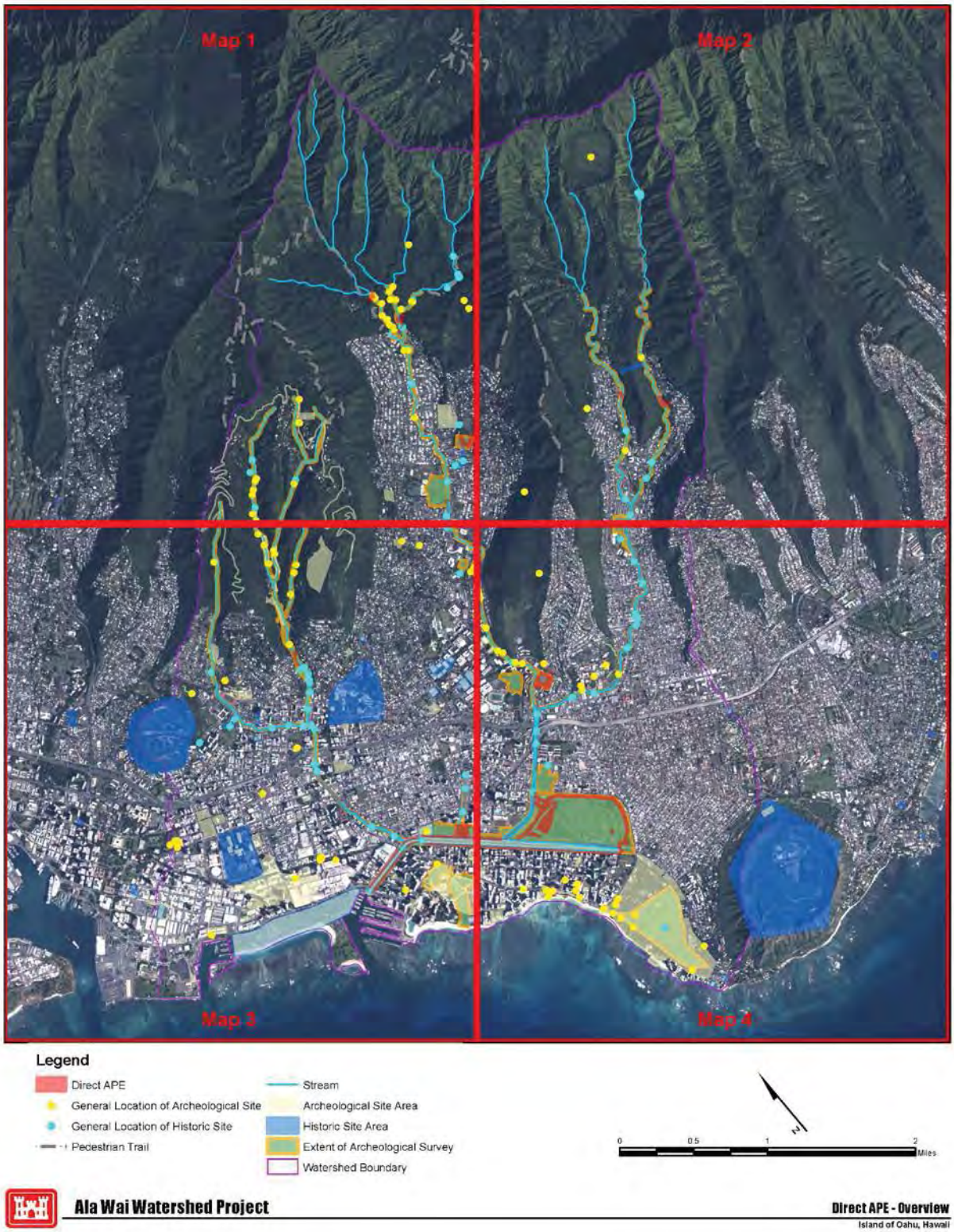


Figure 3 Overview of Historic Properties

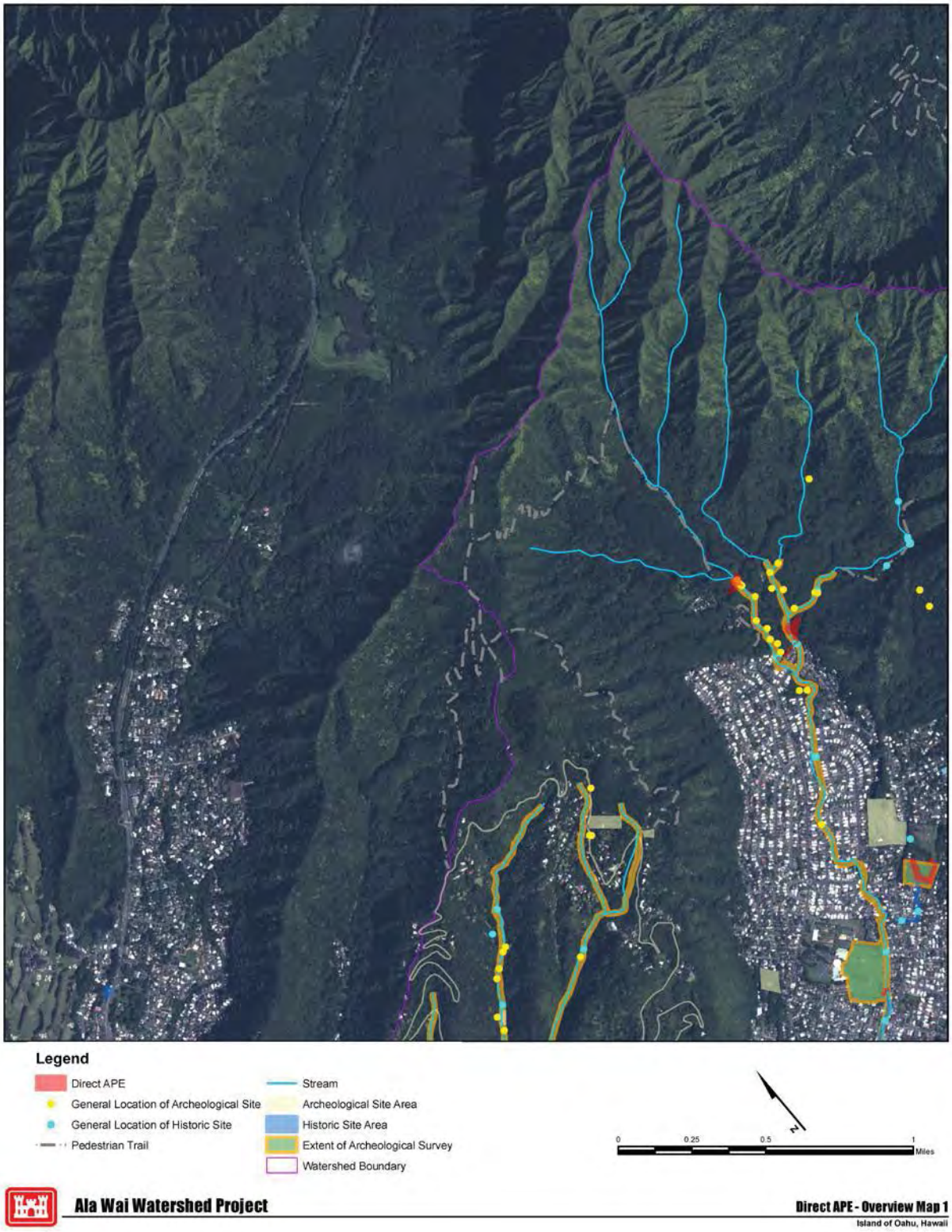


Figure 4 Map 1 from Historic Property Overview

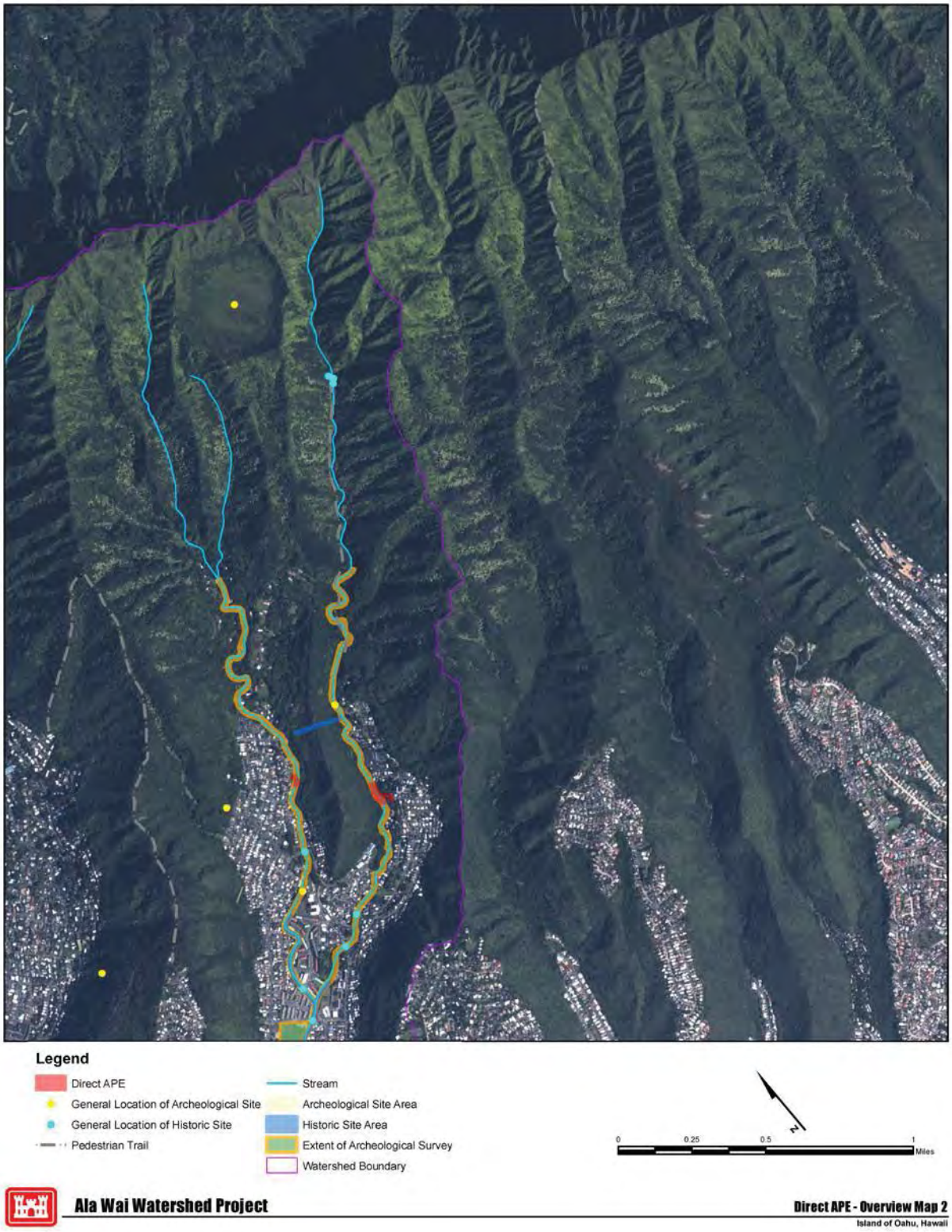


Figure 5 Map 2 from Historic Property Overview

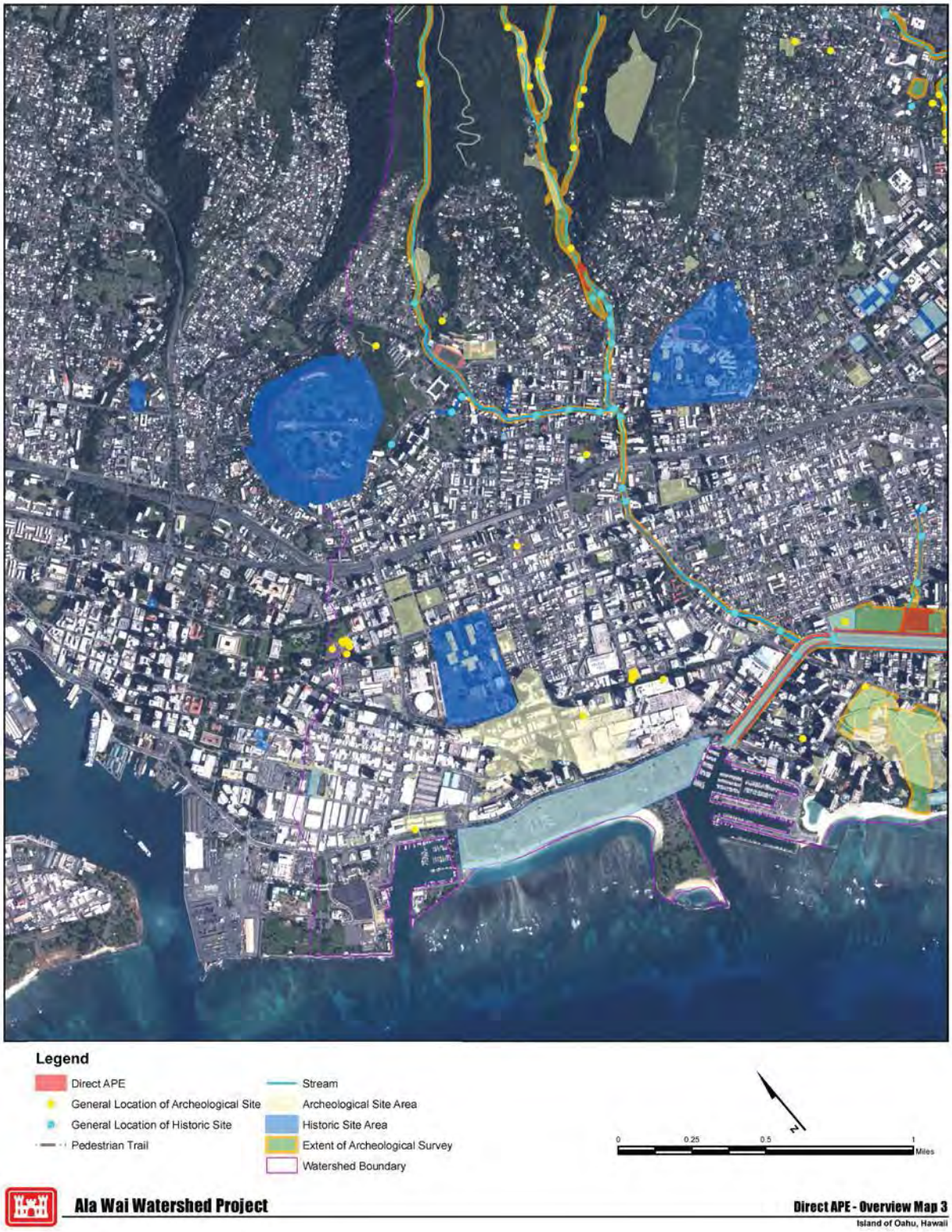


Figure 6 Map 3 from Historic Property Overview

Figure 7 Map 4 from Historic Property Overview

Makiki
Measure No. 1: Makiki Debris and Detention Basin (Figure 8)

a. Description of the measure
Earthen berm, approximately 24' high and 100' across, with an arch culvert to allow small storm flows to pass. Construct a 90' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Debris catchment feature located on upstream end of culvert. Create new access road for construction and O&M. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. What can area be used for after the measure
Normal stream flow will not be affected; new measure will impound (pool) water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use (including adjacent recreational use of open space areas) will not change; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 92, Archie Baker Park, constructed 1934, is eligible for listing on the National Register of Historic Places (36 CFR 60.4), and the Hawaii Register of Historic Places (HAR §13-198-8) under criteria A and C. A portion of the park will be used as a staging area during construction. As mitigation for impacts during construction, the park will be returned to pre-construction condition after construction of the Makiki Debris and Detention Basin. There is a stand of kukui trees within the park that will be avoided during construction. No adverse effect.

2. WITHIN CONSTRUCTION FOOTPRINT: Makiki Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion E per HAR §13-275-6. Construction of the Makiki Debris and Detention Basin could have an adverse effect on resources collected within the stream and along the stream banks. As mitigation for impacts, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed. We will also look if there is a way to distribute rocks excavated from within the stream, that cannot be used for the project, to community members within the *ahupua'a* where they were found. If redistribution of rocks is permissible, terms and conditions to be worked out through a Programmatic Agreement (PA).

3. OUTSIDE FOOTPRINT: Site 50-80-14-6717, Terrace, along Kanealole Stream at *mauka* end of 100 yr detention pool, eligible for listing on the National/State Register under criterion D. Mitigation: avoidance during construction, and only impacted by temporary water inundation during the 100 yr pooling event. No adverse effect.

4. OUTSIDE FOOTPRINT: Inventory No. 11, Makiki Stream Channel, constructed in 1934, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

5. OUTSIDE FOOTPRINT: Inventory No. 17, Makiki Street Bridge, constructed in 1912 and reconstructed in 1953, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

6. OUTSIDE FOOTPRINT: Inventory No. 18, One`ele Place Bridge, constructed c.1909, privately owned, eligible for listing on the National/State Register under criteria A and C. No direct impact to resource, no effect.

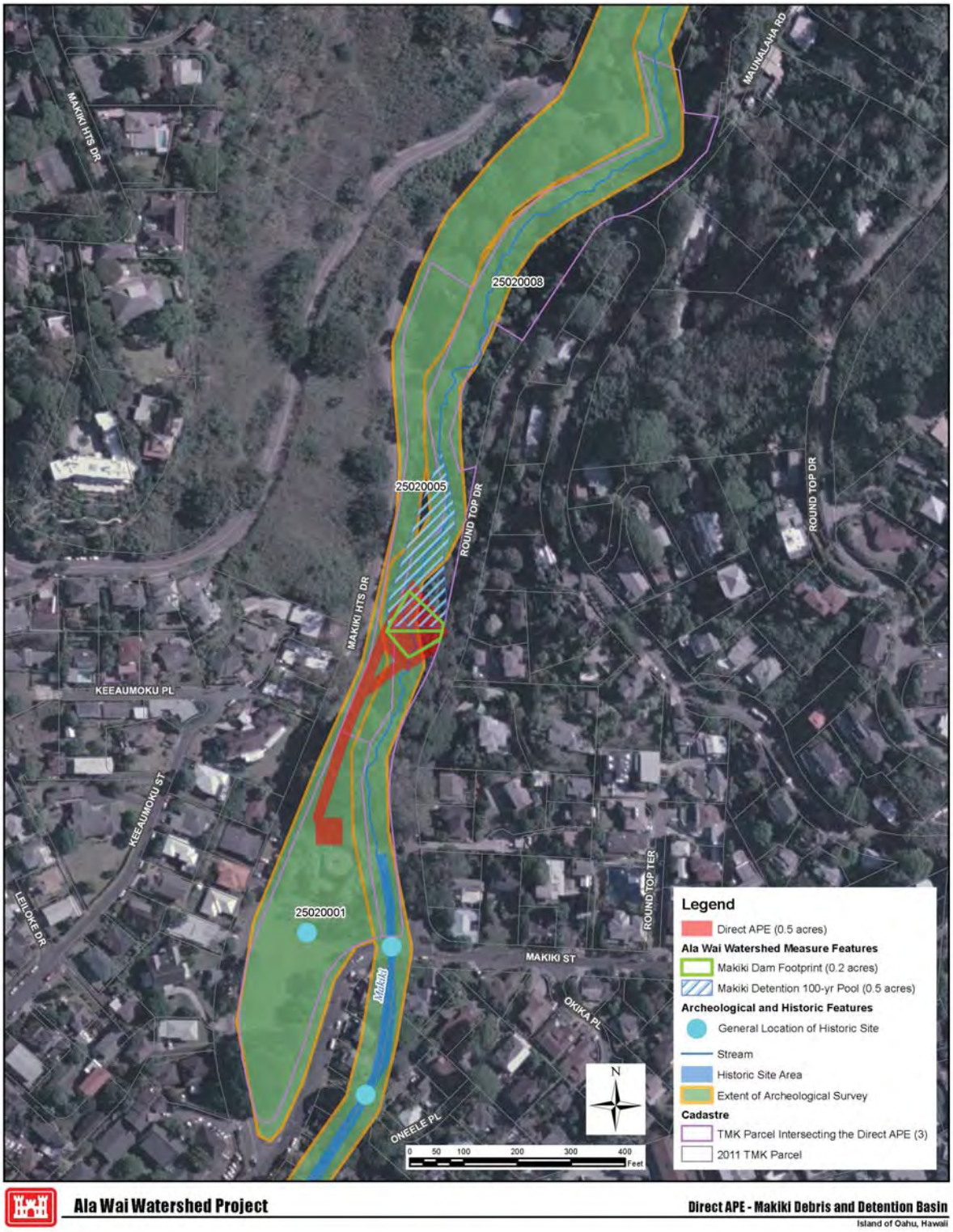


Figure 8 Cultural Resources near Makiki Debris and Detention Basin

Manoa Valley
Measure No. 2: Waihi Debris and Detention Basin (Figures 9 and 10).

a. Description of the measure

Earthen berm, approximately 24' high and 225' across, with an arch culvert to allow small storm flows to pass. Construct a 124' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Debris catchment feature located on upstream end of culvert. Create new access road for construction and O&M. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. What can area be used for after the measure

Normal stream flow will not be affected; new measure will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Site 50–80–14–6734, walls, mounds, and platforms, on east bank of Waihi Stream. Feature A is a platform constructed on top of a large basalt boulder and bedrock outcrop. Feature B is a faced mound constructed on top of a large basalt boulder. Feature C is a platform built over several large basalt boulders. Feature D is a platform constructed at the base of a low bluff. Large basalt boulders were incorporated into the base of the platform. Feature E is located immediately downslope of Feature D. The feature consists of four basalt boulders stacked on a large basalt boulder, which is embedded in the soil surface. Feature F is a faced mound constructed on top of several large basalt boulders. Feature G consists of a long, loosely stacked stone retaining wall, constructed against a soil embankment along the eastern edge of Waihī Stream. Feature H is a faced mound along the eastern edge of the Feature G wall. Site 6734 is eligible for listing on the National/State Register under criterion D, and is eligible under Site Significance per HAR §13-275-6, criterion e. The current best engineering location for this measure places the Waihi Debris and Detention Basin directly over portions of Site 6734 resulting in an adverse effect. As mitigation for impacts to Site 6734, we will first try to avoid the site by adjusting the culvert and spillway downstream. If the site cannot be moved enough to avoid the site, then mitigation would include data recovery with more detailed recording and subsurface testing at the site. If features associated with Site 6734 are disturbed, then the project will reuse the rocks in construction of the flood protection measure, or will solicit community assistance in rebuilding features impacted.

2. WITHIN CONSTRUCTION FOOTPRINT: Waihi Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Construction of the Waihi Debris and Detention Basin could have an adverse effect on resources collected within the stream and along the stream banks. As mitigation for impacts, the reconstruction will use natural stream cobble/boulder

materials to blend in with the streambed. We will also look if there is a way to distribute rocks excavated from within the stream, that cannot be used for the project, to community members within the *ahupua‘a* where they were found. If redistribution of rocks is permissible, terms and conditions to be worked out through a PA.

3. OUTSIDE FOOTPRINT: ‘Aihualama Lo‘i. The proposed measures at Waihī Stream, is located *makai* of ‘Aihualama Lo‘i, which should not directly impact the integrity of the *lo‘i*. However, any inundation behind basins during and after heavy storms could impact the *lo‘i*. There is also possibility of temporary loss of access to cultural sites and areas of cultural practices during construction. No adverse effect.

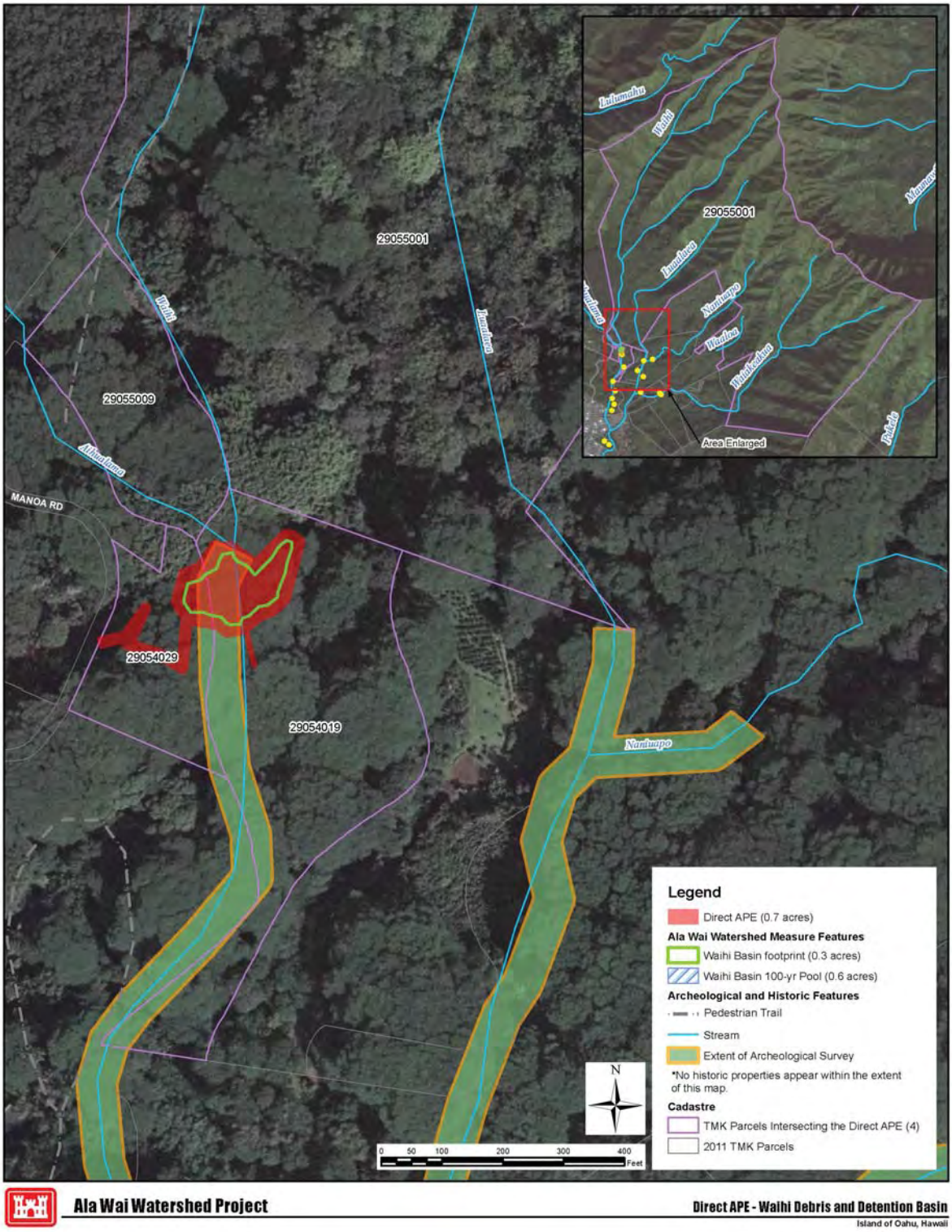


Figure 9 Cultural Resources near Waihi Debris and Detention Basin

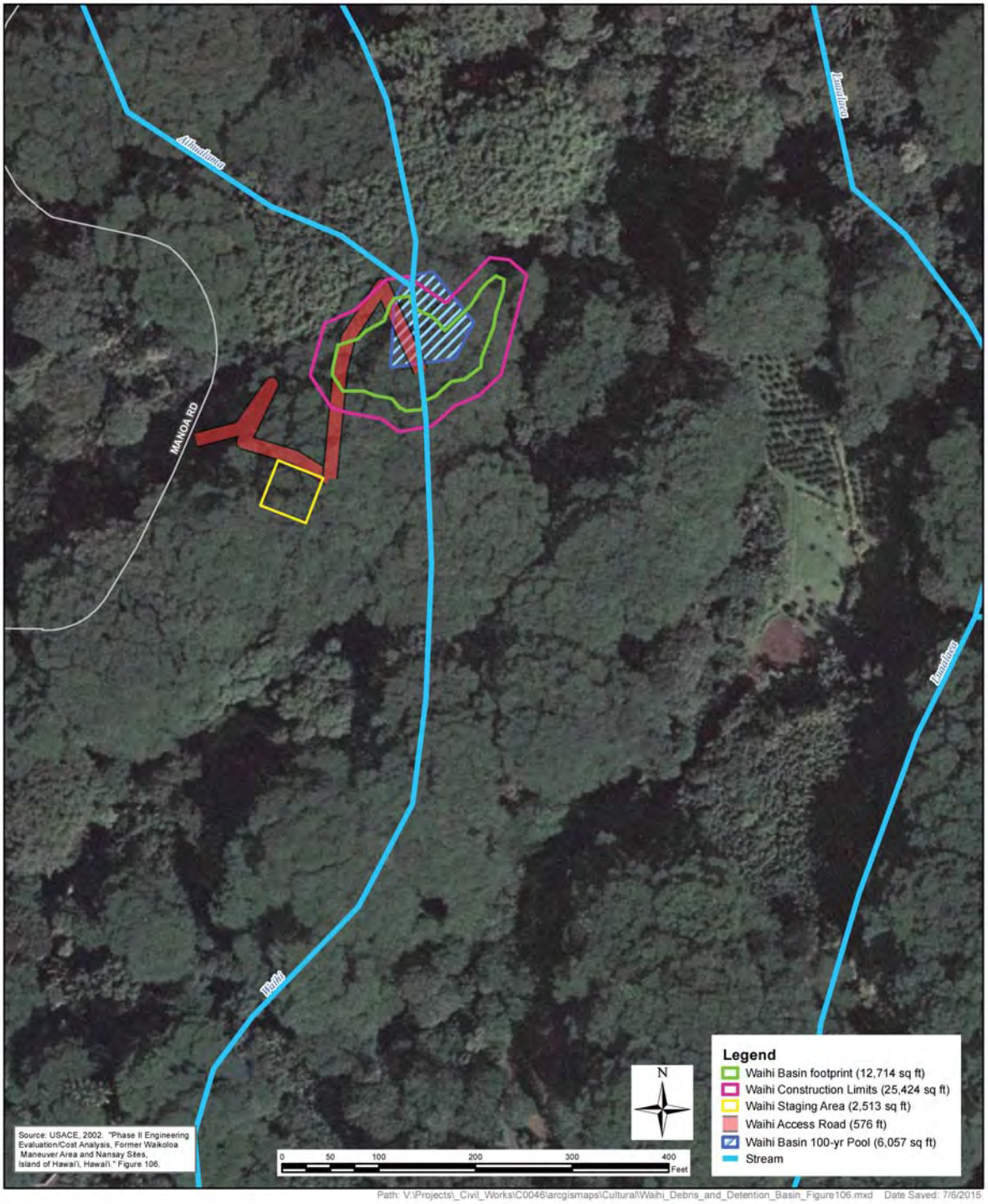


Figure 10 Overlay of Site 6734 at Waihi Debris and Detention Basin

Manoa Valley
Measure No. 3: Waiakeakua Debris and Detention Basin (Figure 11)

a. Description of the measure

Earthen berm, approximately 20' high and 185' across, with an arch culvert to allow small storm flows to pass. Construct a 105' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Debris catchment feature to be located on upstream end of culvert, and energy dissipation structure (concrete blocks) to be located on downstream end of culvert. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. What can area be used for after the measure

Normal stream flow will not be affected; new measure will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Wa`aloa Way Bridge 1, this bridge primarily services a BWS road, and receives very limited public use, dating from 1967, this bridge is not presently considered historic, but will be 50 years old in two years. The bridge will need to be reinforced, perhaps temporarily, to support construction equipment and future monitoring activities. As mitigation for impacts to the bridge, appropriate historic documentation will be worked out with the State Historic Preservation Division (SHPD). The result is no adverse effect with this stipulated condition.

2. OUTSIDE FOOTPRINT: Site 50-80-14-6736/Inventory No. 54, Waihi Stream Dam. Dam will not be impacted during construction of the Waiakeakua Debris and Detention Basin. However, the dam will be altered to improve fish passage as a biological mitigation, and is discussed under Measure No. 13, Aquatic Habitat Mitigation.

3. OUTSIDE FOOTPRINT: Inventory No. 53, Waihi Stream Gaging Station, constructed in 1936-1937, eligible for listing on the National/State Register under criteria A and C. Associated with, and located on the stream bank above the Waihi Stream Dam, there will be no changes made to the gaging station, resulting in no direct impacts to the resource, and a no effect determination.

4. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 51, Wa`aloa Way Bridge 2, constructed in 1965, eligible for listing on the National/State Register under criterion C. This bridge primarily services a BWS road, and receives very limited public use. It will need to be reinforced, perhaps temporarily, to support equipment access during construction of the measure. As mitigation for impacts to the bridge, appropriate

historic documentation will be worked out with the SHPD. The result is no adverse effect with this stipulated condition.

5. OUTSIDE FOOTPRINT: Inventory No. 55, Waiakeakua Stream Gaging Station. Gaging station features will not be impacted during construction of the Waiakeakua Debris and Detention Basin. However, the Parshall Flume and stilling well will be altered to improve fish passage as a biological mitigation, and is discussed under Measure No. 13, Aquatic Habitat Mitigation.

6. WITHIN CONSTRUCTION FOOTPRINT: Waiakeakua Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Construction of the Waiakeakua Debris and Detention Basin could have an adverse effect on resources collected within the stream and along the stream banks. As mitigation for impacts, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed. We will also look if there is a way to distribute rocks excavated from within the stream, that cannot be used for the project, to community members within the *ahupua‘a* where they were found. If redistribution of rocks is permissible, terms and conditions to be worked out through a PA.

7. OUTSIDE FOOTPRINT: Site 50-80-14-6735, two small terrace features near the east bank of Waihī Stream, eligible for listing on the National/State Register under criterion D. No direct impact to resource, no effect.

8. OUTSIDE FOOTPRINT: Site 50-80-14-6737, historic house site on east bank above Waihi Stream, eligible for listing on the National/State Register under criteria C and D. No direct impact to resource, no effect.

9. OUTSIDE FOOTPRINT: Site 50-80-14-6738, historic house site on east bank above Waihi Stream, eligible for listing on the National/State Register under criteria C and D. No direct impact to resource, no effect.

10. OUTSIDE FOOTPRINT: Site 50-80-14-6744, historic bridge foundation across the *makai* (ocean side) portion of Waiakeakua Stream, eligible for listing on the National/State Register under criteria C and D. No direct impact to resource, no effect.

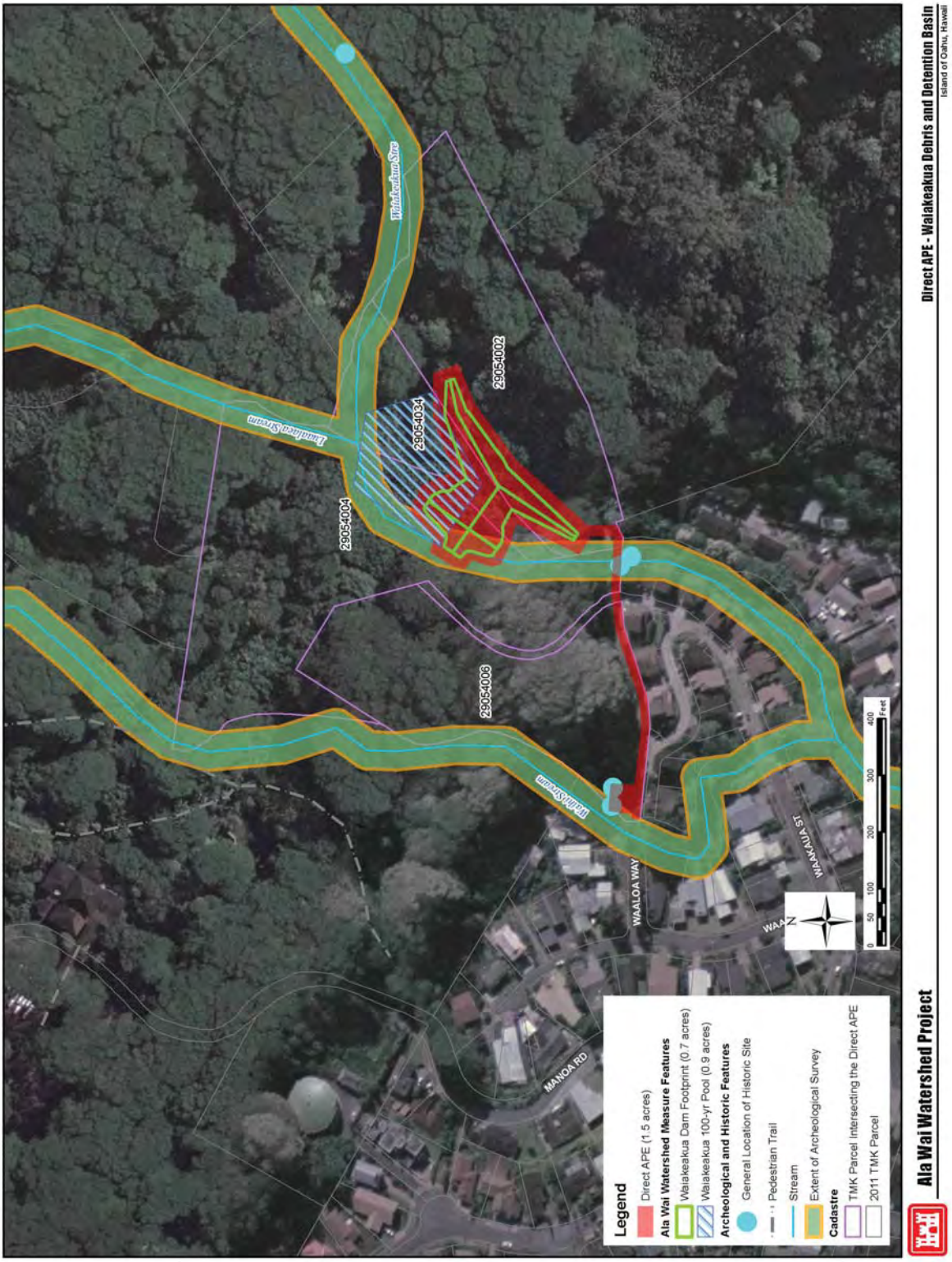


Figure 11 Cultural Resources near Waiakeakua Debris and Detention Basin

Manoa Valley
Measure No. 4: Woodlawn Ditch Detention Basin (Figure 12)

a. Description of the measure

Construct three-sided berm, approximately 15' high and 840' long to create the detention basin. Construct arch culvert with 80' wide concrete grouted riprap spillway above culvert at west corner of berm. Arch culvert and spillway will tie into Woodlawn Ditch for drainage. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.

b. What can area be used for after the measure

Normal ditch flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; agricultural operations may continue, but would be subject to flooding; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Open space area adjacent to Woodlawn Stream. No historic properties have been included in either the Hawai'i, or National Register of Historic Places within this area.

2. OUTSIDE FOOTPRINT: Inventory No. 42, Woodlawn Ditch, constructed in 1933-1934, eligible for listing on the National/State Register under criteria A and C. No direct impact to resource, no effect.

3. OUTSIDE FOOTPRINT: Inventory No. 47, East Manoa Road Manoa Park Ditch Bridge, constructed in 1938, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

4. OUTSIDE FOOTPRINT: Inventory No. 48, East Manoa Road Culvert, construction date unknown, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

5. OUTSIDE FOOTPRINT: Inventory No. 49, Kaamamilo Drive Driveway Bridge, constructed sometime between 1941-1954. Bridge is eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

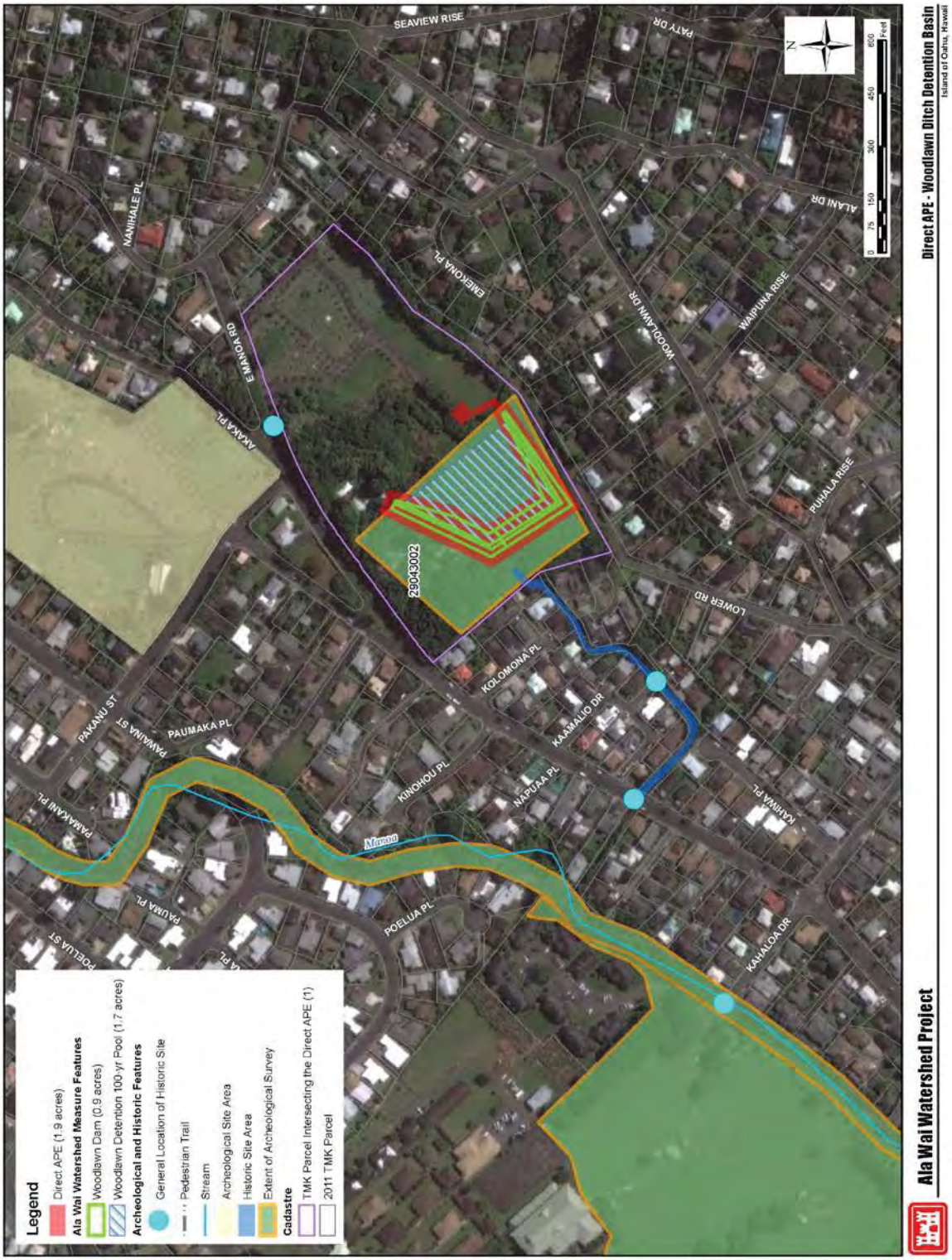


Figure 12 Cultural Resources near Woodlawn Ditch Detention Basin

Manoa Valley
Measure No. 5: Manoa In-Stream Debris Catchment (Figure 13)

a. Description of the measure

Construct concrete pad over stream bed, approximately 8' wide and 60' across, with steel posts up to approximately 7' high, evenly spaced at 4' apart along concrete pad.

b. What can it be used for after the measure

Normal stream flow will not be affected; will require occasional maintenance; no changes to land use; no impact on recreation at adjacent park; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 41, Manoa Stream Channel, constructed in 1952, eligible for listing on the National/State Register under criteria A and C. Construction of concrete pad and steel posts (bollards) will have an adverse effect on the Manoa Stream Channel. As mitigation for impacts to the stream channel, appropriate historic documentation will be worked out with the SHPD. The result is no adverse effect with this stipulated condition.

2. OUTSIDE FOOTPRINT: Inventory No. 45, Lowrey Avenue Bridge, constructed in 1953, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

3. OUTSIDE FOOTPRINT: Inventory No. 46, Kahaloa Drive Bridge, constructed in 1954, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

Figure 13 Cultural Resources near Manoa In-Stream Debris Catchment

Manoa Valley
Measure No. 6: Kanewai Field Multi-Purpose Detention Basin (Figure 14)

a. Description of the measure

Construct approx. 7' high earthen berms around 3 sides of the field to create a detention basin. Construct 60' wide inflow spillway of concrete, with grouted rip rap on the stream side, on the northwest end of the field that allows high stream flows to enter the new detention basin. Existing drainage pipe at south end of basin will allow water to re-enter the stream. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.

b. What can it be used for after the measure

No work will be conducted in stream; normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access to the park would be restricted during flood conditions; will require occasional maintenance; land use will not change during non-flood events; the berm feature is multi-purpose, it can be used for spectating; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 94, Kanewai Field, constructed in 1955, eligible for listing on the National/State Register under criterion C. New earthen berm will have an adverse effect on the 1950s era playground landscape by introducing a visual impact on the open space. As mitigation, the resulting berm will be grass-covered to blend in with the surrounding area, the Hawaiian style restrooms and recreation center buildings will not be touched, and mature trees in area will not be disturbed. The result is no adverse effect with these stipulated conditions.

2. OUTSIDE FOOTPRINT: Inventory No. 36, Manoa-Palolo Canal, constructed in 1935, eligible for listing on the National/State Register under criteria A and C. No direct impact to resource, no effect.

3. OUTSIDE FOOTPRINT: Inventory No. 40, Old Waialae Road Bridge, constructed in 1953, eligible for listing on the National/State Register under criterion C. No direct impact to resource, no effect.

4. OUTSIDE FOOTPRINT: Inventory No. 63, Palolo Stream Channel, constructed between 1951-1955, eligible for listing on the National/State Register under criteria A and C. No direct impact to resource, no effect.

5. OUTSIDE FOOTPRINT: The proposed measures at Kanewai Field are located *makai* (toward the ocean) of Kanewai Loʻi, which should not directly impact the integrity of the *loʻi*. However, any inundation behind basins during and after heavy storms could impact *loʻi*. There is also possibility of temporary loss of access to cultural sites and areas of cultural practices during construction. No adverse effect.

Figure 14 Cultural Resources near Kanewai Field Multi-Purpose Detention Basin

Palolo Valley
Measure No. 7: Pukele Debris and Detention Basin (Figure 15)

a. Description of the measure

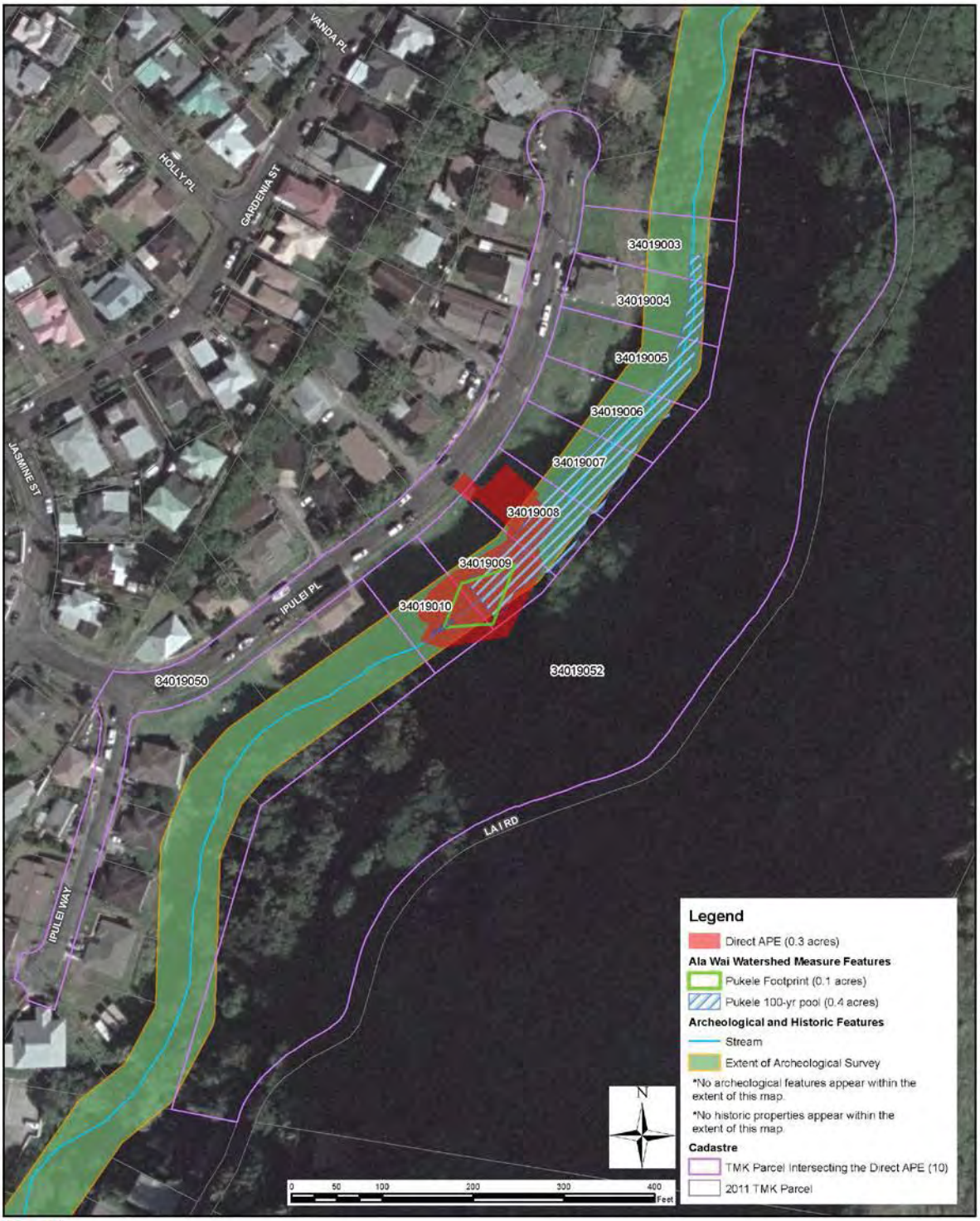
Earthen berm, approximately 24' high and 120' across, with an arch culvert to allow small storm flows to pass. Construct a 110' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Debris catchment feature located on upstream end of culvert. Create new access road for construction and O&M. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained.

b. What can it be used for after the measure

Normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Pukele Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Construction of the Pukele Debris and Detention Basin could have an adverse effect on resources collected within the stream and along the stream banks. As mitigation for impacts, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed. We will also look if there is a way to distribute rocks excavated from within the stream, that cannot be used for the project, to community members within the *ahupua'a* where they were found. If redistribution of rocks is permissible, terms and conditions to be worked out through the PA.



Ala Wai Watershed Project

Direct APE - Pukele Debris and Detention Basin
Island of Oahu, Hawaii

Figure 15 Cultural Resources near Pukele Debris and Detention Basin

Palolo Valley
Measure No. 8: Waiomao Debris and Detention Basin (Figure 16)

a. Description of the measure

Earthen berm, approximately 24' high and 120' across, with an arch culvert to allow small storm flows to pass. Construct a 110' wide concrete spillway above culvert, with grouted riprap on upstream and downstream side. Debris catchment feature located on upstream end of culvert. Excavate approximately 2,000 cubic yards of soil to provide required detention volume upstream of berm. Low-flow channel with existing substrate to be restored following excavation. Create new access road for construction and O&M. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Existing Waiomao USGS Gaging Station will be demolished during construction of this measure.

b. What can area be used for after the measure

Normal stream flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); will require occasional maintenance; land use will not change; no significant changes to access within project vicinity.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Waiomao Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Construction of the Waiomao Debris and Detention Basin could have an adverse effect on resources collected within the stream and along the stream banks. As mitigation for impacts, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed. We will also look if there is a way to distribute rocks excavated from within the stream, that cannot be used for the project, to community members within the *ahupua‘a* where they were found. If redistribution of rocks is permissible, terms and conditions to be worked out through the PA.

2. WITHIN CONSTRUCTION FOOTPRINT: Existing USGS Gaging Station on Waiomao Stream will be demolished during construction of this measure. This gaging station was not identified in the Historic Structures Inventory Survey, and therefore will not be treated as historic.

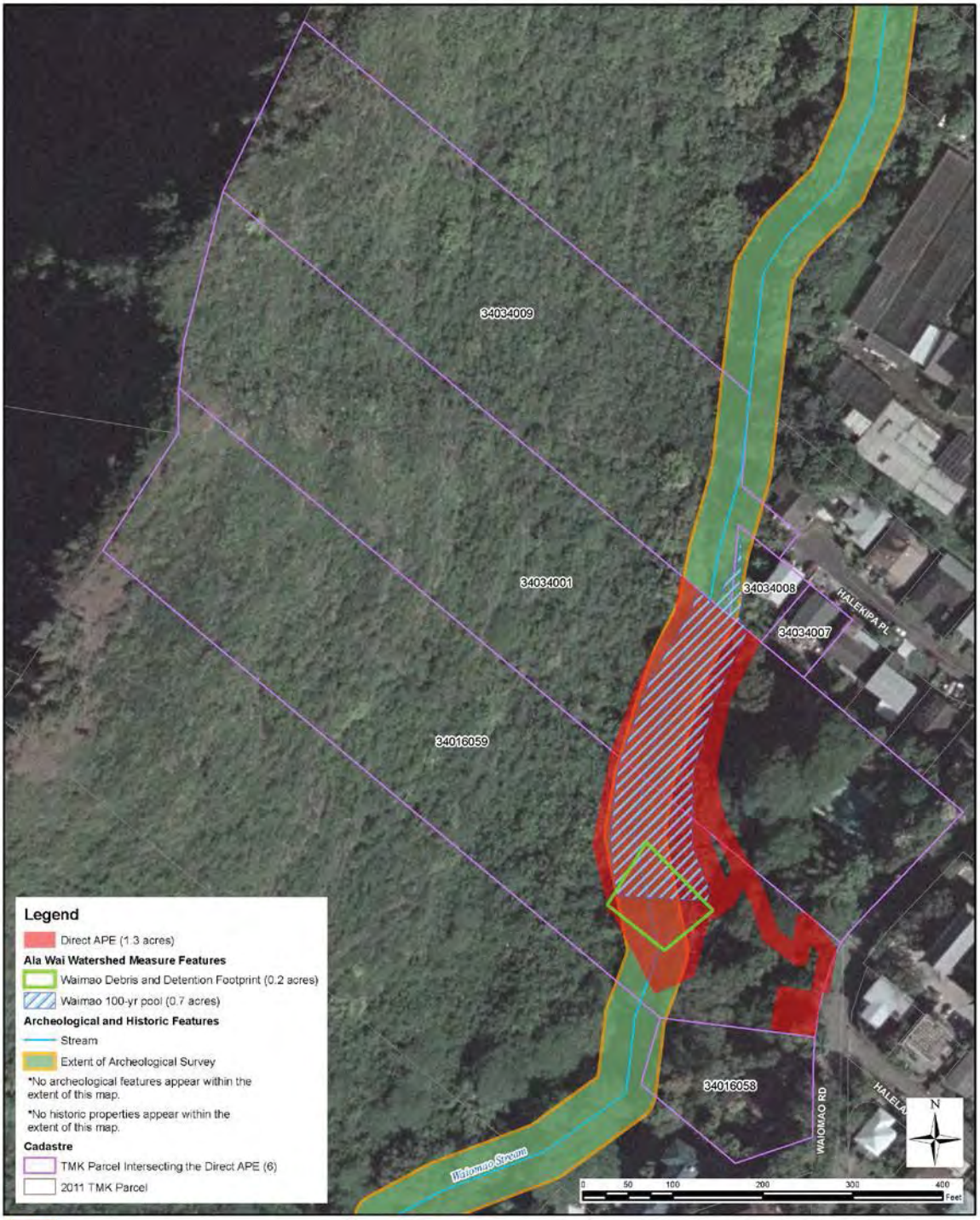


Figure 16 Cultural Resources near Waiomao Debris and Detention Basin

Ala Wai
Measure No. 9: Hausten Ditch Detention Basin (Figure 17)

a. Description of the measure

Add 4.3' high concrete floodwalls and earthen berm around a portion of the Ala Wai Park to provide detention for local drainage. Install slide gates at existing bridge to control flow of floodwaters between Hausten Ditch and the Ala Wai Canal.

b. What can area be used for after the measure

Normal ditch flow will not be affected; will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access to the park would be restricted during flood conditions; will require occasional maintenance; land use will not change during non-flood events. Proposed measure is multi-purpose, berm can be used for spectating; no significant changes to access within project vicinity; no restriction of access for adjacent canoe clubs

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Ala Wai Park is not eligible for listing on the National/State Register. Even though the Park is not identified as an historic property, the new earthen berm and floodwalls will have a visual impact on the open space. As mitigation, the resulting berm will be grass-covered to blend in with surrounding area.

2. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 82, Alanaio Stream Channel (now called Hausten Ditch), was constructed in 1929, eligible for listing on the National/State Register under criteria A and C. The stream runs through Ala Wai Park in a realigned channel with a natural bed and vegetated banks. Project will be adding slide gates to the Ala Wai Canal end of Hausten Ditch, resulting in an adverse effect on the resource. As mitigation for impacts to Hausten Ditch, appropriate historic documentation of Hausten Ditch will be worked out with the SHPD. The result is no adverse effect with this stipulated condition. Two pedestrian bridges cross the park section of the stream. Neither bridge is considered to be historic.

3. WITHIN CONSTRUCTION FOOTPRINT: Site 50-80-14-9757, Ala Wai Canal. The same slide gates identified above that will be added to Hausten Ditch, will also have an adverse effect on the existing Ala Wai Canal walls. Appropriate historic documentation of the Ala Wai Canal walls will be worked out with the SHPD. The result is no adverse effect with this stipulated condition.

4. OUTSIDE FOOTPRINT: Inventory No. 84, box culvert at Date Street, constructed in 1934, eligible for listing on the National/State Register under criteria C. No direct impact to resource, no effect.

5. OUTSIDE FOOTPRINT: Inventory No. 85, box culvert at Kapiolani Boulevard, constructed in 1934, eligible for listing on the National/State Register under criteria C. No direct impact to resource, no effect.

Figure 17 Cultural Resources near Hausten Ditch Detention Basin

Ala Wai

Measure No. 10: Ala Wai Golf Course Multi-Purpose Detention Basin (Figure 18)

a. Description of the measure

Construct earthen berm, up to approximately 7' high, around northern and eastern perimeter of golf course property. Construct 60' long concrete inflow spillway with grouted rip rap along bank of Manoa-Palolo Canal to allow flood waters to enter golf course. Add floodgate that crosses main entrance to the golf course. Excavate sediment basin within "rough" (out of bounds) areas of the golf course to act as sediment catchment during storm events with passive drainage back into Ala Wai Canal.

b. What can it be used for after the measure

No change in existing land use (except during flood conditions); will impound water and debris only during flood conditions (pooling will last for less than 12 hours); access would be restricted during flood conditions; will require occasional maintenance.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Ala Wai Golf Course. The golf course has been in operation for over fifty years, and has undergone several major renovations. There will be a short term construction impact to the cart paths while the berm is being installed. Elements to be constructed have been sited to minimize impacts to day to day use, availability, and operations of the golf course. Burials have previously been identified at the golf course. As mitigation, excavation for new berm construction around north and east sides of the golf course is not to exceed 2 feet below the existing grade. Archaeological Monitoring requirements will be worked out with SHPD. There will be replanting within the newly constructed detention basin portion of the golf course. Mitigations will be worked out in more detail with SHPD, resulting in a no adverse effect with conditions.

2. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 36, Manoa-Palolo Canal, constructed in 1935-1936, eligible for listing on the National/State Register under criteria A and C. Project will be creating an inflow spillway to flow into the golf course in an area of the canal where there is a natural (unconstructed) stream bank and bottom. This measure will have an adverse effect on the Manoa-Palolo Canal. As mitigation, appropriate historic documentation will be worked out with the SHPD. The result is no adverse effect with this stipulated condition.

3. WITHIN CONSTRUCTION FOOTPRINT: Kapahulu (or Ala Wai Golf Course) Drainage is located near the cart path/berm. This 56' wide, reinforced concrete open channel was constructed in 1974, and therefore is not considered to be historic.

4. OUTSIDE FOOTPRINT: Inventory No 37, Date Street Bridge, constructed in 1937, eligible for listing on the National/State Register under criteria A and C. No impacts to the resource, no effect.

Figure 18 Cultural Resources near Ala Wai Golf Course Multi-Purpose Detention Basin

Ala Wai
Measure No. 11: Ala Wai Canal Floodwalls and Pump Stations (Figure 19)

a. Description of the measure

Add concrete floodwalls along Ala Wai Canal ranging in height up to approximately 4.7 feet high. Floodwalls will be offset from existing canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to canal. Add three Pump Stations and gates to prevent drainage flooding that may be caused on the exterior of the new Ala Wai Floodwalls. Pump Stations to be located at (1) Diamond Head end of Ala Wai Canal, (2) within Ala Wai Golf Course at head of Kapahulu Ditch, and (3) in Ala Wai Park, near Hausten Ditch Detention Basin. Slide and flap gates will be installed at existing drainage pipes along the entire canal to prevent backflow out of the canal. New floodgate to be installed at Ala Wai Clubhouse near McCully Street.

b. What can it be used for after the measure

New walls will not restrict pedestrian access, but will limit views along/across/toward, and from Canal; no changes to land use; no restriction of access for adjacent canoe clubs. Pump stations will displace open space.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: Site 50-80-14-9757, Ala Wai Canal, on State Historic Register since 1992. Construction of floodwalls and pump stations along both sides of the Ala Wai Canal will impact the view planes from, and towards Waikiki and the Ala Wai Golf Course. Tentatively Selected Plan will construct a wall behind existing canal walls, and install slide and flap gates at existing drainage pipes along the entire canal. For mitigation, we will continue to solicit design and wall placement input from interested consulting parties and SHPD, and incorporate such input as feasible into the final design and construction of the floodwalls and pump stations. Appropriate historic documentation of the Ala Wai Canal will be worked out with the SHPD. Project planning and siting will be conducted in a manner so as to best integrate the project components with the natural characteristics of the site and minimize visual impacts to the greatest extent possible. Pump station design would be compatible with other Ala Wai Canal pump stations recently constructed. With stipulated conditions in place, the result will be no adverse effect.

2. WITHIN CONSTRUCTION FOOTPRINT: Site 50-80-14-1388/Inventory No. 90, the Ala Wai Clubhouse, located at the corner of McCully Street and Kapiolani Boulevard, was listed in the Hawaii Register of Historic Places in 1988 as part of the City & County of Honolulu Art Deco Parks thematic nomination. Tentatively Selected Plan has new canal floodwalls attaching to the Clubhouse, and a floodgate added to the front of the building. This design was selected to maintain canoe access. For mitigation, we will continue to solicit wall design and placement input from interested consulting parties and SHPD, and incorporate such input as feasible into the final design and construction of the floodwalls. With stipulated conditions in place, the result will be no adverse effect.

3. WITHIN CONSTRUCTION FOOTPRINT: The practice of paddling an outrigger canoe has been identified as an historic and traditional cultural practice. It is significant under criterion e per HAR §13-275-6. Construction of floodwalls and pump stations will have an adverse effect on the setting, feeling, and visual integrity of the practice along the Ala Wai Canal. There may also be temporary displacement of access during construction activities. As mitigation for impacts, we will continue to solicit design and placement input from interested consulting parties and SHPD, and incorporate such input as feasible into the final design and construction of the floodwalls and pump stations. The result will be no adverse effect.

4. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 2, Kalakaua Avenue Bridge, constructed in 1929, eligible for listing on the National/State Register under criteria A and C. Flood wall improvements will abut the existing bridge structure, and therefore have an adverse effect to integrity of setting, feeling and association. Proposed mitigation for this effect is to design and construct the new floodwalls to blend in as closely as possible to the existing walls that line the Ala Wai Canal resulting in no adverse effect.

5. WITHIN CONSTRUCTION FOOTPRINT: Inventory No. 3, McCully Street Bridge, constructed in 1959, eligible for listing on the National/State Register under criteria A and C. Flood wall improvements will abut the existing bridge structure, and therefore have an adverse effect to integrity of setting, feeling and association. Proposed mitigation for this effect is to design and construct the new floodwalls to blend in as closely as possible to the existing walls that line the Ala Wai Canal.

6. WITHIN CONSTRUCTION FOOTPRINT: The pump station within the golf course will be constructed at the head of Kapahulu (or Ala Wai Golf Course) Drainage. This 56’ wide, reinforced concrete open channel was constructed in 1974, and therefore is not considered to be historic.

Figure 19 Cultural Resources near Ala Wai Canal Floodwalls

Watershed
Measure No. 12: Flood Warning System

a. Description of the measure
Install three real-time rain gages (Manoa, Makiki and Palolo Streams), and one real-time streamflow or stage gage (in Ala Wai Canal) as part of flood warning system for the Ala Wai watershed. Locations of gaging stations to be determined, but will be sited based on flood warning need, peak flow locations, and accessibility to the site.

b. What can it be used for after the measure
No change to use.

c. Historic Properties

1. WITHIN CONSTRUCTION FOOTPRINT: The Manoa, Makiki and Palolo Streams have all been identified for consideration as a Traditional Cultural Properties. They are significant under criterion e per HAR §13-275-6. Installation of the rain gages and streamflow gage could have an adverse effect on setting. As mitigation for impacts, the locations will selected to minimize impacts to TCPs and other extant cultural resources.

2. WITHIN CONSTRUCTION FOOTPRINT: Site 50-80-14-9757, Ala Wai Canal, on State Historic Register since 1992. Streamflow gage will have a visual impact on the canal walls. For mitigation, we will continue to solicit input from interested consulting parties and SHPD, and incorporate such input as feasible into the final design and construction of the streamflow gage. Project planning and siting will be conducted in a manner so as to best integrate the project components with the natural characteristics of the site and minimize visual impacts to the greatest extent possible. Conditional no adverse effect.

Figure 20 Example of out-of-stream components of a stream gauge on Makiki Stream. A rain gauge would be similar to this “house” component.

Watershed

Measure No. 13: Aquatic Habitat Mitigation. Direct and Indirect APEs are being provided for aquatic habitat now that these proposed measures have been further defined.

a. Description of the measure

The following measures are being considered to mitigate impacts to aquatic habitat.

1. Remove existing passage barriers (Figures 22 and 23): A combination of demolition/removal of existing concrete, and reconstruction with a boulder and/or riprap step-pool structure (Figure 21) to create continuous water surface contact for fish passage.

Figure 21 Example of step-pool-structure designed to improve fish passage

1) Falls 6: Proposed action will not be undertaken as part of this project

2) Falls 7 (0.6 mile above Manoa District Park)

a. WITHIN BIOLOGICAL MITIGATION FOOTPRINT: The Manoa Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Installation of a step-pool-structure could have an adverse effect on setting. As mitigation, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed, and improve overall appearance. The result is no adverse effect with this stipulated condition.

3) Falls 8 (0.7 mile above Manoa District Park)

a. WITHIN BIOLOGICAL MITIGATION FOOTPRINT: The Manoa Stream has been identified for consideration as a Traditional Cultural Property. It is significant under criterion e per HAR §13-275-6. Installation of a step-pool-structure could have an adverse effect on setting. As mitigation, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed, and improve overall appearance. The result is no adverse effect with this stipulated condition.

4) Falls 11 (at USGS Gaging Station on Waihi Stream)

a. WITHIN BIOLOGICAL MITIGATION FOOTPRINT: Site 50-80-14-6736 / Inventory No. 54, Waihi Stream Dam, constructed c.1936, eligible for listing on the National/State Register under criterion A. Described as a Parshall Flume and small concrete rubble weir situated in the stream below, and associated with, the Waihi Stream USGS Gaging Station. The Waihi Stream Dam has been identified as a location for Aquatic Habitat Mitigation (Falls 11), and is expected to be reconstructed to add a surface to the feature that allows for better fish passage. Changes to the Waihi Stream Dam will have an adverse effect on the resource. As mitigation, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed, and improve overall appearance. The result is no adverse effect with this stipulated condition.

b. OUTSIDE FOOTPRINT: Inventory No. 53, Waihi Stream Gaging Station, constructed in 1936-1937, eligible for listing on the National/State Register under criteria A and C. Associated with, and located on the stream bank above the Waihi Stream Dam, there will be no changes made to the gaging station, resulting in no direct impacts to the resource, and a no effect determination.

5) Falls 12 (at USGS Gaging Station on Waiakeakua Stream)

a. WITHIN BIOLOGICAL MITIGATION FOOTPRINT: Inventory No. 55, Waiakeakua Stream Gaging Station, constructed in 1936-1937, eligible for listing on the National/State Register under criteria A and C. The gaging station was originally a wooden structure; however, it was replaced by the present metal structure in 1953. The concrete Parshall Flume and a stilling well in the stream below the gaging station are included with the gaging station structure for this historic structure inventory survey number. The Parshall Flume and stilling well within the stream have been identified as a location for Aquatic Habitat Mitigation (Falls 12), and will be reconstructed to add a

surface that allows for better fish passage. Changes to the concrete Parshall Flume and stilling well will have an adverse effect on the historic property. As mitigation, the reconstruction will use natural stream cobble/boulder materials to blend in with the streambed, and improve overall appearance. The result is no adverse effect with this stipulated condition. There will be no changes made to the gaging station metal structure.

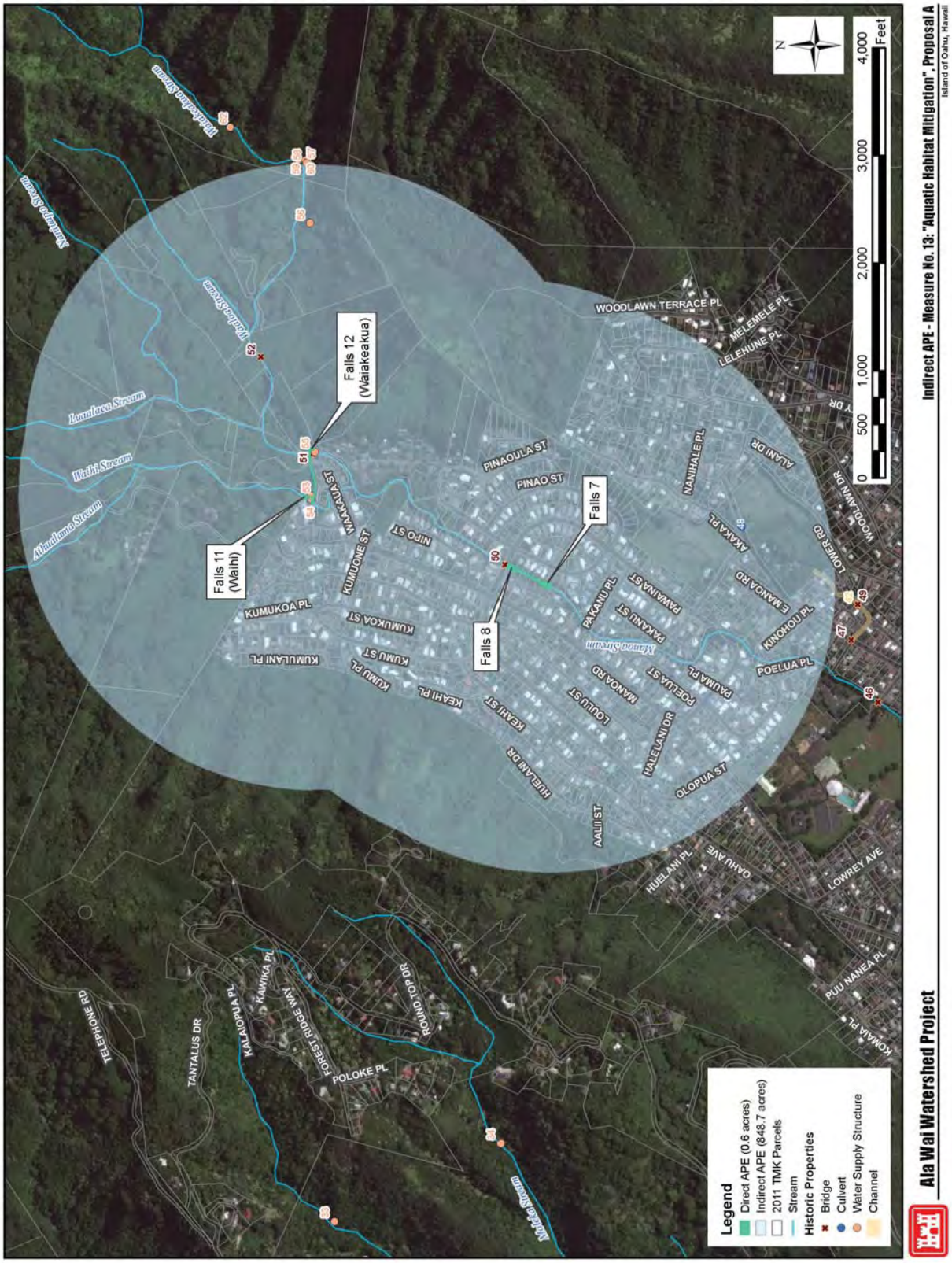


Figure 22 Indirect APE for Aquatic Habitat Mitigation at Falls 7, 8, 11 and 12

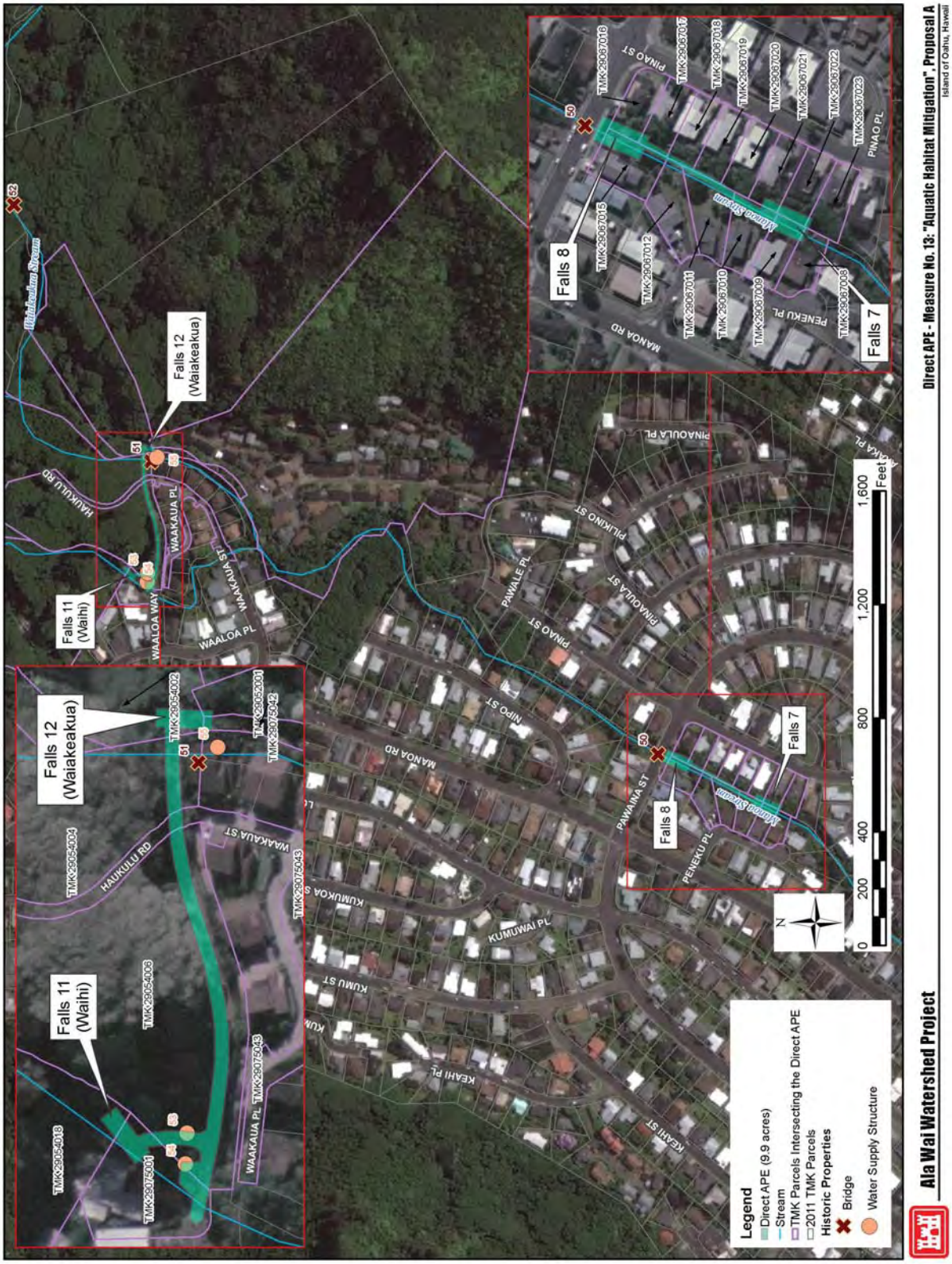


Figure 23 Direct APE for Aquatic Habitat Mitigation at Falls 7, 8, 11 and 12

2. Improve passage corridor and/or in-stream habitat in channelized reach (Figures 24 and 25). The following improvements to Manoa Stream Channel will cover a distance of approximately 1,100 linear feet:

a. Improve native species passage by excavating a roughened low-flow channel through center of existing concrete channel.

b. Improve in-stream habitat by excavating (approx. 8) habitat pools at regular intervals within existing concrete channel.

c. Improve native species passage by installing (approx. 8) resting riffles spaced at regular intervals within existing concrete channel.

1) WITHIN BIOLOGICAL MITIGATION FOOTPRINT: Inventory No. 41, Manoa Stream Channel, constructed in 1952, eligible for listing on the National/State Register under criteria A and C. These proposed improvements will have an adverse effect on the Manoa Stream Channel. As mitigation for impacts, we will continue to solicit design and placement input from interested consulting parties and SHPD, and incorporate such input as feasible into the final design and construction of the habitat improvements to the channelized reach. Appropriate historic documentation of Manoa Stream Channel will be worked out with the SHPD. The result will be no adverse effect with these stipulated conditions.

2) Palolo Stream: Proposed action will not be undertaken as part of this project

3. Bank stabilization.
Proposed action within Manoa Stream (above Kahaloa Bridge near District Park) will not be undertaken as part of this project.

