ALA WAI CANAL FLOOD RISK MANAGEMENT STUDY
O'AHU, HAWAI'I

FINAL FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX B
ECONOMIC ANALYSIS

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ALA WAI CANAL PROJECT
OAHU, HAWAII

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

APPENDIX B

ECONOMIC ANALYSIS

Honolulu District
March 2017

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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 analysis, methodologies, modeling and assumptions involved in evaluation of flood risk in the Ala Wai Canal watershed. The flood risk was initially analyzed in terms of a future without-project condition. Subsequently, the future without-project condition analysis served as a baseline condition for consideration and comparison of alternatives. This analysis resulted in the selection of a National Economic Development (NED) Plan, a Tentative Selected Plan (TSP), and ultimately a recommended plan.

Economic efficiency is not be the only decision point for selection of the preferred alternative, as many other criteria exist. However, it is critical to the success of any water resources project to ensure that recommended alternatives do not cause dramatic and possibly harmful changes to the nation's economy, regional and local 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 flood plain is generally defined by its 0.002 annual chance exceedance (ACE) flood plain. A total of about 200,000 people live in this inundation area, which also includes approximately 6,800 residences, 1,900 commercial buildings and 250 public buildings. The value of these properties, along with public infrastructure such as city streets, is an estimated $9 billion in 2017 dollars. 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 the public structures are found in the Manoa Valley, where the main campus of the University of Hawaii is located along with 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. Commercial development is expected to follow suit, but it is impossible to say exactly which buildings will be replaced and by what types of occupancy. Therefore, this study does not assume any significant future changes to the structure inventories or other assets supporting damage estimation. Future conditions will be the same as present conditions for purposes of calculating damages or costs except for the inclusion of sea-level rise parameters which will result in somewhat higher water surface profiles in some portions of the basin in the future condition. However, the number of people potentially placed in harm's way from a flood, whether they be residents, workers, shoppers, tourists or motorists traveling through the flood plain, will clearly be increasing over the 50-year planning horizon

The primary economic benefit associated with a flood risk management project is the reduction in inundation damages to structures, structure contents (furniture, equipment, inventory, etc.) and infrastructure. All categories of economic benefits considered in this study involve reduction of potential physical flood damages to structures and contents as well as infrastructure. These categories are unquestionably the most significant drivers of National Economic Development (NED) benefits. The economic evaluation of physical flood risk is accomplished through the use of two programs developed by the USACE Hydrologic Engineering Center: HEC-RAS, the River Analysis System which computes stream flows and stages along with the relative frequency of various magnitudes of flooding; and HEC-FDA, the Flood Damage Analysis program, which estimates expected annual economic damages and damages reduced (benefits) as well as project performance under conditions of risk and uncertainty. 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 existing, base year and future conditions.

The plan formulation for this project follows recently-issued USACE guidelines for implementing the SMART Planning paradigm. A detailed account of how the Project Delivery Team (PDT) screened various project alternatives and selected the recommended plan, along with the planning objectives and selection criteria followed, can be found in Chapters 3 and 4 of the main section of this feasibility report. This economic appendix picks up the SMART planning process in the later stages of plan comparison and describes and quantifies the economic results behind such decisions as:

- How alternative 5, a stand-alone nonstructural flood risk management plan, was developed and considered and why it ultimately was dropped from further consideration;
- Why alternative 3A was selected as superior to Alternative 2A in the final array stage;
- How the multiple measures comprising alternative 3A were economically justified;
- How alternative 3A was optimized, leading to its emergence as the NED Plan and the TSP;
- How alternative 3A was confirmed as the recommended plan in the final stages of completion of this feasibility study.

In summary, alternative 3A, 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, is the recommended plan. The economic benefit-cost analysis of the recommended plan quantified the plan's economic outputs as shown in Table ES-01 below:

Table ES-01. Economics of the Recommended Plan
Oct. 2016 prices ($000s); 2.875% discount rate

Total First Cost	$306,095,000
Total Investment Cost (with IDC)	$319,697
Total Annual Cost	$48,331,000
Expected Annual Benefits	$13,117,000
Benefit-Cost Ratio	3.7
Net Annual Benefits	$35,214,000

By implementing the recommended plan, equivalent annual damages (EAD) to structures and contents within the watershed are anticipated to fall from approximately $53.7 million in without-project conditions to $5.4 million, reducing the EAD to about 10 percent of without-project EAD. The reduction is even more impressive in the three Ala Wai Canal reaches, where Waikiki flooding is of upmost concern; there, residual damages to structures, contents and infrastructure would be reduced to well under 1 percent of their without-project levels. Non-physical costs of flooding not quantified for this analysis, including emergency costs, traffic interruption impacts and business interruption costs, would be expected to follow suit. In addition, with the recommended plan's floodwalls in place, there is a greater than 99% assurance that the project would successfully contain a 0.01 ACE event under both current and projected (2025 and 2075) conditions and assuming either low, intermediate or high sea level rise scenarios.

Ala Wai Canal Project Feasibility Study,
Oahu, Hawaii
Economic Analysis
March 2017

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ALA WAI CANAL PROJECT FEASIBILITY STUDY
OAHU, HAWAII
ECONOMIC ANALYSIS

1.0. INTRODUCTION

1.1. Purpose. The purpose of this economic analysis is to describe the economic methodologies, modeling, assumptions and findings of the Ala Wai Canal economic analysis which ultimately led to the selection of the recommended plan. The flood risk was initially analyzed in terms of economic damages estimated for future without-project conditions. Subsequently, this future without-project analysis served as a baseline condition for consideration and comparison of alternatives. This analysis resulted in the selection of, successively, a National Economic Development (NED) Plan, a Tentative Selected Plan (TSP), and a recommended plan.