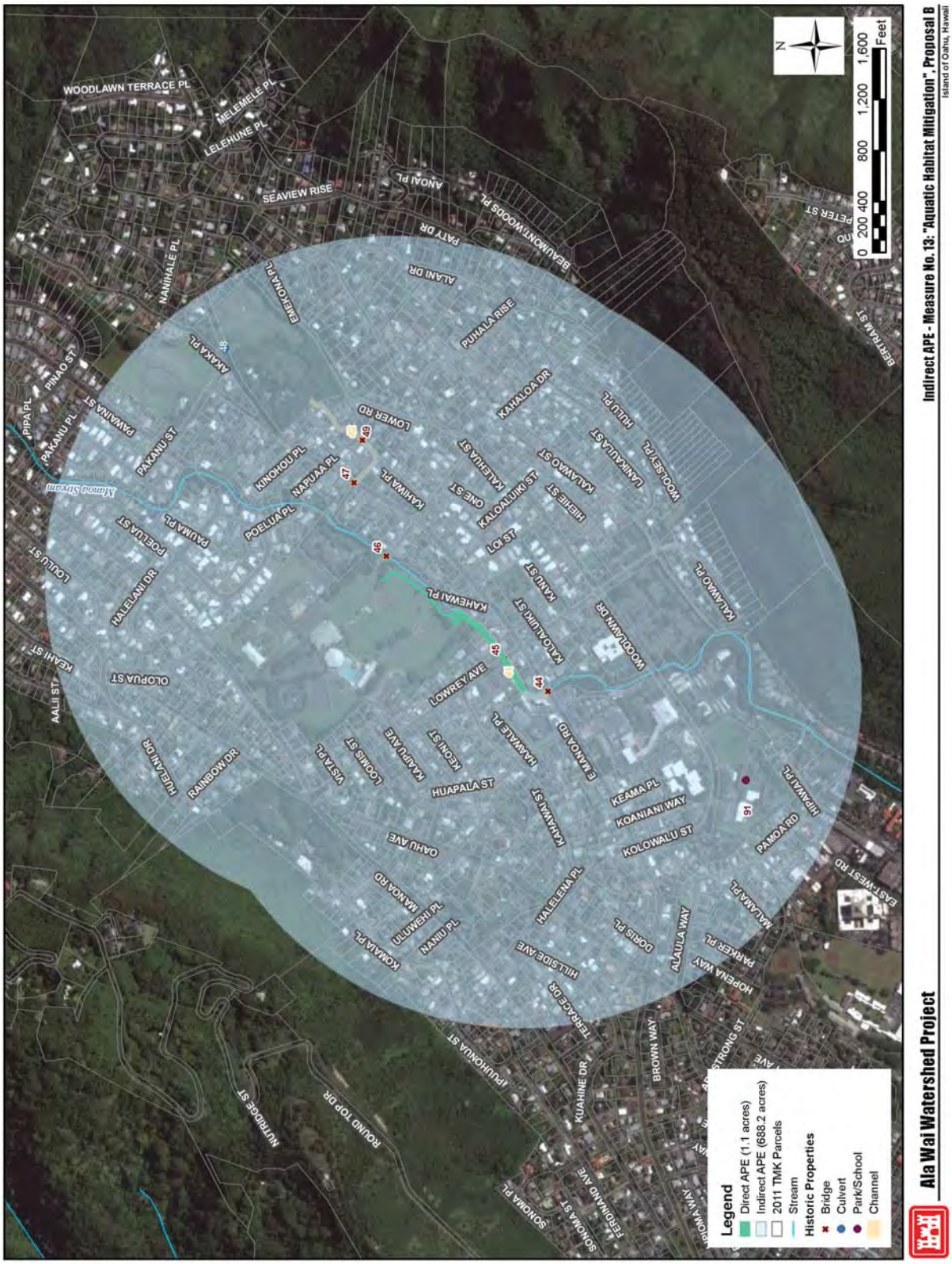


Figure 24 Indirect APE for Aquatic Habitat Mitigation at Manoa Stream Channel

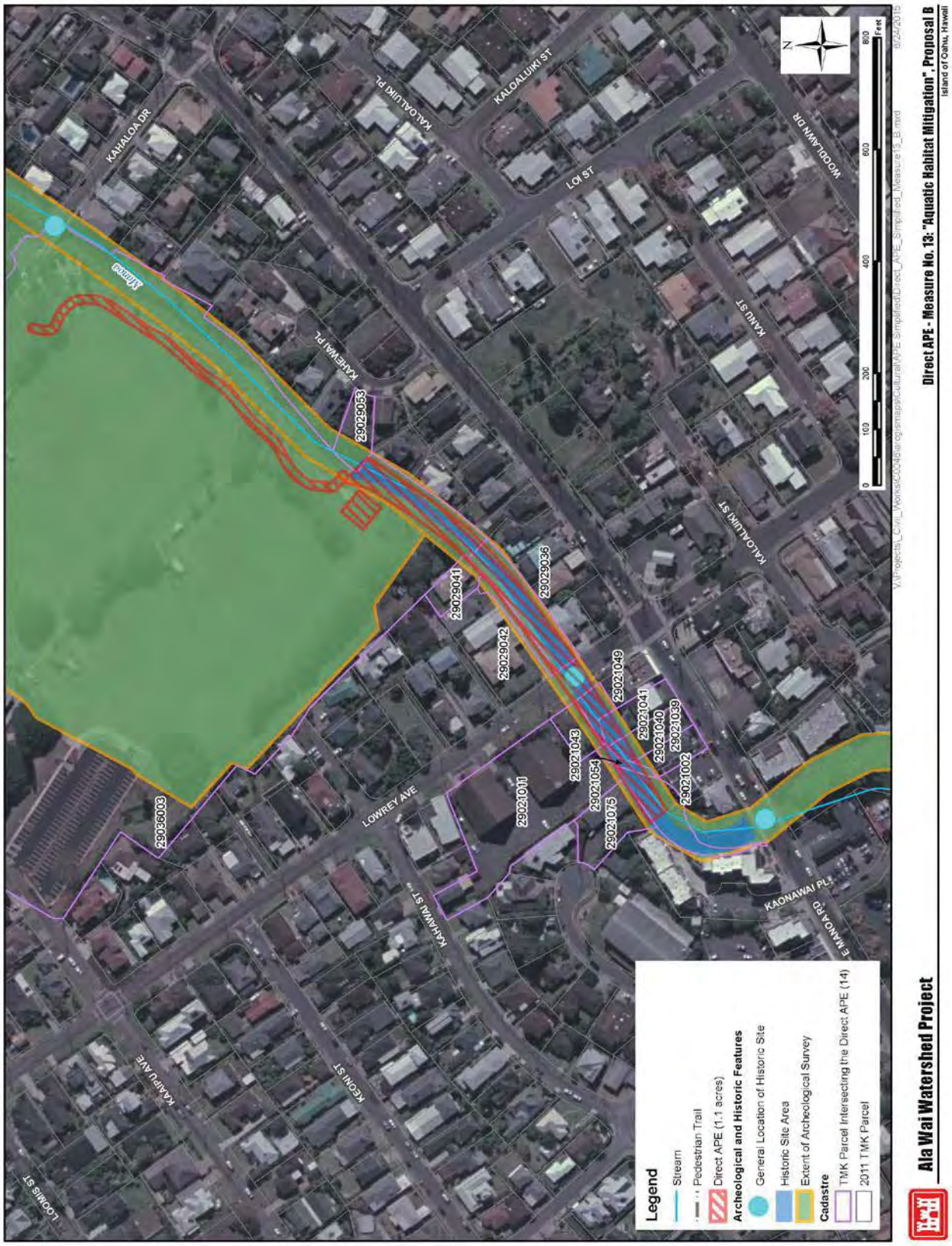


Figure 25 Direct APE for Aquatic Habitat Mitigation at Manoa Stream Channel

Enclosure 3

List of Consulting Parties

List of Consulting Parties

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ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

SECTION 209 OF FLOOD CONTROL ACT OF 1962 (PUBLIC LAW 87-874)

APPENDIX F2

CULTURAL RESOURCES

Cultural Impact Assessment

FINAL

Cultural Impact Assessment for the Ala Wai Canal Project, Waikīkī, Pālolo, Makiki, and Mānoa Ahupuaʻa, Honolulu (Kona) District, Oʻahu TMKs: [1] 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9; [1] 3-1, 3-2, 3-3, and 3-4

Prepared for
CH2M Hill

Prepared by
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Management Summary

Reference	Cultural Impact Assessment for the Ala Wai Canal Project, Waikīkī, Pālolo, Makiki, and Mānoa Ahupua‘a, Honolulu (Kona) District, O‘ahu, TMKs: [1] 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9; [1] 3-1, 3-2, 3-3, and 3-4 (Kamelamela, Ishihara, Magat, and Hammatt 2014)
Date	July 2014
Project Number (s)	CSH (Cultural Surveys Hawai‘i) Job Code: AWRP 18
Agencies	State of Hawai‘i Department of Health/Office of Environmental Quality Control (DOH/OEQC)
Project Location	The project area covers large sections of Makiki, Mānoa, and Pālolo Ahupua‘a on the island of O‘ahu. The project area includes the Kaka‘ako and Waikīkī areas and drainages of the Makiki, Mānoa, and Pālolo Streams.
Project Description	The overall purpose of the project is to reduce stream flood hazards to property and life safety within the Ala Wai watershed. In response to flood-related problems and opportunities within the watershed, potential flood-risk management measures were identified and formulated into an array of alternative plans; the measures that comprise the final array of alternative plans are listed in Table 1 and shown in Figure 1 and Figure 2. As part of the feasibility planning process, the alternative plans will be evaluated and compared, leading to identification of a plan for implementation; the results of this process will be presented in an Integrated Feasability Report and Environmental Impact Statement (EIS). The purpose of this CIA is to assess cultural resources and practices within the project area, so as to support the feasibility planning and environmental impact review process.
Project Acreage	19 sq miles
Area of Potential Effect (APE) and Survey Acreage	The APE is defined as the approximately 19 sq miles in total, which includes the entire *ahupua‘a* (land divisions) of Waikīkī, Pālolo, Makiki, and Mānoa.
Document Purpose	This CIA was prepared to comply with the State of Hawai‘i’s environmental review process under Hawai‘i Revised Statutes (HRS) §343, which requires consideration of the proposed project’s potential effect on cultural beliefs, practices, and resources. Through document research and cultural consultation efforts, this report provides information compiled to date pertinent to the assessment of the proposed project’s potential impacts to cultural beliefs, practices, and resources (pursuant to the Office of Environmental Quality Control’s *Guidelines for Assessing Cultural Impacts*) which may include Traditional Cultural Properties (TCPs). These TCPs may be significant historic properties under State of Hawai‘i significance criterion “e,” pursuant to Hawai‘i

	Administrative rules (HAR) §13-275-6 and §13-284-6. Significance criterion “e” refers to historic properties that “have an important value to the native Hawaiian people or to another ethnic group of the state due to associations with cultural practices once carried out, or still carried out, at the property or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group’s history and cultural identity” (HAR §13-275-6 and §13-284-6). The document will likely also support the project’s historic preservation review under HRS §6E and HAR §13-275 and §13-284. This CIA investigation may also be used to support the National Historic Preservation Act Section 106 and the NEPA consultation, but does not, in itself, satisfy the cultural consultation requirements of either Section 106 or NEPA.
Community Consultation	Several attempts were made to contact individuals, organizations, and agencies relevant to the Ala Wai Canal project. Specific results of community consultations are presented in Table 2 in Section 3
Results of Community Consultation	CSH contacted 93 individuals for this cultural impact assessment; of those, 17 responded; five suggested referrals, four provided consultation summaries, and five participated in formal interviews. Community consultation indicates: According to several participants, the source of the problem from the 2004 flood of Mānoa stems from the Woodlawn Bridge area. Mr. George Arizumi, Ms. Evelyn Giddings, and Mr. Makahiapo Cashman have all asserted that the Woodlawn Bridge area is low and debris tends to gather in this area. Mr. Arizumi and Ms. Giddings have stated that the area between Woodlawn Bridge and Noelani Elementary School is the lowest lying area. Water tends to collect around the University of Hawai‘i at Mānoa’s College of Tropical Agriculture and Human Services and flows back into the stream in the back. Participants shared that the geology of Mānoa Valley contributes to the flooding problems. Mr. Arizumi, a third generation resident of Mānoa, spoke of differing geologic ages of substrates in the valley. The older substrate of the valley is located on the Makiki side and slopes down allowing for movement towards the ocean. The younger substrate is located on the Pālolo side of the valley which is wide and flat with a reduced slope. Thus the Woodlawn Bridge area is closer to the younger substrate, which creates a slow and shallow flow of water making it easy for this area to get backed up. Director of Ka Papa Lo‘i ‘o Kānewai, Mr. Cashman shared a *mo‘olelo* (story) which connects to the cultural landscape of the valley. Kākea, a *mo‘o* (lizard), has the ability to change into different *kino lau* (many forms taken by a supernatural body) including a destructive wind that

	rushes through Mānoa Valley. He can also turn into a *pu‘u* (peak). The *pu‘u* is critical because an eruption in Mānoa has caused the water system to shift towards the Wa‘ahila side of the valley. Ms. Giddings has also seen the stream shift back and forth on the valley floor. A popular childhood pastime amongst participants was swimming in the various streams and ponds. Mr. Arizumi shared that downstream of Woodlawn Bridge were two deep pools of water known as “Boy’s Pond” and “Girl’s Pond” where each would go to their own ponds to swim. A storm in the 1950s filled Girl’s Pond with silt and gravel. Eventually everyone swam at Boy’s Pond. Ms. Dwynn Kamai, *kama‘āina* (native born) of Pālolo, shared her memories of Pālolo where she recalled playing in the stream. Waterways not only provided recreation but sustenance. Mr. Arizumi recalled the streams containing *‘o‘opu* (general name for fishes included Eleotridae, Gobiidae, and Blennidae), crayfish, *‘ōpae* (general name for shrimp), and *pipipi* (general name for small mollusks). Everything was cooked over an open flame with the exception of the *pipipi*. The meat from the *pipipi* was picked out with a safety pin prior to its being cooked. The stream banks were lined with California plum which is still there today. Other fruits gathered included mountain apple, mango, and lychee for snacking. Ms. Kamai recalled catching guppies and seeing *‘ōpae* in Pālolo Stream. Mr. Cashman stated that Kānewai Lo‘i currently cultivates 63 of the 69 known varieties of *kalo* (taro; *Colocasia esculenta*). The Mō‘ili‘ili karst system is an underground waterway that extends from Kaimuki, Mō‘ili‘ili, and Waikīkī. Mr. Lao, a former Board of Water Supply employee, has been inside the karst system and has seen blind spiders and catfish in the caverns. On another occasion while visiting the karst, he saw *‘ōpae* in the water. However, he did note that the water in the karst is murky and the caves contain a high level of carbon monoxide. Mr. Lao discouraged anyone from accessing the caves. Ms. Kamai recalled a large *laua‘e* (a fragrant fern; *Phymatosorus scolopendria syn. Microsorium scolopendria*) patch deep in Pālolo Valley. This particular variety of *laua‘e* was the mountain variety having no seed pods and the leaves being very large. Her *‘ohana* (family) gathered the *laua‘e* for *lū‘au* (Hawaiian feast) and for its scent, as it was reminiscent of *maile*. Agriculture and aquaculture are not only used for food consumption, but can also be used for ceremonial purposes. Ms. Paulette Ka‘anohi Kaleikini, State of Hawai‘i recognized lineal descendant, shared that her *kūpuna* (ancestors) practiced *la‘au kāhea* (a type of faith healing of broken or crushed bones or sprains) and *la‘au lapa‘au* (Hawaiian healing

	medicine). Ms. Kaleikini's mother gathered *la‘au* (tree, plant) in Mānoa at a Royal Patented property and also in Makiki. Ms. Kaleikini's mother rarely gathered from Pālolo, but on occasion her cousins would. *Pa‘akai* (salt) and *limu* (seaweed) were used for food preparation and *la‘au*. *Pa‘akai* for food preparation was acquired locally, while salt for ceremonies were imported from Moloka‘i. *Limu* was gathered at Kālia until Ms. Kaleikini's mother determined that the water was too dirty. Her mother continued to gather *limu* at Gray's Beach until that *limu* bed was destroyed. Mr. ‘Īmaikalani Winchester, teacher at Hālau Kū Māna public charter school and caretaker for ‘Aihualama Lo‘i, stated that water from the stream is used for ceremonial purposes during Makahiki. Rocks are gathered from stream beds for cultural practices as well. Mr. Arizumi looks for *imu* (underground oven) rocks under the Woodlawn Bridge, specifically looking for those that have holes. Mr. Cashman gathers rocks at Kānewai Lo‘i where he divides them into different piles: rock wall building, *imu* use, and *pōhaku ku‘i ‘ai* (poi pounder). Mr. Winchester gathers rocks as well further *mauka* (towards the mountain) at ‘Aihualama Lo‘i where he uses them for rock wall building. Ms. Kaleikini shared that her family settled into the *‘ili* (land section) of Kālia located in Waikīkī Ahupua‘a. She stated that remnants of historical sites may be imbedded in the sediments, thus including the possibility of encountering burials at these sites. Because this particular project is in the urban corridor and it was once an area Native Hawaiians were known to inhabit, she stressed the project proceed with caution. She added that streams and waterways were also areas inhabited by Native Hawaiians. Participants shared *mo‘olelo* describing the *wahi pana* (storied place) of the *ahupua‘a*. *Mo‘olelo* shared also reflected the weather patterns of the area. Ms. Kaleikini shared the *mo‘olelo* of Kauatunahineomanoa, which taught her to call out to Tuahine while walking or hiking in the valley. Tuahine is a soft, gentle rain whereas Wa‘ahila is a heavier, masculine rain. As mentioned earlier, Mr. Cashman shared the story of Kākea. It is the story of a set of twins named Wa‘ahila and Kilihune who come from Mount Ka‘ala on the Wai‘anae Mountain Range. The twins run away from their mother in Wai‘anae to Mānoa. Their mother finds them and takes them to Wai‘anae where they are beaten. Wa‘ahila and Kilihune escape from their mother again and find refuge in the lower portion of Mānoa where they befriend Kākea. The boy tells Kākea he wants to make a spring for his sister so she can shower and make food. The two go to Kānewai Spring and dig an underground cave. In the *‘ili* of Haukulu (literally "dripping dew"), Mr. Winchester recalled the *mo‘olelo* of Kahalaopuna that takes places there. There are many different versions of Kahalaopuna, but in one account, Mr. Winchester recalled a saying that every time a chief died a *hau* (beach hibiscus; *Hibiscus tiliaceus*)

	tree could be seen crying. When he goes to Haukulu ‘Ili, the rain collects on the *hau* and if you sit underneath it gives the impression that it’s crying on you. Ms. Kamai and participant Mr. Gregg Kashiwa also shared that the first nine-hole municipal golf course opened in Pālolo Valley in 1931. The course incorporated the natural features of the valley including two streams, rolling fairways, hills, gullies, ditches, and bunkers. The clubhouse was located at Palolo Avenue and Kalua Road. The course was popular until World War II when it closed. The golf course was cleared for the construction of approximately 100 homes for emergency evacuation for those in low lying areas. An airstrip was also near the golf course. Participants shared their memories of the Ala Wai Canal: Mr. Lao shared that the idea of the Ala Wai Canal was originally conceived in 1927 and was dubbed by the developers as the “Venice of the Pacific.” The original plan was to have an entrance and exit from the canal, buildings were to line the canal, and boats and gondolas were to navigate the Ala Wai waters. However, an exit from the canal was never constructed. The proposed exit was to extend to the current location of the Waikīkī-Kapahulu Public Library and turn *makai* (towards the ocean) connecting to the sea at the Kapahulu Groin so the canal could have better circulation. Due to the current construction of the canal without an exit, the water is very stagnant, especially near the Kapahulu area where it is filled with debris and other noxious items. Ms. Evelyn Giddings, long-time resident of Mānoa, recalled walking over the McCully Bridge as a child where she observed fishing platforms lining the banks of the Ala Wai Canal on the Waikīkī side where people caught mullet. She added that the McCully Bridge had tracks for trolley cars. The tracks were supported by posts which acted like a debris catchment system. Rats, chicken coops, and dead pigs would get trapped under here as they washed down from the *mauka* areas. According to historical maps, the Waikīkī Shell was once part of an area that was formerly a duck pond. Chair of the Diamond Head Scenic Byway Committee, Ms. Michelle Spalding Matson pointed out that a remnant of the wetland is still present behind the Waikīkī Shell. A restoration project called the Kaneloa Wetland Project was funded by the EPA and began in 2000 with the purpose of restoring the wetland remnant. However, the Army volunteers who were helping restore the area were called into active duty following 11 September 2001 and EPA funding ran out near completion of the project. Native plants still continue to thrive in the wetland area including bacopa, Native Hawaiian sedge, and *‘ākulikuli* (general name for succulent plants). During the

	winter months, the water levels rise in the wetland remnant. Brackish water enters via a channel or karst and tilapia can be seen. Ms. Matson is unsure where the tilapia enter, but has suggested the Ala Wai Canal or Kapahulu Groin. *Note: Native plants used for medicinal and religious purposes are often found along stream banks. However, participants did not specifically mention the locations of plants within the study area in response to CSH interview questions.
Community Recommendations:	Based on information gathered from the community consultation, participants voiced the following concerns: Mr. Arizumi supports improvements to Mānoa Stream that would help reduce the threat of flooding but with sound practices. He does not want the channelization of Mānoa Stream to be extended, if possible. Ms. Kaleikini is concerned about any pre-Contact or historic properties that may be found under sediments. Her *‘ohana* are recognized by the State of Hawai‘i as lineal descendants to burials in the *‘ili* of Kālia which is located in the *ahupua‘a* of Waikīkī. She stated that there is a possibility burials might be encountered in the Kālia area. Also, because this project is within the urban corridor and also in an area that was once densely inhabited by Native Hawaiians, there is a chance that burials might be encountered. She added that caution must be used in stream areas as well since these were also areas inhabited by Native Hawaiians. Ms. Kamai believes periodic cleaning and maintenance of Pālolo Stream would be sufficient to keep the waterway flowing. She added that Ala Wai needs to be cleaned. Ms. Giddings raised concern over the state of the drainage system, stressing the necessity of cleaning the drains regularly even if it’s not a rainy season. She added that the current storm drains are inadequate, stating that they are out of date, have not been cleaned, and do not have the capacity to handle the volume of water that can flow at once. Ms. Giddings recommended that if project proponents want to learn about water behavior, they should contact Jennifer Greene who established The Water Institute. Ms. Giddings added that Ms. Greene has remediated many streams and is known to work with stagnant streams. Mr. Cashman opposes the installation of debris catchments throughout the stream. He added that the debris catchment system will slow the flow of water in the stream, decreasing flow rates. He believes periodic cleaning of the stream is the best way to prevent flooding. Mr. Winchester is concerned about heavy machinery. He noticed there was obvious removal of stream banks and rocks were being removed where Pālolo Stream and Mānoa Stream converge. He advocated that all

	resources found within the stream should be distributed to community members within the *ahupua‘a* they were found in. If there is no way to redistribute these resources, organizations interested in these resources should be recognized and contacted during excavation. Native Hawaiian families and groups within the area should be notified in order to relieve the City and County or any other agency of these natural resources. Ms. Matson raised concerns about the proposed walls and gates that would surround the historic Ala Wai Canal which was placed on the State Historic Register in 1992. Her main concern is that if structural modifications are made to or around the canal, it could create a detrimental precedent for all historic sites and laws protecting them. Mr. Kashiwa expresses that he is opposed to changing any part of the Ala Wai Golf Course for flood control.
Impacts and Recommendations	Based on information gathered from the cultural and historic background and community consultation detailed in this CIA report, the proposed project may potentially impact Native Hawaiian burials and subsurface cultural layers. CSH summarizes below the potential impacts and recommendations gleaned from the community consultations: There is high possibility that *iwi kūpuna*, ancestral bones, may be present within the project area and that land-disturbing activities during construction may uncover presently undetected burials or other cultural materials. In addition, a community participant has indicated that undetected burials might be found on her family *kuleana* (property) and within areas that were densely inhabited by Native Hawaiians. Personnel involved in the project construction activities should be informed of the possibility of inadvertent cultural finds, including human remains. Should burials or other cultural finds be identified during ground disturbance, the construction contractor should immediately cease all work and the appropriate agencies be notified pursuant to applicable law, HRS §6E. Project proponents should consult with lineal and cultural descendants of Makiki, Mānoa, Pālolo, Kaka‘ako, and Waikīkī to develop a reinterment plan and cultural preservation plan in the event that any human remains or cultural sites or artifacts are uncovered during construction or long-term maintenance for the project. Project proponents should consult with the State Historic Preservation Division in regards to altering a registered State Historic Property, the Ala Wai Canal, State Inventory of Historic Properties (SIHP) # 50-80-14-9757. Construction of floodwalls along the *makai* side of the Ala Wai will impact the view planes from Waikīkī to the study areas. Significant berms will also have a similar impact on the visual landscape and the

	integrity of the cultural landscape of Mānoa, Pālolo, Makiki, and the Ala Wai Canal. Participants did not specifically mention potential impacts to *lo‘i*. However, participants made comments and recommendations on streams and the immediate surrounding areas that would potentially affect *lo‘i* health. Comments and recommendations made by community consultants include avoiding channelization of the stream to minimize environmental impacts such as heavy water flows that would affect stream life, surrounding vegetation causing erosion to streambanks, and limited access to adjacent organizations and individuals that utilize the stream for cultural practices. Community consultants recommend that the City and County of Honolulu consider the following mitigation measures to minimize potential adverse impacts instead of the proposed measures: i. Development of a scheduled vegetation clearing plan (e.g. cut down large and/or invasive trees such as albizia) both upstream and downstream of the various tributaries within the Ala Wai Watershed system to allow for maximum water and to prevent future blockages that may result in area flooding. ii. Development of a scheduled maintenance plan upstream and downstream of the various tributaries and trouble spots within the Ala Wai Watershed stream system to prevent future blockages that may result in area flooding (e.g. debris such as tree branches, leaves, trash, etc.). The proposed measures at Waiakeakua Stream, Waihī Stream, and Kānewai Stream are located *makai* of ‘Aihualama Lo‘i and Kānewai Lo‘i, which should not directly impact the integrity of the *lo‘i*. However, any inundation behind basins during and after heavy storms could directly impact those *lo‘i*. There is also possibility of loss of access to cultural sites and areas of cultural practices during construction as well as potention long term impacts to cultural sites.

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Section 1 Introduction

1.1 Project Background

At the request of CH2M Hill, Cultural Surveys Hawai‘i Inc. (CSH) conducted a cultural impact assessment (CIA) for the proposed Ala Wai Canal Project, a flood damage reduction project sponsored by the U.S. Army Corps of Engineers (USACE) and the State of Hawai‘i, Department of Land and Natural Resources (DLNR). The project area includes the Waikīkī, Pālolo, Makiki, and Mānoa Ahupua‘a, Honolulu (Kona) District, O‘ahu TMKs: [1] 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9; [1] 3-1, 3-2, 3-3, and 3-4.

The overall purpose of the project is to reduce stream flood hazards to property and life safety within the Ala Wai watershed. In response to flood-related problems and opportunities within the watershed, potential flood-risk management measures were identified and formulated into an array of alternative plans; the measures that comprise the final array of alternative plans are listed in Table 1 and shown in Figure 1 and Figure 2. As part of the feasibility planning process, the alternative plans will be evaluated and compared, leading to identification of a plan for implementation; the results of this process will be presented in an Integrated Feasibility Report and Environmental Impact Statement (EIS). The purpose of this CIA is to assess cultural resources and practices within the project area, so as to support the feasibility planning and environmental impact review process.

Table 1. Alternatives for the Ala Wai Canal Project

Ahupua‘a	Measure	Location	Description of Measure
Mānoa	Detention and debris basin	Waiakeakua Stream	Earthen berm; 20 ft high and 185 ft across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm
	Detention and debris basin	Waihī Stream	Earthen berm; 24 ft high and 225 ft across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm
	Debris catchment	Waiakeakua Stream	Concrete pad; 8 ft wide and 140 ft across; steel posts (up to approximately 7 ft high) evenly spaced 4 ft apart along concrete pad
	Debris catchment	Waihī Stream	Concrete pad; 8 ft wide and 140 ft across; steel posts (up to approximately 7 ft high) evenly spaced 4 ft apart along concrete pad
	Detention basin	Woodlawn Ditch	Three-sided berm, approximately 15 ft high and 840 ft across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on

Ahupua‘a	Measure	Location	Description of Measure
			upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm and potential flood area
	In-stream debris catchment	Po‘elua Place	Install basin with small berm and debris catcher to capture debris on east side of stream; install grate with inlet to culvert for delivery of water to Mānoa District Park detention basin; requires acquisition of residential lot
	In-stream debris catchment	Adjacent to Mānoa District Park	Concrete pad, approximately 8 ft wide and 60 ft across; steel posts (up to approximately 7 ft high) evenly spaced 4 ft apart along concrete pad
	Multi-purpose detention basin	Mānoa District Park	Earthen berm (approximately 13 ft high) around 3 sides of Mānoa Park; intake pipe from Po‘elua Place to bubble-up structure in detention area; concrete spillway with riprap on detention and stream sides; 2 ft drain pipe to release water back to stream
	In-stream debris catchment	Innovation Center	Acquisition of residential property; lower grade to allow high flows across site; debris catchment structures installed along edge to catch debris as flows re-enters stream
	Multi-purpose detention basin	Kānewai Park	Earthen berm (approximately 7 ft high) around 3 sides of field; spillway on the northwest end that allows high flows to enter the basin; existing drainage pipe at south end to allow water to re-enter stream; 20 ft-wide perimeter to be maintained as cleared around the perimeter of the berm and the potential flooded area
Pālolo	Detention and debris basin	Wai‘ōma‘o Stream	Earthen berm (approximately 24 ft high and 120 ft across); arch culvert to allow small storm flows to pass; concrete spillway above culvert, with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm; excavate approximately 1,500,00 cubic feet to provide required detention volume
	Debris catchment	Wai’ōma’o Stream	Concrete pad, approximately 8 ft wide and 50 ft across; steel posts (up to approximately 7 ft high) evenly spaced 4 ft apart along concrete pad
	Detention and debris basin	Pūkele Stream	Earthen berm, approximately 24 ft high and 120 ft across; arch culvert to allow small storm flows to

Ahupua‘a	Measure	Location	Description of Measure
			pass; concrete spillway above culvert with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm
	Debris catchment	Pūkele Stream	Concrete pad, approximately 8 ft wide and 25 ft across; steel posts (up to approximately 7 ft high) evenly spaced 4 ft apart along concrete pad
	Floodwalls	Mānoa-Pālolo Drainage Canal	Add floodwalls (9-12 ft high) along the right bank of the canal from the Ala Wai Canal up to Date Street
Makiki	Debris and detention basin	Kanaha Stream, above Roosevelt High School	Earthen berm, approximately 24 ft high and 260 ft across; arch culvert to allow small storm flows to pass; concrete spillway with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm
	Debris and detention basin	Upstream of Makiki Pumping Station	Earthen berm, approximately 24 ft high and 100 ft across; arch culvert to allow small storm flows to pass; concrete spillway to above culvert with riprap on upstream and downstream side; 20 ft-wide perimeter to be maintained as cleared around perimeter of berm
Ala Wai	Floodwalls	Ala Wai Canal	Add floodwalls along Ala Wai Canal; concrete walls and/or earthern berms, ranging up to 5 ft high
	Multi-purpose detention basin	Ala Wai Golf Course	Earthen berm (up to approximately 7 ft high) around outside perimeter of golf course property; passive drainage back into Ala Wai Canal
	Detention basin	Hausten Ditch	Add floodwalls and earthen berm (4.3 ft high) to provide detention for local drainage; install sluice gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal

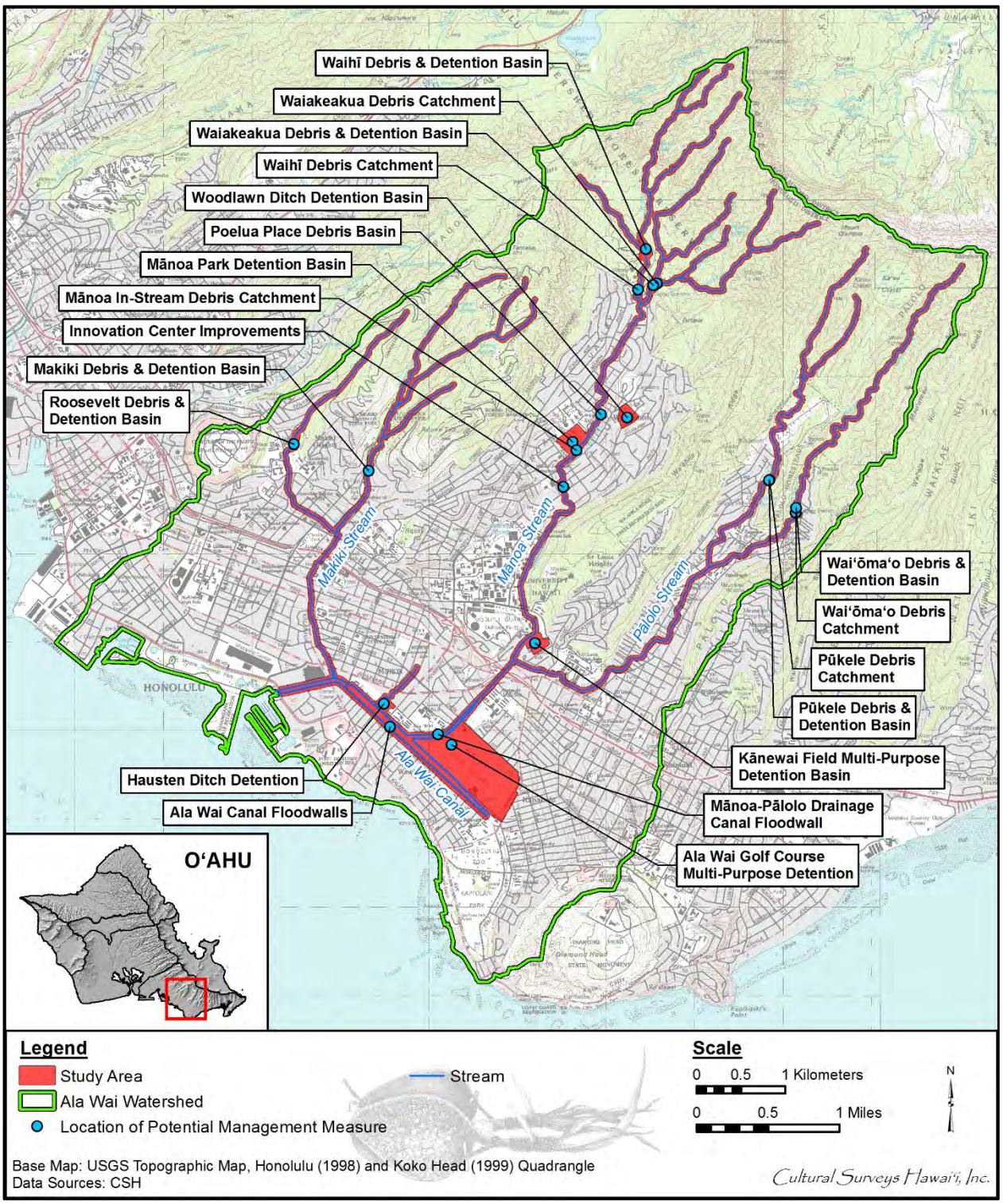

Figure 1. 1998 Honolulu and 1999 Koko Head USGS Topographic Quadrangles depicting project areas and proposed management measures

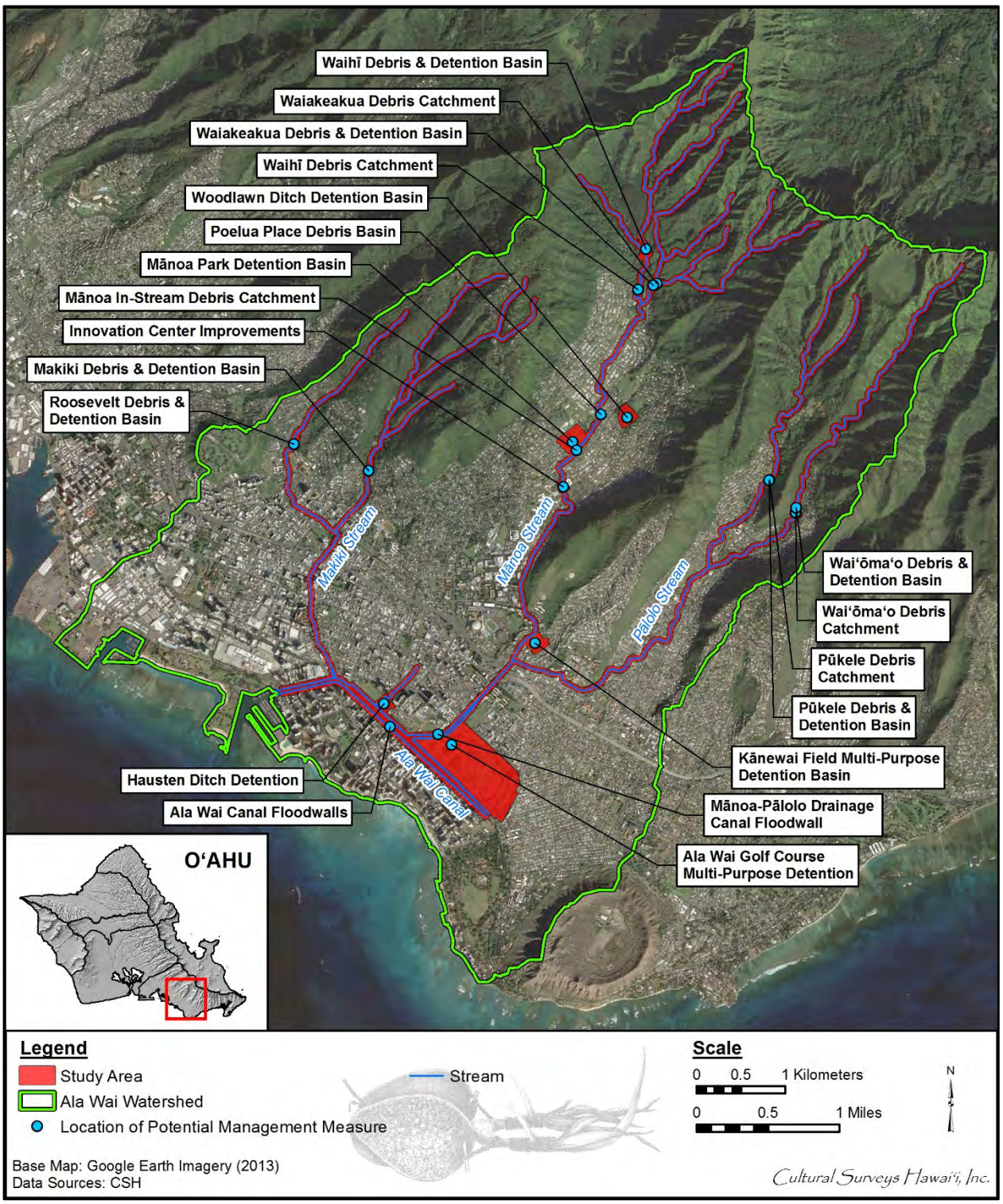

Figure 2. Google Earth Imagery (2013) depicting project areas and proposed management measures

1.2 Previous Cultural Resource Assessment Efforts

This study is intended to build on previous project-related efforts, which included archaeological and archival research and community consultation during earlier stages of project development, as described below.

An assessment was initially completed in 2004 (O’Hare et al. 2004) that incorporated the traditional and historical background history of Makiki, Mānoa, Pālolo, and Waikīkī Ahupua‘a; archaeological work conducted previous to 2004; as well as the findings of field surveys carried out by CSH archaeologists in 2004 for the Makiki, Mānoa, and Pālolo Ahupua‘a. The field surveys included a 10-m section on either side of the streams in the Makiki Watershed (Makiki Stream and the upper tributaries), Mānoa Stream up to the junction with its tributaries, and Pālolo Stream and the lower portions of its tributaries (Pūkele and Wai‘ōma‘o Streams). A total of 38 sites were recorded during these surveys and were described in the 2004 report.

An updated report was subsequently completed in 2010 (O’Hare et al. 2010). The 2010 report contained additional *mo‘olelo* (traditional stories), background historical information, historic maps, historic photographs, as well as a discussion of archaeological work conducted from 2004 to 2009 for Makiki, Mānoa, Pālolo, and Waikīkī Ahupua‘a. A new section focusing on the Kaka‘ako area was added to the 2010 report, including traditional background, historical background, and previous archaeology work.

As part of the additional work conducted in 2010, an ethnographic study was conducted based on oral histories and consultation with community members knowledgeable about the past and present cultural practices within the project area, in order to compile a detailed historical and cultural narrative that incorporates this unique knowledge of tradition. In addition to perpetuating cultural knowledge associated with the project area, the purpose of the study was to identify culturally significant sites and provide an understanding of historical conditions, cultural practices, and sites pertaining to the watershed as a whole, as needed to guide the feasibility planning process.

This assessment builds on the previous ethnographic study, with additional community consultation and interviews informed by results of the alternative plan formulation process.

1.3 Scope of Work

The project requires compliance with the State of Hawai‘i environmental review process legislation (Hawai‘i Revised Statutes [HRS] §343), which requires consideration of a proposed project’s effect on cultural practices. Through ongoing cultural consultation efforts, this report provides information pertinent to the assessment of the proposed project’s impacts to cultural practices and resources. The impacts may be associated with Traditional Cultural Properties (TCPs) of ongoing cultural significance, which may be significant historic properties under State of Hawai‘i significance criterion “e,” pursuant to Hawai‘i Administrative rules (HAR) §13-275-6 and §13-284-6. Significance criterion “e” refers to historic peroperties that “have an important value to the native Hawaiian people or to another ethnic group of the state due to associations with cultural practices once carried out, or still carried out, at the peroperty or due to associations with traditional beliefs, events or oral accounts—these associations being important to the group’s history and cultural identity” (HAR §13-275-6 and §13-284-6). The document will likely also support the project’s historic preservation review under HRS §6E and HAR §13-275 and §13-284.

This document has been prepared in accordance with the Office of Environmental Quality Control's *Guidelines for Assessing Cultural Impacts*. It is intended to support the project's environmental review and may also serve to support the project's historic preservation review process under Section 106 of the National Historic Preservation Act (NHPA) and HRS §6E.

Section 2 Methods

2.1 Archival Research

Historical documents, maps, and existing archaeological information pertaining to the project area were researched at the CSH library and other archives including the University of Hawai‘i at Mānoa’s Hamilton Library, the State Historic Preservation Division (SHPD) library, the Hawai‘i State Archives, the State Land Survey Division, and the Bishop Museum Archives. Previous archaeological reports for the area were reviewed, as were historic maps and photographs and primary and secondary historical sources. Information on Land Commission Awards (LCAs) was accessed through Waihona ‘Aina Corporation’s Māhele database (Waihona ‘Aina 2000) and the Office of Hawaiian Affairs (OHA) Papakilo database (Office of Hawaiian Affairs 2014) as well as a selection of CSH library references.

For cultural studies, research for the Traditional Background section centered on Hawaiian activities including religious and ceremonial knowledge and practices, traditional subsistence land use and settlement patterns, gathering practices and agricultural pursuits, as well as Hawaiian place names and *mo‘olelo*, *mele* (songs), *oli* (chant), *‘ōlelo no‘eau* (proverb) and more. For the Historic Background section, research focused on land transformation, development, and population changes beginning in the early post–Western Contact era to the present day (see Scope of Work above).

2.2 Community Consultation

2.2.1 Sampling and Recruitment

A combination of qualitative methods, including purposive, snowball, and expert (or judgment) sampling were used to identify and invite potential participants to the study. These methods are used for intensive case studies, such as CIAs, to recruit people who are hard to identify, or are members of elite groups (Bernard 2006:190). Our purpose is not to establish a representative or random sample. It is to “identify specific groups of people who either possess characteristics or live in circumstances relevant to the social phenomenon being studied . . . This approach to sampling allows the researcher deliberately to include a wide range of types of informants and also to select key informants with access to important sources of knowledge” (Mays and Pope 1995:110).

We began with purposive sampling informed by referrals from known specialists and relevant agencies. For example, we contacted the SHPD, OHA, O‘ahu Island Burial Council (OIBC), and community and cultural organizations in the Honolulu (Kona) District for their brief response/review of the project and to identify potentially knowledgeable individuals with cultural expertise and/or knowledge of the study area and vicinity, cultural and lineal descendants of the study area, and other appropriate community representatives and members. Based on their in-depth knowledge and experiences, these key respondents then referred CSH to additional potential participants who were added to the pool of invited participants. This is snowball sampling, a chain referral method that entails asking a few key individuals (including agency and organization representatives) to provide their comments and referrals to other locally recognized experts or stakeholders who would be likely candidates for the study (Bernard 2006:192). CSH also employs

expert or judgment sampling which involves assembling a group of people with recognized experience and expertise in a specific area (Bernard 2006:189–191). CSH maintains a database that draws on over two decades of established relationships with community consultants. These are cultural practitioners and specialists, community representatives and cultural and lineal descendants. The names of new potential contacts were also provided by colleagues at CSH and from the researchers' familiarity with people who live in or around the study area. Researchers often attend public forums (e.g., Neighborhood Board, Burial Council, and Civic Club meetings) in (or near) the study area to locate potential participants. Please refer to Table 2 in Section 3 for a complete list of individuals and organizations contacted for this CIA.

CSH focuses on obtaining in-depth information with a high level of validity from a targeted group of relevant stakeholders and local experts. Our qualitative methods do not aim to survey an entire population or subgroup. A depth of understanding about complex issues cannot be gained through comprehensive surveying. Our qualitative methodologies do not include quantitative (statistical) analyses, yet they are recognized as rigorous and thorough. Bernard (2006:25) describes the qualitative methods as "a kind of measurement, an integral part of the complex whole that comprises scientific research." Depending on the size and complexity of the project, CSH reports include in-depth contributions from about one third of all participating respondents. Typically this means three to 12 interviews.

2.2.2 Informed Consent Protocol

An informed consent process was conducted as follows: 1) before beginning the interview the CSH researcher explained to the participant how the consent process works, the project purpose, the intent of the study, and how his/her information will be used; 2) the researcher gave him/her a copy of the Authorization and Release Form to read and sign (Appendix A); 3) if the person agreed to participate by way of signing the consent form or providing oral consent, the researcher started the interview; 4) the interviewee received a copy of the Authorization and Release Form for his/her records, while the original was stored at CSH; 5) after the interview was summarized at CSH (and possibly transcribed in full), the study participant was afforded an opportunity to review the interview notes (or transcription) and summary and to make any corrections, deletions or additions to the substance of their testimony/oral history interview (accomplished either via phone, post or email or through a follow-up visit with the participant); 6) the participant received the final approved interview and any photographs taken for the study for their records. If the participant was interested in receiving a copy of the full transcript of the interview (if there is one, as not all interviews are audio-recorded and transcribed), a copy was provided. Participants were also given information on how to view the report on the OEQC website and were offered a hardcopy of the report once the report is a public document.

If an interviewee agreed to participate on the condition that his/her name is withheld, procedures were taken to maintain his/her confidentiality (see Protection of Sensitive Information below).

2.2.3 Interview Techniques

To assist in discussion of natural and cultural resources and cultural practices specific to the study area, CSH initiated semi-structured interviews (as described by Bernard 2006), asking questions from the following broad categories: gathering practices and *mauka* (towards the mountain) and *makai* (towards the ocean) resources, burials, trails, historic properties and *wahi*

pana (storied places). The interview protocol is tailored to the specific natural and cultural features of the landscape in the study area, identified through archival research and community consultation. For example, for this study fishing, *ala hele* (trails), and salt gathering were emphasized over other categories less salient to project area. These interviews and oral histories supplement and provide depth to consultations with government agencies and community organizations that may provide brief responses, reviews and/or referrals gathered via phone, email, and occasional face-to-face commentary.

2.2.3.1 In-depth Interviews and Oral Histories

Interviews were conducted initially at a place of the study participant's choosing (usually at the participant's home or at a public meeting place) and/or—whenever feasible—during site visits to the project area. Generally, CSH's preference is to interview a participant individually or in small groups (two–four); occasionally participants are interviewed in focus groups (six–eight). Following the consent protocol outlined above, interviews may be recorded on tape and in handwritten notes, and the participant photographed. The interview typically lasts one to four hours, and records the who, what, when, and where of the interview. In addition to questions outlined above, the interviewee is asked to provide biographical information (e.g., connection to the study area, genealogy, professional and volunteer affiliations, etc.).

2.2.3.2 Field Interviews

Field interviews are conducted with individuals or in focus groups comprised of *kūpuna* (elders) and *kama‘āina* (native born) who have a similar experience or background (e.g., the members of an area club, elders, fishermen, hula dancers) who are physically able and interested in visiting the project area. In some cases, field visits are preceded with an off-site interview to gather basic biographical, affiliation, and other information about the participant. Initially, CSH researchers usually visit the project area to become familiar with the land and recognized (or potential) cultural places and historic properties in preparation for field interviews. All field activities are performed in a manner to minimize impact to the natural and cultural environment in the project area. Where appropriate, Hawaiian protocol may be used before going on to the study area and may include *ho‘okupu* (offering) of *pule* (blessing) and *oli*. All participants on field visits are asked to respect the integrity of natural and cultural features of the landscape and not remove any cultural artifacts or other resources from the area.

2.2.4 Study Limitations

Cultural impact assessments are limited by the time frame and costs of the study as well as community participation. Often, researchers have little control over the time frame or budget available for a project but may have more discretion over study design and the methodologies employed to illicit public participation. Various factors may affect participation, such as the availability of contact information for community members during the recruitment process, the interest of the community in the project, and the commitment of participants through several phases of the interview process. For example, once an interview is scheduled and conducted, CSH engages the interviewee at least one more time (in person or by email or phone call) to gain their approval of the interview transcript or summary and to incorporate any changes they make. The voluntary nature of community participation in this process, combined with restraints on time and

costs, often limits the number of interviews and the depth of information gathered during the interviews.

2.3 Compensation and Contributions to Community

Many individuals and communities have generously worked with CSH over the years to identify and document the rich natural and cultural resources of these islands for cultural impact, ethno-historical and, more recently, TCP studies. CSH makes every effort to provide some form of compensation to individuals and communities who contribute to cultural studies. This is done in a variety of ways. Individual interview participants are compensated for their time in the form of a small honorarium and/or other *makana* (gift). Community organization representatives (who may not be allowed to receive a gift) are asked if they would like a donation to a Hawaiian charter school or nonprofit of their choice to be made anonymously or in the name of the individual or organization participating in the study. Contributors are provided their transcripts, interview summaries, photographs and—when possible—a copy of the CIA report; CSH is working to identify a public repository for all cultural studies that will allow easy access to current and past reports. CSH staff do volunteer work for community initiatives that serve to preserve and protect historic and cultural resources (for example in Lāna‘i and Kaho‘olawe). Generally our goal is to provide educational opportunities to students through internships and sharing our knowledge of historic preservation and cultural resources and the State and Federal laws that guide the historic preservation process, and through involvement with an ongoing working group of public and private stakeholders collaborating to improve and strengthen the §343 environmental review process.

Section 3 Community Consultation

Throughout the course of this assessment, an effort was made to contact and consult with Hawaiian organizations, agencies, and community members including cultural descendants of Waikīkī, Pālolo, Makiki, and Mānoa Ahupua‘a in order to identify individuals with cultural expertise and/or knowledge of these areas. CSH initiated the outreach effort in April 2014 through letters, email, telephone calls, and in-person contact. CSH completed the community consultation in June 2014. In the majority of cases, letters along with a map and an aerial photograph of the project area were mailed with the following text:

> Cultural Surveys Hawai‘i Inc. (CSH) is conducting a Cultural Impact Assessment (CIA) for the Ala Wai Canal Project, a flood damage reduction project sponsored by the U.S. Army Corps of Engineers (USACE), in coordination with the State of Hawai‘i, Department of Land and Natural Resources (DLNR) and City & County of Honolulu Environmental Services (ENV). This project is located in the ahupua‘a of Waikīkī, Pālolo, Makiki and Mānoa, Kona District, Island of O‘ahu, Tax Map Key (TMK): [1] 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9; [1] 3-1, 3-2, 3-3, and 3-4. The project acreage of the Ala Wai watershed is approximately 19 square miles. Please see the attached United States Geological Survey (USGS) map and an aerial image.
>
> The overall purpose of the project is to reduce stream flood hazards to property and life safety within the Ala Wai watershed. In response to flood-related problems and opportunities, a variety of management measures have been identified with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, (4) channel maintenance considerations, and (5) minimization of flood damages. The management measures have been combined into alternative plans, which are being evaluated and compared, leading to identification of an alternative plan for implementation (proposed action); the results of this process will be presented in an Integrated Feasibility Report and Environmental Impact Statement (EIS).
>
> The purpose of this CIA is to assess cultural resources and practices within the project area with a focus on, but not limited to, the areas where potential management measures may be located, as indicated in the attached figures. This study is intended to build on previous efforts, which included archaeological and archival research and community consultation during the initial project development phase from 2009 to 2010. The results of the current study will be presented as part of the Integrated Feasibility Report and EIS. We are seeking your input on any of the following aspects of this study:
>
> **•General history and present and past land use of the project area.**
>
> **•Knowledge of cultural sites (for example, historic sites, archaeological sites, and burials).**
>
> **•Knowledge of cultural gathering practices in the project area, both past and ongoing.**

•Cultural associations of the project area, such as legends and traditional uses.

•Any other cultural concerns the community might have related to cultural resources and practices within or in the vicinity of the project area.

•Referrals of kūpuna and kama‘āina who might be willing to share their cultural knowledge of the project area and the surrounding ahupua‘a lands.

The CIA investigation may also be used to support the National Historic Preservation Act (NHPA) Section 106 and the National Environmental Policy Act (NEPA) consultation efforts, but does not, in itself, satisfy the cultural consultation requirements of either NHPA Section 106 or NEPA.

In most cases, two or three attempts were made to contact individuals, organizations, and agencies. Community outreach letters were sent to a total of 93 individuals or groups; 17 responded, and nine of these *kama‘āina* and/or *kūpuna* met with CSH for short consultations or a more in-depth interview. The results of the community consultation process are presented in Table 2. Consultation summaries are presented in Section 1.1 to Section 3.3. Interview summaries are presented in Section 4 Full transcriptions of each interview can be found in Appendix B through Appendix F .

Table 2. Results of Community Consultation

Name	Ahupua‘a	Affiliation	Notes
Agard, Louis “Buzzy”	Waikīkī	*Kupuna* (ancestor)	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014; email returned 7 May 2014
Ah Mai, Karen	Waikīkī	Executive Director, Ala Wai Watershed Association	Referred by Lynette Cruz and Pi‘ilani Kaopuiki; letter and figures sent via email 23 April 2014; follow-up email with letter and figures sent 30 May 2014
Arizumi, George	Mānoa	Mālama Mānoa, Adopt-A-Stream Coordinator	Letter and figures sent via email 23 April 2014; second email sent by community participant Kim Birnie to connect Mr. Arizumi with CSH 28 May 2014; Mr. Arizumi called CSH 2 June 2014 to schedule an interview on 5 June 2014; Mr. Arizumi interviewed by CSH 5 June 2014; CSH met with Mr. Arizumi 3 July 2014 to review consultation summary; CSH sent consultation summary via email to Mr. Arizumi 4 July 2014; Mr. Arizumi called CSH 5 July 2014 with recommendations and approval of summary; CSH sent updated summary for review 7 July 2014

Name	Ahupua‘a	Affiliation	Notes
Ayau, Halealoha	Hawaiian Islands	Hui Mālama I Nā Kūpuna ‘O Hawai‘i Nei	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014
Becket, Jan	Hawaiian Islands	Author, photographer, and teacher at Kamehameha Schools	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014; Mr. Becket responded via email 7 May 2014 suggesting several sites including an unnamed site near the entrance to Mid-Pacific Institute, Hipawai Heiau at Saint Francis School, and *lo‘i* (irrigated terrace) upstream of University of Hawai‘i at Mānoa, Hawaiian Studies building along Kānewai Stream; Mr. Becket also suggested Kawapopo Heiau on Anuenue Street; CSH responded to Mr. Becket via email 7 May 2014 indicating we are open to visiting cultural sites but with a focus on the waterways
Birnie, Kim Ku‘ulei	Mānoa	Member of Mālama Mānoa, cultural practitioner	CSH called Ms. Birnie 23 April 2014 asking if she would be interested in participating in the project; letter and figures sent 23 April 2014; CSH called Ms. Birnie 7 May 2014; tentative interview dates for either 19 May 2014 or 23 May 2014; CSH met with Ms. Birnie 24 May 2014 for a driving tour of Mānoa Ahupua‘a; Ms. Birnie sent an email to Mr. George Arizumi and CSH 28 May 2014; CSH followed up with Ms. Birnie regarding consultation 5 June and 2 July 2014 but was unable to confirm with Ms. Birnie
Boyd, Manu	Waikīkī	Cultural Director, Royal Hawaiian Center	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Cashman, Makahiapo	Mānoa	Caretaker, Kānewai Garden	Letter and figures sent via email 1 April 2014 Mr. Cashman replied to CSH via email 1 April 2014 with the following: *I would like to participate. Let me know how I can help. Mahalo nui.* CSH emailed Mr. Cashman 2 April 2014 to make arrangements for a time and place to

Name	Ahupua‘a	Affiliation	Notes
			interview; CSH followed up with Mr. Cashman via email setting a time and date for an interview; interview scheduled for 15 April 2014 at 9:00AM at Kānewai *lo‘I*; interview conducted, authorization form signed 15 April 2014; CSH sent Mr. Cashman his interview transcription for approval 23 April 2014; Mr. Cashman approved hard copy of interview transcription 12 May 2014; CSH sent Mr. Cashman an email 14 May 2014 to confirm time and date to pick up hard copy of interview transcription; Mr. Cashman will follow up with CSH the week of 27 May 2014; CSH sent follow up email to Mr. Cashman 3 June 2014; CSH stopped by Kānewai *lo‘i* to drop off a self-addressed stamped envelope for Mr. Cashman 5 June 2014; CSH sent a follow up email to Mr. Cashman 20 June 2014; CSH visited Kānewai *lo‘i* 7 July 2014; CSH followed up with Mr. Cashman via email 8 July 2014; Mr. Cashman emailed CSH 9 July 2014 to confirm time and date to meet; CSH met with Mr. Cashman 11 July 2014 to review transcription and summary
Crabbe, Kamana‘opono	Hawaiian Islands	CEO, OHA	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Cruz, Lynette	Hawaiian Islands	Professor of Anthropology, Hawai‘i Pacific University, Lei Maile Hawaiian Civic Club	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014 Ms. Cruz replied to CSH via email 7 May 2014 suggesting to contact Karen Ah Mai
DaMate, Leimana	Hawaiian Islands	Advisor, Department of Land and Natural Resources–‘Aha Moku Council	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014
Del Toro, Benjamin	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014

Name	Ahupua‘a	Affiliation	Notes
Del Toro, Daniel	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Del Toro, Rachel	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Del Toro, Samuel	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Downing, George	Waikīkī	President, Save Our Surf	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014
Finley, Robert J.	Waikīkī	Chair, Waikīkī Neighborhood Board	Letter and figures sent 28 March 2014; Mr. Finley contact CSH via email 9 April 2014 with the following reply: *Sadly I am not able to really contribute much to this survey about the Ala Wai project. My knowledge is limited to the current use of the canal by canoe clubs and recreational paddlers.* *I would hope that on completion of the project there will be less waste entering the Ala Wai and the flood preventive improvements will protect our residents from flooding and danger in the future.*
Gomes, Phoebe	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Gomes, Robin	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Gon, Dr. Sam ‘Ohu	Hawaiian Islands	Senior Scientist and Cultural Advisor, The Nature Conservancy of Hawai‘i	Letter and figures sent via email 1 April 2014
Goodyear-Kaopua, Noelani	Mānoa	Professor of Political Science, University of Hawai‘i at Mānoa	Letter and figures sent to Ms. Goodyear-Kaopua 7 April 2014; Ms. Goodyear-Kaopua responded via email 10 April 2014 with the following: *Mahalo for including me in this. I don’t think I would have much to offer you folks in your study, but I’d be willing to join you for your talk story with Imai and see if I can add anything.*

Name	Ahupua‘a	Affiliation	Notes
			Ke aloha, *Noe* CSH replied via email 11 April 2014 with the following: *Aloha Noe,* *Mahalo for your response. Sounds good, working out a time to talk story with Imai. If we are all able to hui at the same time that'd be maika‘i. Looking forward to scheduling a meeting with you folks.*
Hawai‘i Stream Research Center	Hawaiian Islands		Letter and figures sent 7 April 2014
Hind, Mehana Nicole	Pālolo	*Kama‘āina* of Pālolo	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Ho, Ivan	Pālolo	Resident of Pālolo, past referral of SHPD	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kāko‘o ‘Ōiwi	Hawaiian Islands	Native Hawaiian Organization focusing on restoration, food security, maintaining cultural practices, and ocean resources	Letter and figures sent via email 1 April 2014
Kaleikini, Ali‘ikaua	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kaleikini, Hāloa	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kaleikini, Kala	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kaleikini, Moehonua	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kaleikini, Noe‘au	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kaleikini, Paulette Ka‘onohi	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014; CSH called and left a message for Ms. Kaleikini 20 May 2014; Ms. Kaleikini called back and agreed to participate in the study

Name	Ahupua‘a	Affiliation	Notes
			via email; CSH sent third letter and figures 21 May 2014; CSH followed up with Ms. Kaleikini 8 July 2014 regarding consultation summary via email and phone; Ms. Kaleikini stated she would like all family members to receive participation requests; all information she knows comes from her mother and grandmother; as the youngest, she would follow her mother and meet various family members collecting stories of lifestyles and historical landscapes; Ms. Kaleikini responded to CSH 8 July 2014; did not approve consultation summary CSH provided; CSH responded to Ms. Kaleikini 9 July 2014 stating that we look forward to her revisions; Ms. Kaleikini responded to CSH via email 9 July 2014 requesting her original testimony be submitted as-is; CSH responded to Ms. Kaleikini via email that submitting her testimony as-is is possible
Kamai, Dwynn	Waikīkī	*Kama‘āina*	Letter and figures sent via email 1 April 2014; Ms. Kamai responded via email 2 April 2014; Ms. Kamai emailed CSH a summary 14 April 2014; CSH responded to Ms. Kamai 17 April 2014 that CSH would begin writing a consultation summary; CSH emailed Ms. Kamai 13 May 2014 with questions to fill in areas on her consultation summary; CSH sent a follow up email 22 May 2014 to Ms. Kamai; Ms. Kamai responded to CSH via email 26 May 2014 with answers and an attached article about Pālolo Golf Course; CSH emailed Ms. Kamai 28 May 2014 her draft consultation summary; Ms. Kamai responded 28 May 2014 approving the consultation summary
Kaopuiki, Pi‘ilani	McCully area	President, League of Women Voters in Hawai‘i	Letter and figures sent via email 23 May 2014; Ms. Kaopuiki replied via email 25 May 2014 stating she is a lifelong resident of the McCully area but not familiar with waterways; she will provide referrals; CSH sent a follow up email to Ms. Kaopuiki 26 May 2014; Ms. Kaopuiki replied to CSH via

Name	Ahupua‘a	Affiliation	Notes
			email 29 May 2014; referred Karen Ah Mai; CSH responded to Ms. Kaopuiki 30 May 2014
Kashiwa, Gregg	Waikīkī	Kupuna LLC	Letter and figures sent via email 1 April 2014; Mr. Kashiwa responded to CSH via email 2 April 2014 with the following response: *May I comment as follows: When Carlos Long decided to develop housing in Palolo Valley, there was a public nine (9) hole golf course in the valley. It was popular among locals who had nowhere else to play and there was a golf club, called Palolo Golf Club that is still headquartered at Ala Wai Golf Couse. Palolo Golf Club had many past golf champions such as Charlie Makaiwa, Ted and Bob Murata. The City proposed closing Palolo Golf Course and building Ala Wai Golf Course in its place. Today Ala Wai is the heaviest played municipal course in the U.S. with over 200,000 rounds played per annum. When I attended the UH, I played there with a student card that cost $10.00. I learned how to play golf there with the help of men like Sam Kapu, and Charlie Kaaihue, both starters. I joined Palolo Golf Club (no dues) and played in many tournaments representing the club. When I think of Ala Wai golf course, these days and memories flash back into my mind.* *I would oppose changing any part of the golf course for flood control. Its history is rich, painted by local faces and carried forth with good will and aloha. Before embarking on any flood control in the Ala Wai, I ask the city to put a building moratorium on any further housing in Manoa. No more run-off!!!* *Ala Wai canal already is the Manoa dumping grounds. I for one would like to see the proposed flood control plans and required permits therefore. Let’s not fool*

Name	Ahupua‘a	Affiliation	Notes
			around with history. No [o]ne told the fools in Manoa to build in a flood plain. *Since any flood control project must impact the extant golf course, it must first pass public review, comment and ona ona. I bet you would fill the club house on that night!!!!* *Your friend,* *Gregg Kashiwa* *April 2014*
Keana‘āina, Betty	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Kīhei	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Luther	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Noelani	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Regina	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Vicky	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keana‘āina, Wilsam	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kekaula, Mary K.	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keli‘inoi, Kalahikiola	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keli‘inoi, Kilinahe	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keli‘inoi, Moani	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keli‘ipa‘akaua, Chase	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keohokālole, Ema	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keohokālole, Jeanine	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014

Name	Ahupua‘a	Affiliation	Notes
Keohokālole, Joseph	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keli‘ipa‘akaua, Justin	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Keohokālole, Lori	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kikiloi, Scott Kekuewa	Mānoa	Resident	Recommended by Kim Ku‘ulei Birnie; letter and figures sent via email 23 April 2014; CSH spoke with Mr. Kikiloi 8 May 2014; he is open to an interview after final weeks at University of Hawai‘i at Mānoa are completed
Kini, Debbie	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Kini, Nalani	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Lao, Chester	Makiki	Board of Water Supply	Letter and figures emailed 28 March 2014; second letter and figures emailed 1 April 2014; Mr. Lao responded to CSH via email 5 May 2014 saying he would participate but is going on vacation for a week; CSH replied to Mr. Lao 5 May 2014 saying to call or email when he returns from his vacation to meet for an interview; Mr. Lao emailed CSH 22 May 2014 stating he returned from his trip and is willing to meet; CSH responded to Mr. Lao’s email 22 May 2014 stating 27-29 May after 9 a.m. would be ideal to meet; CSH interviewed Mr. Lao at the Hawai‘i State Public Library 4 June 2014; authorization form signed 4 June 2014; CSH sent Mr. Lao his transcription via email 20 June 2014; Mr. Lao emailed CSH 24 June 2014 with changes to his transcription; CSH sent Mr. Lao a draft interview summary 30 June 2014; Mr. Lao emailed CSH his edits to his draft interview summary 7 July 2014
Lew, Haumea	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014

Name	Ahupua‘a	Affiliation	Notes
Lopes, Leina‘ala	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Luka, Alika	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Mamac, Violet	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Matson, Michelle	Waikīkī	Waikīkī Residents Association	Letter and figures sent 28 March 2014; Ms. Matson called CSH 7 April 2014 willing to participated in the project; Ms. Matson believes this project will need a Section 106 component; she has a lot of information about the Waikīkī area and is involved with the Diamond Head Scenic Byway Project which spans from Kapi‘olani Park to Diamond Head Crater; will contact CSH at a later date to participate in study; second letter and figures sent 7 May 2014; Ms. Matson emailed CSH 13 May 2014 with receipt that she received a second letter and agreed to participate in the project; CSH emailed Ms. Matson 15 May 2014 asking for her dates of availability; Ms. Matson called CSH 2 June 2014 stating she can meet CSH 12 June 2014; CSH interviewed Ms. Matson at Kapi‘olani Park 12 June 2014; authorization form signed 12 June 2014; CSH sent Ms. Matson a copy of her transcribed interview 19 June 2014 via email; Ms. Matson emailed CSH 23 June 2014 with edits to her transcription and information on the Diamond Head Scenic Byway; also referred Harlin Young who grew up in the Ala Wai area; CSH replied the same day thanking her for the referral and the additional handouts; CSH emailed Ms. Matson her draft interview summary 3 July 2014; Ms. Matson called CSH and emailed 8 July 2014 with edits to her interview summary and transcription
Medeiros Jr., Clarence	Waikīkī	Cultural descendant	Letter and figures sent via email 15 May 2014; CSH called Mr. Medeiros 16 May 16,

Name	Ahupua‘a	Affiliation	Notes
			2014; no answer; CSH sent a follow up email 16 May 2014
Navales, Pauline	Waikīkī	President, Kumuola Foundation	Letter and figures sent via email 23 April 2014
Nobrega, Malia	Waikīkī	President, Waikīkī Hawaiian Civic Club	Letter and figures sent via email 1 April 2014; second letter and figures sent 7 May 2014
Norman, Carolyn	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Norman, Eileen	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Norman, Kaleo	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Norman, Keli‘inui	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Norman, Thedore	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Paik, Kaleo	Hawaiian Islands	Cultural practitioner	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Papa Jr., Richard Likeke	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Pascua, Bruce H.	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Perry, Wendell Kekailoa	Waikīkī	Assistant Professor, University of Hawai‘i at Mānoa, Caretaker, Kānewai Garden	Letter and figures sent via email 23 April 2014; Mr. Perry responded to CSH 25 April 2014 via email stating he will put together a list of canoe contacts that have utilized the Ala Wai for the last 30-80 years; CSH responded to Mr. Perry via email 28 April 2014 emphasizing the types of contacts and participants needed for the study (e.g., cultural practitioners, *kama‘āina*, etc.); figures resent
Preza, Donovan	Mānoa	PhD student, University of Hawai‘i at Mānoa	Referred by ‘Īmaikalani Winchester; letter and figures sent via email 12 May 2014

Name	Ahupua‘a	Affiliation	Notes
Rash, Regina	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Rodrigues, Hinano	Hawaiian Islands	Interim Culture and History Branch Chief, SHPD	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014
Roy, Corbett	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Shirai, Jacqueline	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Shirai, Thomas T.	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Soares, Moani Kaleikini	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Spinney, Charles	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Sproat, D. Kapua‘ala	Waikīkī	Assistant Professor of Law, William S. Richardson School of Law	Letter and figures sent via email 1 April 2014
Stroud, Soulee LKO	Hawaiian Islands	Association of Hawaiian Civic Clubs	Letter and figures sent via email 1 April 2014
Takaki, Moses	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014
Tengan, Ty and Ku‘ulei	Mānoa and Pālolo	Professor of Ethnic Studies, University of Hawai‘i at Mānoa	Letter and figures sent via email 1 April 2014; second letter and figures sent via email 7 May 2014
Waikīkī Community Center	Waikīkī		Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Water Resources Research Center	Hawaiian Islands		Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Williams, Evern	Island wide	Community Outreach Manager, ‘Ōlelo	Letter and figures sent via email 23 May 2014; Ms. Williams replied to CSH via email 23 May 2014; second letter and

Name	Ahupua‘a	Affiliation	Notes
		Community Media	figures sent 24 May 2014; CSH followed up with Ms. Williams 30 May 2014
Winchester, ‘Īmaikalani	Makiki, Mānoa	Teacher, Hālau Kū Māna Public Charter School ‘Aihualama *lo‘i* caretaker	Letter and figures sent via email 7 April 2014; CSH contacted Mr. Winchester 18 April 2014 to set up a time to interview; confirmed for 18 April 2014; CSH interviewed Mr. Winchester at ‘Aihualama *lo‘i* in Mānoa 18 April 2014; authorization form signed by Mr. Winchester 18 April 2014; CSH sent an email to Mr. Winchester 16 May 2014 with transcription, maps, and photos; CSH met with Mr. Winchester at ‘Aihualama *lo‘i* to review the transcription; CSH sent a follow up email 2 June 2014; CSH picked up the revised transcription from Mr. Winchester at ‘Aihualama *lo‘i* 5 June 2014; CSH sent Mr. Winchester his draft consultation summary via email 2 July 2014; CSH met with Mr. Winchester at ‘Aihualama *lo‘i* 5 July 2014 to review his draft consultation summary; Mr. Winchester sent revised consultation summary 7 July 2014
Wong, Hinalei	Hawaiian Islands	Chair, O‘ahu Island Burial Council	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Yee, Christian	Island wide	Cultural practitioner, knowledge of cultural sites and *mo‘olelo*	Letter and figures sent via email 1 April 2014
Yokooji, Dayleen	Waikīkī	Cultural descendant	Letter and figures sent 28 March 2014; second letter and figures sent 7 May 2014
Young, Harlin	Waikīkī	Grew up in the Ala Wai area	Referred by Michelle Matson; consultation period was closed; did not have enough time to contact

3.1 Consultation Summary for George Arizumi

Mr. George Arizumi is a third generation resident of Mānoa Valley and a proud member of the Mānoa community. After Mr. Arizumi's father's parents' plantation contract was completed, they settled in Mānoa to start a new life and the family has been in Mānoa since then. He doesn't know of any other third generation families still alive in the valley outside himself. He wishes this was not the case, but noted that many of the old people and families that have passed away held memories that described the valley in much larger historical contexts. Mr. Arizumi was at first reluctant to be interviewed because he does not consider himself an expert historian. CSH is appreciative of his time, memories, experiences, and contributions to this project.

Since 2001, Mr. Arizumi has been a coordinator for Mālama Mānoa's participation in the City and County of Honolulu's Adopt-A-Stream program. Mālama Mānoa is a community organization whose mission is to "promote community, to celebrate cultural diversity and heritage; and to preserve, protect and enhance the special qualities of historic Mānoa Valley." Mālama Mānoa has formally adopted a section of Mānoa Stream from Kahaloa Drive Bridge to Woodlawn Bridge. Mr. Arizumi hosts stream clean-ups two to four times a year. Community members, volunteers, and groups help rid the banks and streams of debris. He shares vibrant, fond memories of growing up near Mānoa Stream. These remembrances of Mānoa Stream are in part what fuels his commitment to the Adopt-A-Stream program.

On 3 June 2014 Mr. Arizumi contacted CSH, facilitated by Ms. Kim Ku‘ulei Birnie. There was brief consultation on the phone and Mr. Arizumi agreed to meet in Mānoa with CSH. On 4 June 2014 CSH met with Mr. Arizumi at the Woodlawn Bridge across from the Mānoa Shopping Center and next to the University of Hawai‘i College of Tropical Agriculture and Human Resources, Magoon Research Station. Mr. Arizumi allowed for voice recording of the session for note taking purposes only.

Looking downstream from Woodlawn Bridge, Mr. Arizumi explained that he likes to bring people to this area because this is where debris washed down and was caught underneath the bridge resulting in the flood of Hamilton Library at the University of Hawai‘i Mānoa campus in 2004 (Figure 3). As seen in Figure 4, trees hang over into the stream as vegetation also creeps down the side of the reinforced rock walls. In the downstream view from Woodlawn Bridge note the build-up of rocks and materials. The height of the bridge from the stream is no more than 7 ft (Figure 5). Debris often gets washed downstream, building up in this area if it is not maintained. The City and County clears the area under the Woodlawn Bridge of rocks and plants with large machinery. The debris collected from under the bridge is then hauled off via dump truck. Mr. Arizumi does not know where the rocks and plant debris are placed after removal from the stream. Since the City and County has been removing the rocks, Mr. Arizumi slowly collects rocks for *imu* (underground oven). In particular, he looks for rocks with *pukas* or holes. He gives them to people he knows who practice *imu* cooking rather than have them be thrown away, possibly in a landfill.

Mr. Arizumi spoke of the differing geological ages of substrates in the valley and how this has helped contribute to the flooding problems in Mānoa. The older substrate that is located on the Makiki side of the valley has a slope allowing for movement towards the ocean and deposition of rocks from street run-off. The younger substrate, as seen in Figure 4 and Figure 5, is on the Pālolo side of the valley and is flat and wide with a reduced slope. This creates a slow and shallow flow

Figure 3. Woodlawn Bridge located on Woodlawn Drive connects opposite sides of Mānoa Stream. This is where the backup occurred during the last serious flooding events on Halloween night 2004 (CSH 2014).

Figure 4. Downstream view from the Woodlawn Bridge; note the buildup of rocks and plant material. This is removed by the City and County of Honolulu a few times a year (CSH 2014).

Figure 5. Photo of Mr. Arizumi in the streambed of Mānoa Stream, with Woodlawn Bridge above, demonstrating how debris can easily get caught (CSH 2014)

downstream, backing up the water above Woodlawn Bridge. An example can be seen by the "island" of pebbles and rocks that has accumulated under the bridge. The age of the pebbled island may be identified by the height and density of the flora, which in the picture consists of various grasses (*Poaceae*) and Job's Tears (*Coix lacryma-jobi*).

The geologic history of the area also explains why the stream hugs the Wa‘ahila side of Mānoa Valley as opposed to going down the middle of the valley, which is typical of many bodies of water in Hawai‘i. The stream was pushed east due to an eruption at the area commonly known as Round Top, which divides Makiki Ahupua‘a from Mānoa Ahupua‘a. Downstream of the Woodlawn Bridge there is an S-turn and lack of sufficient slope. This area also contributes to backup of water flow during high rainfall events. Many Federal, State, County and private organizations have come to the Mānoa community for solutions. Mr. Arizumi has participated along with other community members interested in mitigating flood issues. To remedy the flooding, he has heard many of the recommendations such as raising Woodlawn Bridge, channelization, reservoirs, and fixing the S-turn section. So far, none of the recommendations provided by the community have been implemented.

Mr. Arizumi mentioned an idea from a previous member of the Mānoa community who was a City and County of Honolulu engineer and his father's boss, who has since passed, named Mr. Okuda. The area around the University of Hawai‘i at Mānoa's College of Tropical Agriculture and Human Services is the lowest lying part of the Woodlawn area. Large storms often create pooling of water in this area (Figure 6). Mr. Okuda's recommendation includes allowing Mānoa stream, or diverting it, to overflow down Woodlawn Drive then turn into the College of Tropical Agricultural and Human Resources and returning back to the stream, a total distance under 200 m. The water would overflow from Woodlawn Bridge in events of debris blockage, go down Woodlawn Drive and turn left at a lowered Magoon Drive, returning to the natural streambed. This proposed path is the lowest point on Woodlawn Drive that water would naturally follow. If the road here at the intersection between the current Mānoa library and the Magoon Research Institute entrance was lowered then flooding at Noelani Elementary and the University of Hawai‘i further down may be mitigated. This path allows for natural flow of water to occur with minimal construction. This proposal would also reduce the amount of water through the previously mentioned S-turn. Mr. Arizumi agrees that this idea is a feasible way to reduce flooding in the greater Mānoa area until further improvements are made. This suggestion would be a temporary but quicker mitigation method while government agencies may take years to solve the greater watershed issues.

Mr. Arizumi reminisced about landmarks of the past in Mānoa. He recalled Mānoa housing, a school for children from Mānoa housing, and an open field where Mānoa Marketplace currently stands. Downstream of Woodlawn Bridge there were two deep pools of water known as "Boy's Pond" and "Girl's Pond." Each would go to their own ponds to swim. Mr. Arizumi fondly recalled playing all day as children and not returning home until the sun began to set. During the daytime children would play in the stream and he shared that "the stream was our playground." Mr. Arizumi recalled many parents not allowing their children to swim in the stream. He shared that if you swam with your clothes on, parents knew you were at the stream. To avoid getting in trouble, children would remove their clothes, jump in, and put their dry clothes back on. Because all clothes were removed this was the reason for the separate ponds. Mr. Arizumi recalled being a rascal and attempting to peek in Girl's Pond. To his dismay they had a "bodyguard" posted in front so no

Figure 6. View looking *mauka* on Woodlawn Drive; location of the lowest point of Woodlawn Drive identified by the manhole cover; water naturally pools here (CSH 2014)

boys were able to enter or peek. After a big storm in the mid 1950s, Girl's Pond was filled in with silt and gravel. After this event, everyone swam and played at Boy's Pond.

Mr. Arizumi expressed with all of his *aloha* (love and affection) that "kids don't know about the stream now days." Today, children are chauffeured over the bridges by their parents without noticing the stream. Mr. Arizumi noted that children today hang out at malls, roam at fancy parks, or play on their electric devices not appreciating the stream or the natural environment. "It's sad that they don't appreciate nature as much." He has *aloha* for the stream and sees it as a metaphor of the valley where "the stream created the valley, it is the most important [part of the landscape]."

The stream provided sustenance as well as entertainment during the daytime. He related that *‘o‘opu* (general name for fishes included in the families of *Eleotridae*, *Gobiidae*, and *Blennidae*) fish were about 4 to 8 inches long and crayfish (*‘ōpae‘oeha‘a; Macrobrachium grandimanus*; Tahitian prawn; *Macrobrachium lar*) were almost the same size claw to claw. These would be eaten whole with bones or shell still intact. Children gathered these morsels from the stream, as well as the small white translucent *‘ōpae* (general name for shrimp) and *pipipi* (general name for small mollusks; *Theodoxus neglectus*). Mr. Arizumi remembered using a safety pin to pick out the meat from these shells. As children, he recalled creating a fire, throwing the fish or crayfish and other treats over the fire, then consuming them whole with the exception of the *pipipi*, where they only ate the meat. When eating the *‘o‘opu* they didn't worry about the bones inside the fish because they were soft. Today, Mr. Arizumi has not seen any *‘o‘opu* or *‘ōpae* in the streams, but noted that crayfish are still available. However, the crayfish do not grow as large as they once did. In addition, the children gathered fruits of all sorts such as mountain apple (*‘ōhi‘a‘ai*; *Syzygium malaccense*), mango (*Mangifera indica*), lychee (*Litchi chinensis*), and California plum (Java plum; *Syzgium cumini*) for snacking. California plum trees still line the banks of Mānoa Stream next to Woodlawn Bridge. Mr. Arizumi recalled a specific mountain apple tree area in the mountains that his father showed him. That area was abundant with fruits when in season. When children returned home, chores were the only activity allowed. The stream and its accompanying flora provided a full day of events. Mr. Arizumi pointed up towards the Wa‘ahila side of Mānoa and remembered the sleeping giant whose silhouette can still clearly be seen to this day. He doesn't remember the name of the giant but remembers the outline and general story associated with the landscape feature.

Mr. Arizumi's father often showed him all of the places that had *lo‘i* throughout Mānoa Valley. He recounted that while the Hawaiian population was diminishing, Chinese plantation workers from the sugar cane fields took responsibility for the land and cared for the taro or planted rice in the *lo‘i*. There were quite a lot of rice fields for a while and not much taro, he said. At this time farmers followed the stream down to Waikīkī and traded taro for fish. There was a ditch on Dole Street that fed taro patches in the area where the University of Hawai‘i's Hawaiian Studies complex, Kamakakūokalani, stands today. Mr. Arizumi used to play in the ditch as a kid. He mentioned that "Hawaiians were smart" because they engineered a system to bring water from a low lying stream uphill to the *lo‘i*. This area was restored by students of Hawaiian Studies and is one of the last few remaining cultural areas in the valley and is known as Ka Papa Lo‘i ‘o Kānewai. Mr. Arizumi pointed to another terraced area that is under restoration by the Lyon Arboretum. This place is known as the ‘Aihualama *lo‘i*.

Unrelated to the stream, Mānoa was the location for Queen Ka‘ahumanu's summer palace. Similar to Queen Emma having her summer palace in Nu‘uanu to escape the heat of the season,

Queen Ka‘ahumanu had a similar dwelling in Mānoa. This area was marked by a *hau* (beach hibiscus; *Hibiscus tiliaceus*) on the Makiki side of the valley. He stated that developers were permitted to remove the summer palace so it no longer remains. However, the *hau* tree still remains at the site.

Mr. Arizumi stated that the entire community of Mānoa once relied on the stream for basic necessities including washing clothes, gathering water to cook and clean with, agricultural maintenance, and recreation. There was no dirty water upstream; everyone needed access to clean water. Everyone abided by a general *ahupua‘a* system. This basic shared need for water from the stream contributed to the maintenance and minimization of unnecessary inputs by neighbors up and downstream. The removal of the taro patches and addition of infrastructure resulted in less area for the water to flow during high volume events.

In current times Mr. Arizumi takes pride in his initiatives to work with the stream. He does so because they remind him of good times gone by and he hopes that children today can also partake in those memories. Today, he noted there are little or no *‘o‘opu* but there are other types of fish, most of which are invasive. He attributes the lack of *‘o‘opu* to the channelization of the stream which occurred in the 1950s. When the bottom of the stream was widened and poured over with concrete, it created an environment unsuitable for the *‘o‘opu*. The water, because it is shallow, is easily warmed up by the heat of the sun, creating temperatures that are intolerable for *‘o‘opu* and other native species but appropriate for introduced species. In addition, the smooth bottom and sides of the channelized regions do not add oxygen to the water making it hard for any species to breathe freely. The channelization also acts as a chute during high rain events which significantly increases stream flow speed. The areas that still have natural rocks, boulders, and stream widths provide habitat suitable for the *‘o‘opu*. When the water runs over the rocks and boulders it creates bubbles that incorporate oxygen into the water. The rocks and boulders slow the water and also make good stones for *imu*. Mr. Arizumi encourages conditions that will help the return of *‘o‘opu*, *‘ōpae*, and other native species such as fresh water *pipipi*.

In closing, Mr. Arizumi stated that he supports improvements to Mānoa Stream that help reduce the threat of flooding, but are also in keeping with environmentally sound or "*pono*" practices. Mr. Arizumi ended by saying that he and other community members do not want the channelization of Mānoa Stream to be extended, if possible.

3.2 Consultation Summary for Paulette Ka‘anohi Kaleikini

CSH contacted Paulette Ka‘onohi Kaleikini 27 May 2014 via email. The information provided below is correspondence exchanged between CSH and Ms. Kaleikini that she approved to be released for this project; the bold face indicates CSH.

> **Aloha e Aunty Kaonohi,**
>
> **Mahalo again for the quick follow up phone call yesterday afternoon. At this point in time your ‘ohana [family] is the only respondent from the Waikiki area who has identified interest in participating with feedback on the proposed project area, so for this mahalo nunui loa [thank you very much]. This email is to clarify questions we are asking participants. Mahalo for participating via email. We understand your steadfast commitment to ‘aina [land] and ‘ohana**

and appreciate any time spent towards informing this Ala Wai Restoration Project process.

For affirmation I have attached the letter received in the mail, requesting participation along with the printed maps you have.

You may be able to zoom in on the maps with the computer for more clarity on potential project areas.

The main questions we are asking participants are bolded in the letter to request participation and slightly reiterated below.

In particular, due to the nature of this project, there is focus on stream areas which drain into the Ala Wai Canal (Makiki, Manoa, Palolo).

Of course we are interested in connecting:

1) How is your ‘ohana connected to Waikiki?