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 selected floods—the 0.02, 0.01 and 0.002 ACE (annual chance exceedance) events, assuming an intermediate sea level rise (SLR) scenario. 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 project.

As shown in Table B-1, these six neighborhoods comprising the Ala Wai watershed, shown in Table B-1, had a total population of about 200,000 in 2010, and their population has been increasing at an annual rate of about 2.1 percent since 2010. Overall, population growth in the watershed has increased an estimated 9.2 percent up to 2014 since the 2000 census. This is less than the City of Honolulu's 12.2 percent population increase over roughly the same time period and is also less than the comparable state and national increases. The Ala Moana neighborhood showed the largest percentage growth, 29 percent, among the Ala Wai watershed neighborhoods; it also has the smallest population among these neighborhoods. Waikiki had the next highest rate of growth with a 17 percent change. The largest population totals are to be found in the Kaimuki/Palolo and Manoa areas, while the McCully/Moiliili area has seen an outmigration of 13 percent since 2000.

The population of 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 flood plain are fully built-out, with little room available for construction of new structures without the demolition of existing structures. Given the 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. 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 flood plain who will potentially be placed in harm's way from a flood will clearly be increasing over the 50-year period of analysis.

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%

The total asset base as defined by depreciated replacement value of all the structures, structure contents and infrastructure in the watershed is approximately $8.9 billion in 2017 dollars. 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 along the Ala Wai Canal. 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 public schools. The Manoa area also includes a large portion of the study area's residential properties, including many of the more upscale properties. Makiki also has a high portion of its total investment in residential properties, which include numerous small apartments. Other areas with especially dense residential development include Waikiki, Kapahulu, and Palolo.

Figure 1. Flood Inundation Outlines for Selected Events

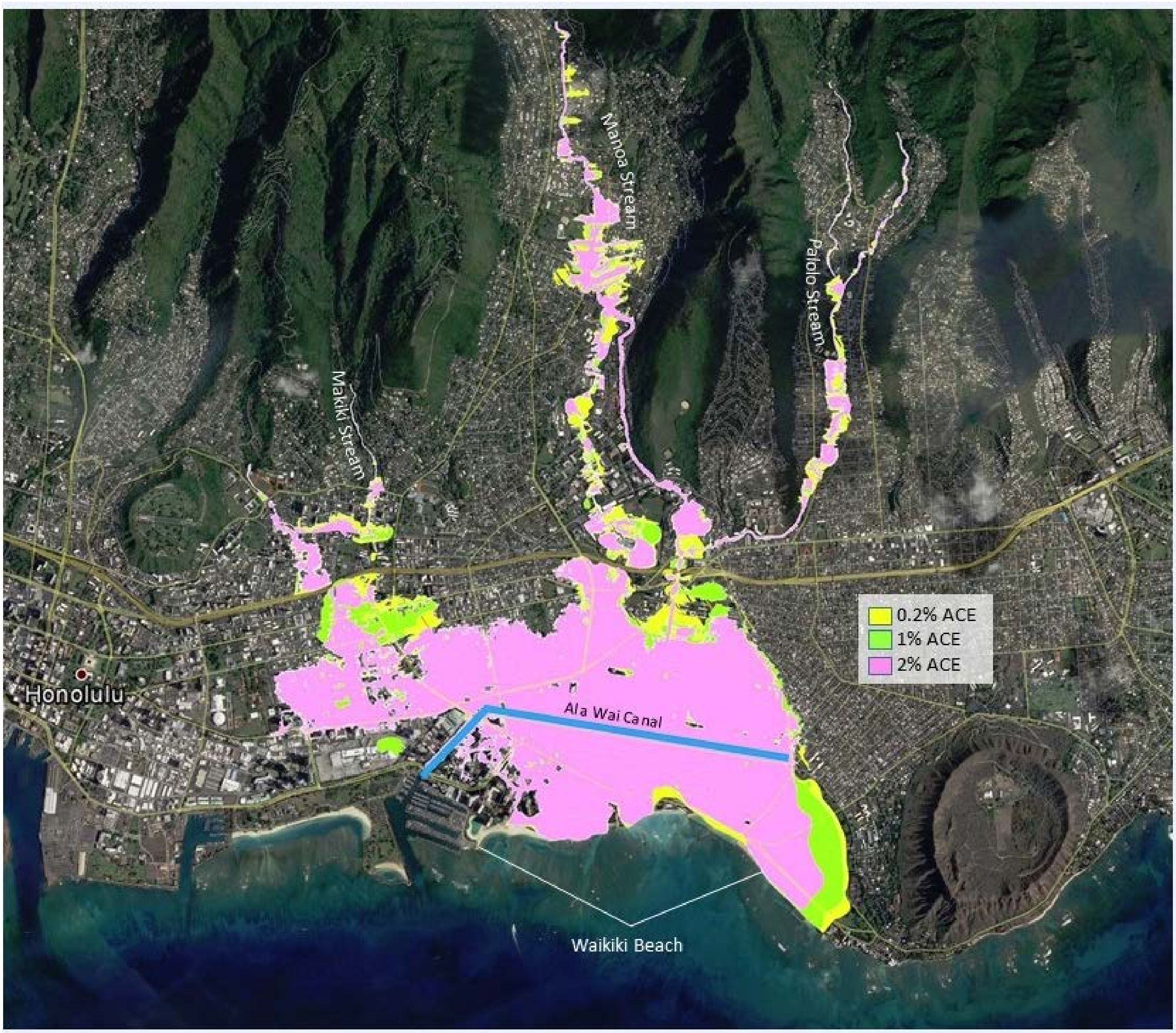
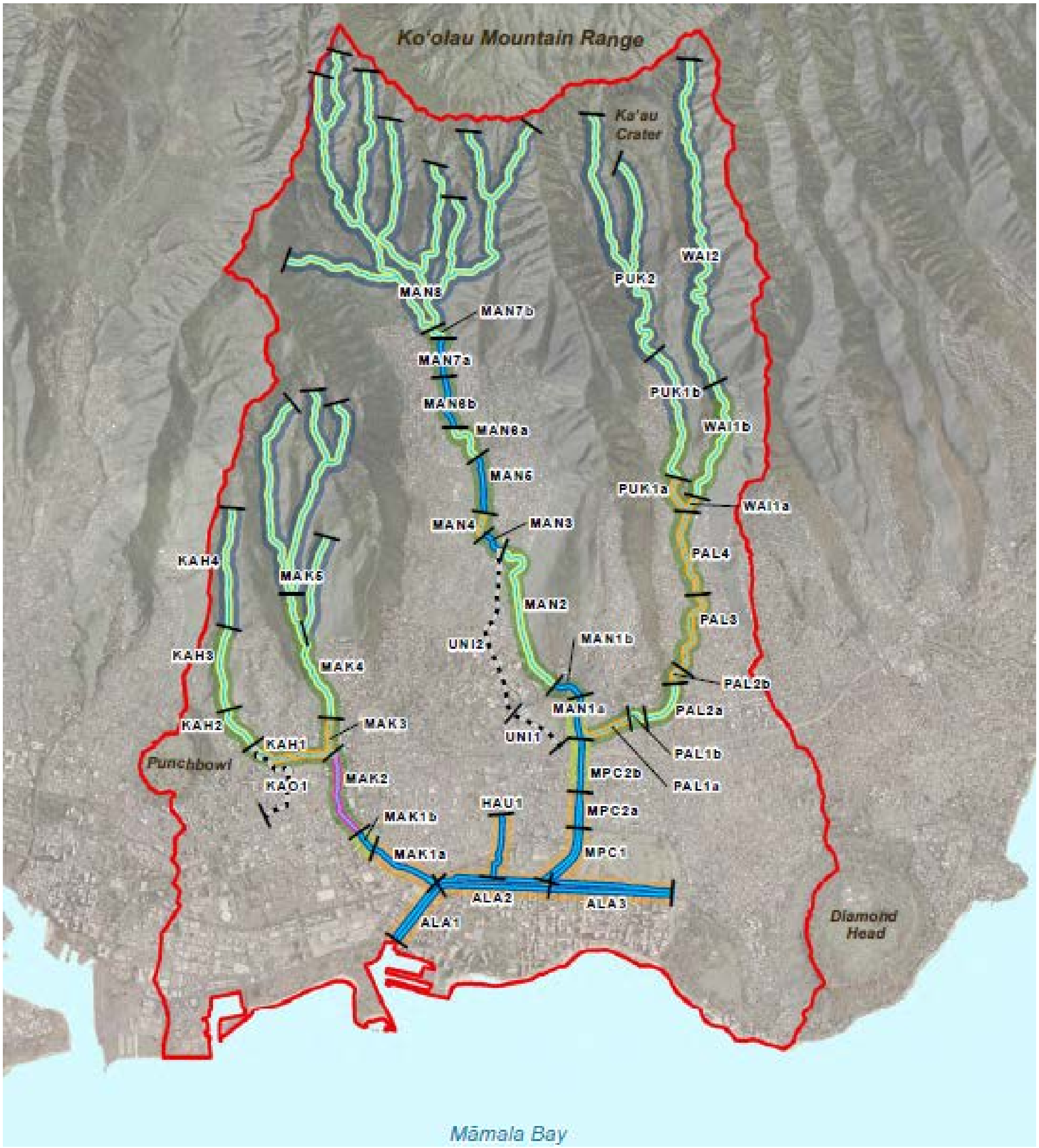