My ‘ohana are State recognized lineal descendants to ‘ohana burials in the ‘ili [land section] of Kalia, Waikiki ahupuaa.

My great-great-grandfather was from Kaawaloa Kona Hawaii. He traveled to Oahu with the chiefs as part of their entourage and was pilikoko [blood relative] to them. He was their kahu [guardian] and he took care of their spiritual well-being. One had to be pilikoko to get close to the alii [chief]. He was also the kahu of Hikiau Heiau in Kealakekua. Waikiki was one of the favorite spots on Oahu for the alii.

My kupuna settled in Kalia Waikiki. One of the reasons Kalia was chosen is because there were two ponds on this land. The smaller pond was used for the same purposes as the pond at Kealakekua (Kaluaopae); for spiritual ceremonies only. After my g/g [great-great] grandfather returned to Kealakekua, the pond was never again used for ceremonial purposes. My great grandfather returned to the property in Kalia years later. Presently, the Allure condominium sits on that pond.

Also on this property was a larger fishpond. It was dredged in 1927 to allow for the Ala Wai canal project. The Hawaii Convention Center sits directly on a part of this pond. It was called Kuwili pond and was directly associated with the Kuwili pond in Iwilei. My g/g grandfather started and raised moi [threadfish; *Polydactylus sexfilis*] in Kuwili pond. The moi he raised in Kalia was reserved for the chiefs and their entourage. However, because the moi was plentiful in this pond the chiefs often fed the people; Kamehameha being the most generous of the chiefs.

During the Mahele, that property was awarded to Kaunuohua. She in turn gave it to her husband William Luther Moehonua. Moehonua was the first cousin of my great grandfather. Moehonua’s mother was the sister of my g/g grandfather and she returned to Kaawaloa. The father of Moehonua was Aikanaka, the grandfather of Kalakaua and Liliuokalani. After Moehonua passed away, the property in Kalia was inhabited by my great grandfather. My grandfather and his siblings were born on that property. My mother and her siblings were born on that property. All of my siblings were born on that property in Kalia.

This is my genealogical tie to Waikiki. Many ‘ohanakoko [family blood], who were descendants of the Kona chiefs remained on Oahu and never returned to Hawaii island. Waikiki was one of the areas where they dominated. After the Mahele, the families were awarded kuleana [parcel] lands. Many were ‘ohana to Kauikeaouli. In this way, the families continued to live on Oahu, in Waikiki, until the lands were stolen and non-native Hawaiians began to quiet title the lands belonging to and were the homes of the native Hawaiians. My ‘ohana eventually were victims of this larceny and my family moved away after the passing of my great grandmother. She left the lands to my grandfather and his siblings. His sister illegally signed the property over to Ethan Magoon. My grandfather and his brothers never signed over or relinquished their interest in the land. The land being a Royal Patent to my kupuna, could not have been given, sold or traded to anyone and should have been returned to the king or kingdom of Hawaii. We all know what happened there; our lands were slowly being stolen, then finally, the kingdom. So the lands in Kalia of my kupuna’s inheritance was stolen. But their iwi [bones] lie deep in its bosom.

These are some of the ‘ohana who lived in the affected areas of this project: Kahalehau, Namaka, Kawaa, Kuahine and Kahai were the ‘ohana that lived mauka along Pahoa stream. Living makai along Pahoa stream were the Mahuka, Namaile, Wailehua, Male, Waahee, Kapilimanu who were displaced by the rice fields. Living mauka along Kalia stream were the Aea and Hulilau who lived in Piliamoo ‘ili. Kaupe, Kahakai, Kukahiko, Kaohe, Uma, Lahilahi, Kamaka, Pupuka, Kaluahinenui were the ‘ohana who lived makai along the Kalia stream and were displaced by the rice fields. All these ‘ohana were originally from Hawaii island.

The rice fields were eventually displaced by the Ala Wai canal.

i.e. general history of present and past land use relevant to your family and highlighted areas of the proposed project

See above for some past land use that was relevant to my family.

2) Are there areas of cultural significance within the proposed project area?

i.e. historic sites, archaeological sites, or burials, family gathering sites

There are many historic and archaeological sites within the project area or what may remain of it. Most areas were destroyed by the influx of western civilization and development. However, there may be remnants of these sites deep in the sediments that will reveal the history and moolelo of the families who lived there. Of course, where families lived, is where they buried their ‘ohana, so there is always a possibility of encountering burials at these sites. This project is in the urban corridor; an area where native Hawaiians were known to have heavily inhabited. Knowing this, the project must proceed with caution even in areas of streams and especially in the areas of streams. Our people acquired fresh water from these streams and also inhabited areas near these streams. I provided the names of some of the ‘ohana above.

3) Are you or your ‘ohana knowledgeable to any past or ongoing gathering practices?

i.e. la‘au lapa‘au [Hawaiian healing medicine], fishing, hunting, plants, minerals (pa‘akai [salt], ‘alae [mud clay], lepo [dirt])

Yes, my kupuna practiced la‘au kahea [a type of faith healing of broken or crushed bones or sprains] and la‘au lapa‘au; most pre-contact native Hawaiians did. Along with this kuleana [responsibility], there were certain la‘au [plant] that was used and they always had these planted surrounding their kauhale [group of houses comprising a Hawaiian home]. I remember times when my mother would go into the yard at sundown and gather la‘au for someone who required it. My kupuna were spiritual healers. La‘au was gathered with great care. There was pule before gathering. La‘au was gathered at certain times of the day. La‘au was gathered on certain moon nights. La‘au was prepared for a particular person only. And in some cases, the la‘au had to come from a certain location. My mother went to Manoa to gather a certain la‘au from a Royal Patented property that was inherited by my grandfather until that property was quiet titled and stolen. She gathered at Makiki; rarely in Palolo but whenever she needed la‘au from Palolo, her cousins usually had it available. She preferred la‘au from Manoa and Nuuanu. La‘au kahea was much more spiritual. One had to be pilikoko to the gods themselves to hold the mana [divine power] of la‘au kahea. My g/g grandfather from Kaawaloa had such a kuleana. He used it to treat the chiefs, their warriors and their ‘ohana to heal illness, broken bones, lacerations and strengthen them with his breath alone. As their kahu, this was part of his kuleana. The mana of la‘au kahea was passed down through the generations and the last to have it in my ‘ohana was my mother’s uncle. He wanted to pass the kuleana down to my mother but she refused. She later explained that the responsibility was too great and it could possibly affect her family and she did not want that. So when uncle passed away, the kuleana went with him. There was no one else in the ‘ohana lineage that would have been capable to carry the kuleana. These traditional and cultural practices radiated in with my kupuna for at least 4-5 generations that I know of.

Another of my kupuna’s kuleana was to care for the fishponds of the chiefs. My great grandfather continued care for the fishpond in Kalia until he no longer could. I have no knowledge of the kuleana continuing to my grandfather’s generation. By then, western habitation of the lands was changing the landscape. Dredging for the Ala Wai began in 1927 and it destroyed Kuwili pond.

Paakai was used a lot in my ‘ohana, for food preparation and ceremony. For food preparation, paakai was acquired locally. Paakai for ceremony was brought over from Molokai by ‘ohana. Limu [seaweed] was used for la‘au and food. My mother and her ‘ohana gathered limu in Kalia until my mother determined that the water was getting too pilau [putrid]. But she continued to gather a certain limu at the mouth of the stream near Gray's beach in Kalia until even that limu bed was destroyed. She said that all limu were la‘au as long as the water source was clean. She was very disturbed at the way western civilization had disturbed the limu beds in Kalia and all else in the environment of the lands she grew up on.

The kane [male] of my ‘ohana hunt in these project areas; some still do. They walked along the stream when going hunting in Palolo, Manoa, Makiki, Nuuanu, Kalihi. When there was water in the stream, the animals went there to drink. One hunting technique was to follow the tracks of the animal from the stream.

4) Are there any cultural associations of the project area, such as legends and traditional uses?

Two legends immediately come to mind. The legend of Kauatuahineomanoa generates from the valley of Manoa. Kauaowaahila generates from the valley of Palolo. My mother’s ‘ohana lived in these valleys and we grew up with these legends instilled in us. They taught us to kahea [to call] Tuahine whenever we went walking or hiking in the valley. Tuahine is a gentle, soft rain. Waahila, on the other hand, always seemed heavier, masculine and soaked us to the bone. My daughter and son are named for these legends; Tuahine and Waahila.

i.e. is this area connected through stories/relationships/people to other parts of the island/archipelago. Why may these be significant connections to understand.

I explained the connection of my kupuna to the affected areas of this project. They were from another island but generations continued to live on the lands in Kalia Waikiki, Kiki, Piliamoo, Waiaka, Kamoku, Niukukahi, Pahoa, Mookahi, Waiaala, Kaluaolohe, Kalehua, Kolowalu mauka, Maunalaha Makiki, Pahao, Kaaipu Manoa, Puahia, and continued traditional and cultural practices. This may be an important factor to understand when it comes to traditional and cultural practices in that it could have differed from island to island, ahupuaa to ahupuaa, ‘ohana to ‘ohana. Some of these traditional and cultural practices were of kuleana pertaining to more mauka regions of the islands. Some ‘ohana were bird catchers and remained in the more mountainous regions. The birds were caught for eating as well as for the feathered adornments for the chiefs. Some ‘ohana often visited the mountains to care for family burial caves. Their kuleana differed from ‘ohana living mauka.

5) Do you have any mana‘o [thought, opinion] about the Ala Wai (and the immediately surrounding area)?

See above for my family’s tie to the Ala Wai by way of the Royal Patented lands and the pond that was on it.

The land (Royal Patent) of my kupuna included part of the Ala Wai; the lands makai of the Ala Wai Bridge, Diamond Head makai end of the Ala Wai canal, makai of Kalakaua Avenue along Ala Moana Blvd down to the ocean including the Ilikai Hotel. The Hawaii Convention Center sits on part of Loko Kuwili that belonged to the Royal Patent of my kupuna. It was a large pond and it was dredged to create the Ala Wai canal. The mauka end of the Ala Wai destroyed lands that belonged to ohana;

6) Do you have any cultural concerns the community might have related to cultural resources and practices within or in the vicinity of the project area?

The land is heavily impacted by western society. It is a strain to visualize any remnants of our cultural resources surviving in the community. If it does exist, it would not be in the realm of pre-contact native Hawaiian traditions and cultural practices. This is the era that I am particularly concerned about. However, there is always a possibility that there may exist historic properties lying in the sediments just beneath the present post contact environment. This was a very productive fertile land for our ancient kupuna. There was abundance of fresh water as well. These areas were heavily populated in ancient times. Many were killed by the small pox epidemic. They died suddenly and in great numbers. Where they died is where they were buried by ‘ohana. Their iwi could still be buried undisturbed in the earth.

i.e. Do you think there will be any impacts to the cultural landscape due to this project? If yes, why. If no, why.

There will always be impacts on cultural landscape by any project on our islands. The whole island is a cultural landscape. Most of the top layer of the landscape was impacted generations ago. Beneath the impacted layer lie the cultural history of our people of that area. The mauka regions were often visited, used and inhabited by our people during the rainy season. They went mauka to tend lo‘i and other agricultural practices and gathering. So there should be an honest search in these areas for evidence of the layer of their time on that landscape.

7) Do you have referrals to any other Waikiki ‘ohana, kupuna or kama‘aina who might be willing to share their cultural knowledge of the project area and the surround ahupua‘a lands?

I will refrain from referrals.

3.3 Consultation Summary for Dwynn Kamai

CSH contacted Mrs. Winona (Nona) Kamai, Alaka‘i (Director) of the Waikīkī Hawaiian Civic Club for a previous project on 2 December, 2013 via email. Aunty Nona’s daughter, Dwynn, responded to CSH on behalf of her mother and herself on 13 and 14 January 2014 with a series of statements. CSH contacted Dwynn and Aunty Nona on 1 April 2014 for the Ala Wai Canal Project. Dwynn responded to CSH via email on 2 and 14 of April, as well as 25 May 2014 regarding the project area. These statements are presented below.

Pālolo Valley is a special place for the Kamai ‘Ohana. Dwynn described her childhood, growing up in Pālolo Valley. In a previous interview about Waikīkī, Dwynn talked about how Waikīkī was once a special place for her and her mother. Today, the shores of Waikīkī area are lined with hotels and condominiums. In contrast to Waikīkī, Pālolo Valley is easily accessible.

As a child, Dwynn recalled playing in Pālolo Stream. Just below the Pālolo Chinese Home is a side street where her family would park and follow a trail to access the stream. She recalled her father having her and her siblings pick up the trash in and around the stream and take it to the curb on the street prior to playing in the stream. Once they took care of their *kuleana* to *mālama* (take care of) the stream, the children were allowed to play in the stream, catching guppies and crayfish for their fish tank. Dwynn recalled seeing *‘ōpae* as well. Today the area the Kamai ‘Ohana

frequented is overgrown. Farther down where the Kamai ‘Ohana played the stream is a man-made channel which eventually leads to the Ala Wai.

One thing Dwynn recalled about the waterways of Pālolo was that they never flooded or caused damage to life and/or property that she knows of. Another waterway that Dwynn recalled but never actually visited was a swimming hole in Ka‘au Crater. The trail to Ka‘au Crater is located in the back of Pālolo Valley. After hiking to the back of the valley, traversing the stream several times, and scaling a couple of waterfalls, one reaches Ka‘au Crater. Ānuenue School is a public Hawaiian immersion school located in the back of Pālolo Valley. Dwynn was told a few years ago that part of the Ānuenue School football team’s daily training is for each player to pack a trash bag, run the trail to Ka‘au Crater, and on the way back down to pick up trash along the way. Not only are the *haumāna* (students) training for sports but they are also helping keep our *‘āina* (land) clean. Dwynn remembered hiking Pālolo Valley with her father and her siblings. She recalled hunters frequenting the valley. Dwynn recalled a large *laua‘e* (*Phymatosorus scolopendria syn. Microsorim scolopendria*; fragrant fern) patch deep in the valley. This particular variety of *laua‘e* is the mountain variety. Dwynn described this variety as having no seed pods and the leaves being very large. Her *‘ohana* would gather the *laua‘e* for *lū‘au* (Hawaiian feast) and for the scent as it was reminiscent of *maile* (*Alyxia olivaeformis*; native twining shrub).

Dwynn added that Veteran’s Village was where her grandmother resided. The Veteran’s Village is located on Ua Drive. The small community was primarily comprised of veterans. Pālolo Stream runs through the village with three bridges strategically placed throughout the community. These three bridges provided shortcuts to Pālolo Hongwanji and Jarrett Intermediate School. Over time the bridges were removed. Dwynn’s grandmother and other women of the Village tended their personal gardens and the community garden known as the Victory Garden. Because the village consisted of veterans, the wives regularly rolled bandages for veterans. Dwynn’s grandmother expanded her portion of the Victory Garden into her own personal garden where she cultivated *kalo* (taro), watercress, mango, and coconuts. She used her runoff laundry water to water the yard. The Kamai ‘Ohana still retain their property at the Veteran’s Village.

She recalled *bon* (a Japanese Buddhist custom to honor the spirits of one’s ancestors) dances being held at Pālolo Hongwaji. She and her siblings would hear the drums from the *hongwanji* (Japanese temple), get ready, and the family would go to the temple to dance in line. She added that Pālolo Valley also had a golf course and a landing strip. The golf course was located where Jarrett Intermediate School stands today. The airstrip was near the golf course.

The nine-hole municipal golf course opened in 1931 and was designed by Alex Bell, a professional golfer at the O‘ahu Country Club. Early golf courses in Hawai‘i were all private, however, the Pālolo location was the first municipal links in the Islands. A Honolulu Star-Bulletin article stated it was “one of the finest in the world” (*Honolulu Star-Bulletin* 2014). Other sites considered for the first nine-hole municipal course included Ala Moana, Kalihi Valley, and Koko Head. During construction of the golf course, Pālolo Valley was the site of several farms, two dairies, and a rock quarry with most of the streets being narrow dirt roads. The 3,225-yd course incorporated the natural features of the valley into play including two streams, rolling fairways, hills, gullies, ditches, and bunkers. The clubhouse was located at what is now Palolo Avenue and Kalua Road. The course was popular amongst the public in the 1930s until World War II, which

brought everything to an end. Approximately 100 homes were built on the golf course for emergency evacuation of those who were in low lying areas.

In regards to the project, specifically Pālolo Stream, Dwynn doesn’t believe it needs a major overhaul. Periodic cleaning and maintenance of the Pālolo Stream would be sufficient to keep the waterway flowing. She advised not touching the water or eating anything from the Ala Wai Canal. She added that the Ala Wai needs to be cleaned up as well.

Section 4 Interviews

4.1 Acknowledgements

The authors and researchers of this report extend our deep appreciation to everyone who took time to speak and share their *‘ike* (knowledge) and *mana‘o* (thought, opinion) with CSH whether in interviews, brief consultations, including contacts who opted not to contribute to the current cultural impact assessment, but nevertheless spent time explaining their position on the proposed project. We request that if these interviews are used in future documents, the words of contributors are reproduced accurately and in no way altered, and if large excerpts from interviews are used, report preparers obtain the express written consent of the interviewee/s.

4.2 Chester Lao

CSH interviewed Chester Lao previously on 6 December 2009 for the first installment of the Ala Wai Watershed Project. CSH interviewed Mr. Lao on 4 June 2012 at the Hawai‘i State Library on King Street for additional information on the Ala Wai Watershed. Similar to his previous interview conducted in 2009, Mr. Lao shared his knowledge of springs, ponds, and waterways within the Ala Wai Watershed.

Born in 1931 in Menlo Park, California, Mr. Lao moved to O‘ahu in 1962 when he was 31 years old. He worked for the Board of Water Supply for approximately 43 years. Mr. Lao began the interview describing the water table in the caprock aquifer, which is a lower-permeable formation but has permeable marine formations that overlies highly permeable volcanic rock. When the missionaries first arrived in Hawai‘i the water table was high within the caprock aquifer. The location of the Mission Homes and the Board of Water Supply in downtown Honolulu overlies cinders and coral that collect water. Another source of water for the area was in the coral limestone beneath the cinders that form part of the caprock. A hand-dug well at the Mission Homes, which is approximately 25 ft in depth, contained water suitable for everyday drinking and cooking. The water quality in the area extending to the Board of Water Supply and the Alapai Transit Center was also similar to that of the Mission Homes. Mr. Lao shared that the water fountain that stands in front of the Board of Water Supply building on South Beretania Street is fed by a slightly brackish well, usable for landscaping; the water was fresher before but has become brackish over time.

Moving east, Mr. Lao gave the background of the former Ward Estate, which is now the current site of the Neal S. Blaisdell Center. The Ward Estate was owned by the Ward sisters and was famous for its ponds and springs. The Kaka‘ako area contains brackish water. During the construction of the Neal S. Blaisdell Center two wells were drilled. The well farthest *makai* was considered very brackish and saltwater fish were dropped into the newly created pond. The *mauka* well was still usable but too brackish to drink, so it was used to raise *koi* (carp; *Cyprinus carpio*). The lower pond surrounding the arena is strictly artificial and fish such as *pāpio* (juvenille crevalle), tangs, tilapia, and *‘ōmilu* (variety of crevalle) can be seen. Mr. Lao stated that approximately ten years ago a sewer project was being conducted along Ward Avenue, which drained off a lot of brackish water so the water table became increasingly salty.

Traveling to the eastern portion of Kaka‘ako and the edge of Kālia ‘Ili in the *ahupua‘a* of Waikīkī, the Ala Moana Center and vicinity was also very swampy. Mr. Lao recalled traveling

toward Diamond Head on Ala Moana Boulevard and turning *mauka* onto Atkinson and noting the whole area was very swampy—filled with stagnant and probably brackish water. To create the Ala Moana Center, the area used fill material from Ala Moana Beach Park. Mr. Lao added that Hawaiian Dredging Construction Company was smart when they offered to dredge the canal if they could keep the debris. The debris was then transferred and used to fill the Ala Moana Center. The last area was filled with material from other sources. The areas around the center including Liberty House (now Macy's), the Ala Moana Hotel, and the Ala Wai Hotel were not filled in until about 1966. Mr. Lao shared that a small community of Native Hawaiian families called the swampy Ala Moana area home until they were displaced for the construction of the shopping center. The families eventually made their way *mauka* onto Board of Water Supply land. The Board of Water Supply was given land via a Presidential Decree to create several sites for water tunnels including a future Papakōlea Shaft, Wai‘alae Shaft, and the Kalihi Shaft. The Papakōlea Shaft was located just *mauka* of Roosevelt High School. During Mr. Lao's employment at the Board of Water Supply, he recalled the Land Division getting many complaints of a piggery near the Papakōlea Shaft. Schools and neighbors complained of the smell the piggery emitted. Upon inspection, he added that one particular family raised a pig that weighed approximately 500 pounds. The outcome of the constant complaints was that the Board of Water Supply eventually gave 10 acres to the Department of Hawaiian Homelands and to the squatters. The Board of Water Supply only kept 1 acre of land. Approximately ten years ago the Department of Hawaiian Homelands utilized the land to build a subdivision.

The former KGMB TV station and offices were once located near the intersection of Kapi‘olani Boulevard and Ke‘eaumoku Street. Mr. Lao recalled the TV station being there for the last 50 years. Mr. Lao said there are a couple reasons why the TV station chose to stay at the Kapi‘olani Boulevard location for so long. The first reason was that swampy land was cheap. Prior to development of the Kapi‘olani Boulevard area, the land was originally swampy. The second reason was that the swampy location made for good ground conduction of the transmission tower. As Mr. Lao explained, plain water is a conductor. However, when salt is mixed in it is an even better conductor. Mr. Lao recalled his mother-in-law sharing her stories of the area around Kaheka Street, which is located near the former KGMB TV station location that was also swampy here and there. Mr. Lao's mother-in-law once frequented the area to purchase duck eggs, swamp cabbage, watercress, and taro. Once the Ala Wai Canal was dredged, development of the area, and sewers were constructed, the swampy areas in the vicinity eventually dried out.

Mr. Lao shared that the Ala Wai Canal was originally conceived in 1927 by the developers as the "Venice of the Pacific." The original plan was to have an entrance and an exit in the canal; buildings were to be constructed along the canal; and boats and gondolas were to navigate the Ala Wai waters. However, an exit from the canal was never constructed. The proposed outlet would have extended to the current location of the Waikīkī-Kapahulu Public Library and would have turned *makai* connecting to the sea at the Kapahulu Groin so the canal could have better circulation. Due to the current construction of the canal without an outlet, the water is very stagnant, especially near the Waikīkī-Kapahulu Public Library, and filled with debris and other noxious items. To Mr. Lao's recollection, the last time the area by the library was cleaned out was approximately 15 to 20 years ago. He believes it was mostly a surface cleanup of cars, tires, and grocery carts at the eastern end. The western length was suction dredged and the spoils were dumped out to sea.

From McCully Street to Beretania Street, this area was also considered swamp land containing shallow, open water. The reason this area existed as a swamp was the Waikīkī area acted as a large beach berm. Mr. Lao explained that over time waves piled up sand above the tidal line which eventually accumulated over the years. At low tide a connection was made between Waikīkī and the “mainland” portion where people used go on horse drawn wagons to enjoy long holiday weekends and access the beach. Mr. Lao noted that members of the Hawaiian monarchy had dwellings in the area as well.

The Date Street area was also known for intermittent ponds. Mr. Lao recalled a sewer project conducted along Date Street which did a lot to dry up the caprock. He explained that below the surface is the caprock coral. The caprock that dried up in this area was the first 40 to 50 ft of formation below the surface. He shared that the location of the Saint Louis Clubhouse was once famous for its springs and ponds where Hawaiian royalty once bathed. Later the springs and ponds were used to farm *koi*. Japanese wives liked the *koi* from these specific ponds because the fish supposedly had significant healing properties for women after giving birth.

Traveling further east toward the Kaimuki Shopping Center is one branch of the famous Mōʻiliʻili karst cave. Mr. Lao doesn’t believe it’s a karst, but rather an existing surface water feature on the caprock. He also shared a story about these underground features:

> The Kaimuki Inn as it was known, was a famous place for eating. A good friend of mine used to go there and grew up around there as a kid. It was known for not being very well kept ‘cause it had holes in the floor and stuff. Its attraction was good economical meals and the local atmosphere. One of the guys I know, I never asked him directly, but the person that knew him, this guy used to fish through cracks in the floor boards. He used to fish for things like mullet. And things like that. So that was a famous story. One of the legends there Mōʻiliʻili is that the sharks used to come up to Kaimuki—swim up from Waikīkī and listen. The sharks would listen to the fishermen. And when the Hawaiians would go down the sea to fish the sharks would scoot back down to Waikīkī and gobble up the fishermen for dinner.

Mr. Lao added that the area around the former location of the Varsity Theater was once swamp land. Father of Kui Lee, Billy Lee, reminisced about the area with him:

> And Kui Lee’s father called me up one time and said, ‘Oh yes, we used to get fish out of there.’ That’s Kui Lee’s father. Yeah. Out of the ponds where the church is located—Church of the Crossroads? There were springs there when the former water table was high.

Mr. Lao had also been inside the Mōʻiliʻili cave system. After entering the limestone cavern, Mr. Lao traveled to the far end, which was blocked in due to a collapse. The area was filled with broken rock and rubble making it impassable. Mr. Lao noted that water was still able to pass through, however, people were unable to continue any further. As Mr. Lao stood there, he felt something slither over this foot. A scientist from Bishop Museum was with Mr. Lao on this particular field trip and noted that blind spiders and catfish are present within the cave system. Mr. Lao recalled the water being murky and being able to see approximately a foot down into the water before visibility was unclear. He added that wading through the water and kicking up mud below didn’t help the visibility factor either. On another occasion, Mr. Lao recalled taking an aquatics biologist into the cave system when he noticed *ʻōpae*. Mr. Lao indicated that Mōʻiliʻili is

approximately 2 to 3 miles from the nearest outlet to the ocean so the *‘ōpae* were from a freshwater source.

People have asked Mr. Lao if he could guide them on a tour of the Mō‘ili‘ili cavern or where they could enter the karst, but he highly discourages anyone from accessing the caves.

> One time I was with some people from work, some guys from my section. One of the guys had a gas meter along and he said, ‘Hey, hey look! Look, look! This thing, the carbon monoxide level here is on the verge of being dangerous. This cannot be so good for unsuspecting people.’ And this reminds me of a time I went down there 10-15 years previous to that, that I was down in there and I thought, ‘Gee, you know, being down underground should be cool instead I’m on the verge of sweating.’ And so was the person from the *Advertiser* who was with me and he felt that way too. But the sweating and the feeling of being hot is a typical reaction to carbon monoxide poisoning but I was not aware at the time. If the carbon monoxide content was higher, I wouldn’t be here but the concentration was high enough to make me react.

CSH asked Mr. Lao if he knew the source of water that feeds the cave system. He explained that there are three levels of water: surface, caprock, and via underground pores in the basalt bedrock. The water source that feeds the karst system comes from all three of these sources. He explained that the water from the surface enters the porous and permeable parts of the caprock. Eventually some of this water collected from the surface infiltrates the caprock and enters the cave system. The water that travels through the pores of the basalt through the thin caprock located at the edges of the mountains and valleys. The Mō‘ili‘ili cave system is primarily fed from the watersheds of Mānoa and Pālolo. When asked if the proposed detention basins would have an effect on the cave system and the creatures that live there, Mr. Lao stated he does not think it would, at least not pollution-wise.

The cleanest drinking water is available closest to the mountain range but it begins to get polluted when it encounters development on weathered or non-weathered volcanoes. For example, in areas above the H-1 freeway that are not developed and where the peaks are high, the water is considered to be very pure. However, once the water begins to enter the area of the plains, encounters development, or areas that were formerly used for agriculture such as sugar cane, pineapple, and cattle—then the land use will affect the water quality.

> For example, the pineapple plantations—when they were in existence they used pesticides that got into the ground water. So you have pesticide pollution all over Pearl Harbor. So Pearl Harbor in general—not as clean as you might think. And the towns that grew up around there—if they had cesspools like back in the old communities—then the water went down directly, through the weathered basalt, down into the basalt caprock, where it affects good water. And even in the modern community, the fact they’re on land that was used for agriculture and something like—they do have—sugar left its imprint, but not as bad as pineapple. Pineapple pesticides were a lot higher in toxicity. And in the places they proposed replacement agriculture that’s got to be watched carefully too to make sure the insecticides, herbicides, and fertilizer don’t get into our water.

Mr. Lao stated that sugar cane cultivation utilized more brackish water by pumping from sources located beneath the caprock and pumped to cane at higher elevations. The brackish irrigation water escaped the root zone, infiltrated the water table, and increased its saltiness from its natural state. Without any development or agriculture the water was fine. In contrast, Mr. Lao added that previous agricultural efforts in ancient times such as *lo‘i* had no negative effects on water use. Taro cultivation needed to be as waterproof as possible so water was kept inside the *lo‘i*. As taro cultivation began to transition to rice cultivation, agricultural methodology was similar so there were no major changes especially to the ecosystem. Pesticides and insecticides were not used for taro and rice cultivation. Mr. Lao suggested that animals such as water buffalo were probably used to till the *lo‘i* under the Chinese for taro and rice.

As previously mentioned, another method of retrieving water was via tunnels and wells. The Board of Water Supply drilled several tunnels in Honolulu during the early 1900s and stopped by the early 1930s. Several tunnels exist within the Ala Wai Watershed including two tunnels in Mānoa, one in Pālolo, and as previously mentioned, a proposed one in Makiki slightly *mauka* of Roosevelt High School. The water derived from the tunnels is described by Mr. Lao as pristine due to the fact that there was no development in the vicinity. Tunnels are drilled at a slight incline upwards. The Pālolo tunnel is drilled under Ka‘au Crater. The tunnel is at an elevation of approximately 1,000 ft, has a length of several hundred ft, and yields about half a million gallons of water per day. Mr. Lao stated the tunnel sometimes has a bit of bacterial pollution. This might be attributed to the fact that there is a swamp within Ka‘au Crater that empties into the Pūkele Stream that eventually connects to the Pālolo Stream. Another reason for the bacterial pollution is human and animal contact with the water.

Newspaper articles and hiking books discussing various hikes and associated waterways island-wide attract adventure seekers. When people do not *mālama* hiking trails and waterways, many of these resources become polluted with trash and/or bacteria, such as giardia, a bacteria transmitted via human fecal matter. Mr. Lao is aware of giardia cases on Maui and doesn’t doubt O‘ahu had a few cases. Giardia causes violent diarrhea and other gastro-intestinal problems. Leptospirosis is a common bacterial infection known throughout the Hawaiian Islands spread by rodents. Mr. Lao stated that leptospirosis has been present in theIislands for centuries and was probably brought by the first Polynesian settlers. Shigella is another bacterial infection transmitted via snails. Although shigella is transmitted by all snails, the most common carrier snail is the African snail. Originally, African snails were brought to Hawai‘i as a food source but it was later discovered that they are disease carriers. Today, African snails are a backyard nuisance but they are still considered to be a delicacy in other parts of the world. All of these bacterial infections are spread when an infected person or animal comes in contact with a water source. When a person enters the infected water source with an open wound, ingests the water, or opens their eyes underwater—they become infected.

As far as fish and/or wildlife that utilize the streams of Mānoa and Pālolo, Mr. Lao stated that you will find some fish where the water source begins. As you travel *makai*, you will begin to see native species of fish. As you travel further down and encounter brackish water, you will encounter tilapia and saltwater fish. Mr. Lao is aware of an *‘o‘opu* population in Mānoa. An aerial image with the location of significant sites such as springs, ponds, wells, etc. pointed out by Mr. Lao is depicted in Figure 7.

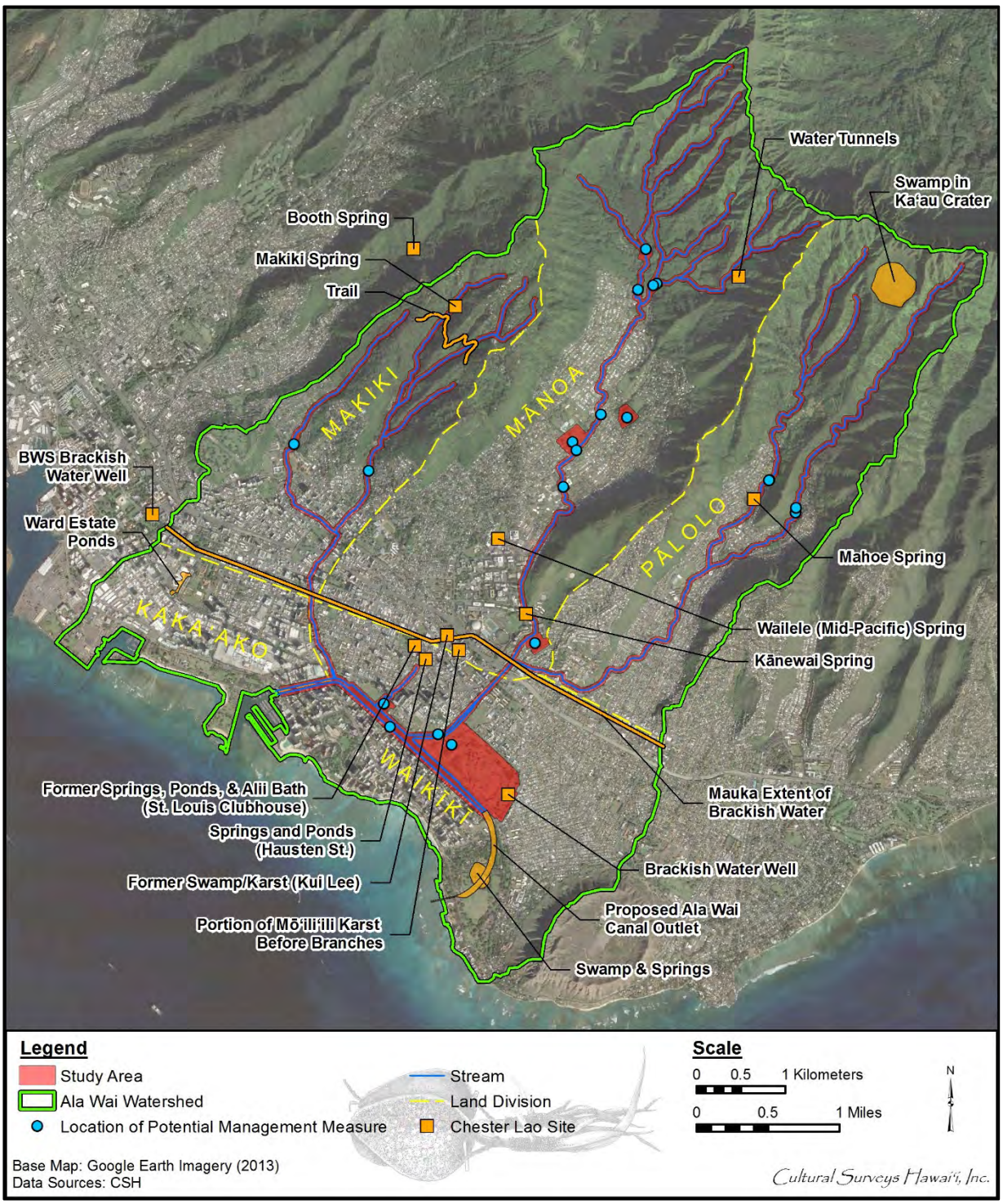

Figure 7. Google Earth Imagery (2013) depicting the Ala Wai Watershed, potential management measures, and significant historic and archaeological sites pointed out by Mr. Lao

4.3 Evelyn Giddings

CSH interviewed Kupuna Evelyn Giddings on 27 May and 11 June 2014 via telephone. Ms. Giddings was born on 28 March 1925, in Pā‘auhau, Hawai‘i. Her parents, Fred Giddings and Eva (Clapper) Giddings, were both from the mainland East Coast. Her father, a school teacher in Vermont, was drawn to Hawai‘i to plant coffee in 1899 but instead took a series of odd jobs while her mother taught school at Kukuihaele Elementary. The Giddings family moved to Honolulu when Ms. Giddings was two years old, and except for a stint in New York state as a little girl and later in college, she has lived in Hawai‘i since she was born.

As a ten-year-old girl, Ms. Giddings lived in Kapahulu. Each Saturday, she walked to French class rain or shine, and walked the whole length of Ala Wai Canal to the McCully Bridge. She recalled the platforms along the edge of the Ala Wai Canal on the Waikīkī side, where people would catch mullet, and the way the area flooded during heavy rain, bringing debris from *mauka* all the way down:

> There were all these fishing platforms, with the little planks that went out and there was this little chair with somebody sitting there catching mullet. So that was always interesting. But the most interesting part of it was when there was heavy rain, and the floods would bring all this debris down.

At that time, McCully Bridge had tracks for trolley cars, and the tracks of the trolley cars were supported by posts. The posts acted like a debris catchment:

> And that made all the debris back up against it, because it was like a dam, it strained all that debris and the water went through the spaces in between . . . You know those trolley cars, some of them didn’t have any sides. They just had a railing and you can stand by the railing and hold on to a bar. Wow, it was scary when it went across the bridge. You were standing on the little running board holding on to the bar.

The posts on the Diamond Head side of the bridge acted sort of like a dam, trapping a lot of the debris, all along the Ala Wai Canal. “There was so much stuff floating, the rats were running around like it was dry land,” Ms. Giddings stated. “They thought it was a picnic. It was a sight!” She particularly remembers the time she accidentally dropped her French book one rainy day when the bridge had flooded, and she had to fish it out from amongst all the floating debris.

Besides rats, the flow of water in the Ala Wai Canal during times of heavy rain brought all kinds of other debris, including things she did not expect such as chicken coops and dead pigs. Ms. Giddings remarked that only recently was she able to make the connection that she had moved to a place where the debris she had seen as a child had originated. She stated the following:

> There was all kinds of debris, and there were chicken coops and all that. I had never made this connection before, when I was 16 and moved to Mānoa, that we moved to the place where chicken coops come from. Because at that time, people who were farmers were still living along the stream, in Mānoa.

Ms. Giddings explained that the section of the Ala Wai Canal before McCully Street is water from two streams which connect down by Kānewai Park: “It’s the Palolo and Mānoa Stream(s). They meet somewhere above—by the time they reach Kaimuki High, they are already connected.”

In 1943, Ms. Giddings graduated from Roosevelt High and went on to the University of Hawai‘i at Mānoa until 1945. She left that year to attend art school in New York State. When she came back in 1949, she lived in Waimānalo for three years where she bought a 2-acre farm plot with her husband and their friends.

Ms. Giddings and her husband divorced when their second child was three years old. When her two girls were 12 and 14, she adopted her third daughter. Ann, Lynn, and Morlee all together have ten children making Ms. Giddings a proud mother and grandmother.

In the past, Ms. Giddings noted that one could expect a rainy season and a dry season. But these days, she related that “You can’t tell when you’re going to have a flood.” The flood of 30 October 2004 particularly stands out in her mind as the worst flooding that she can remember in all the years she has lived in Mānoa. During a period of a few hours, heavy rainfall resulted in over 10 inches of rain measured at the Mānoa Lyon Arboretum, according to the National Weather Service.

Ms. Giddings was in Mānoa living in the Krauss house on top of a hill when the 2004 flood occurred.

> We knew it was raining hard, we didn’t go anywhere, and we had no idea that Safeway and Longs were nearly flooded. When we came back and saw the car up on the tree . . . the [Mānoa] stream goes past faculty housing and the debris stuck three feet high up the fence, we couldn’t believe that was going on and we were all sitting at home and thinking, ‘My, it is raining hard.’

It was during the aftermath of the 2004 flood, while surveying the damage it wrought, that Ms. Giddings had a sudden insight that the flood was caused in part by the water pursuing a former path: “I had sort of an intuition that the river remembered how it used to go. And it went on an old path. Because I can imagine that it has moved back and forth across the valley for thousands of years.”

She described the effect of the water being “plugged up” somewhere combined with the intense rainfall. This resulted in the streets becoming rivers in their own right:

> It started raining down. I guess it came from Woodlawn. The paving of the street is always like a river, right? If it can’t go down the storm drains, then the streets look like rivers and it’s all collected right there by Safeway . . . When it was coming down on Woodlawn, it was already outside the river. It was coming down the streets, and there by Long’s Drug Store, it just kept on going and through the Noelani School and then through the University Campus. Instead of going down by the little East West Center Garden, then it started organizing by the dormitories and it went back to its bed . . . it went on the back corner Mid-Pacific and down through the library, and back into the quarry . . .

When asked how high the waters rose, Ms. Giddings related that there was debris stuck along the chain link fence on the side of Noelani School that was more than 2 ft high: “It was right there, I guess it’s the lowest point where all the water from Woodlawn [was] coming down the pavement. The paved streets all connected together with the water.”

A “big torrent” rushed down Woodlawn Drive, and it went through the school yard of Noelani, through the cafeteria and the rest of the East West Center before making its way down to the basement of Hamilton Library at University of Hawai‘i (UH) at Mānoa. Ms. Giddings even saw debris that was left stuck on the fence by St. Francis School.

By the next day, the flood had abated and people were able to drive around Mānoa. Ms. Giddings recalled her astonishment at seeing cars wedged in trees along with lots of debris at the 3 or 4 ft high mark along the UH faculty housing fence next to Mānoa Stream.

When asked if there were other floods besides that of October 2004, Ms. Giddings shared the following: “I don’t think we ever saw anything like this, on such a big scale. When we first moved to the valley, my brother and I would go out during heavy rains to see what the streams were doing under the bridges and all. But now I stay home to keep dry.”

When she was 10 to 12 years old, Ms. Giddings also remembered seeing people fishing along the Ala Wai Canal for mullet. But she does not know if the fishing was for commercial or for individual consumption. As for swimming, she has never seen anyone swim in the canal: “Nobody ever did it. It wasn’t very inviting. It always looked slimy and it looked like stuff was floating in it.”

Discussing the proposed project’s plan to put in a series of flood walls, Ms. Giddings noted the wall on the Waikīkī side is higher than the golf course. “I can imagine it might back up higher than Kaimuki high school, it might,” she stated. “They just have to make sure it gets out to sea.” Making the walls at least 3 ft tall is a good idea because, as Ms. Giddings pointed out, “the sea is mostly rising anyway. I think it’s like putting sandbags; you got to keep making it higher and higher.”

In addition to Mānoa, Ms. Giddings is also familiar with parts of Makiki Stream, as she and a friend used to walk along the stream to attend meetings for the Girl Scouts. They would go underground as the stream wound up going through the tunnel below Prospect Street:

> I remember it was spooky going through those tunnels [laughs]. We would always be afraid there would be a flash flood somewhere above there and there would be a wave of water that would come down; it was a silly thing to do. But we did it because we were children.

Fortunately, no flash floods occurred during her forays into the tunnel but Ms. Giddings described that Makiki Stream did not have much water in it and she was surprised at how much of the stream was channeled in tunnels:

> We’d walk over to Makiki Street, and then get down to walk through the tunnels to Beretania Street . . . I think we couldn’t get out until King Street . . . it was between the market [on Beretania] and that church [Church of Jesus Christ, LDS] there.

In contrast to Makiki, Ms. Giddings’ recollections about Mānoa Stream are much more extensive, with her experiences with the latter stream closer to its source, in the uplands of Mānoa:

> The Mānoa stream, we experienced all above Punahou, up in the valley. It was like rock-hopping and doing waterfalls, swimming holes and all that. But by the time we found Makiki Stream, going under Nehoa, it was almost flat . . . there wasn’t as much water. We never experienced much water.

Ms. Giddings described her first summer in Mānoa, in the summer of 1941, when she was 16 years old:

> I was really happy because there was a vacant lot next to our house, and the person who lived at the other side of the vacant lot had a horse, a horse tied up in the vacant lot. Oh, she got tired of riding her horse, so I would exercise her horse for her. Would I ever! [Laughs] I almost thought I died and went to heaven. So every day I would ride this horse up the trails. The street ended where the flashing light is, above Wai‘oli Tea Room . . . So all that has been developed since 1945, since there were no houses built during the war.

Numerous trails allowed people to ride up Mānoa Road to Lyon Arboretum. Ms. Giddings recalled that at the end of the street, there was a house of a man named Mr. Agee.

When asked what Mānoa looked like before the UH faculty housing, Long's Drugs, and Safeway were built as part of the Mānoa Marketplace, Ms. Giddings related that the flat area by the drug store chain was populated by rows and rows of temporary housing made of canec. Canec consists of sugar cane fiber, the material left over from sugar cane after the juice has been removed. It was used as a fiberboard material in the construction of houses in Hawai‘i from the 1930s to the 1950s (Hawaii State Department of Health 2011). Ms. Giddings shared the following:

> They really were temporary but they kept them for years and years. After the war, these rows and rows of houses, they would joke about people getting mad and punching the wall and their fists going through the neighbor's house. They were just canec.

The houses could be rented by anyone who needed housing. They extended all the way from where Long's Drugs is to across the stream behind McDonalds, where the Innovations Center is currently located.

The discussion turned to locations where water could be detained, especially Woodlawn Basin, by East Mānoa Road and by Lowrey Road. Ms. Giddings noted the location is right below the cemetery, as "that's the only place with no houses." She explained the place where the Woodlawn Detention Basin is according to her understanding:

> When you go up East Mānoa Road, past Safeway and all of that . . . and just before the road divides and one goes to the cemetery and before it goes up to houses, then on the Pālolo side, of East Mānoa, is another section of the cemetery and the arm that goes over toward one of the little rivers . . . but oh, there's not much water . . . The big part of Mānoa stream goes on the ‘Ewa side of the cemetery. And that would be just a catchment for that little arm.

After asking the definition of catchment dams, Ms. Giddings commented on the Waihe‘e Debris Basin, which she described as being "over the Pālolo side of the bird park up there." The discussion shifted to the reservoir in Nu‘uanu, which Ms. Giddings described as being a big reservoir. Although she noted that Nu‘uanu is an entirely different shaped valley, Ms. Giddings believes it can be a good example. What is needed is something that can hold enough water with the capacity to release the water slowly:

> If there was something that can retain the water and let it out more evenly when it's running . . . because all of that water comes rushing down . . . I am sure that's what happened in October [2004] because the streets acted like tributaries of a river and they brought all the water together; every street was feeding the big rush that came down on Woodlawn Drive and into the lowlands.

Because the streets had effectively become tributaries of Mānoa Stream, feeding the surging flood on Woodlawn Drive, the resulting force was powerful enough to lift cars up into trees, a fact that Ms. Giddings emphasized several times during the course of the interview with CSH. She pointed out the drainage systems also need to be addressed in order to prevent future floods:

> I've driven down the university on University Avenue and seen the manhole go 'puputt-pupputt.' Because there was so much water rushing down underneath the manhole covers that it was lifting the manhole covers up. There aren't enough underground storm drains to be adequate for floods. And are we going to have more floods now because of global warming? We are.

Water, according to Ms. Giddings, has its own nature and does not like to be forced to turn corners. She explained the following:

> You know the place behind . . . where Lowrey Avenue joins East Mānoa? That culvert has to turn corners. Water doesn't like to do that. It likes to meander and it's not natural for it to be cooped up like that. I can't imagine what that must have looked like when the flood was coming; it was of course going over the bridge in Lowrey Avenue, I'm sure. Oh, water, water, water.

While discussing the definition of debris and catchment basins, Ms. Giddings pointed out the two proposed systems near Waiakeakua, Waihī Debris Catchment and Waiakeakua Debris Catchment:

> You can't really tell here how steep it is getting [looking at map]. That's where the Arboretum houses are. The place where they have Waiakeakua is farther than where there was a swimming hole. We used to ride our bicycles there when we moved back to Mānoa . . . in 1953.

Ms. Giddings voiced her curiosity about what the debris catchment is composed of and who will clean it:

> They also have a detention basin. I imagine [these] are meant to hold water. But my goodness, debris catchment . . . I don't care about the difference but I want to know what they consist of. What is one and how much water does one detention basin hold? Would it be like what is in Nu'uanu? A reservoir? Would it be like a reservoir?

Another concern is the state of the drainage system. She stressed the necessity of cleaning the drains regularly and ensuring that people do not throw trash into the storm drains as such actions will plug them up:

> The storm drainage does not work—it's too small for that kind of storm. They need to be cleaned regularly, inside and out. Even when it is not a major flood. You see

> people raking in their leaves, into the storm drains. They are not supposed to put anything in there, as these are just for the water, to clear it.

One time Ms. Giddings was driving down University Avenue, past the law school and manholes, and she saw that it had been opened and "it spilled out grass. It looks like a horse . . . it got lifted by the pressure of the water and had had a bunch of grass sticking out of it."

According to Ms. Giddings, no major floods have to occur in order for the drainage system to show its defects in Mānoa:

> It was not even a bad flood, there was not even a lot of water, not even a major flood. All that water coming, I never thought of streets being like tributaries carrying all that water, each one feeding the one below. Until they get to Woodlawn Drive, where it usually gets wide.

The lower part of Woodlawn Drive is wide because at one point, a tunnel was planned to go from Mānoa through Waimānalo.

When asked if she has any recommendations regarding the drainage system for Mānoa, Ms. Giddings stated the following:

> When you think of those storm drains, they are about 10 (years old), things are growing in them . . . The storm drains are inadequate. They can't handle that kind of problem, that much water at once . . . So the storm drains, the streets turn into tributaries of the river.

Whether it is due to inadequate size, or being clogged up, the drainage's inability to clear water in times of a flood or heavy rainfall leads to water overflowing so that "the streets become the river." Ms. Giddings stated, "It's just going down and meeting another street and going down and meeting another street . . . These are the streets being tributaries. It's kind of amazing to me that streets would act like rivers."

In response to CSH's query if she can recall Makiki Stream acting the way Mānoa Stream does, Ms. Giddings noted that the Makiki Stream that she experienced was different because the water was already tamed by the cement as well as distance from its source:

> It [Makiki] was different from the part of Mānoa that I knew. I knew the upland. The river above the valley. And this was the end of Makiki stream and was just all channels and cement . . . even when it was going under apartment buildings and things.

According to Ms. Giddings, the October 2004 flood probably started gathering force while still upland and by the time Mānoa Stream reached Kanaloa Drive and Woodlawn Drive, the flood waters could not be contained.

By the time the water had come rushing down Woodlawn Drive, it arrived in a place where the street was much wider; because there was so much water during the October 2004 rainfall, even though the street was broader, the water was still 3 to 5 ft high. Ms. Giddings emphasized her surprise at the sheer volume of water: "That's a lot of water. All the *puka* [hole] in the chain link fence had grass stuck on them. It was just unbelievable . . . This is a street, not a river, but a street."

It did not help matters that below Lowrey Avenue, the water is all channeled and cemented, and it forces the water "to turn corners and bump into walls [and] it doesn't like that."

Although Ms. Giddings did not witness the flood as it was happening, she saw its immediate aftermath:

> I just saw the results . . . of course the university. There were people trapped in the library. They had to get out from the windows . . . and all that stuff stored in the basement of the library . . . it took them years to dry it out. Some of it was ruined.

Water, whether in the form of rain or the surrounding seas, is a valuable resource that Hawaiian culture understands and integrates into everyday life, as Ms. Giddings illustrated in this *mo‘olelo*: "It's just that my father came in 1899, from Vermont . . . He asked this Hawaiian man, 'Where is Judd Street?' This Hawaiian man said, 'You walk up Nu‘uanu Street, and when it starts to rain, that's where it is.'"

Years later, the continuing resonance of using the natural landscape to explain borders was made readily apparent when Ms. Giddings took a tour with the Board of Water Supply and a speaker explained geological and cultural issues connected to water:

> When we got to the big reservoir in Nu‘uanu, the woman who was talking about the cultural side said each kind of rain has its own name. There's one rain that comes down to the valley and stops on Judd Street. And that's what the Hawaiian man had told my father a hundred years ago.

Using rainfall as a natural way to demarcate and mark borders is part of Hawaiian culture and such things were not understood by Westerners who carved up the land without much consideration or appreciation of its natural and cultural features, noted Ms. Giddings while musing over her father's story of Judd Street. In Mānoa, Ms. Giddings related that "Lowrey Avenue is our Judd Street here in Mānoa."

On 11 June 2014, CSH provided Ms. Giddings the answers to her questions regarding the debris catchment which is designed to catch tree branches and urban trash debris with the use of embedded steel poles in trenches that resemble a comb. Debris catchment will be placed where workers can clear it. The discussion focused specifically on the Woodlawn Debris Catchment, and then the Detention Basin, a three-sided basin constructed over and around the ditch with a culvert that allows normal water through while stopping water from gushing. A detention basin holds excess water to be released later.

Visualizing the volume of water in a detention basin, Ms. Giddings asked who is expected to open the gate of the basin in cases of flooding. She also wondered how the system of gates would work. Her point was that the detention basin has to be located in a place where no houses are above it. "The debris will make its own dam, you see. So they will make their dam where they please."

Noting that she has seen gates in Mānoa located where the road divides and one branch goes to the Arboretum, Ms. Giddings asked what would the gate(s) be for Woodlawn Detention Basin, or in the Debris Basins, and how would the gates be activated. (In a follow up call, CSH provided the answer that no gates will be on any of the debris and detention basins, and the Woodlawn Ditch Detention Basin has an arch culvert that is 4 ft 1 inch high and 12 ft wide.)

She related that the gate in Mānoa and the ones she has seen are ordinarily made of two cement walls, with an opening of 2 to 3 ft with slots that stop the water. The one she has seen in the Mānoa area may have been something to back up the water in order for farmers to receive irrigation for their crops, including bananas, ginger, and ti leaves.

Ms. Giddings then related her memory of a stream up on Mānoa Road, where the road becomes more narrow and goes to the Arboretum. The stream is located by the end of the Mānoa bus line, on the Pālolo side and where the bird park used to be which is now Treetops restaurant. She recalled that when she experienced this stream during 1941 to 1945, the water was running and it was clear.

The reservoir in Nu‘uanu is something that Ms. Giddings considers a model, and if there would be three of these kinds of reservoirs above the houses, such a plan would be “a good thing, depending on how much water they would hold.” Having the same kind of reservoir is not exactly what she would want for Mānoa, but for her, what is critical is that the reservoir water in Nu‘uanu percolates down. Ms. Giddings suggested that a combination of debris catchments and detention basins would be best in Mānoa, above the houses where the farmers are.

When asked what she thinks of the proposed detention basins and debris catchments, Ms. Giddings shared that she is fine with what is being proposed, and that the goal is to ensure that Mānoa Stream maintains its course:

> I think the most important part is to prevent it from changing its course. That’s what happened in the university, and the basement in the library getting all flooded. That was edging forward in getting run over where the campus is . . . It needs to be retained.
>
> As I said, water likes to meander, it doesn’t like to turn corners the way it did by Lowrey Avenue. They’ve got it contained in straight lines . . . from Lowrey behind the apartments, and it goes under around Woodlawn. It goes to East Mānoa and then Woodlawn. There’s a very low place behind the information center.

The way the 2004 flood invaded Hamilton Library at the university was unexpected, Ms. Giddings maintained, because the stream is far enough from the library:

> Yeah, that’s a far place from the library . . . geographically speaking it isn’t, but still nobody expected the way water to be running all the way to where they built the library. Look at all the work they had to do to make the library waterproof . . . it’s been more than a year drying out all the papers.

The flood was such a threat that people were climbing out of the library windows because water was starting to pour in, and they could have drowned in the basement of the library, stated Ms. Giddings. As a result of the flood, Hamilton Library lost thousands of archival photographs, at least 90,000 maps from the library collection, countless government documents, some of which had floated down to Dole Street. The flood also shut down computer servers and the School of Library and Information Sciences (Leidemann 2004).

Even to this day, reflecting on the Mānoa Stream she has known since she was a girl, Ms. Giddings still found it astounding the way the water behaved that day, on 30 October 2004:

> It was a weekend, a Saturday afternoon. I just can't believe I was sitting there in Beatrice Krauss' house, not knowing that this flood was happening down there. But seeing the streets, the roads, act like tributaries and they make their own river, and they are all paved. If it has been raining . . . it's all going to run. You can make a road map and it would look like a river, with all the tributaries, and cul de sacs and the whole thing.

Speaking about the topic of water remediation, Ms. Giddings recommended that if project proponents want to learn about how water can behave, they should contact Jennifer Greene who established The Water Institute. Ms. Greene is a specialist regarding water who integrates the ideas of early twentieth century philosopher and social reformer Rudolf Steiner:

> She has remediated a lot of streams in places where it has gotten stagnant and the fish has all died . . . She's using his [Steiner's] ideas about how things work together. Water doesn't work by itself—it has to do with the boulders and the mud, to breathe and everything.

Ms. Giddings noted that in Oregon where her daughter lives, boulders were installed in one place to help aerate the water:

> It's splashing and gurgling around these boulders—it cleaned the whole thing up. It needs aeration and that's how the flora and the fauna can get their sustenance from the river. If it's not aerated, then too bad.

Although Ms. Greene is known to work with stagnating streams, she may well be able to assist with Mānoa Stream, which Ms. Giddings characterized as "an overactive stream," in order to prevent such floods like 2004 from happening. The key is also to look at the drainage: "It's a big drainage when you look at it, from above like that. And there's only two roads to get out, only Punahou and University Avenue."

Ms. Greene is "a water whisperer" who demonstrated the way water acts. Ms. Giddings described an event where Ms. Greene took a waxed sliding door and poured water from the top: "And the water didn't just run down—it went 'owee, owee, owee' back and forth—what water likes to do . . . it has to do with channeling water."

Ms. Giddings met Ms. Greene when the latter came to the Waldorf High School to talk about water. Afterwards, she took Ms. Greene to Kawaiku‘i Park, at the shore in the southeast, between ‘Āina Haina and Niu Valley where there is a hill called Pu‘u Ikena. Bubbling springs underwater are exposed when the tide is low.

> Each time the tide goes out, it makes little rivulets. It springs out of the sand and meanders down into salt water. And it makes a little dam. It's fun to watch and it's fun for even the elementary school to see what water does.

Ms. Giddings collected seaweed for her composting in Kawaiku‘i, and related that debris was brought to the area by the action of the tides and water:

> And then, of course you can see all kinds of debris down that little cove . . . So I would clean up plastic bags and people's underwear, whatever happened to come . . . because there is a culvert there too. There's a culvert where the rainwater comes from the streets on the hill above the park. But the springs come from underground.

Due to its shape of a square sea wall that is farther out than the coast line, Kawaiku‘i Park might have once been a fishpond. Ms. Giddings also shared that there are huge coral boulders that are from an earlier geological time, when the water was lower from the ice age. It reminded Ms. Giddings of another experience when she witnessed what she thinks was once the edge of the island.

She was assisting an artist who was painting a fresco mural (painting on partially dried plaster) and he was using volcanic cinders to make a wall 20 ft high and 90 ft long in the Leeward Community College Theater. The project needed "a lot of plaster and a lot of sand," so Ms. Giddings was driving down Ward Avenue one day, at the intersection of Ward Avenue and Kina‘u Street, where there was digging for a parking lot:

> And up this ramp comes a big truck loaded with black sand. I parked my car . . . talked to the contractor, and he said ‘Oh, you could have all you need and I will fill the truck for you . . . ‘
>
> I looked down and there were three different distinct layers of black sand, each separated by a white crust. And you can see that something happened between each layer, and below those three layers of cinders, there was white coral beach sand. At one time, this had been the edge of the island; that's how the Hawai‘i Island is growing, little by little.

4.4 Makahiapo Cashman

On 1 April 2014 Mr. Cashman was contacted to participate with the Ala Wai Watershed Restoration project. Mr. Cashman agreed to assist in the project process. On 15 April 2013 CSH met with Mr. Cashman at Ka Papa Lo‘i ‘o Kānewai, also known as Kānewai, a Hawaiian cultural research and outreach program where he is the Director. In the *ahupua‘a* of Waikīkī, Kānewai is the only centrally located venue in Honolulu that provides a culturally place-based experiential learning center and *pu‘uhonua* (place of refuge or sanctuary) for Hawaiian lifestyles as well as Native and Polynesian introduced plants. Kānewai provides a venue for Hawaiian and Pacific cultural activities with hands-on experience through experiential learning curricula and lessons. Kānewai is located on Mānoa Stream and was the first *lo‘i* to be reopened after the development of Mānoa Valley in the early 1980s.

Mr. Cashman is from O‘ahu and grew up in ‘Ewa Beach and Hau‘ula. He attended school at St. Joseph's in Waipahu then transferred to Kamehameha Schools when he was a freshman in high school. Mr. Cashman later moved to the island of Hawai‘i and attended the University of Hawai‘i at Hilo. He returned to O‘ahu to attend Leeward Community College, later graduating from the University of Hawai‘i at Mānoa with a degree in Hawaiian Studies. He has been at the University of Hawai‘i at Mānoa since 1988 and became part of Kānewai during his undergraduate years as a member of Hui Kama‘ilio, a Hawaiian conversation group, and Kua‘ana, a Native Hawaiian Student Development Services Center. As a student, Mr. Cashman once resided in the student dorms across Mānoa Stream from Kānewai *lo‘i*. He would cross Mānoa Stream *makai* of Kānewai as a shortcut between the dorms and parking areas on Dole Street. Students would make it "real nice so everybody could cross." However, during flash floods rocks would be washed downstream. Students would fix the area to cross the stream again. He noted that people still cross the stream to get to the dorms, not in the same place, but still carry their *‘ukana*, or baggage, that way because

it is shorter than walking around. Mr. Cashman has many memories and lessons learned at Kānewai. Kānewai is part of his family and his family are a part of Kānewai.

Before its rediscovery in the early 1980s Kānewai was cultivated by *maka‘āinana*, commoners, then transitioned to care by farmers of Chinese and Japanese ancestry. The overgrown area became part of the landscape of the University. Guided by Kupuna Uncle Harry Kunihi Mitchell, Ka Papa Lo‘i ‘o Kānewai was reopened by a student group named Ho‘okahe Wai Ho‘oulu ‘Āina in the early 1980s. Leaders in this movement included Keoni Fairbanks, Naohua Lucas, Lolana Festemacher, Ekela Kanaiaupi‘o-Crozier, and Kawehi Lucas who were also part of Hui Aloha ‘Āina Tuahine, a Hawaiian language group. University affiliation and recognition was necessary in order to save the parcel; students being part of both groups allowed for this process. Directors of Kānewai prior to Mr. Cashman included Charlie Kupa and Pōmaika‘i Kani‘aupi‘o-Crozier. In 2007, Kānewai became its own Cultural Learning Center. In 2014, they dedicated their first building as the Harry Kunihi Mitchell Building. Today Kānewai hosts about 25,000 visitors a year for education and cultural classes.

Kānewai *lo‘i* is located just *makai* of the Mānoa Stream Bridge on Dole Street (Figure 8). One of the greatest resources for Kānewai is Mānoa Stream. The water moves through various parts of the *‘auwai*, ditch system (Figure 9). It is vital to keep all the pathways, including the stream, clear of debris. Parts of the upper system of the *lo‘i* include the *kahawai* (stream), the *mānoawai* (water and life, akin to the heart and circulatory system), and the *po‘owai* (water source likened to a dam) (Figure 10). The staff and volunteers at Kānewai maintain this upper region of the system and about 20 to 30 yards of stream above it. They take care of the surrounding banks as well as stream overhang, making sure the flow of water entering the property is not affected by blockages. There is constant cleaning and clearing by staff and volunteers within and in the upper system of the *lo‘i*, ensuring there are no big trees or branches blocking the waterway. Vigilance helps keep the water moving both in the stream and through the *lo‘i*.

Currently there are 17 *lo‘i* at Kānewai and each of them are named (Figure 11). Mr. Cashman says, “We name all our *lo‘i*, that was named by a lot of the group that was here first Ho‘okahe Wai. And you know when you name things you’re calling out *kuleana*, just like us we have first name, middle name, last name. And it tells you what families we belong to, what our family *kuleana* is, what our *kuleana* is. That’s why we use names and it is specific to place sometimes, specific to events, things happening.” A *lo‘i* name with historical precedence is Kaleiheana. Kaleiheana was the *konohiki* (headman of an *ahupua‘a* land division under the chief) who used to take care of Kānewai. He was also one of the main warriors under Ke‘eaumoku, a general under Kamehameha I. It is believed that Kamehameha I gave Ke‘eaumoku oversight of this area in order to govern the water. Today, as in earlier times, all the water that flows through the *lo‘i* returns to the stream so others downstream may also utilize the resource.

According to Mr. Cashman, historical *mo‘olelo* account for the place name of Kānewai. He noted there are several versions that involve Kāne, the leading of the four great Hawaiian gods, and Kanaloa, a major god associated with ocean life.

> So Kāne and Kanaloa come from Kahiki, they come from this side. And Kahiki doesn’t mean Tahiti it’s just another place. And they come from Kahiki and they kind of going through the different islands and they end up spending time on the Big Island at Mo‘okini Heiau and while they are there, they are spending time there,

Figure 8. View of Ka Papa Lo‘i o Kānewai from Kamakakūokalani Center for Hawaiian Studies (CSH 2014)

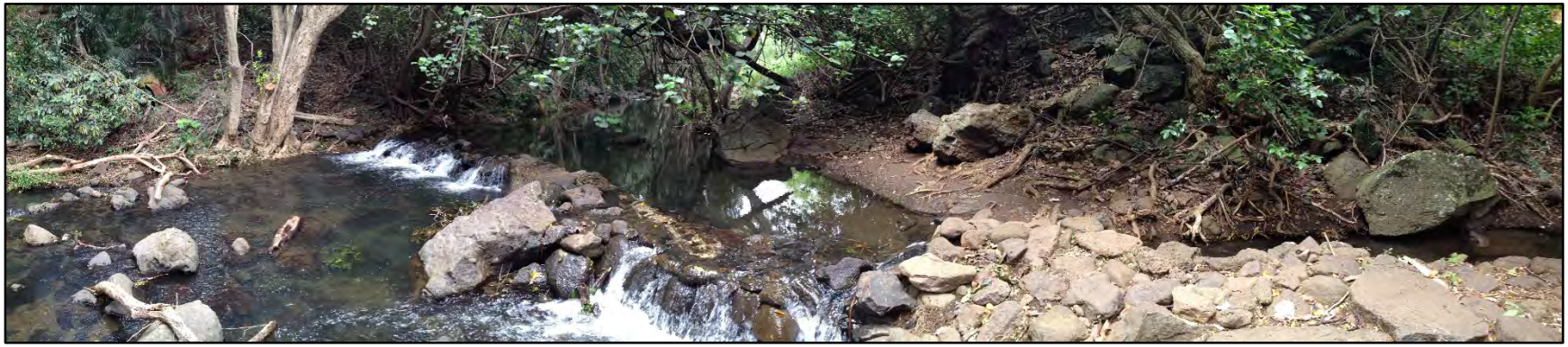

Figure 9. View of convergence of Kānewai *lo‘i* and Mānoa Stream (CSH 2014)

Figure 10. View of Mānoa Stream looking *makai* showing the *mānoawai*, *po‘owai*, and water separating into the *‘auwai*; note branches and other debris in the background, which has since been removed from the stream (CSH 2014)

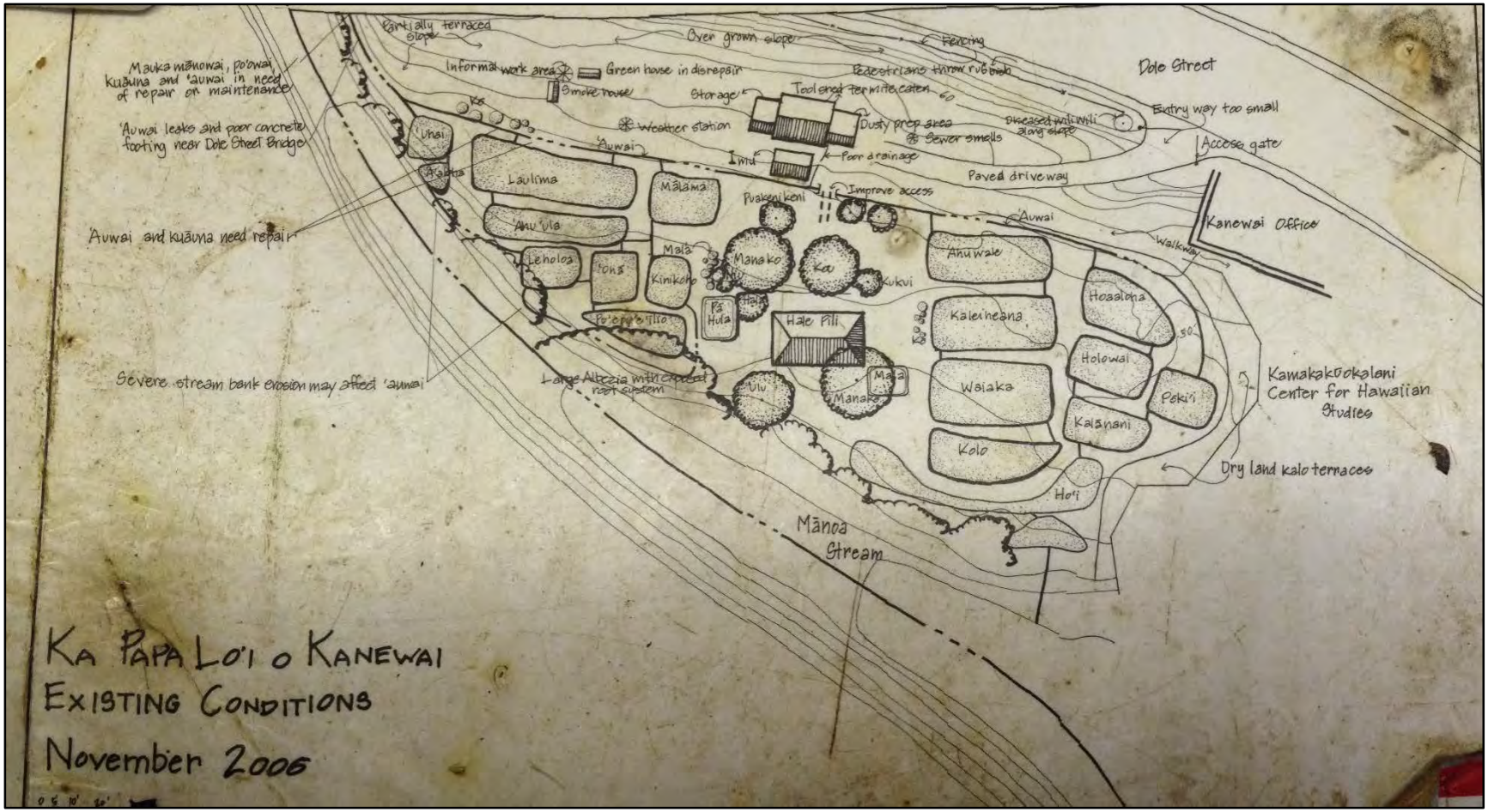

Figure 11. Map of Ka Papa Lo‘i o Kānewai created by Pomaika‘i Kaniaupo-Crozier, previous Director, showing conditions existing in November 2006; note location of Mānoa Stream, names of *lo‘i*, and the layout of the *‘auwai* system (CSH 2014)

> they receive certain *kuleana*. After that they start to make their way through the different islands coming back this way. They are especially known for creating springs. And it's the two of them, some of them consider them brothers, you know even in the *Kumulipo* [origin, gensis] they are right next to each other in being born. Kāne and Kanaloa are together and one story has them coming up from the Kāhala area. There is actually a place in Kāhala called Kānewai too. It has direct association with this Kānewai too.
>
> What happens is they come, and the other story is they come up from ‘Āpuakēhau, where the Moana Hotel is. So the two of them come out of the ocean and they want to rinse off, they want to rinse off and they want to drink *‘awa* [kava-kava; *Piper methysticum*], they want to relax. So the two of them, Kāne and Kanaloa, start to make their way up here and Kanaloa is bugging Kāne and saying, ‘You hurry up, find water already.’ And Kāne his *‘ano* [nature or disposition] is to be real *‘olu ‘olu*, real easy going so he's telling ‘No, be patient, be patient, just wait.’
>
> So the two of them are coming up, making their way up and finally Kāne decides on this area to make the, to make his spring. So he sticks his *‘ō‘ō* [a digging stick, or digging implement] into the ground and a huge spring comes up and that, that spring is known as Kānewai. The two of them are able to rinse off, relax and they start to drink *‘awa* as well. Another thing they are known for too is *‘awa* drinking. They spend some time here and after they are done here they make their way up toward Mānoa as well too, and they create springs up there too.
>
> We think, just doing research that Kāne has the ability to hear water move underground. Because he can do that, he can find the springs, create the springs. I think the spring is still here today and I think it's an underground spring, a cave. It's right on the other side of the Hawaiian Studies parking lot between the tennis courts. It's a small area like that but if you go it is all covered with bushes and it's all barred up.

Each time *kūpuna* visit Kānewai, Mr. Cashman asks them if they may know where the spring is. He continued there are springs that seep inside the *lo‘i*. From Kamehameha Schools he has acquired a map with the springs' location identified.

Another story Mr. Cashman shared is that of Kākea who is a *mo‘o*, a lizard. Kākea also appears in other forms such as a big destructive wind that rushes through Mānoa and also as a *pu‘u* or hill. Mr. Cushman stated the following:

> We think that the *pu‘u* is critical because it, when there was another eruption in Mānoa it moved that whole water system, the whole stream and it moved it alongside Wa‘ahila, right here. That's why you see the way the stream is now, it's kind of alongside here.

He then connected Kākea with a story of a set of twins that come from Mount Ka‘ala in the Wai‘anae Mountain range. They go over to stay with their mother but she is cruel. The twins move to Mānoa to escape her but she finds them, takes them back, and beats them. They come back again to Mānoa and take up residence in lower Mānoa. Their names are Wa‘ahila and Kilihune, the names for the wind and rain. These two become good friends or relatives to Kākea. One day

the boy tells Kākea that he wants to make a spring for his sister so that she can shower and make food. So Kākea, along with the boy, goes to Kānewai Spring and digs an underground cave. This is the waterway that creates Punahou, the Punahou Spring where Punahou Schools stands today. Mr. Cashman shared the following:

> What is Kākea? Who is Kākea in this form? We think Kākea is a *mo‘o*, he is that movement when, like I said how Pu‘u Kākea moved the *kahawai*, Pu‘u Kākea also moved the underwater waters as well, too. And when that happened is that movement when he pushed that *pu‘u* was formed from the volcano. It pushed the *kahawai* over and pushed that underwater spring all the way to here to Kānewai and shot it back to Punahou. That kind of movement, there was a, I think it was a lava tube. Some kind of thing that created this ability for the Kānewai Spring to hook up with the Punahou Spring.

Going through out the landscape nearby, Mr. Cashman mentioned the legend of Mō‘ili‘ili who battles Hi‘iaka, the littlest sister of Pele. In this other *mo‘o* story of the area, Hi‘iaka returns from Kaua‘i and defeats Mō‘ili‘ili creating a small hill. He views this as Hi‘iaka having the ability to make things grow along with Pele’s *kuleana* to make things fertile; “They are part of that family, the genealogy.” Mr. Cashman shared another story of the valley, Kāhalaopuna:

> And it talks about the rain, you know, Tuahine and the father Kahaukani, and then the grandparent’s area Akaaka, the mountain in the back of Mānoa, and then the mother is Kaleihuaakaaka which is that *lehua* ridgeline but together they create that water source. They’re that, they’re the ones that *hānau* [to give birth] the water, without that it’s not possible for the wind and rain of Mānoa to be. They give birth, that’s the birthing of Tuahine and Kahaukani, the wind and the rain, again twins. There’s always *māhoe* [twins] someplace in there, some stories. That’s the wind and the rain there and then their child is Kāhalaopuna, which is the rainbow. And that’s that story and it’s a beautiful story, a beautiful tragic story about kinda like the genealogy of the phenomenon that went on in Mānoa, that’s related to here. *Keaomelemele*, to me is a genealogy of how Nu‘uanu which is the border of the Waikīkī Ahupua‘a. But Keaomelemele, to me is a genealogy of how Nu‘uanu came to be, you know, how I think the valleys were together and then Keaomelemele had the ability to separate it and create Nu‘uanu Valley. That’s why I think Kāhalaopuna is important for over here too.

Mr. Cashman maintained that these stories are what binds people to the land, the learning of place names for mountains, winds, rains, rainbows, springs, and more, all of which share genealogical connections to Mānoa Valley. These *mo‘olelo* contribute to landscape and weather features we see today as well as add to geological and meteorological understandings of Kānewai, Mānoa and Mō‘ili‘ili.

> Well, what we see today, how the weather moves here, how the area was created more or less. But it’s genealogy there and it’s woven into a really elaborate beautiful story which our *kupuna* had the ability to do. I think only now we are starting to, I think before they understood it too but we are starting to see it again, understand it a little more. At least I am . . . That’s how we do stuff, that how’s our *kupuna* do stuff. They tell real beautiful stories and it helps them to remember, really good

> scientists if you will. They had the ability to observe, to notice how things were, and then create this beautiful mo‘olelo to remember it by. You talk about layers of *kaona* [the hidden meaning, as in Hawaiian poetry] that's perfect right there.

Historical legends and current history make for a rich past within the Kānewai area of Mānoa. Current Hawaiian cultural practices in the area utilize natural resources such as water and rocks from Mānoa Stream. Types of rocks gathered include *pōhaku* (rock, stone) for the reinforcing of rock walls, to build and rebuild walls, like the *pā* (fence or wall). The gathering of stones occurs during stream cleaning, usually after a big rain event happens or every first Saturday when large volumes of volunteers are available to support Kānewai.

> All the rock work here all the *pōhaku* is from the stream . . . you know we are always looking, my thing too is we are always in there cleaning and just like when we clean the *‘auwai* system it's really important that the water [is] moving. When the water moves how it does in the *‘auwai* and through the *lo‘is* and through the stream it tells me the water is cool, it's doing what it's supposed to do, and that's why when you have a lot of debris and stuff in there the water down, changes the temperature and even in the *‘auwai* system when the water slows down the *lo‘i* the water gets hotter, it gets warmer. Which is not a good thing, it comes, it can get to the point where it is hot, warm and stagnant water . . . . So it's real important that we're in there cleaning it all the time. So that's always a function of ours too and it just helps to mitigate, regulate the water coming down because if we [are] not taking care, what's going to happen is that everything is going to build up and then we are just going to get overwhelmed with water. It's just going to build a big wall and big flash flood, a big tsunami coming this way.

Rock collection is dependent on the amount of volunteers. Gathering happens more often during first Saturdays of the month, when Kānewai is open to community volunteers with up to 300 pairs of hands at a time. A line is made down to the stream with leaders from the *lo‘i* at the front and end of the line. Rocks are passed by hand up the stream and placed for future building of walls. *Pōhaku* are also separated from the pile to make *imu*, or underground ovens. As the rocks are coming up from the stream they are looking for *imu* stones. If a stone looks good for making *pōhaku ku‘i ‘ai* (*poi* pounders) then those are also separated. Workers also utilize the stream to cool off, to clean off after working, and to bring the community together. There is a lot of community involvement in keeping the stream clear as well as gathering resources for cooking food, making walls, and *poi* pounders.

Mr. Cashman noted members from the general community also access their pathway and driveway in order to gather rocks. He said many people don't have access to entry points, especially in the city, so different groups ask permission to park in the area so they don't have to carry the resources too far. For Mr. Cashman it is critical that people be able to access the stream and that Kānewai is in a position to help these community members. It is important to him for people to be able to practice traditions at home and Kānewai is one point for them to gather resources.

An earlier proposed project threatened cultural practices and access to resources. Mr. Cashman spoke out against the addition of a concrete wall to Mānoa Stream from the "*po‘owai* to the end of Kānewai." A cement wall was to be put up by a contractor which would restrict access to the

stream as well as make the current *lo‘i* area into a construction vehicle parking area. Mr. Cashman said, “Keep it the way it is because we need it, that’s our resources, we need access to the river.” As a counter offer, the contractor mentioned they could construct stairs to access the river. There was clear opposition from Mr. Cashman to any permanent alterations in the stream and the Kānewai area. Mr. Cashman continued with the following statement:

> I think it’s okay. For even for it to make this turn it’s a big turn and the water flies through here when it’s rushing. We’re talking 30 or 40 miles per hour, kind just moving. That’s why if there is something blocking, ‘Boom!’ you know that’s why you gotta keep cleaning. That’s my thing is that you gotta keep cleaning, somebody’s gotta keep cleaning like all the way up too. We can clean this area, we had a tree fall across there, a huge tree. Like this kind tree [points to a mango with a diameter of about 7 ft]. We was like, ‘Oh my gosh, we gotta appraise to see how much it would take to take it out.’ And we were like, it was like a couple grand, five-six thousand because they had to bring a crane and everything. So oh man, how are we going to do that? Then one day we came back and the tree was gone, was like, ‘Whoa what happened to the tree?’ But it got washed out that’s how when it flashes over here it just flashes. It’s heavy.

In 2004, Kānewai was inundated with water (Figure 12). The *‘auwai* pathway going to Kānewai, next to Mānoa Stream, is 5 to 6 ft above the stream. The water came through the *hale* (house). The high water mark rose to the height of the black tarps identified in Figure 13. Mr. Cashman asserted that the 2004 flood was “manmade.” He remembers that at Mānoa Marketplace, near the Woodlawn Drive Bridge, that the bridge was low, “the bottom part of the river was rising because of all the debris settling in that area and slowing everything down. So all the rocks gathered there, all the debris gathered there and then when it started raining the *puka* [hole, opening] was too small under the bridge and it started building up debris and wood and all kinds of stuff. So it built this big mountain of water and then it decided, it had to go somewhere.” By the next morning the water was gone but all the *‘ili‘ili* (small stones), *lau hala* (Pandanus) mats, and benches were spread about the property. Mr. Cashman stressed that,

> So you gotta go in, you gotta clean out the rubbish and clean out the big trees especially, those kinds of things. So that when the water comes it can just stay on its course. So when you get stuffs in there blocking, naturally it [is] going to slow down. Even in the *‘auwai*, something as simple as two or three leaves can screw everything up so you gotta keep walking through [Figure 14]. So we are always having the kids do that, little things. But it makes a difference. Even something simple like this when it comes in, it’s already leaking water so if down here is plugged up all over here is going to overflow, it’s going to get real bad.