Figure B-2. Overview of Stream Reaches



1.3. Economic Study 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 purposes of this economic analysis, the watershed is divided into 27 economic reaches along 10 streams in four subbasins. Each reach has specific characteristics that make it unique. Figure B-2 displays the 27 reaches. (It should be noted that there are several reaches shown in the upper Ala Wai watershed in Figure B-2 that were included in early phases of the feasibility study but are not discussed here since they were dropped from the study early on.) The Ala Wai Canal itself is divided into three reaches, while streams such as Makiki, Manoa and Palolo have as many as seven reaches. A few smaller areas include only one or two reaches. A description of the four subbasins and the 27 economic reaches follows, while investment in the individual subbasins and reaches is summarized in Table B-2.

1.3.1. Ala Wai Reaches

The Ala Wai subbasin is one of four subbasins within the Ala Wai watershed. It includes the Ala Wai Canal and the Manoa-Palolo Canal. The latter, which flows into the Ala Wai Canal, is the lower portion of the Manoa and the Palolo streams. This subbasin has by far the highest investment value of the four subbasins, with total investment estimated at $5 billion, more than half of the total investment in the study area. More than 4,200 structures are located in the Ala Wai subbasin, which includes five reaches:

ALA1 is the last leg of the Ala Wai Canal before it arrives at the ocean. This reach is the western portion of Waikiki and includes such points of interest as the Ala Moana Shopping Center, Ilikai Hotel and Hawaii Prince Hotel. The tourist population density is relatively heavy in this area. Other than Ala Moana Mall, most businesses are small retail stores and restaurants. The economic structure inventory accounts for 472 structures, of which nearly three-fourths are commercial or public. The commercial properties have much more value and potential to be damaged by flooding than the approximately 130 residential properties in this reach. Most residents live in apartments and large condominiums. There is a handful of single-family residences, but space is extremely limited, so the housing lots are relatively small. Total investment in this reach is estimated at approximately $2.18 billion, which is the highest investment value of all 27 reaches in the study. More than $2 billion of this total is accounted for by commercial and public uses. Equivalent annual damages (EAD) for this reach total $11.1 million.

ALA2 is the middle section of Waikiki and it extends into McCully, up to King Street. As in ALA1, the tourist population density is heavy and is primarily located around the hotels next to the ocean. Points of interest include the Hale Koa Hotel, Fort DeRussy, the Hilton Hawaiian Village, the Trump International Hotel, and the Waikiki Beachwalk. A mix of commercial activity is located around these centers; most businesses are small to medium-sized restaurants and retail stores. The estimated total investment in ALA2 is $1.24 billion, the second-highest investment value of the 27 study reaches. ALA2 also has the highest estimated EAD of all reaches in the without-project condition, with a total of $18.2 million in annualized economic damage potential. Of the nearly 1,800 structures in the reach, 84 percent are residential. Most residents, who tend to be older than average, live in apartments and condominiums. Northwest of the Ala Wai Canal is the community of McCully, which is made up of small to medium-sized residential homes along with a number of condominiums.

ALA3 is the southeastern part of Waikiki, starting at the beginning of the Ala Wai Canal and ending at Iolani School. It is the reach nearest Waikiki's main beaches as well as Diamond Head. As such, many of Waikiki's landmark hotels are found in this reach. 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. Key properties in ALA3 include the Royal Hawaiian Hotel, the Halekulani Hotel, the Royal Hawaiian Shopping Center, the Moana Surfrider, the Hyatt, the Waikiki Beach Marriott, and the Sheraton Princess Kaiulani Hotel. Residents typically live in apartments and condominiums, and about three-fourths of the more than 600 structures in the reach are residential. Total investment for the reach is $961,000, and ALA3 also has the second-highest economic damage potential of all reaches ($13.6 million in EAD).

MPC1 is one of two reaches on the Manoa-Palolo Canal. It is located south and southeast of the University of Hawaii and at the confluence of the canal with the Ala Wai Canal. This reach has a mix of residential, commercial, and public uses, but residential is predominant, typically in the form of single-family homes and small apartments. About 90 percent of the nearly 500 structures in this reach are residential. Commercial activity in this reach generally consists of convenience stores, restaurants and a small shopping center. Kapahulu Avenue, which runs from the university to Waikiki, is lined with restaurants and other businesses. The Ala Wai Golf Course is also a major point of interest in this reach. Kaimuki High School is a significant public facility. Total investment in MPC1 is almost $250 million.

MPC2, the upper reach of the Manoa-Palolo Canal, is a relatively large, L-shaped reach that encompasses some areas of McCully-Moiliili, runs through Iolani School, and ends at the Ala Wai Golf Course. Like MPC1, this reach is located south of the University of Hawaii. About 60 percent of the more than 800 structures in the reach are residential properties, but there is also a significant commercial sector and a few public facilities, particularly the Iolani School. Total investment is estimated at $340 million. Taken together, the two Manoa-Palolo Canal reaches account for about $2.2 million in EAD.

1.3.2. Makiki Reaches

In addition to the four reaches along Makiki stream, the Makiki subbasin also includes the Kanaha Ditch and Kanaha Split. There are more than 2,000 structures in this subbasin, with a total investment estimated at $1.44 billion.

MAK1 is the lower portion of Makiki, where it flows into the Ala Wai Canal. The more than 1,200 structures in this reach are divided fairly evenly between residential and non-residential uses, and the total investment of approximately $865 million is one of the five largest investment totals among the 27 reaches. Many single-family homes and small apartments are to be found in this reach, but the area is known more as a busy commercial area with some of the largest groceries and department stores in the watershed.

MAK2 is in the center of Makiki. It is primarily residential with a mix of apartments, condominiums, and especially single-family homes. More than 70 percent of the nearly 300 structures in the reach are residential. Total investment in MAK2 is estimated at more than $330 million.

MAK3 is a relatively small reach in the upper portion of the Makiki Valley with fewer than 100 structures, nearly all of them residential, including apartments and single-family homes. There are no significant commercial activities in this reach. Total investment is estimated at $43 million, but there is very little susceptibility to flood damage in this reach.

MAK4, the fourth of the four Makiki reaches, is at the upstream end of the subbasin and has the highest elevations along the Makiki Stream. MAK4 consists solely of 75 single-family homes with a value of approximately $32 million. Susceptibility to economic flood damages is relatively low here.

KAH1, along the Kanaha Ditch, is in the upper Makiki Valley. There are just over 100 structures, all but one residential, valued at $48 million. The residences tend to be single-family houses on small lots of less than 5,000 square feet, but some smaller apartments and condominiums also are to be found here. No significant commercial activity exists in this area.

KAH2, along the Kanaha Ditch just upstream from reach KAH1, is located next to Roosevelt High School. The relatively small reach has about 20 single-family homes and two public structures valued at $13 million. The reach contains no businesses, and flood risk is relatively minimal.

KAO1 is another small reach located next to the Kanaha Ditch. It stretches from the upper Makiki Valley into Makiki. About 93 percent of the more than 200 structures are residential, with a mix of condominiums, single-family homes and especially apartments. The estimated total investment of $113 million also includes several small and medium-sized businesses.

1.3.3. Manoa Reaches

This subbasin consists of seven reaches along the Manoa Stream as well as a “university split” running through the University of Hawaii area. The university dominates land use in the lower portion of this subbasin, which has total investment estimated at nearly $2.2 billion.