Mr. Cashman described a recent flash flood event while rethatching the *hale* in 2014:

> We were up on the top in the attic area and we heard like thunder, ‘Boom! Boom!’ and it was kind of raining that time. Kind of thunder, lightning during spring break. Then it started over here ‘Boom! Boom!’ and I was like ‘Whoa, wow that was close.’ And the next thing you hear is ‘Boom!’ and then we look out into the river and the thing wen’ flash. It wasn’t real high but it was strong. You know was real dark dark brown water, plenty of debris inside. It was just moving but you could

Figure 12. Kānewai *‘auwai* (left); during the 2004 flood, the Mānoa Stream (right) rose and inundated Kānewai *lo‘i*; note the *‘auwai* is approximately 5 to 6 ft above Mānoa Stream (CSH 2014)

Figure 13. Kānewai *lo‘i* with *hale* in the background (right); the 2004 flood high water mark is demarcated by the black tarp fencing in front of the *hale*; Mānoa Stream is behind the *hale* on the left (CSH 2014)

Figure 14. Mānoa Stream with Mānoa Stream Bridge in background; the *‘auwai* (left) dates from 1400 AD and leads the water from the stream to Kānewai *lo‘i* (CSH 2014)

> hear everything moving now and that thing was a couple of rocks or trees coming down.

In regards to the Ala Wai Watershed Restoration project, Mr. Cashman is opposed to the input of combs throughout the stream. He stated that the comb will slow the flow in the stream and catch items which will further decrease flow rates. He believes that cleaning the stream, like in traditional times where everyone got involved, is the best way to prevent flooding. Kānewai staff clear the stream every first Saturday with the help of volunteers and clear the *‘auwai* daily, sometimes multiple times a day.

Kānewai is a *pu‘uhonua* for people, plants, and animals. Students, volunteers, and administrators have worked together to keep this area as Mānoa once was. Currently, Kānewai cultivates 63 of the 69 known varieties of *kalo*. In keeping with traditional management techniques, there is no use of pesticides, herbicides or other poisons. Everything is hand processed and redistributed through composting, using *kukui* (candlenut tree; *Aleurites moluccana*) and *hau*. Ash is also input to the *lo‘i* from completed *imu*. Patches are left fallow for 6 to 12 months. Removal of synthetic agents from *lo‘i* maintenance means no unnecessary inputs to the stream. Today native birds such as *manuokū* (white tern; *Cygis alba rothschildii*) and *auku‘u* (black-crowned night heron; *Nycticorax nycticorax noactli*) occupy this area.

Mr. Cashman shared his personal experiences of Mānoa Stream in the Kānewai area. Kānewai was reopened in the early 1980s after students, along with Kupuna Harry Kunihi Mitchell, discovered the *‘auwai*. The health of the stream is critical to the operations of Kānewai and to the connections visiting community members are able to make. Kānewai has been a constant location where students and community members gather to work as a community toward a practice of *‘aloha ‘āina*, caring for the land. Mr. Cashman mentioned legends related to place names, winds, rains, mountains, and springs that entwine genealogy and landscape. He is adamantly opposed to inputting more concrete or combs to mitigate flooding problems. He suggested constant cleaning of the stream area by community members as a solution to flooding, getting organizations, schools or anyone interested in the stream to help clean the stream of debris. Mr. Cashman was appreciative of CSH soliciting input from Kānewai about plans for the Ala Wai Restoration project.

4.5 Hayden ‘Īmaikalani Winchester

Since 2004, Mr. ‘Īmai Winchester has been a teacher at the Hawaiian charter school Hālau Kū Māna and he has been involved with *lo‘i* in Mānoa Valley for the past 15 years. He has been working with Mānoa Stream since 1999 at Ka Papa Lo‘i ‘o Kānewai, a Hawaiian cultural research and outreach program. He moved to Mānoa Valley in 2005-2007, through a Memorandum of Agreement with the University of Hawai‘i Lyon Arboretum and Botanical Garden, as the caretaker of ‘Aihualama *lo‘i*. ‘Aihualama *lo‘i* is adjacent to ‘Aihualama Stream in the back of Mānoa Valley. ‘Aihualama *lo‘i* is the second *lo‘i* to be reopened in Mānoa Valley. The first is Ka Papa Lo‘i ‘o Kānewai which is located next to Mānoa Stream below the Kamakakūokalani Center for Hawaiian Studies (Figure 15). Mr. Winchester is an active member of Onipa‘a Nā Hui Kalo (ONHK), a statewide organization of taro farmers. Mr. Winchester has hosted workdays at ‘Aihualama for ONHK, bringing students, general community members, and volunteers to the area for maintenance and cleaning of the stream and *lo‘i.* He currently resides in Kānewai *uka*, *mauka* or

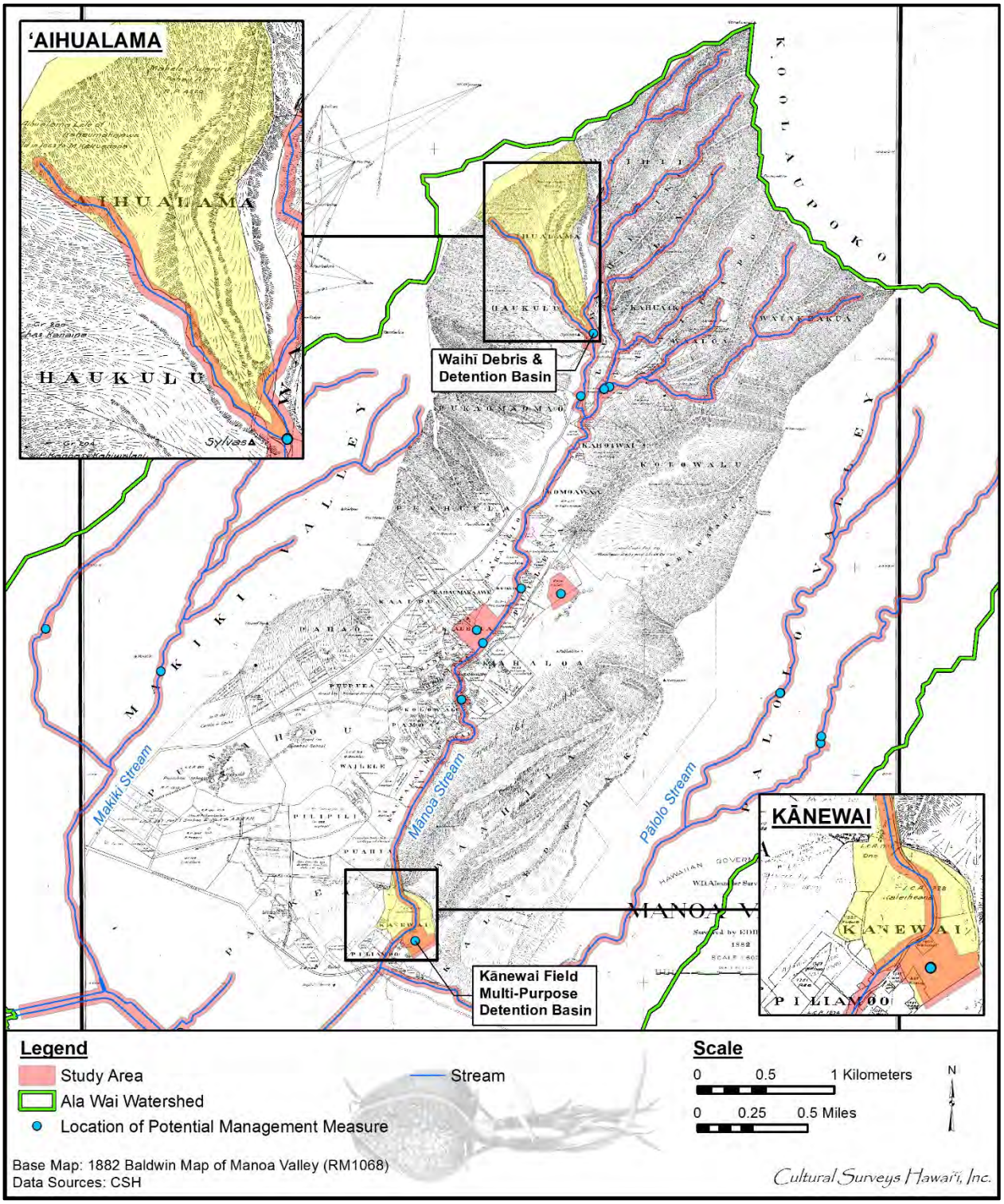

Figure 15. 1882 Baldwin map of Mānoa Valley identifying proximity of ‘Aihualama and Kānewai *lo‘i*

mountainside of Kānewai Park, and has been living in the general Mānoa and Mō‘ili‘ili areas since 1998.

Mr. Winchester was born and raised in Waipi‘o on the island of O‘ahu. He attended a public elementary school and later graduated from Kamehameha Schools. Mr. Winchester attended the University of Hawai‘i at Mānoa where he received his undergraduate degree in Hawaiian Studies and a master's degree in Political Science. Early on in his college career, Mr. Winchester became involved with Ka Papa Lo‘i ‘o Kānewai where Polynesian landscaping and cultivation of taro was being preserved through education and community involvement. Through inspiring engagements with Native Hawaiian academics and community members such as those of the Protect Kaho‘olawe ‘Ohana (PKO), various fishponds, and *lo‘i* restoration projects, Mr. Winchester is rooted to his present *lo‘i kuleana* at ‘Aihualama. As he sees it, Mr. Winchester's present *kuleana* is to "bring life to the *lo‘i* with the hands of our students with traditional practice, production of food, with serving of food, to regenerate our systems again." He identifies the stream as a "primary resource" to "opening and maintaining *kalo*" or taro, as well as "to getting kids involved, active and aware of the world outside of the city."

CSH interviewed Mr. Winchester on 18 April 2014 at ‘Aihualama *lo‘i* in Mānoa Valley (Figure 16). We parked in the residential area at the corner of Wa‘aloa Place and Wa‘akaua Street (Figure 17). On our way to ‘Aihualama, we passed over several bridges that connected opposite sides of ‘Aihualama Stream (Figure 18). We walked from a residential area to a commercial area before making our way to conservation land. The residential locations of the stream are clear of any canopy and channelized whereas the upper regions of the stream are overhung with plants such as albizia (*Albizia chinensis*), Chinese banyan (Indian laurel, *Ficus microcarpa*), and others with natural rocky bottom (Figure 19 and Figure 20). There were no observations of fish or other aquatic fauna on this day.

In previous years Mr. Winchester has walked from the Ala Wai Canal access up to Mānoa Valley. He noted that due to time constraints he has not taken his own students on this walk up towards ‘Aihualama but recalled that other teachers have done so. He noted that water from ‘Aihualama goes through the residential section of Mānoa suggesting that knowingly or unknowingly items are dumped into the canal through "big rain" or other mechanisms. Mr. Winchester recalled seeing ducks at Mānoa Park. He also traced the stream moving from residential areas to commercial areas before passing through Kānewai *lo‘i*. After the water flows through Kānewai, it travels onto cement before exiting into the Ala Wai Canal. He also reviewed the path of Makiki Stream, which is next to the main campus of Hālau Kū Māna in Maunalaha Valley. Mr. Winchester shared briefly some of the challenges of removing invasive species and big trees as well as successes in planting edible ferns and weed control utilizing edible plants. The school's parcel is an old Hawaiian residence near a popular public trail under jurisdiction of the State of Hawai‘i, Department of Land and Natural Resources. Unlike conducting regular stream studies with students at ‘Aihualama, Mr. Winchester noted that they have a hard time doing the same near the school because "it's not too clean."

> Even at Makiki you can see our stream go down and it eventually disappears and then the residential. It goes right past the pump station, goes into the channel section, gets run underneath the road and then you don't see it until it pops up. You got to go by this small section maybe two blocks below, other than that, you not

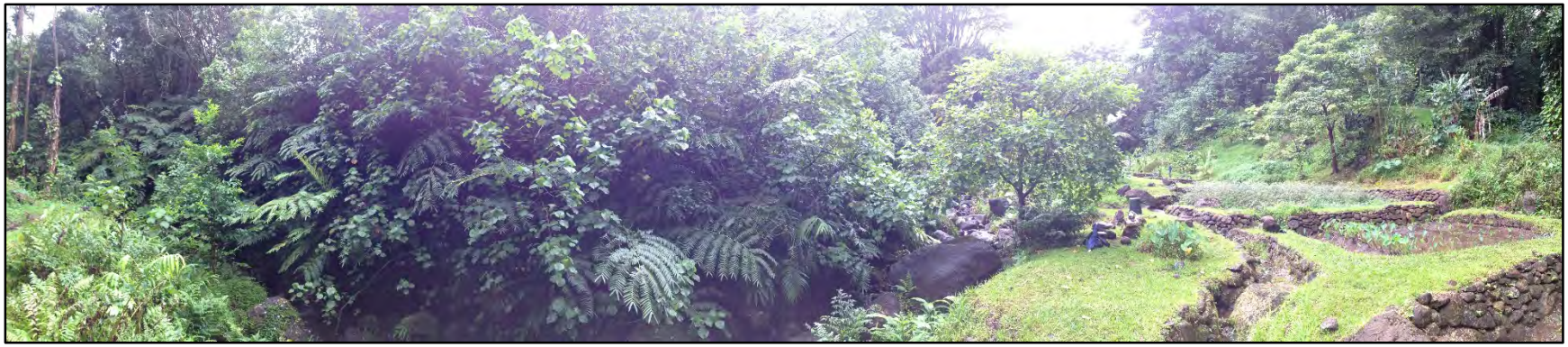

Figure 16. ‘Aihualama *lo‘i* (right) and stream (left) looking *mauka*; Lyon Arboretum is to the left of the stream (CSH 2014)

Figure 17. Photo of the corner of Wa‘aloa Place and Wa‘akaua Street, the parking area for ‘Aihualama *lo‘i* in Mānoa Valley; the walk from the residential neighborhood to the *lo‘i* is approximately 30 minutes (CSH 2014)

Figure 18. Photo of bridge with remnant signage (CSH 2014)

Figure 19. ‘Aihualama Stream from the *po‘owai* looking *mauka*; note fiddlewood hanging over the stream with white ginger and shoebutton ardisia on the right bank (CSH 2014)

Figure 20. Photo of albizia tree in the back of Mānoa Valley; note cones at bottom foreground are scaled at 2.5 ft for tree height; this road leads to Mānoa Falls then Lyon Arboretum; albizia are typical along the banks of Mānoa Stream (CSH 2014)

> going see anything until it hits the Ala Wai. So a lot of stream diversion. What can people do?

Upon reaching the limits of ‘Aihualama *lo‘i* we stopped and Mr. Winchester offered *‘oli,* or chants. CSH waited for his signal to enter. We immediately checked the small waterways between the banks, the *makawai*, as well as the waters that exit the *lo‘i* back into the stream, the *ho‘i wai*. Currently there are seven separate *lo‘i* at ‘Aihualama stocked with *huli*, or taro tops used for planting. The *huli* are from *lo‘i* in Waiāhole, Moloka‘i, and Kānewai. After clearing waterways of debris we headed directly for the *po‘owai* that feed the *lo‘i*. The fiddlewood (spiny fiddlewood, *Citharexylum spinosum*) canopy above the *po‘owai* was hanging into the stream; we cleaned the area and cleared the *po‘owai* of leaf litter debris, which greatly increased the effectiveness of flow into the *lo‘i*. The stream was flowing and approximately ankle deep. The vegetation surrounding the banks was thick with white ginger (*Hedychium coronarium*) and shoebutton ardisia (*Ardisia elliptica*). Utilizing available materials in the area, a *mānōwai*, small dam, was created with boulders to protect a pipeline that carries water approximately 100 m from the *po‘owai* to the *lo‘i*. After the stream and attached waterways were cleared of debris the structured interview commenced.

Mr. Winchester defined the boundaries of responsibility of Hālau Kū Māna’s engagement with ‘Aihualama *lo‘i* as beginning and ending in the stream. This region extends from the *po‘owai* to the *ho‘i wai* as well as above and below these areas in the stream. He noted that they work approximately three hours a week with Lyon Arboretum staff to conduct clearing of different species in order to open areas to sunlight, to clear “rubbish,” as well as to keep the place safe for students and visitors. He stated that in cleaning an area for the *lo‘i* they must also clean the stream:

> Primarily it’s [the goal] to get these *lo‘i* functional, get kids to become interested in working in the *lo‘i,* to have them love working in the *lo‘i* and to produce taro. And in so doing, I think you know, it means we are going to be cleaning up the streams because that’s our resource for us to take care of and I think the more we have invested in this *lo‘i*, the more likewise we have invested inside the stream. That goes likewise [for] everything below us, I think the more people trying to engage this stream, of who are attached to this stream, have a responsibility to that stream. So I like to think that because we are at the top of the first of seven waterways in Mānoa and we know that through cultural knowledge that everything goes down, we need to be specifically conscious and responsible about things we do up over here.

In the back of Mānoa Valley seven waterways consist of ‘Aihualama, Waihi‘iiki, Waihi‘inui, Naniapo, Lua‘alaea, Wa‘aloa, and Waikeakua (Figure 21). Mr. Winchester stated that “*the kapu* [taboo, prohibition, special privilege] should be extra high over here cause the things that we do influences [those downstream].” Cultural practices at ‘Aihulama *lo‘i* include *‘oli*, *ahu* (altar, shrine) and *lele* (sacrificial altar or stand) offerings, and servicing the spiritual aspect of the landscape that is ingrained in the management protocols or reciprocal relationship between *kanaka maoli* and the *‘aina*. While engaging in these protocols Hālau Kū Māna focuses on bringing back a sense of *mana*, or divine power, with the use of *‘ōlelo Hawai‘i*, the Hawaiian language. As part of shaping the physical landscape, caretakers are advised to hand weed and refrain from the use of

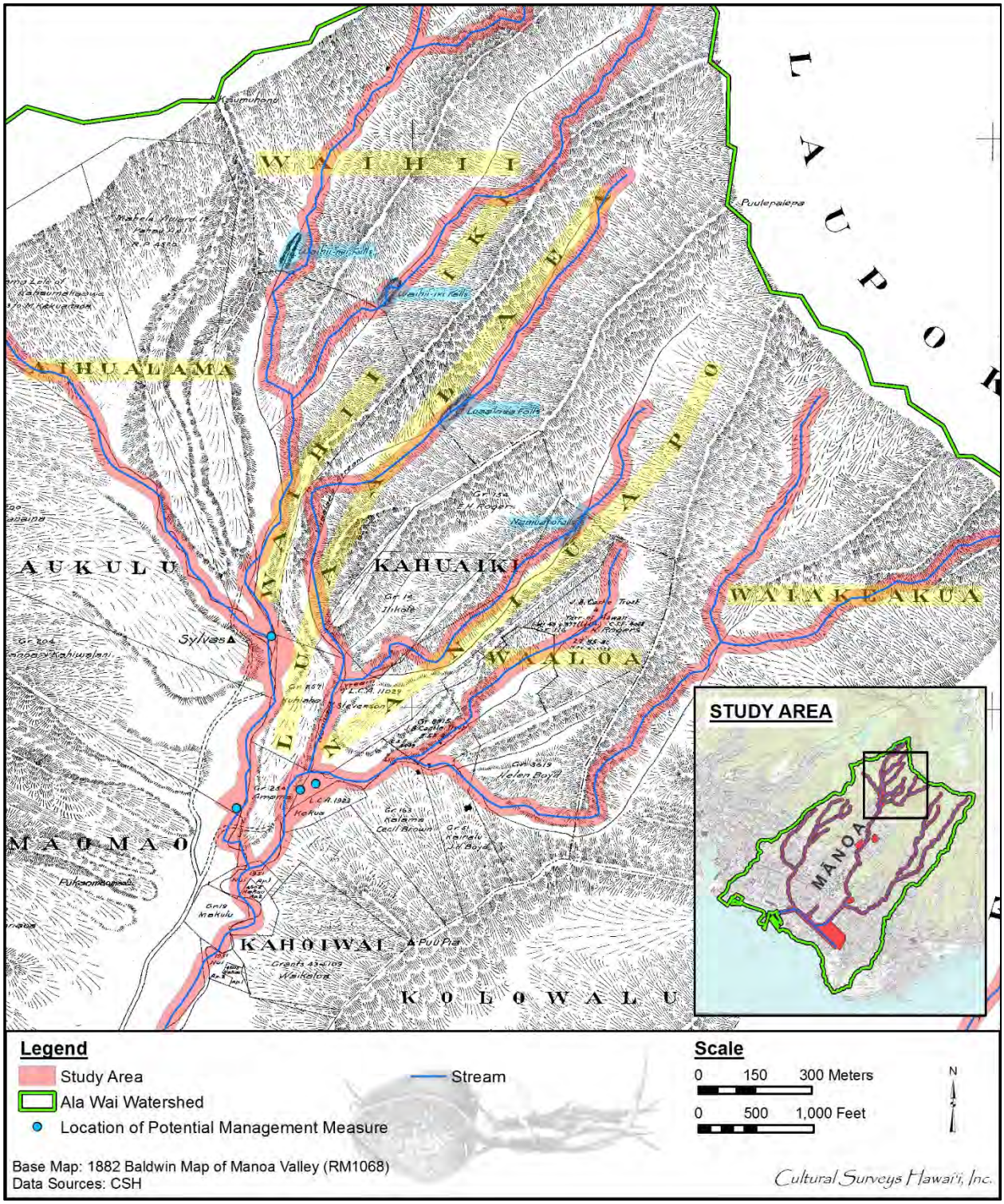

Figure 21. 1882 Baldwin map of Mānoa Valley indicating the streams of Mānoa Valley that merge into Mānoa Stream

pesticides, herbicides, and heavy machinery. The main focus is on group activities and recording constant observations of water levels and quality throughout the work day and year.

> So when we are here, just work projects that we do, we have science, we have science projects that assess the stream that we do daily whenever we come up. That includes three major sources, three sections of the stream, the *po‘owai*, this section that we cross right over here the *kahawai*, that's the *ho‘i wai*. The kids basically measure how much water is coming in and going out and try to generate percentages of how much water is being used. They take temperature, take turbidity, oxygen, just try to get a good baseline data of what's going on at the *lo‘i*. Cause I mean not too many guys have been here long enough to say anything empirically of how the water has been, you know. Without having it written down, and written down, written down, you know.

In his years at ‘Aihualama, Mr. Winchester has observed seasonal ebbs and flows in stream water levels. He recalled from 2004 to 2007 that summertime water levels were at an all-time low and the *po‘owai* was unable to draw water from the stream. Water flow was inconsistent and it rained just enough to "wet the ground." These types of flows were not enough to keep a *lo‘i* cold, an ideal environment for growing taro, or enough to move fallen leaves and debris from the stream. From 2010 to the present, there has been much more steady rain. Mr. Winchester shared his general observation that "water jumps real high."

This is indicative of flash flooding, storms, low flowing summers, heavy winds, and what he describes as "chocolate water" (Figure 22). All events have hazardous potential for stream and *lo‘i* health. Mr. Winchester emphasized a few other hazards along the stream such as the large albizia, banyans, and other trees that line the banks, the need to clean up where sides of banks have eroded, and the buildup of *‘ōpala* (trash), which includes wood remnants and leaf debris.

> There is a lot of stuff that ends up in the stream, ends up clogging and disrupting the system that we have for our *‘auwai* [ditch]. So it takes a lot of, I think not heavy work at times but a little bit of consistency, come in for a little while when the water kind of, sort of manages itself once you kind of give it a kick start . . . And it starts with us, you send guys in there and try to clean and just remove rubbish and we go up through the whole way and spend the whole time inside over there. But you would try want to do especially that like those times, especially heightened during summer time. Less water, less push, so the *‘ōpala* backs up faster. You get heavy winds, yeah usually after heavy winds, ripping through over here, guarantee get plenty rubbish all over the place. That's the stuff clogging up all the streams. That's what I, I more or less see from [this] section that we access and then the bridge is right over there . . . Rainfall is the greatest determinant of how that stream is going to be. Definitely in the last three years or so I think I noticed more or less an improvement in the rain quality. But when it goes back to dry season again I'm just kind of worried how long it will last. It seems like the wet season is shifting. Like it's still now yet, *Lono* [one of the four major gods brought from Kahiki] not *pau* [finished, ended] but I don't think anyone told Lono that. He's still cranking, get Lono winds, you know get action.

Figure 22. Photo of the *po‘owai* of ‘Aihualama Stream in July 2013; the 4-inch pipe leads to the *lo‘i* (courtesy of ‘Īmaikalani Winchester)

As Mr. Winchester described the winds and weather through characteristics or personality traits of the Hawaiian god Lono, he also reflected on stories that occurred in traditional times within the area of ‘Aihualama. In the next *‘ili* over there is an *‘awa* patch taken care of by the Lyon Arboretum called Haukulu, literally “dripping dew.” It is here where different types of *hau* were planted and also where part of the story of Kahalaopuna, a chiefess of Mānoa, takes place. Kahalaopuna is betrothed to Kauhi, who kills her several times. In some versions he takes Kahalaopuna away for good and in another it is her father, who is turned into a *hau* tree. Mr. Winchester remembered a saying that every time a chief died this *hau* tree could be seen crying and he recounted, “when I come over here because Haukulu, you know when it rains over here all of that water kind of gathers on the *hau* and then just sitting underneath it you know it’s kind of like it’s kind of crying right on top of you . . . because there have been a lot of different plantings of different types of *hau* and I know that ‘Aihualama, this stream, was mentioned inside of that story that Kahalaopuna was taken on several journeys through Mānoa.”

After mentioning the presence of several *heiau* (pre-Christian place of worship) previously in Mānoa, Mr. Winchester focused on Kūka‘ō‘ō, an agricultural *heiau* for Kāne, the leading of the four great Hawaiian gods. Kūka‘ō‘ō is a historical site located on the premises of the Mānoa Heritage Center. This *heiau* dates back to the time of Kuali‘i who had battled and defeated the original engineer of the *heiau*, the Menehune. The Menehune are believed to be a legendary race of small people who worked at night building fishponds, roads, and temples.

Mr. Winchester noted that Kūka‘ō‘ō “is kind of a super good zone, if you can imagine Mānoa without residential, if you can imagine without the big invasive trees, you know with a healthy system with taro fields all over the place that would probably be one of the spots that you know you would want to be as far as a *konohiki* . . . it’s just the perspective you get.” He continued to list some Hawaiian chiefs and dignitaries who after the partitioning of the land in 1848 came to dwell in Mānoa. This included Queen Ka‘ahumanu who once owned parcels of land below ‘Aihualama. After the passing of Queen Ka‘ahumanu, the Roman Catholic Church acquired her parcels, as well as chief Boki.

Looking toward the Ko‘olau, the windward side of the mountain range, and the back of Kōnāhuanui, Mr. Winchester recounted a famous story he had heard on the Ko‘olau side of the island. The story is of a man or a giant who fell off the precipice and on the way down flashed his *kōnāhuanui* (large testicles) right up the valley. This is why that portion of the mountain range is named *Kōnāhuanui*. Mr. Winchester also pointed out that along the general mountain area were caves where “a lot of people believe that there is a good chance that you find burials if you plan to go *nīele* [inquisitive].”

Regarding gathering practices and activities, a primary recent work project includes the building of stone walls. Many of the rocks come from ‘Aihualama Stream and they range in size from *‘ili‘ili* to *pōhaku* to the *niho*, which are stone sets that interlock, as in a wall. The appropriate time to gather rocks from the stream bed is after heavy storms. Project activities are heavily dependent upon weather, the number of volunteers present, and the ages of the individuals in attendance. Water is also gathered from the stream from the *po‘owai* to feed the *lo‘i* and then is returned to the stream after flowing through the systems. When water levels are high, such as during a flash flood, the *po‘owai* is closed then reopened when the stream has returned to base flow conditions. Water is also gathered from springs for *ho‘okupu* to be given at Makahiki, the

ancient festival beginning about the middle of October and lasting for about four months with sports and religious festivities and taboo on war, as well as for other ceremonies. Besides their own gathering activities, Mr. Winchester knows that some *hula hālau* (hula group) and a few *la‘au lapa‘au* have begun gathering resources from the area but he does not know who they are.

In regards to supporting the stream, Mr. Winchester raised some concerns about maintenance and awareness. He’s an advocate for systemically involving community organizations: “I think people in the stream, you know, is a big deal because a lot of times you know maybe guys just don’t get opportunities to get into the stream. So why care about something that you have no connection to?”

He stated that cultural practices conducted in this area are definitely significant “because [of] our relationship, our hands on relationship.” The stream is a way to interconnect people, “you know, you need to kind of depend on each other so I think that it connects, it [is] the stream, and it] is what connects.” He continued as follows:

> Usually in the olden days, you know, the first Hawaiians they weren’t dumb, they didn’t stray very far from where the water was and all the first civilizations, all the first taro patches, all of the wild ones that was released and then later cultivated, you know all of that happened along the stream so it just tells you how important the water is . . . Oh yeah the stream is pretty important . . . I’m not really a big *‘o‘opu* guy but I try and see what kind of fishes, you know try and check it out but I do know that more and more we’ve been getting bigger and bigger fish coming up, there is even more life, more happiness in the stream. I think it has more to do with the rain but I also think it has to do with presence. I think presence, because now, how aggressive a lot of stuff is it’s kind of important. Presence is important just because, you know, you need the *kanaka* [human being] to merge with the *‘āina* to make everything well balanced.

Recommendations Mr. Winchester has made for improved stream maintenance include:

> Whatever they are diverting break that and open up the stream and then start chopping these big albizias, chopping this big rubbish trees and try to clear the banks off a little bit more and replant, maintain, open up the waters . . . you know, just a good campaign of at least you know it’s a pilot project or something. I think Mānoa would be a great place to start you know stream clean ups, a systemic form of community participation, engagement or involvement. I think that’s kind of important stuff that can be done at schools, you know in big organizations but can be encouraged through other means if creative. I don’t know if the economy is willing to shift for that quite yet but I think changing the mentality has something to do with it, taking care of the stream we got to stop thinking so da kine, what is that? . . . *Haole* [means of foreign introduction].

When reviewing this summary for the report, Mr. Winchester raised concerns about heavy machinery he had noticed *mauka* of the Pālolo Stream Bridge just below Kānewai. He noted there was clear removal of stream banks and voiced apprehension about this activity, especially about the resources such a rocks being removed. If rocks are being removed and dumped into a landfill he suggested this is not the best way to utilize resources from the stream. He recommended that

all resources found within the stream should 1) be redistributed to community members within the *ahupua‘a* they were found in, 2) if there is no way to redistribute these resources, organizations interested in these resources should be recognized and contacted during excavation, and 3) Native Hawaiian families and groups within the area should be notified in order to relieve the City and County or any other agency of these “unwanted” natural resources. It is better to use these resources for cultural practices such as *imu* and rock wall building than to throw them away. Mr. Winchester also shared that the color of the water was like that of “chocolate milk” and knowing that the Ko‘olau mountain rains recharge the general Mānoa area, he wasn’t sure how to reduce the mineral run-off from the range. He said that ‘Aihualama *lo‘i* are the caretaker’s highest in Mānoa Valley, closest to the mountains. No one else is above ‘Aihualama, so why is there so much red runoff?”

Mr. Winchester made two referrals: the Kumuola Foundation, a new *lo‘i*, located in Lua‘alaea on the opposite side of Mānoa valley, and Donovan Preza, a Ph.D. student in the Geography Department at the University of Hawai‘i at Mānoa who has previously facilitated research on ‘Aihualama and the greater Mānoa area. Both were sent letters of invitation to participate but no response was received.

4.6 Michelle Spalding Matson

CSH interviewed Michelle Spalding Matson on 12 June 2014 at Kapi‘olani Park in Waikīkī Ahupua‘a. Ms. Matson chairs the Diamond Head Scenic Byway Committee for the Hawai‘i Scenic Byways program, is president of the O‘ahu Island Parks Conservancy, and has been an elected member of the Diamond Head/Kapahulu/St. Louis Heights Neighborhood Board’s Diamond Head Subdistrict 3 since 1991. Her interest and expertise on the history of Diamond Head and Kapi‘olani Park began with long-standing family ties to the area.

While Ms. Matson was born and raised in the San Francisco Bay Area in California, she spent many summers of her youth in Hawai‘i with her grandmother, Alice Spalding Bowen, whom she adored and greatly admired. Alice Spalding Bowen was born in Honolulu, one of five children of Edward Irwin Spalding whose family arrived in Hawai‘i during the mid-1800s from Boston. Leaving a family of mariners and merchant traders with a shipping business in Boston, two of the Spalding sons—one was Edward Irwin Spalding— traveled around Cape Horn to Hawai‘i and later made their home in the Islands.

Alice Spalding Bowen’s grand-uncle was William G. Irwin, a respected businessman, financier and philanthropist in Hawai‘i during the kingdom, republic, and early territorial periods. Irwin owned a shipping agency on Pier 10 in Honolulu adjacent to the Oceanic Steamship dock, where he was the shipping agent for a major industrialist in the Hawaiian Islands, Claus Spreckels. While conducting research at the Hawai‘i State Archives, Ms. Matson discovered correspondence authorizing Irwin to install a spur for the sugar cane train along Fort Street to the docks in this area. The coal supply for the steamships was stored in the adjacent block that was later dedicated as Irwin Memorial Park, the first waterfront beautification project built along with Aloha Tower. Irwin also shared interests in several Hawai‘i plantations and once owned the island of Lāna‘i. Irwin and Spreckels started Spreckels Bank in Honolulu, which later became Bishop National Bank and today is known as First Hawaiian Bank. Also a close friend to King David Kalākaua, Irwin was a member of the King’s Privy Council for a time. Later, King Kalākaua and the Minster

of the Interior, along with William G. Irwin and the Kapi‘olani Park Association established Kapi‘olani Park. Today the park is protected by the provisions of the Kapi‘olani Park Trust, which Irwin established in 1896 to protect the park in perpetuity for the people of Honolulu.

In 1877, King Kalākaua dedicated Kapi‘olani Park as the first free public park in Honolulu. Kapi‘olani Park was designed to duplicate important Victorian parks in Europe and America where the recreational activities of the era included carriage rides, picnics, boating, horse racing, and polo (Figure 23, Figure 24). A network of carriage paths once existed in the vicinity of the current Dillingham Fountain, and the central portion of the park was a ceremonial ground and race track. The park’s historic landscape was designed by Princess Kai‘ulani’s father, Archibald Cleghorn. The north end of the park consisted of a natural wetland system featuring lagoons and Makee Island, where people would row boats to have picnics and enjoy the Royal Hawaiian Band at the park’s first bandstand. The lagoons were fed by the Tampong Ditch, which carried water from the Mānoa and Pālolo streams across today’s Ala Wai Golf Course to the park. The lagoons were eventually filled to erradicate the mosquito breeding ground, and to make way for relocation of a small zoo from the central portion of the park. While the lagoons and Makee Island no longer exist, a small remnant of the natural wetland system still exists behind the Waikīkī Shell.

Ms. Matson further noted that in the 1930s her grandmother built her home on the slopes of Diamond Head on Makalei Place, where she bought a lot from the Gaylords in the “Makalei tract” with inheritance from her parents. It is believed that Sanford Dole once owned a large amount of acreage in this vicinity, which was then used for cattle grazing. Significantly, long before this, an ancient Hawaiian trail near Makalei Place once connected the many *heiau* of the Diamond Head area. Historian and author Kathleen Mellon, who also lived in the neighborhood, shared with Ms. Bowen that she would often hear *ali‘i* night marchers there.

During the 1960s, developer Chinn Ho declared his intention to build high-rises around Diamond Head. Residents of the area and many other concerned citizens became extremely alarmed about the future of Diamond Head and established a “Save Diamond Head” coalition. Knowing some of the ancient history of the area, Mrs. Bowen decided to research this further at the Hawai‘i State Archives, where she was led to an old map showing the location of Papa‘ena’ena Heiau near the base of Diamond Head. Mrs. Bowen then approached anthropologist Kenneth Emory at the Bishop Museum to assist with locating the *heiau*. They conducted a pedestrian survey of the area, and after reviewing the map and observing the contours of the land near the Dillingham’s villa known as La Pietra, they located the *heiau* platform under the home’s rose garden, with the lower terrace where Kapi‘olani Park’s Diamond Head tennis courts are today (Figure 25, Figure 26, and Figure 27). While the stones defining the *heiau* walls were removed long ago during Queen Emma’s time, today the terraced contours can still be seen in areas between the tennis courts, a portion of the park’s plant nursery, and a gated community of condominiums. The upper platform once stood where the last two condominiums are located today.

When Ms. Matson moved to Honolulu to take care of her grandmother and her affairs, she recalled her grandmother telling her the story of how she discovered the site of Papa‘ena‘ena Heiau:

> She would always tell me the stories of Papa‘ena‘ena. She was so proud of finding the old map in the archives and finding the site of the *heiau* under Louise

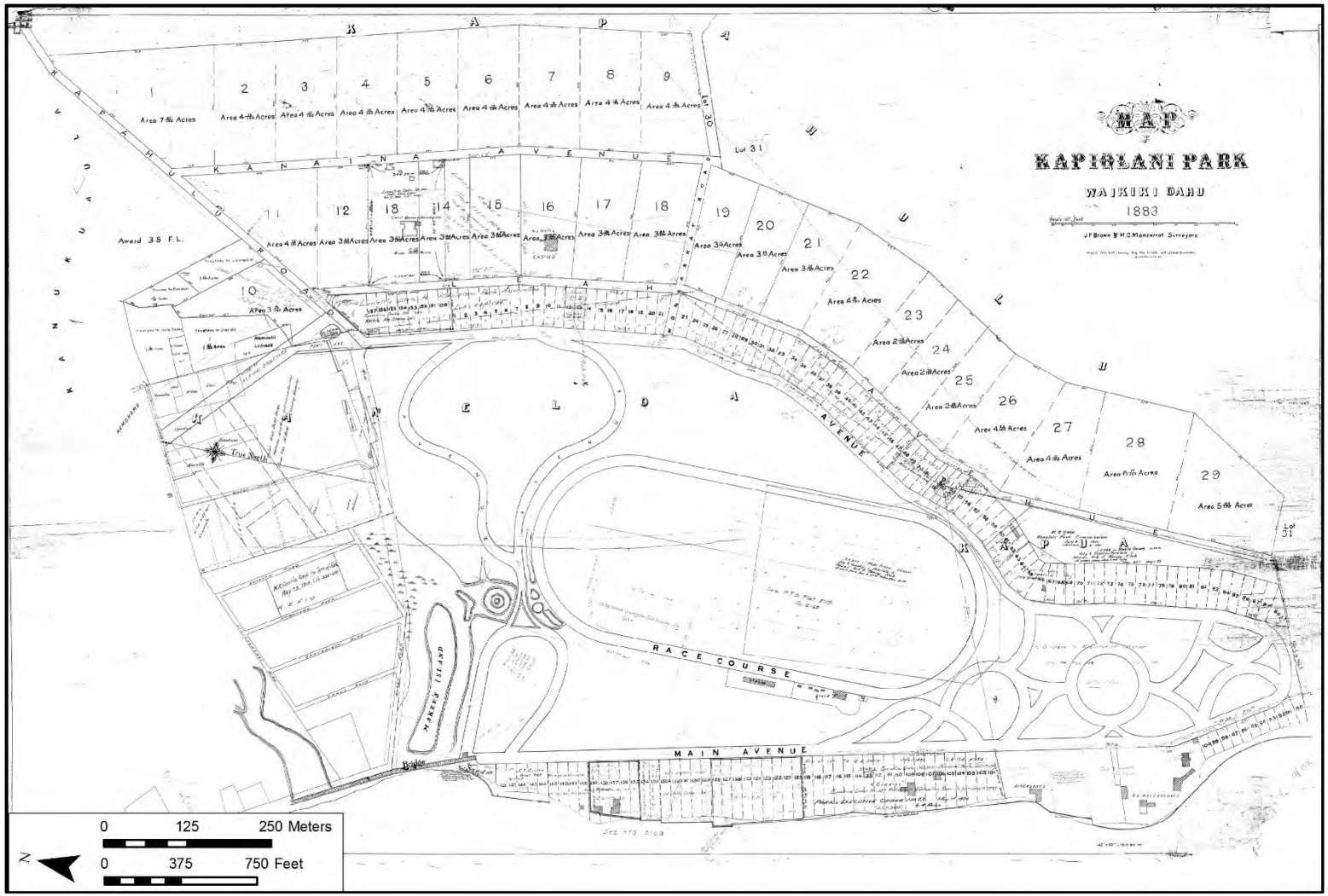

Figure 23. 1883 Monsarrat map of Kapi‘olani Park; note the racetrack in the central portion of the park, the carriage paths to the south, and Makee Island to the northwest

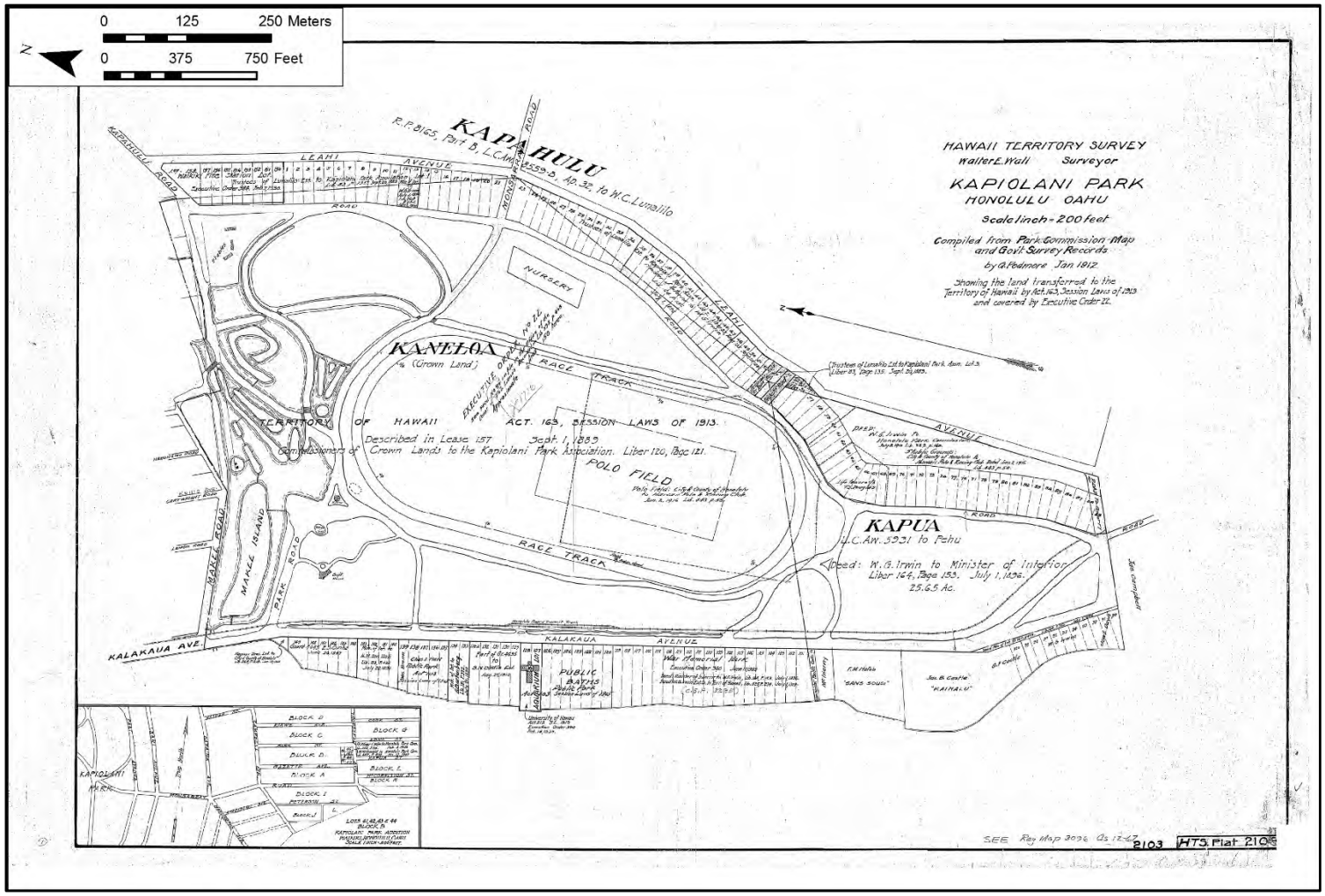

Figure 24. 1912 Podmore map of Kapi‘olani Park; note the race track is still present, however, a polo field has been constructed in the middle of the track, the carriageway has been demolished and Makee Island and the lagoons are still present

Figure 25. Photo of the Dillingham’s residence, La Pietra, today the site of an all-girls preparatory school; note the condominiums

Figure 26. Kapi‘olani Park tennis court parking lot with nursery in background; note the slope in the area of the nursery (CSH 2014)

Figure 27. Photo of the area where Papa‘ena‘ena Heiau and the archery range once stood; note left background is the location of the Kapi‘olani Park tennis court parking lot (CSH 2014)

> Dillingham’s rose garden. As she put it, ‘It was under Louise’s rose garden!’ Of course, such a significant site.

It was this effort that led to the designation of Diamond Head as a State Historic Monument in 1965 and a National Natural Landmark in 1968.

Mrs. Bowen was a dedicated historic preservationist who contributed historic preservation research to the Hawai‘i State Archives and assisted in the restoration of ‘Iolani Palace, working closely with Princess Abigail Kawānanakoa. Her professional life began with a correspondence course in design and evolved into a successful business:

> She walked into Gump’s in San Francisco after she had taken a correspondence course in interior design, and she walked into the administrative offices and asked senior Mr. Gump if he would like to be her partner because she was coming to Honolulu and she’d like to open a little shop. He was blind, but remarkably he could tell the color and the quality of jade just by touching it. And that’s how great a connoisseur he was. Gump’s would import these treasures from the east—the Orient—and I guess because he was blind and so sensitive to sound and touch—he could sense something in her voice, and he agreed to be her partner.
>
> So he commissioned a store to be built here on Lewers and Kalākaua. Hart Wood did the design and my grandmother worked with him on it. Now it’s the Louis Vuitton shop. It’s on the Historic Register, with the blue tile roof.

Mrs. Bowen managed that store from 1923 to 1953 until she opened her own shop at the Royal Hawaiian Hotel, Alice Spalding Bowen’s Oriental Arts Shop, which she sold in 1972.

Ms. Matson’s memories of her grandmother and family visiting Hawai‘i include spending time at Makalei Beach looking for shells with her mother She recalls that residents of Makalei Place were given a key to a gate to Makalei Beach prior to it becoming a park. On one occasion, she found a very unusual shell:

> I found one that was really tiny—white, a single shell. And it had very fine red stripes, vertically, evenly spaced, and a couple horizontally. Very fine, red stripes. And we took that to Spencer Tinker, who was the director of the Aquarium at thetime. My grandmother knew him very well and we asked him about this shell. He looked it up and he said, ‘Well, this is a very rare shell.’ So I kept it and treasured it.

Following in her grandmother’s footsteps, Ms. Matson has assimilated the history of Kapi‘olani Park and Diamond Head, and continues to advocate for the protection and preservation of this culturally and historically significant area. She noted from her research that Papa‘ena‘ena Heiau was once one of the most significant *heiau* on the island. It was originally a surfing *heiau* when the Polynesians colonized the Waikīkī area approximately 1,500 years ago, and was where the *kahuna* would raise flags to signal to *ali‘i* that surfing conditions were favorable. *Ali‘i* did not tend to the fields like *maka‘āinana*, instead they practiced *lua* (a type of dangerous hand-to-hand fighting) or pursued perfecting their recreational activity of surfing. But during conquests of O‘ahu by other chiefs and after Kamehameha arrived on O‘ahu at Diamond Head, Papa‘ena‘ena Heiau became a sacrificial *heiau.* Papa‘ena‘ena Heiau was eventually dismantled by Queen Emma in 1874, and most of the stones that formed the walls of the *heiau* were later used for walls and streets

in town and for the Waikīkī estate that she inherited from King William Lunalilo. It has been reported that a few remaining stones were covered when a retaining wall was reconstructed near the park's former archery range. Ms. Matson added that a stream once ran next to Papa‘ena‘ena Heiau, but today only a drainage culvert remains through the park's nursery leading to a swale across the park.

Ms. Matson knows of the navigational *heiau* below the summit of Diamond Head, or Lē‘ahi, where fires were lit to guide canoes in ancient times, and her research has also revealed several other *heiau* within the park and Diamond Head area including Kupalaha at Queen's Beach, Makahuna at the foot of Diamond Head crater, and Pahu a Maui, a fishing *heiau* at the current location of the Diamond Head Lighthouse Coast Guard Facility (Figure 28).

Ms. Matson researched much of the history of Diamond Head when she and her colleagues effectively worked together with state legislators and city council members to confront the proposed 38,000 sq ft expansion of the former Federal Aviation Administration (FAA) aircraft control facility within Diamond Head's natural crater. Community opposition mounted following completion of the final federal EIS for the project, and subsequently in 1992 State legislation was enacted to protect the monument. Eight years later the FAA site on the crater floor was restored to natural vegetation after successfully relocating the control facility to the airport.

Ms. Matson also spearheaded the Diamond Head Scenic Byway project, for which she conducted research on the numerous significant sites within the scenic byway corridor around Diamond Head. The Diamond Head Scenic Byway qualifies under the National Scenic Byways program by meeting all six designation criteria—scenic, natural, archaeological, historic, recreational, and cultural—and was successfully designated as a Hawai‘i State Scenic Byway in December 2013.

Ms. Matson pointed out that an interesting feature within Kapi‘olani Park relevant to the current Ala Wai Canal Project is the remnant wetland feature behind the Waikīkī Shell (Figure 29). In ancient times and prior to the construction of the Waikīkī Shell, old maps show it was part of a large duck pond. The new Kapi‘olani Park Bandstand was built with a symbolic new pond where ducks swim today. The present wetland is the site of the Ala Wai watershed Kaneloa Wetland Project funded by an Environmental Protection Agency (EPA) grant and begun in 2000 with the purpose of restoring the remnant wetland with native plants as a natural and educational attraction in the park. Army volunteers who had helped with the Kaneloa Wetland project were called into active duty following 11 September 2001 and the EPA funding ran out near project completion. The native coastal plants that have continued to thrive naturally include bacopa, Native Hawaiian sedge (see Figure 30), and *‘ākulikuli* (general name for succulent plants). Non-native plants visible within the wetland include opiuma trees and date palms. The date palms were part of a historic allée bordering a secondary carriageway accessing the race track in the middle of Kapi‘olani Park, and are a remnant of Archibald Cleghorn's landscape design features (Figure 31).

Ms. Matson pointed out that during the winter the natural swale fills with brackish water and tilapia enter the area (Figure 32):

> There is some sort of channel underneath in the porous, what do you call it, a karst? And tilapia swim in from somewhere, from the canal but we don't know where . . .

Figure 28. Photo of the former location of Pahu a Maui Heiau from the top of Diamond Head; today it is the location of the Diamond Head Lighthouse Coast Guard Facility (CSH 2014)

Figure 29. Photo of the Kaneloa Wetlands behind the Waikīkī Shell (CSH 2014)

Figure 30. Umbrella sedge (*Cyperus involucratus*) within the Kaneloa Wetlands (CSH 2014)

Figure 31. Photo of date palms, part of a historic allée near the former race track at Kapi‘olani Park landscaped by Archibald Cleghorn (CSH 2014)

Figure 32. Photo of drainage where tilapia swim during the winter months; background is the Waikīkī Shell, Royal Hawaiian Band parking lot entrance (CSH 2014)

> It would become flooded and we would see tilapia coming up here . . . I understand that a lot of the drainage water goes under the zoo and out to the Kapahulu Groin.

She noted that although the Kapi‘olani Park area no longer has a stream that runs *mauka* to *makai*, there are five artesian wells in the park and the culvert made from the stream that once flowed next to Papa‘ena‘ena Heiau. She added that during the wet season waterfalls can be seen on the sheer slope of Diamond Head and "the natural elements are here, but they've been diverted with culverts and swales." She further mentioned a noteworthy drainage report on this area by Dr. Roger Fujioka of the University of Hawai‘i's Water Resources Research Center.

In relation to the Ala Wai Canal project, Ms. Matson is very concerned about the present proposal to construct walls and large sluice gates around this historic structure. The Ala Wai Canal was built in the 1920s and was placed on the State Historic Register in 1992. If any structural modifications are made to or around the Ala Wai Canal, Ms. Matson pointed out that this could create a detrimental precedent for all historic sites and today's laws protecting them in the greater public interest. She posed the question: "What kind of precedent does that create for all historic sites? For ancient *heiau*?"

Section 5 Cultural Landscape

Discussions of specific aspects of traditional Hawaiian culture as they may relate to the project area are presented below. This section integrates information from Sections 3 and 4 in examining cultural resources and practices identified within or in proximity to the project area in the broader context of the encompassing Waikīkī, Pālolo, Makiki, and Mānoa landscapes.

5.1 *Wahi Pana* and *Mo‘olelo*

Community contacts shared their knowledge on various *wahi pana* throughout the project area. Participant Michelle Spalding Matson shared her knowledge of several *heiau* in the Kapi‘olani Park area, the most southern portion of the project area. She knows of several *heiau* in this area including a navigational *heiau* below the summit of Diamond Head; Kupalaha Heiau at Queen’s Beach; Makahuna at the foot of Diamond Head crater; and Pahu a Maui, a fishing *heiau* at the current location of the Diamond Head Lighthouse Coast Guard Facility. The most important *heiau* in the Kapi‘olani Park area was Papa‘ena‘ena Heiau. The general location of the *heiau* was at the former Dillingham residence, La Pietra, which is an all-girls preparatory school today. Below La Pietra is a gated community containing condominiums. Below the condominiums is Kapi‘olani Park. It is believed that the *heiau* and its multiple terraces spanned this area. Papa‘ena‘ena Heiau was originally a surfing *heiau* where *kahuna* raised flags signaling *ali‘i* that surfing conditions were favorable. After Kamehameha I arrived on O‘ahu and conquered the island, Papa‘ena‘ena Heiau became a sacrificial *heiau*. Eventually the *heiau* was dismantled in 1874 by Queen Emma and most of the stones were used to form a wall around her Waikīkī property. It was reported that a remnant of the wall terracing was still visible at one point, but a pedestrian survey of the area with Ms. Matson was inconclusive.

Traveling *mauka*, former Board of Water Supply employee Chester Lao shared his knowledge of springs, ponds, and water in general. The location of the Saint Louis Clubhouse in Mō‘ili‘ili was once famous for its springs and ponds where Hawaiian royalty once bathed. Later the springs and ponds were used to farm *koi*. Japanese women liked the *koi* from these specific ponds because the fish supposedly had significant healing properties when used after childbirth.

Mr. Lao also expressed his knowledge of the Mō‘ili‘ili karst system, which branches throughout the Mō‘ili‘ili, Kaimuki, and Waikīkī areas. Mr. Lao mentioned a couple of entrances into the karst system including near the Kaimuki Shopping Center and at the former location of the Kaimuki Inn restaurant. Mr. Lao knows of someone who once fished for mullet through the floor boards at the Kaimuki Inn. He also shared a legend of the Mō‘ili‘ili karsts in which sharks swam from Waikīkī to Kaimuki. The sharks would listen to the fishermen and when they traveled to Waikīkī, the sharks would swim down as well and eat the fishermen.

Photographer and author Jan Becket suggested visiting several cultural sites including an unnamed site outside the entrance of Mid-Pacific Institute, Hipawai Heiau at Saint Francis School, Kawapopo Heiau on Anuenue Street in Mānoa, and a *lo‘i* upstream of the University of Hawai‘i at Mānoa, Hawaiian Studies building along Kānewai Stream.

At Kauaowa‘ahila in Pālolo and the valleys of Mānoa, Paulette Ka‘anohi Kaleikini shared the legend of Kauatuahineomanoa. This particular legend was imparted to her by her *‘ohana* from a very young age. Lessons from this legend include to *kāhea* or call on Tuahine whenever walking or hiking in the valley. Tuahine is a soft, gentle rain whereas Wa‘ahila is a heavier, masculine rain.

Caretaker of Kānewai Lo‘i, Makahiapo Cashman, shared the *mo‘olelo* of Kahalaopuna which also describe the *wahi pana* of Mānoa Ahupua‘a. The *kūpuna* area is known as Akaaka which is the mountain in the back of Mānoa Ahupua‘a. The mother of the story is known as Kaleihuaakaaka, the *lehua* ridgeline of Mānoa. These characters and *wahi pana* work together to create a water source for the valley. Without these topographic features, the birthing of the twins Tuahine and Kahaukani, the rain and wind, respectively, would not be possible. Mr. Cashman described these *wahi pana* to *hānau* or birth these elements of Mānoa. He stated that without Tuahine and Kahaukani there would be no Kahalaopuna or rainbow. Mr. Cashman stressed the importance of these *mo‘olelo* and how they are the genealogy of these places and spaces. These stories paint a picture of the landscape, weather features, and sometimes describe geological and meteorological phenomena.

‘Īmaikalani Winchester, educator and cultural practitioner, shared a different version of the *mo‘olelo* of Kahalaopuna. Kahalaopuna is a chiefess of Mānoa and the story takes place in the *‘ili* of Haukulu (“dripping dew”). The *‘ili* of Haukulu is located on the Makiki side of Mānoa Valley and neighbors ‘Aihualama ‘Ili. In one version of the *mo‘olelo*, Kahalaopuna is betrothed to Kauhi who kills her several times. In another version, Kauahi takes Kahalaopuna away. However, in one version, Kauahi is her father and is turned into a *hau* tree. Mr. Winchester recalled a saying that every time a chief died, the *hau* tree could be seen crying. Mr. Winchester related the *mo‘olelo* to being physically at Haukulu beneath the *hau* after a heavy storm where “it’s kind of crying right on top of you.” He also stated that ‘Aihualama Stream is mentioned in the *mo‘olelo* of Kahalaopuna along with several places in Mānoa.

Mr. Winchester also shared the *mo‘olelo* of Kōnāhuanui. Looking towards the Ko‘olau, the windward side of the mountain range, you can see the backside of the peak Kōnāhuanui. Mr. Winchester recounted the *mo‘olelo* of Kōnāhuanui, the large giant who fell off the mountain and flashed his *kōnāhuanui* or large testicles, toward the valley.

Mr. Winchester also knows of several *heiau* in Mānoa but he focused on Kūka‘ō‘ō, an agricultural *heiau* for Kāne, one of the four main Hawaiian gods. Kūka‘ō‘ō is located on the premises of the Mānoa Heritage Center and dates to the time of Kuali‘i. The engineers of the *heiau* were the Menehune, a legendary race of small people who worked at night constructing fishponds, roads, and temples.

Mr. Cashman shared the *mo‘olelo* of how Kānewai Spring and *lo‘i* received its name. Two Hawaiian gods, Kāne and Kanaloa, arrive from Kahiki. After traveling to the different Hawaiian Islands, they arrive at ‘Āpuakēhau ‘Ili in Waikīkī. The two gods want to relax after traveling, so they decide they want to rinse their bodies and drink *‘awa*. As they travel *mauka* toward Mānoa, Kanaloa is impatient and asks Kāne to hurry up and find a water source. Kāne’s disposition is easy going so he tells Kanaloa to be patient. Kāne arrives at a place and takes his *‘ō‘ō* or digging stick and pierces the ground. A spring comes up and it became Kānewai. Mr. Cashman added that Kāne’s ability to hear water move underground means he can find and create springs. Mr. Cashman

stated that an underground spring is between the Hawaiian Studies parking lot and Kānewai Park tennis courts. He noted a small barred area that is choked by bushes.

Another *mo‘olelo* that Mr. Cashman shared is of Kākea, a *mo‘o* or lizard. Kākea’s other *kino lau* are a destructive wind that rushes through Mānoa Valley and a *pu‘u*. According to Mr. Cashman, the *pu‘u* is critical because an eruption in Mānoa caused the water system to shift towards the Wa‘ahila side of the valley. Mr. Cashman connected the story of Kākea with another *mo‘oleo* about a set of twins who come from Mount Ka‘ala in the Wai‘anae Mountain range. The twins, Wa‘ahila and Kilihune, the names for wind and rain, attempt to stay with their mother but she is too cruel, so they move to Mānoa to escape her. Their mother finds them, takes them back to Mount Ka‘ala, and assaults the twins. The twins escape their mother, go back to Mānoa, and reside in the lower region of the *ahupua‘a*. It is here that Wa‘ahila and Kilihune befriend Kākea. One day the boy tells Kākea that he wants to make a spring for his sister so she can shower and make food. Kākea and the boy go to Kānewai Spring and dig an underground cave. This is the waterway that creates Punahou Spring where Punahou School stands today. Mr. Cashman related the *mo‘olelo* of Kākea—the *mo‘o* that moved Pu‘u Kākea, which moved the *kahawai* and the water underground—together.

George Arizumi stated that Queen Ka‘ahumanu’s summer palace was located in Mānoa Valley. The area was marked by *hau* trees on the Makiki side of the valley. Although the summer palace has been demolished, the *hau* trees still remain today.

As a child, participant Evelyn Giddings recalled walking with a friend to Girl Scout meetings and following the Makiki Stream. They would go underground via a tunnel below Prospect Street. She was afraid that maybe a flash flood and a wave of water would sweep them away. Fortunately, there were no flash floods while they were in the tunnels. Ms. Giddings described the Makiki Stream being relatively dry.

5.2 Cultivation and Gathering

Ms. Kaleikini’s *‘ohana* settled into the *‘ili* of Kālia located in Waikīkī Ahupua‘a to be near two fishponds in the area. The smaller pond of the two was used for ceremonial purposes only by her great-great-grandfather. Today, the Allure condominium sits on the site of that particular fishpond. The second fishpond was known as Loko Kūwili. Ms. Kaleikini’s great-great-grandfather raised *moi* in Loko Kūwili which was reserved only for *ali‘i* and their entourage. *Moi* was plentiful in Loko Kūwili and therefore chiefs often fed the people, with Kamehameha I being the most generous. Her great-grandfather continued to care for Loko Kūwili until 1927 when the dredging of the Ala Wai Canal began. Ms. Kaleikini added that Western habitation also changed the landscape. Ms. Kaleikini’s *kūpuna* practiced *lā‘au kāhea* and *lā‘au lapa‘au*. *Lā‘au* was planted near *kauhale* for convenience and gathered at specific times of the day or moon phases. In some cases, *lā‘au* was also gathered from different locations. Ms. Kaleikini’s mother’s favorite areas for gather medicinal plants were in Mānoa and Nu‘uanu Ahupua‘a. She also gathered in Makiki and sometimes Pālolo. Salt and *limu* were also abundant in the Kālia area until the water became too dirty. Ms. Kaleikini’s mother still gathered *limu* at a mouth of a stream near Gray’s Beach in Kālia until the *limu* bed was completely destroyed. Both salt and *limu* were used for food preparation, and for ceremonial purposes including *lā‘au*. The *kāne* in Ms. Kaleikini’s *‘ohana* would hunt

within the project area. Ms. Kaleikini shared that some of her family still hunts within the project area today.

Participant Dwynn Kamai played in Pālolo Stream with her siblings regularly. They caught guppies and crayfish to add to their fish tank at home. In addition, Ms. Kamai recalled seeing *‘ōpae* in the stream. Further in Pālolo Valley, she gathered large *laua‘e* for *lū‘au* and for the scent, as this particular mountain variety’s fragrance was reminiscent of *maile*.

There are currently 17 taro patches at Kānewai Lo‘i located at the Hawai‘inuiākea School of Hawaiian Knowledge at the University of Hawai‘i at Mānoa. Each taro patch was named by the first student group that reopened Kānewai Lo‘i, each named after places or events. One *lo‘i* with historical precedence is Kaleiheana. The *lo‘i* was named after the *konohiki* who cared for Kānewai and was also a main warrior under Ke‘ewaumoku, a general under Kamehameha I. Currently, Kānewai Lo‘i cultivates 63 of the 69 known varieties of *kalo*. Following traditional cultivation techniques, there are no pesticides, herbicides, or other poisons used for the management of the *lo‘i*.

Three participants (Mr. Cashman, Mr. Winchester, and Mr. Arizumi) regularly collect rocks from the streambeds in Mānoa Ahupua‘a. Mr. Cashman collects rocks from Kānewai Stream for the use of rock wall building, *imu*, or *pōhaku ku‘i ‘ai*. Mr. Winchester collects rocks from ‘Aihualama Stream for the use of rock wall building as well. He also collects water from the stream for *ho‘okupu* during Makahiki. Mr. Arizumi collects rocks for *imu* practitioners from the Woodlawn Bridge area, specifically looking for those containing holes.

Mr. Arizumi grew up in Mānoa Ahupua‘a and recalled gathering *‘o‘opu*, crayfish, *‘ōpae*, and *pipipi* from the stream as a child. All the creatures collected from the stream were then cooked over a fire and eaten whole with the exception of the *pipipi*, as that meat was picked out from the shell with a safety pin. Mr. Arizumi noted that he has not seen *‘o‘opu* and *‘ōpae* in the streams but crayfish are still present. He attributed the lack of *‘o‘opu* to the channelization of the stream, which has created an unsuitable environment for the native fish. Widening of the stream bed combined with a concrete bottom and the heat of the sun creates intolerable water temperatures for native fish. The smooth bottoms and sides of the channelized stream beds do not produce oxygen in the water. Oxygen is produced in natural stream beds when water flowing over rocks and boulders creates air bubbles.

Mr. Arizumi also gathered fruits including mountain apple, mango, lychee, and California plum as a child in Mānoa. California plum trees still line the banks of Mānoa Stream next to Woodlawn Bridge. Mr. Arizumi’s father pointed out to him locations of *lo‘i* throughout Mānoa Valley. Due to a dwindling Hawaiian population, Mr. Arizumi recalled *lo‘i* being cared for by Chinese plantation workers. *Lo‘i* also transitioned to rice paddies. Farmers in Mānoa followed the stream to Waikīkī where they traded taro for fish.

5.3 Burials

Ms. Kaleikini and her *‘ohana* are recognized by the State of Hawai‘i as recognized lineal descendants to burials in the *‘ili* of Kālia located in the *ahupua‘a* of Waikīkī. Ms. Kaleikini emphasized that numerous historic and archaeological sites are within the project area. Most sites have been destroyed by development, however, remnants can still be found on the surface and also within sediments. She stressed that these sites can reveal history, *mo‘olelo*, and the traditions of

those who once inhabited these sites. She cautioned that there is a possibility of encountering *‘iwi kūpuna* or ancestral bones at these sites, especially because the project area is within the urban corridor, which was a densely inhabited area occupied by Native Hawaiians.

5.4 Water

Mr. Lao shared that the entire Kaka‘ako area is comprised of brackish water. The Ward Estate, now the current site of the Neal S. Blaisdell Center, was famous for its pond and springs. However, construction in the area has broken into the water table creating saltier water. The *‘ili* of Kālia in the *ahupua‘a* of Waikīkī, which is near the outlet of the Ala Wai Canal, was once very swampy and most likely consisted of brackish water.

Ms. Matson shared the history of Kapi‘olani Park. The park first opened in 1877, designed after and inspired by the Victorian parks of Europe and America. Recreational activities of this era included carriage rides, picnics, boating, horse racing, and polo. The north end of the park consisted of a natural wetland system featuring lagoons and Makee Island. People rowed boats to Makee Island where they picnicked and enjoyed the Royal Hawaiian Band at the park’s first bandstand. The lagoons were fed by the Tampong Ditch, which carried water from the Mānoa and Pālolo streams across to the current location of the Ala Wai Golf Course to the park. The lagoons began to harbor mosquitoes and in addition a small zoo was planned for the central portion of the park. Eventually the natural wetland system was filled in to prevent mosquitoes from breeding and to make way for the zoo. Although the lagoons and Makee Island no longer exist, a small portion of the natural wetland system still exists behind the Waikīkī Shell. During the winter months, a natural swale fills with brackish water and tilapia can be found swimming there. Ms. Matson believes there is a channel or a possible karst that allows the tilapia to enter from the canal.

Although Kapi‘olani Park no longer has a stream that runs *mauka* to *makai*, Ms. Matson pointed out there are five artesian wells within the park and a culvert from the stream that once flowed next to Papa‘ena‘ena Heiau. During the wet season, waterfalls can be observed on the sheer slope of Diamond Head.

In the *mauka* reaches of Pālolo, Ms. Kamai recalled playing in Pālolo Stream regularly. Her father would have her and her siblings pick up all the trash along the stream and take it to the curb prior to playing in the stream. Ms. Kamai stressed that the area where she once played with her *‘ohana* is now overgrown. Another swimming hole that Ms. Kamai recalled but never visited is within Ka‘au Crater. Accessing the crater requires traversing the stream several times and scaling a couple of waterfalls. One thing Ms. Kamai recalled about the waterways of Pālolo is that they never flooded or caused any damage to life and/or property that she knows of.

Mr. Cashman recalled a previous project that would have restricted access to the water source and threatened their cultural practice of tending to the *lo‘i*. In the past, a concrete wall had been proposed to run from the *po‘owai* of Mānoa Stream to the end of Kānewai Lo‘i. The current *lo‘i* area was proposed as a construction vehicle parking lot and the contractor offered to build a staircase for easier access to the stream. Mr. Cashman strongly opposed any alterations to the stream and the Kānewai area. No alterations were made to the stream or Kānewai Lo‘i.

Mr. Winchester who maintains ‘Aihualama *lo‘i* recalled the water levels being at an all-time low during the summers of 2004 through 2007. Water flow must be consistent and temperatures need to be cold to maintain a healthy *lo‘i*. However, if there’s too much water that includes flash

flooding, storms, and what Mr. Winchester describes as “chocolate water” entering the *lo‘i*, this is also hazardous to the stream and *lo‘i*. Another hazard to *lo‘i* health is the large trees that line the stream banks including albizia and banyans. Erosion and the buildup of *‘ōpala* such as branches and leaves clogs and disrupts water flow.

5.5 Flooding

A common topic for participants was flooding, especially in the Mānoa area. Based on the topography of Mānoa, Mr. Arizumi believes this is one of the reasons the valley has a flooding problem. The older substrate of Mānoa is located on the Makiki side of the valley, which has a slope allowing movement from *mauka* to *makai*. The Pālolo side of the valley is the younger substrate and is flat and wide with a reduced slope, creating a slow and shallow flow, thus backing up water above Woodlawn Bridge. The geologic makeup of Mānoa is another factor. Pu‘u Ualaka‘a, commonly known as Round Top or Tantalus, divides Makiki from Mānoa Ahupua‘a. An eruption at Pu‘u Ualaka‘a pushed the stream towards the Wa‘ahila side of Mānoa Valley. The combination of pushing the stream towards the side of the valley with a slower and shallower slope contributes to the backup in water flow. Mr. Arizumi hosts stream clean-ups two to four times a year in the Mānoa area. He specifically takes volunteers to Woodlawn Bridge across from the Mānoa Shopping Center because this is where a majority of the debris accumulates. In 2004, this area was the source of water flow that flooded Hamilton Library at the University of Hawai‘i at Mānoa.

Ms. Giddings also recalled the aftermath of the 2004 flood. While Ms. Giddings was surveying the damage, she had a sudden insight that the flood was caused in part by the water pursuing a former path. Due to the water moving back and forth across the valley for thousands of years, the river followed an old path. A combination of “plugged up” streets and intense rainfall resulted in the flood. Ms. Giddings feels the source of the flood was from the Woodlawn area and that the area near Noelani School is the lowest point of that area. She continued, saying, “It kept coming down the streets, and there by Long’s Drug Store, it just kept on going and through the Noelani School and then through the University Campus.” When the rains subsided the following day, she inspected the damage. Debris was stuck on the fence at St. Francis School. In addition, cars were wedged in trees and debris was stuck in the University of Hawai‘i faculty housing fencing next to the Woodlawn Bridge.

In 2004, Kānewai was inundated with water. The *‘auwai*, which runs parallel to Mānoa Stream, is approximately 5 to 6 ft above the stream. The water rose above and beyond the *‘auwai* flooding the Kānewai property. Mr. Cashman added that when water rushes through the Kānewai area, it can travel at speeds from 30 to 40 miles per hour. He stressed the importance of cleaning the stream. He added that the 2004 flood was “manmade” and the source of the problem was at the Woodlawn Drive Bridge. He added that the bridge is low. The combination of a low bridge and settling debris underneath slowed the flow of water.

5.6 The Ala Wai Canal

Mr. Chester Lao stated that plans for the Ala Wai Canal were first conceived in 1927 by developers who dubbed the project “The Venice of the Pacific.” The original plan for the Ala Wai was to have an entrance and exit from the canal with buildings along its sides with boats and gondolas to navigate the waterway. The proposed exit from the canal would have extended to the

current location of the Waikīkī-Kapahulu Public Library and would have turned *makai* connecting to the sea at the Kapahulu Groin so the canal could have better circulation. However, the exit was never constructed and the only outlet is in the *‘ili* of Kālia near Ala Moana Shopping Center.

Community contact Evelyn Giddings recalled platforms along the length of the Ala Wai Canal on the Waikīkī side, where she passed each week as a 10-year-old girl, and where she witnessed people catching mullet. Each time heavy rain came, the resulting floods brought debris from *mauka* all the way down:

> There were all these fishing platforms, with the little planks that went out and there was this little chair with somebody sitting there catching mullet. So that was always interesting. But the most interesting part of it was when there was heavy rain, and the floods would bring all this debris down.

Section 6 Summary and Recommendations

CSH undertook this CIA at the request of CH2M Hill. The research broadly covered the entire *ahupua‘a* of Waikīkī, Pālolo, Makiki, and Mānoa, including the 19-sq-mile project area.

6.1 Results of Community Consultations

CSH attempted to contact Hawaiian organizations, agencies, and community members as well as cultural descendants of Waikīkī, Pālolo, Makiki, and Mānoa in order to identify individuals with cultural expertise and/or knowledge of the project area and vicinity. Community outreach letters were sent to a total of 93 individuals or groups; 17 responded, five suggested referrals, four provided consultation summaries, and five participated in formal, in-depth interviews. Community consultation indicates the following:

1. According to several participants, the source of the problem from the 2004 flood of Mānoa stems from the Woodlawn Bridge area. Mr. George Arizumi, Ms. Evelyn Giddings, and Mr. Makahiapo Cashman have all asserted that the Woodlawn Bridge area is low and debris tends to gather in this area. Mr. Arizumi and Ms. Giddings have stated that the area between Woodlawn Bridge and Noelani Elementary School is the lowest lying area. Water tends to collect around the Univeristy of Hawai‘i at Mānoa’s College of Tropical Agriculture and Human Services and flows back into the stream in the back.
2. Participants shared that the geology of Mānoa Valley contributes to the flooding problems. Mr. Arizumi, a third generation resident of Māoa, spoke of different geologic ages of substrates in the valley. The older substrate of the valley is located on the Makiki side and slopes down allowing for movement toward the ocean. The younger substrate is located on the Pālolo side of the valley and is wide and flat with a reduced slope. Thus the Woodlawn Bridge area is closer to the younger substrate, which creates a slow and shallow flow of water making it easy for this area to get backed up. Director of Ka Papa Lo‘i ‘o Kānewai, Mr. Cashman shared a *mo‘olelo* that connects to the cultural landscape of the valley. Kākea, a *mo‘o*, has the ability to change into different *kino lau* including a destructive wind that rushes through Mānoa Valley. He can also turn into a *pu‘u*. The *pu‘u* is critical because an eruption in Mānoa has caused the water system to shift towards the Wa‘ahila side of the valley. Ms. Giddings has also seen the stream shift back and forth on the valley floor.
3. A popular childhood pastime amongst participants was swimming in the various streams and ponds. Mr. Arizumi shared that downstream of Woodlawn Bridge were two deep pools of water known as “Boy’s Pond” and “Girl’s Pond” where each would go to their own ponds to swim. A storm in the 1950s filled Girl’s Pond with silt and gravel. Eventually everyone swam at Boy’s Pond. Ms. Dwynn Kamai, *kama‘āina* of Pālolo, shared her memories of Pālolo where she recalled playing in the stream.
4. Waterways not only provided recreation but sustenance. Mr. Arizumi recalled the streams containing *‘o‘opu*, crayfish, *‘ōpae*, and *pipipi*. Everything was cooked over an open flame with the exception of the *pipipi*. The meat from the *pipipi* was picked out with a safety pin prior to its being eaten. The stream banks were lined with California plum that are still there today. Other fruits gathered included mountain apple, mango, and lychee for snacking. Ms. Kamai recalled catching guppies and seeing *‘ōpae* in Pālolo Stream. Mr. Cashman stated that Kānewai Lo‘i currently cultivates 63 of the 69 known varieties of *kalo*.

5. The Mō‘ili‘ili karst system is an underground waterway extending through Kaimuki, Mō‘ili‘ili, and Waikīkī. Mr. Lao, a former Board of Water Supply employee, has been inside the karst system and has seen blind spiders and catfish in the caverns. On another occasion while visiting the karst, he saw *‘ōpae* in the water. However, he noted that the water in the karst is murky and the caves contain a high level of carbon monoxide. Mr. Lao discouraged anyone from accessing the caves.
6. Ms. Kamai recalled a large *laua‘e* patch deep in Pālolo Valley. This particular variety of *laua‘e* was the mountain variety having no seed pods and very large leaves. Her *‘ohana* gathered the *laua‘e* for *lū‘au* and for its scent, as it was reminiscent of *maile*.
7. Agriculture and aquaculture were not only used for food consumption, but also for ceremonial purposes. Ms. Paulette Ka‘anohi Kaleikini, State of Hawai‘i recognized lineal descendant, shared that her *kūpuna* practiced *lā‘au kāhea* and *lā‘au lapa‘au*. Ms. Kaleikini’s mother gathered *lā‘au* in Mānoa at a Royal Patented property and also in Makiki. Ms. Kaleikini’s mother rarely gathered from Pālolo, but would on occasion gather from her cousins’ property. *Pa‘akai* and *limu* were used for food preparation and *lā‘au*. *Pa‘akai* for food preparation was acquired locally, while salt for ceremonies was imported from Moloka‘i. *Limu* was gathered at Kālia until Ms. Kaleikini’s mother determined that the water was too dirty. Her mother continued to gather *limu* at Gray’s Beach until that *limu* bed was destroyed. Mr. ‘Īmaikalani Winchester, teacher at Hālau Kū Māna public charter school and caretaker for ‘Aihualama Lo‘i, stated that water from the stream is used for ceremonial purposes during Makahiki.
8. Rocks are gathered from stream beds for cultural practices as well. Mr. Arizumi looks for *imu* rocks under the Woodlawn Bridge, specifically looking for those that have holes. Mr. Cashman gathers rocks at Kānewai Lo‘i where he divides them into different piles: rock wall building, *imu* use, and *pōhaku ku‘i ‘ai*. Mr. Winchester gathers rocks as well further *mauka* at ‘Aihualama Lo‘i where he uses them for rock wall building.
9. Ms. Kaleikini shared that her family settled into the *‘ili* of Kālia located in Waikīkī Ahupua‘a. She stated that remnants of historical sites may be imbedded in the sediments, thus including the possibility of encountering burials at these sites. Because this particular project is in the urban corridor and it was once an area inhabited by Native Hawaiians, she stressed that the project proceed with caution. She added that streams and waterways were also areas nhabited by Native Hawaiians.
10. Participants shared *mo‘olelo* describing the *wahi pana* of the *ahupua‘a*. *Mo‘olelo* shared also reflected the weather patterns of the area. Ms. Kaleikini shared the *mo‘olelo* of Kauatunahineomanoa, which taught her to call out to Tuahine while walking or hiking in the valley. Tuahine is a soft, gentle rain whereas Wa‘ahila is a heavier, masculine rain. As mentioned earlier, Mr. Cashman shared the story of Kākea. In connection to Kākea, Mr. Cashman shared a story of a set of twins named Wa‘ahila and Kilihune who come from Mount Ka‘ala in the Wai‘anae Mountain Range. The twins run away from their mother in Wai‘anae to Mānoa. Their mother finds them and takes them to Wai‘anae where they are beaten. Wa‘ahila and Kilihune escape from their mother again and find refuge in the lower portion of Mānoa where they befriend Kākea. The boy tells Kākea that he wants to make a spring for his sister so she can shower and make food. The two go to Kānewai Spring and dig an underground cave. In the *‘ili* of Haukulu (literally “dripping dew”), Mr. Winchester recalled the *mo‘olelo* of Kahalaopuna that takes places there. There are many different

versions of Kahalaopuna, but in one account, Mr. Winchester recalled a saying that every time a chief died a *hau* tree could be seen crying. When he goes to Haukulu ‘Ili, the rain collects on the *hau*; if he sits underneath it gives the effect that it’s crying on him.

11. Ms. Kamai and participant Mr. Gregg Kashiwa also shared that the first nine-hole municipal golf course opened in Pālolo Valley in 1931. The course incorporated the natural features of the valley including two streams, rolling fairways, hills, gullies, ditches, and bunkers. The clubhouse was located at Palolo Avenue and Kalua Road. The course was popular until World War II when it closed. The golf course was cleared for the construction of approximately 100 homes for emergency evacuation for those in low lying areas. An airstrip was also near the golf course.
12. Participants shared their memories of the Ala Wai Canal:
    a. Mr. Lao shared that the idea of the Ala Wai Canal was originally conceived in 1927 and was dubbed by the developers the “Venice of the Pacific.” The original plan was to have an entrance and exit from the canal, buildings were to line the canal, and boats and gondolas were to navigate the Ala Wai waters. However, an exit from the canal was never constructed. The proposed exit was to extend to the current location of the Waikīkī-Kapahulu Public Library and turn *makai* connecting to the sea at the Kapahulu Groin so the canal could have better circulation. Due to the current construction of the canal without an exit, the water is very stagnant especially near the Kapahulu area where it is filled with debris and other noxious items.
    b. Ms. Evelyn Giddings, long-time resident of Mānoa, recalled walking over the McCully Bridge as a child where she observed fishing platforms lining the banks of the Ala Wai Canal on the Waikīkī side where people caught mullet. She added that the McCully Bridge had tracks for trolley cars. The tracks were supported by posts that acted like a debris catchment system. Rats, chicken coops, and dead pigs would get trapped under there as they washed down from the *mauka* areas.
    c. According to historical maps, the Waikīkī Shell was once part of an area that was formerly a duck pond. Chair of the Diamond Head Scenic Byway Committee, Ms. Michelle Spalding Matson, pointed out that a remnant of the wetland is still present behind the Waikīkī Shell. A restoration project called the Kaneloa Wetland Project was funded by the EPA and began in 2000 with the purpose of restoring the wetland remnant. However, the Army volunteers helping restore the area were called into active duty following 11 September 2001 and EPA funding ran out near completion of the project. Native plants still continue to thrive in the wetland area including bacopa, Native Hawaiian sedge, and *‘ākulikuli*. During the winter months, the water levels rise in the wetland remnant. Brackish water enters via a channel or karst and tilapia can be seen there. Ms. Matson is unsure where the tilapia enter, but has suggested the Ala Wai Canal or Kapahulu Groin.

*Note: Native plants used for medicinal and religious purposes are often found along stream banks. However, participants did not specifically mention the locations of plants within the study area in response to CSH interview questions.