MAN1, with total investment estimated at $93 million, has a mix of residential and public properties, including some of the University of Hawaii buildings. The more than 100 residences, generally in the form of single-family homes, account for 90 percent of the structures in the reach, but a dozen public structures account for 60 percent of the investment value. This area has significant exposure to potential flooding.

MAN2 is mainly University of Hawaii facilities and housing. The nearly 200 structures, valued at $70 million, include faculty apartments, classrooms, lecture halls and administration offices as well as some single-family houses. The university has taken steps in recent years to sharply reduce its exposure to flood damage in this area, and the overall flood risk in the reach is minimal.

UNI1, adjacent to MAN1, is the lower part of the University of Hawaii campus. The estimated $323 million in investment accounts for about 20 public structures and facilities, including athletic fields, tennis courts, portable classrooms, a parking structure, the sports administration department, a recreation center and a few gymnasiums. A major landmark in this reach is the Stan Sheriff Center. As in MAN2, the university has made strides in recent years in reducing its economic flood risk, but larger floods could still get into many of their buildings.

UNI2 is the main campus of the University of Hawaii. The majority of the campus consists of buildings of up to 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 points of interest in this reach are Hamilton Library, the Campus Center, the Biomedical Building, and Kuykendall Hall. Total investment, which is spread over more than 50 public structures, is estimated at nearly $1.08 billion, making UNI2 one of the five study area reaches with the largest investment. It is also one of the five reaches with the highest economic flood exposure. This area sustained heavy damage during the 2006 storm event, particularly Hamilton Library.

MAN3 is the beginning of the residential section of the Manoa Valley. About 85 percent of the more than 100 structures in this reach are single-family homes. A handful of small businesses and a medium-sized commercial shopping center, Manoa Market Place, are also located in MAN3. Total investment is valued at $92 million. Economic flood risk is relatively small in this reach, however.

MAN4 has nearly 200 structures, nearly all of them single-family residences. A few small businesses are also found here. Total investment is an estimated $88 million. Residences in MAN4 generally are potentially susceptible to significant economic flood damages.

MAN5 has 270 structures and a total investment of $125 million. As in MAN4, the vast majority of the structures are residential, but public structures nevertheless have a substantial presence in terms of land use within the reach. 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 rest of the area contains single-family housing as well as a few apartments adjacent to the district park. Only one business is located in MAN5. Flood exposure is quite significant for the public and residential structures in this area.

MAN6, farther up the valley from MAN5 and MAN4, is mostly residential properties, many of which are in the flood plain and have significant flood damage exposure. Well over 400 residences are located in this reach, along with two public structures. Also located in the middle of the area is a 34-acre cemetery, Manoa Chinese Cemetery. Although the cemetery is quite large, it is built into the mountain which makes it less susceptible to flood waters. Total investment is estimated at $236 million for this reach.

MAN7 is the farthest upstream reach in the Manoa Valley watershed. The district is residential, with more than 200 homes valued at $78 million. The residences here tend to be single-family homes. There are no commercial properties or public structures. Flood exposure in this reach is minimal.

1.3.4. Palolo Reaches

This subbasin includes the Palolo Stream (four reaches) as well as the Waiomao and Pukele streams that join to form the Palolo. Total investment in the subbasin is estimated at more than $330 million, by far the smallest total among the four subbasins.

PAL1 is immediately upstream from the Manoa-Palolo Canal and southeast of the University of Hawaii. The $40 million in total investment in the reach is spread among 60 residences (single-family homes and small apartments) as well as several businesses. The flood risk to these residences and businesses, as well as to city streets in the area, is significant, and nearly all of the significant flood exposure in this subbasin is located within this reach.

PAL2 is west of PAL1 and consists of nearly 100 structures, primarily single-family homes but also a few businesses and public structures. Investment in this area is an estimated $36 million, but there is relatively little flood risk compared to most of the other study reaches.

PAL3 is northeast of PAL2 and consists entirely of more than 300 residential properties, mostly single-family homes, which are valued at $90 million. Flood risk is light to moderate in this area.

PAL4, which is northeast of PAL3, contains more than 200 structures, more than 90 percent residential. Most of the residential properties are single-family homes, and there are also several public housing units located in this reach. Also located here are Jarrett Middle School and Palolo Valley District Park. Total investment is estimated at $65 million, but flood exposure is relatively light.

PUK1 is on the Pukele Stream to the northeast of PAL4 and south of WAI1. Most of the flood exposure in this reach is residential: more than 200 residences are located here, as well as a few public structures. Investment is estimated at $61 million. Potential susceptibility to flood losses is very light.

WAI1, on the Waiomao Stream, is the northern-most reach in Palolo Valley. It includes more than 100 residential properties, primarily single-family homes and small apartments, valued $39 million. No businesses or public structures are found in this reach. This upstream reach has virtually no flood exposure.

1.4. Historical Damages. Historical flood events such as the November 1965 and December 1967 storms and the passage of Hurricane Iniki in 1992 have caused damage in the Ala Wai watershed. The 1967 storm, for example, reportedly resulted in $10,000 in damages around the Ala Wai Canal area, according to the USACE Circular C47. This total would be equivalent in

2017 dollars to approximately $90,000. The Manoa Valley flood of 30 October 2004 reportedly caused $80-$100 million in damage at the University of Hawaii campus.