6.2 Community Recommendations

Based on information gathered from the community consultation, participants voiced the following concerns:

1. Mr. Arizumi supports improvements to Mānoa Stream that would help reduce the threat of flooding with sound practices. If possible, he does not want the channelization of Mānoa Stream to be extended.
2. Ms. Kaleikini is concerned with any pre-Contact or historic properties that may be found under sediments. Her *‘ohana* are recognized by the State of Hawai‘i as lineal descendants to burials in the *‘ili* of Kālia located in the *ahupua‘a* of Waikīkī. She stated that there is a possibility burials might be encountered in the Kālia area. Also, because this project is within the urban corridor and also in an area that was once densely inhabited by Native Hawaiians, there is a chance that burials might be encountered. She added that caution must be used in stream areas as well since these were also areas inhabited by Native Hawaiians.
3. Ms. Kamai believes that periodic cleaning and maintenance of Pālolo Stream would be sufficient to keep the waterway flowing. She added that Ala Wai needs to be cleaned.
4. Ms. Giddings raised concerns over the state of the drainage system, stressing the necessity of cleaning the drains regularly even if it’s not a rainy season. She added that the current storm drains are inadequate stating that they are out of date, have not been cleaned, and do not have the capacity to handle the volume of water at once. Ms. Giddings recommended that if project proponents want to learn about water behavior, they should contact Jennifer Greene who established The Water Institute. Ms. Giddings added that Ms. Greene has remediated many streams and is known to work with stagnant streams.
5. Mr. Cashman opposes the installation of debris catchments throughout the stream. He added that the debris catchment system will slow the flow of water in the stream. He believes that periodic cleaning of the stream is the best way to prevent flooding.
6. Mr. Winchester is concerned about heavy machinery. He noticed there was obvious removal of stream banks and rocks were being removed where Pālolo Stream and Mānoa Stream converge. He recommended that all resources found within the stream should:
    a. Be distributed to community members within the *ahupua‘a* where they were found.
    b. If there is no way to redistribute these resources, organizations interested in these resources should be recognized and contacted during excavation.
    c. Native Hawaiian families and groups within the area should be notified in order to relieve the City and County or any other agency of these natural resources.
7. Ms. Matson raised concerns about the proposed walls and gates that would surround the historic Ala Wai Canal which was placed on the State Historic Register in 1992. Her main concern is that if structural modifications are made to or around the canal, it could create a detrimental precedent for all historic sites and laws protecting them.
8. Mr. Kashiwa expresses that he is opposed to changing any part of the Ala Wai Golf Course for flood control.

6.3 Recommendations

Based on information gathered from the community consultation detailed in this CIA report, the proposed project may potentially impact Native Hawaiian burials, stream life, historic

properties, etc. CSH summarizes below the potential impacts and recommendations gleaned from the community consultations:

1. There is high possibility that *iwi kūpuna*, ancestral bones, may be present within the project area and that land-disturbing activities during construction may uncover presently undetected burials or other cultural materials. In addition, a community participant has indicated that undetected burials might be found on her family *kuleana* and within areas that were densely inhabited by Native Hawaiians.
    a. Personnel involved in the construction activities of the project should be informed of the possibility of inadvertent cultural finds, including human remains. Should burials or other cultural finds be identified during ground disturbance, the construction contractor should immediately cease all work and the appropriate agencies be notified pursuant to applicable law, HRS §6E.
2. Project proponents should consult with lineal and cultural descendants of Makiki, Mānoa, Pālolo, Kaka‘ako, and Waikīkī to develop a reinterment plan and cultural preservation plan in the event that any human remains or cultural sites or artifacts are uncovered during construction or long-term maintenance for the project.
3. Project proponents should consult with the State Historic Preservation Division in regards to altering a registered State Historic Property, the Ala Wai Canal, State Inventory of Historic Properties (SIHP) # 50-80-14-9757. Construction of floodwalls along the *makai* side of the Ala Wai will impact the view planes from Waikīkī to the study areas. Significant berms will also have a similar impact on the visual landscape and the integrity of the cultural landscape of Mānoa, Pālolo, Makiki, and the Ala Wai Canal.
4. Participants did not specifically mention potential impacts on *lo‘i*. However, participants made comments and recommendations on streams and the immediate surrounding areas that would potentially affect *lo‘i* health. Comments and recommendations made by community consultants include avoiding channelization of the stream to minimize environmental impacts such as heavy water flows that would affect stream life, surrounding vegetation causing erosion to streambanks, and limit access to adjacent organizations and individuals that utilize the stream for cultural practices.
5. Community consultants recommend that the City and County of Honolulu consider the following mitigation measures to minimize potential adverse impacts instead of the proposed measures:
    a. Development of a scheduled vegetation clearing plan (e.g. cut down large and/or invasive trees such as albizia) both upstream and downstream of the various tributaries within the Ala Wai Watershed to allow for maximum water and to prevent future blockages that may result in area flooding.
    b. Development of a scheduled maintenance plan upstream and downstream of the various tributaries and trouble spots within the Ala Wai Watershed stream system to prevent future blockages that may result in area flooding (e.g. debris such as tree branches, leaves, trash, etc.).
6. The proposed measures at Waiakeakua Stream, Waihī Stream, and Kānewai Stream are located *makai* of ‘Aihualama Lo‘i and Kānewai Lo‘i, which should not directly impact the integrity of the *lo‘i*. However, any inundation behind basins during and after heavy storms could directly impact those *lo‘i*. There is also possibility of loss of access to cultural sites

and areas of cultural pratices during construction as well as potential long term impacts to cultural sites.

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Appendix A Authorization Form

Cultural Surveys Hawai‘i, Inc.
Archaeological and Cultural Impact Studies
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AUTHORIZATION AND RELEASE FORM

Cultural Surveys Hawai‘i (CSH) appreciates the generosity of the *kūpuna* and *kama‘āina* who are sharing their knowledge of cultural and historic properties, and experiences of past and present cultural practices for the proposed Ala Wai Canal Project, a flood damage reduction project sponsored by the U.S. Army Corps of Engineers (USACE), in coordination with the State of Hawai‘i, Department of Land and Natural Resources (DLNR) and City & County of Honolulu Environmental Services (ENV). This project is located in the *ahupua‘a* of Waikīkī, Pālolo, Makiki and Mānoa, Kona District, Island of O‘ahu, Tax Map Key (TMK): [1] 2-3, 2-4, 2-5, 2-6, 2-7, 2-8, and 2-9; [1] 3-1, 3-2, 3-3, and 3-4.

We understand our responsibility in respecting the wishes and concerns of the interviewees participating in our study. Here are the procedures we promise to follow:

1. The interview will not be tape-recorded without your knowledge and explicit permission.
2. If recorded, you will have the opportunity to review the written transcript of our interview with you. At that time you may make any additions, deletions or corrections you wish.
3. If recorded, you will be given a copy of the interview notes for your records.
4. You will be given a copy of this release form for your records.
5. You will be given any photographs taken of you during the interview.

For your protection, we need your written confirmation that:

1. You consent to the use of the complete transcript and/or interview quotes for reports on cultural sites and practices, historic documentation, and/or academic purposes.
2. You agree that the interview shall be made available to the public.
3. If a photograph is taken during the interview, you consent to the photograph being included in any report/s or publication/s generated by this cultural study.

I, _____, agree to the procedures outlined above and, by my
(Please print your name here)
signature, give my consent and release for this interview to be used as specified.

_____
(Signature)

_____
(Date)

Appendix B Chester Lao Transcription

Interview with Chester Lao, former Board of Water Supply employee on June 4th, 2014 at the Hawai‘i Public Library

CL: Chester Lao

CSH: Cultural Surveys Hawai‘i

CSH: Ok. Alright. So it's June 4th and we're here at the public library, I'm interviewing Chester Lao. That's correct, yeah?

CL: Correct.

CSH: Ok, alright. So did you want to start from…again, from Kaka‘ako towards Kaimuki side. You want to talk about the water from that side?

CL: Ok. Well….

CSH: Again. Sorry, you have to repeat yourself.

CL: Well, let's take it downtown.

CSH: Ok. Sure.

CL: As a starting point. Historically, when the Missionaries first came, the water tables in the caprock aquifer were high and at the present site of the Missionary home which is a tourist museum piece of what life was like during those times. The water table, the geology of the area was such that right downtown here by the Board of Water Supply and the Missionary Homes is in cinders, a lot of cinder. And in the cinders there was water collected in the cinder. And more importantly down in the coral below, water collected the coral limestone that forms that forms part of the cap rock. And they had a well, they dug a well--hand dug--around 25 feet and the water was suitable for drinking and cooking but it probably wasn't the best quality, not more brackish like today, but it was adequate for survival of life. The missionaries used it for cooking, washing, and for sustaining life. And in the vicinity where the busses are, the bus collection area, is by the Board of Water Supply. That area and across the street had similar water. Across Beretania street, was swamp. I remember looking at maps in the Archives that show this area has been swamp land. And of course the Blaisdell Center that was owned by the Ward sisters was famous for the ponds and springs they had there. The current situation is there is still brackish water there. Blaisdell Center drilled two wells and the one furthest *maka*i was a bit more brackish. So they put salt water fish in. And the one *mauka* of that was still usable. It was not too bad, a little too brackish to drink. So in that pond they raised *koi* and stuff like that. And in the lower pond by the athletic center you see that most of the fish are marine fishes. You see things like *pāpio*, tangs, and other salt water fish like that and some fish like that. And some tilapia as well.

CSH: And the *‘ōmilu* that you said earlier.

CL: Yes. So those are the remnants of the swamps in the area. And then going further Diamond Head. Um…

CSH: Hold on one second. So the fish that were there was that in there from in there when the Ward sisters were living in there? No this is now?

CL: No, no, no. The big pond around the Blaisdell sports arena is strictly artificial and the Blaisdell people planted fishes that were increasingly more and more marine type fishes as the water got brackish. And the sewer project a few years ago, maybe less than ten years ago, that went down Ward Avenue probably drained off a lot of brackish water and so the water got salty. And then further along Kapi‘olani Boulevard, around the area of Ke‘eaumoku Street, before we get to Ke‘eaumoku, the KGMB TV station used to be located there and one reason for its location there, of course there are several reasons. One is the land is cheap because it’s all swampy. But the swampy area also made for good ground conduction for the transmission tower—that’s always a good thing. So KGMB only recently moved out so they had what existed there in that area for probably 50 years.

CSH: So salt water is a good conductor?

CL: Oh yeah, salt water is an even better conductor. Just plain water is a conductor any salt mixed in makes it an even better conductor.

CSH: Interesting.

CL: And then going across the way into….what’s the name of that street now? Kaheka.

CSH: Ok.

CL: Kaheka was a swamp too because my mother-in-law remembers going down there to buy duck eggs, swamp cabbage, watercress, and taro. So that whole area was intermittingly swampy. So that continues on across. Now going into where the Ala Wai Clubhouse is, that area there was swampy and became dried out when they put in the Ala Wai Canal. The Ala Wai Canal was originally conceived by the developers as the “Venice of the Pacific” where they would have buildings along the canal and would have boats—gondolas and so forth like that. But originally when the project was conceived, there were supposed to be an outlet, not only the current inlet by the current Ala Wai boathouse but also going along Kapahulu, Ala Wai Boulevard—all the way down Kapahulu and then taking a turn makai and the tunnel….the canal was supposed to be connected by an open water-way from the Kapahulu Groin to the Ala Wai boathouse so that would’ve had good circulation with the canal. Currently as it exists since it doesn’t have an outlet, the water is backed in all the way to right there…..Ala Wai library is stagnant so that area is known for growth of *limu* and other noxious things too.

CSH: Invasive *limu*? What did you say? It has invasive *limu*?

CL: No, it has noxious.

CSH: OH!

CL: And things like that….

CSH: And that’s where all the debris kind of…

CL: Collect.

CSH: Ok.

CL: Uh huh. So way up in the *mauka* portion, it's pretty pristine. But where it encounters civilization it becomes more polluted so probably pretty vile once it reaches below the university. And umm, it's particularly, the times with high pollution are probably when the streets are flushed after the first rains because all the drainage that goes into the canal is off the streets and all the debris collects in the street. Not only all the rubber from the tires, oil that leaks from the vehicle, and rubber…there's probably a lot of rubber there too.

CSH: Do you know if people clean the….outlet, I mean not the outlet, but that area by the library? Does someone go in and take out the debris regularly?

CL: No, not on a regular basis that I know of. I know that it's been done on occasion. It probably makes the newspapers and you can read it there. To my recollection it's only been done once and maybe that was 15 or 20 years ago and I think that was mainly a surface thing to bring out all the grocery carts and all the junk cars and everything else in there, but not only regular debris . Okay now we're back just about to McCully Street now. From McCully Street all the way up to Beretania Street. About half a dozen blocks or so…that area there was swampy. Open water. Shallow. But the reason why that area exists as it did was because Waikīkī is what you call, a large beach berm, where waves and things piled up sand above the tidal line and that grew over the years—geologic years, until there was a connection at low tide between that area known as Waikīkī and the mainland portion. So people used to have holidays and go over there. Beach life I imagine in those times. The Hawaiian royalty had places down there and it wasn't very, very accessible to ordinary people. Backing up a bit, you know the area around Ala Moana Center that was very swampy. Especially where the areas of…I can remember the 1960s before you, if you go to Koko Head on Ala Moana Boulevard and turn up Atkinson, that whole area before Atkinson was all swampy.

CSH: So was there any ducks or taro or anything there?

CL: No. I think that was….

CSH: Just stagnant water?

CL: Yeah that was stagnant water, maybe brackish too. But that Ala Moana Center was created with fill from Ala Moana Park. Hawaiian Dredging was smart. They offered to dredge the canal if they could keep the debris.

CSH: Oh.

CL: They took all the debris and made the shopping center.

CSH: Oh.

CL: And they didn't have enough to fill in that area where the Ala Wai Hotel, Ala Moana Hotel and the Liberty House—that whole area—and that wasn't filled in until about 1966. Let me show you. But that's got an interesting history too. But because the Hawaiian families that were living in Ala Moana they were displaced with nowhere to go.

CSH: Do you know the name of that family?

CL: I'm sorry?

CSH: Do you know the name of that family?

CL: No, no. A whole bunch of families!

CSH: Oh! Not just one? A little community?

CL: A whole community of people. Cause you can see that the filled area is a large area, right? Well they all moved up to and settled onto Board of Water Supply land. That's the reason I know. And the Board of Water Supply land was given by a Presidential Decree, three sites for developments like Halawa Shaft which is a tunnel. We got, starting on the east we get Kaimuki then we had…what's the name of that area? The Hawaiian Homelands area. Papakōlea?

CSH: Papakōlea?

CL: Papakōlea Shaft. Wa‘ialae Shaft. Kalihi Shaft. And one more shaft by Kam [Kamehameha] School.

CSH: Ok.

CL: Right there. So that's where they settled. And the reason I know about it is because we got complaints about a piggery up there. The Hawaiians raised pigs. In particular, one family raised really a big, big--almost a thousand pounds. A really big pig! We used to get complaints about smell from the schools and people living near the school.

CSH: Yeah.

CL: And just *mauka* of Roosevelt School that's where the Papakōlea Shaft is. And that's the reason why they didn't get any homes through Hawaiian Homelands but…they might have been on the list but they never made it.

CSH: Yeah.

CL: They never made it. The outcome of that is the Board of Water Supply finally gave up and said, "You guys can have the property.' BWS gave the property to Hawaiian Home lands.

CSH: Wow.

CL: To the squatter and to Hawaiian Homelands they gave up 10 acres essentially except for one acre….to Hawaiian Homelands to build homes for Hawaiians—a new subdivision up there—about ten years old. Nice subdivision! Nice homes up there, you ought to go up there and see it some time.

CSH: Ok.

CL: And so from the swamp lands down there by Ala Moana Park going back again up into up along Date Street.

CSH: Ok.

CL: Ok, Date Street. That area used to known with a lot of intermittent ponds and that stuff too. But they put in a sewer project along Date Street and that really dried things up.

CSH: So when you say "dry things up" this is the cap rock?

CL: Cap rock, right. Just the surface, we're only talking of maybe the upper 40-50 feet—not that much. And from what became swamp—well there's two wells put in at Ala Wai Golf Course. One that produces brackish water but still fresh enough if mixed with City water to irrigate the golf course with. You can see the pond down there near Kapahulu Avenue. The City saves money by mixing the brackish water with water you can drink. And so that brings us over going *mauka* now,

we talked about the area around the high school being swampy and then going up along that area. Well, let’s just back off a little from Kapahulu Avenue and go to Hausten Street.

CSH: Ok. By the Willows and stuff?

CL: What’s the name of that other street?

CSH: Isenberg? Is it Isenberg?

CL: Isenberg, right! Isenberg, ok. On Isenberg Street that was swampy too.

CSH: Swamp?

CL: Huh?

CSH: It was swamp?

CL: Yes!

CSH: Ok.

CL: As a matter of fact, where the St. Louis Club House was it was famous for springs and ponds where the Hawaiian royalty, princes, where supposed to have bathed.

CSH: In that area?

CL: In that area. There were legends about that one because they said that the Japanese wives liked the *koi*…not the *koi*….I guess the *koi*, yep. The gold fish, the carp. Liked the carp from that pond because the fish were supposed to have significant healing properties for women having given child birth. It was famous for that. And there’s another story about that if you go a little bit further eastward and go to the area known as the Kaimuki Shopping Center and the so-called karst cave, I don’t think it’s a karst cave, it’s just a pond. An existing feature—surface water feature on the cap rock. Anyways, the Kaimuki Inn—the Kaimuki Inn as it’s known, was a famous place for eating. A good friend of mine used to go there and grew up around there as a kid. It was known for not being very well kept cause it had holes in the floor and stuff. One of the guys I know, I never told him directly, but the person that knew him, he used to fish thru cracks in the floor boards.

CSH: Oh.

CL: He used to fish for things like mullet. And things like that. So that was a famous one and one of the legends there is that the sharks used to come up to Kaimuki—swim up through the connection to the sea…

CSH: Through the underground cave as well?

CL: Swim up from Waikīkī and listen. And listen. The sharks would listen to the fishermen. And when the Hawaiians would go down there to fish so the sharks would scoot back down to Waikīkī and gobble up the fishermen for dinner.

CSH: Oh my gosh! Ok, so earlier we were talking about the karst system so the Mō‘ili‘ili karst and the Kaimuki karst they’re all...

CL: Right, they’re the same.

CSH: They all are together.

CL: Right. The area known as the Varsity Theater used to known as a swamp. And Kui Lee's father called me up one time and said, "Oh yes, we used to get fish out of there." That's Kui Lee's father!

CSH: Wow. He would fish out of the karst?

CL: Yeah. Out of the ponds where the church is located—Church of the Crossroads? There were springs there when the water table was high.

CSH: Wow, that's cool. So what other animals were in there besides sharks and mullet?

CL: Ok, now going into the tunnel through the limestone there….one time when I went down there. I went down into the very far end, which was blocked off, because one of the karsts one of the roofs of the cavern fell in. They filled it up with broken rock—crushed rock. So we couldn't go any further. So although all the water could flow through, people couldn't go through. But I was standing there at the end of the cavern as far as I could go and something slithered over my foot. In that cavern were blind spiders and blind catfish.

CSH: Wow.

CL: This person, this scientist from the Bishop Museum was with me. And so he had been in there independently ahead of me and he said "Yeah, there's blind catfish in there." But I didn't never saw any fish cause it was too murky to see even though we had lanterns—we had Coleman gas lanterns—real bright—couldn't see.

CSH: Was the water clean?

CL: No, it wasn't. It wasn't enough to see my toes. I could maybe see a foot down but not any deeper than that. Too murky. Of course, us going through, wading through the mud and stuff…

CSH: I know. It kicks it up and stuff, right? Is this is the time you went down with someone and they had the little tester and they were looking for the carbon monoxide?

CL: Oh no, this is another time. This is many years later. And then people ask me, "Can I go down with you sometime?" or "Where's the entrance?" And I say, "No." I would discourage it. One time I was with some people from work. Some guys from my section. One of the guys had a gas meter and he said, "Hey, hey look! Look, look! This thing, the carbon monoxide level here is on the verge of being dangerous. This cannot be so good for unsuspecting people." And this reminds me of a time I went down there 10-15 years previous to that that I was down in there and I thought, "Gee, you know, being down underground should be cool instead I'm on the verge of sweating." And so was the person from the Advertiser who was with me and he felt that way too. But the sweating and the feeling of being hot is a typical reaction to carbon monoxide poisoning but I was not aware at the time. If the carbon monoxide content was higher, I wouldn't be here but the concentration was high enough to make me react.

CSH: Yeah.

CL: So I discourage people from going down there.

CSH: Uh hmm. So the water that feeds the karsts, this is coming from up above?

CL: Oh yes.

CSH: So this is coming from Mānoa? Pālolo?

CL: Yes and Pālolo.

CSH: Ok, and then….so it comes onto the surface and then there’s the cap rock.

CL: Seeps down into the cap rock.

CSH: And then there’s this underground tunnel as well.

CL: Yes.

CSH: But does that water come from the cap rock also?

CL: No, that’s cap rock water—yes. But all the rainfall that falls on the parts that are porous and permeable in Mānoa, seep down and ultimately reach this level. The rainfall that falls upon the weathered basalt basement rock escapes the cap rock. The cap rock forms as a result of the weathering and collection of sediments of the *ko‘olaus*. Let’s say this is the *ko‘olaus* here. A *ko‘olau* here. The stuff that washes down here collects in the valley and it builds up like this. And so, it depends where you are and on the edges of the valley the cap rock is thin. As you enter the bottom of the old valley, it gets thicker.

CSH: Ok.

CL: In the history, the geologic history of O‘ahu, the sea level rose and fell in response to when water was held or released by the ice caps during the Ice Age when the glaciers melted then sea level rose above the current levels we have now. And this occurred when the cap rock, when the coral formed inland as far as it did to Mō‘ili‘ili. In the vicinity of Honolulu Community College right along Kapi‘olani Boulevard, you can see the cap rock, coral cap rock, exposed along the sidewalk. You can see these marine forms--clams, oysters, and so forth along there. And when the ice was held up by the glacier, the sea level falls. In that case, the sediments were washed out further than it does now.

CSH: Yeah. So where is the cleanest drinking water? It would come from the *ko‘olaus*?

CL: Oh yes.

CSH: Ok. Where does it get more polluted? Or where should you not drink it anymore?

CL: If you’re only talking about the water in the volcanics, it’s pure until development is on the portions of the weathered or non-weathered volcanoes. For example, the whole area around Pearl Harbor and the area all above—the developed areas above H-1 those areas where the peaks are high and no one is living the water seeps right down into there and that’s good water. That’s very pure water. But once it starts getting out to where the land is plains and either inhabitable, unusable or things like sugarcane, pineapple, or cattle and so forth—then the land use affects the quality of water. For example, the pineapple plantations—when they were existence they used pesticides that got into the ground water. So you have pesticide pollution all over Pearl Harbor. So the Pearl Harbor aquifer in general—not as clean as you might think. And the towns that grew up around there—if they had cesspools like back in the old community—then the water went down directly, through the weathered basalt, down into the basalt cap rock, where it contains good water. And even in the modern community, the fact they’re on land that was used for agriculture and something like—they do have--sugar left its imprint, but not as bad as pineapple. Pineapple

pesticides are a lot higher. And in the places they propose agriculture that’s got to be watched carefully too to make sure the insecticides, herbicides, and fertilizer don’t get into our water. The main affect from sugar was from, because they used more brackish water, that they pumped from the cap rock or near the cap rock, they transported brackish irrigation water would escape the root zone and go into the water table so that caused increasing saltiness of the water from the natural state. Naturally it was good. Naturally without any development, without any agriculture—the water was good.

CSH: Was there any….do you know of any pineapple or sugar cane plantations that is within the project area now, which is Makiki, Mānoa, Pālolo, this Mō‘ili‘ili area? Or was it mostly just taro and vegetable farms?

CL: Yes. In the ancient agriculture—when I say ancient--had no effect. Because the taro was in paddy culture where they wanted to waterproof as possible to keep water from seeping away from taro, so that was fine. Things like watercress and swamp cabbage—oriental paddy culture—pretty much the same. Because in those days they didn’t use insecticides. And if they used anything it was probably animal. And because they were adjusted to the bugs, they probably see feel any affects from it.

CSH: Ok. So going closer to the *ko‘olaus*…can you tell me more about the tunnels?

CL: The tunnels? Ok. Well on this side of the *ko‘olaus* in the Honolulu area—in the Ala Wai Watershed—they were tunnels drilled for water. And that was done mainly in the time between, say about 19—say early 1900s and the last one was probably around 1930. So we have several tunnels in Mānoa Valley that develop water and it’s nice, pristine water when it leaves the tunnels because there’s no development above it so the water is very clean.

CSH: Does this go all the way through? Or no?

CL: Oh no, these don’t go through that far.

CSH: Is it like this? Or is it like this? Horizontal.

CL: They go like this. Slightly at an incline upwards. Cause if you went this way you’d drown.

CSH: Right.

CL: So you have to go this way.

CSH: Ok, ok.

CL: So we have two of them in Mānoa. And then….

CSH: Is there one in Pālolo or Makiki area?

CL: There’s one in Pālolo—good thing you mentioned it! It was about to escape me! But the current supply is good for about a half million gallon a day and it’s drilled at about a 1,000 feet elevation and it’s a high level tunnel, its right below Ka‘au Crater. I’ve been in it a couple of times.

CSH: Below Ka‘au Crater?

CL: Yes, right below Ka‘au Crater. It only goes in a few hundred feet. But it gets a little bit of bacterial pollution sometimes. But there’s a swamp on top.

CSH: Inside the crater?

CL: Inside the crater. And you know, this is one thing you read articles and you'll find booklets both in the stores and places like that, that show where all the hiking trails are on O‘ahu and all this other kind of….and how to get there.

CSH: I'm guilty of that.

CL: Right. And you know, giardia, which is common to the continental U.S. was not found in Hawai‘i until after the more development occurred and the hippies, the hippies came. And then giardia was found on Maui and it's probably on O‘ahu now. But you know, these guys, what gets me about is their saying. "Oh yeah, there's a nice washing/wading pool as you go up there."

CSH: Is this what they would call lepto? Leptospirosis?

CL: No, leptospirosis is by rats.

CSH: Ok.

CL: It's carried by rats. It was probably brought by the ancient Hawaiians.

CSH: Oh ok.

CL: It probably came with the rats. I think it may be in mice too because they're rodents. But not giardia. Giardia is something that gives you the runs and stuff like that.

CSH: Ok.

CL: Well, it's not, may not be fatal but you probably won't feel good about it.

CSH: So that just happens with human fecal matter?

CL: Humans, yes.

CSH: Ok. And this?

CL: Leptospirosis is by rodents.

CSH: Ok, do you just get that the same way like a cut or if you drink the water or if you open your eyes in the water…whatever. Ok.

CL: In open water, even springs and stuff like that, if you have snails, you can probably get other water borne disease too like shigella. Is that right? We get liver flukes. Liver flukes. The things that affect the kidneys and liver. I'm not sure that's right. I don't think its right.

CSH: What kind of snails? Like African snails? Or…

CL: Sickness is carried by snails period. You know the story behind African snails don't you?

CSH: No, not really. I know the giant ones have some kind of…I don't remember what it was though. I forgot what disease it was. It's a carrier of it.

CL: Yeah, well.

CSH: You can refresh my memory.

CL: Well, they were brought in for food.

CSH: African snails? Ick.

CL: Yeah, and then it was discovered that they contained diseases and so the news for that….they made a big juicy…

CSH: Escargot?

CL: Yeah! The same thing goes with snails when I grew up on the mainland. And we see snails all over the place. But now there’s a big market for them. People go around collecting them and they collect them and feed them for a couple weeks and they sell them for big money. And it’s for…what do they call this? This snail delicacy. Delicacy.

CSH: That’s here? On this island?

CL: No, no on the mainland! You can order them here too I think.

CSH: I can ship them all of the snails in my garden then. They just eat my lettuce.

CL: And here we used to stomp on them…

CSH: And put salt!

CL: And things like that.

CSH: Yeah. Ok. Um. Do you know if there was any kind of fish or any wildlife that lived in these upper….where the streams in Mānoa or Pālolo? Makiki?

CL: Where the water begins here you will probably find some fish. Some snails probably too. But as you go down the streams here in Mānoa, then it starts getting, you get some Native Hawaiian fishes. Get gobies [*‘o‘opu*]. Gobies and stuff like that. And then as you get all the way down to brackish salt water then you’ll find things like tilapia. What’s the name of the….? Well, all the salt water fish. And…

CSH: So earlier when we were outside we were talking about the Ala Wai. And that they had closed off…was it the water ways? There were streams, right? Wasn’t there streams? We were talking about that earlier.

CL: No, they had to allow them to exit down into the Ala Wai that was the drain. So things like Makiki Stream, Mānoa Stream, Mānoa, Pālolo Stream….they all exit into the Ala Wai. So they have all the fishes that the Ala Wai has. You know, I took an aquatics biologist into the caverns and he was noticing the shrimp. The fresh water—little small things.

CSH: So *‘ōpae*?

CL: Yeah but… *‘ōpae*, yeah. But that’s how far from the ocean—three miles.

CSH: Three miles?!

CL: Yeah, three miles in from Mō‘ili‘ili down from the outlets. Two, three miles.

CSH: So, then maybe we should bring out the maps. I’m going to move all this stuff.

CL: What time is it now?

CSH: It’s almost 11. Do you need to feed your meter or anything like that?

CL: No, no. I don’t have to feed my meter. Do you have to feed your meter?

CSH: At 11:30. Or no, no. No, I don’t actually. No.

CL: Oh, we should’ve been talking from this map! This is good that you’re familiar with these areas.

CSH: Ok, so we made this map.

CL: We should’ve brought this map out earlier!

CSH: Oh yeah, I should’ve brought this out earlier. Ok, so you can go ahead and mark things up. Whatever you want. We have….this is the….so the green is the Ala Wai Watershed. And this blue is the waterways….the streams. And the red is the project areas. So, the debris catchment….are you familiar with these terms?

CL: Yeah.

CSH: Ok, so you know what a debris catchment is then? And what the detention basin is then, right? So we have all these call outs here. And then this is what you had previously noted before. Reservoir…..chlorinators….Pālolo Tunnel. And then we just have some markers here, so you didn’t write these, this is just markers, so we kind of have an idea that we know where things are cause it’s kind of smaller, right? So we know this is the UH area and stuff. Ok. So if you want to go ahead and mark it up. We have some areas over here where you noted that this was the brackish water area. And if you want to note also where the karsts are.

CL: This is a pretty good map.

CSH: Ok.

CL: This is a pretty good map showing the area of brackish water. The Board of Water Supply.

CSH: You know, I wanted to ask you since we’re looking at this map and we were just talking about the *‘ōpae* and the mullet and all that in the karsts.

CL: It’s right there.

CSH: You want to mark that area then? Do you feel that if we have these detention basins that this would affect the karst system and the creatures that live in it? Or that would it not affect it?

CL: I don’t think so.

CSH: Ok.

CL: It wouldn’t pollution wise because a lot of junk is things like dog waste and things like that.

CSH: Ugh, yeah. Excellent.

CL: But we have, let’s see….

CSH: So you noted this is a water tank.

CL: Ok.

CSH: This is Punchbowl.

CL: Trail goes around here and we have a couple of tunnels up in here too.

CSH: You want to make a note of that?

CL: Uh hmm. Gee.

CSH: This looks like this is the Pali Highway right here. So this would be the Pauoa area.

CL: Somewhere near is Booth Spring. And Makiki Springs too! They're all located in here somewhere. I can't tell you exactly where on this map but you can find them on a regular topographic map.

CSH: Ok, so I'm just going to put Makiki Spring?

CL: Yeah. Uh hmm. And these springs that occur as a result of water that is pushed within the cinders. Then….let's see. No, I think I'll have to locate everything on a topographic map. I think the springs are located in this general area there or over here.

CSH: So it's actually a little further up?

CL: Yeah, I think so. You can find them on topographic maps.

CSH: So it's not here, it's a little bit more up? Or is it a separate spring?

CL: It seems to me it should be up here somewhere. Its a little bit east of where I think it should be.

CSH: You can mark that area too then if you feel that it's further up.

CL: Yeah, but this is…the location of Mānoa tunnels.

CSH: Oh, that's another tunnel?

CL: No, no, there's two tunnels up there.

CSH: Oh, so there's two tunnels?

CL: Yeah.

CSH: Alright.

CL: So you already know about the Ward Estate down there?

CSH: Right.

CL: I have to mark that.

CSH: This is McKinley….so…..it's right next door. Right? That's Pensacola. McKinley. Oh no, this is….this would be the….

CL: The stadium.

CSH: This is the Blaisdell right here. So maybe we should make a note of that too this is where there were ponds there.

CL: Ponds? Ok. I was gonna say something. You know there's a brackish water well at the Board of Water Supply that is used for irrigating the grounds….

CSH: Oh, I didn't know that. And they still use it today?

CL: Yup. Still being used. I'm having trouble finding it though.

CSH: Is…where is that?

CL: Oh, there's the Capitol.

CSH: Ok, this is the Capitol. So….

CL: Right here.

CSH: Is that the Board of Water Supply?

CL: There’s a well, right?

CSH: Is that the water fountain in the front?

CL: RIGHT!

CSH: Oh, so that’s brackish?

CL: Yeah, that’s…its slightly brackish. It was usable for landscaping.

CSH: Ok, I’m going to write…slightly brackish well?

CL: Uh hmm. It was fresher before. And it has become more brackish.

CSH: Where is that…..you were talking about where the koi was and the *ali‘i* used to bathe.

CL: Oh ok, that.

CSH: So this is UH. This would be South King. Oh no, this is the H-1. Sorry.

CL: This is Hausten here, I guess. No.

CSH: That’s University here, coming down.

CL: Yeah. That’s Star Market.

CSH: This is that park. So this would actually be South King.

CL: Ok. This looks like the St. Louis Clubhouse. And the Willows…must be this one here?

CSH: So the karst….was just a series of tunnels that went to different branches? Or was it just one wing?

CL: See, all the water flows the caprock through so it doesn’t have to be in streams. Pretty small flows, that’s what counts. This is…this is where…

CSH: So that’s where the *ali‘i* would bathe?

CL: Yeah.

CSH: Ok. I’m going to write that.

CL: I think this is Hausten here and Willows. Yes. We had a big spring here at one time. This is from here.

CSH: And which one is this?

CL: This is about the *makai* extent of the springs and then this is the….this is an old map.

CSH: Is it?

CL: Yeah, an old photograph.

CSH: Yeah, I don’t know when they made the years of this aerial.

CL: And the freeway doesn't show.

CSH: This is the freeway right here.

CL: Oh. I'm sorry. I'm looking too far up ahead.

CSH: So this Hausten is….I'm sorry which one was this again? Is this a spring?

CL: Yeah, it's a spring.

CSH: Oh ok, so this one is also just a pond? A spring?

CL: A spring, a pond. The spring's located where the ponds were.

CSH: Spring. Pond. Sorry.

CL: And this is, this is where the….this is where the tunnel was. From here it branches different ways. Some go this way, some go that way.

CSH: You want to just circle the area that is just the main area? For the….

CL: Yeah.

CSH: Wow, so it goes from here. Cause this is Pālolo, right? And this is, this is already Kaimuki. So it goes from here—all the way there?

CL: Umm. This….this is Mid-Pac. Mid-Pac Springs. And locally we call this Mid-Pac Springs. And the Kānewai Spring. I'm having trouble locating Date Street. Forgot to mention the springs at Punahou School.

CSH: What are you….OH! Hmmm….

CL: Not as easy as I thought it was. I thought it was real easy.

CSH: Let me see if I can look for it on my phone and then figure out from there. Ok. Ok, so let's see. King.

CL: Here somewhere. Trying to find Date Street.

CSH: King. This is Kapi‘olani. Ok, this is going to be the Convention Center. Ok. So ‘Iolani should be….South King. Where's South King? This is Kapi‘olani. South King is this one so….it's gotta be in this area. I wonder if this is it. Cause this looks like a track field so this must be where ‘Iolani…

CL: That must be ‘Iolani.

CSH: …so it's gotta be in this vicinity.

CL: This was all the back area.

CSH: Yeah, so either like somewhere in this area must be Date Street. Just like right in this area.

CL: I'll draw this.

CSH: Ok, yeah. Yeah.

CL: Kapahulu exit of the Ala Wai Canal.

CSH: I think this is Date here cause this is called La‘au Street. Ok. That was pretty easy. Ok, so this is…

CL: This is the proposed outlet.

CSH: This is the tunnel?

CL: No, no that’s the proposed exit for the canal.

CSH: For the Venice. Proposed outlet. Do you know the developer who thought of that?

CL: No, no I don’t.

CSH: Ok.

CL: I don’t recall it. If I heard it I might.

CSH: What year is this?

CL: 1927, I think. I think that well…Ala Wai.

CSH: That’s one of them?

CL: And they have a pond over here. A well.

CSH: Uh hmm.

CL: You put fresh water with the brackish water too, right?

CSH: Oh, that’s right, that’s right.

CL: This is Kaimuki High School.

CSH: What are you looking for?

CL: I’m sorry?

CSH: What are you looking for?

CL: Oh no, I was just saying this is probably Kaimuki High School over here. Kapahulu Avenue here. This is Kaimuki up in here. There’s a spring here. Way up in there.

CSH: Over here?

CL: Yeah, the spring. It’s way up here. Then we have the *lo‘i* with the springs over here and its right below the ridge.

CSH: Yeah.CL: Hmm. Well, I guess that’s about all I can think of right now. I’ll probably remember something later. That’s what always happens.

CSH: That’s OK. That’s alright. So what I’m going to do is I’m going to transcribe your interview. And then you can go ahead and make edits. And then I’m going to give this to our GIS Department, the guy who created this map. And he’s going to take all your little markings and I’ll have him label them, take off these other ones. But I’m going to leave these. The one’s from your previous interview. And then from there, you can review the map and see if everything looks good. And at that time if you feel that, “Oh yeah, I remember there was a spring!” Then we can go ahead and add that on. And we can always meet again if you’re more comfortable with that too.

CL: We got all that?

CSH: Yes, slightly brackish? Was there any more brackish water anywhere else?

CL: No, I think that’s about it.

CSH: And I just wrote here that this is a portion of the karst, right here. Cause it kind of branches out but we’re just unsure, yeah? Ok. Oh maybe we should mark here too that there was a pond or something….swamp area you were saying, right?

CL: Ok.

CSH: Is that the Shell? I can’t even see!

CL: This is going to be the spring area.

CSH: Oh there’s a spring there?

CL: Yeah there’s a swampy area. And so the pond was here. Something like that. Maybe even a couple of springs.

CSH: And that was swamp?

CL: Uh huh. A pond.

CSH: Ok, thank you Chester.

CL: Ok.

CSH: That’s a lot of info!

Appendix C Evelyn Giddings Transcription

Interview with Evelyn Giddings, *kūpuna* and longtime resident of Mānoa, on 27 May, 2014 via telephone

EG: Evelyn Giddings

CSH: Cultural Surveys Hawai‘i

CSH: …How about we start with your birthdate.

EG: March 28, 1925

CSH: March 28, 1925. That’s a very good date.

EG: It’s my grandmother’s birthday actually, on my father’s side. And I have had lots and lots of friends during my life, lots of people that have that same birthday.

CSH: So were you born in Hawai‘i?

EG: I was born in a hospital in Pā‘auhau, at Pā‘auhau.

CSH: Where’s that exactly?

EG: It’s on the Hilo side of Honoka‘a. My mother taught school at Kukuihaele High.

CSH: So you were born on the Big Island.

EG: I was.

CSH: In Pahoa---

EG: No, in Pā‘auhau.

CSH: …So what are your earliest memories of the Big Island or did you leave right away?

EG: …My father was a Freemason, it’s a fraternal order and they believed very strongly in public school…Anyway, and my mother of course was a school teacher and she knew I wouldn’t get a very good education with public school in the plantation. So he [father] gave up his wild ways, and came to the big city and sold real estate.

CSH: So he was a Freemason but what did he do on the Big Island?

EG: …He came with his brother, in 1899...He had become a school teacher in Vermont. I have a very funny picture of him. Some of his students were bigger than he is [laughs].

CSH: Wow.

EG: …He and his brother came to Hawai‘i to plant coffee. Which they never did. They just got odd jobs on plantations. But the woman he was engaged to died; the night that she died in Vermont, he had a dream here in Hawai‘i that she was lying in her bed, with all of her family standing around. So in 1899, that would be…

CSH: Premonition, probably.

EG: My father and I were sort of psychic that way. I knew when my stepmother died. I was in New York City, and I was very upset and I didn't know why, anyway.

CSH: That kind of happened to me too, that's very interesting.

EG: I am that way with my older daughter too. But…

CSH: How many children do you have?

EG: I have three daughters. Two of them I made, one of them came when she was 13. I say that I made, because I made two and one I shaped up a little…

CSH: …When your dad came to Honolulu, how old were you?

EG: I think I must have been two years old…my cousins were older and they were in high school when I was a two year old. They used to come and visit, I can remember them looking at me in my crib [laughs].

CSH: Oh, you have such good memory!

EG: Oh, that's just that. I have two or three memories. We lived at the corner of 12th Avenue and Harding. I would take people to show them the shower tree that I planted, and I remember when I planted it because a big bumble bee came and stung me [laughs].

CSH: It's striking you remember people looking at you in your crib…

EG: It's little snatches like that. I don't remember the time I came in…I came into the house, I had an Easter egg hunt, and I came into the house, and the neighbor's puppy was eating my Easter eggs. I said, "That God damn---I saw that [puppy] eating my Easter eggs! They couldn't understand where I learned to swear. This was when I was a two or three year old.

CSH: You must have heard it around.

EG: But I do remember the day I scribbled on the walls, and my father came home and said, "Oh, Evelyn May, it looks like someone scribbled on the walls. We can't play with the house like we used to, because we have to scrub the walls." And I cried and cried because I know who scribbled. Little things like that I remember.

CSH: That's still very good memory. Now when you came to Honolulu, you first lived in Kapahulu?

EG: No, we lived in Kaimuki.

CSH: Kaimuki?

EG: Harding Avenue goes up from Kapiolani Boulevard up to this crest and then it goes to Kahala.

CSH: And your dad was a real estate person you said?

EG: That's what he did, he got a job with this guy.

CSH: And your mom taught?

EG: I don't think she worked anymore after I was born.

CSH: So you came when you were two years old; did you have any siblings?

EG: No, none until my mother died and my father married my wicked third grade teacher [laughs].

CSH: Your stepmother was your third grade teacher? I'm sure you have stories. So here you are, growing up in Kaimuki. What's the earliest memory you have about water around you? What can you remember about streams over there?

EG: My mother took me to visit her family in New York State, and then the Depression hit and nobody was buying houses and she couldn't afford to bring me home. And I don't think my mother liked Hawai‘i as much as my father did. My grandfather kept bellyaching that 5,000 miles was too far away…we stayed there eventually. I think it was a separation thing because big boxes of toys like a tricycle would come. My father kept trying to sell real estate in Hawai‘i. Then I came back when I was eight years old and went to Ali‘iolani in second grade. My mom was a teacher…I could write cursive already in second grade and the kids were all confused [laughs]…

CSH: So you were in New York for about four years?

EG: It was about four years.

CSH: So when you came back, you were living where?

EG: In Kapahulu then, in a house in a development. You know where Rose Garden is? Down there by the zoo? It was just off Lē‘ahi Avenue…

CSH: So when you came back to Kapahulu, you had mentioned to me that you have a clear memory of going to French class by the Ala Wai Canal in Waikīkī.

EG: That must have been when I was 10 or 11 years old.

CSH: Can you share with me what you noticed about the area in terms of waterways around you when you were going to French class?

EG: There were all these fishing platforms, with the little plank that goes out and there was this little chair, and somebody's sitting there catching mullet. So that was always interesting. But the most interesting part of it was when there was heavy rain, and the floods would bring all this debris down. Besides that, the McCully Bridge at that time had trollies, and tracks of trolley cars and that was supported with these little posts…And that made all the debris back up against, because it was like a dam, it strained all these debris and the rest of it went through the spaces in between…You know those trolley cars, some of them didn't have any sides. They just had a railing and you can stand by the railing and hold on to a bar. Wow, it was scary when it went across the bridge. You were standing on the little running board holding on to the bar.

CSH: Now you mentioned the posts on the bridge acted sort of a like a dam.

EG: Yeah.

CSH: So they trapped a lot of the debris.

EG: It was on the Diamond Head side of the bridge. Of course all along the [Ala Wai] canal. There was so much stuff floating, the rats were running around like it was dry land.

CSH: Wow, that's a sight to see!

EG: They thought it was a picnic. It was a sight! I dropped my French book one day, oh my gosh, and I had to fish it out!

CSH: Ok, so there was so much debris the rats thought they were on land and could just go all over the place.

EG: They were just running around. There was all kinds of vegetation debris, and there were chicken coops and all that. I had never made this connection before, when I was 16 and moved to Mānoa, that we moved to the place where chicken coops had come from. Because at that time, people who were farmers were still living along the [Mānoa] stream, in Mānoa.

CSH: Uh-hmm. That’s interesting that you said you never made the connection until later. So here you are, you saw the end result coming down from Mānoa.

EG: Then I went to the roots of it.

CSH: The stream underneath is Mānoa, beneath McCully Bridge?

EG: Well McCully Bridge comes before Makiki Stream runs into it but it’s the Pālolo and Mānoa Stream(s). They’ve already met when they have come into the canal. They meet up somewhere above--by the time they’ve met at by Kaimuki High, they’ve already connected.

CSH: When it comes to this kind of flooding, how often do you remember it occurring during that time you were walking along the canal?

EG: I don’t know. But enough that I was impressed by it. We used to have more of a rainy season than a dry season. Now you can’t tell when you’re going to have a flood…May I talk about the October floods in 2004?

CSH: Of course. Yes.

EG: I was living in the Krauss house, and it sits upon a hill. It’s got a lot of lava rocks sticking up on it that connected to the center of the earth. So it’s up there and it’s for real. Kamānele Park has a mound in there too, where there are lava rocks. So, we knew it was raining hard, we didn’t go anywhere, and we had no idea that Safeway and Longs were all underwater. When we came back and saw the car up on the tree…the [Mānoa] stream goes past faculty housing and the debris stuck three feet high up the fence, we couldn’t believe that was going on and we were all sitting at home and thinking, “My, it is raining hard.”

But anyway, it did all happen and I had sort of an intuition that the river remembered how it used to go. And it went on its old path. Because I can imagine it’s moved back and forth over the thousands of years, different streams which headed off in different directions. In the University campus, where it used to be, it used to be the middle of the stream.

CSH: This intuition you had, about the river flowing the way where it remembered, during the flood of 2004, the river was flooding toward what direction?

EG: Instead of going past, what is that Catholic school there [Saint Francis School]?

CSH: I know which one you are talking about, when you are going on the back of the campus?

EG: Yeah.

CSH: The Catholic school that has a swimming pool [Saint Francis School]?

EG: Is it Sacred Heart?

CSH: Let me double check that.

EG: [Thinking] No, Sacred Heart is in Kaimuki.

CSH: I can find out more…Go ahead with your story about---

EG: What it did this time, was that it plugged up somewhere there, and it started raining down. I guess it came from Woodlawn. The paving of the street is always like a river, right? If it can't go down the storm drains, then the streets look like rivers and it's all collected right there by Safeway…When it was coming down on Woodlawn, it was already outside the river. It was coming down the streets, and there by Long's Drug Store, it just kept on going and through the Noelani School and then through the University campus. Instead of going down by the little East-West Center Garden, then it started organizing by the dormitories and it went back to its bed, but…

CSH: You said the Catholic school, the name I will look up later, it kind of went around the Catholic school, or?

EG: …It went on the back corner Mid-Pacific and down through the library, and back into the quarry…

CSH: From your vantage point, you are living in this house up above. I missed the name. Where were you on top?

EG: It's a place they used to call College Heights. I was living with Beatrice Krauss, whose father was [Frederik George Krauss], I was living in their laundry room…

CSH: So it had the vantage point of everything below?

EG: We really couldn't see it. We didn't know what was going on.

CSH: When did you find out that it had flooded?

EG: Next day, I guess.

CSH: And how high do you think it was when it came and flooded Safeway and Long's Drugs?

EG: I just know there was debris stuck in the chain link fence that goes along the side of Noelani School, up above about two feet, more than two feet, that was stuck along the thing. It was right there, I guess it's the lowest point where all the water from Woodlawn coming down the pavement, the paved streets, all connected together with the water that was in it, instead of its own bed…I'm sure some of it went behind and down by the East-West Center…What was the name of that school?

CSH: It's on the tip of my tongue too. You mentioned that…in 2004 that flood, mostly the area where most of it started to come out seriously was around Woodlawn, you said?

EG: Yeah, it was such a big torrent coming down from the street, coming down Woodlawn Avenue…Woodlawn Drive, I think they call it.

CSH: So that's the torrent that came and joined the other streets that were flooding already. Was that what happened?

EG: No, I think it went through the school yard of Noelani, through the cafeteria…and then the rest of the East-West Center. Then it made its way down to the library.

CSH: Saint Francis is the name of the school.

EG: Saint Francis, San Francisco, thank you that is the name of the school.

CSH: At Saint Francis, how did the water act there?

EG: I don’t know. I wasn’t there. I can just see where the debris was stuck in the fence.

CSH: Besides 2004, what other floods in the area can you remember?

EG: I don’t think we never saw anything like this, on such a big scale. When we first moved to the valley, my brother and I would go out during heavy rains to see what the streams were doing under the bridges and all. But now I stay home to keep dry.

CSH: Evelyn, you’re cutting out, are you there? I was saying, besides the 2004, are there any other floods that are memorable?

EG: I don’t.

CSH: What I got from you was that you don’t remember anything specific about other floods, but you do remember the 2004 one very well.

EG: I remember seeing the results, but I didn’t see the flood itself.

CSH: How long do you think it took for the water to abate, to go down, for 2004?

EG: I don’t know what that is. I remember in the morning, the next day, we could go and drive down there.

CSH: So it went away fairly quickly.

EG: It went away.

CSH: So let’s go back to your French class, because we were starting to talk about that in McCully Bridge, the endpoint where all this stuff from Mānoa was going down. Those days, what did the people do when the bridge flooded like that?

EG: It didn’t seem to rise and go over into the land…At least that’s how it was used to be before, anyway…I don’t think it ever rose up. There used to be a foot bridge, from Waikīkī side…to where the golf club is, so people can walk across, and which way got to the fire station and the canal. It was a little fun thing…a bridge. I never wanted to cross it because I don’t play golf. Then they took it away, I don’t know when they took it away.

CSH: So when you were crossing the bridge and it was all flooded, you were crossing the bridge and there was all this debris, and your French book fell.

EG: It didn’t fall too far out. I just had to get a stick, to pull it back a little bit [laughs].

CSH: Thank goodness. And it was rain or shine, when you went to class.

EG: Yeah.

CSH: When it raining, you went there…You went there several years?

EG: I think maybe two years? Let’s see, when I was ten [calculates time]…’36 to ’37, maybe.

CSH: So two years. And what else can you remember besides the vivid memory of the flooding of McCully? Can you remember people fishing along the Ala Wai, you said?

EG: I don’t know if it was commercial, but there was fishing there.

CSH: Where exactly where they fishing, in the location of the map, if you were to pinpoint it to me.

[silence]

CSH: Evelyn, are you still there?

EG: [Inaudible]. In the fresh water…

CSH: Our connection is a little funny. I was asking you a question…do you know the location of where people were fishing if I was to pinpoint it in the map?

EG: [Inaudible]. I have no idea how it worked…I’ve never seen anybody swimming in the canal.

CSH: In all the years you have live in Honolulu, you’ve never seen people swimming in the canal.

EG: No.

CSH: What did you hear about it? Was it a big no-no to swim in the canal?

EG: Not necessarily. Nobody ever did it. It wasn’t very inviting. It always looked slimy and it looked like stuff was floating in it.

CSH: The people that you saw fishing along there. Did you see what kind of fish they got?

EG: I think everything that was there was mullet.

CSH: Mullet. Do you know if people would eat that? Would you eat it if it came from the canal?

EG: [Inaudible]. What was the question?

CSH: Would you ever eat something that came from the canal?

EG: Not now, I wouldn’t. Yeah, I supposed I would’ve then. But I don’t know where they were available, to buy. Maybe they were doing it for some fish markets, some way of making some money for them, I’m not sure at all. I just know they were there.

CSH: Right. You know, this project, do you have any questions about it? They want to put in a series of flood walls, detention basins in certain areas that would help reduce the possibility of flooding.

EG: The golf course, the golf course wall is higher than the Waikīkī side.

CSH: They’re talking about putting a wall.

EG: On the golf course side.

CSH: So you like that idea?

EG: Well, I can imagine it might back up higher than Kaimukī high school, it might. They just have to make sure it gets out to sea.

[CSH discusses project]

EG: I read the thing that you sent me…I have thought about it. Actually, the sea is mostly rising anyway. I think it’s like putting sandbags; you got to keep making it higher and higher.

CSH: So how high do you think it should be? They're saying three to five feet.

EG: [Inaudible]. Well, yeah.

CSH: Did you say three feet? That's what they are trying to do. So three feet seems high to you, that's good. I don't know if you want to take a look at the maps that I sent you.

EG: I've got it right here.

CSH: So you can see that they've pinpointed the places where they want to put the catchment system, the basins along Mānoa, Pālolo, and I'm trying to find McCully Bridge.

EG: Well it's McCully Street, where they had trolley cars run across. It's a proper bridge now.

CSH: Okay, where Mānoa and Pālolo meet.

EG: No, they meet before Kaimukī High School. They meet up there by Kanewai Park, is that where they meet?

CSH: I don't know where they meet. But in the map, it says they meet in this one area…I cannot see exactly…

EG: Well it's below the University, and it's to the east side by Kānewai Field.

[CSH discusses map]

EG: They connect by the Oasis Nightclub, where the Oasis used to be. They connect down Kānewai Park; Pālolo hasn't joined it yet.

Another funny thing I used to do with a friend was to walk down Makiki Stream to get to the Girl Scout meeting. And then we have to go underground because Makiki Stream goes underground, along that way below Prospect Street, no…

CSH: So you would go down Makiki stream, what happened?

EG: I remember it was spooky going through those tunnels [laughs]. We would always be afraid there would be a flash flood somewhere above there and there would be a wave of water that would come down; it was a silly thing to do. But we did it because we were children.

CSH: Wow.

EG: Now there would be all kinds of people smoking crack and stuff.

CSH: In that tunnel. So you would rush through the Makiki Tunnel…? Flashfloods, was that frequent during the time you were growing up?

EG: Oh no, it wasn't necessarily but it was something daring to do, I guess.

CSH: Was the Makiki Stream unruly, as unruly as the other streams were…?

EG: There wasn't that much water…

CSH: So it didn't have a lot?

EG: Surprising how much of it was underground.

CSH: So the fact that it was mostly underground didn't really--

EG: The part of it was… [Inaudible]

CSH: Can you repeat that again?

EG: [Inaudible]…it goes from Punahou to Roosevelt.

CSH: …Unlike Mānoa Stream, it was pretty flat by the time it went through. Correct me if I am wrong as I am having trouble hearing you.

EG: We'd walk over to Punahou, and then get down and [inaudible] and walk, through the river and Beretania…[inaudible]…I think we couldn't get out until King Street…it was between the market and that church [Church of Jesus Christ Latter-day Saints] there [thinking].

CSH: The market, you said?

EG: On Beretania Street, from Beretania Street from the corner there is a spot on Punahou Street.

CSH: Its Foodland now, isn't it?

EG: Whatever it is, maybe Foodland. But the church there is [Church of Jesus Christ Latter-day Saints], the old church, by Punahou.

CSH: So we were talking about that church by Punahou.

[Discussion about the Church of Jesus Christ Latter-day Saints]

EG: There's a beautiful mural in front of it…what's the church that allows you multiple wives?

CSH: Mormon.

EG: Mormon, that's it. There's a tabernacle there.

CSH: Let's go back to what you were saying there. Because you were saying when you went by Nehoa, can you trace that route again?

EG: The Mānoa Stream, we experienced all above Punahou, up in the valley. It was like rock-hopping and doing waterfalls, swimming holes and all that. But by the time we found Makiki Stream, going under Nehoa Stream, it was almost flat…there wasn't as much water. We never experienced much water.

CSH: What about Pālolo stream? Do you have any experience with that?

EG: No memories of Pālolo stream. No.

CSH: Can you mention to me memories of Mānoa stream…you had mentioned in a previous interview that you found a unnamed swimming hole above, close to a marker.

EG: Well, we used to take ah, well that was later though, when we had the horses.

CSH: When did you move to Mānoa?

EG: 1941, the summer of 1941…

CSH: …You were 16 years old, and you moved there?

EG: Right.

CSH: What did you think of it?

EG: I was really happy because there was a vacant lot next to our house, and the person who lived at the other side of the vacant lot had a horse, a horse tied up in the vacant lot. Oh, she got tired of

riding her horse, so I would exercise her horse for her. Would I ever! [Laughs] I almost thought I died and went to heaven. So every day I would ride this horse, up the trails. The streets ended at the time where the flashing light is, above Wai‘oli Tea Room, there is a flashing light. So all that over that has been developed since 1941, 1945, since there were no houses during the war.

CSH: So it was all undeveloped and you could run up the horse there?

EG: We could ride up the trails; we could ride up Mānoa, up Mānoa road which was up to where the Arboretum is now. It was the Arboretum then too. It was the house of Mr. Agee at the end of the street. It was wonderful.

CSH: I only have experience with Mānoa Stream…

EG: Now you're breaking, say that again.

CSH: I've only had experience with Mānoa Stream seeing it contained in its little culvert, behind faculty housing, along there. During this time, can you describe what Mānoa stream looked like when you were riding the horse, up and down the trail?

EG: So that would be 1941 or '42. I didn't take the horse down the stream much, ever, really. But I know it was before they channeled the river under the bridge [thinking]. I should have had more of my green tea this morning.

CSH: We can go back later. I am curious…to picture in my head, how it looked like, the area where the faculty housing is now, and Long's Drugs. What did it look like before?

EG: All that flat area where Long's Drug Store is…was all this temporary housing things built out of canec (canec is made from sugar cane fiber after the juice is squeezed out and then used for fiberboard material for Hawaii houses in the 1930s and 1950s). They really were temporary but they kept them for years and years. After the war, these rows and rows of houses, they would joke about people getting mad and punching the wall and their fists going through the neighbor's house. They were just canec.

[Discussion about the spelling of canec and canec properties]

EG: …It's made out of the leftovers of the sugar mill, all those fibers.

CSH: And who lived in those houses?

EG: Whoever needed shelter, I guess. You can rent them, I guess.

CSH: And those shelters were from Safeway and Long's Drugs all the way to the faculty housing?

EG: Right across the stream behind McDonalds, sort of part of the Innovations Center is now …I remember one time a flood came, and a horse was tied up, and the horse drowned…I think there was once a flood that killed somebody…there was a little pocket and it was low there.

CSH: This was before 2004?

EG: Oh yes, way before. This was during the war or shortly after the way (World War II)….I went away to school, '45. 1945. I didn't come back until 1949.

CSH: So you remember someone had died in a flood, was that in 1945, before you left [for New York?]

EG: …I graduated from Roosevelt in 1943…I was in UH [University of Hawai‘i at Mānoa] in 1945. In 1945 I left for New York, I went to school in New York State for three years…so I was gone for those late ‘40s. And then when we came back, we lived in Waimānalo for three years.

CSH: Where did you live again?

EG: In Waimānalo. We lived by the slaughterhouse, we bought a two-acre farm plot…

CSH: You and your husband?

EG: And friends. Two couples. We bought the plot of land together…we made the down payment. He had reparations from being a prisoner of war so we put in $1,000 and he had a job, so we made the monthly payment of the other $1,000.

CSH: Why don’t you tell me a little bit about your husband and your children?

EG: Well, my husband…we divorced when our second child was three years old.

CSH: And you never married again?

EG: No, I never did. And then when the girls were about 12 and 14, we took in another.

CSH: The third girl.

CSH: So you really have three daughters.

EG: I really do.

CSH: How many grandchildren do you have?

EG: I think 10.

CSH: Ten grandchildren?

EG: Ann has three; she lives on Hawai‘i island now…no, Ann has four now, and Lynn lives in Oregon and has three. And Morlee has three…Both she and Ann have three, and they married Hawaiian men.

CSH: And where does Morlee live?

EG: She lives on Maui. She is a school teacher. And a very good one.

[Discussion of Morlee]

EG: When she first came to live with us, I was driving on the freeway. And they were paving the freeway…behind Bishop Museum. They had paved it and it was all white lines…And everybody was driving what could have been four lanes.

And it was spooky, very spooky, when we were in line and we didn’t know for sure where we were. Right? So I went and got Morlee and we drove up there, and I demonstrated what it’s like to have no lines. And it was a good metaphor. She loved me. She was good for me.

CSH: …What year did Morlee come to you?

EG: ’66 or ’67….It wasn’t until her mother moved to the mainland. Her mother and father divorced...She didn’t like her mother much....She always had to stay in her bedroom every Saturday because she had been bad about doing something or not doing something.

[Discussion of Morlee]

EG: Her [Morlee] father was a landscape architect. And he is the one who planned to make a walking path all the way to the Ala Wai canal to the Mānoa falls. That was one of his big ideas…

[CSH discusses maps of detention basin in Mānoa Park and another one near it. Evelyn asks questions regarding location and project plan]

EG: I’m curious where they would detain water in Woodlawn.

[CSH discusses location of Woodlawn Basin, by East Mānoa Road and by Lowrey Avenue]

EG: Okay. That’s just below the cemetery…

CSH: What do you think of the location?

EG: That’s the only place with no houses…

CSH: It looks like there’s a couple of buildings…

EG: Are you familiar with Mānoa?

CSH: Yes, I lived there.

EG: When you go up East Mānoa Road, past Safeway and all of that…and just before road divides and one goes to the cemetery and before it goes up to houses, then on the Pālolo side, of East Mānoa, is another section of the cemetery and the arm that goes over toward one of the little rivers…but oh, there’s not much water, let me think about it…

The big part of Mānoa stream goes on the ‘Ewa side of the cemetery. And that would be just a catchment for that little arm [EG consults maps]. It looks like they have two of them, one up here, the Waihe‘e Debris basin. That’s above the bird park, or over the Pālolo side of the bird park up there.

[Discussion of the project plans. EG asks question about definition about catchment dams, which is to catch debris]

EG: It seems to me that there is a big reservoir in Nu‘uanu, of course Nu‘uanu is an entirely different shaped valley…

CSH: Can you expand on that?

EG: If there was something that can retain the water and let it out more evenly when it’s running…because all of that water comes rushing down…I am sure that’s what happened in October [2004] because the streets acted like tributaries of the river and they brought all the water together, every street was feeding the big rush that came down on Woodlawn Drive and into the lowlands…one car was lifted up in a tree somehow, it must have been really strong…

CSH: So if the water was detained long enough so that the water was left out more evenly…could that help prevent what happened in 2004 when all the streets were acting like tributaries carrying that water?

EG: I've driven down the University on University Avenue and seen the manhole go "puputt-pupputt." Because there was so much water rushing down underneath the manhole covers that it was lifting the manhole covers up. There aren't enough underground storm drains to be adequate for floods. And we are going to have more floods now because of global warming? We are.

CSH: All the memories you shared with me about the 2004 flood are very vivid probably because it was probably the worst that you can remember living in Mānoa?

EG: The 2004 (flood)?

CSH: Yes.

EG: Yeah. Yeah, I think so. You know the place behind…where Lowrey Avenue joins East Mānoa? That culvert has to turn corners. Water doesn't like to do that. It likes to meander and it's not natural for it to be cooped up like that. I can't imagine what that must have looked like when the flood was coming, it was of course going over the bridge in Lowrey Avenue, I'm sure. Oh, water, water, water.

CSH: Regarding your comment about water liking to meander and not turning corners… [discussion about the definition of the debris and catchment]. Woodlawn Detention Basin is the one catching water…

EG: I know where that one is…

CSH: There's a Mānoa Park Detention Basin.

EG: That's farther down.

CSH: And you think the detention basin should be farther up?

EG: There's one called Waihī that takes on one arm of the river [looking at project info]. And the other one takes care of the other tributaries.

[Discusses project maps]

CSH: What map are you looking at?

EG: I'm looking at the map of the streets that you sent me. I love that thing. I love seeing where the mountains are. I have a friend who lives in Pālolo and I wonder if she is just over the Waihī Ridge?

[Discusses map. CSH discusses debris and catchment systems]

EG: They have two up there in Waiakeakua…

CSH: Do you think the detention basin should be further up…?

EG: You can't really tell here how steep it is getting [looking at map]. That's where the Arboretum houses are. The place where they have Waiakeakua is farther than where there was a swimming hole. We used to ride our bicycles there when we moved back to Mānoa…in 1953 about. That's getting to be old history too, isn't it?

CSH: So you moved back in 1953, so you have a memory of being around there?

EG: I was thinking about my father. After we got the horses, when Morlee came to live with us, because she liked horses and I thought that would keep her out of trouble…My daughters went to

Japanese school when they were in Mānoa school, and they would walked to the Japanese school. I always wanted to attend Japanese school…

CSH: When you moved back after your divorce, in 1953, you were going to say something about the detention basin up there?

EG: I think it looks like it's somewhere above the Arboretum or near the Arboretum. I'd really like to know what it consists of.

[EG asks what a debris catchment is and who will clean it]

EG: They also have a detention basin. I imagine are meant to hold water. But my goodness, debris catchment…I don't care about the difference but I want to know what they consist of. What is one and how much water does one detention basin hold? Would it be like what is in Nu‘uanu? A reservoir? Would it be like a reservoir?

CSH: That is a great question. How much water does a detention basin hold? Would it be like a reservoir?

EG: What gets me is, the drainage system. The storm drainage does not work--it's too small for that kind of storm. They need to be cleaned regularly, inside and out. Even when it is not a major flood as you never know. You see people raking in their leaves, into the storm drains. They are not supposed to put anything in there, as these are just for the water, to clear it…I remember driving down University Avenue, when you are passing by the law school and you get to this manholes, you can see it has been opened and it spilled out grass. It looks like a horse…it got lifted by the pressure of the water and had had a bunch of grass sticking out of it.

CSH: So what you are saying is that the drainage system doesn't work even where there is no flood.

EG: It was not even a bad flood, there was not even a lot of water, not even a major flood. All that water coming, I never thought of streets being like tributaries carrying all that water, each one feeding the one below. Until they get to Woodlawn Drive, where it usually gets wide. Do you know why Woodlawn Drive is so wide? The part in front of the cemetery...Because they were going to put a tunnel through Mānoa through Waimānalo. They had that idea so they made the street so wide.

CSH: So the tunnel would have held the water?

EG: No, no. A tunnel for cars.

CSH: Oh, a tunnel for cars.

EG: At least it's a nice wide Mānoa, until it gets to whatever street that is that goes over to the park…The Woodlawn bus route is a training ground for the bus. They got the worse turns and parking on both sides of the street. What a test.

CSH: Not to mention those storm drain systems.

EG: And all these people walking their dogs.

CSH: Great training ground.

[Conversation cut off for a few minutes. Discussion of Evelyn questions, including what it a detention basin, what it consists of]

CSH: Going back to the drainage system for Mānoa, is there anything else you want to add for that part? Strengthen them?

EG: When you think of those storm drains, they are about ten [years old], things are growing in them…The storm drains are inadequate. They can’t handle that kind of problem, that much water at once…So the storm drains, the streets turn into tributaries of the river.

CSH: Can you say that again?

EG: Storm drains are inadequate, so the streets become the river. It’s just going down and meeting another street and going down and meeting another street. I was really, I love these times you haven’t thought about before and these are the streets being tributaries. It’s kind of amazing to me that streets would act like rivers.

CSH: Do you recall Makiki acting like this, or the areas around Makiki?...In Makiki, did it act like the way it does around Mānoa when the rainfall is heavy, or do you think it has adequate drainage?

EG: Maybe, but that was a different part of Makiki. It was different from the part of Mānoa that I knew. I knew the upland. The river above the valley. And this was the end of Makiki stream and was just all just channels and cement…even when it was going through apartment buildings and things.

CSH: In Mānoa, where you know the upland and the stream, where do you think it started gathering force in 2004?

EG: I think…probably by the time it got to the wide place, what is the name of the street that goes over the Mānoa Community Gardens, the park and the school?... The intersection area, from East Mānoa to Woodland Drive to East Mānoa…

CSH: What about that street?

EG: By the time it came down from Woodlawn, there, that’s where it came to a place where Woodlawn Drive was wider…but even so it was coming down three to five feet high. That’s a lot of water. All the *pukas* in the chain link fence had grass stuck on them. It was just unbelievable.

CSH: A torrent that was coming down.

EG: Yeah. This is a street, not a river, but a street.

CSH: The river was supposed to be on the other side.

EG: Right…

CSH: So you wonder what the river itself looked like.

EG: I would have liked to have seen it…must have been an amazing sight…And there I was perched on that little hill. Not knowing anything except it was raining.

CSH: You didn’t see any of this on top?

EG: No, I just saw the results…of course the university. There were people trapped in the library. They had to get out from the windows…and all that stuff stored in the basement of the library…it took them years to dry it out. Some of it was ruined.

CSH: Never could be fixed any more. So why don’t we go ahead and you tell me about that story regarding Nu‘uanu?

EG: It’s just that my father came in 1899, from Vermont…He asked this Hawaiian man, where is Judd Street? This Hawaiian man said, you walk up Nu‘uanu Street, and when it starts to rain [laughs]

CSH: That’s where it is.

EG: That’s where it is…I went on tour with the Board of water supply, and there it was a different ahupua‘a. They had a speaker about the geological parts of things, and someone told legends…it was very interesting. When we got to the big reservoir in Nu‘uanu, the woman who was talking about the cultural (side) said each island rain has its own name. There’s one rain that comes down to the valley and stops on Judd Street. And that’s what the Hawaiian man had told my father a hundred years ago.

I think Lowrey Avenue is our Judd street here in Mānoa…

CSH: That’s where you know it is going to start to rain…I found the name of the street. So where did you think the water gathered in October 2004, by Kahaloa Drive? Is that it?

EG: Right there by Woodlawn Drive, where Woodlawn Drive gets wide right there…Woodlawn Drive ends on the Pālolo side of the real stream bed, over by the park…Of course some stuff went under the bridge by Long’s Drug Store, but not much of it. It was on its way down on Woodlawn Drive. Then of course it comes to a hill…

CSH: I’m looking at the map, where you talk about the garden and Kahaloa Drive. Mānoa stream comes close to it.

EG: Yes, the stream comes near the low cost housing that’s between the community garden and the river..below Lowrey Avenue the water is all channeled and cemented and it has to turn corners and bump into walls.

CSH: It doesn’t like that.

EG: It doesn’t like that.

CSH: Is there anything else you want to mention before we discuss the answers to your answers?

EG: The only thing is I went to follow the trolleys in Makiki Stream.

(Discussion Part 1 concludes)

Part 2 of Interview (Discussion of Questions, June 11, 2014)

CSH discusses questions, such as “what exactly is a debris catchment?”

A debris catchment simply catches tree branches and urban trash debris. [CSH reads the definition of Debris Catchment. A trench would be dug in the stream bed and steel poles will be embedded, resembling a comb to catch debris. Debris catchment will be placed where workers can catch it.]

EG: Without getting drowned.

CSH: There are a number of debris catchment throughout the watershed.

EG: In this island or just this water shed?

CSH: I think the Ala Wai Watershed. [Discussion about the Woodlawn Debris Catchment, then discussion on Detention Basin, a three-sided basin that is constructed over and around the ditch with the culvert that allows normal water through. It stops water from gushing as it holds excess water for a while for releasing it.]

EG: So it has something like a gate?

CSH: Something like that. Let me find out. [Discussion about Detention Basin being unobtrusive as possible.]

EG: I wonder if the engineer can see the volume the way we do it, like 10 quarts of water. They see it as volume but we see it as numbers.

CSH: [CSH discusses the detention basin volume.] Do you have any questions based on the replies?

EG: I know there's places where they have gates already. I wonder…in cases of flooding if someone is expected to go up and open the gate…[Ms. Giddings discusses types of gates, such as gates that are like boards which are just put in place.] It has to be in a place where there are no houses above it.

CSH: So the detention basin, you said, should be in a place where there no houses.

EG: The debris will make its own dam, you see. So they will make their dam where they please.

CSH: You've mentioned about the gates that you've seen. Is that in the Mānoa area?

EG: Yeah, it's all there where the road divides, where one goes to the Arboretum…

CSH: You gave me an idea of how small the gate is.

EG: It's just a small one, it makes a little swimming hole.

CSH: Do you have an idea of how big that gate is?

EG: In my memory, maybe what it is, is just something to back the water up so the farmers above can get irrigation…the farmers above there grew bananas, and ginger and tea leaves. So, it is probably two to three feet high.

CSH: The gate that they are building for the detention basin, I don't know how big the gate would be.

EG: Or how big the detention basin is going to be, either.

[CSH and Ms. Giddings discusses the amount or volume can hold, but there is no comparison to the ones that are already present. Also, Ms. Giddings would like to know how the system of gates would work.]

EG: Somebody would have to run up there and activate it…Is it going to have slots, and how will they close the gate?

CSH: How they would close the gate and how would they activate it?

EG: Ordinarily, there are two cement walls, and an opening of two to three feet, and it’s got slots and you just drop it one on top of the other. And it stops the water.

CSH: Ordinarily, right? But you noticed that the gate was about 3 feet tall?

EG: I don’t think it’s that tall, even. I can go and look…there was a place that we used to jump into the water…

(EG then discusses childhood memory of a neighbor who parked his Model T truck, on King Street and sold hibiscus. The neighbor made cuttings and developed new varieties. He would also park his two Model-T cars near the stream close to the bird park and these cars were rotting away.

EG would swim in the stream with her friends. During rainy season, it would rise a little bit and people would put sand bags which stopped water from flooding. She does not know the name of the stream. It is located up Mānoa road, where the road becomes more narrow, and goes straight ahead to the Arboretum, and where one would turn right. It is there by the end of the Mānoa bus line, on the Pālolo side and where the bird park used to be which is now Treetops restaurant. She recalls that when she swam in this stream, the water was running and it was clear).

CSH: Do you have specific comments on certain areas and what you would like to see?

EG: I think about that reservoir in Nu‘uanu…and if it was going to be like that, like three of these above the houses, maybe four, above where people are living. That would be a good thing, depending on how much water they would hold.

CSH: …Do you want the same for Mānoa?

EG: Not necessarily, but their system (in Nu‘uanu)…they want their water to percolate down.

CSH: Not necessarily the same…

EG: Not necessarily the same but great.

CSH: You said three (basins) around there for Mānoa would be good?

EG: I beg your pardon, say that again?

CSH: You mentioned it would be ideal to have about three or four of them in Mānoa?

EG: This is really more than that but if there were four of them above the houses, that’s where a few farmers are living.

CSH: What exactly would that four be? Detention basins? Or debris catchment?

EG: Unless you want it to be detention basins, it would be debris catchment…debris catchment would be near the houses…

CSH: Let me see if I got that correctly. What you would like to see is a combination of detention basin and debris catchment above the houses where the farmers are?

EG: Right.

CSH: So maybe four?

(EG looks at maps to see which ones are detention basin and which are debris catchment).

EG: They all are…I think that’s good.

CSH:…So far, you are okay with what they are proposing.

EG: Oh yeah, they know what they are doing.

CSH: Is there anything else you would like to see besides what you can determine from the maps, what they are planning on doing?

EG: I think the most important part is to prevent it (the river) from changing its course. That’s what happened in the university, and the basement in the library getting all flooded. That was edging forward in getting run over where the campus is…It needs to be retained.

As I said, water likes to meander, it doesn’t like to turn corners the way they did by Lowrey Avenue. They’ve got it all logged up in straight lines.

CSH: Okay, I’m noting it down that water likes to meander, and doesn’t want to go in straight lines.

EG: From Lowrey behind the apartments, and it goes under around Woodlawn. It goes to East Mānoa and then Woodlawn. There’s a very low place behind the information center…the sign across the stream from McDonalds…up on stilts. It’s way up high…

CSH: So when the 2004 flood when into the library in the campus of UH, what do you think that could have prevented that from happening?

EG: Well that’s hard to say because they were right up against the wall a lot…the way it (water) has been running around East-West Center behind whatever that hall is…

CSH: The way water has been running is behind the East-West Center, I know that area.

EG: Yeah, that’s a far place from the library…geographically speaking it isn’t, but still nobody expected the way water to be running all the way to where they built the library. Look at all the work they had to do to make the library waterproof…it’s been more than a year drying out all the papers.

CSH: That’s terrible.

EG: There were people climbing out of the window because they were in there when the water started pouring in.

CSH: They could have drowned.

EG: They could have, very easily. It was a weekend, a Saturday afternoon, I think. I just can’t believe I was sitting there in Beatrice Krauss’ house, not knowing that this flood was happening down there. But seeing the streets, the roads, act like tributaries and they make their own river, and they are all paved. If it has been raining…it’s all going to run. You can make a road map and it would look like a river, with all the tributaries, and cul de sacs and the whole thing.

CSH: I wanted to ask you what you were saying last week, about Jennifer Greene (Executive Director, The Water Institute), and what you were saying about that whole thing, how we can better guide the water?

EG: I just know that she has remediated a lot of streams in places where it has gotten stagnant and the fish had all died. In Oregon where my daughter lives, they put in a bunch of boulders in one

place, which aerated the water. It’s splashing and gurgling around these boulders---it cleaned the whole thing up. It needs aeration and that’s how it the flora and the fauna can get their sustenance from the river. If it’s not aerated, then too bad.

CSH: Who is Jennifer Greene for people who don’t know, and what would you like people in Honolulu to know about what can be done for our watershed?

EG: Well…

CSH: You had mentioned that Jennifer Greene worked with Rudolph Steiner?

EG: She’s using his ideas about how things work together. Water doesn’t work by itself---it has to do with the boulders and the mud, to breathe and everything.

I know she did a demonstration with a big pane of glass, a sliding door actually, that was waxed. She poured water from the top and the water didn’t just run down---it went “owee, owee, owee” back and forth---what water likes to do…it has to do with channeling water.

CSH: So she is like a water whisperer.

EG: She just knows how to remediate where the fishes have died…I think she did one in Santa Cruz.

CSH: Have you had a chance to meet her?

EG: She came here and talked to the Waldorf high school. I didn’t actually hear her speak but I did take her to the park where water streams out of the sand during low tide. It’s springing out during high tide too. During low tide, the birds come and drink water and take a bath and all that. But that’s in the southeast shore.

CSH: What made you want to take her out there?

EG: Because each time the tide goes out, it makes little rivulets. It springs out of the sand and meanders down into salt water. And it makes a little dam. It’s fun to watch and it’s fun for even the elementary school to see what water does.

CSH: And what did she say about it?

EG: She said it was the highlight of her trip. To see what this place was doing. It’s water that comes, just makai of the ridge, comes down between ‘ĀinaHaina and Niu Valley. It’s called, the hill is called Pu‘u Ikena, where the houses are (a gated community).

CSH: And the springs are below.

EG: The springs which pop up.

CSH: And the name again?

EG: Kawaiku‘i.

CSH: And these are springs that just bubble up, depending on the tides?

EG: The springs are always under the water but you can only see them when the tide is low and the beach is exposed.

CSH: That’s fascinating.

EG: And then, of course you can see all kinds of debris down that little cove. That's where I collect seaweed in the low tide for my composting. So I would clean up plastic bags and people's underwear, whatever happened to come…because there is a culvert there too. There's a culvert where the rainwater comes from the streets on the hill above the park. But the springs come from underground.

There was someone there who said when he was a kid, there was a place where you turn off the highway and cross over the highway to get to Pu‘u Ikena, and---(another phone call interrupts).

There were big coral boulders from the time of, that's another story, when the water was all lower from the ice age, and that beach was all exposed. And the reef that had been there all died. So you could climb down, he said, in the place where there was a turnaround is now, and wait for the light to change and cross the highway. You could climb down the rocks, and underneath, there is all this water that I spoke off running out into the ocean. You could also play in the fresh water, not just the birds. But you can't get down that way anymore…

Actually, Kawaiku‘i Park might have been a fishpond. It's a square sea wall that is farther out than the coast line. It had a big house there, and lots of interesting trees…

CSH: Going back to what you said about Jennifer Green and this particular example of her putting boulders in a stream in Oregon, is that something you recommend in terms of preventing or help remedy?

EG: That's more for helping a stagnant stream. We are wanting to do something for an overactive stream, for Mānoa.

CSH: So Mānoa is an overactive stream.

EG: …Yes. It's a big drainage when you look at it, from above like that. And there's only two roads to get out, only Punahou and University Avenue.

CSH: And in the event of a rain, those roads get really, slippery, don't they?

EG: Yeah.

CSH: I wonder if she can work with this overactive stream?

EG: I don't know. You would have to talk to her.

CSH: At least it's good that you mentioned her, because it's important to you that you mentioned it to me. Because she has ideas that may help, and it's good to know about her. But I am wondering if you ever heard of her working with an overactive stream like Mānoa?...She may have ideas of how water moves and the way it is channeled.

EG: She does, she really does.

CSH: Is there anything else you want to mention?

EG: I just started on a story…I helped an artist painting his frescoes. And frescoes is when you paint on partially dried plaster…he liked to use volcanic cinders because they have corners. Beach sand was more like stacking marbles and that's why he liked to use cinders. He has a great big wall, 20 feet high, and 90 feet long in the Leeward Community College Theater, that's a lot of plaster and a lot of sand. Where are we going to get so much volcanic cinders? Driving down Ward

Avenue one day…at the intersection of Ward Avenue and Kīna‘u Street, diagonal to the back of the museum of art, if you see that corner, that ‘Ewa mauka corner, Kīna’u and Ward Avenue, they were digging down for a parking lot. And from this ramp comes a big truck loaded with black sand.

I parked my car…talked to the contractor, and he said “Oh, you could have all you need and I will fill the truck for you.” I said, “Not right now,” and I looked down and there were three different distinct layers of black sand, separated by a white crust. And you can see that something happened between each layer, and below those three layers of cinders, there was white coral beach sand. At one time, this had been the edge of the island; that’s how the Hawai‘i Island is growing, little by little. I was so excited...I have a geologist friend…who lectured to middle school friends which eruptions made which layer of sand. And he said the beach sand, had been the edge of the island during the ice age when so much water was frozen in the northern parts. There was the edge of O‘ahu, up there by where the art museum is now, isn’t that exciting?

CSH: Yes, all this background you gave me was really rich. I was trying to find out more information about Jennifer Greene so maybe she can be contacted.

[Discussion about Jennifer Greene.]

So you recommend contacting her?

EG: Yeah, you can. I think everybody needs to be edified.

CSH: All right, Evelyn, I will write up our conversation in the form of a transcript, and…after you read and review, I will make the summary [discussion of the transcript and summary process].

Appendix D Makahiapo Cashman Transcription

Interview with Makahiapo Cashman, Director of Ka Papa Lo‘i o Kānewai, on April 15, 2014 at Ka Papa Lo‘i o Kānewai

MC: Makahiapo Cashman

CSH: Cultural Surveys Hawai‘i

CSH: Thank you Makahiapo.

MC: Yeah.

CSH: Really appreciative of your time. Um just for the record this is for the Ala Wai Watershed Restoration Project and just for the record what’s your name and where are you from?

MC: Okay my name is Makahiapo Cashman. I am from the island of O‘ahu. I grew up in ‘Ewa Beach, Hawai‘i. Also grew up on the other side of the island in Hau‘ula, that area too. Yep went to school in Waipahu, St. Joseph’s, and then to Kamehameha as a freshman and then from there went to Hilo for a year. Then transferred back to O‘ahu Leeward then hear at the University so still here at the University, so yeah.

CSH: What was the year you got to Mānoa?

MC: I think the year was around ‘88. Yeah, around there. Then I became a Hawaiian Studies major and that's how I really started to become part of Kānewai. Actually the first time I came to Kānewai was, I was in Hawaiian language with Larry Kimura. I think it was 201 or 202, and then he was saying, “Oh you know let's go down to Kānewai as a Friday night and, was a Friday night but everybody used to meet down here for *Hui Kama‘ilio* [Hawaiian conversation group]. Like this was the area, yeah, so that was my first time coming down here. That was during the evening and then slowly became part of the place. As a student, as a Hawaiian Studies student as a, I used to work with operation Kua‘ana [Older sibling, Native Hawaiian Student Development Services] as well too. So we used to do a lot of activities down here. We used to just hang out. In fact what was convenient for me was I was staying in Laulima, the dorms right here, so I could always just peak out my window and just see what was going on and just come down.

CSH: Oh cool.

MC: So you know it was real continent. And then you just started spending lots of time here, hanging out, sleeping. Whatever was being done that day, that's what we did. From *imu* [underground oven] to just hanging out, yeah, it was good fun.
CSH: When you started coming down here did it look like how it does today?

MC: Um, no. It was mostly this side but I can still remember opening up the side of the Waikīkī side, Diamond Head side closer to Hawaiian Studies Building now. Opening up these *lo ‘i* [irrigated terrace, especially for taro] as well too, yeah. And before used to have the parking lot, where Hawaiian Studies building was, and that's where I used to park, cause I, because I was from this island I used to drive here and then stay in the dorm and leave my car in the lot. There the gravel pit, we used to call it.

CSH: [Agreeing]

MC: And we used to cross the stream down here. Yeah we used to always kind of make it real nice so everybody could cross. And then, when the water would flash everything get washed out and then make it all nice again. You know at least so people can walk back and forth, so we could walk back and forth with our laundry and all our *ukana* [baggage, supplies] and stuff like that crossing the river, yeah, so.

CSH: Do you see people still crossing?

MC: Oh yeah.

CSH: Like how you guys used to before?

MC: I mean it’s not from the same spot, because the spot we used to cross was closer to Hawaiian Studies but a lot of the students cross through here, yeah. To get to this trail right by the bamboo, by the *‘ohe* [bamboo]. To get up that trail which is just a lot steeper and more critical than before. Before on that side used to be nice easy way up and down on both sides. But now it’s just more rock, yeah. But students don’t want to walk because a lot of them park on the street here and they don't want to walk all the way around they want to find the quickest route.

CSH: When you started here where was Kānewai in its development? There was a student *hui* [club, association, society]?

MC: Right, right. Well when I came here there were several *huis*, or two *huis* that I was familiar with. Was Hui Aloha ‘Āina Tuahine and that was a Hawaiian Language club with Hawaiian Language and it’s still in existence. It’s kind of off and on depends who the advisor and who the students are. And the other one was Ho‘okahe Wai Ho‘oulu ‘Āina, which was kind of like, was which was the group that opened up Kānewai, yeah. Mainly Keoni Fairbanks, Naohua Lucas, Lolana Festimiester, Uncle Harry Mitchell, Ekela, Kawehi, those kind of, those people that were apart of Ho‘okahe Wai, the ones that opened up the place. And there were student groups but by the time I was here there were older, they were kind of the next, not the next generation but the wave before us, I guess. I like to see things come in waves, yeah. But they, they were very much a part of the place Ho‘okahe Wai and they were also very much a part of Hui Aloha ‘Āina Tuahine. And when they opened up the place it, their group didn't really have a UH affiliation to anything. So that's how they kind of got involved with Hui Aloha ‘Āina Tuahine, yeah that was really important. And you can see I have a lot of the notes from Ho‘okahe Wai and they kept really good

notes in their meetings. And you can see the struggle they are going through of, “Are we going to do this, are they going to take this away from us, you know somehow we have to figure out how we can become a part, part of the Kānewai Park on this side,” because I think at one time this area was the people who owned it was the city. So they were trying to figure out how to get involved with the City so that they could be part of the park and kind of preserve that this area, the *lo‘is*, the waterway. So you see that struggle and then eventually they come under. Cause what’s happening is that they are running groups already, yeah, people are coming and people are visiting and people are helping them open and maintain the area. So what’s happening is people are calling the Hawaiian Studies department and saying, “Oh how do we get involved?” because it’s a lot of stuff going on down here and people want to be involved. So eventually the group goes under Hawaiian Studies and at that time Hawaiian Studies is, and there is a lot of *pilikia* [trouble of any kind] that goes on, a lot of battles or arguments that’s going on but you see what happens is they eventually go under Hawaiian Studies and Hawaiian Studies is under Indopacific, not Indopacific Languages, SHAPS--School of Hawaiian Asian Pacific Studies. So they are under Ho‘okahe, no Kānewai is under them. So the leadership changes as well it’s more like Haunani K. [Trask] has kind of been there and then when they were building this building there was a lot of fights going on because the proposed Hawaiian Studies building was supposed to be where the *hale* and this mango tree is, yeah.

CSH: Oh wow.

MC: And then eventually they got it pushed back a little bit more. But there were *lo‘i* over there too, yeah. So it’s a big thing so it just kind of interesting. There was actually a point where Ho‘okahe Wai members were suing Haunani K. And then Haunani K. kind of put a TRO on them saying that, you know, you guys cannot come here anymore. Cause we, this is our area. So Ho‘okahe Wai was bitter for a while and they weren’t actually allowed on campus, yeah, because of the TRO. So that was kind of like, changed the thing too. At that time Charlie Kupa was kind of like the coordinator of this area and he passed away already, Uncle Charlie. And he was the coordinator when I was a student here, he was the one you know like how I am now. He was the one kind of running things. He was having hard time with Hawaiian Studies as well too he was kind of part of the older guys, Ho‘okahe Wai them. So 2007, even a little bit before that when Po was running the place there was talk of building a new school Hawai‘ianuiākea. There was talk of possibly the *lo‘i* becoming its own center, so I remember Po and I having good discussions about that. “Oh you know what you think? You know, Is this good?” “Yeah! You know this is a real good idea, can kind of make our own decisions we no need hang on their whim all the time, directors always changing,” you know those kinds of things. “We can kind of do our own thing.” And then so finally it went through in 2007, we became our own center, the University created Hawai‘ianuiākea and then we were a center alongside Hawaiian Studies and Hawaiian Language. Which was cool so they took Hawaiian Language away from Indopacific Languages and Hawaiian Studies away from SHAPS and took us away from Hawaiian Studies so we became our own center. So that was nice and it's been, we’ve been enjoying that for a while too. So it kind of gives us the freedom to do our thing, do stuffs like the resource center, and not really, not like we don't have to ask permission but kind of like just decide, eh this is what we want to do let’s go for it. We can go for grants, we can go for, we kind of have our own budget on the side too so operating funds. But then we just have to go to more meetings [chuckles].

CSH: About how many part time or full time staff, besides yourself, are at Kānewai now?

MC: Besides myself full time I have two other full time, Nahulu is a full time person. And then Dana who is our fiscal officer for our place she is full time as well. And then I have a half time position and then I have right now, I have two G.A.s [Graduate Assistant].

CSH: Oh good.

MC: This is like I’m running fat right now. I don’t, I’m not going to be able to keep them for that long too. Especially in the climate now. And then I have, how much *limahana* [laborer, worker] do I have? One, two, three, four, five. But they all share 60 hours.

CSH: Oh.

MC: Yeah, and the reason for that is because they are students, yeah. That’s always the case with students they got to go school yeah. Actually the monies for my *limahana* comes from Punalu‘u. From KS [Kamehameha Schools’] monies. So a lot of the work they do here is for Punalu‘u. So what like they will do over here is they’ll get the *lo‘i*, they are going to pull *kalo* [taro, *Colocasia esculenta*] and all the *huli* [taro top, as used for planting] and stuff like that is going to go to Punalu‘u.

CSH: Okay.

MC: And even a lot of the stuff that comes from Punalu‘u the *kalo* will process it here. Because this is where everybody is and all of our stuff is too. But they’ll help with that, they help a lot. And then when a groups are there they help, they help maintain the area out there. So, but I need that 60 hours and I need to spend it by June 30th so that’s why I need so much of them, they cannot all work 20 hours a week. Some can only work ten, some can only work five. But when I really need them I just need good people, that's. Because our groups are so diverse and we do so many different activities in the stream up here, I just need good people that I can trust [chuckles].

CSH: What kind of activities do you guys do in the stream? In Mānoa Stream?

MC: We’ll do, one of our big ones is going up to the *po‘o* [head, water source] and just showing them the water system. Lot of people come here thinking just kalo but they don’t realize that they also coming here to see the water and what’s happening with the water. How the water moves through our place and it comes down the stream. We are fortunate because our *‘auwai* [ditch, canal] system dates back to 1400 AD. So we’ll go through the different parts of the *lo‘i*, the different parts of the *kahawai* [stream], the *mānowai* [source of water and of life], the po'o wai [water source or head] and the function of it and the purpose of it, the traditional uses of it, those kinds of things and then we’ll also have the groups help us maintain that area. We kind of maintain a little above the *po‘o*, maybe a good 20 yards above it, 30 yards. And then we’ll maintain all this area surrounding us here as the *kahawai* comes here. So we’re all in there cleaning, clearing stuff, and making sure there’s no big trees, um branches you know what ever is blocking. Just to kind of keep the water moving that’s what we’ve been noticing. So we’ll do that with groups. We’ll do

that like a first Saturday when there's lots of people. Another thing that we do is the stream is, it's a besides being a valuable water source for us it's also a resource for us as, to get *pōhaku* [rock, stone]. So it's almost like every big rain we get a fresh supply of *pōhaku* and stuff too. So we are always using the *pōhaku* you know to reinforce walls, to rebuild walls, to build walls, like the *pā* [fence, wall], all this rock work you see here. All the rock work here all the *pōhaku* is from the stream.

CSH: Oh okay.

MC: So we'll bring, because it's right here. So like a first Saturday we'll have like this last one we had over three hundred people. So what we did was we make a line down to the stream and sometimes the line can go all the way to this point here and it's coming all the way around and it goes up to there. It would be easier to just run it straight but it's just an easy access and we have so much people. So what we do is we'll put all of the boys in the front, all the boys that we trust and know kind of what they are doing and they'll go out and they'll pull rocks. You know decent size rocks and then get it to the line. And then the line moves it up to the different sections over here. The project we are working on now is after we finish with the resource building we are going to face this cement slab over here.

CSH: Nice.

MC: We are going to make a run right here and a little bit around the corner. So we stacking it all up, that's our resource. Another valuable resource for us in the *pōhaku* even for *imu*. So even as the rocks are coming up I am looking for *imu* stones. So I'll be at the end, "Oh put that one over here. Put that one over here. Put that one over here." So, or if it looks good for a *pōhaku ku‘i ‘ai* [poi pounder]. It's like "Oh I like that one." Even my staff even try and catch it down there because you like be first to the good *pōhaku*. So those that know, know that, "Oh this, all the *pōhaku* is coming up we are going to try and see what's coming up." Because everyone is pulling. If you was to do that by yourself it would take years and just for us too if was just our staff grabbing *pōhaku* it would take us months to get that kind of *pōhaku* in like 45 minutes an hour.

CSH: So there is a lot of community involvement in and incorporation in keeping the stream clear as well as gathering resources.

MC: Right, right.

CSH: Cooking food, for making walls, for making *pōhaku ku‘i 'ai*.

MC: Yeah. You know we always looking, my thing too is we are always in there cleaning and just like when we clean the ‘auwai system it's really important that the water is moving. When the water moves how it does in the *‘auwai* and through the *lo‘is* and through the stream it tells me the water is cool, it's doing what it's supposed to do, and that's why when you have a lot of debris and stuff in there it slows the water down, changes the temperature and even in the *‘auwai* system when the water slows down and the *lo‘i* slows down the water gets hotter, it gets warmer. Which is not a good thing, it comes, it can get to the point where it is hot, warm, stagnant water. So when

the water is moving it tells us it's good, it's healthy, even our *kalo* likes the cool water. Even us we prefer cool water as opposed to warm stagnant water. We spend, imagine like the *kalo* you spend nine to twelve months in warm stagnant water you going get all *loliloli* [soggy, gummy, tough and watery, as overripe taro] (laughs), all *kaki‘o* [mange, impetigo, itch] on your body too, so same thing too yeah. So it’s real important that we’re in there cleaning it all the time. So that’s always a function of ours too and it just helps to mitigate, regulate the water coming down because if we not taking care, what’s going to happen is that everything is going to build up and then we are just going to get overwhelmed with water. It’s just going to build a big wall and big flash flood, a big *tsunami* [tidal wave] coming this way.

CSH: About how high is Kānewai from, like up above is Kānewai, from the stream?

MC: I don’t know the exact distance but I would say a good five or six feet, above, from this rim right here but that big flood all the water came through here. Was going through the hale maybe about this high flowing through this whole area. All through the hale too. Actually where that black tarp is up there that's where the water level was.

CSH: What!

MC: Yeah, just inundated with water. To me that flood was manmade. People go, “What do you mean manmade?” But what I mean is what happened was and this is my take on the whole thing when I went to go up to check it out. All up where the Mānoa Marketplace is there is that bridge there so what happened, so what I think happened and what looked like happened was the bottom part of the river was rising because of all the debris settling in that area and slowing everything down. So all the rocks gathered there, all the debris gathered there and then when it started raining the *puka* [hole, opening] was too small under the bridge and it started building up debris and wood and all kinds of stuff. So it built this big mountain of water and then it decided, it had to go somewhere. Just like any dam you build it builds up a lot of energy and then it *puka’d*, it took another route. And that route when it decided to take that route it was a flash from above the big rain came one time and then it just took off down Mānoa and that's what we see when it came around the corner here it was just too much. And it just filled up all in here and it went down. Actually it hit this side where Hawaiian Studies is and that is why Hawaiian Studies is so high because it’s out of the 100-year flood zone, just like us here. So what actually what happened was it came more this way around this corner and it came down here, up like that. That’s why even our building when we first initially designed it, it was two pieces, like that but it was a lot higher so when we brought it more this way we were able to bring it down. It was out of the 100-year zone.

CSH: Whoa mean.

MC: Impressive yeah.

CSH: Yeah.

MC: Water. Just got to get out of its way [chuckles].

CSH: Yeah that was the 40 days, 40 nights of rain?

MC: Yeah, well this one was I think it was October 31 it was Halloween night, that's how I remember it because I was on this side with my family like in Kāhala area and then we, when we saw the rain we were moving, we were driving past Kānewai. Every once in a while, if I am in the area I'll drive past at least to check up on stuff. So we came by and what "Whoa", yeah.

CSH: Do you guys have pictures of that event?

MC: No, I don't. No, no.

CSH: How long did it take for the water to drain out of here and to kind of?

MC: I think the next day it was out already. The next morning it was gone. But all the *‘ili‘ili* [pebbles, small stone] and everything was all moved into this area. All the lau hala [Pandanus; *Pandanus odoratissuimus*] was all up in the trees and stuff like that. The benches too was all up there, but that's about it. Other than that it was okay, yeah. Yeah it was just unreal, unreal. But again like I was saying I think that one was more manmade if anything. Just because that, what happened up there and we know the waters coming so you got to keep the river clear, you know of debris. So you got to go in, you got to clean out the rubbish and clean out the big trees especially, those kinds of things. So that when the water comes it can just stay on its course. So when you get stuffs in there blocking naturally it going to slow down. Even in the *‘auwai*, something as simple as two or three leaves can screw everything up so you got to keep walking through. So we are always having the kids do that, little things. But it makes a difference. Even something simple like this when it comes in, it's already leaking water so if down here is plugged up all over here is going to overflow, it's going to get real bad. In fact yesterday this *lo‘i* was plugged had couple rocks got stuck in the *makawai* [small outlets for water through banks of taro patches, small waterways; water sources] so it just flooded all up over here. So something real small can just affect everything and I really think that what is important to is we had another project trying to go through here and they were trying to cement all the way over here. From the *po‘owai* all the way across here to the end of Kānewai there and they wanted to put a wall literally a wall up all the way around to help get the water through this area. And we were like "No!" in fact the Dean just came on she was her second week or something. And we had the meeting down here, the guys was like, "Yeah, yeah we are going to put a wall [the contractor], we going put one wall right here but you know we no more one access so we just going come down here cover up the lo'i take one picture first, then cover them all up, we going we need one place to have all the rocks too so we are going to take all the rocks over here and bank the wall." Oh man I almost fight in that meeting. I almost ripped their face off, like I was standing up and the Dean was like, "Oh no Hiapo, please don't hit anybody," but I was like pacing, so upset. I told him, "You no need one cement through away over here. Keep it the way it is because we need it that's our resources, we need access to the river, we no need that, we no need." They said, "Oh no, we'll put a stairs down for you guys." I go, "Yeah but not going have any water, that's what you're trying to do. You're trying to eliminate the water from this place." You look at St. Louis over here they have that same thing, there's no, there's water running little bit but you cannot go in there and rinse off, you cannot do you things down there that you need to do. Rinse off, you know, but I don't know. I think having

it this way, where the water meanders and does it things like that that is how it was meant to be, you know. Like this river has been here for millions of years already, it’s like why would you change it. And it’s not eroding, I mean right now, I think that it’s okay. For even for it to make this turn it’s a big turn. And the water flies through here when it’s rushing. We’re talking thirty or forty miles per hour, kind just moving. That’s why if there is something blocking “Boom” you know that’s why you got to keep cleaning. That’s my thing is that you got to keep cleaning, somebody’s got to keep cleaning like all the way up too. We can clean this area, we had a tree fall across there a huge tree. Like this kind tree [points to a mango with a diameter at breast height of about six to eight feet]. We was like, “Oh my gosh, we got to appraise to see how much it would take to take it out,” and we were like, it was like a couple grand, five-six thousand because they had to bring a crane and everything. So oh man, how are we going to do that. Then one day we came back and the tree was gone, was like, “Whoa, what happened to the tree?” But it got washed out that’s how when it flashes over here it just flashes. It’s heavy. In fact when we were doing, a couple of weeks ago we were working on the hale on the other side where we were replacing some of the beams and stuff like that, some of the posts. We were up on the top in the attic area and we heard like thunder “Boom! Boom!” and it was kind of raining that time. Kind of thunder, lightning during spring break. Then it started over here “Boom! Boom!” and I was like, “Whoa, wow that was close.” And the next thing you hear “Boom!” and then we look out into the river and the thing when flash. It wasn’t real high but it was strong. You know was real dark, dark brown water, plenty of debris inside. It was just moving but you could hear everything moving now and that thing was a couple of rocks or trees coming down.

CSH: Oh okay.

MC: That was moving, that was the sound we heard. Was loud [chuckles]. We was like, “Ohhh,” wow impressive.

CSH: Is there a cycle throughout the year with flash flooding or is it just...

MC: I think it starts like October and then usually to now [April], usually January, February, this kind of time. I think pretty soon it going to change, we are going to go into summer. But there is always some chances of it flashing, I mean even a small rain can bring a flash flood too. But I think the critical part is having everything clear, constantly two or three time a year. Like you know summer time everything is going to get dry and fall so then you have to go in and clean out. And just before the big rains again, clear out again. So that’s my thing is the consistent management of the place, all the rubbish and stuff like that, that’s real important.
CSH: Do you notice anybody else other than your staff or volunteers coming through this stream area and maybe gathering *pōhaku* or other things?

MC: Yeah. I’ll see other practitioners come through, yeah because a lot of people don’t have points to enter. Especially in the city and stuff like that. We have lot of different groups that'll come in and say, “You know we can come in and get *pōhaku*.” We’ll say, “Yeah, yeah, yeah,” but actually they want to be able to park close so that they don’t have to carry the stuff far, so that’s what they looking for. And they looking for easy place to get down to. So here, they walk up there and grab *pōhaku*. So they’ll like fill up their buckets and then carry it, so like whoa plenty work. But that’s

what they are looking for, that kind of access to places so that's real critical to this is to me that is what the place is for to help people to that. So that they can practice stuff at home too. And then you get plenty people from the area coming. There is another group, a Mānoa group, Mālama Mānoa, something like that. I think they do work in the stream to and they come here as well too. They just trying to see different organizations they can team up with and work with so they come down here and we talk story, they come down here and work with us too. We work in the stream together. So us our big event is the first Saturday when we got like couple hundred people and we can fill the stream up, picking up little pebbles even, there's so much people. And I think too having the people in and out and through the stream helps the water move better too.

[CSH reviews list of questions, MC says *mahalo* (thanks, gratitude) to staff worker]

CSH: Is there any stories of, to why this place is called Kānewai?

MC: Yes there is the story of Kāne [the leading of the four great Hawaiian gods] and Kanaloa [a major god] and there are several versions. So Kāne and Kanaloa come from Kahiki [any foreign country, abroad, foreign], they come from this side. And Kahiki doesn't mean Tahiti it just another place. And they come from Kahiki and they kind of going through the different islands and they end up spending time on the Big Island at Mo‘okini Heiau [Pre-Christian place of worship, shrine] and while they are there, they spending time there, they receive certain *kuleana* [right, privilege, responsibility]. After that they start to make their way through the different islands coming back this way. They are especially known for creating springs. And it's the two of them, some of them consider them brothers, you know even in the Kumulipo [origin, genesis, source of life, and name of Hawaiian creation chant] they are right next to each other being born. Kāne and Kanaloa are together and one story has them coming up from the Kāhala area. There is actually a place in Kāhala called Kānewai too. It has direct association with this Kānewai too. What happens is they come, and the other story is they come up from ‘Āpuakēhau, where the Moana Hotel is. So the two of them come out of the ocean and they want to rinse off, they want to rinse off, they want to drink *‘awa* [kava, *Piper methysticum*], they want to relax. So the two of them Kāne and Kanaloa start to make their way up here and Kanaloa is bugging Kāne and saying, "You know hurry up, find water already." And Kāne his *‘ano* [kind, nature, character, disposition] is to be real *‘olu‘olu* [pleasant, nice] real easy going so he's telling, "No, be patient, be patient just wait." So the two of them are coming up making their way up and finally Kāne decides on this area to make the, to make his spring. So he sticks his *‘ō‘ō* [digging stick, digging implement] into the ground and a huge spring comes up and that, that spring is known as Kānewai. The two of them are able to rinse off, relax and they start to drink *‘awa* as well, another thing that they are known for too is *‘awa* drinking. They spend some time here and after they are done here they make their way up toward Mānoa as well too, and they create springs up there too. We think, just doing research that Kāne has the ability to hear water move underground. Because he can do that, he can find the springs, create the springs. I think the spring is still here today and I think it's an underground spring, a cave. It's right on the other side of the Hawaiian Studies parking lot in between the tennis court. It's a small area like that but if you go it is all covered with bushes and you go and it's all barred up.

CSH: Oh okay.

MC: It’s all barred up. That’s, I think, that’s Kānewai. I'm not sure and every time I get *kupuna* [grandparent, ancestor, relative or close friend of the grandparent’s generation] here that’s the first thing I ask, “You know where the Kānewai spring stay?” “Oh no I heard it was over there someplace.” So but they don’t know exactly where it was, but the other story which is interesting as well too is Kākea [name of a stormy wind], Kākea is a *mo‘o* [lizard, reptile of any kind; water spirit] and there are a lot of *mo‘o* stories. Of course *mo‘o*, Mō‘ili‘ili [pebble lizard (Mō- is short for *mo‘o*, a lizard destroyed by Pele’s younger sister, Hi‘iaka; his body was cut into pieces and formed a hill across from Kū-hiō School)] is a shortened version of Mo‘o‘ili‘ili but there are lots of *mo‘o* stories but one that is interesting to us and we’ve been looking at is Kākea. Kākea is a *mo‘o* but we see Kākea's name appear several times up here in Mānoa. One is the wind, there is a real big wind, destructive wind that comes through Mānoa and the other Kākea we see is a *pu‘u* [hill, peak, cone, hump, mound] Kākea and it’s a *pu‘u*. We think that *pu‘u* is critical because it, when there was another eruption in Mānoa it moved that whole water system, the whole stream and it moved it alongside Wa‘ahila [a rain in Nu‘u-anu and Mānoa Valleys and the name of a ridge separating Mānoa and Pālolo Valleys], right here. That’s why you see the way the stream is now, it’s kind of alongside here. That’s because of that *pu‘u*, Pu‘u Kākea, that came in and we also starting to think that possibly because there is another story of Kākea in the *mo‘olelo* [story] and he is responsible, what is the two twins? The two twins that come from Ka‘ala [Gulch and highest mountain (4,020 feet) on O‘ahu, Wai‘anae range], Mount Ka‘ala the Waianae Mountain range. They actually come over staying with the mother and the mother is kind of like step mother kind of deal and she is cruel to them. So the two of them move to Mānoa and then she finds them, she takes them back, she beats them and that kind of stuff then they come back again. So I think that movement is a seasonal wind that comes back and forth. That’s what I’m starting to learn too a lot of our *mo‘olelo* now are real elaborate genealogy stories of how our valleys and islands came to be, like the Pele stories like that too. This one is the winds of Mānoa, one of the winds and the rains. I think the two of them are called Wa‘ahila and the other one is called Kilihune [fine, light rain, wind-blown spray, drizzle; to shower lightly] I think. I forget what the other rain name is, shucks I forget, I can’t believe I forgot it. Anyway there are twins and again they are going back and forth because the mother finds them and everything so eventually they take up residence on lower Mānoa and then he, the boy, becomes good friend or is a relative of Kākea. Kākea is a *mo‘o* and the two of them, and he the boy tells Kākea that he wants to make a spring for his sister so she can shower, to bathe and do everything and they can make food and stuff like that. So Kākea with the boy they go to Kānewai Spring and they dig a cave underneath, a waterway and then that’s what creates Punahou [new spring], the Punahou Spring. So they are able to have this thing, this area to cruise in and then they make *lo‘i*, food and all that kind stuff in that area. But my, again, what does that mean, what is Kākea? Who is Kākea in this form? We think Kākea is a *mo‘o*, he is that movement when, like I said how Pu‘u Kākea moved the *kahawai*, Pu‘u Kākea also moved the underwater waters as well, too. And what happened is that movement when he pushed that *pu‘u* was formed from the volcano it pushed the *kahawai* over and pushed that underwater spring all the way to here to Kānewai and shot it back to Punahou. That kind of movement, there was a, I think it was a lava tube. Some kind of thing that created this ability for the Kānewai Spring to hook up with the Punahou Spring. I’m not a geologist but that’s just my take on it, does that make sense?

CSH: No, yea totally.

MC: So yeah. That’s why we see that Kākea name pop up all over. And in this story when we were looking we found the story as well too, it is a well-known story. But it also describes that wind. When we look in the papers, the newspapers, the rice farmers are describing it because that is the one that destroys all of their rice fields in Mānoa.

CSH: The water?

MC: No, the wind.

CSH: Oh the wind!

MC: Kākea wind. Yeah wind.

CSH: It turns down their crops.

MC: Yeah.

CSH: Oh...

MC: Cool yeah? Cool stuff.

CSH: Well that is mean.

MC: So that’s some of the water stories just associated with Kānewai, there’s plenty that’s why, there’s so much.

CSH: I didn’t know the Kākea...

MC: Because I think Hi‘iaka spends time here to. She fights Mō‘ili‘ili I think I'm not sure, so there’s lot of *mo‘o* stories, what does that mean? I see Hi‘iaka as a phenomenon, a natural phenomenon, that’s why she’s the sister of Pele...then Hi‘iaka comes this way, not Pele. It’s Hi‘iaka that comes back to Kaua‘i but she’s the one that’s making it everything fertile again, making things grow, not fertile I think Pele is a part of that too. But I think the Pele clan has *kuleana* where they help make things grow after that but they are all part of that family, the genealogy. Does that make sense?

CSH: Yeah, yeah, yeah.

MC: That’s why I think Pele stays here but Hi‘iaka and the family, she leaves family members along the way.

CSH: That makes sense.

MC: Then Kāhalaopuna is another genealogy story of the valley as well too. And it talks about the rain, you know, Tuahine and the father Kahaukani, and then the grandparents are Akaaka, the mountain the big mountain in the back of the Mānoa , and then the mother is Kaleihuaakaaka which is that *lehua* [the flower of the *‘ōhi‘a tree*, Metrosideros polymorpha] ridgeline but together they create that water source. They're that, they're the ones that *hānau* [to give birth] the water, without that it's not possible for the wind and rain of Mānoa to be. They give birth, that's the birthing of Tuahine and Kahaukani, the wind and the rain, again twins. There's always *māhoe* [twins] someplace in there, some stories. That's the wind and the rain there and then their child is Kāhalaopuna, which is the rainbow. And that's that story and it's a beautiful story, a beautiful tragic story about kind of like the genealogy of the phenomenon that went on in Mānoa, that's related to here. Keaomelemele is one for Nu‘uanu which is the border of the Waikīkī Ahupua‘a. But Keaomelemele, to me, is a genealogy of how Nu‘uanu came to be, you know, how I think the valleys were together and then Keaomelemele had the ability to separate it and create Nu'uanu Valley. That's why I think Kāhalaopuna is important for over here too.

CSH: So all of the genealogies that you've mentioned, they all attribute to historic sites or not historic sites but what we see today?

MC: Yeah. Well what we see today, how the weather moves here, how the area was created more or less. But it's a genealogy there and it's woven into a really elaborate beautiful story which our *kupuna* had the ability to do. I think only now we are starting to, I think before they understood it too but we are starting to see it again, understand it a little more. At least I am [chuckles].

CSH: It helps to create some form of priority.

MC: Yeah. And that's how we do stuff, that how's our *kupuna* do stuff. They tell real beautiful stories and it helps them to remember really good scientists if you will. They had the ability to observe, to notice how things were, and then create this beautiful *mo‘olelo* to remember it by. You talk about layers of *kaona* [hidden meaning, as in Hawaiian poetry; concealed reference] that's perfect right there.

CSH: Speaking of names, there is the mechanical names of the *lo‘i*: *po‘owai*, *‘auwai*, *makawai*, do you have names for different, besides the mechanical parts. Do you have names, do you name your *lo‘i* in Kānewai?

MC: Yeah.

CSH: All of your *lo‘i* have names?
MC: We name all our *lo‘i* that was named by a lot of the group that was here first, Ho‘okahe Wai. And you know when you name things you're calling out *kuleana*, just like us we have first name, middle name, last name. And it tells you what families we belong to, what our family *kuleana* is, what our *kuleana* is. That's why we use the names and it is specific to place sometimes, specific to events, things happening. I think we have 17 *lo‘i* here and then all of the *lo‘i* up there the first one is: *‘Uhai* [same as *hahai*], that's the one when they first opened Kānewai. *‘Uhai* means, like *hahai* [persons following; to follow, pursue, chase, hunt] like to follow and the *mana‘o* [thought,

idea, belief, opinion] there, *‘uhai* is that when Uncle Harry named it the hope was that more *lo‘i* would be built in Hawai‘i, in our community. I think since 1980 there is only maybe you can count on only one hand on this island, there is only a few, still maybe two hands. But now you can see almost every valley especially on the Windward side has all *lo‘i*. You can see the difference in that. That‘s ‘Uhai, ‘A‘aloha, Leholoa, Laulima [cooperation, joint action] is the one they are in now, ‘Ahu'ula [royal cloak], ‘Ohā [taro corm growing form the older root, especially from the stalk called *kalo*; tender plant, shoot, sucker, branch] , Pu‘epu‘e [hill, as of sweet potatoes], Pu‘epu‘e ‘Īlīo, Mālama [to take care of, tend, attend], Ahuwale [exposed, conspicuous, prominent], Kaleiheana and Kaleiheana is the *konohiki* [headman of an *ahupua‘a* land division under the chief] that used to *mālama* this area before and he was actually one of the main warriors under Ke‘eaumoku. So when Kamehameha came through here he was putting all his generals, all his big dudes in charge of certain areas, and Ke‘eaumoku was like his “bu.” So he put, there was a reason why he put Ke‘eaumoku here is, we think he put Ke‘eaumoku here was to govern the water, to manage the water, to make sure everybody had enough water and this area was being fed with water. So that's our, I think you can kind of see it in the research as well. Then Waiaka [laughing water], Kolo [to creep, crawl; move along, as a gentle breeze or shower], and then Holowai [water ditch or course; to run in such courses], Hoaloha [beloved companion], Kalānani, and then Pōki‘i [younger brother or sister or closely related younger cousin]. That’s all ours.

CSH: The Pōki‘i is the one that goes back out.

MC: The Pōki‘i, and then the *ho‘i* [to leave, go or come back].

CSH: Ho‘i.

MC: Ho‘i is the final one. Ho‘i means to return, go back and that is what the water is doing. So a lot of even the parts of the system, the water system, the mechanical parts it’s always about what the water is doing. The description. Like *mānowai*, *po‘owai*, *kahawai*. So *kaha* it means to cut, and again what is the water doing its cutting, it moves and cuts so that’s where it gets the word *kahawai*. Mānowai, kind of describes the water when it hits and moves over the *mānowai*. So it comes in one piece and then when it hits the *mānowai* it kind of breaks up into little waterfalls.

CSH: [Agrees]

MC: So that’s what it’s describing. Like *mano* is like plenty, thousand, choke. That’s what mano means. But kind of helps the water move to the *po‘owai*, *po‘owai* is like the headwater and then *‘auwai*, this is the *‘auwai* and like when you go and play in the water take a shower, it’s called *‘au‘au* [to bathe] and it’s because when you in there you are moving around and the water is moving back and forth. In this case *‘au* refers to the water moving from “Point A” to “Point B” which is the *po‘owai* and then going out the *ho‘i*. So it’s moving in one direction, that’s what *‘au* is. It’s, everything is descriptive. And then the *ho‘i* and everything goes back in the *kahawai*, it goes all the way down.

CSH: So everything that comes in goes out? It goes through the whole system.

MC: Yes through our *lo‘i* system.

CSH: And then it returns back to the stream.

MC: Even our practices here we don’t use fertilizer, we don’t use poison, those kinds of stuff, any chemicals that’s synthetic kind stuff. We all try to do, we do, we mulch everything. A lot of things that we like to use is the *kukui* [candlenut tree, *Aleurites moluccana*]. Again *kukui* is a *kino lau* [many forms taken by a supernatural body] of Lono, so when you introduce Lono [one of the four major gods brought from Kahiki] to your *lo‘i* you allow him to take care of his *kuleana*. So even when we do *imu* we’ll take couple, in fact all our kindling is either mango or *kukui* and when it breaks, after the *imu* is *pau* [finished, ended] with all the *halihali* [to transport] and everything like that we take it and put it in the *lo‘i* again.

CSH: The ash?

MC: The ash, the *halihali*, everything.

CSH: Okay.

MC: All of that goes right back in, the banana stump, the ti leaf. All of that the banana leaf all goes back. Even the worms they like the bananas too. They like the layers in there, they like that, they know the earthworms are a good indicator things are doing well. Then we let it sit fallow for a little while and then we’ll let it sit fallow a good six to nine to 12 months. So then the other thing that we like to use is *hau* [beach hibiscus; *Hibiscus tiliaceus*], *hau* leaves, *hau* branches and stuff like that too. Again *hau* is a *kuleana*, is a *kinolau* of Haumea [One of several names of Papa, wife of Wākea and mother of Hawaii’s war god, Kekaua-kahi, and of Pele]. So when you introduce her to the *lo‘i* she can do her, her *kuleana* of making things grow. That’s Haumea. Like that idea in your head that just pops out. That’s Haumea.
CSH: *Puka ka lolo* [to exit from the brain].

MC: Yeah that’s Haumea, that’s what Haumea is. That’s her thing, what does that mean? A lot of her children, and stuff, are coming from her head, all over. Cool stuff.

CSH: Yeah.

MC: Yeah.

CSH: There's choke stuff.

MC: And there is probably way more lot here we do that I just forgot. That’s why good be down here.

CSH: So you guys get, give or take, of course it’s an ebb and flow, including Saturdays and all of your guys’ visitors about how many people a month or in a school year?

MC: Like a year is, trying to like 20 to 25,000. Just nonstop, so part of it is just managing that keeping people safe, because we have plenty young ones too. That's why having people that I can trust and do stuff is critical. You like them be *‘olu‘olu* so when the groups comes they connect and “Oh I like bring my family next time,” you know that's what you hoping. Better give them good experiences, try to keep them together, you know, so common, so they can share stuff when they go back. So teachers can build stuff too, so that's what we are trying to do. Sometimes they tell us what they like do. “Oh can we go in that *lo‘i* now,” “Okay, just go.” If can then we go because actually they like go in everything and see, they are in here already, they are looking in this one, looking in that one, they trying to, but that's how. It's good to be young now. We never have this when we were in school yeah?

CSH: Yeah.

MC: The *lo‘i*.

CSH: Not easy access as such, had to go Ka‘ala farms.

MC: Yeah.

CSH: So besides just the education center do you also play a role as a *huli* bank?

MC: Yeah, so.

CSH: For the island or...

MC: *Huli* is another big thing for us too. I think out of all the 69 Hawaiian varieties we got about 63 Hawaiian varieties. So I manage that. We go out and collect if we hear something like we just got one the other week was ‘Owene [a variety of taro, same as *mana ‘ulu* except that the petiole is pinker] and we haven’t see ‘Owene in a while. So we got one *huli* of that so we are taking care of that now. So what happens is that when I get the *huli* I get maybe three or four put it in the ground, put it in the *lo‘i* then I manage it and then when it starts to really take off here then I take some to Punalu‘u then we can really...One row in Punalu‘u is 25 or 30 in a row, so the *lo‘i* there are way bigger. It’s like the whole area here is one *lo‘i* so it’s just bigger, can do a lot more. So it helps us manage. So the kids are kind of pulling it out now and then it’s all good. When I take care of it I make maps of everything. I map every *kalo* that goes in the ground, I account for. It just helps me later on when I need to know it’s easy to remember like, “Okay what was that again? [Chuckles] I have my own way, my own way that I set it up a lot of people come in and say, “Why don’t you just follow Bulletin 84 and go 1, 2, 3, 4, 5, 6, 7, 8, 9, 10?” I go, then everyone else is going to know and I am going to be missing *kalo*. So I kind of have my own system because a lot of them are real similar but a lot of them are real different too so I’ll mix it up just so that it’s easier to tell. Just like this one right here is when, it’s like I have that *lo‘i* there Laulima, and then Ahu‘ula all the *kalo* that’s planted in Ahu‘ula came from Laulima. So what I’ll do is I’ll stand in the middle right there and each row is a different variety. So I’ll have my class and go, “Okay you got this one, you got this one, you got this one,” so each of them has their own variety. Then we take it, we cut it, we make the *huli*, we make the *kalo*, put it all separate. We take the *huli*, we cross it right over and

then we plant another row. So that's how, and then I map it all out or I have someone helping me map. That's how I manage. That's my way. Even my staff go, "Can you send me a copy of the map?" "Make your own map. How are you going to learn?" It's easy for me just look at it and throw it on the side. But if you really care then you will make your own and learn, and they do. But me I get *kuleana* [chuckles] so I'm a little more anal about stuff. But maybe in the management of the water in the *lo‘i* is critical too. Like when we plant we don't put as much water inside, trying to get all the roots and stuff established because if you have too much water it'll just erode all of the *pu‘e* [hill, as of sweet potatoes] and everything will float away like that. So we try to manage that. I can tell by the amount of leaves, like three or four leaves you've got a pretty good spread of roots in there, kind of holding it there.

CSH: Oh, three leaves on the plant?

MC: Yeah, like *laupa‘e* [first two leaves of a taro shoot (according to some, the first three leaves)] they call it. So you looking for that three or four and every week you get one more leaf. So after three or four weeks you can let little bit water in and then later on when it gets real big then you can let little more water in. But not, there's such a thing as too much water too. That's why when I look at some *lo‘i* I see, "Oh, plenty water." But the *kalo* can actually drown, it's not going to do well, it's struggling. But the *kalo* loves sun that the other thing too it loves sun. So even this tree, I was like this tree is getting big but we're okay. But I get the *manu o Kū* [white tern, fairy tern] that lives up in this tree, this *kukui* tree.

CSH: Oh yeah?

MC: And they been in there for like seven generations. Yeah so and even like this they don't make a nest they lay their eggs in the nook of the tree and then the baby just hangs out on the branches. Thing no really, and even in this wind the thing handles.

CSH: So did the *manu o Kū* and the ducks over here help out with the *lo‘i* maintenance too?

MC: To me it's always an indicator, especially when you get native species here, to me you're doing something right. They like the *kukui* for some reason. I've never really see them making nests, I see them cruising but they won't go in the mango tree. I never see them in the mango tree, but I'll see them they'll go into this tree right here. They go in this *kukui* here and there is another *kukui* there, they'll just kind of meander in there. I don't know what it is about that. Must have a story about it that relationship that they have, I just haven't had time to go look it up.

CSH: Looks like you have plenty to do already.

MC: Yeah, even the *‘auku‘u* [black-crowned night heron, *Nycticorax nycticorax noactli*] we see here once in a while too. But *‘auku‘u* are very shy, like once you'll see them early, early in the morning or late in the evening. I know when people start coming in they kind of goes up in these trees and cruises up in here. Sometimes when we walking we can see them in the stream and then he'll kind of bounce out of sight and when you come up you'll go to the next one like that. It's kind of like *‘auku‘u* style. But the ducks they don't really bother us, they don't really bother the

kalo, they like the water. They like to keep their *‘ōkole* [anus, buttocks] clean in the water and they pretty mellow. See like this they actually walking to the people, they pretty tame sometimes you just walk right past them and you don’t even know that they are there cause they are kind of hiding in the *lo‘i*, with the *kalo*. Even these guys they just kind of come they feel comfortable, that’s all the babies too. These ones right here. You can hear them squeaking they are asking for food, they no more their color yet.

CSH: That’s why it has a brown head.

MC: See like the adult.

CSH: Redhead cardinal?

MC: Yeah, the red head.

CSH: And then that one has a brown head.

MC: It’s just young, it never get the color yet. So birds are real critical to us. Might not be native but if you get one native then great. You get like the *ae‘o* [Hawaiian stilt bird, *Himantopus mexicanus knudseni*] or the *alae ‘ula* [Hawaiian gallinule or mudhen, *Gallinula chloropus sandvicensis*], those guys, if you get them then is like “right on.” That’s a good indicator. We get the *ae‘o* and the *‘ulili* [wandering tattler, *Heteroscelus incanum*] too out at Punalu‘u. So to me that’s always important because that means you get the kind of surroundings that they like. Even birds, birds are, I like birds they are like a good indicator for me. That things are okay and mellow, the mongoose can play a role in that too. We used to have plenty mongoose and then they started trapping, we started trapping too but, yeah. They get people really into animal cruelty and stuff like that, too. But they are just a pest. [Chuckles] Even the kids they bring lunches and stuff.

CSH: [Agrees]

MC: The kid put his lunch down, go grab a drink, come back his lunch gone. [Chuckles] All his friend’s laughing, stuff like that so. And they come into bathe and stuff like that too, the birds.

CSH: Oh okay.

MC: So like this area right there, see where the bucket is down by that *makawai* that’s like the car wash over there. But they all line up in the trees and they take turns you can see them all moving and taking turns. So it’s pretty cool, so that’s another good indicator that things are okay. Of course I would like to see more natives but the flora and fauna around here is different you not going to see the natives too much unless you way up in the valley.

CSH: In regards to the waterways over here is there anything that you would like to add that I have maybe not asked about?

MC: I think I mentioned it but the critical things is maintenance on the stream, keeping it clear of debris and stuff and then not cement the area [chuckle]. I think that is problematic too. Because eventually what happens is everything ends up in the ocean anyway so you changing the temperature, I don't know. At least in our area we are lucky, we are okay. [Cough]

CSH: Do you guys have, just a map of the names of the lo'i that I could take a picture of?

MC: Yes.

CSH: And maybe include in the report?

MC: Yeah, yeah.

CSH: If that’s okay?

MC: No, that’s cool.

CSH: And then also maybe ask if I can take pictures up by the *po‘owai* and stream and then I'll go down to the *ho‘i* so that I can like, when the map goes inside I can map the, I can connect the map with the pictures and stuff like that.

MC: Okay.
CSH: So that people can get a visual of what’s going on and how things look like. Cool. Well if you don’t have anything now you can contact anything later and I’ll get to transcribing this. Thanks Makahiapo! That was super awesome.

MC: Thank you.

Appendix E Hayden ‘Īmaikalani Winchester Transcription

Interview with Hayden ‘Īmaikalani Winchester, Educator at Hālau Kū Māna and Director of ‘Aihualama *lo‘i* on April 18, 2014 at ‘Aihualama *lo‘i*

IW: ‘Īmaikalani Winchester

CSH: Cultural Surveys Hawai‘i

CSH: Shoots. *Aloha* thanks ‘Īmai for meeting with us to talk about ‘Aihualama, your experiences in Mānoa and your connection with the streams in this area. I'm Katie Kamelamela for the record and can you please share your name and where you're from?

[Rain starts to pour]

[Laughter]

Alright, in the beautiful rain of Mānoa.

IW: *Aloha mai* my name is ‘Īmai Winchester. I was born and raised in Waipi‘o O‘ahu in a place called Mililani. My mom is Emerald Waine‘e and my father is Jim Winchester, both from O‘ahu (via Ni‘ihau). I grew up on O‘ahu, went to public school when I was younger. Then when I was in high school age I got a chance to go to a private school. Found myself at college when I was 18. At college I took several classes met a bunch of influential people and found myself studying a lot of traditional Hawaiian skills and practices not really knowing why or what I was going to do with it. But all I knew was that it really kept my interest so I pursued it then when I finished I was lucky enough to land with a Hawaiian Charter School, Hālau Kū Māna. Like 10 years ago, 2003-2004 then I started with them. I was 23 and just started grad school studying political science which it was good and it helped me to learn a lot of things. When I was younger I was, after taking classes with influential people like Haunani K. Trask, Kanalu Young, Jon Osorio, Lilikalā, you know that was the old or sort of the pioneering professors in Hawaiian knowledge and Hawaiian history at the university level. I got inspired by what they taught and just by meeting a lot of people including all the guys at Kaho‘olawe and different work projects at the fishpond or *lo‘i s* [irrigated terrace]. Once specific *lo‘i* Kānewai was very important to my sort of introduction and eventual rooting into *lo‘i kuleana* [right, privilege, concern], I guess. This Kānewai *lo‘i* where we met several influential uncle and aunties, *kūpunas* [grandparent, ancestor], *‘ōpios* [youth, juvenile], brothers and sisters, and through learning from those guys, partying with those guys, traveling with those guys. It kind of helped to reform who I thought I could be as a Hawaiian, I guess, living today. And so I've been a teacher at the Hawaiian charter school at Hālau Kū Māna for the last 10 years. And then through that time our first school was actually right at Kānewai the bottom, or when I first entered the school our campus had already been moved from Hawaiian Studies to YMCA Atherton now on to Paradise Park. So my first year was our first year at Paradise Park. Kawika Winter had been working up over here at the arboretum. He was in charge of the ethnobotany section and he had, then one of our friend's and stuff like that. So we had hooked up and started bringing our students up over here through whatever, memorandum of agreement and then long

story short they've been trying to open up and maintain *kalo* [taro, *Colocasia esculenta*] and use the stream as a primary resource. And try to engage culture and traditional knowledge, try to get kids involved and active and aware of a world outside of the city.

CSH: What year did you end up at Kānewai? Or did you start participating at Kānewai, or about?

IW: I guess maybe my first or second year, I guess in college. By the time I was a sophomore I was already going back and forth into the lo‘i.

CSH: So 90-?

IW: 99 or 2000 or so, somewhere around there.

CSH: And how long have you been caretaking up at ‘Aihualama lo‘i?

IW: Um, shoots. I would say since maybe around 2005 or 2006 or so. Somewhere around that range, maybe 2007.

CSH: What has been your main responsibility at ‘Aihualama since your time here? How has your role evolved to your present *kuleana*? What is your present *kuleana*?

IW: My present *kuleana* is to, you know, bring life to the *lo‘i* with the hands of our students with traditional practice, production of food, with serving of food, to regenerate our systems again. And me what was important was as a *kumu* [teacher, tutor] to make sure you can speak, and you know what you're speaking about. That takes practice that takes time, it takes messing up and it takes a lot of things that, for me and my interests and I thought is a good place for me to be over here. We work with ethnobotany and they sort of take care of a lot of the surrounding areas. But primarily Hālau Kū Māna's engagement is with the lo‘i planting section. Kind of basically up to the *po‘o wai* [water source] all the way down to the *ho‘i wai* [where water goes back to the stream] and then we work together with the arboretum staff to do a lot of the clearing of different spaces to open up more sunlight, less rubbish and rainfall just to make the place a little bit safer. But primarily it's to get these *lo‘i* functional, get kids to become interested in working in the *lo‘i* to have them love working in the *lo‘i* and to produce taro. And in so doing, I think you know, it means we are going to be cleaning up the streams because that's our resource for us to take care of and I think the more we have invested in this *lo‘i* , the more likewise we have invested inside the stream. That goes like wise everything below us, I think the more people trying to engage this stream, of who are attached to this stream, have a responsibility to that stream. So I like to think that because we are at the top of the first of the seven waterways in Mānoa and we know that through cultural knowledge that everything goes down, we need to be specifically conscious and responsible about the things we do up over here. So the *kapu* [taboo, prohibition, special privilege] should be extra high over here cause the things that we do influences and, you know, the system is there. There's more people too that need to adopt that, that type of mentality, that type of action more or less. And that's what I think maybe a lot of our system for our programs is putting action back to the stories we read about *lo‘i* and stuff like that is to, is to give kids a chance to connect at least for a couple of years to a specific place so they can have aloha for a specific place that grows taro. So one of these fools comes back to replace, you know, because sooner or later I'm not going to walk up this hill. So lot of it is to put babies out and try to see which ones can become *makuas* [parent, any relative of the parents' generation] and if they come back then you know you plant. But otherwise a lot of the cultural stuff that we do as far as *‘oli* [chant that was not danced to], or we've made it through different *ahu* [altar, shrine] and *lele* [sacrificial altar or stand]. We are trying to

bring back more of a sense of *mana* [divine power], you know, with just presence and bringing back *‘ōlelo Hawai‘i* [Hawaiian language]. We kind of feel that’s a significant role that we service too. You know back over here we try get the kids to *‘ōlelo Hawai‘i* as much as can cause, you know, if we don't how many other groups or how much *‘ōlelo Hawai‘i* does this *kupuna* valley hear anymore, you know? So I like to think that we sort of try to service that as well, with the spiritual aspect of it. Because I’m not sure what in terms of Lyon Arboretum side what they do in terms of that. You know there’s a lot of science, and a lot of good work they do but in terms of the culture and stuff like that I know that they lay next to, is pretty much absent, I know that on their guys side it make them appreciate. It kind of, seeing in terms, people see maybe schools or groups who are *ma‘a* [accustomed, used to, knowing thoroughly] with a zone. Hopefully it makes them kind of rethink or recalibrate how they see Hawaiians, or how they see education, and what it can offer, I mean, kind of a special type of class room we got over here.

CSH: What's the name of this stream that helps to feed the *lo‘i*? And how often do you guys interact with this stream, next to the *lo‘i*?

IW: Our *lo‘i* is located right next to or adjacent to ‘Aihualama stream. It’s one of the first of the seven streams in Mānoa at least the [unclear].

CSH: What are their names? Do you know their names?

IW: ‘Aihualama , Waihi‘iiki, Waihi‘inui, Naniapo, Lua‘alaea, Wa‘aloa, Waikeakua.

CSH: Sorry.

IW: And, sorry what was the other question?

CSH: You were talking about ‘Aihualama is the stream, and how often do you guys engage with the stream with the *lo‘i*?

IW: Well we actually only get a limited amount of opportunity I think, well in my opinion to grow food, to be successful at the things we do it takes a lot of time. For us guys we are only allotted a few hours out of the week. Which generally turns into maybe, somewhere around the park of three hours, I guess, a week. So on project day which is Wednesday, this year, it changes sometimes. We have a handful of kids and do different work projects and stuff like that. One of the main things we have been doing a lot of lately, the last few years is a lot of stone wall building and a lot, all of these came from over there, and they are from the stream. And so we spent actually a quite a bit of time collecting and gathering inside of the stream we using the little kids, we using them to the *‘ili‘ili* [pebble, small stone], to the *pōhaku* [rock, stone], to the *niho* [stones set interlocking, as in a wall], you know. So we have been in their quite a bit more so than I think than when we first kind of got in here we were spending a lot of time just trying to collect rock to restore a lot of the walls and stuff like that over here. So when we are here, just work projects that we do, we have science, we have science projects that assess the stream that we do daily whenever we come up. That includes three major sources, three sections of the stream, the *po‘owai*, this section that we crossed right over here the *kahawai* [stream], that’s the *ho‘i wai*. The kids they basically measure how much water is coming in and going out and try and generate general percentages of how much water is being used. They take temperature, take turbidity, oxygen, just try to get a good baseline data of what’s going on at the *lo‘i*. Cause I mean not too many guys have been here long enough to say anything empirically of how the water has been, you know. Without having it been written

down, and written down, written down, you know. So it's good that we are trying to do that. Its slow going by we are trying to do it.

We always take *wai* [water, liquid or liquid of any kind other than sea water], usually our *po‘owai* is always open typically so we are always drawing from the major water source. If it gets real crazy, you know, I think the water jumps up real high, flash flood or something like that then it’s inaccessible and people need to stay out. If it’s real heavy winds and stuffs like that typically we don’t bring any workers down over here because the hazard potential. There is a lot of that stuff ends up in the stream, ends up clogging and disrupting the system, that we have for our *‘auwai* [ditch]. So it takes a lot of, I think not a lot of heavy work at times but a little bit of consistency, come in for a little while when the water kind of, sort of manages itself once you kind of give it a kick start. But otherwise yeah our class, at least over here, comes in just usually once a week and if there is a major storm or something like then we have to close the *po‘owai* then usually I'll come up and close it down so we don't lose our pipes or anything like that. Or it's just not good to take in too much water, you know especially chocolate water. Chocolate water you know like chocolate milk.

CSH: In your time being here do you notice seasonal or yearly ebbs and flows in the stream?

IW: Oh yeah, definitely the seasons have really changed in the last handful of years, possibly five or six years. It seems that our wet seasons have come later, our dry seasons last longer.

CSH: From when and when, when and when?

IW: I'll say about ‘04, ‘05 or about maybe ‘06, ‘07. Our lows are really, really low. That summer time low is really, really low. Like we weren’t drawing anything from the stream. The springs were still really low, then maybe in about, maybe like 2010 or 2011 that’s when we’ve have, at least for the past three years, more healthier rain when it’s come through. Before it seems like it was just kind of sparse, wet the ground rain. But it wasn’t really enough to fill up the stream and get it going so a lot of times like our first four years or so like that most of our time was just getting above our *po‘owai* . Trying to get our stream flowing as much as it could but it was flowing like as small as this [points to *makawai* (small outlets for water through banks of taro patches, small waterways) feeding into *lo‘i*] this is a closed *‘auwai*. This is all excess flow coming out of this guy. But that was what, you know, a good day for us. We were like “Yeh we have water today!” Like it’s certainly not enough to keep a patch, you know, cold or anything like that. *Kala mai* [pardon] [opens up the *makawai* to the *‘auwai* spoken of previously].

CSH: No, yeah. Opening up the *makawai*.

IW: Yeah, so we divert ‘em. Then we channel, bust this guy out.

CSH: Do you notice if anybody uses, accesses or gathers in this area other than Lyon Arboretum or Hālau Kū Māna? Either within your property or responsibility or your perimeters of it?

IW: Yeah, I know Masturi [previous Lyon Arboretum employee] guys, they planted some stuff over here. Sort of on this bank, it was a native something or other they were excited about. Which, whatever they don’t take care of it so all good. But other than that most of the stuff that I deal with is strictly with the *lo‘i* stuff. People going inside, coming in to work with these guys. That’s usually when I’ll come in. But I think for that other kind of stuff like the plantings around, the *‘awa* stuff like that, that’s all Līloa folk. This section over here is actually not even part of, this ridge line is

not part of the arboretum. Anything on this side West end of ridge. All that stuff that fell, you can actually go on the top up there and look down. All of that stuff is state land but I think there are a few *hālaus* [a house for hula] that come over here that were doing some gathering over here. I know, she, you know who Emmalani something or other is? She does *lā‘au lapa‘au* [medicine]. Well, I guess she has interest, she is one of the new hires over here and I guess they already have a *lā‘au lapa‘au* garden so I think they are making segue to be a program like that, for that. I think they do classes up here on the weekend or something. We are the only ones that I know, I know of that we grab the rocks from over here. I know the arboretum they run an education stream study, kind of. The kids catch fish, they use it as an educational tool as well as far as accessing.

CSH: What do you guys use the rocks from the stream for and when do you gather them? Or when are times that are appropriate to gather those rocks?

IW: Typically after big rains after it kind of calms down and it gets low and it’s easier to see to pull them out. The when just sort of depends on how many hands. Like if I ever get a big group like 40 or 60 guarantee we are grabbing rocks. If I only get four or six guys, like I don’t think I want. So it just sort of depends, 40-60 kindergarteners then we probably going to fill up 5 buckets of *‘ili‘ili*. “Okay you guys are going to grab who ever loses they are going to go in the *lo‘i* and do a push up.” You try to just use the ebb and flow of the visitors as a resource as well, you know. Try and take advantage of those. Sometimes it’s not, like if it rains heavy then you don’t want to bring a lot of people here, because you don’t want them to kick up a lot of stuff inside the *lo‘i* and send it down into the stream, it should be running, should be running pretty hard. But anyways it’s pretty hard. Also the ground over here gets really soggy, so if you have a lot of people up here in wet conditions it gets muddy fast. It just makes it look ugly and well obviously not safe. But we usually have rainfall is the greatest determinant of how that stream is going to be. Definitely in the last three years or so I think I have noticed more or less an improvement in the rain quality. But when it goes back to dry season again I’m just kind of worried how long it will last. It seems like the wet season is shifting. Like it’s still now yet Lono [one of the four major gods brought from Kahiki] *pau* [finished, ended] but I don’t think anyone told Lono that.

CSH: [Chuckles]

IW: He’s still cranking, get Lono winds, get Lono, you know get action. So I don’t know, you know, whatever is going on but it’s gonna play through how all the seasons are. And that’s kind of what our theory is, I guess. That we get the conditions of what we get.

CSH: Are there any hazards based along the stream? That you are aware of?

IW: Yeah, there’s a lot of, you can see a lot of the major, if you look down Mānoa valley you will find a line of *Albizias* that are going down all the way to the bottom and right below all of those *Albizias* is the stream. They all connect until these guys come over, and we are at the top this is where everything goes down into the valley it gets dispersed. And so for us heading back over here, you know those kind of things like keeping the big banyans that were put in over here. Some of them 60, 80, 100 years ago by sugar interests. Who they were trying to create and divert, you know trying to play with the water system over. And all because of that I think you know there is a lot of clean up to do, to happen. You know and a lot of the erosion and run off of, you know where the sides of the banks and stuff like that, a lot of buildup of you know just *‘ōpala* [trash, rubbish, refuse, litter, waste matter] wood. Back from over here, where we were at the *po‘owai*

from there up to the actual the waterfall. Because there is an actual path to the waterfall but I mean for the amount of 100s of people that go up there we count probably, how many times people have accessed between our *po‘owai* and that water inside this stream, you know on one hand. And it starts with us, you send guys in there and try to clean and just remove rubbish and we could go up through the whole way and spend the whole time inside over there. But you would try want to do especially that like those times, especially heightened during summer time. Less water, less push, so the *‘ōpala* backs up faster. You get heavy winds, yeah usually after heavy winds, ripping through over here, guarantee get plenty rubbish all over the place. That’s the stuff that clogging up all the streams. That’s what I, I more or less see from section that we access and then the bridge is right over there. And the bridge we when cross, walking over the stream right over here. But from that bridge to over here we are sort of the, just in this small section, seasonally, summers is pretty tough because no more too much rain. So the water that we can access goes down, which means the amount of kalo we plant goes down and the yield isn’t as great, or whatever you know.

CSH: Do you know of anyone else above your *po‘owai*?

IW: I know there are a couple of gardens that they have going on here at the arboretum. I don’t know of any of them, it’s all.

CSH: Of anybody that taps the stream?

IW: There’s a couple of old stations over there. I don’t know if they work at all. You know there are a couple of pipes you can see walk up the stream. There’s a couple of old stations over there. I don’t know if they work at all. You know there are a couple of pipes you can see walk up the stream. You can see a couple of pipes going in and a couple of pipes coming back out. But whether they are working right now, I don’t really think so. The water stays pretty consistent all the way up basically to the water part which is relatively small it’s not like a grand waterfall or it goes up, there’s a small little pond but it doesn’t give off a whole lot. It looks more like it’s a spring coming down, you know. There are different springs that at least for us guys we access those springs for *ho‘okupu* [to cause growth, offering] or *Makahiki* [ancient festival beginning about the middle of October and lasting for about four months, with sports and religious festivities and taboo on war], or for if get ceremony or something like that. And those would be nice to, if we had more time. That is something that I would definitely be interested in and try and repair that, that kind action.

CSH: With your time spending in Mānoa and ‘Aihualama are there any stories that stand out about place names or anything like that? Myths, stories or?

IW: Yeah, get plenty stories around over here like I don’t know I guess the closest one was right over here Haukulu. On this *‘ili* [land section, next in importance to *ahupua‘a* and usually a subdivision of an *ahupua‘a*] over here where all the *‘awa* [kava, *Piper methysticum*], across from ‘Aihualama stream it’s called Haukulu. We are sitting on the dividing line of ‘Aihualama, which is kind of structured like a *mo‘o* [narrow strip of land, smaller than an *‘ili*] as ‘Aihualama. But Haukulu is interesting because of the *hau* [beach hibiscus, *Hibiscus tiliaceus*], there is an old story of Kahalaopuna. Who is the chiefess of Mānoa, who is betrothed to Kauhi, who kills her several times and in some versions she is taken away for good and her father it says in one of the stories, I guess, went back to Mānoa and turned into a *hau* tree. It was said that every time a chief died this *hau* tree could be seen crying [weeping]. And it’s kind of interesting because over here there is a whole bunch of *hau* and stuff like that and I always kind of think of that *mo‘olelo* [story, tale,

myth, history] when I come over here because Haukulu, you know when it rains over here all of that water kind of gathers on the *hau* and then just sitting underneath it you know it’s kind of like it’s kind of crying right on top of you. And I don’t know, I don’t necessarily, well it’s just interesting section I think because there have been a lot of different plantings of different types of hau and I know that ‘Aihualama this stream was mentioned inside of that story as one of the spots that Kahalaopuna was taken on several journeys through Mānoa. On the top of the valley is the back of Konahuanui, which is sort of famous on the other side, actually on the Ko‘olau side. I think that’s the back of Keahiakahoe side. I know get that one *mo‘olelo* of the guy or the giant who had off of that precipice and on the way down had flashed his *konahuanui* [large testicles] [Chuckles]. But that’s right over here on the top of, right up the valley. And that’s kind of a famous story at least on the Ko‘olau side I remember several. *Wahi pana* of Mānoa? Or just right over here in general?

CSH: I guess any stories that you feel add to your relationship with Mānoa? Or do you know any relationships of the places within Mānoa? Or of any *heiau* [Pre-Christian place of worship] or outlook spots?

IW: Yeah so I guess according to a bunch of readings, old readings there used to be several *heiau* throughout Mānoa because it was so, I guess it was so productive in terms of its taro yield Mānoa and Pālolo was like the super cherry taro growing zone, I guess my district ‘Ewa was the other good zone. But anyway one of the old agricultural temples to Kāne which is still there. I think Billy Fields guys was up on that crew who restored it. It’s called Kūkaō‘ō. That kind of has an interesting history, you know, dating back to Kuali‘i who had battled and defeated the original engineers of, that *heiau*, who were *menehune* [legendary race of small people who worked at night, building fish ponds, roads, temples] according to the old stories. It’s kind of an interesting place. If you actually go on to, where is that, that rock stacking is and you go to kind of take a look off. You know it’s kind of a super good zone, if you can imagine Mānoa without residential, if you can imagine it without the big invasive trees, you know with a healthy system with taro fields all over the place. That would probably be one of the spots that you know, you would want to be as far as a *konohiki* [headsman of an *ahupua‘a* land division under the chief], a land manager or steward. That kind of struck me the two times I’ve gone over there, it’s just the perspective you get.

CSH: [Sneezes] Excuse me.

IW: Otherwise most of the other *heiaus* were destroyed. It's sort of an ugly history with land turn over in Mānoa. A lot of the fields, I guess, you know the great dying of the *po‘e Hawai‘i* [Hawai‘i people, persons]. A lot of fields, a lot of families were really hugely affected. That included how much people could get out into the *lo‘i* and work. Some fields got abandoned, couldn’t take care of some, there wasn’t enough people available who were able to work on land. It kind of knew was to shift into currency, people were starting to get jobs, land taxes, and new businesses came in. Mānoa has a, we still sort of feels like sort of a land tenure ship, you know post Māhele [land division of 1848] when lands were being allotted out. A lot of which came to some Hawaiian chiefs, Ka‘ahumanu has land right below us that the Roman Catholic Church was given back to her in passing. I think had a governor, his name escapes me that owned land right over here in Haukulu. Shoots.

CSH: Boki?

IW: No. It was somebody else. But Boki did have land in Mānoa, it is just a little bit more down, Kamehameha used to have residence over here, until whatever. I guess it’s famous for a lot of the caves like that inside of the mountains so, a lot of people believe that there is a real good chance that you find burials if you plan to go *nīele* [to keep asking questions, often used pejorative sense, as of a busybody asking things that do not concern him]. What else?

CSH: Have you seen the LCA for this parcel of land?

IW: I saw some of the old map from when we worked with Donovan a couple years ago when Noe [‘Īmai's wife] was doing research. She was writing an article about Mānoa and ‘Aihualama but it was sort of a while ago. We had the one map the tax map that we sort of used, you know just as a general introductory with some of the different, I guess, names from that area that we try to keep reference to, you know. So we try and bring back the idea that that’s Haukulu, not Lyon Arboretum. That’s Wahi‘i, it’s not Mānoa stream. And that has, hopefully, spreading up there too.

CSH: Shoot. Is there anything that you would recommend for the maintenance of the streams? Within, actually do you take care of or does HKM campus have Makiki stream running through it or next to it?

IW: Yeah so. Our Makiki campus is actually it’s a small little strip right alongside Makiki stream in Maunalaha. Which is, runs right up to Maunalaha valley which is an old Hawaiian residents that DLNR has under their jurisdiction. It’s a pretty popular trail so at least at the school we have been trying to work through limiting and removing some of the invasive stuff like taking down some of the bigger trees. Then there are times that we don’t get up and the gets established, trying to put up ferns that we can eat, trying to do a little more weed suppression, weed control using edible plants. Trying to be *akamai* [smart, clever] about waste removal. A lot of our land, a lot of the stream is diverted, not diverted but a section of it was diverted and subsequently a large tree last week just fell on top of right over the stream and into our *māla* [garden, plantation, and patch].

CSH: Yikes.

IW: Yeah, so we spent Monday chopping it up, and chipping it up and moving it out. But because of the way it grew against the side of a cinder, you know black cinder wall, this is the wall over here and it just grew and grew up so boom. So this hole came out. So there is this whole big chunk of cinder that we really have to clear out before we cut it down. So now there is a huge gash which leaves the potential for slide or whatever you know. Which is not good. So hopefully we get ourselves stable enough to a point and get good people in place that we need to, that we can do more work of maintaining the stream but as of now it's pretty difficult without actually having specific allotted time throughout the day. Relying on volunteers and then that kind of work is difficult because on our part requires someone is there to do it you know. So it could be good in some sense but it could be more work in other sense which, it’s just political. We try do stream study at least at that stream next to our campus. We have a hard time because it’s not too clean.

CSH: Have you ever walked this whole length of this stream or Makiki stream from *mauka* [inland] to *makai* [ocean]?

IW: I’ve taken it from just above the Ala Wai access and go and come up but that was like undergrad school time. But with the kids we haven’t done it. Once we sort of established our time here up at ‘Aihualama, we sort, of because time is limited, when we first were here it was twice a week we could come up to the top. Now because it’s once and basically it is just half a day, it’s

we sort of focus more of our energy on being over here and taking care of these zones and it has come at the cost of being able to do larger projects that would, you know, would take up several hours. You know when you think about it in hours, which we don’t like to but, if you have to you just don’t get a whole lot of time here. So the hours we take to walk the stream which would take one or two classes, two classes maybe, three classes maybe. I think that Trevor and his class has walked a good sized section of this stream. I know when I first came here Kamuela Yim had done it with a class.

CSH: What’s the, is there a transition from *makai* to *mauka* with the water quality or the types of plants, or the flow?

IW: Transfer in terms of?

CSH: Oh like is there a transition from *mauka* to *makai*? With the water?

IW: Yeah so that water up here at least runs through the heart of Mānoa and goes through a bunch of residential. Some of which, especially big rain and stuff, end up, dumping either knowingly or unknowingly. A lot of stuff goes into the stream goes through at least that canal right next to Mānoa which I know does a dreadful harm to the life inside of the stream. Even though I saw a bunch of ducks cruising by Mānoa Park so there must be some sort of action over there that they like. And then it goes through again, more residents the shopping center. I know Kānewai in terms of who we linked up with next. That's the person that we are sort of connected to at least our water, at least in terms of *lo‘i*, *lo‘i mana‘o* [thought, idea, belief]. We are connected to them, through Mānoa [stream]. And I recall spending a lot of time over there. Had plenty of *‘ōpala* in the stream and I know there were sometimes people there’s overspill or something got to close the *‘auwai*. I remember several times when we need to, you know, at least one time having to rip out *kalo* that bad water ran through. Just several more of those cements that go down and kind of leads into the Ala Wai. Even at Makiki you can see our stream goes down and it eventually disappears and then the residential. It goes right past the pump station goes into a channel section gets run underneath the road and then you don’t see it until it pops up. You got to go by this small section maybe two blocks below, other than that, you not going to see anything until it hits the Ala Wai again. So a lot of stream diversion. What can people do? I don’t know, start chopping down some bad stuff. I guess, I think that its maintenance, I think its consciousness and awareness, you know. I think that it would be good systemically, I think systemically it would be good to involve at least community, community organizations not to do community work but whether its churches or whether its schools, boy scouts, or football teams you know. They institutionalize that, whatever public thing they should have a public service, you know I don’t know, opportunity or mandate but I think that would be, I could definitely see Mānoa doing it. Even I think Mānoa has a pretty strong neighborhood council guys I could foresee them getting something together. But I think people in the stream, you know, is a big deal because a lot of times you know maybe guys just don’t get opportunities to get into the stream. So why care about something that you have no connection to?

CSH: You’ve talked about your connection with Kānewai physically with the water that comes through here and going to there. Are there other people as linked to the stream water in Mānoa or Makiki organizations or farms?

IW: Kumuola Foundation who is a couple of years old run by Kuki Kaiwa and her *kāne* [male, husband] and their group have been taking care of a ginger farm in the back of, right next to Lua

‘Alaea stream, that’s where they grab their water from. Which is right on the other side of Mānoa from us. And so they have been farming taro too for a while, in addition to gardenias and they have been making it happen over there. They are bringing groups, I know they have several groups pretty often I think so. They introduce people or reintroduce people to taro work, to cleaning up the stream. I know they go up there and they do a stream clean up as well kind of make sure that their water source is running well, running strong so those guys I think they are a non-profit other than Kānewai.

CSH: Are there other people you think that we should talk to or recommend, that you know have any relationships with the streams within Mānoa, Pālolo or Makiki, the Ala Wai watershed?

IW: I think Donovan, what Donovan’s last name there over at the University?

CSH: Preza?

IW: Preza, Donovan maybe a good guy to talk to. He has all of maps and he has more information. That’s the guy we talked to. I tagged around with Noe and she went to go do a bit of research for that, go talk to Donovan. Maybe she’ll be able to set you up and talk to Donovan, he has some interesting stuff maybe the land change, maybe even have conditions of what the stream used to look like. And because, just looking over here looks like this stream used to have a lot of water inside of it before. It just seems very, very low but that would be a good guy I would suggest you talk to. Kuki guys you know they would be good guys to talk to, they can share their experience and what their needs are, how they can best serve that stream source over there. The other guys that I…

CSH: Okay. Is there anything that you think we may have missed during this talk story or cultural significance of the area? Or cultural practices that are significant to people who have relationships with this area, to this area?

IW: Well it’s definitely significant to us because our relationship, our hands on relationship. Other guys, I don’t know what it means to them other than that’s another *lo‘i* over there, but I think other guys who work *lo‘i* they come around and check it out I think it is beneficial to have *lo‘is* around you know. I think that it’s beneficial to have *lo‘i* around. It's good to have the opportunity because there are other people who feel the same way. I think it’s a good networking source to have different spots, you know, that are accessible to many. And I think that’s one of the strengths with the *lo‘i* ideology is, you know, the idea of diversity, you know trying to spread it out. You cannot horde everything, you cannot just have everything in one zone got to decentralize. Because there is that, you know, you need to kind of depend on each other so I think that it connects it the stream is what connects. Usually in the olden days, you know, the first Hawaiians they weren’t dumb, they didn’t stray very far from where the water was and all the first civilizations, all the first taro patches, all of the wild ones that was released and then later cultivated, you know, all of that happened along the stream so it just tells you how important the water is. And I am certain that if you continue to go down there and clean, clean, clean, clean, clean, I am certain that you would find old of remnants. You know there’s old ranch stuff that’s all stuff that we saw down Lua ‘Alaea by Nick guys they showed me an old spot over there. I’m sure there were old residential spots, you know all along this area. I know that there’s ranching stuff that happened, ranching was a large part of the reason why the native flora ended up not being able to reproduce, but a lot of *keikis* [child, offspring] just got whacked. Oh yeah the stream is, the stream is pretty important. And you

know for us guys I'm not really a big *‘o‘opu* [general name for fishes included in the families *Eleotridae*, *Gobiidae*, and *Blennidae*]. I don't really have the *‘o‘opu* eye, I can't really tell the difference you know but I try and see what kind of fishes, you know try check it out but I do know that more and more we've been getting bigger and bigger fish coming up, there is even more life, more happiness in the stream. I think it has more to do with more rain but I also think that it has to do with presence, I think presence, because of how, how aggressive a lot of the stuff is it's kind of important. Presence is important just because, you know, you need the *kanaka* [human being] to merge with the *‘āina* [land, earth] to make everything well wet.

CSH: How many *lo‘i* do you guys have here at ‘Aihualama? I should have asked that and where do you get your *huli* [taro top, as used for planting] from?

IW: We have seven right now, we are probably. Yep seven, we have seven right now and it still continues up actually by where those logs and stuff like that are. Eventually we'll *hemo* [loose, separated, untied] that stuff. These are all old piles of logs at one point, all these. All of our *lo‘i* right now have huge piles of logs under and it's again moved out and help to spread out. But it's given based on how much water we can draw from wish we could have 1,000 *lo‘i* but if we only have water for one or two then whatever. Most of our *huli* comes from Waiāhole, comes from Moloka‘i, it's kind of a pish posh right now. I know I just got a bunch from Kānewai. Couple of varieties that we have lost but then we had a large selection but we sort of thinned it out. Trying to maybe be more selective of the ones that do well. And maybe just be, try to focus I think, try to shift more towards production whereas I think before we were just trying to get, trying to see if we could make a *lo‘i*, trying to see if we could flood it, if we could level it, trying to see if we could grow something. But right now I think you know, now that we kind of got, getting to the next level. Because we don't really consider this a farm, you know, we are not here long enough to, you know, like this water will change in a few hours, you know, you don't have to be here every second but if you can come in once or twice, three times a day just to check the water, balance the water that would make a huge difference. I've only been coming once, for three hours a week. I would rather come an hour a day three times and we could do a better job managing the water because once it's going it's easy to maintain but if you don't do it for a long, long time it kind of takes a while. I'm kind of key on that aspect of it is having presence. Just a little bit of presence can go a long way. If properly allocated take advantage of that resource but I think that it's happier over here when get people here. I'm happier when no more people but I think the *lo‘i* is happier when there's people.

CSH: So I guess do you have recommendations for the maintenance of the stream?

IW: Yeah, whatever they are diverting break that and open up the stream and then start chopping these big *Albizias*, chopping these big rubbish trees and try to clear the banks off a little bit more and replant, maintain, open up the waters and I don't know I think, you know, just a good campaign of at least you know it's a pilot project or something. I think Mānoa would be a great place to start you know stream clean ups a systemic form of community participation, engagement or involvement. I think that's kind of important stuff that can be done at schools, you know in big organizations but can be encouraged through other means if creative, I don't know if the economy is willing to shift for that quite yet but I think changing the mentality has something to do with it, taking care of the streams we got to stop thinking so da kine, [pause] what is that? *Haole* [formerly, any foreigner; foreign, introduced, of foreign origin].

CSH: Do you have anything that you want to add? I think at this point we covered a broad area, a good base, is there anything that you wanted to add to wrap this up?

IW: No.

CSH: Thanks for your time ‘Īmai.

IW: Yes, yes.

CSH: Okay.

Appendix F Michelle Spalding Matson Transcription

Interview with Michelle Matson, Diamond Head/Kapahulu/St. Louis Heights Neighborhood Board No. 5 – Subdistrict 3 member and Diamond Head Scenic Byway committee member. She is also a descendant of financier and philanthropist during the kingdom, republic, and territorial periods, William G. Irwin. Ms. Matson was interviewed on June 12, 2014 at Kapi‘olani Park.

MSM: Michelle Spalding Matson

CSH: Cultural Surveys Hawai‘i

MSM: The Ala Wai Canal was a big project in the early 1900's….it started with Pinkerton who was an engineer, in 1917. And with Dillingham they planned this huge water reclamation project, building the canal diverting Pālolo and Mānoa Streams. Actually what they did also was divert the water from the Tampong Ditch that fed Kapi‘olani Park's lagoons, and I'll show you map of the lagoons. And they filled in the swamp land at Waikīkī to build it out. And this was much, much later than when King Kalākaua and the Minister of the Interior and William G. Irwin and the Kapi‘olani Park Association formed the plan for Kapi‘olani Park. In 1877, King Kalākaua dedicated Kapi‘olani Park as the first free public park in Honolulu. Thomas Square was the first park, but they called this the free public park. It was designed after the important parks in Europe and America—the Victorian parks. And of course during those days, horse racing and polo and carriage rides were all part of the recreational activities. There were was a network of carriage paths around where Dillingham Fountain is now. And in the central portion of the park was the race track. The park's landscape was designed by Archibald Cleghorn, He was Princess Kai‘ulani's father and they lived at ‘Āinahau. The Monarchy didn't have the money to develop the park so they devised a plan to lease lots all around the open space of the park to pay for developing the park. And these were very small lots—they were like little vacation cottage lots for the people in town who would invest in the lease, At first it was a 30 year lease, and then it was extended again to 30 years in 1888.

CSH: So was that just their weekend home?

MSM: Well, it was a big recreation area. So they called it recreation and resort but it wasn't the resort like you think of hotels.

CSH: Yeah.

MSM: It was resort as if, for relaxation and recreational entertainment.

CSH: Yeah. Right, right, right.

MSM: And so this was the first major public park that was dedicated for the public, and it was way outside of town at the time. This was a big flat plain so it was ideal for a large park on the shoreline. I'm skipping around a little bit because—actually, I'm going backwards. 1900s-1920s, the Waikīkī area was developed with the Ala Wai Canal. The park was dedicated 1877. But way, way, way

before that when the first colonization by the Polynesians began here about 1500 years ago, the culture developed with of course the *heiau*, and building the heiau Papa‘ena‘ena—we’ll go up there, it’s right up here, the site is. It was a surfing *heiau* at first. The *kahuna* would raise flags when the surf was up, and that would signal the *ali‘i* that surfing conditions were good. This is what the *ali‘i* did. They didn’t work in the fields. There were lots of fields around the swamp land. But the *ali‘i* practiced their war games and surfing. You probably know more about that than I do, but this was the area they did this in, around the *heiau* and all over plain here—this whole area was the *ali‘i* training ground for practicing warrior activities, *lua* and things like that. This area has a very, very old history. I call it an evolutionary history because it began in very ancient times and went through the Monarchy, and then it went through westernization. But virtually the park has been untouched by redevelopment because of the Kapi‘olani Park Trust that was established in 1896. That was a result of the Overthrow, when nobody knew what was going to happen because there was so much disruption. We just found out from Chasmin Sokolosky - she’s a member of our Diamond Head Scenic Byway Committee and a past president of the Prince Kūhio Hawaiian Civic Club - and she was talking with one of her *kupuna* who told her about the actual site where the counter-revolutionary guns were buried at Diamond Head to try to fight the people who overthrew the Monarchy, and where a few lives were lost. The address is actually on Diamond Head Road, just outside the watershed area. But it’s part of the history here that the Overthrow affected this area immensely and so they wanted to protect the park. And the way they did that was attributed to William G. Irwin. I’ll show you the maps here. Irwin was on King Kalākaua’s Privy Council for a short time. He was also the shipping agent for Claus Spreckels, and he put a spur in for the sugar cane train at what is now Aloha Tower. Piers 10 and 11 were Spreckels’s Oceanic Steamship wharf, where Irwin’s shipping agency was. He also had interests in plantations on Kaua‘i and other islands, and he once owned Lāna’i. Irwin was a financier and a philanthropist when the discussions began for developing this park, the Kapua portion, below where Papa’ena’ena and the Kaneloa Crown Lands portion. [Pointing to the map] All this and beyond were Crown Lands and this is the boundary between the two. Kapua was a Land Court Award to Pehu, and it changed hands again and Allen Herbert came to own it, and then Irwin bought it from Allen. A portion of the coast is still private because Irwin retained this. But this central area was all part of what the plan was for the park, so he exchanged the land to make the park whole…he exchanged this land for some lots up here and where the Natatorium War Memorial Park is here – 25 acres for 10 acres of equal value.