But overall, the record of historical floods in the study area provides minimal assistance in estimating either the hydraulic or economic components of flood risk in the Waikiki area, for several reasons:

- Documentation of historical floods in the study area has been unsystematic and sparse. There are only a few damage estimates from historical flood events that are documented to any extent at all, and these are generally anecdotal rather than comprehensive. For example, no damage estimates, apart from the report of $10,000 in damages referred to above, were found for the 1965 and 1967 storms.
- Previous floods in the Waikiki area at the center of this study are particularly lacking in documentation because the reporting stream gauges are farther upstream in the basin, located in areas where the very hilly topography is completely at odds with the flat oceanfront Ala Wai Canal area. The 2004 event, the most recent event of significance and the only one with much documentation, was centered specifically on the Manoa Valley, making that experience more difficult to apply to other areas in the basin. A gauge was installed along the Manoa-Palolo Canal following the 1967 flood, and historical data from that gauge were used in the frequency estimation of events for this study, but otherwise, any analysis of previous floods in the Ala Wai basin relies upon rainfall data from the upper basin.
- The historical flood record here does not include any past floods that would be comparable in magnitude to current estimates of a 0.01 ACE (or larger) flood. Even the catastrophic rain event in the Manoa Valley that resulted in the 2004 flood is believed to have been only a 0.2 ACE event. No flood events of even moderate magnitude have occurred in the Ala Wai subbasin and affected the Waikiki area.

The lack of documentation pertaining to historical economic flood damages is unfortunately a significant limitation in calibrating synthetic estimates of flood risk in this watershed. That said, documentation of historical floods is sparse, unsystematic and generally unsatisfactory in most watersheds, and the Ala Wai area is really no different in that regard.

1.5. Economic Parameters. The comparison and evaluation of alternatives that will evolve from the planning process involves consideration of the effects that the plans would have on planning objectives and constraints. The economic analysis presented in this appendix begins by addressing existing conditions and the future without-project condition, establishing a general description and baseline for the primary impact area.

Investment, damages, benefits and costs are expressed in FY 2017 prices (index: 1 October 2016). Costs and benefits occurring at different points in time are converted to an expected annual equivalency basis over the 50-year period of analysis using the Federal discount rate prescribed for water resources projects of 2.875 percent for FY 2017.

Analysis of existing conditions is indexed to 2015, while the base year of the analysis, defined as the initial year of project operation, is FY 2025. However, there is no difference in the assumptions for the existing and base year conditions, which are based on identical hydrologic and hydraulic data and identical economic structure inventories. Thus, estimated damages for the future without-project condition will not differ at all from existing condition estimates. (Due to sea level rise, there might be a small increase in water surface profiles between 2015 and 2025, but the difference was not deemed significant enough to justify major revisions in the hydrologic and hydraulic modeling for the study.) A future condition, indexed to 2075, also is analyzed. The future year analysis also uses the same structure inventory and economic assumptions as the existing and base year analyses, but the hydrologic and hydraulic data are changed for the 2075 analysis.

Reduction in potential flood damage to structures, structure contents and infrastructure is the sole basis of damages and benefits estimated in this economic analysis. These categories of economic impact, while not all-inclusive, are unquestionably the most significant from the standpoint of National Economic Development (NED) effects and the economic justification of the recommended plan. Although not included in this economic analysis, there are other possible sources of NED benefits from implementation of the recommended plan, including emergency costs, traffic interruption costs and damages to utilities. These benefit categories are not included here because of a lack of sufficient data available for quantifying them as well as their relative insignificance in the context of the many millions of dollars in damages reduced. In addition, inclusion of these secondary benefits would not be expected to affect plan selection since they tend to be fairly constant from one alternative to another and also because these categories of impacts tend to be closely correlated with reductions in physical flood damages to structures and contents and would be similar for all structural alternatives considered; thus, their inclusion would not change the ranking order of structural solutions considered, and would contribute only incidentally to the benefits of nonstructural plans. The economic analysis, however, did give a significant amount of attention to public safety aspects of flood risk.

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 that there is a 1 percent chance of an event occurring capable of producing the flow or stage in excess of a particular value. Therefore, this former terminology has been replaced by more contemporary risk and uncertainty language, and the event formerly referred to as a “100-year flood” is now expressed as a 0.01, or 1 percent, ACE (annual chance exceedance) event.

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 economic flood damage and damage reduction is accomplished through the use of two models developed by the USACE Hydrologic Engineering Center. HEC-RAS (the River Analysis System program) computes flows, stages and frequencies characterizing a range of possible flood events. HEC-FDA (the Flood Damage Analysis program) computes important economic metrics, including expected annual damages, expected annual benefits and equivalent annual benefits, in a risk-based context. In addition to these economic outputs, HEC-FDA also estimates project performance under a range of risk and uncertainty assumptions.

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. Estimates of the range of possible base and future year river flows and their associated probabilities of exceedance are provided by the Project Development Team (PDT) hydrologic engineer. The sampled river flow is then paired with a stage, or water surface elevation, from a distribution of possible values, provided by the PDT's hydraulic engineer. This water surface elevation is compared to the top of stream bank elevation or the top of levee elevation at the index point or a reach to determine whether the sampled event results in damaging overbank flooding. In the event that the river stage induces flooding, water surface elevations are computed and compared with ground and first-floor elevations to determine the depth of flooding at each structure within a given reach. This depth of flooding is transformed into flood damages using depth-percent damage functions and depreciated structure values estimated by the PDT economist. These reach-by-reach damage estimates are paired with the river flow percent exceedance probability to produce a damage-probability function. These functions, the basis of the economic outputs, are expressed as expected annual damages under without-project and with-project conditions. The difference between the without and with-project conditions in terms of expected annual damages essentially constitutes the benefit of reducing the risk of inundation.