CSH: There’s a railroad track [pointing to the map].

MSM: That is the trolley line.

CSH: Oh!

MSM: Later they brought the horse-drawn trolley in here. That’s why the aquarium is where it is--because they built the aquarium as an attraction to bring the people to the park.

CSH: Right!

MSM: And the first trolley stop was right across from the aquarium.

CSH: Nice!

MSM: And it’s still …a replica is still there. But the trolley line then went to the end of the park.

CSH: And it just kind of….

MSM: And it went back.

CSH: Back. It didn’t turn around.

MSM: Well, actually if you can see this, it looks like a little turn around area here.

CSH: Interesting.

MSM: So, what is interesting about this and its association to the present wetland, the Ala Wai Canal and the watershed is this--the lagoons were here, Makee Island and the lagoons. They were wetlands fed by the Tampong Ditch that ran through here, which is now the golf course. And there is still a remnant wetland here behind Royal Hawaiian Band building, and I’ll show it to you. And that wetland in the winter fills with brackish water, and so there is some sort of…

CSH: Oh, underneath.

MSM…channel underneath in the porous, what do you call it, a karst? And tilapia swim in from somewhere, from the canal but we don’t know where. And for the Ala Wai Watershed Project with the EPA [United States Environmental Protection Agency], we started the Kaneloa Wetland Project in 2000 There may still be visible parts of it, we’ll go see.

CSH: So…a couple of questions. The lagoon, it’s just all from pond or spring then? And some kind of underground tunnel that gives it the brackish water?

MSM: Well, that’s the present wetland. The lagoons were down here, let’s see the map.

CSH: But there’s an island?

MSM: There was Makee Island. It was all filled in for the zoo.

CSH: So…was it just a little hill that went up? Was it artificial?

MSM: It was beautiful! People would take row boats out there and picnic. And the first bandstand was on Makee Island.

CSH: But it wasn’t artificial?

MSM: It was a natural wetland system.

CSH: Like a berm?

MSM: They called it lagoons because it was very large and it was like a waterway they could row boats on and go between the islands to have picnics.

CSH: That’s beautiful.

MSM: It was very Victorian. But unfortunately mosquitoes were brought in and they festered and bred in the water, and it became such a problem that in the end they filled it up.

CSH: And that’s where the zoo is today?

MSM: And that’s where the zoo is today. It’s all part of Kapi‘olani Park, its all part of the Trust land. But it’s of course very different now.

CSH: Do you know what the depth of it was?

MSM: No, I don’t know. There are old photographs. I have a book that has some of them.

CSH: I’ve seen some of them where I’ve seen bridges and they have these white, I don’t know, lattice almost looking sides and they kind of go up like this—like an arch. And I’ve seen row boats. I’ve seen those pictures before. Very beautiful.

MSM: Yes.

CSH: Victorian is a good word. Yes. To describe that.

MSM: You know, this was all watershed. Obviously there were streams here. Papa’ena’ena had a stream going right along here and down into the park, what is now the park where there is a swale, and a drainage culvert that is still there. That was built later but you can see where the runoff goes and where the natural stream fed into this.

CSH: Do you know of any other *heiaus* in the park?

MSM: There were several, but below the summit of Diamond Head and on the other side. Near the lighthouse was one. Right down here was another one. I have the names in our Scenic Byway book…

CSH: So another one was closer to Tong’s area?

MSM: It was….probably it was down near that corner of the park.

CSH: Ok.

MSM: On this side of Diamond Head Road, I think.

CSH: So east of Papa’ena’ena.

MSM: Yes. Now we have this old, old map of the area. My grandmother had heard about the *heiau*, when in the 1950s developer Chinn Ho wanted to build high rises around Diamond Head. The residents here were extremely concerned about what that would do to the area and they formed a “Save Diamond Head” group, and my grandmother, who had heard of the ancient history here, went to the Archives and an old Chinese archivist came out with a map of where the *heiau* was. She then went to Kenneth Emory at the Bishop Museum, and they came out here to look around and found the *heiau* site with the contours…

CSH: Right.

MSM…where Paki Avenue is here, it curves around, .and they started looking in this area. The Dillingham’s villa, La Pietra, was right up here, and she knew Louise Dillingham quite well. And they looked around, and the high platform was one of the *heiau* terraces, here. This was the lower terrace—where the tennis courts are.

CSH: Ok. Yeah, you can kind of tell it’s something.

MSM: You see the configuration of the land? And up there, where the condos…the last two condos are…was the upper platform.

CSH: Ok.

MSM: It wasn’t condos then. It was a rose garden. It was Louise Dillingham’s rose garden.

CSH: Ok.

MSM: And that's what my grandmother…when I came over here to take care of her when she was in her 90s, to take care of her affairs and things, she would always tell me the stories of Papa'ena'ena. She was so proud of it. Of finding the old map in the archives and finding the site of the *heiau* under Louise's rose garden. As she put it, "It was under Louise Dillingham's rose garden!" Of course, such a significant site, and it…. CSH: So, it was under….that was the first platform?

MSM: It was located there, the upper platform.

CSH: Ok.

MSM: And here we have the story. "Kamehameha landed in two flanks. One on each side of Diamond Head." I found a quote very recently about where on Diamond Head - just in the front, basically where the park is now—the shoreline of the park. And farther *mauka* on the map was the Papa'ena'ena Heiau platform. It was at first a surfing *heiau*, and then later before Kamehameha arrived it became a sacrificial *heiau*. But it was the most significant *heiau* on O‘ahu at one time. "And it was dismantled in 1874 by Queen Emma, the widow of King Kamehameha IV who used the *heiau* stones to build a wall around the Waikīkī estate she inherited from King William Lunalilo. Some wall fragments remained at the *heiau* site near the stream that runs through the present plant nursery"— it's now a culvert—"but these have since been concealed." So I can take you and we can walk around there—I'll show you where that is. Here's a photograph of this map, showing the *heiau* here.

CSH: So what sparked your interest in Kapi‘olani Park? Is it that your family has always been involved? Or you lived nearby?

MSM: Well, my grandmother built her house on Makalei Place. Her grandmother was William G. Irwin's sister.

CSH: Oh. Ok.

MSM: She was an Irwin and she married a Spalding. There were three Spalding families here in the mid-1800s. I think they were all from Boston. I looked in the archives and read about them. Our family had a shipping business with ships in Boston. They were merchant traders, and they would go around Cape Horn. But that was the life then.

CSH: Right, right, right.

MSM: They were mariners from Boston and two of the sons came over here. They wanted to stay and—I don't know what they did with their ships, whether they kept them here or sent them back—but they stayed. One of their sons was my great-grandfather. Claus Spreckels and Irwin started Spreckels Bank in Honolulu, and he became an executive officer there. This later became Bishop National Bank, and it's now First Hawaiian Bank. They were all sort of interconnected that way, and when my grandmother received her portion of inheritance from her parents, she bought a lot from the Gaylords up on Makalei Place. They had the first big property up there before it was subdivided, I think before that, somewhere around there, Sanford Dole had a huge property. I think the original road went up in that direction, where there was an ancient Hawaiian trail. My grandmother's friend Kathleen Mellon, who was a well-known writer, lived in this area and she said she heard Night Marchers. *Ali‘i* Night Marchers.

CSH: Oh my gosh!

MSM: My grandmother knew her well and I think that's probably how she found out about the *heiau* here, with all the discussion of the history of the area. She had designed and built her house on Makalei Place, and was then involved in the huge fight to save Diamond Head from Chinn Ho's development. Irwin, her uncle, had helped protect this area as a park, and I learned about all of this when I came over and studied her files. She helped restore ‘Iolani Palace and worked closely with Princess Kawānanakoa. So I learned—I just sort of assimilated the history. And then one day, I heard about the Neighborhood Board because we had a problem on Makalei Place when I was living there. The kids would go up to the old reservoir that has since caved in.

CSH: Where is that?

MSM: It's above Makalei Place. There was a trail going up near Munro Garden, the botanical garden that George Munro planted above Makalei Place. I think some plants are still there, but it's been long forgotten. And so these kids were bringing beer bottles down from their parties up at the reservoir and dumping them in my grandmother's driveway, and I didn't know who to call or what to do so I went to the Neighborhood Board meeting and told them about this. And they said, "Oh you live at Diamond Head. Well, we have a seat here." And there I heard about FAA [Federal Aviation Administration] wanting to expand their big, windowless green building another 38,000 square feet as an aircraft control facility in Diamond Head Crater. They were just finishing the EIS, when I took that up, and we all worked together on the Neighborhood Board. I also met with our legislators and council members. I had done research at the library on the history of the crater and its interior, and I took this around to their offices. Senator Ihara was our House Representative for the area then, and he too took this on. I went to work at his office to learn about legislation, and we worked on a bill to preclude development inside the crater other than for park purposes. This bill passed the Legislature and was signed into law, and helped stop the FAA development. Eight years later the FAA site was restored to natural vegetation on the crater floor after they relocated the control facility to the airport area, thanks to Les Ihara with Senator Dan Inouye's assistance. And that's how I really became involved with this area and really active ….after all the research and really understanding the history and what it meant to protect it from the shoreline all the way to the crater.

CSH: Yeah.

MSM: And why it was protected. Diamond Head was a State Historic Monument. In 1965 it was designated under Governor Quinn, and in 1968 -, after all this pilikia with the high rises and threatened development, and the findings from all that—it was designated as a National Natural Landmark. They wanted a National Historic Landmark designation because it had more strength, but politics intervened and they were able to get a National Natural Landmark designation.

CSH: Yeah.

MSM: So all those things helped—building on all those things helped preserve what we have today. And in the late 90s we were able to expand the protected Monument's boundaries all the way to the shoreline with all of the public lands—the parks around Diamond Head.

CSH: So are you still on the Neighborhood Board?

MSM: I am.

CSH: Is your jurisdiction all of Waikīkī or just this area?

MSM: No. Just the sub-district, Diamond Head Sub-District. Sub-District 3. There are five representatives for each sub-district. Another is Kapahulu and the other is Saint Louis Heights.

CSH: Oh ok.

MSM: So it’s like an *ahupua‘a* neighborhood board.

CSH: Right, right, right.

MSM: It was very, very active when I first got involved. We had some great people on the neighborhood board who really got into the issues. They were very productive. They were very supportive. We had great committee meetings and really gained a lot of headway. It’s not like that anymore. But we don’t have many controversies right now. But it’ll happen.

CSH: Never say never.

MSM: I know! People are always after the park to develop it some way.

CSH: I’m curious. You were talking about the tilapia coming up. So…

MSM: We’ll go over there. But, first let’s get out and go up to the *heiau* area.

CSH: Ok. That sounds good.

MSM: And let’s see, is there anything else I needed to show you. There are different eras of maps here. And our Diamond Head Scenic Byway book, which was our presentation for the nomination of the Scenic Byway. Then we had to go through the designation, and it was formally designated by the State in December. But this I put together knowing quite a bit about the history and where everything was. Scenic Byways have six criteria for qualification: scenic, natural, archaeological, historic, recreational, and cultural. Actually, cultural is first for this purpose. [Referring to the photos] This is the reinterment of the *‘iwi kūpuna* from all the beach redevelopment in Waikīkī and down here near Queen’s Beach that is in front of the zoo, the Kahi Hali‘a Aloha. That is actually the beginning of the Byway. This is the historic King’s Carriageway, where King Kalākaua would come up from Kalākaua Avenue and go along this carriageway to his viewing stand above the ceremonial grounds and race track, which was down there. And this is an old picture of that. I can show you where that is when we drive around. This is all….

CSH: Is this the….

MSM: Actually, that’s the new bandstand Mayor Harris recreated. They also recreated a pond. There was originally a huge duck pond here. So now even today this is very symbolic of the history because the ducks come, and swim around it.

CSH: Is this part of that swampland?

MSM: No, this is all new. This is by the bandstand and it’s a pond that they created when they built the bandstand, but it’s quite symbolic.

CSH: Right, right.

MSM: Here is Papa’ena’ena on the old map, and this is the configuration of Paki Avenue. And over here was the big duck pond, where the Shell is now.

CSH: Ok.

MSM: And so this is just a symbolic recreation.

CSH: Ok.

MSM: I don’t think they expected the ducks. At first they got a lot of frogs and they dumped chlorine in and blew up the frogs. But apparently there is no more chlorine because the ducks are now swimming there. These are the other features. Lowell Dillingham, when he was a teenager, was instructed by his father Walter to go and do something good in the park. So his good deed was to plant about seven banyan trees. And these are the seven exceptional banyan trees here today.

CSH: Are these the ones by the zoo too?

MSM: Yes, and there’s one on the beach across from the zoo. This is Archibald Cleghorn’s feature when he designed the park, an allée, or double row, of ironwood trees, which is still there. Date palms were also one of the landscape features of the park at the time. This is an old picture of the lagoon area, it’s not very clear. Here’s the zoo. And here is the trolley stop. And this is the dedication plaque for Diamond Head National Natural Landmark, which is a beautiful view from this area in the park—very significant. Here is Papa’ena’ena. We’ll go up there. The War Memorial Natatorium—clearly a historic site with a significant purpose. The land was Irwin’s actual house lot here, and when he died in 1914 the family sold it to the four counties of the Territory for the purpose of a war memorial, and that’s why that boulder and plaque are located there. The Territory’s leaders decided to build out from that land and the seawall. They built a salt water pool and the arches and the bleachers for the living portion of the war memorial. They wanted to have a memorial to those who died but they also wanted it symbolic in an element that showed perpetuation of life and freedom, which the pool was.

CSH: What’s going to happen with that?

MSM: We don’t know. It was just designated a National Treasure by the National Trust for Historic Preservation. They were just out here and had an event over there. It’s highly political, very volatile.

CSH: Yeah.

MSM: My personal feeling is not to create artificial shorelines. But that is today’s thinking, not the thinking of the 1920s era. Salt water pools were the rage. There were a few on the mainland and one down at Black Point later. There’s still one at Black Point, and this. And so they decided this is what they should do—a salt water pool with the ocean integrated with this living feature of the Memorial. And so I respect that. It is listed on the historic register. And you think, well, if they demolish the pool and arches, and at one time they were going to leave the arches , and cut the historic site in half, what sort of precedent does that create for all historic sites? For ancient *heiau*? That are big complexes of land that have significant…

CSH: That would open a flood gate.

MSM: And even historic Mānoa estates in later times. What sort of precedent does cutting a national historic site in half create for every other historic site, large or small? So I had to make a personal decision. Regardless of my dedication to natural shorelines, my decision was that this must be restored and protected—respected as a whole. Because cutting it in half would destroy its integrity. It would create a horrible precedent. It would show that politics will win over public principles and values, and would replace our legal system for preservation of significant sites. So

that’s how I feel about the Natatorium. What will happen? Nobody knows right now. [Referring back to the book of photos] Here, Robert Louis Stevenson stayed for quite a while at San Souci and, this is the Hau Tree Arbor that is still there.

CSH: Right.

MSM: And that was in 1905, I believe—in that period of time. These are….

CSH: So beautiful. I love those homes.

MSM: And these are all on the Historic Register. Noted architect Charles Dickey’s house is here in this little enclave.

CSH: OH! What’s this?

MSM: This is an exposed coral layer. When Diamond Head was formed the sea was much higher here than it is now and there was volcanic movement lifting up the coral. And so this became exposed. It’s right at the beginning of Diamond Head Road, just past the curve where that property caved in up there—but it’s all intact still. And it’s outside the watershed boundary….

CSH: That’s still cool though.

MSM: It is a geologic feature of the crater. And the remainder of the Scenic Byway goes all the way around past KCC, through the crater and all that.

CSH: Ok.

MSM: So what we’re interested in here is seeing a couple of things in person now that we’ve taken a paper tour.

CSH: Yeah.

[Walking toward the area where Papa’ena’ena Heiau once stood.]

MSM: Papa‘ena’ena Heiau had a clear view of that whole area. It was positioned near the streams, with a purposeful positioning to be able to observe the surf and canoes coming in. And the navigation, although the heiau near the summit was a navigational *heiau* where they lit fires to signal and guide the canoes in here.

CSH: Like a lighthouse?

MSM: There’s a little channel down there and it’s on the historic map, It shows where the passage was—the canoe passage—the channel to the park here. It wasn’t a park then, it was an open plain.

CSH: Just flat land.

MSM: So the *heiau* was positioned this way. And it was also a strategic position later on when it was used as a sort of a defense *heiau* where they could see who was coming in. The park’s plant nursery has taken all of this over as a nursery supply staging area.

CSH: Yeah.

MSM: And it’s really too bad because it could be quite beautiful and symbolic. We might have to go around, it looks like the gate is locked.

CSH: Looks like we might have to go around. But you can kind of tell this was something just because it kind of goes up like this.

MSM: Well, the contours of the land. All of this has not been developed, and you can see the rise up here.

CSH: Right.

MSM: These are last couple of condos. The photograph that I took came in from that direction. I took the photograph from where you couldn't see any of the development and you could just get a sense of…

CSH: Yeah.

MSM …the *mana* here. Just the elements that this area has always possessed. And when the City built that wall and put in the lights over there, they re-stabilized that whole area. Back there is where the old *heiau* remnant was. The rock remnant—the remaining remnant.

CSH: So is it gone?

MSM: It's covered up. I think we should go over there.

CSH: Ok.

MSM: But this and the wetland are key to this area as historical elements.

CSH: So do you know what year the Ala Wai was created? It was built?

MSM: That was…I think it was 1927. Dillingham dredged it. It was placed on the historic register in 1992. And this is the problem we have about the Army Corps of Engineers coming in and proposing walls around the historic structure and sluice gates ten feet high and at sixty feet wide at the stream channels. Because again here we have a historic structure that is, you know, respected. It's been registered. It has this huge history. And the bulldozers and the concrete come in and it loses its integrity and its history.

CSH: Yeah.

MSM: And they reconfigure the surrounding elements into modern ramps and walls and platforms. But then the question is: Is it really going to make a difference?

CSH: Yeah.

MSM: At a 1% chance of a major flood? And all that money—millions of dollars spent to do all that? [Continuing to walk toward the area where Papa‘ena‘ena once stood.] They have prohibited archery here. They've taken down all of the targets because it got too dangerous. The arrows were ending up in the tennis court.

CSH: Why would they put an archery range here?

MSM: Oh, it's been here forever.

CSH: It's all open!

MSM: It was a use for this open area. This was all Irwin's land here. He kept this and when he moved to San Francisco in 1910he contributed this 11 acres to the park Trust, as long as it will

always remain in trust as a public park and recreation ground. So this has remained as open space. I think the original park caretaker’s house was right here.

CSH: Oh look! The ducks are there. They’re like up there.

MSM: Oh, that’s interesting. I didn’t know they lived in the park. Maybe they go down to the pond from here.

CSH: Yeah.

MSM: So here. I don’t know if it was over here or over there….

CSH: But this is the vicinity of where the remnant was.

MSM: There was a remnant in here.

CSH: Like you could clearly see the paving?

MSM: I never saw it but my good friend and mentor, Allan Voronaeff, filled me in on a lot of the history that he knew from Lowell Dillingham, who knew the history well. Then when they built the wall, they covered it up. They walled it in and you can’t see anything now.

CSH: But you can see some rocks but you don’t know if they’ve fallen down over the years. Or if it just got dozed from up above.

MSM: Yes, you never know.

CSH: So you can’t really….

MSM: But the significant portion was up here and terraced downhill.

CSH: So do you have any recommendations of how they could….I don’t know….make changes to the Ala Wai area? The canal area—what they could propose instead of the wall….

MSM: You mean engineering recommendations? No….. [Laughing].

CSH: I mean, if you don’t agree with the walls….what are some other alternatives?

MSM: It will destroy the historic integrity of the structure.

CSH: Yeah.

MSM: I understand even the City doesn’t want that to happen. Bruce Tsuchida of Townscape, the consultant, held the public meeting and right now they’re trying to get a sense of what the best thing to do would be.

CSH: Yeah.

MSM: And then the Waikīkī interests proposed six bridges associated with the Ala Wai Canal. Over the Ala Wai and here—in Kapi‘olani Park—one at the end of Paki Avenue and Kapahulu. And one right here at Monsarrat. Bicycle and pedestrian overpass bridges.

CSH: Those are monstrous.

MSM: Well, the people who are active on that proposal are the hotel interests and I sense that they want to see their tour vehicle flows move faster and not be inhibited by pedestrians and bicyclists, so they’re proposing these overpasses. Even DTS [Department of Transportation Services] was

not familiar with that plan. They said when they did the Waikīkī Circulator Study they talked about a bridge over the Ala Wai, but not six bridges!

[Driving to the remnant wetland area in Kapi‘olani Park]

CSH: So did you grow up in this area?

MSM: No, but my grandmother was born here and my mother was born here, but I was born in the San Francisco Bay Area.

CSH: Ok.

MSM: So I'm not a *keiki o ka ‘āina*, but my heart is here, and my heritage.

CSH: Did you used to visit your grandma here when you were younger?

MSM: All the time, all the time.

CSH: So what are some of your memories growing up?

MSM: Oh, I just adored her. I admired her. I wanted to live here with her and didn't want to go back home.

CSH: Did you spend a lot of time at the beach?

MSM: Some. There was Makalei Beach and at the time there was not a park there, but just a narrow little pathway and you had to have a key to the gate. The residents on Makalei used that access path to go to the beach. And I would go down there—it was beautiful and sandy on this side. And my mother and I would look for little shells. And I found one that was really tiny—white, a single shell. And it had very fine red stripes, vertically, evenly spaced, and a couple horizontally. Very fine, red stripes. And we took that to Spencer Tinker, who was the director of the Aquarium at the time. My grandmother knew him very well and we asked him about this shell. He looked it up and he said, "Well, this is a very rare shell." So I kept it and treasured it. And then in a move—when I was packing it got crushed, and I was crushed.

CSH: Yeah. Yeah.

MSM: That was one memory. And then just being with my grandmother in her home. She had a view of the ocean and she had planted *kukui* trees all across the hill on her property and it was like a green carpet of leaves and then the ocean beyond.

CSH: Oh nice.

MSM: And I would just love to be there. And, well, you know. My grandmother meant a lot to me and it was my favorite place.

CSH: Yeah, did you guys used to fish or pick *limu* or use the *kukui* nuts or anything?

MSM: No, we didn't do any of that. My grandmother was a very well-known interior designer. She had an antique shop with fine oriental art. Antiques. Lacquers. She had her first shop….well actually she walked into Gump's in San Francisco after she had taken a correspondence course in interior design, and she walked into the administrative offices and asked senior Mr. Gump if he would like to be her partner because she was coming back to Honolulu and she'd like to open a little shop. He was blind, but remarkably he could tell the color and the quality of jade just by touching it.

CSH: Wow!

MSM: And that’s how great a connoisseur he was. Gump’s would import these treasures from the east—the Orient—and I guess because he was blind and so sensitive to sound and touch—he could sense something in her voice, and he agreed to be her partner. So he commissioned a store to be built here on Lewers and Kalākaua. Hart Wood did the design and my grandmother worked with him on it. Now it’s the Louis Vuitton shop. It’s on the historic register, with the blue tile roof.

CSH: Right! That’s right!

MSM: So she was part of that, and she managed that store from 1923 until 1953. Then she opened her own shop at the Royal Hawaiian Hotel, first in the arcade and then in the lobby. Alice Spalding Bowen’s Oriental Arts Shop was in the lobby for many years and she closed it in the late ‘60s. But people would sail over on the *Lurline* to shop there because she was well known for the quality of the pieces she had. She would go to the Orient every six months on a buying trip. [Entering the Shell service area and approaching the Royal Hawaiian Band building and Kaneloa wetland site.] Ok, I’m hoping this gate is open—yes. Oh, they have their own sign out now—that’s nice.

CSH: So what did you used to do with your grandma? Just listen to her and all her stories and hang out when you were here?

MSM: Well, I was usually here on summer vacation when it was hot. And my brother and I would go to the beach and then we’d have dinner with her and my parents. And I don’t know—just kid stuff. I got to know the neighborhood children and we got together.

[Entering the Kaneloa wetland site.]

CSH: Is this the natural ditch?

MSM: Further on up here it is. They haven’t changed it. There’s our storage—that was all our wetland project equipment. And now the baby chicks!

CSH: Cute! So cute!

MSM: This was covered with a lot of invasive bushes, but they’re gone now. We cleaned out a lot of the invasive growth and this is some of the bacopa that we found growing here naturally, and this is the *‘ākulikuli*. These are native wetland plants in here, we tried to really get this going over here. When I first came here in the winter, this whole drainage swale was covered with the bacopa.

MSM: These opiuma trees are junk trees, and we were going to take them out.

CSH: So this was all swamp?

MSM: Look at the eggs…chicken eggs.

CSH: Oh yeah.

MSM: Well, the homeless used to live in here now the chickens do.

CSH: So this was swampy?

MSM: All of that, down there, is a native Hawaiian sedge.

CSH: Oh! I do see it.

MSM: We planted a lot of native coastal plants. I don't know what's left. When 9-11 hit in 2001, it took our Army volunteers and things just—you know, we didn't have the help and we didn't have the funds to continue. Initially with the EPA grant and got as far as doing the landscape plan with native Hawaiian plants, but then nobody was left to help maintain it. This is part of the pathway we did. We made a gravel path and then we had some raised stepping stones for crossing the wetland. In the winter the wetland ran all the way to the fence. We have photographs of what it was like.

CSH: Is this where you were saying during the winter this is where the tilapia….no?

MSM: Yes, they were down here! There was a lot of water in this area. It would become flooded and we would see tilapia coming up here, but we didn't know where they were coming from.

CSH: Interesting. That is interesting.

MSM: You can see this is wetland and native Hawaiian sedge right there. It's a wetland plant, so there'd be a lot of subsurface water here still. And it's probably brackish.

CSH: Yeah. Even that one is too. I've seen that one before.

MSM: Yes, it's not papyrus but it's in that family.

CSH: But people wouldn't gather that tilapia to eat it, right? You guys would just see it here, right?

MSM: We'd see it, but I don't know if anybody was actually taking them. It was very seasonal.

CSH: I gotta ask.

MSM: It was very seasonal.

CSH: Is that? That looks like a kind of old wall? Like, a portion of it. Is that something?

MSM: There is a swale that comes through the park here. That's the drainage area I was talking about. And you have a lot of the runoff coming in here. Where is it? I know it's here, but where are you looking?

CSH: I saw it better when we were in the other place. But its right….here! It's like a historic wall.

MSM: Well, it's old, you know. It's part of that….

CSH: Drainage.

MSM: Yes, it's part of the park's drainage system. These are old stones.

CSH: Yeah.

MSM: This possibly could be from when the park was first built. I never thought about how old that might be. And you'll notice there's no graffiti on it, thankfully!

CSH: Yeah!

MSM: It's hidden. And these date palms are part of a historic allée. This was another pathway, a carriageway right here for the race track. And the date palms were on each side. That's another of Archibald Cleghorn's landscape design features, and there are still remnants of this. There used to be a driving range over here, so sometimes…

CSH: I do see the golf balls.

MSM….we picked up a lot of the golf balls when we were doing this project. We had buckets of golf balls. It goes down there, and then the big deep swale is over there and it runs all the way down across the park, and that swale is lower than sea level. And the duck pond was right in here.

CSH: In this area?

MSM: Yes. It probably extended out quite a bit when they built the race track. And part of the race track actually went through the present zoo. So this was all along the race track. But the duck pond was over here. Somebody could map it on a GIS. All we have is that old, old map to refer to right now. So this is the wet land remnant. I think this is as close to watershed as we'll get in this developed area.

CSH: Yeah. That is really interesting though that the tilapia during the winter are over here!

MSM: Well, they would come up and just stay around the deepest part around on the other end, as this end became more shallow. The wetland would extend up here but it was quite shallow. We had a gate installed over there at the time, sort of an entrance.

CSH: Cause it is far from the Ala Wai and it is…there is a curiosity of where they…

MSM: You wonder how the water gets through.

CSH: Yeah.

MSM: See, there's more bacopa here. This was all…

CSH: I do see that ground cover.

MSM: And more sedge here. So the wetland is still here. Of course, this is summer and if you come back in the winter we might be able to see something more.

CSH: Yeah, that would be interesting to come during the winter time with some work boots and see what's over here!

MSM: And Nicole, what I can also do is I can send you sections of our Scenic Byway presentation and you can pull out information that you think is of interest.

CSH: Sure! That will just strengthen your interview. That would be wonderful! Thank you.

MSM: I would be happy to do that.

CSH: Just in review, this area didn't have any direct streams coming through it like the Mānoa Stream starts from the top of the ahupua‘a and comes down. This area was just fed by springs or had ponds?

MSM: There are springs here. Artesian wells. I think there are about five of them in this area. And there was a stream that ran by Papa'ena'ena….

CSH: That's right. That came down…

MSM….that came down through the park and probably went out that way, past the lagoons.

CSH: But where was the source of that? Was that from Diamond Head?

MSM: The water? I'm sure it was seasonal. Sometimes there's a lot of water on Diamond Head! We can see the beginning of waterfalls on Diamond Head when it rains heavily on the sheer part of the slope.

CSH: Really?

MSM: You can see the water, it's white, but it's not into a gushing fall.

CSH: Not like the *ko‘olaus*.

MSM: It's moving.

CSH: But it is visible.

MSM: So the natural elements are here, but they've been diverted with culverts and swales.

CSH: Yeah.

MSM: Now, this is part of the drainage system. This was completely overgrown when we were doing the wetland project. And the tilapia came in up there. This is all new. This must have been plugged up with all that vegetation. Maybe that was part of the problem here?

CSH: Ok, so the other drain?

MSM: Well, they didn't come through the park. Now that I'm looking at this without the vegetation, maybe they had enough water to swim all the way over there when we saw them. We never saw them in here because this was all overgrown—we couldn't see. This modification looks very recent, too, but it's possible.

CSH: It's just a matter of where does it all come from or travel.

MSM: I understand that a lot of the waste water goes under the zoo and out to the Kapahulu Groin. UH Water Resources Management at the Environmental Center had a water drainage specialist, Roger Fujioka, who came out here. He may be retired now. So if you think of anything else you'd like to see or you have any questions or….

CSH: Yeah, I'll definitely call.

MSM: …come across any information, just feel free to call me anytime. And I think in the next couple of days, or by the first of the week, so I should have the other information emailed to you to see if there's anything there of interest.

CSH: Sure. Thank you.

ALA WAI CANAL PROJECT
O'AHU, HAWAI'I

DRAFT FEASIBILITY STUDY REPORT WITH
INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX G
PUBLIC AND AGENCY INVOLVEMENT

G1	**Distribution List for Draft Feasibility Report/EIS**
G2	**Stakeholder Involvement Plan for Current Project Phase (2013)**
G3	**Focus Meeting Summary (2014)**
G4	**Open House Meeting Summary (2014)**
G5	**Legislative Briefing Summary (2014)**
G6	**EIS Preparation Notice (2014)**
G7	**EIS Scoping Meeting Notes (2004 and 2008)**
G8	**Notice of Intent (2004 and 2008)**

Appendix G1
Distribution List for Draft Integrated Feasibility Report and EIS

APPENDIX G1

Distribution List for Draft Feasibility Study Report with Integrated Environmental Impact Statement

FEDERAL AGENCIES	
U.S. Geological Survey, Pacific Islands Water Science Center	Federal Aviation Administration
Department of the Interior, U.S. Fish and Wildlife Service	Federal Transit Administration
Department of Commerce, National Marine Fisheries Service	Federal Highways Administration
Department of the Interior, National Parks Service	U.S. Coast Guard
Dept. of Agriculture, Natural Resources Conservation Service	U.S. Environmental Protection Agency
U.S. Army Corps of Engineers	Advisory Council on Historic Preservation
Department of the Navy	Federal Emergency Management Agency, Region IX
STATE AGENCIES	
Department of Agriculture	DLNR, Division of State Parks
Department of Accounting and General Services (DAGS)	DLNR, Historic Preservation Division
DAGS, Archives Division	Oahu Island Bural Council
Department of Business, Economic Dev. and Tourism (DBEDT)	Honolulu County Soil and Water Conservation Districts
DBEDT, Research Division Library	Department of Transportation
DBEDT, Strategic Industries Division	University of Hawaii, Office of Capital Improvement
DBEDT, Office of Planning	University of Hawaii, Office of Emergency Management
Department of Defense	University of Hawaii, Water Resources Research Center
Department of Education	University of Hawaii, Environmental Center
Department of Hawaiian Home Lands	University of Hawaii, Center for Conservation Research and Training
Department of Health, Environmental Health Administration	University of Hawaii, College of Tropical Agriculture and Human Resources
Department of Land and Natural Resources (DLNR)	University of Hawaii, Sea Grant Program
DLNR, Division of Boating and Ocean Recreation	Research Corporation of the University of Hawaii
DLNR, Division of Forestry and Wildlife	University of Hawaii, Social Science Research Institute
DLNR, Na Ala Hele	University of Hawaii, Marine Program
DLNR, Division of Aquatic Resources	University of Hawaii, Lyon Arboretum
DLNR, Land Division	Office of Hawaiian Affairs
DLNR Office of Conservation and Coastal Lands	Hawaii Emergency Management Agency
DLNR Commission on Water Resource Management	
CITY AND COUNTY OF HONOLULU	
Board of Water Supply	Department of Planning and Permitting
Department of Customer Services Municipal Library	Department of Parks and Recreation
Department of Design and Construction	Police Department
Department of Environmental Services	Department of Transportation Services
Department of Facilities Maintenance	Department of Emergency Management
Fire Department	Department of Enterprise Services
Department of Community Services	
ELECTED OFFICIALS	
U.S. Senator Brian Schatz	State Representative Bertrand Kobayashi (District 19)
U.S. Senator Mazie Hirono	State Representative Calvin Say (District 20)
U.S. Representative Mark Takai	State Representative Scott Nishimoto (District 21)
U.S. Representative Tulsi Gabbard	State Representative Tom Brower (District 22)
Governor David Ige	State Representative Isaac Choy (District 23)
Senate President Ronald Kouchi	State Representative Della Au Belatti (District 24)
State Senator Sam Slom (District 9)	State Representative Sylvia Luke (District 25)
State Senator Les Ihara (District 10)	State Representative Scott Saiki (District 26)
State Senator Brian Taniguchi (District 11)	State Representative Derek S.K. Kawakami
State Senator Brickwood Galuteria (District 12)	State Representative Chris Lee
State Senator Suzanne Chun-Oakland	State Representative Ryan Yamane
State Senator Glenn Wakai	Mayor Kirk Caldwell
State Senator Clarence Nishihara	City Councilperson Trevor Ozawa (District 4)
State Senator Mike Gabbard	City Councilperson Ann Kobayashi (District 5)
House Speaker Joseph Souki	City Councilperson Carol Fukunaga (District 6)
NEIGHBORHOOD BOARDS	
Kaimuki Neighborhood Board No. 4, Lyle Bullock, Jr. (chair)	Waikiki Neighborhood Board No. 9, Robert Finley (chair)
Diamond Head-Kapahulu Neighborhood Board No. 5, George West (chair)	Makiki-Tantalus Neighborhood Board No. 10, John Steelquist (chair)
Palolo Neighborhood Board No. 6, Beverly Mau (chair)	Ala Moana-Kakaako Neighborhood Board No. 11, Larry Hurst (chair)
Manoa Neighborhood Board No. 7, Eric Eads (chair)	Nuuanu/Punchbowl Neighborhood Board No. 12, Philip Nerney (chair)
McCully-Moiliili Neighborhood Board No. 8, Ron Lockwood (chair)	
COMMUNITY GROUPS, ORGANIZATIONS AND ASSOCIATIONS	
Aha Wahine	Makiki Stream Stewards
Ala Wai K9 Park	Malama Manoa
Ala Wai Plaza	Manoa Innovation Center

Distribution List for Draft Feasibility Study Report with Integrated Environmental Impact Statement

Ala Wai Watershed Association	Manoa Marketplace
Ala Wai Watershed Working Group	Marco Polo
Association of Hawaiian Civic Clubs (Oahu Council)	Na Ohana o Na Hui Wa'a Canoe Association
Be Ready Manoa Team	National Disaster Preparedness Training Center
Bernice Pauahi Bishop Museum, Native Hawaiian Culture & Arts Program	Oahu Hawaiian Canoe Racing Association
Century Center	Oahu Island Parks Conservancy
Council on Native Hawaiian Advancement	Palolo Community Council
Friends of Tantalus	Palolo Homes Mutual Housing Association of Hawaii
Harbor View Plaza	Palolo Tenant Association
Hawaii Lodging and Tourism Association	Papa Ola Lokahi
Hawaii Maoli	Papakolea Community Development Association
Hawaii Nature Center	Paradise Park
Hawaii State Hazard Mitigation Forum	Pig Hunters Association of Oahu
Hawaiian Civic Club of Honolulu	Shriners Hospital
Hawaiian Trail and Mountain Club	Surfrider Foundation
Healani Canoe Club	Tantalus Community Association
Historic Hawaii Foundation	The Outdoor Circle
Hui Malama I Na Kupuna 'O Hawaii Nei	Waikiki Beach Boys Hu`i Waa
Hui o Makiki	Waikiki Business Improvement District Association
Kawahapai Ohana	Waikiki Hawaiian Civic Club
Koolau Mountains Watershed Partnership	Waikiki Improvement Association
Ku'iwalu	Waikiki Surf Club
Kumuola Foundation	Yacht Harbor Towers
LANDOWNERS	
Colin & Magdalena Petko	Trustees of Carole N Haida Trust
Trustees of Jon L & Amy E Manago Trust	Howard T. Takaki
Trustees of Hiroshi Yamamoto Trust & Family Trust	Marlon P. & Kathleen S. Dyer
Harry N. Yoshino & Pamela M. Amano	Baruch Bakar
Trustees of Roy E & Ann Sato Trust	Sen-Ming Lin
Trustees of Stephen H Sato Trust and Florence H Sato Trust	Manoa Shangri-La Community Association
Trustees of Katsugo Miho Trust and Laura M Miho Trust	Trustees of Michael S. Aramaki Trust & Fumiko Aramaki Trust
Ray H & Dorothy K. Sakata	Trustees of Michael J. Shapiro Trust
Trustees of Kenji Kawano Trust & Peggy S T Kawano Trust	Trustees of Marivic G. Dar Trust
Masayuki Najita Gen Trans Trust & Masayuki Najita Res Trust	Trustees of Osato Family Trust
Trustee of Pauline I Segawa Trust	Dave K. & Nola S. G. O. Watase
Fred S & Edith H Takaki and Trustees of Carole N. Haida Trust	Lin Yee Chung
SCHOOLS	
Iolani School	St. Francis School
Kuhio Elementary School	Maryknoll School
Ala Wai Elementary School	Palolo Elementary School
Hokulani Elementary School	Jarrett Middle School
Kaimuki High School	Manoa Elementary School
Chaminade University	Noelani Elementary School
St. Louis School	Lincoln Elementary School
Mid Pacific Institute	Stevenson Middle School
Ke Kula Kaiapuni 'O Ānuenue	Roosevelt High School
Hanahauoli School	
UTILITIES	
Hawaii Gas	Hawaiian Telcom
Hawaiian Electric Company, Inc.	Oceanic Time Warner Cable
LIBRARIES	
Hawaii State Library, Hawaiʻi Documents Center	Hawaii State Library, Lihue Regional Library
Hawaii State Library, Kaimuki Regional Library	Hawaii State Library, Waikiki-Kapahulu Library
Hawaii State Library, Kaneohe Regional Library	Hawaii State Library, Library for the Blind and Physically Handicapped
Hawaii State Library, Pearl City Regional Library	Hawaii State Library, McCully-Moiliili Library
Hawaii State Library, Hawaii Kai Regional Library	Hawaii State Library, Manoa Library
Hawaii State Library, Hilo Regional Library	Legislative Reference Bureau Library
Hawaii State Library, Kahului Regional Library	University of Hawaii, Thomas H. Hamilton Library
NEWS MEDIA	
Honolulu Star Advertiser	Hawaii News Now
Honolulu Civil Beat	

Appendix G2
Stakeholder Involvement Plan for Current Project Phase (2013)

ALA WAI CANAL PROJECT - PHASE IV

PUBLIC INVOLVEMENT PLAN (v.04)

Prepared for:
U.S. Army Corps of Engineers
and
CH2M Hill

Prepared By:
Townscape, Inc.

June 2013

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ACRONYMS

AWCP	Ala Wai Canal Project
ENV	City and County of Honolulu Department of Environmental Management
DFM	City and County of Honolulu Department of Facility Maintenance
DLNR	State of Hawaiʻi Department of Land and Natural Resources
EIS	Environmental Impact Statement
FAQs	Frequently Asked Questions
HRS	Hawaiʻi Revised Statutes
NEPA	National Environmental Policy Act
PDT	Project Delivery Team
TAT	Technical Advisory Team
TSP	Tentatively Selected Plan

1 Project Management Meetings

Project management meetings will be held to coordinate actions within the project and among related projects in the watershed. While these efforts are primarily for coordination purposes, there are elements of public outreach and involvement and are therefore mentioned briefly below.

1.1 Project Delivery Team (PDT) Meetings

Purpose: To discuss project status and resolve issues and/or reach decisions on project development and execution.

Participants:

- USACE (lead)
- CH2M Hill
- Project sub-consultants, as necessary
- DLNR (project sponsor)
- City and County of Honolulu ENV and DFM (project sponsor)

Process: The PDT will meet monthly and will be convened by the USACE project manager.

1.2 Stakeholder Meetings

Purpose: To inform stakeholders on project development progress and to coordinate with other organizations, studies, and efforts that are occurring within the watershed.

Participants:

- USACE (lead)
- CH2M Hill
- Project sub-consultants, as necessary
- DLNR (project sponsor)
- City and County of Honolulu ENV and DFM (project sponsor)
- Representatives from community and private organizations
- Public agencies (non-project sponsor)
- Elected officials (or their representatives)
- Representatives from related projects

Process: These meetings will be held at specific milestones (to be determined), possibly once or twice a year, to review the status of the Ala Wai Canal Project (AWCP) and other projects and programs in the Ala Wai Watershed. These meetings are primarily update briefings and opportunities to raise issues and to coordinate amongst related projects; they are not meant to be working meetings where issues are resolved.

1.3 Technical Advisory Team (TAT) Meetings

Purpose: To provide a forum for key PDT members and key stakeholders to work through specific technical issues for expeditious decision-making.

Participants:

- CH2M Hill (lead)
- USACE
- Federal, State and Local agencies as applicable
- Project sub-consultants, as necessary

Process: TATs will be formed around specific issues and will be made up of working level technical experts. Meetings will be held as needed until the issue is resolved.

2 Public Involvement

Several public participation techniques will be used to reach out to various stakeholder groups at different points in the process. Different techniques should be used depending on the group targeted and the purpose of the involvement. The following is a list of proposed techniques that may be employed during this phase of the project.

2.1 Individual Interviews and Small Group Meetings

Purpose: To get early feedback on specific flood reduction measures. This input will inform the alternatives analyses that result in the tentatively selected plan (TSP).

Participants:

- Townscape (lead)
- USACE (support)
- CH2M Hill (support)
- Landowner and community leaders
- Community and private organizations
- Public agencies
- Quasi-governmental organizations
- Elected officials (possibly)

Process: Two or three potentially controversial flood reduction measures will be identified. A Focus Group meeting will be held on each measure identified to get input on user concerns, potential "deal-breakers," and acceptable conditions or mitigation measures. Specific groups and individuals will be invited to participate.

2.2 Briefings to Stakeholder Groups

Purpose: To update key stakeholders on the project.

Participants:

- USACE (lead)
- Remaining PDT members (support)

Process: Briefings may be scheduled based on a formal request from an entity or individual representing a key constituency (e.g., elected official). Alternatively, a briefing might be proposed by the PDT. If a briefing is determined to be beneficial and/or necessary, USACE will coordinate and conduct the briefing with support from the rest of the PDT, as needed.

2.3 Open House Meetings

Purpose: To provide community members with opportunities to learn about the Ala Wai Canal Project and the Tentatively Selected Plan (TSP), and to build community support for project implementation.

Participants:

- Townscape (logistics and coordination)
- USACE (presentation)
- CH2M Hill (support)
- All stakeholders would be invited to attend

Process: Hold two public meetings in an "Open House" format to present preliminary project concepts to the public. The Open House would begin with a brief overview presentation and question and answer session. After the presentation and discussion, attendees may circulate and view maps and other graphics illustrating preliminary project concepts. Project staff would be on hand to answer questions and hear comments. Comment sheets would provide a way for participants to submit written questions and comments.

2.4 EIS Public Meeting

Purpose: To gain public feedback on the proposed alternatives and TSP and to satisfy the requirements of HRS Chapter 343 and NEPA.

Participants:

- Townscape (logistics and coordination)
- USACE (presentation)
- CH2M Hill (support)
- All stakeholders would be invited to attend

Process: One public meeting on the Draft EIS will be held at an accessible location within the watershed. The various alternatives will be presented and feedback from the public will be recorded for consideration when developing the Final EIS and preferred alternative.

2.5 Project Information Sheet/FAQs

Purpose: To introduce the project to stakeholders and provide them with basic information.

Process: A Project Information Sheet will be developed as a concise handout to use in stakeholder meetings that includes information such as the project purpose, goals, process, map of the project area, and contact information.

2.6 Project Website

Purpose: To provide the larger public with background information and materials to keep them apprised of project progress, next steps, and how they can provide input.

Participants:
- CH2M Hill (lead)
- Remaining PDT members (support)

Process: A project website will be developed and regularly updated to provide information on the project, including project background, purpose, upcoming meetings and events, contact information, and review materials. Materials for download from the website could include the project information sheet, notes from the public meeting, the Notice of Intent and EIS Preparation Notice, and the Draft and Final Feasibility/EIS Report.

2.7 Email Updates

Purpose: To alert key stakeholders and interested parties of project milestones and to direct them to the project website for materials and information.

Participants:
- CH2M Hill (lead)
- Remaining PDT members (support)

Process: Periodic updates will be sent to interested parties using project email list that will be compiled and maintained. Email topics may include milestone highlights, announcements of meetings and comment deadlines, and notifications of new materials on the project website. Townscape will provide a spreadsheet of previous project contacts.

2.8 News Media

Purpose: To notify the general public of highlights and progress of the project.

Participants:
- USACE (lead)
- Remaining PDT members (support)

Process: All media requests will be referred back to the USACE for comment. If press releases are determined to be necessary or beneficial, the appropriate team member(s) will draft the content of the piece and review it with the PDT before forwarding it to USACE and DLNR for final approval and release.

3 National Flood Risk Management Program Public Involvement Pilot Project

The AWCP was selected as one of five flood risk management projects nation-wide to be the recipient public involvement services to complement public involvement efforts already planned as a part of the project. The scope of these services are yet to be determined.

Purpose: To work with the tourism industry, and Waikīkī interests in particular, to raise their awareness about flood risks in the Ala Wai Watershed and to improve their understanding of their role in mitigating those risks.

Participants:

- USACE (lead)
- Waikīkī and Tourism Industry Interests:
  - Hawai‘i Tourism Authority
  - Hawai‘i Hotel and Lodging Association
  - Waikīkī Business Improvement District
  - Waikīkī Improvement Association
  - National Disaster Preparedness Training Center

Process: To be determined.

4 Townscape Effort

The current phase of the AWCP has been broken down into four major tasks: (1) Project Management, (2) Draft Integrated Feasibility/EIS Report, (3) Public Involvement, and (4) Final Integrated Feasibility/EIS Report.

4.1 Task 1: Project Management

Townscape will participate in the various project management meetings (PDT, TAT, and Stakeholder), as needed, providing support to USACE and CH2M Hill.

4.2 Task 2: Draft Integrated Feasibility/EIS Report

Townscape currently has no activities associated with this task.

4.3 Task 3: Public Involvement

Townscape will solicit public involvement through small group meetings (focus groups) and open houses to better understand community concerns regarding specific proposed flood mitigation measures and a public meeting on the Draft Integrated Feasibility/EIS Report.

4.3.1 Focus Group Meetings

Focus group meetings will be held on up to three specific flood mitigation measures or groups of measures in order to identify public concerns about each measure or measure grouping that should be taken into account during measure design, alternatives analysis, and selection of TSP. The measures selected for discussion will be those that are potentially the most controversial for the public.

The PDT will agree upon up to three measures/measure groupings that are anticipated to be controversial. Measures preliminarily proposed for focus group meetings include the following:

1. Mānoa Detention
   - Wet/Dry Dam in Mānoa Valley
   - Detention Basins in Mānoa Valley
   - Multipurpose Detention at Mānoa District Park
2. Ala Wai Golf Course
   - Multipurpose Detention at Ala Wai Golf Course
   - Ala Wai Golf Course Sediment Basin (DLNR)
3. Ala Wai Canal modifications
   - Widen Mouth of Canal
   - Modify McCully Street Bridge
   - Levees around the Canal
   - Pump System

Townscape, with assistance from other members of the PDT as needed, will present the overall project purpose, goals, and objectives. After briefly outlining the list of proposed measures, Townscape will describe the specific measure that the focus group is convened to discuss. This description should include location, need, potential benefits, and tradeoffs. After this, the focus group will be asked the following questions:

- What concerns do you have about this proposed measure
- Is this measure a "deal-breaker" for you?" What about it makes it a "deal-breaker?"
- What conditions or mitigation measures would make the measure acceptable to you?

Discussion from the focus group meeting will then be taken back to the PDT for incorporation into the project. It is anticipated that the feedback will inform design of the measures to make them more acceptable to the community and alternatives analysis during selection of TSP.

4.3.2 Public Meeting

The public meeting will aid in understanding potential impacts and concerns associated with the project alternatives, and is also mandated by NEPA. One public meeting will be held within the watershed, possibly at the Hawai'i Convention Center, where the EIS Scoping Meeting was previously held, or at an area school.

Townscape, with the assistance of the PDT, will present the project purpose, goals, objectives, alternatives, potential impacts, proposed mitigation measures, and TSP. The public will then be provided an opportunity to ask questions and comment on the project, possibly through verbal comment, one-on-one discussions with project team members in an "open-house" format, and/or written feedback. Attendees should be informed of how they may provide further comment on the Draft Integrated Feasibility/EIS Report, and of the deadline for public comment. This information, as well as notes from the public meeting should be posted to the project website.

The PDT should use the feedback from the public meeting along with any other comments received on the Draft Integrated Feasibility/EIS Report to select a preferred plan.

4.3.3 Briefings to Stakeholder Groups

Townscape will coordinate a limited number of briefings to key stakeholder groups that the PDT identifies. Depending on the nature of the update, other members of the PDT may be needed to present project material and/or answer questions.

Appendix A: Stakeholder Groups

The range of potential stakeholders is large and includes land owners, community members, environmental and community organizations, elected officials, and public agencies. The following is a listing of individuals and groups that the project team should consider contacting as part of the public involvement process, as well as a short description of who they are and why they should be included.

A.1. Community at Large

The community at-large includes anyone that may have an interest in the project; they do not represent anyone or anyone's interests other than their own.

A.2. Landowners and Community Leaders

Landowners and other individuals to be contacted as a part of the stakeholder involvement process have a particular interest in the project, but may not have a formal organization to represent them. Private landowners include those that either have been impacted by previous flooding or will be impacted by the implementation of one or more measures proposed by this project. This group may share maintenance responsibilities, or may need to be approached to negotiate easements through their property or for land acquisition. Community associations may be able to represent the interests of several individual landowners.

Because it will not be possible to meet individually with everyone who might be affected by the project, it would be beneficial to target those individuals that residents have been identified as being representative of their community, or have significant knowledge of certain aspects of the community. These may include long-time residents, or other individuals who have been active in the Ala Wai Watershed, but may not necessarily hold official leadership positions in organizations at this time.

A.3. Businesses

This group includes businesses whose operations either were previously impacted by flooding or will be affected by the implementation of one or more measures proposed by this project. This group may share best management practices and maintenance responsibilities, or they may need to be approached to negotiate easements through their property. Business associations may be able to represent the interests of several individual businesses.

A.4. Community and Private Organizations

Community and private organizations are formally organized 501(c)(3) non-profit organizations as well as less formal groups with a membership and a focus of interest that may be related to or affected by the project, but are not necessarily landowners in the watershed. These organizations range in purpose and demographics and offer a way to sample various perspectives within the community. Examples of Community and Private Organizations include the Ala Wai Watershed Association (AWWA), Canoe and Rowing Clubs, Hawaiʻi Transportation Association, Kapiʻolani Park Preservation Society, Makiki Stream Stewards, Mālama Mānoa, Pālolo Community Council, The Outdoor Circle, Waikīkī Yacht Club, and others.

A.5. Public Agencies

Public agencies are a part of the executive branch of government at the Federal, State, and local levels. Several public agencies are a part of the sponsoring team that is developing the project. In addition, some agencies currently have other projects or initiatives within the watershed that should be coordinated with the planning of this project, and some agencies will also be responsible for actions throughout this phase of the project, as well as during implementation and subsequent operations and maintenance.

City Agencies and Affiliated Entities

Because the City administers several permits that may be necessary to complete the project, they should be included in the process to ensure that final designs conform with permit restrictions and requirements, thus improving the likelihood of implementation. Portions of the streams and surrounding areas are owned by the City and some of the recommended project features may be sited on these lands. Some of these features may also require the City to operate and maintain them, thus making the City's participation critical to this process.

The City Department of Environmental Services is also a sponsor of the AWCP. Additionally, the City was also a local sponsor in the Mānoa Watershed Project (MWP) and may have special insight into what might be appropriate regarding the planning and design of the AWCP.

State Agencies

Like the City, the State also administers permits that may be required for implementation of the project, thus making it important that they participate in the planning and design phase. The State, through the DLNR, is also a local sponsor in this phase of the project and will provide input on planning and design. Project sponsors are expected to participate in planning and technical meetings, as appropriate, and offer guidance to ensure that the project is implementable, as well as to ensure that the project features address their needs and standards.

The Ala Wai Canal and portions of its tributaries and surrounding areas are owned by the State and some of the recommended project features may be sited on these lands. If needed, the State may also be responsible for land acquisition costs, construction costs related to modifications to infrastructure such as roads and bridges, and operation and maintenance of features on their lands.

The University of Hawai`i is also considered a State Agency and can provide local expertise on several aspects of the project including watershed ecosystems, invasive species impacts, hydrology, etc. Additionally, the University of Hawai`i at Mānoa campus is located along Mānoa Stream, was previously impacted by flooding, and has implemented projects to protect themselves from future flood events.

Federal Agencies

Federal agencies will participate primarily in the environmental review process through various consultations and assessments. Early consultation with agencies regarding Federal permits and EIS requirements will benefit project implementation. Some agencies also have data records and expertise in developing an understanding of the area and past flood events, and designing for future occurrences. Other agencies have expertise on ecosystem restoration best practices. One federal agency, USACE, is a project co-sponsor and is responsible for funding, technical assistance, project management, and stakeholder consultation. Other federal agencies, i.e., the Natural Resources Conservation Service and the Federal Emergency Management Agency, were or are sponsors of other related projects in the watershed.

A.6. Quasi-Governmental Organizations

A quasi-governmental organization is one that is linked to or supported by a public agency, but acts as an independent entity. Some of these organizations have areas of focus that extend beyond the Ala Wai Canal Watershed. Examples of Quasi-Governmental Organizations include the Neighborhood Boards, Ala Wai Marina Board, the Koʻolau Mountains Watershed Partnership, and others.

A.7. Elected Officials

Elected officials are persons that are voted into public office to represent the community at the local (City Council), State (State House of Representatives and Senate), and Federal (U.S. Congress) levels. It is important to keep elected officials apprised of the project and to have their support because they will be critical in getting permit approvals, implementation funding, and maintenance agreements. Their interest in the project will ensure that it maintains a high priority for agencies. Also, as representatives of the community, they should be approached for an overall understanding of the major issues that need to be considered, as well as details that should be addressed.

Appendix G3
Focus Meeting Summary (2014)

TOWNSCAPE, INC.
Environmental & Community Planning

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ALA WAI CANAL PROJECT
MEMORANDUM (REVISED 4/15/14)

Date: **March 27, 2014**
To: **Project Files**
From: **Townscape, Inc.**
RE: **Focus Group Meeting on Proposed Measures on or Near the Ala Wai Canal**

Participants:	**Ala Wai Watershed Association**	Tom Heinrich
	O'ahu Hawaiian Canoe Racing Association	Luana Froiseth
	Na 'Ohana o Na Hui Wa'a	Kauokalani Moikeha
	Neighborhood Board #5: Diamond Head/Kapahulu/St. Louis Heights	
		Daisy Murai
		Woody Chang
	Waikīkī Improvement Association	Rick Egged
	City Department of Design & Construction	Tim Trang
	City Department of Enterprise Services	Garrick Iwamuro
	City Department of Environmental Services	Gerald Takayesu
	City Department of Facility Maintenance	Lan Yoneda
	City Department of Parks & Recreation (DPR)	Karen French
	State Department of Land and Natural Resources (DLNR), Division of Boating and Ocean Recreation (DOBOR)	Meghan Statts
	DLNR Engineering Division	Gayson Ching
	U.S. Army Corps of Engineers (USACE)	Athline Clark
		Michael Wong
	CH2M Hill	Lisa Kettley
	Townscape, Inc.	Bruce Tsuchida
		Sherri Hiraoka

The purposes of the meeting were to (1) share measures proposed on or near the Ala Wai Canal with stakeholders who may be directly affected by those measures, (2) answer questions about the project and the proposed measures, (3) gather feedback on how those measure would impact stakeholders, and (4) discuss possible design options or operational methods that could lesson those impacts.

Athline Clark started the meeting by introducing the project team, then asked the participants to each introduce themselves. She then gave an overview of the U.S. Army Corps of Engineers' (USACE) role in the Ala Wai Canal project. She explained that the USACE is involved at the request of the State of Hawai'i Department of Land and Natural Resources (DLNR) and is serving as a technical resource. The non-federal sponsor (DLNR) is responsible for making decisions regarding project implementation based on the technical information developed by the USACE. She emphasized that no decisions have yet been made for the Ala Wai Canal project. She explained that the purpose of the meeting was to get input from the group regarding the flood risk reduction measures that are being considered in the Waikīkī/Ala Wai Canal area; this input will be used to further develop the project and will be considered in the decision-making process.

Athline then reviewed a powerpoint presentation with the group; the presentation addressed: (1) project authority and objectives, (2) planning process, (3) extent of past and potential flooding in the watershed, (4) potential flood-related damages, (5) criteria and strategies used to formulate alternatives, (6) process and results of screening and evaluation of alternatives, and (7) overview of the flood risk reduction measures in the tentatively selected plan (TSP). Michael Wong provided a detailed review of the conceptual design information for each of the measures in the Waikīkī/Ala Wai Canal area.

Following the presentation, Athline explained that the intent of the focus group meeting was to get input specifically for the measures in the Waikīkī/Ala Wai Canal area; particular items of interest include the potential impacts to stakeholders/users and design features that could potentially mitigate those impacts. The group then provided the following comments and questions:

GENERAL QUESTIONS AND COMMENTS

- Is the project intended to only address large storm events, or would it also account for tsunami?
  - The following conditions were taken into account: The capacity of the Ala Wai Canal after its last maintenance dredging, storm conditions, and high tide.
  - Hurricanes can cause wave "set-up," which increases the tidal level, but this is not considered part of the study as the seasonal nature of hurricanes is typically not coincident with large storm events.
  - A tsunami event during a flood event has not been modeled.
- Does the project have to address the 100-year flood?
  - No, the project does not have to address the 100-year flood. It can address a lower level of protection, i.e., a 50-year or 25-year flood event.
  - The analysis starts at the 100-year level of protection, but that can be adjusted depending on the needs of the local sponsor (in this case, the State Department of Land and Natural Resources).
  - If the project is designed to address a lower level of protection, it would still need to provide enough benefits to justify implementation, i.e., the project would still reduce enough damages and potential loss of life to make it worth implementing.

- There are several projects that are being pursued in the Ala Wai Canal area. At what point will coordination occur with these other transportation and recreation projects?
    - The Waikīkī Regional Circulator Study proposes a pedestrian bridge over the Ala Wai Canal at University Avenue and the Waikīkī Landing Project at the Ala Wai Small Boat Harbor proposes water taxis in the Canal.
    - Coordination amongst the projects is very important and these other efforts should be acknowledged as part of the current designs
    - The project team has already begun consulting with other known projects such as the Waikīkī Regional Circulator Study and will continue to coordinate with them as we develop the project.
    - This phase of the Ala Wai Canal Project will conclude with a Feasibility Report and Environmental Impact Statement and will include designs at the 35% level. Even at that point, there would still be opportunities for detailed integration of the other efforts if/when the project moves forward into the design phase.
- Debris has a big impact on the Ala Wai Small Boat Harbor.
    - Most of the debris is generated in the upper watershed. All of the proposed features in the upper watershed have debris catchment features. There are also two mid-valley detention catchment measures.
    - These features are meant to capture large debris like tree limbs; none of these features is specifically designed to capture trash.
    - The DLNR Division of Boating and Ocean Recreation (DOBOR) is more concerned with the large debris as it costs approximately $8,000-$10,000 each time it needs to clear the Boat Harbor of debris.
    - The Project should consider debris catchment makai of Dole Street because some debris comes from the mid-valley area. The community could be engaged in cleaning and maintenance activities, although this would require access to the stream.

FLOODWALLS AROUND THE ALA WAI CANAL

- The concept drawings are intended to show typical concepts, not specific dimensions. Therefore, the existing sidewalk/pathway may be wider than is shown on the concept drawings. The final designs for the project will reflect the actual dimensions.
- The width of berms and floodwalls around the Canal would vary, depending on a number of factors.
    - In general, a berm could be as wide as 30+ feet (as shown in Concept C) and a floodwall could be as narrow as 8 inches (as shown in Concept B).
    - A combination of these different concepts will likely be needed, based on the constraints along the various portions of the Canal (e.g., integrity of the existing wall, available space, etc.). Floodwalls may be used in areas where there is not much space and berms may be used where there is more space.
    - The sides of berms will need to have a shallow enough slope to accommodate stability, safety, and maintenance issues.

FLOODWALLS AROUND THE ALA WAI CANAL (continued)

- None of the concepts would make the Canal narrower since that would reduce its capacity to hold floodwaters. Instead, a wider area would be available for Canal flows during a flood event.
- There may be concerns with homeless people or others loitering on the inner side of the wall. This will need to be considered as we design and implement the project.
- The Ala Wai Canal itself is historic so we need to take that into consideration when we plan for and design measures that will impact its walls.
- Concept D (Concrete floodwall and earth levee) will likely need a safety railing to protect people from falling into the Canal.
- Can we use flood gates (moveable walls) instead of solid walls to preserve access to the Canal?
  - Yes, but it is more of a burden on the local sponsor because it will require someone to manually move the wall into place every time there is a threat of flooding. A passive solution such as a wall would always be in place.
  - Flood gates could be a good solution for areas that are actively used as launch points for the canoe clubs.
  - We would need to consider how much lead time we would have before the Ala Wai Canal overtops, and whether or not that is enough time to reasonably ensure that someone could get to the moveable section and secure it in place.
  - If a movable wall were constructed, a flood warning system would be required.
- Are there floodwalls proposed around the Canal where the Hausten Detention Basin berms are proposed?
  - There are currently floodwalls/berms proposed along with the Hausten Ditch Detention Basin berms, but the Project can consider ways in which these could be combined.
- Concept C (Earth levee) would need to be about four feet high near the canoe club launch areas (near Station 48+47).
- Canoes are stored and launched at three different locations along the Ala Wai Canal: near McCully, at the bottom of University Avenue, and near the Golf Course at Kapahulu.
  - There would be no floodwalls along the Canal at the Golf Course, but the perimeter berm for the Golf Course detention basin will need to consider access for the canoe clubs
  - Berms with flatter slopes may allow for canoes to go over them at the McCully and University launch sites.
- What would happen to the existing coconut trees, landscaping, and benches along Ala Wai Boulevard? Residents and users along the Waikīkī side of the Ala Wai Canal are very invested in the "linear park" that runs along the entire length of the Canal and have high expectations that this area be accessible and well-maintained.
  - Some of these features may have to be removed, depending on the space available, the floodwall design selected for that area, and the exact placement of the features, but this has not yet been determined.
  - The project should coordinate with the City Department of Transportation Services about potential impacts to the roadway, parking, and landscaped area.

FLOODWALLS AROUND THE ALA WAI CANAL (continued)

- Are the storm drains that feed into the Ala Wai Canal above water level? In some cases, the existing storm drains are partially submerged.
- How many flap gates will be needed to prevent backflow into the storm drains?
  - There are at least 40 locations where a flap or sluice gate is needed.
  - Flap gates have high maintenance requirements, and are considered a high liability if they fail; they noted the need to use high quality products.
- How will the project affect dredging of the Canal?
  - The project is expected to increase capture of sediment and debris before they reach the Canal, and therefore it is not expected to increase the need for dredging.
  - Dredging was considered as a measure to increase the Canal's capacity; however, the dredging would need to be maintained to provide ongoing flood protection, and the maintenance requirements are extremely high. As such, this measure was dropped from consideration.
  - The flood modeling is based on the capacity of the Canal following the last dredging event.
  - The DLNR periodically dredges the Canal and is currently assessing the timing for the next maintenance dredging event.
- There are existing steps leading into the Canal on the Waikīkī side, providing access for fishermen. This needs to be considered as part of the design.
- How will the berm/wall accommodate Makiki Stream at the confluence with the Ala Wai Canal?
  - The berm/wall will likely need to be continued up Makiki Stream to tie into an existing feature (e.g., bridge) in order to maintain protection in this area.
  - The stream is very narrow and this area is very flood-prone.
  - Makiki Stream is also highly constrained by existing development: many structures are built close to the stream, the stream is partially underground, private decks cross the stream, etc.
  - It will be very difficult to provide flood protection in this area. As an example, in order to contain the floodwaters within the stream (near Jack in the Box), the floodwalls would need to be 16 feet high. As this is not practicable, detention basins are being considered in the upper watershed.
  - There will still be areas within Makiki that cannot be protected.
  - There are plans to build a condominium in the parking lot on the corner of Kapiʻolani Boulevard and Kalakāua Boulevard, adjacent to the Century Center building. The City had a maintenance easement through this lot to clean Makiki Stream.
- The McCully Bridge restricts Ala Wai Canal water flow but modifying it would have been extremely costly.

ALA WAI GOLF COURSE DETENTION BASIN

- The berm for the golf course detention basin is in the vicinity of the entrance road.
  - The City is currently working on a stormwater project in that area that involves repaving the access road and installing rain gardens.
  - The detention basin design can accommodate these improvements.
  - A flood gate across the entrance road could be used to maintain access to the Golf Course.

ALA WAI GOLF COURSE DETENTION BASIN (continued)

- Can the cart path be located on top of the berm for the detention basin?
  - This is what is currently shown on the conceptual design, but there is flexibility. The design can accommodate changes in the cart path, as well as the placement of the holes.
  - A suggestion was made to consult with a golf course designer as a part of this effort.
- There are examples of areas where the rough is successfully used to accommodate floodwaters, with minimal impact to the course. However, the tees/greens would likely need to be raised significantly to minimize flood-related damages, which would be extremely expensive and time-consuming to repair after a flood.
- The State, in collaboration with the Ala Wai Golf Course, has also studied using the Golf Course as a sediment basin to improve water quality.
  - An inflatable dam would be used in the Mānoa-Pālolo Drainage Canal during small flood events, and the sediment basin would be used to reduce sediment/pollutants associated with these "first-flush" events.
  - It would be an open-channel feature (designed to function similar to a wetland).
  - Maintenance responsibility would need to be defined and coordinated by the State.

HAUSTEN DITCH DETENTION BASIN (at Ala Wai Community Park)

- What would the berms around the ball field look like and what would they be built from?
  - The berms would be about four-feet high earthen berms, covered with grass to minimize erosion.
  - The City Department of Parks and Recreation's (DPR) concerns relate to maintenance and emergency access to this area.
  - Berms would have a 3:1 slope to allow for a riding mower to drive on it for maintenance purposes.
  - A paved path could be built over the berm to provide emergency vehicles with access to the ballfield.
- Canoe clubs use a portion of the park near the end of the parking lot as a turning area for their trailers and to get their canoes from the halau into the Ala Wai Canal and back again. The project team will see if there is a way to align the berm to not block this access while still accommodating the ball field.
- The park where the detention basin is located is heavily used for softball. There may be specific safety concerns associated with placing berms/walls near the playing fields.
- The detention basin is more appropriate at the current location than the ball field on the 'Ewa side of Hausten Ditch, which is more heavily used.
- It was suggested that the berms could serve as an outfield observation area. This is a possibility but DPR would need to consider this idea further.

Athline concluded the meeting by thanking the participants. She encouraged the participants to provide any follow-up input in the next several weeks and noted that the next opportunities for input would be during a series of open house meetings, which are expected to occur in May.

Appendix G4
Open House Meeting Summary (2014)

TOWNSCAPE, INC.
Environmental & Community Planning

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ALA WAI CANAL PROJECT
MEMORANDUM

Date: **May 20 & 21, 2014**
To: **Project Files**
From: **Townscape, Inc.**
RE: **Open Houses on the Ala Wai Canal Project and Proposed Alternative 3A**

Two community Open Houses were held for the Ala Wai Canal Project: one at Mānoa Valley District Park and one at Stevenson Middle School. Each Open House ran from 5:00 pm to 8:00 pm to allow attendees flexibility in accommodating their schedules. Thirty five people signed in to the May 20 Open House in Mānoa and 20 people singed in to the May 21 Open House at Stevenson.

The purposes of the Open Houses were to (1) update the community on the status of the Ala Wai Canal Project (AWCP), (2) inform the community of the measures currently being proposed for implementation, and (3) provide the community with the opportunity to ask questions and comment on the project and proposed measures in advance of the Draft Feasibility Study/Environmental Impact Statement (FR/EIS).

A brief slideshow was presented at 5:00 pm to provide Open House participants with background on the project and its current status. The slideshow was then looped continuously for those who arrived later to view. Three information stations were set up around the room with different topics:

1. Project Background;
2. Measures Proposed in the Mid- to Upper-Watershed; and
3. Measures Proposed in the vicinity of the Ala Wai Canal.

Participants were free to view the maps, drawings, and displays at their leisure, ask questions of staff, and comment on the proposed project and measures. Questions and comments raised at the Open Houses are recorded below.

PROJECT BACKGROUND AND GENERAL QUESTIONS AND COMMENTS

- Cost/Funding/Timing/Phasing
  - Are the State and City participating?
  - Check with the Oʻahu Metropolitan Planning Organization (OMPO) for Federal Transportation funds.
  - Incorporating climate change helps drive funding.
  - Can the USACE/DLNR really build this for $200 million?
  - Would construction start in the upper watershed or the lower watershed?
  - When would construction start? How long will it take?
  - What is the project timeline?

PROJECT BACKGROUND AND GENERAL QUESTIONS AND COMMENTS (continued)

- Operations and Maintenance
  - Maintenance will always be an issue.
  - Operations and maintenance needs to be addressed.
    - Community is losing faith because of past lack of support and follow through.
    - Need maintenance of ditch that flows into Mānoa Stream (community can't help if basic maintenance is not provided).
  - We need to organize communities to take care of their neighborhoods in new ways. It's the "kuleana frontier." An example of this is community-based disaster preparedness.
  - Revisit the idea of a stream access corridor, i.e., "Greenbelt," for maintenance, recreation, water quality, and floodway expansion. This could be a project for the UH Planning School to take up.
- What is one cubic feet per second (CFS) in gallons per minute (GPM)?
  - 1 CFS = ~449 gallons/minute
- Flood mapping
  - What happens in a smaller event?
  - What about the existing Federal Emergency Management Agency (FEMA) Flood map?
    - The local sponsor would have to request FEMA to revise the Flood Insurance Rate Map.
  - In a 1% storm, how deep are flood waters without the project? With the project?
  - Show existing flooding and with-project flooding side-by-side for comparison.
- Climate Change
  - What happens with climate change?
  - How has sea level rise been considered?
  - How will storm surges change as a result of climate change? How will this affect flooding?
  - Has climate change been considered? Rainfall, storm surges, probability analysis (1-year, 5-year, 10-year, etc.). Frequency/intensity of rainfall.
  - Design elements seem to focus on getting water into the Canal. How is sea level rise factored in?
- Coordination and Outreach
  - Can the Project team do a presentation to the Mānoa Neighborhood Board?
  - It is important to coordinate with the Neighborhood Boards. Use the Neighborhood Boards as a conduit to other stakeholders. Some neighborhood Boards also televise their meetings.
  - Is the project coordinated with other developments in the area, e.g., transit, high rises in the lower watershed, etc.?
  - Coordinate with the Waikīkī Circulator Study
  - Will there be more meetings to discuss the conceptual designs?
    - Concerns about impacts of flood walls on recreational access.
    - What is involved with installing walls?
- Are there other flood control projects on-island that can be examples of successes and failures?

- Low Impact Development
  - Consider incentivizing control of stormwater runoff as a possible solution.
  - These solutions are beneficial for small-scale events but don't help large-scale events much.
  - Mandate additional permeable surfaces and passive drainage to help deal with current and future peaks from climate change. Write into code. Lower insurance rates as an incentive. Use this to supplement the engineering solution.
- Ecosystem Restoration
  - Would some of these measures improve water QUALITY?
  - Will the project address water quality (not just quantity)?
  - Are there considerations for taking out channelization for ecosystem restoration?
  - Use permeable surfaces (pervious pavers) and more vegetation (native plants), e.g. Buzz's Steakhouse, Kailua; Kaelepulu Stream

MEASURES PROPOSED IN THE MID- TO UPPER-WATERSHED

- Makiki Stream
  - What is the plan for Makiki Stream? It needs maintenance!
  - My neighbor built OVER the stream!
  - Would there be increased flooding in Makiki in the with-project condition?
- Mānoa Stream
  - There are cultural sites in upper Mānoa Valley
  - Concern with flooding of farms as water backs up behind basins in Mānoa (Wong property).
  - Debris in Mānoa Stream (stumps) seen by resident and reported to the City. No action taken. Likely illegal dumping. Pack trunks and branches along banks. Heavy rainfall dislodges debris upstream of Mānoa District Park and could clog up the proposed debris catchment at the Park during a storm.
  - The Waiakeakua flume is eroding and needs repair.
  - Woodlawn chute structure
    - How does it work both with and without the AWCP (question came from a home owner whose property is near the bridge).
    - What does the chute structure do and does it work with the Ala Wai Canal Project?
  - Need to consider local storm drainage pipe at Kahewai Place (Paul Araki, homeowner) between Kahaloa and Lowrey.
    - Drainage pipe is perpendicular to stream flow and during high flows, it causes backup
    - It would help to redirect the drainage pipe to better merge with stream flow (by angling it so the outflow comes out in the same direction as streamflow).
- Waihī Detention/Debris Basin
  - Who owns the land?
  - Ala Wai Watershed Association (AWWA) project location on the Paradise Park property. Coordinate with AWWA on location of their project in proximity to the Waihī detention basin.

- General comments and questions regarding Mid- to Upper-Watershed Planning
  - How do the debris/catchment basins work?
  - Are debris catchment posts high enough? Would logs float over them during a flood?
  - How will you avoid buildup of debris, trash, and sediment before a storm?
  - What happens when debris catchment backs up during a storm? We won't be able to clean it out during a storm. Will this increase flooding upstream?
  - Detention Basins: can we tap into the water that is held back and make use of it for irrigation. We would need to use pipes to distribute the water to irrigation areas.
  - Re-development increases runoff.
  - Will there be access roads for maintenance?
  - Will there be takings of property?
  - Operations and maintenance is a concern.
  - What type of materials will be used?
  - Does the Ala Wai Canal Project work with the UH Drainage Project?
  - Will there be coordination with the Rail project?
  - Special taxation district? Rate that is no net increase with respect to flood insurance rates.

MEASURES PROPOSED IN THE VICINITY OF THE ALA WAI CANAL

- Hausten Ditch Detention Basin
  - Is there a lot of debris, or is it not too bad?
  - The Marco Polo "maze" system captures lots of debris before it can get into the Canal.
  - Where would the sluice gate be placed?
  - The Hausten Ditch sluice gate "looks like an industrial area" and will destroy this important cultural asset.
  - Sluice gates: are lower gates or flap structures possible, or would "hinge" structures require more maintenance?
  - Can the mouth of Hausten Ditch (where it connects to the Ala Wai Canal) be smaller?
  - There is no need for a detention basin at Hausten Ditch.
- Flood Walls Around the Ala Wai Canal
  - Location and height of flood walls
    - A berm wouldn't work on the makai side of the Canal because there isn't enough space to accommodate the slope needed for safety and maintenance reasons.
    - Do you need flood walls on the mauka side of the Ala Wai Canal? Why not put berms around Ala Wai School and Noelani School? Water naturally dissipates (based on personal observations). When told that the USACE is modeling a much bigger storm event, the response was that the USACE is going overboard.
    - There needs to be a flood wall to protect 'Iolani School
    - A berm around Ala Wai Elementary School would suffice.
    - Could a new flood wall be built on top of the existing wall after it is repaired?
    - Do the flood walls need to be so high?
    - How high will the flood walls be? Three feet? Four feet? Five feet?

- Aesthetics
  - Design the flood walls to match the existing historic walls with arched shapes.
  - "Fake archways" on the wall could look better than plain concrete.
  - Berms on the mauka side of the Canal could have a "wavy" alignment.
  - Flood wall aesthetics: a "pattern" would help and is preferable to "plain concrete."
  - Aesthetically pleasing walls on the Ala Wai Canal would be an improvement.
  - Make the walls look better for tourists. Double walls will turn them off.
  - Consult with the Diamond Head and Waikīkī Special Districts about potential view corridor issues.
  - See Cedar Falls as a good example of flood walls
- Historic/Archaeological/Cultural Concerns
  - The entire Canal is on the Historic Register. The proposed flood wall would compromise the integrity of the historic Canal.
  - Can ask the State Historic Preservation Division for a variance. Design the wall to appear similar to the historic resource.
- Accessibility
  - How many ramps over the flood wall will be needed?
  - Need to consider whether access points into the Canal should be Americans with Disabilities Act-compliant. Existing stairs are not compliant because they are historic. Would the project change this?
  - What is impact on recreational uses and pedestrians? What about during construction?
  - Some coaches for the canoe clubs walk along the wall to coach the paddlers.
- Safety
  - Safety concern: visibility will be restricted behind the wall, particularly if the sidewalk is on the Canal side of the wall. Consider talking with the Waikīkī Business Improvement District about safety concerns and programs.
  - Major concern for placement of the wall down at the historic section of the walls. Recommend moving the wall next to the historic walls or the area will become a Mecca for homeless.
- We are getting higher tides, especially with the full moon.
- City prefers no flood walls.
- Where does the rain falling in Waikīkī go? Will the new flood wall trap water in Waikīkī?
- Will the flood wall cause Waikīkī to flood even more in a tsunami? Have the effects of tsunami been considered?
- How will the flap gates affect the subsurface drainage systems?
- Look into retention system expansion: cancel Ala Wai Canal walls, 10-foot high industrial sluice gate structures, concrete ramps and any other structural elements that will destroy: the character, the integrity, the visual appearance and aesthetics, the cultural value, and the Hawaiian sense of place of the Ala Wai Canal walls and promenade. This is a historic Place. Please do not adversely impact this major public asset.

- Ala Wai Golf Course Detention Basin
  - Why is there still flooding behind the golf course under the with-project condition?

- Additional comments and questions regarding Ala Wai Canal-area planning
  - Can we raise Ala Wai Boulevard?
  - Can we have a wide/raised promenade?
  - Measures around the Canal should have their own break-out sessions, stakeholder charrettes to factor in design considerations for users. Include recreation features such as improved walkways to make the concepts more palatable to the community.
  - Dredging
    - How much sediment is accumulating annually in the Canal?
    - Is dredging the Ala Wai Canal a possible solution?
    - Did you look at dredging the Ala Wai Canal?

Ala Wai Canal Project

May 2014

The Ala Wai Canal Watershed, comprised of the communities of Makiki, Mānoa, Pālolo, McCully, Mōʻiliʻili, Kapahulu, Ala Moana, and Waikīkī, is susceptible to flooding due to aging and undersized flood conveyance infrastructure. Additionally, flooding often occurs rapidly as "flash floods," when heavy rains run downstream extremely quickly due to steep topography and relatively short stream systems. The Ala Wai Canal has overtopped its banks in 1965, 1967, and in 1992. More recently, a 2004 storm caused over $85 million in damages to the Mānoa area and 40 days of consistent rainfall in 2006 caused flooding in Makiki.

The State Department of Land and Natural Resources (DLNR), together with the U.S. Army Corps of Engineers (USACE) are leading the proposed Ala Wai Canal Project. The goal of this study is to increase life safety and reduce flood risk. A key collaborator in this process is the City and County of Honolulu.

This dense area of urban Honolulu contains over 3,000 properties; 54,000 residents; 85,000 students and workers; and 79,000 visitors within the floodplain. A 1% chance flood event would cause an estimated $397 million (October 2013 dollars) in property damages. The majority of the economic damages are expected to occur in Waikīkī, where the density is highest. Additional economic losses to businesses would increase this estimated economic impact.

The Ala Wai Canal Project is currently in the Feasibility Study Phase, which will conclude with the publication and filing of a joint Federal and State Feasibility Study and Environmental Impact Statement (EIS). The EIS will describe and compare project alternatives and their respective impacts on the community, environment, and economy. The final Feasibility Study and EIS will be used to support a Chief of Engineer's Report. That report will then be sent to the U.S. Congress to seek authorization for construction of the project.