More specifically, HEC-RAS estimates inundation areas and depths associated with 0.5, 0.2, 0.1, 0.05, 0.02, 0.01, 0.005 and 0.002 ACE flood events. HEC-FDA then calculates the economic effects of flooding on the thousands of structures in the Ala Wai Canal flood plain by comparing the water surface elevations for the range of flood events listed above with the first-floor elevations for each structure in the flood plain inventory. This process determines the estimated depth of flooding at each structure for any given flood event. HEC-FDA analyzes damages to each structure and its contents as a percentage of their total depreciated replacement value. 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 flood plain, 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 variables necessary to flood damage analysis are not known with certainty. To model these variables in a risk-based context, the probability distributions of the pertinent variables are estimated and entered into HEC-FDA. The program then applies Monte Carlo simulation techniques to the data using discharge-probability, stage-discharge, and stage-damage functions utilizing these distributions. Using a large number of iterations, the program computes the probabilistically-informed expected value of annual damages, 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 damage-probability distributions generated by HEC-FDA, taking into account uncertainties in stage-damage, stage-discharge and discharge-frequency relationships. EAD describes the flood damages that one would expect to be incurred in any given year under base or future conditions absent any prior knowledge of whether any flooding will occur. Since EAD represents an annualized weighted average, it simultaneously overestimates the actual flooding that occurs in most years (since no flooding occurs in most years) and underestimates 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. It is a measure of the reduction in flood damages attributable to the implementation of a particular alternative.

1.6.5 Equivalent Annual Damages. Equivalent annual damage (which, like expected annual damages, are referred to as EAD) is an annualized net present value accounting for expected annual damages over the entire period of analysis, given the transition from base year to 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 at a consistent point in time. EAC begins with a detailed estimate of a project's total construction cost and annualizes it in much the same way 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 interest during construction (IDC), a non-financial economic cost that accounts 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 emphasized contributions to only two of these, NED and EQ, as national objectives. As ecosystem restoration has risen in importance as a USACE priority mission, its principal EQ objective, national ecosystem restoration (NER) outputs or benefits, has become an important driver of plan formulation for these types of projects. Additionally, with each passing decade since the 1970s, USACE has been encouraged by national policymakers to give increasing weight to OSE in addition to its focus on NED and NER (USACE, 2009).

For purposes of this feasibility study, 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. Flood plain 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 of the Ala Wai Canal project are anticipated to be positive and extensive from reducing the risk of flooding in neighborhoods and commercial areas.

If a Federal flood risk management or ecosystem restoration project is constructed in the watershed, the spending would likely result in a temporary increase in jobs on the island of Oahu. At the same time, the construction might contribute positive NED impact by employment of unemployed workers. Federal income taxes would be paid on earnings that might otherwise not have existed. Hotels and restaurants that might have been shut down during a flood event would remain open, resulting in payment of more wages and taxes. 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 but do not represent a change in national economic outputs. Consequently, RED benefits are usually not considered 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 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 an important goal by state and local governments. However, if these effects occur in one region at the expense of another region, they amount to transfers from one region to another and do not involve net economic gain to the nation; thus, they would be considered regional benefits. 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 flood plain can be a significant RED benefit of providing flood protection. 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 that 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/operator in an alternate location; this might be a loss to the region, but not the nation since 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 comparable substitutes for Hawaii (and Waikiki Beach), as well as the large proportion of tourism dollars coming from international sources, many of these impacts that would usually be regarded as RED could, in fact, be NED impacts in the Ala Wai context.

The determination of 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 will multiply several times over as they purchase goods and services through interconnected business sectors in the region’s economy.

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. 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 and 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 resources project in the Ala Wai Canal watershed, there would be maintenance and operation jobs associated with the new project. In addition, there could be ongoing 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. Capturing and quantifying complex regional, indirect and induced economic impacts is beyond the scope of this study, which concentrates on estimating the value of reduced exposure to flooding from the Federal perspective and in terms of primarily NED impacts. The purpose of this feasibility study is to formulate and compare alternatives and, ultimately, to select a plan that is economically justified in terms of NED benefits. The potential exists for developing a quantifiable amount of RED benefits (albeit at a considerable additional expense for the analysis) 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 in this report.

2.4. Environmental Quality. Over recent decades**,** the Corps of Engineers 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, simply, to contribute to national ecosystem restoration (NER). NER benefits, although normally not monetarily quantifiable, have become an important component in the economic justification 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. The present study of the Ala Wai Canal area initially began as a combination ecosystem restoration and flood risk management study, but ecosystem restoration was subsequently dropped as a primary project purpose. For further information, see Section 1.6, *Study History and Background*, of the main report.

2.5. Other Social Effects (OSE). Another set of hard to quantify impacts from a water resource projects is lumped into the OSE account. These impacts can range widely but typically include considerations of public safety, including potential for life loss, and environmental justice (USACE, 2009).

The potential for flooding creates a life safety risk for people working in, living in or passing through a watershed. The affected population within the existing 0.01 ACE Ala Wai flood plain on any given day is comprised of an estimated 54,000 residents, plus an estimated additional 79,000 visitors in Waikiki. 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.

No instances of fatalities during historical floods in the Ala Wai watershed have been discovered, but several factors nonetheless increase the risk to public safety:

- The nature of flooding in the Ala Wai Canal area is essentially flashy, allowing little warning time to tens of thousands of tourists, workers and residents who might be in the area.
- The combination of limited warning time, the large number of people in a relatively compact area, and the location of most of the primary egress routes, which must cross the 0.01 ACE flood plain, raises the risk that escape from the inundated area could be slowed to a standstill during flood events with a sudden onset.
- A great many people within the study area – particular tourists – could be expected to be unaware of the potential threats and unprepared or unable to respond.
- A significant amount of the watershed's critical infrastructure is located within the existing 0.01 ACE flood plain, which elevates the life safety risks and decreases the community's ability to recover from potential flooding events. The critical infrastructure in this area includes four fire stations, one police station, two hospitals, two nursing facilities and nine emergency shelters.
- Public safety concerns also encompass threats to health and safety posed by movement of debris and/or exposure to contaminated floodwaters.