For more information, please contact:

Athline Clark, Project Manager
U.S. Army Corps of Engineers
808-835-4032
athline.m.clark@usace.army.mil

State of Hawaiʻi
Department of Land and Natural Resources

US Army Corps of Engineers
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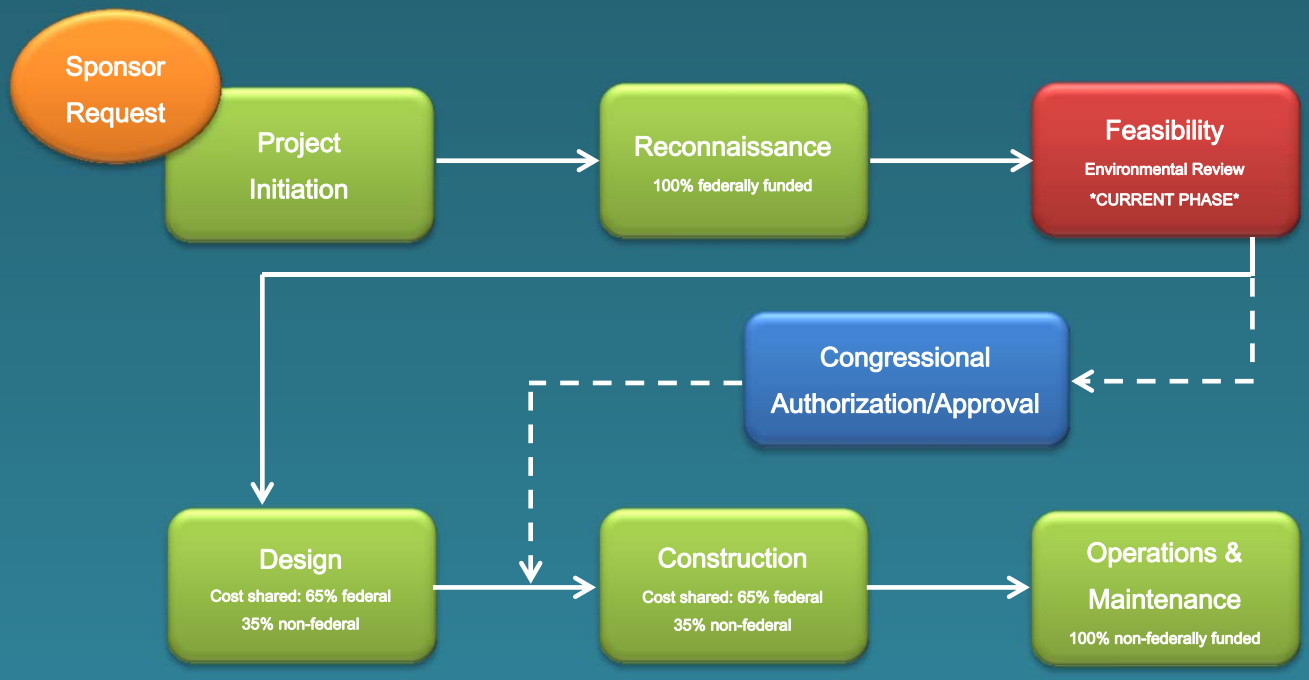
Ala Wai Canal Project



Expected flooding during a 1% chance flood event

Appendix G5
Legislative Briefing Summary (2014)

From: Sherri Hiraoka <Sherrihiraoka@townscapeinc.com>
Sent: Tuesday, June 03, 2014 12:41 PM
To: Rep. Joseph Souki; Sen. Donna Mercado Kim; Rep. John Mizuno; Sen. Ronald D. Kouchi; Rep. Mark Hashem; Rep. Bertrand Kobayashi; Rep. Calvin Say; Rep. Scott Nishimoto; Rep. Tom Brower; Rep. Isaac W. Choy; Rep. Della Belatti; Rep. Sylvia Luke; Rep. Scott Saiki; Sen. Sam Slom; Sen. Les Ihara, Jr.; Sen. Brian Taniguchi; Sen. Brickwood Galuteria; Sen. Suzanne Chun Oakland; Rep. Chris Lee; Sen. Mike Gabbard; Rep. Henry J.C. Aquino; Sen. Will Espero; Rep. Cindy Evans; Sen. Malama Solomon; Sen. Gilbert Kahele
Cc: 'Carty.S.Chang@hawaii.gov'; 'Karen Ah Mai'; Sherri Hiraoka; 'athline.m.clark@usace.army.mil'; Floriene Hamasaki; Gina Williams; Christine Fehn; Harrison Kawate; Kathy Kato; Edward Thompson, III; Evelyn Hee; Kevan Wong; Cynthia Nyross; Carole Hagihara; Jon Kawamura; Julie Yang; Jonathan Tungpalan; Melvin Ah Ching; Heather Bolan; Susan Miyao; Tommie Suganuma; Raytan Vares; Alisha Leisek; Tyrell Maae; Jennifer Wilbur; Rock Riggs; Donna Lay; Maureen Andrade; Marlene Uesugi; Teriitavae Perez; Roth Puahala; Linda Menda; Tom Heinrich; Kettley, Lisa/HNL; Bruce Tsuchida; Gayson.Y.Ching@hawaii.gov
Subject: ALA WAI CANAL PROJECT - Open House Recap

Aloha:

As mentioned in the briefing provided to you and your staff on May 13, 2104, the Ala Wai Canal Project Team held two Open Houses on May 20 and 21, 2014 to update the community on the project, share the measures being considered, and provide an opportunity to receive comments in advance of the Draft Feasibility Report and Environmental Impact Statement (EIS), which is expected to be published in late 2014. The first Open House was held at Manoa Valley District Park and the second at Stevenson Middle School. A total of 45 people signed in, but it was noted that some attendees did not sign in.

Open House participants were curious and engaged and had great discussions with project staff. Common questions and comments from both the Open Houses and the Legislative Briefing included:

- Operations and maintenance are of concern because existing projects are not maintained. The community could help, but needs support.
- Climate change impacts such as sea level rise and larger storms need to be factored into the project.
- This project needs to coordinate with other projects in the area such as rail, new high rises, the UH Drainage Study, and the Waikiki Circulator Study.
- How do the detention basins and debris catchments work? Will they flood upstream areas? How will they be cleaned?
- The proposed Hausten Ditch detention basin sluice gates are ugly and do not fit into the surrounding park/open space area. Is there a way to make them smaller or use a different, less intrusive mechanism?
- Consider potential uses outside and adjacent to the Ala Wai Golf Course when designing the berms. Many ideas have been proposed on the Date Street/Kapahulu sides of the Golf Course but have been restricted due to lack of space.
- Is there a way to make the proposed flood walls around the Ala Wai Canal lower? How does this impact the view plane and open space benefits currently provided by the Canal, parks, and golf course?
- Any flood walls around the Ala Wai Canal should be aesthetically pleasing, especially for the tourists. A blank wall may invite graffiti.
- Flood wall design should consider safety, particularly regarding homeless congregation, visibility, and protection from falling into the Canal.
- Flood walls need to allow for recreational access into and around the Canal, particularly for pedestrians and canoe paddlers.

The Project Team is reviewing the questions and comments and is folding the concerns raised into the

Feasibility Study/EIS.

Thank you for your continued interest and involvement in the Ala Wai Canal Project. The slideshow from the Open Houses is posted at the project website at:
http://alawaicanalproject.com/meetings/AlaWai_OpenHouse_presentation_20May2014.pdf.

We will be sure to inform you when the Draft Feasibility Study/EIS is published and the Public Hearing is scheduled. Until then, please feel free to contact myself or the Project Manager from the US Army Corps of Engineers or the Department of Land and Natural Resources with any questions. Our contact information is provided below.

Athline Clark, Project Manager
US Army Corps of Engineers, Civil and Public Works Branch
(808) 835-4032
Athline.M.Clark@usace.army.mil

Carty Chang, Chief Engineer
Department of Land and Natural Resources, Engineering Division
(808) 587-0230
carty.s.chang@hawaii.gov

Mahalo,
Sherri

Sherri Hiraoka
Senior Planner

TOWNSCAPE

900 Fort Street Mall, Suite 1160
Honolulu, Hawaii 96813
Phone: (808) 536-6999 (option 6)
Fax: (808) 524-4998
Email: sherri@townscapeinc.com
Website: www.townscapeinc.com

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Appendix G6
EIS Preparation Notice (2014)

October 23, 2014

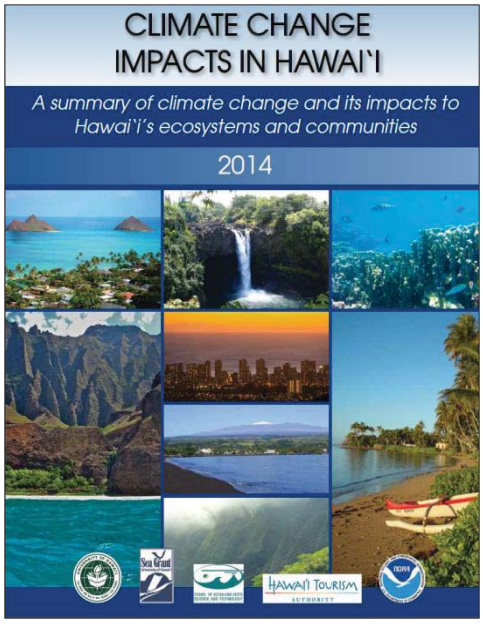
OFFICE OF ENVIRONMENTAL QUALITY CONTROL

The Environmental Notice

A Semi-Monthly Bulletin pursuant to Section 343-3, Hawai'i Revised

Climate Change Impacts in Hawai‘i

The University of Hawai‘i Sea Grant College Program (UH Sea Grant) prepared a report that summarizes the current state of scientific knowledge regarding climate change and how it is anticipated to affect Hawai‘i.



Climate Change Impacts in Hawai‘i - A Summary of Climate Change and its Impacts to Hawai‘i’s Ecosystems and Communities was written to provide communities and government agencies with a fundamental understanding of the effects of climate change so that Hawai‘i can be better prepared for changes to come.

OEQC recently released ***The Hawai‘i Environmental Policy Act Citizen’s Guide*** which discussed the need to incorporate sea level rise and other climate change impacts in environmental review documents. As this ***Climate Change Impacts in Hawai‘i*** report is structured to serve a broad audience it may assist both document preparers and reviewers to incorporate climate change impacts into plans for future development.

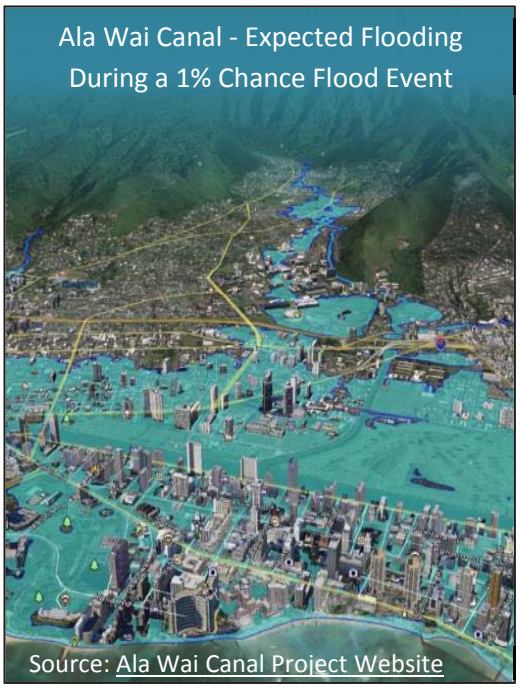
Ala Wai Canal Project EISPN

The Ala Wai watershed (comprised of the communities of Makiki, Mānoa, Pālolo, McCully, Mōili‘ili, Kapahulu, Ala Moana and Waikīkī) is the most densely populated watershed in Hawai‘i.

The Ala Wai Canal is susceptible to flooding due to aging and undersized flood conveyance infrastructure.

The State of Hawai‘i Department of Land and Natural Resources and the U.S. Army Corps of Engineers are conducting a feasibility study to address flood risk associated with the Ala Wai Canal and its contributing watershed. The objective of the project is to reduce riverine flood hazards to property and life safety in the Ala Wai watershed.

See page 6 for more details.



Source: Ala Wai Canal Project Website

O‘AHU (HRS 343)

5. Ala Wai Canal Project EISPN

Island: O‘ahu
District: Honolulu
TMK: Various TMKs in Zone 2, Sections 3-9 and Zone 3, Sections 1-4
Permits: Clean Water Act §404 compliance; National Environmental Policy Act (NEPA) compliance; National Historic Preservation Act (NHPA) §106 compliance; Coastal Zone Management Act (CZMA) compliance; Fish and Wildlife Coordination Act (FWCA) compliance; Request for Use of State Lands; Hawaii Revised Statutes (HRS) §343 compliance; Department of Health §401 Water Quality Certification; National Pollutant Discharge Elimination System (NPDES) permit; Conservation District Use Permit, Stream Channel Alteration Permit; HRS §6E Historic Preservation review; Special Management Area (SMA) permit; Waikīkī Special District permit; Community Noise Permit; Grading and Building Permits
Proposing Agency:
Department of Land and Natural Resources, Engineering Division, P.O. Box 373, Honolulu, Hawai‘i 96809.
Contact: Gayson Ching, gayson.y.ching@hawaii.gov, (808) 587-0232
Accepting Authority:
Governor, State of Hawai‘i
Consultant: CH2M HILL, 1132 Bishop Street, Suite 1100, Honolulu, Hawai‘i 96813
Attn: Lisa Kettley
Status: Statutory 30-day public review and comment period starts; comments are due by November 24, 2014. Please send comments to the proposing agency and consultant.

The State of Hawai‘i Department of Land and Natural Resources (DLNR) and the U.S. Army Corps of Engineers (USACE) are conducting a feasibility study to address flood risk associated with the Ala Wai Canal and its contributing watershed, including Makiki, Mānoa and Palolo Streams. The Ala Wai watershed is the most densely populated watershed in Hawai‘i; in addition to residential, commercial, and institutional development, the watershed also includes the Waikīkī District, a prime tourist destination and economic engine of the State. It is estimated that the Canal has the capacity to contain about a 20- to 10-percent chance (5- to 10-year) flood before overtopping the banks; overtopping of the Canal has previously caused flooding in Waikīkī multiple times. Upstream areas are also at risk of flooding, as demonstrated by an October 2004 storm in Mānoa, which caused an estimated $85 million in damages. Initial modeling efforts indicate that the 1-percent chance (100-year) flood would result in damages to more than 3,000 structures throughout the watershed, with property damages exceeding $311 million (based on 2009 price levels).

The objective of the project is to reduce riverine flood hazards to property and life safety in the Ala Wai watershed. In response to identified flood-related problems and opportunities, a variety of measures were identified. These measures were combined into a range of alternatives, which were evaluated through an iterative screening and reformulation process, resulting in identification of a Tentatively Selected Plan (TSP). The TSP involves construction of (1) a series of in-stream detention basins in the upper reaches of Makiki, Mānoa and Palolo streams, (2) additional detention basins adjacent to the Ala Wai Canal, (3) debris catchment in portions of the developed watershed, (4) floodwalls along the Ala Wai Canal and (5) various non-structural measures (e.g., flood-proofing). Given the scope and scale of the measures being considered, it is expected that implementation of the TSP will result in unavoidable adverse impacts. As such, it has been determined that an Environmental Impact Statement (EIS) will be required. The EIS will describe the TSP (proposed action) and the range of reasonable alternatives, and will address the potential for direct, indirect, and cumulative effects on

the human, natural, and cultural environment; mitigation measures that avoid or minimize the potential adverse effects will also be identified. Pursuant to Hawaii Revised Statutes (HRS) Chapter 343, an EIS Preparation Notice (EISPN) has been prepared to inform interested parties of the project, and to seek input on issues or resources of concern that should be addressed in the EIS.

6. Camp Pūpūkea Mater Plan FEA (FONSI)

Island: O‘ahu
District: Ko‘olauloa
TMK: (1) 5-9-005:002 and (1) 5-9-005:077
Permits: Conservation District Use Permit; National Pollutant Discharge Elimination System Permit; Department of Health Wastewater Permit; Building Permits
Applicant: Aloha Council Boy Scouts of America, 42 Pū‘iwa Road, Honolulu, Hawai‘i 96817
Contact: Jeff Sulzbach, (808) 595-0859
Approving Agency:
Department of Land and Natural Resources, 1151 Punchbowl Street, Honolulu, Hawai‘i 96813, Contact: Kimberly (Tiger) Mills, Ph.: (808) 587-3822; Fax (808) 587-3827
Consultant: PBR Hawaii & Associates, Inc., 1001 Bishop Street, Suite 650, Honolulu, Hawai‘i 96813. Contact: Tom Schnell, (808) 521-5631; Fax (808) 523-1402
Status: Findings of No Significant Impact Determination

Boy Scouts of America Aloha Council have used Camp Pūpūkea for overnight camping and recreation since the early 1960s. This former military training area is the largest and busiest Boy Scout activity center in the Pacific. Its summer camp program plays host to troops from throughout Hawai‘i and the United States Mainland. It is used year-round for camping, training, and other various activities.

The Boy Scouts are proposing various improvements at Camp Pūpūkea. Upgrades include infrastructure improvements (particularly wastewater improvements to eliminate the use of portable toilets), renovation or relocation of some existing structures, and new facilities. Improvements are expected to be completed in three phases over a period of 20 or more years.

The proposed improvements will address facility deficiencies and have beneficial impacts by creating safer conditions and improved facilities. Potential adverse impacts, while minimal, can be mitigated.

7. Fuller Residence FEA (FONSI)

Island: O‘ahu
District: Ko‘olaupoko
TMK: (1) 4-5-047:116
Permits: City and County of Honolulu, Shoreline Setback Variance, and Building Permits (building, plumbing and electrical).
Approving Agency:
Department of Planning and Permitting, City and County of Honolulu, 650 South King Street, 7th Floor, Honolulu, Hawai‘i 96813, (808) 768-8000
Applicant: Herb Fuller, 45-038 Ka Hanahou Place, Kāne‘ohe, Hawai‘i 96744
Consultant: R. M. Towill Corporation, 2024 North King Street, Honolulu, Hawai‘i 96819, Contact: Chester Koga, (808) 842-1133
Status: Findings of No Significant Impact Determination

Appendix G7
EIS Scoping Meeting Notes (2004 and 2008)

LINDA LINGLE
GOVERNOR OF HAWAII

PETER T. YOUNG
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

DAN DAVIDSON
DEPUTY DIRECTOR - LAND

YVONNE Y. IZU
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

POST OFFICE BOX 621
HONOLULU, HAWAII 96809

JUN 17 2004

Dear Interested Party:

Ala Wai Canal Project – Environmental Impact Statement Scoping Meeting

The US Army Corps of Engineers and the State of Hawaii Department of Land and Natural Resources announce their intent to prepare an Environmental Impact Statement (EIS) for the Ala Wai Canal Project. This is a multi-purpose project that incorporates flood hazard reduction and ecosystem restoration for the Ala Wai watershed, which encompasses the Makiki, Manoa, and Palolo sub-watersheds, as well as Waikiki. Flood hazard reduction concepts being considered include flood walls around the Ala Wai Canal, dredging, flood water storage, widening the Canal, and modification of bridges spanning the Canal. Ecosystem restoration concepts include stream channel restoration, stream bank stabilization, riparian re-vegetation, check dam installation, sediment basin construction, and wetland re-construction.

In preparation of the EIS, the sponsors are requesting public input on the scope of analysis for the Draft EIS studies. A public EIS scoping meeting is being held to discuss the proposed project and its possible impacts, and to identify community concerns:

Ala Wai Canal Project - EIS Scoping Meeting
Tuesday, June 29, 2004
Hawaii Convention Center, Theater Room 320
6:30 p.m.
Parking will be free with validation

The project team will present the preliminary concepts, discuss the EIS, and explain the procedure for providing comments. The overall project schedule will also be covered.

Availability of the EIS Preparation Notice was published in the State Office of Environmental Quality Control June 8, 2004 Environmental Notice. We welcome your participation in this process and look forward to working together to create a safe and healthy watershed for the Ala Wai community.

This public meeting is accessible for individuals with disabilities. For more information or to request an auxiliary aid or service (e.g., sign language interpreter, designated parking, materials in alternate format), please contact Mr. Andrew Monden of the Engineering Division, at 587-0227 seven days before the meeting. Also, should you have any questions or concerns, please contact Mr. Monden.

Sincerely,

Peter T. Young
Chairperson

TOWNSCAPE, INC.
ENVIRONMENTAL AND COMMUNITY PLANNING

900 Fort Street Mall, Suite 1160, Honolulu, HI 96813
Telephone (808) 536-6999 Facsimile (808) 524-4998
email address: mail@townscapeinc.com

ALA WAI CANAL PROJECT
To: Project Files
Date: July 7, 2004

NOTES FROM EIS SCOPING MEETING held on June 29, 2004

This memo generally summarizes the Ala Wai Canal Project (AWCP) Environmental Impact Statement (EIS) Scoping Meeting held on Tuesday, June 29th at 6:30 pm at the Hawaii Convention Center Theater 320. Approximately 130 people attended the meeting.

Members of the project team gave a slide show presentation on the general nature of the AWCP as well as on the flood damage reduction and ecosystem restoration concepts they are considering. Additionally, the EIS process and public comment opportunities were described. After the presentation, meeting participants were asked to provide their comments on the project. Verbal comments were as follows:

Renwick "Uncle Joe" Tassill – Concerned Citizen, Ala Wai Watershed Association (AWWA), Tour Industry (leads ahupua'a system discussion at Hilton Bishop Museum)

- If we are designing for the 100-year storm, where are we in that 100-year cycle? What is the relationship of the timing of this project with the expected occurrence of the storm? Are there weather patterns/studies to figure this?
- A: The term 100-year storm refers to the statistical probability that a storm of this magnitude will occur once every 100 years. This does not mean that it will only happen once every 100 years. There is a 1% chance that this large of an event will happen in any given year. The term 25- or 100-year storm also means the magnitude of the storm.

- This project should be taken down to the children because it will affect them, too.

Raymond Gruntz – Safety Chair, Waikīkī Neighborhood Board

- How far up the Canal does the salt water travel and mix with the fresh water?
- A: During high tide, the salt water can go as high as Kaimukī High School.

- If you flood the golf course, will the salt water kill the grass?
- A: No, because the diversion to the golf course will be located upstream, above the tidal influence, putting only fresh water onto the course.
- The project team is invited to the Waikīkī Neighborhood Board to speak about the project.

Clifton Takamura – Mō‘ili‘ili Neighborhood Board, resident

- Remembers the 1965 flood and how it flooded Ala Wai Elementary. Does not want children to have to experience the flooding that happened in the past.
- This project should have been coordinated with the dredging project last year.
- Wondered why flooding of Hausten Ditch and other streams has not been addressed, and recommended a cross-circulation idea for the Canal to the Corps but did not see that in the presentation.
- Project should also improve circulation in the streams, including Hausten Ditch.

Bill Tom – Marine Consultant

- Damming of streams not the answer, removal of trash is the answer. Need to concentrate on trash and sediment upstream, which will reduce pressure on the Ala Wai Canal.
- In Los Angeles, they have an ‘inverted skateboard ramp’ to collect trash – each city is responsible for collecting trash. Looking at this method to pick up trash and put in a chute would be good.

Petra Fetcher – former resident near the canal

- Experienced a 100yr flood in Ashland, OR, which has a similar geography to the Ala Wai watershed. Depended on the National Guard for 2-3 weeks, without sanitation and living off of rain barrels.
- We should all be concerned with the 100-year flood and come together to clean the streams.

Lance Grolla – former City Planner

- Based on his work experience, he thinks that 30 and 60-day review periods were not long enough. It takes time for people to write, also time to review. Extensions should be given so the community can adequately respond to the project.
- Create terraced channels/Canals in the upper watershed to catch water. There were terraced taro patches in Hawaiian history.
- Plant the terraces.
- Catch rainwater by draining water directly down into the aquifer (a system used in Australia) vs. the impermeable surfaces that we see in the developed areas. Australia

uses a piping system to catch water from impervious surfaces that runs directly into the catchment channels and the aquifer. This also prevents flooding.

He complimented the panel on the presentation.

(Tsuchida noted that there may be a problem with runoff from neighborhoods; they may contain contaminants that we do not want to get into the ground water. Lance replied yes, would have to use something like charcoal.)

Steve Kubota – Ahupuaʻa Action Alliance, AWWA, worked on Kaneohe-Kahaluu Stream Restoration and Maintenace Guidebook

- Make ahupuaʻa the knowledge base for designing restoration. William Kikuchi of Kauai reported on hydraulic infrastructure – heiau, loʻi system, and fish ponds is a graphical image of water systems Hawaiians used. It is a water management system; not a preservation system; i.e., loʻi was irrigation and fishponds were sediment traps. Its features include restoration of the aquatic ecosystem.

- Recreate landscapes. The National Research Council developed a manual: Restoration of Aquatic Ecosystems, in 1992. It is a formal process that the Federal government is trying to develop. It advocates using historical records, oral histories, GIS, and other tools as a guide for restoration. There is also extensive literature on the subject at the UH libraries.

- Need to look at history past the construction of the Ala Wai Canal. Utilize information on historic caves. He e-mailed Derek Chow about the 1935 Star-Bulletin article "Romance of the Caves" regarding John Williamson and the historic caves. It documents pre-historic activities relating to limestone caves. There is a wealth of clues that could be used to map the earlier hydraulic landscape. These caves may be used as conveyance for water and as restoration opportunities for their unique organisms, such as blind mullet.

- Rainwater catchment would cool water and address the bacteria problems.

Yoshimi Endo - Retired

He lived in the Moiliili Quarry area from 1963 to 1971. Flood waters covered the entire lower campus of UH.

- Tourism is the #1 economy; opposes dikes or barriers that tourists could see.

- Kaimuki High School could be used as a catch basin instead of an area where tourists can see.

Rick Egged – Waikiki Improvement Association

He complimented the panel and had the following thoughts and concerns:

- Damage estimates are rather low. Loss of business costs, etc., need to be included in the estimates.

- The flood is a community problem. It is not just a Waikīkī problem but it affects residents of McCully, Kaimukī, and all surrounding areas.

- Building walls and widening the Canal should be the last resort. It would negatively impact the community. The panel needs to look at every other option before doing that. Dredging helps and it is preferred to building walls and widening the Canal.

- Create another method for water to move from the Canal to the ocean, such as a drainage system to flush at Kapahulu end to increase capacity. This would be preferable to walls and/or widening.

(Chow's response was that we will try to avoid building walls but the situation must be evaluated. The original study in 2001 focused on just dredging or just walls and it determined that flood walls alone would need to be 10 to 13 feet high. However, the purpose of the study was to identify engineering solutions toward getting the Corps involved in the project. The best solution is a combination of all concepts because it would minimize the impacts of each individual action.)

Alan Ewell - Tantalus Association

- Restoration and flooding are integrated and should not be looked at as separate. Start at the top of the watershed and work down to prevent flood water from even reaching the Canal. There are lots of other options than what has been presented, e.g., green roofs, wetlands throughout the watershed, rainwater catchment for commercial and residential areas. Are these being considered?
- A: Tsuchida explained that we are looking at concepts such as catchment and wetlands, but we need to determine how much effort is needed to gain any measurable benefit. Chow stated that the Federal Government can't solve everything, but wants to help jump start the community.

- Economic, recreational development should all be considered at this stage. Previous proposals included using the Canal for commercial ferries and turning the golf course into a park, which would include wetlands. This team should coordinate with the appropriate State and City agencies to ensure that this project fits into their overall economic development plans for the area.

- A: Tsuchida explained that we are not considering redesigning the golf course for a park but we are looking at it as a storm water retention basin. We will coordinate with the appropriate agencies to ensure that this project does not conflict with future planned uses.

David Ogura – private citizen

- Provide a path or pipe on the Diamond Head end of the Canal to help with the conveyance during floods, running offshore instead of affecting nearshore.

- Consider draining out of both sides. The Canal can be made such that it will only be used in case of a flood.

- Widen and deepen stream beds to settle out sediments before they get to the Canal. Disposal of sediment will then be easier because it is not contaminated by salt water.

He lives on the Windward side and is experiencing sediment problems in the stream near his home. He has found that the permits and approvals process is time-consuming and suggested that the process should be streamlined. He indicated his frustration and said that while awaiting permits, approvals, and cleaning of the stream, the streambed near his home erodes and continues to get wider.

Patrick Chun – Ala Wai business owner

- Mr. Chun asked why the Ala Wai Canal had not been completed on the Kapahulu side?
- A: Frankly, they ran out of funding.

- Further, besides dredging deeper, what are the benefits of lining with concrete to convey water faster?
- A: Chow said we are trying to make the project area more natural; however, we cannot get more conveyance through the Canal by just dredging. We want to minimize the use of more concrete.

- Mr. Chun also noted that in keeping things natural, unless the streams and plantings are maintained properly, they may add to debris that clogs the stream and Canal.

Eric DeCarlo – private citizen

The stream in the Canal has never been dredged to its original depth. Can take core samples to tell what the original depth was. He noted that it is a Canal, not a stream, and by definition, it will never flow down hill, though at the onset, the Kapahulu end was higher.

Most of the sediment comes from the upper watershed. Fifty percent of the sediment load of Pālolo and Mānoa comes from above Waiakeakua. The Canal is a sediment trap; it is perfectly designed. Eighty percent of the sediment comes from the Conservation District; therefore, he believes that anything that is done toward abatement of the problem in the urbanized areas will have no impact on the sedimentation. Nature used to have sediment traps in the upper watershed.

(Chow's response was that we are looking at the upper watershed system to reduce the amount of sediment and contaminants.

Bourke stated that we need to balance the project such that sediment traps can be put in the upper watershed; we are trying to reinvent ways to capture sediment in the upper areas without negatively impacting the aquatic biology. This may include check dams, but anything bigger runs into hydraulic problems.)

Michael Cain – private citizen; SSRI Environmental Planner

Mr. Cain asked if the bike path in the diagram is an element being considered.

(Tsuchida responded that we would like to improve access on public lands where it is feasible.)

Lauren Roth –private citizen; also with UH Manoa

- Clean the pollution coming down into the Canal.
- Need to consciously build settling ponds and constructed wetlands for sediment and remediation issues, so that functional guardians are addressed, not just "restoration".
- Need native plants, wetlands features, widening of the banks, gardens that have purpose.

Lorraine Cypher – Waikiki condo owner, originally from the mainland

Ms. Cypher needed contact numbers in regard to suspicious substances in the Canal.

Mr. Takayesu provided numbers for the City Environmental Concern Line – 692-5656 and for the State Department of Health Clean Water Branch – 586-4309.

Chad Durkin – Biologist

Mr. Durkin is doing work in the Ala Wai watershed; he is looking at restoration and "natural engineering."

- Restore water quality integrating modern engineering with ancient Hawaiian practices and natural engineering. This technology exists, and need to incorporate this.
- Maintain the nutrient balance.

- Control the volume of water in the streams. The goal is to have more water in the streams on a daily basis and control water on a flooding basis.

- Plan for water re-use. We need to reduce water demand so we can get more water in the stream for native species.

He offered his project for those interested in participating – the Makiki Ecological Demonstration at the Hawaii Nature Center. He is there every Monday, Thursday, and Saturday from 10 a.m.-12 noon.

Sally Moses

We need to be concerned about our environment; we need to do what is pono. Ms. Moses lives in the uplands of Makiki and has seen the water in the stream go down to nothing in a 6-year period.

- A dry stream is a dangerous stream and will cause damage once a storm hits. Becomes overgrown with weeds.

- Get the charter and DOE schools involved in the project; turn this into a curriculum-based program; get the youth involved.

- Take care of the land, there is no other place to go.

Lionel Aono – Chair of Board of Public Golf Courses

There will be problems in using the golf course for drainage retention. After the water is drained, there will be a lot of silt and that will kill the grass for at least a year. The aftermath will result in a bad smell, muck, debris, and health problems. He noted that the West Loch golf course was flooded recently when a small stream overflowed due to a light rain; the course was closed for six months. Have the impacts of storm water on land been explored?

- Get the water out into the ocean. Storing the water on land will damage the environment.

(Tsuchida responded saying that we will look at those impacts over the next few months.)

Jim Harwood – Mānoa N.B.; AWWA

We need to consider the impacts of rain, wind, hurricane, and tsunami. The walls will hold tsunami back and keep the Canal from draining.

- Consider how this project will impact the area under these scenarios.

Unnamed female

- Do not widen the Canal due to recreational impacts. Prefer deepening. The Canal was dredged in 2003; the previous dredging was in 1973. Once in thirty years is not enough.

Wenhao Sun – former UH Researcher, now with private company that is currently involved with the Ala Wai

- Consider phyto-remediation.
- Follow the ahupua‘a concept; restore the back yard. The plant component, e.g., taro, provides lots of functions – takes up nutrients and sedimentation, preventing upstream water from flooding down stream.

Mr. Sun heard a story about the Ala Wai of 20 years ago. It was very clean, marsh land with sea grass and people were able to swim in it.

- Work with nature.
- Create a sustainable system.
- Introduce plants. Introduce sea grass under stream then turn nutrients from pollutants/waste to food for plants; first need to clean up the algae from the water and then introduce the sea grass and establish the system.
- Grow native plants on a floating platform.

Gerald Takayesu for Helen Nakano – Mālama o Mānoa

Mālama o Mānoa cleans a section of the Mānoa Stream and worked under the Kuleana Project last year. Ms. Nakano is able to get the necessary volunteers and would like help from the government in finding a way to make it easier to adopt stream sections for volunteer groups. Has been trying to do this for the last five years but needs help in cutting the red tape.

Ray Pendleton – recreational boating

Mr. Pendleton reminded the panel that there is a multi-million dollar marina at the end of the Ala Wai Canal and they are usually not included in Ala Wai projects. For example, last year’s dredging stopped at the Ala Moana Bridge. A larger-walled Canal, carrying more water, will damage the marina. The boats in the marina take the brunt of the damage. In the last ten years, during heavy rains, boats were carried away.

Karen AhMai – AWWA.

Ms. Ah Mai cited the importance of Mr. Yoshimi Endo's statements regarding the UH Quarry and Kaimukī High School where flood waters could be stored.

She talked of Ho'omaluhia where a huge berm was built. As a result, in the 1965 flood, the Kānewai area people had to climb out of their windows.

For emergency storage areas, consider places like the UH quarry, soccer fields, etc.; look at that type of large diversion. If bermed properly, this area could serve as a detention basin, and concerns of this area being flooded are not as high as other areas.

John Wilbur – citizen / paddler

Mr. Wilbur noted that a complete archaeology history of the watershed has not been done.

Regarding chemicals in Oahu's streams, he asked, "Where do we stand as a state in regard to the Federal Clean Water Act? Are we getting Federal funds because our streams are polluted? Is that why we are trying to clean the watershed area? Are water standards being addressed?"

He felt that this project is a step toward improvement and he appreciates it.

(Tsuchida responded that archaeological and cultural resources studies are currently being done. In regards to the Clean Water Act, while this project cannot solve all of the water quality issues for the state or for this area, we are working to do what we can so together, with other groups and agencies, we can work toward that goal)

Robert Rodman – Waikiki residents association

Mr. Rodman stated that several years ago he wrote to the Department of Land and Natural Resources in regard to flushing fresh water from the Kapahulu groin. In his plan, a one-way valve would flush water into the Canal twice a day with the tides. This could be done without the use of pumps 24 hours a day. The process is to drain out the Canal and bring fresh sea water in. It is a global solution.

There are a large number of pigs in upper Mānoa Valley and that is probably the reason for so much sediment; they are tearing up the forest. Need to look at this part of the problem too.

He is trying to get a grant to automate the cleaning of the debris trap under bridges. The area was not dredged and there is still a lot of sediment under there. If there is a flood, the flood waters would go over the bridge. He further noted that there are large blockages in the Canal.

Lance Grolla

The promenade is the most beautiful, supreme place. He questioned why we would plan to remove 20 feet of it and endanger the root system of the trees. He thinks it would be better to widen the Canal on the Waikīkī side instead.

(Chow responded that there are roadways and utilities involved across the Canal. The promenade side was proposed because of the ease in getting equipment in there and the lesser impacts on utilities.)

Petra Fletcher

Ms. Petra cited the beauty of the Amsterdam Canal as well as the deterioration of canals in Italy and Greece. Bad pollution kept tourists away for years. She feels that we need to talk to the proper people, the baby boomers who are creating the trash, not the children. We need a public education program.

Edgar Akina – from Kalihi

- Finish the Canal on the Diamond Head side.
- Do bio-remediation.
- Increase storm water capacity and get all issues addressed before proceeding with dredging. This project should have been coordinate with the previous dredging.

Mr. Akina stated that it was promised that the dredge material would be taken out to the ocean. He saw the barge; it was tilted and the sediment was spilling into the ocean, all the way to the disposal site. We need a new concept other than ocean disposal; we cannot take pollution from one area and take/spread it to another area.

He feels that we need to lessen the impact to Waikīkī but noted that flooding will still happen, there will still be damage. He questioned if it is worth all of this.

In regard to environmental justice, with a 100-year flood, all islands will be affected. He therefore feels that the flood problems should be addressed throughout all of the islands.

Michelle Matson – Kapi‘olani Park Advisory Council

Ms. Matson noted we need to be aware of historic elements of the Ala Wai Canal, e.g., two historic bridges, banyan, bridal path, trees.

On the east side, there is still part of a drainage area that feeds into Māmala Bay – Kaneloa (by Waikiki Shell). It is working wetland with native plants and animals that needs to be investigated.

Jackie Miller – UH Environmental Center

Ms. Miller asked if the study of the boundaries of the 100-year flood is close to reality at this stage?

(Chow responded that previously, a traditional Corps model was used; they are now using numeric models that provide more exact data. The boundaries are expected to be the same with the new model, but the flood depths will be more accurate.)

Steven Kubota

He feels that we need to develop material for teachers to use in the classrooms. In regard to environmental justice, he noted that there is a high population of low-income and Asian and Pacific Islanders in the affected area. Fifty percent of the students are from non-English speaking homes. Many residents are first generation families where children are the translators to their parents. Need to remember that not everyone speaks English.

Yoshimi Endo

Makiki Stream runs below the H-1 Freeway and with a large flood, it will break through and create impassable conditions. The area between Roosevelt and Stevenson schools will need a bridge.

Ron Lockwood – McCully/Mō‘ili‘ili Neighborhood Board

In regard to Environmental Justice, there are 16 different ethnic groups in the public schools in his area. Fifty to 70 percent of the students are on the reduced lunch program.

About a year ago their Neighborhood Board set the Ala Wai Canal project as a recurring item on their regular monthly agenda. They meet on every first Thursday of the month. All are welcome to attend to discuss this continuous issue. He suggested that members of the panel could attend as liaisons to take the information back to their agencies.

Once everyone had an opportunity to speak, Bruce Tsuchida thanked participants for attending and voicing their opinions and concerns. He reminded everyone that comment sheets may be filled out and submitted to the project team or mailed in at a later date. Official comments on the EIS Preparation Notice are due on July 14, 2004.

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ALA WAI WATERSHED PROJECT

NOTES FROM ENVIRONMENTAL IMPACT STATEMENT SCOPING MEETING

Tuesday, October 21, 2008

An Environmental Impact Statement (EIS) Scoping Meeting was held on October 21, 2008. The purpose of this meeting was to inform the community that the Ala Wai Watershed Project will be developing an Environmental Impact Statement and to allow for public input on possible actions and impacts. Approximately 46 Ala Wai Watershed residents, community members, and other stakeholders attended the meeting. In addition to these attendees, agency representatives included the Federal Natural Resources Conservation Service; the State Departments of Land and Natural Resources (DLNR), Health, and Civil Defense; and the City Departments of Environmental Services (ENV) and Planning and Permitting. Also present were elected officials, or their representatives, from the State Senate, House of Representatives, City Council, and Neighborhood Board.

I. SLIDESHOW PRESENTATION

Cindy Barger from the U.S. Army Corps of Engineers (USACE) welcomed everyone and introduced the project team, including Federal, State and City partners. Gerald Takayesu (ENV) and Carty Chang (DLNR) said a few words as project sponsors. Ms. Barger then presented the project background, including the project goal and objectives, location, previous studies, current and next steps, and some of the other projects that we are currently coordinating with.

Sherri Hiraoka from Townscape, Inc. explained the EIS process and Bob Bourke from Oceanit presented some background data on flooding and ecosystem restoration in the watershed, as well as some preliminary measures that are currently being considered. Ms. Hiraoka then discussed some issues that the project team will need to consider when determining what measures might be acceptable for this watershed and indicated the types of impacts that the team would be studying as a part of the EIS process. Please refer to the slideshow handout for highlights from the presentation.

A few questions were asked about the project background:

What is the DLNR's chute structure project?
After the 2004 flood, DLNR received some funds from the Federal Emergency Management Agency (FEMA) to develop measures to mitigate the flooding that occurred from the overtopping of Mānoa Stream at Woodlawn Drive. The DLNR and FEMA are currently working on the design of a chute structure to improve flow under the Woodlawn Drive Bridge.

What agency is the accepting agency for the EIS?
In Hawai'i's environmental review process, "acceptance" is defined as "a formal determination that the [EIS] fulfills the definition of an environmental impact statement, adequately describes identifiable environmental impacts, and satisfactorily responds to comments received during the review of the statement." The "accepting authority" therefore determines the final acceptability of the document, in this case, the EIS. Based on the guidance in Hawai'i Revised Statutes §343-5(b)(2) and Hawai'i Administrative Rules §11-200-4, the accepting authority for the Ala Wai Watershed Project is the Governor of the State of Hawai'i, or the Governor's authorized representative, because state lands and funds will be used.

In accordance with federal regulations (40 CFR Parts 1500-1508 and ER 200-2-2), USACE is the lead federal agency. As lead federal agency, USACE will be the decision maker and sign the Record of Decision (ROD). While there is no "accepting agency" under the federal process, EPA in accordance with Council of Environmental Quality (CEQ) regulations, reviews and rates all EISs. EPA ratings reflect the strength with which the EIS identifies and recommends corrective action for significant environmental impacts associated with any proposal. Review of the adequacy of the information and analysis contained in the draft EIS will be done as needed to support this objective.

What is the total cost of the entire project from its start in 1998?
The total project planning cost is $5.545 million, including the work that was completed from 1998 through the end of this feasibility phase. The cost of design and construction will be determined based on the preferred alternative.

II. BREAKOUT GROUPS

Meeting participants separated into breakout groups to discuss issues, concerns, and ideas for six neighborhoods within the project area: (A) Makiki, (B) Mānoa, (C) Pālolo, (D) Ala Moana-McCully-Mōʻiliʻili, (E) St. Louis-Kapahulu-Diamond Head, and (F) Waikīkī. The following is a summary of the comments, concerns, questions, and ideas that were raised in each of the breakout groups.

A. Makiki

- *Why have man-made drainage works failed?*
- *Residents are frustrated! They feel that existing drainage systems are not being maintained, and the result is flooding their properties.*
- *The planning team needs to identify what needs to be done to ensure that the existing drainage system works as it should.*
- *Address maintenance issues. We need regular maintenance from government and private owners.*
- *Hold meetings in the community to get real grass roots input.*
- *Make the project relevant to the average citizen*
- *Rockfalls are a problem in Mānoa Valley and sedimentation is a problem in the streams.*
- *Private ownership of the stream is a tough issue – what are the responsibilities and liabilities of private owners?*
- *What is the availability of funds for the project?*
- *What storm strengths are flood hazard reduction measures designed to withstand?*
- *Why did flooding occur in Mānoa in 2004 only and not in other years?*
- *How was the culvert under H-1 sized?*
- *Is there typically flooding at the stream confluences?*

B. Mānoa

- *Concerns about individual property responsibilities, limits of property. Land owners must know their rights and responsibilities.*
- *How are you going to deal with the 150-200 individual [private] property owners?*
- *Concern about measures being forced onto individual and private residences and businesses. Rumor about a drainage pipe being put in underneath the Mānoa Marketplace.*
- *Installation of structures now could affect or limit future development.*
- *Maintenance and safety plan responsibilities, i.e. rapid response with heavy equipment.*
- *Suggest that the area of the stream become the concern of one entity (i.e., a land trust)*
- *Intermittent streams flooding/damage occurred in the 2004 flood, upper Woodlawn*
- *UH Mānoa Landscape Advisory Committee: planning in coordination with UH planning*
- *Are survey teams going out and how often?*
- *Concern about feral pigs*
- *Concern about safety measures for any work, structures, etc. due to children "exploring."*
- *Community education needed*

C. Pālolo

- *Everybody drains into the stream, but there is very little management of the stream.*
- *House was inhabited in 1959, and every time there is rain, it is flooded. The stream was pushed to our property; 3,000 square feet of land was lost because the property on the other side of the stream put walls on the stream bank!*
- *People still get permits to develop the side of the stream.*
- *Now we have a retaining wall that has been okay, but recently the seams are separating. Whose responsibility is it for maintaining the retaining wall?*
- *What are the rights and responsibilities of the stream owners?*

- *Lots of debris and graffiti on the retaining wall*
- *People throw things into the stream*
- *It seems like the City has a policy of maintaining the channel from a certain point down, even if it is privately owned. Problem: can't figure out where that "point" is. Could it be easement lands that the City worked on?*
- *Problem of the ownership of stream land.*
- *Children were able to catch fish in the stream (at least small fish to put into an aquarium), not anymore.*
- *Natural bed on some parts of the stream by Chaminade University, but it's been decreasing in size.*
- *Walls on private lands: if the City builds the walls for the streams, the City should pay the landowner.*
- *There should be a better way of announcing this kind of project so more landowners can come and their concerns can be heard.*
- *Someone should randomly check what the problems are along the stream.*
- *On 10th Avenue, there was recently a rockfall [in the Kuahea Street-Yvonne Place area].*
- *If there's a tsunami, there are different reports on the reach of the inland inundation zone. Want to confirm which one is the right one (concern about the location of the property).*
- *What happens to existing conditions if we factor in tsunami impacts? UH has Tsunami Research Center that may be a good resource.*
- *Big facilities like condos have greater ability to retrofit drainage systems; need some kind of ordinance to force these large facilities to improve drainage.*
- *Flood management and ecosystem restoration are two possibly conflicting objectives of this project.*
- *Upper Pālolo Stream doesn't have the same level of natural/native ecosystem health, when compared to Mānoa. Opportunities for ecosystem restoration should be assessed.*
- *Quality of water in the pipe? Do I get water from within the Pālolo watershed through the BWS system?*
- *What is in the [Ka'au] crater?*
- *Better treatment of both storm and non-storm water discharge (e.g., residue water from car washing, etc.)*

- *All of the lands along the stream should ideally be turned back to natural ecosystems but there is a problem with ownership. Easement credits can be considered to solve this problem.*
    - *Concern about land takings if an easement program is carried out.*
    - *Would easements be forced on the landowner?*
    - *What exactly would the easement do?*

D. Ala Moana-McCully-Mōʻiliʻili

- *Maintenance!*
- *Priority of Improvement: Makiki, Hausten Ditch, Mānoa-Pālolo Drainage Canal*
- *Community Involvement*
    - *Neighborhood Boards*
    - *Representatives*
    - *Religious Groups/Boys and Girls Clubs*
    - *Local Interest/Scientific Groups*
- *Steps that enter the [Ala Wai] Canal are covered with trash and mud.*
- *Canal near Jack in the Box is too low and the walls are not the same height. Will capacity be increased?*
- *Existing storm drains need debris collectors – too much trash.*
- *Street cleaning removes pollutants - why not do more often?*
- *Pālolo junction [Mānoa-Pālolo Canal near Kūhiō School] needs relief – gets flooded. Add additional drainage retention.*
- *Refit cisterns to allow seepage or use pervious pavement. Try to keep water on residential lots.*
- *Other entities that we should coordinate with*
    - *UH Landscape Advisory Committee*
    - *City Parks and Recreation (safety): educate workers who work the grounds*
    - *Large landowners and land developers*
    - *Keep everyone informed – need to emphasize everyone who has a responsibility*

- *Community members contend that local drainage (storm drain) systems are inadequate to handle even moderate rainfall and runoff. Potential measures need to be evaluated with respect to local drainage needs and conditions.*
- *Box jellies have been observed above Date Street.*
- *Golf Course might incorporate water features*
- *Is it possible to use pumps like in New Orleans?*
- *Add second outlet/reservoir for the [Ala Wai] Canal*
- *Restore native species (akulikuli)*
- *Provide shade and cover over the stream*
- *With concrete structures, try to add natural-type features, or at least a native look*
- *Water quality: concern about bacteria from feral cats*
- *Redevelop Alenaio Ditch*
- *Where do we get sandbags for flood protection?*
- *Screen over Hausten Ditch was removed recently – needs to be replaced.*
- *Control/eradicate alien species*
- *How much is for protection of Waikīkī? It is the economic engine of the state.*
- *Archway near Waikīkī entrance could have walls heightened.*
- *Take advantage of all large open spaces.*

E. St. Louis-Kapahulu-Diamond Head

- *St. Louis Heights has no storm drains, water is channeled by streets. This area needs stormwater flow management.*
- *St. Louis/Roberts Drive outlets to a concrete chute at Waʻahila Valley. This creates problems of erosion and sediment discharge in the valley.*
- *Frank Street has storm drains but manhole covers pop off during heavy rains.*
- *Feral pigs at Robert Place, UH, and Waʻahila Valley.*
- *Storm runoff from St. Louis Heights and Waʻahila Valley often crosses over Dole Street, depositing rocks and trash and causing problems on the ma kai shoulder and in the UH Hawaiian Studies building.*
- *At dead end streets where grade flattens out*

- *Board of Water Supply recently replaced a corroded and plugged two-inch pipeline with a four-inch pipeline.*
- *Increased water pressure due to pipeline improvements by BWS in St. Louis Heights have created problems.*
- *Maintain crown in the road for water to flow, but in heavy rain street will not convey water. In some St. Louis Heights areas, the repeated paving and patching have filled the roadway and have eliminated the curbs and gutters.*
- *Use the undeveloped Waʻahila Valley area, above the faculty housing, for storage of water and debris catchment.*
- *Fresh water ʻopihi live on algae on the limestone and were found in the reach between the golf course and Kaimukī High School.*
- *Aboriginal rights were exercised by some for collecting imu stones for home use at the stream intersection of Mānoa with Pālolo.*
- *Ditch and wetland area behind the Waikīkī Shell has:*
    - *Maintenance problems*
    - *Stagnant water*
    - *Homeless*
- *Bertram Street and St. Louis Drive: water goes into homes.*
    - *Residents use sand bags on their own to divert the flood waters*
- *Fire hazard on east side of the St. Louis area [along Kalaepōhaku Ridge].*
- *Kānewai Field – recent repair of the bank near Koali Road required the stream flow to be routed through the field by Hōkūlani School. It created odors and damaged the field so children could not use it. This should be considered if other fields are used for water storage.*
- *Agencies need to be proactive, rather than reactive.*
- *Issue of privately-owned streets in Kapahulu where the City will not make improvements. Most of Kapahulu Streets do not meet current City requirements.*
- *There is a tunnel at Waiʻalae Avenue near St. Louis School – what is its purpose? Is it a part of the storm drain system?*
- *Check into the work that the STEM Program at Kapiʻolani Community College is doing in the area*
- *Herbert Street: in heavy rains water flows down the street*

F. Waikīkī

- *Flooding is the primary issue, but a "wall" around the Ala Wai Canal is not wanted. A "wall" should be a last resort and even then may not be acceptable.*
- *Flooding from the land side and from the ocean (global warming and sea level rise) is a major concern. The group understands that the USACE investigation will consider a "without project condition extending 50 years into the future" and that sea level rise of several feet has been postulated for this time frame by some researchers.*
- *If Waikīkī is flooded, there would be a huge impact on Hawai'i's entire economy. The estimated damages of $135 million as stated in the presentation may be grossly underestimated. After all, if there was $85 million damage at UH Mānoa, just imagine what would happen to Waikīkī, especially if it took several weeks to restore infrastructure and clean up.*
- *If Waikīkī is flooded, there would be a severe impact on the community as a whole because of job loss and tax losses to the State.*
- *USACE should look at less "invasive" measures first, such as widening the Ala Wai Canal as shown in the presentation to improve the capacity of the Canal.*
- *Work in the Canal should include improvements to water quality, such as the seawater flushing which has been proposed in the past.*
- *While a second Ala Wai Canal outlet that discharges in the vicinity of the Natatorium might help with flooding, it would pollute and contaminate Waikīkī beaches, which is intolerable. If this measure is considered, special efforts must be done to study the impacts on reefs, surfers, surf, and beaches because currents flow from east to west along shore in this area.*
- *Consider using Ala Wai Golf Course, Ala Moana Park, and Kapi'olani Park as detention areas. These areas will flood under most conditions anyway, and their use as detention may be a necessity because it is easier to clean up a golf course or park than to clean up houses or Waikīkī.*
- *Can we inject stormwater into caverns in McCully-Mō'ili'ili? Those caverns may not have excess capacity and would be filled up already under such severe rainstorm conditions.*
- *The flow velocity out of the Ala Wai Canal has been so severe sometimes that it damaged piers and boats in the Small Craft Boat Harbor. If more water is to be discharged, the impacts on the Harbor need to be considered.*
- *Property owners have a responsibility to maintain their stream banks, which may produce some of the sediment that fill up the Canal. Their interests need to be balanced with those of the community for flood control.*

III. QUESTIONS AND COMMENTS (VERBAL)

A question and answer session was held after all of the breakout groups shared some of their comments. The comments and questions that were asked are listed below, along with the responses that were given. Expansion of the responses provided at the meeting is provided where appropriate for the benefit of the public.

The project is not addressing the issues of nearshore waters and beach users.
The project analysis does extend past the shoreline to the nearshore waters. We have invited some of those coastal user groups to the meeting, but it is a good reminder to not forget the coastal issues. The Waikīkī group did discuss how a measure such as creating a second outlet from the Ala Wai Canal through the Natatorium area might impact Waikīkī beaches.

Additional Detail: The Project Team is also coordinating with stakeholders that have studied the Waikīkī area, such as the DLNR Office of Conservation and Coastal Lands and the University of Hawai'i School of Ocean and Earth Science and Technology (UH SOEST).

Are there any projects or programs to address flooding that can be done right now, given that implementation of this project is still four years away?
Flood insurance can be quickly obtained at a moderate cost. If you think that you might be exposed to a flood risk or hazard, consider purchasing flood insurance. You do not need to be in a designated flood zone to do so.

Additional Detail: The planning process will identify activities and mechanisms that may be implemented by other federal, state, local, and non-governmental programs to address problems and concerns. We will work with our partners to identify opportunities that may be implemented in the near future, separate from this planning process. Such actions include relaying the specific locations of maintenance concerns to the City and County.

The City Department of Emergency Management should be a partner in this project.

The project is currently reaching out to agencies that are not listed as formal partners. We will contact the City Department of Environmental Management to seek their involvement. Community members are encouraged to recommend partnerships and to indicate your support for the project to agencies.

Sea level rise should be taken into consideration.

The project is required to look at a "without project condition" and assess what might happen in the next fifty years without the project. Sea level rise is a part of that assessment and will also be included in the assessment of different alternatives.

Additional Detail: We have been working with UH SOEST to gain their expertise in calculating the potential sea level rise and its potential impacts on this study.

Is "No Action" going to be considered as one of the alternatives in the EIS?

Yes, the "No Action" alternative will be considered; it is a requirement of all Federal EISs. The "without project condition" would be the result of the "No Action" alternative. The purpose of the "No Action" alternative is to provide a benchmark from which to compare the magnitude of environmental effects of the action alternatives. It also helps to identify reasonable alternatives that are outside the jurisdiction of the lead agency.

IV. QUESTIONS AND CONCERNS (WRITTEN)

Some questions and concerns were written on the green comment sheets provided or index cards and submitted to the project team, either at the meeting, or at a later date. This is a summary of those comments and questions. The responses provided below were not given at the meeting because most of the questions were submitted after the meeting concluded.

Sand bags for big rains

This information will be relayed to the State Civil Defense and the City Department of Environmental Management for their information.

They half okole cleaned Hausten, Isenberg, and Kapiolani; never replaced screen.
This information will be relayed to the City for their information.

When drains have a preventative [screen] in front; dirt and debris pile up and harden so now what?
This information will be relayed to the City for their information.

Curbs, mud, and debris build up when street cleaner [comes through] due to parked cars - unable to do their job.
This information will be relayed to the City for their information.

Clean Canal bus stop
This information will be relayed to the City for their information.

Clogged drains (curbside debris, leaves, mud) flood gutters
This information will be relayed to the City for their information.

There needs to be better notification to affected homeowners so they can participate in these decisions. I accidentally read your small meeting notice in the Advertiser. Every homeowner bordering the streams should be aware of their options.
Thank you. Based on this and other comments, the planning team will re-evaluate the public involvement plan to see how we can improve our coordination and notification to the community on the status of the project.

Define major and minor, large or small potential environmental hazards, and developmental growth that must be addressed before social and cultural impacts would be affected horribly.
Thank you. As we begin to develop alternatives and analyze their potential impacts, we will evaluate these concerns as well.

Future flood plans for Makiki Stream, ex: deepening streambed, dredging debris measures, etc.

Withstanding all agencies, Federal, State, City, etc., what types of water control measures are proposed…Makiki, Mānoa, etc.

At this time, we do not have specific control measures proposed for these areas beyond the general concepts discussed in the Scoping Meeting presentation. We will be developing these measures in more detail as we go forward from the Scoping Meeting. We will keep communication open with the public during this process and will hold a full public workshop on alternatives in Fall 2009.

Short term goals?

Thank you. As we move forward on developing the alternatives, we will identify potential measures that could either be implemented separately from the study by other partners or authorities. We will also identify potential measures or alternatives that could be implemented in the first phase of construction and seek the public's input and comment on a proposed phasing.

Storm drainage capacity of existing storm drains are outdated for McCully/Moiliili and overflowing into streets. Even during minor floods water backs up.

Thank you. As part of the existing hydrology evaluations conducted this past year, we have surveyed the existing drainage in the watershed. As part of the study, we will evaluate potential options and opportunities to update and improve the drainage.

Update all agencies of property ownership of affected areas and mandate a list for future proposals, updates, and "keep them informed!"

Thank you. Based on this and other comments, the planning team will re-evaluate the public involvement plan to see how we can improve our coordination and notification to the community of the status of the project.

One issue that was not discussed was recreation. One of the goals might be to make the canals and streams fishable. A more realistic goal might be to have running paths and bike lanes along the Ala Wai Canal and streams where feasible. This would foster greener living and better appreciation of the aquatic resources by the community. Great examples include Four Mile Run in Arlington, VA; St. Paul MN; Madison, WI. These serve as greenways and areas which can accommodate overflowing storms. Having a green loop around the Ala Wai Canal, into the golf course and bike/pedestrian bridge over the Ala Wai should be incorporated in any landscaping/riparian area management plan.
Thank you. We will look at the opportunities of incorporating this idea and other recreational opportunities in the planning study.

Has consideration been given to utilize Mānoa and perhaps Pālolo stream(s) as bikeways and give residents and students an opportunity to travel from Mānoa Marketplace to the Ala Wai Canal without crossing the street? Not only do people have a safe route to utilize, but it could open another source of funding for the project (transportation) at the Federal and State level.
Increasing recreational opportunities is an objective of the Ala Wai Watershed Project. With all the potential alternatives, we will look at the opportunities to increase recreational use at the proposed project sites including potential bike ways.

Propose a bikeway along Mānoa Stream as a very inexpensive and easy solution conveying UH students from UH to Waikīkī.

- ***Restore a grade-level bridge at the previous bridge crossing at Kānewai field***
- ***At the junction of the Pālolo and Mānoa Streams on Koali Road improve the already existing ramp to go down into the stream bed***
- ***The bike path will stay on the Diamond Head side of the stream--an elevated (1 foot is probably fine as almost all of the year the stream water is below this level and also most flow is in the center of the streambed.***
- ***The path runs under the tangle of streets and freeway on and off ramps.***
- ***Another ramp can be located on the Kaimukī High School property near Kapiʻolani Blvd.***

- ***An optional additional ramp can be located near King street***
- ***The rest of the bikeway is on the existing bike path makai to Date Street***
- ***Date Street is the only street to be crossed (or could the bike path go under?)***
- ***The bikers/walkers can then travel either on the existing Date Street path toward Diamond Head ending at the Waikīkī Library or go 'Ewa and traverse the Ala Wai Park to McCully Street.***

Three foot flood walls along the makai side of the Ala Wai Canal would protect the state's economic engine as well as beautify the canal wall. Storm surges drive ocean and brackish water up the canal and the Mānoa Stream. The water level rise overtopping the banks and popping the storm drain covers.

V. CLOSING

Cindy Barger closed the meeting by reminding everyone of the ways to remain involved in the planning process, including upcoming meetings and documents. Comments from this EIS Scoping Meeting will be added to the public input already gathered in the previous 2004 Ala Wai Canal Project EIS Scoping Meeting, the 2007 Mānoa Watershed Project EIS Scoping Meeting, and the various other stakeholder meetings and correspondence from these two complementary projects. The comments will be addressed, to the extent possible, in the Draft Environmental Impact Statement. If there any further comments, please feel free to send them in using the following contact information:

Cindy Barger, Project Manager
Civil and Public Works Branch
US Army Corps of Engineers, Honolulu District
CEPOH-PP-C, Room 307, Building 230
Fort Shafter, HI 96858
Phone: (808) 438-6940
Email: Ala-Wai@usace.army.mil

Additionally, a project website will be made available in the near future. Thank you to everyone who attended and participated in this meeting!

Appendix G8
Notice of Intent (2004 and 2008)

Normal and Adulterated Urine,'' filed June 18, 2003. Foreign rights are also available (PCT/US03/06283). The United States Government, as represented by the Secretary of the Army, has rights in this invention.

ADDRESSES: Commander, U.S. Army Medical Research and Materiel Command, ATTN: Command Judge Advocate, MCMR–JA, 504 Scott Street, Fort Detrick, Frederick, MD 21702–5012.

FOR FURTHER INFORMATION CONTACT: For patent issues, Ms. Elizabeth Arwine, Patent Attorney, (301) 619–7808. For licensing issues, Dr. Paul Mele, Office of Research & Technology Assessment, (301) 619–6664, both at telefax (301) 619–5034.

SUPPLEMENTARY INFORMATION: The present invention relates to methods and means for detecting oxidants in urine. More specifically, the present invention relates to methods and means for spectroscopic detection of oxidants and oxidizing agents in urine.

Brenda S. Bowen,

Alternate Army Federal Register Liaison Officer.

[FR Doc. 04–13270 Filed 6–10–04; 8:45 am]

BILLING CODE 3710–08–M

DEPARTMENT OF DEFENSE

Department of the Army

Availability for Non-Exclusive, Exclusive, or Partially Exclusive Licensing of U.S. Patent Application Concerning a Method and Apparatus for Generating Two-Dimensional Images of Cervical Tissue From Three-Dimensional Hyperspectral Cubes

AGENCY: Department of the Army, DoD.

ACTION: Notice.

SUMMARY: In accordance with 37 CFR 404.6 and 404.7, announcement is made of the availability for licensing of U.S. Patent Application No. 10/051,286 entitled ''A Method and Apparatus for Generating Two-Dimensional Images of Cervical Tissue from Three-Dimensional Hyperspectral Cubes,'' filed January 22, 2002. Foreign rights are also available (PCT/US02/01585). The United States Government, as represented by the Secretary of the Army, has rights in this invention.

ADDRESSES: Commander, U.S. Army Medical Research and Materiel Command, ATTN: Command Judge Advocate, MCMR–JA, 504 Scott Street, Fort Detrick, Frederick, MD 21702–5012.

FOR FURTHER INFORMATION CONTACT: For patent issues, Ms. Elizabeth Arwine, Patent Attorney, (301) 619–7808. For licensing issues, Dr. Paul Mele, Office of Research & Technology Assessment, (301) 619–6664, both at telefax (301) 619–5034.

SUPPLEMENTARY INFORMATION: This invention relates to detection and diagnosis of cervical cancer. More particularly, this invention relates to methods and devices for generating images of the cervix, which allow medical specialists to detect and diagnose cancerous and pre-cancerous lesions.

Brenda S. Bowen,

Alternate Army Federal Register Liaison Officer.

[FR Doc. 04–13269 Filed 6–10–04; 8:45 am]

BILLING CODE 3710–08–M

DEPARTMENT OF DEFENSE

Department of the Army, Corps of Engineers

Intent to Prepare an Environmental Impact Statement for the Ala Wai Canal Project, Hawaii

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: Pursuant to the National Environmental Policy Act (NEPA), the U.S. Army Corps of Engineers and the State of Hawaii Department of Land and Natural Resources will prepare an Environmental Impact Statement (EIS) for the alternatives and potential impacts associated with the Ala Wai Canal Project Feasibility Study. This effort could result in a multi-purpose project being proposed under Section 209 of the Flood Control Act of 1962 (Pub. L. 87–874) and will incorporate both flood hazard reduction and ecosystem restoration components into a single, comprehensive strategy.

DATES: In order to be considered in the draft EIS (DEIS), comments and suggestions should be received no later than July 14, 2004.

ADDRESSES: Send written comments to U.S. Army Corps of Engineers, Honolulu District, ATTN: Mr. Derek Chow, Senior Project Manager, Civil and Public Works Branch (CEPOH–PP–C), Rm 312, Bldg 230, Fort Shafter, HI 96858–5440.

FOR FURTHER INFORMATION CONTACT: Questions or comments concerning the proposed action should be addressed to Mr. Derek Chow, Project Manager, U.S. Army Corps of Engineers, Honolulu District, Civil Works Branch, Building 230, Fort Shafter, HI 96858–5440, telephone 808–438–7019, E-mail: *Derek.J.Chow@poh01.usace.army.mil* or Mr. Andrew Monden, Planning Branch Head, State of Hawaii Department of Land and Natural Resources, Engineering Division, P.O. Box 373, Honolulu, HI 96809, telephone 808–587–0227, E-mail: *Andrew.M.Monden@hawaii.gov.*

SUPPLEMENTARY INFORMATION: The 11,069-acre Ala Wai watershed is located in the southern portion of the island of Oahu and includes the sub-watersheds of Makiki, Manoa, Palolo, and Waikiki. Approximately 1,746 structures exist within the designated 100-year flood plain. The proposals being investigated incorporate both flood hazard reduction and ecosystem restoration into a single, comprehensive strategy. The Ala Wai Canal watershed is highly urbanized and characterized by significant environmental degradation, including heavy sedimentation, poor water quality, lack of habitat for native species, and a prevalence of alien species. Additionally, there exists a high potential for massive flood damage to the densely populated and economically critical area of Waikiki and the adjacent neighborhoods of McCully and Moilili. The EIS and the Feasibility Study for the Ala Wai Canal Project will be conducted concurrently. The EIS will evaluate potential impacts to the natural, physical, and human environment as a result of implementing any of the proposed flood hazard reduction and ecosystem restoration alternatives arising during the study.

Goals of the Ala Wai Canal Feasibility Study are to identify alternatives that will (1) Protect Waikiki and the surrounding areas from the 100-year flood event, (2) improve the migratory pathway for native amphidromous species, (3) reduce sediment buildup in the streams and Ala Wai Canal, and (4) enhance the physical quality of existing aquatic habitat for native species. Anticipated significant issues identified to date and to be addressed in the EIS include: (1) Impacts on flood control, (2) impacts on stream hydraulics, (3) impacts on fish and wildlife resources and habitats, (4) impacts on recreation and recreation facilities, and (5) other impacts identified by the Public, agencies, or USACE studies. Evaluation of the flood hazard reduction alternatives will take into account a cost-benefit analysis and minimization of impacts to social resources, aesthetics, recreation, historic and cultural resources, and native species habitat. Evaluation of the ecosystem

restoration alternatives will be based on the area of habitat they create, improve, or provide access to, as well as their ability to complement flood hazard reduction measures and minimize adverse impacts to social, economic, cultural, historic, and recreational resources.

A public scoping meeting will be held in the summer of 2004. The date and time of this meeting will be announced in general media and will be at a time and location convenient to the public. Interested parties are encouraged to express their views during the scoping process and throughout the development of the alternatives and the EIS. To be most helpful, comments should clearly describe specific environmental topics or issues which the commenter believes the document should address.

The DEIS is anticipated to be available for public review in early 2005, subject to the receipt of federal funding.

Brenda S. Bowen,

Alternate Army Federal Register Liaison Officer.

[FR Doc. 04–13271 Filed 6–10–04; 8:45 am]

BILLING CODE 3710–NN–M

DEPARTMENT OF EDUCATION

Office of Special Education and Rehabilitative Services; Overview Information; Technical Assistance and Dissemination To Improve Services and Results for Children With Disabilities—IDEA General Supervision Enhancement Grant; Notice Inviting Applications for New Awards for Fiscal Year (FY) 2004

Catalog of Federal Domestic Assistance (CFDA) Number: 84.326X.

Dates:

Applications Available: June 14, 2004.

Deadline for Transmittal of Applications: July 23, 2004.

Deadline for Intergovernmental Review: September 21, 2004.

Eligible Applicants: State educational agencies (SEAs), local educational agencies (LEAs), institutions of higher education (IHEs), other public agencies, nonprofit private organizations, for-profit organizations, outlying areas, freely associated States, and Indian tribes or tribal organizations.

Additional information concerning eligibility requirements is provided elsewhere in this notice under Section III., 1.

Eligible Applicants.

Estimated Available Funds: $6,700,000. Additional information concerning funding amounts is provided elsewhere in this notice under Section II. Award Information.

Estimated Average Size of Awards: See Section II. Award Information.

Estimated Number of Awards: 13. Additional information concerning the number of awards is provided elsewhere in this notice under Section II. Award Information.

Note: The Department is not bound by any estimates in this notice.

Project Period: October 1, 2004–September 30, 2005.

Full Text of Announcement

I. Funding Opportunity Description

Purpose of Program: This program provides technical assistance and information that (1) support States and local entities in building capacity to improve early intervention, educational, and transitional services and results for children with disabilities and their families; and (2) address goals and priorities for improving State systems that provide early intervention, educational, and transitional services for children with disabilities and their families.

This competition contains one funding priority with four focus areas addressing services provided under Parts B and C of the Individuals with Disabilities Education Act, as amended (IDEA).

Priority: In accordance with 34 CFR 75.105(b)(2)(iv), this priority is from allowable activities specified in the statute (see sections 661(e)(2) and 685 of the IDEA).

Absolute Priority: For FY 2004 this priority is an absolute priority. Under 34 CFR 75.105(c)(3), we consider only applications that meet this priority.

This priority is:

Technical Assistance and Dissemination To Improve Services and Results for Children With Disabilities—IDEA General Supervision Enhancement Grant

Background of Priority: Consistent with the No Child Left Behind Act of 2001 (NCLB) and its focus on children with disabilities meeting State educational achievement standards, many States have begun the challenging but important process of—

(1) Developing outcome indicators for children with disabilities;

(2) Developing outcome indicators for infants and toddlers with disabilities;

(3) Developing or redesigning State academic standards and assessment systems using universal design principles; and

(4) Developing or enhancing State systems to disseminate research-based promising practices in education and early intervention.

States may obtain technical assistance on these processes from a variety of sources, including the Office of Special Education Programs (OSEP) funded Technical Assistance and Dissemination Centers such as the National Center on Special Education and Accountability Monitoring, the National Center on Educational Outcomes, the Early Childhood Outcomes Center, the National Dissemination Center for Children with Disabilities, the Regional Resource Centers, and other sources of technical assistance. States may find the technical assistance provided by the Early Childhood Outcomes Center particularly useful with regard to early intervention and preschool outcomes.

Statement of Priority: This priority is to support projects that address the technical assistance and dissemination needs of States to improve services and results for children with disabilities in one or more of the following four focus areas.

Focus 1: Developing or Enhancing Part B State Outcome Indicators and Methods To Collect and analyze Part B outcome indicator data

Background of Focus: The development of outcome indicators, against which progress can be measured, is the cornerstone of any accountability system. State performance reports, self-assessments, and other extant data show that most States, as well as their LEAs, have not developed outcome indicators for children with disabilities served under Part B of IDEA or methods to collect and analyze Part B outcome indicator data, especially for preschool children. Therefore, the States lack the capacity to collect sufficient data to determine the impact of special education services.

Statement of Focus: This focus supports development or enhancement of Part B State outcome indicators and methods to collect and analyze Part B State outcome indicator data. These indicators must provide information about one or more of the following:

(a) The impact of Part B preschool services (age 3–5) on children with disabilities at the State and LEA level.

(b) The impact of Part B services on school-aged children with disabilities at the State and LEA level.

(c) Post-secondary education and employment outcomes (including the impact of Part B services on these outcomes) at the State and LEA level using indicators that have been shown to lead to positive post-secondary school outcomes.

The Commission's rules require futures commission merchants and introducing brokers: (1) To provide their customers with standard risk disclosure statements concerning the risk of trading commodity interests; and (2) to retain all promotional material and the source of authority for information contained therein. The purpose of these rules is to ensure that customers are advised of the risks of trading commodity interests and to avoid fraud and misrepresentation. In addition, the Commission's rules impose obligations on contract markets that are designed to avoid manipulation and fraud. In order to ensure compliance with these rules, the Commission requires the information whose collection and dissemination is required under 17 CFR 1.60.

The Commission estimates the burden of this collection of information as follows:

ESTIMATED ANNUAL REPORTING BURDEN

17 CFR section	Annual number of respondents	Total annual responses	Hours per response	Total hours
1.60	235	1	.10	.10

There are no capital costs or operating and maintenance costs associated with this collection.

Dated: September 26, 2008.

David Stawick,

Secretary of the Commission.

[FR Doc. E8–23220 Filed 10–1–08; 8:45 am]

BILLING CODE 6351–01–P

COMMODITY FUTURES TRADING COMMISSION

Sunshine Act Meetings

TIME AND DATE: 11 a.m., Wednesday, October 29, 2008.

PLACE: 1155 21st St., NW., Washington, DC, 9th Floor Commission Conference Room.

STATUS: Closed.

MATTERS TO BE CONSIDERED: Enforcement Matters.

CONTACT PERSON FOR MORE INFORMATION: Sauntia S. Warfield, 202–418–5084.

Sauntia S. Warfield,

Staff Assistant.

[FR Doc. E8–23418 Filed 9–30–08; 4:15 pm]

BILLING CODE 6351–01–P

COMMODITY FUTURES TRADING COMMISSION

Sunshine Act Meetings

TIME AND DATE: 11 a.m., Friday, October 24, 2008.

PLACE: 1155 21st St., NW., Washington, DC, 9th Floor Commission Conference Room.

STATUS: Closed.

MATTERS TO BE CONSIDERED: Surveillance Matters.

CONTACT PERSON FOR MORE INFORMATION: Sauntia S. Warfield, 202–418–5084.

Sauntia S. Warfield,

Staff Assistant.

[FR Doc. E8–23419 Filed 9–30–08; 4:15 pm]

BILLING CODE 6351–01–P

COMMODITY FUTURES TRADING COMMISSION

Sunshine Act Meetings

AGENCY HOLDING THE MEETING: Commodity Futures Trading Commission

TIME AND DATE: 11 a.m., Friday, October 17, 2008.

PLACE: 1155 21st St., NW., Washington, DC, 9th Floor Commission Conference Room.

STATUS: Closed.

MATTERS TO BE CONSIDERED: Surveillance Matters.

CONTACT PERSON FOR MORE INFOR MATION: Sauntia S. Warfield, 202–418–5084.

Sauntia S. Warfield

Staff Assistant.

[FR Doc. E8–23420 Filed 9–30–08; 4:15 pm]

BILLING CODE 6351–01–P

COMMODITY FUTURES TRADING COMMISSION

Sunshine Act Meetings

AGENCY HOLDING THE MEETING: Commodity Futures Trading Commission

TIME AND DATE: 11 a.m., Friday, October 3, 2008.

PLACE: 1155 21st St., NW., Washington, DC, 9th Floor Commission Conference Room.

STATUS: Closed.

MATTERS TO BE CONSIDERED: Surveillance Matters.

CONTACT PERSON FOR MORE INFORMATION: Sauntia S. Warfield, 202–418–5084.

Sauntia S. Warfield,

Staff Assistant.

[FR Doc. E8–23421 Filed 9–30–08; 4:15 pm]

BILLING CODE 6351–01–P

COMMODITY FUTURES TRADING COMMISSION

Sunshine Act Meetings

TIME AND DATE: 11 a.m., Friday, October 31, 2008.

PLACE: 1155 21st St., NW., Washington, DC, 9th Floor Commission Conference Room.

STATUS: Closed.

MATTERS TO BE CONSIDERED: Surveillance Matters.

CONTACT PERSON FOR MORE INFORMATION: Sauntia S. Warfield, 202–418–5084.

Sauntia S. Warfield,

Staff Assistant.

[FR Doc. E8–23425 Filed 9–30–08; 4:15 pm]

BILLING CODE 6351–01–P

DEPARTMENT OF DEFENSE

Department of the Army, Corps of Engineers

Intent To Prepare a Draft Environmental Impact Statement for the Proposed Ala Wai Canal Project, Honolulu, Oahu, HI

AGENCY: Department of the Army, U.S. Army Corps of Engineers (USACE), DoD.

ACTION: Notice of intent.

SUMMARY: Pursuant to Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969, the U.S. Army Corps of Engineers (USACE) and the State of Hawaii Department of Land and Natural Resources (DLNR) gives notice that an Environmental Impact Statement is being prepared for the Ala Wai Canal Project, City and County of Honolulu, HI. This effort is a multi-purpose project being proposed under Section 209 of the Flood Control Act of 1962 (Pub. L. 87–874) and will incorporate both flood hazard reduction and ecosystem

restoration components into a single, comprehensive strategy.

DATES: In order to be considered in the Draft EIS (DEIS), comments and suggestions should be received no later than 30 days after publication of this notice in the **Federal Register** .

ADDRESSES: Send written comments to U.S. Army Corps of Engineers, Honolulu District, ATTN: Cindy S. Barger, Project Manager, Civil and Public Works Branch (CEPOH–PP–C), Room 311, Building 230, Fort Shafter, HI 96858–5440.

FOR FURTHER INFORMATION CONTACT: Questions or comments concerning the proposed action should be addressed to Ms. Cindy S. Barger, Project Manager, U.S. Army Corps of Engineers, Honolulu District, Civil and Public Works Branch, Building 230, Fort Shafter, HI 96858–5440, Telephone: (808) 438–6940, E-mail: *Cindy.S.Barger@poh01.usace.army.mil*, or Mr. Carty Chang, Project Planning and Management Branch Chief, State of Hawaii Department of Land and Natural Resources, Engineering Division, 1151 Punchbowl Street, Room 221, Honolulu, HI 96813, telephone (808) 587–0227, E-mail: *carty.s.chang@hawaii.gov.*

SUPPLEMENTARY INFORMATION: A preliminary assessment of this federally funded action indicates that the project may cause significant impacts on the environment. As a result, it has been determined that the preparation and review of an Environmental Impact Statement (EIS) is needed for this project. The EIS and Feasibility Study for the Ala Wai Canal Project are being conducted concurrently. The EIS will evaluate potential impacts to the natural, physical, and human environment as a result of implementing any of the proposed alternatives that are developed by this project.

This project will be implemented under Section 209 of the Flood Control Act of 1962 (Pub. L. 87–874), for the purpose of flood mitigation and ecosystem restoration in the Ala Wai Canal Watershed, which consists of the sub-watersheds of Makiki, Manoa, Palolo, and Waikiki. The USACE will work with the affected community and the sponsoring local organization, the State of Hawaii Department of Land and Natural Resources, to develop an acceptable plan to address the flood and ecosystem problems.

The 11,069-acre Ala Wai Canal Watershed is located in the southern portion of the island of Oahu. The Watershed is highly urbanized, with approximately 1,746 structures within the designated 100-year floodplain. There is a high potential for massive flood damage to the densely populated and economically critical area of Waikiki and the adjacent neighborhoods of McCully and Moiliili. Additionally, flooding frequently occurs in lower Makiki and recently in the central Manoa Valley, causing damages to businesses, homes, and academic facilities. There is also significant environmental degradation of the streams and waterways, including heavy sedimentation, poor water quality, lack of habitat for native species, and a prevalence of alien species.

Goals of the Ala Wai Canal Project are to (1) Protect the entire Ala Wai Canal Watershed from the 100-year flood event, (2) improve the migratory pathway for native amphidromous species, (3) reduce sediment buildup in the streams and Ala Wai Canal, (4) enhance the physical quality of existing aquatic habitat for native species, and (5) improve water quality. Anticipated significant issues identified to date and to be addressed in the EIS include: (1) Impacts on flooding, (2) impacts on stream hydraulics, (3) impacts on fish and wildlife resources and habitats, (4) impacts on recreation and recreational facilities, and (5) other impacts identified by the Public, agencies, or USACE studies.

A full range of possible programs and actions will be considered in order to meet the project goals. Currently under consideration are dredging, detention basins, flood walls, debris basins and other debris management actions, bridge modification, flood-proofing structures within the flood plain, diversion of flood waters, flood warning systems, widening of channels, acquisition of properties within the floodplain, maintenance easements, and a drainage district. Ecosystem restoration measures currently under consideration include low-flow channels, creating more natural stream channels, constructed wetlands, trash separators, sediment interceptors, daylighting the stream, increasing or decreasing shade as necessary, reducing the pig population, and stream bank stabilization. As hydrologic, hydraulic, and biological analyses are performed and stakeholder consultations are conducted, additional concepts may be developed.

Evaluation of all of the alternatives will take into account minimization of adverse impacts to social resources, economics, aesthetics, recreation, historic and cultural resources, and native species habitat. Flood hazard reduction alternatives will additionally take into account a cost-benefit analysis and ability to complement ecosystem restoration measures. Evaluation of the ecosystem restoration alternatives will be based on the areas of habitat they create, improve, or provide access to, as well as their ability to complement flood hazard reduction measures.

A DEIS will be prepared and circulated for review by agencies and the public. The USACE and DLNR invite participation and consultation of agencies and individuals that have special expertise, legal jurisdiction, or interest in the preparation of the DEIS. The DLNR will be issuing a state-level Environmental Impact Statement Preparation Notice (EISPN) pursuant to Hawaii Revised Statutes (HRS) Chapter 343. All written and verbal comments received in response to this Notice of Intent and the State EISPN will be considered when determining the scope of the EIS. To the extent practicable, NEPA and HRS 343 requirements will be coordinated in the preparation of the EIS document.

A public scoping meeting will be held on Tuesday, October 21, 2008 at the Washington Middle School Cafeteria at 1633 South King Street, Honolulu, HI 96826, from 6:30 p.m. until 8:30 p.m. to determine the scope of analysis of the proposed action. The scoping meeting will also be announced in local media. Interested parties are encouraged to express their views during the scoping process and throughout the development of the alternatives and EIS. To be most helpful, comments should clearly describe specific environmental topics or issues which the commenter believes the document should address. Further information on the proposed action or the scoping meeting may be obtained from Cindy S. Barger, Project Manager, at (see **ADDRESSES**). The DEIS should be available for public review in early 2010, subject to the receipt of federal funding.

Brenda S. Bowen,

Army Federal Register Liaison Officer.

[FR Doc. E8–23221 Filed 10–1–08; 8:45 am]

BILLING CODE 3710–NN–P

DEPARTMENT OF DEFENSE

Department of the Army; Corps of Engineers

Intent To Prepare a Draft Environmental Impact Statement for the Mississippi River-Gulf Outlet Ecosystem Restoration Feasibility Study

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: The Corps of Engineers (Corps) intends to prepare an