Although the study did not attempt to estimate OSE benefits or beneficial effects attributable to the recommended plan of action, positive OSE impacts in the socioeconomic well-being of the impact region will naturally result from any reduction of flood risk in the watershed. The opportunity now exists to accomplish one of the main objectives of the study, removing people from harm's way while also ensuring that this is accomplished by optimizing and balancing as many types of benefits as possible within the four accounts.

3.0. ECONOMIC DATA AND MODEL DEVELOPMENT

The future without-project condition analysis sets the baseline for measuring future reductions in costs associated with flooding. These reductions in costs are NED benefits, and their estimation is the most important objective of the economic analysis. Once the future without-project condition is established, with an estimated total EAD, project alternatives are analyzed to estimate the amount of residual damages in EAD that would continue to occur with the alternative in place. The with-project EAD total is compared to the future without-project EAD, with the difference between these without-project and with-project damages being the basis of the economic benefits. Alternative plans are screened out until one rises to the top as the alternative that will reasonably maximize net NED benefits. This is accomplished by comparing the incremental expected annual benefits and the incremental expected annual costs of the alternatives being considered. The alternative with a BCR (benefit-cost ratio) greater than one and the highest net incremental benefits over annual costs is designated as the NED. 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 is dropped and the plan is finalized to include all economically feasible and optimal measures

3.1. **Data Gathering: The Economic Flood Plain Survey.** Establishing the future without-project condition begins with a systematic inventory of damageable properties in the flood plain. A comprehensive structure inventory is constructed which includes estimated values, ground and first-floor elevations, stream stations and damage susceptibility for each structure. This structure inventory is loaded into the HEC-FDA program along with the corresponding hydrology and hydrologic data. Specifically, HEC-FDA computes three functions: discharge-frequency, stage-discharge, and stage-damage. From these functions, the damage-frequency function which is vital to the economic analysis can be derived. The damage-frequency curve is applied to the structure inventory, resulting in an Expected Annual Damage (EAD) value. EAD, as explained in Section 1.6, is the estimated average annual damages, taking into account uncertainties in stage-damage, stage-discharge, and discharge-frequency relationships. If a future condition is included in the economic analysis, the equivalent annual damage is also calculated. This total represents the annualized net present value of the expected annual damages over the period of analysis (ordinarily 50 years).

The structure inventory used in the economic analysis must comply with Section 308 of WRDA 1990, which requires that structures built after June 1991 with first-floor elevations below the 0.01 ACE flood stage cannot be included in the benefits analysis for a study. This economic analysis is compliant with Section 308.

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, and many of the largest hotel and condominium properties in Waikiki. In the case of the Ala Wai Canal watershed, the primary impacted area is heavily developed or "built-out" 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 neighborhoods in the study area are highly built-out and heavily urbanized in both their residential and commercial districts.

For the purposes of this study, the area designated as the Ala Wai Canal flood plain is generally defined by its 0.002 ACE flood plain. However, in order to capture everything of value that is at risk of being flooded, a buffer is added to the 0.002 ACE flood plain and more structures than might be affected are accounted for in the model. Otherwise, structures on the fringes of the 0.2 percent flood plain that might be flooded today or in the future could be excluded from the model. This practice also ensures that the model includes structures where the floor elevation may exceed the 0.002 ACE flood height, but the ground elevation of the structure's foundation does not. FDA results generally show that many of these fringe structures in the inventory do not show any damages. This 0.002 ACE flood plain plus its buffer is referred to in this appendix as either the "project area," "study area," or "watershed."

Approximately 200,000 people live in the study area. Approximately 6,800 homes and 2,100 commercial and public structures are included in the study's structure inventory, with a total value of $8.9 billion. 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, which is home to the main campus of the University of Hawaii in addition to research buildings and other district public schools.

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 $128,000 in structural value according to the Tax Map Key (TMK) data. There are about 6,800 homes located within the 0.002 ACE flood plain 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 flood plain being about 1980.

3.1.2. Typical Commercial Structures. 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 1,900 commercial structures in the Ala Wai Canal Project) in the 0.002 ACE flood plain, averaging just over $1 million in structure depreciated replacement value, or about $1.9 million if contents are included. However, structure values vary greatly in the study area given the vast range in occupancies, so that the average structure value has very little meaning here.

3.1.3. Typical Public Structures. Public buildings in the study area are typically large, multi-storied structures averaging $6.1 million in depreciated replacement value. If contents are included, the total depreciated replacement value per structure is approximately $8.4 million. There are 254 public structures located throughout the flood plain of the Ala Wai Canal watershed. 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 0.002 ACE flood plain. 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.

Nearly 150 buildings are spread throughout the University of Hawaii's campus. 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 0.002 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 the source. 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 that, 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.

3.2. Economic Data Development. Values were calculated for structures and contents of residential, commercial and public buildings as well as streets. Structures and street segments were assigned ground and first-floor elevations, study reaches and stream stations within those reaches. Structures were divided into occupancy groups with common value, elevation and damage characteristics. Depth-damage functions, relating percentages of structure or content value to a range of inundation depths, were assigned to each occupancy group. Uncertainty factors were also assigned to elevations, values and damage functions. These processes are described in this section.

3.2.1. Economic Study Reaches. The flood plain 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 delineated by stream and then by similar hydraulic or economic characteristics or political divisions. The reaches used in this study are listed below in Table B-2, which shows the beginning and ending point (station) of each reach as well as its index point. The reaches, as aligned within the overall study area are shown in Figure B-2, which for convenience is repeated here from earlier in this appendix (where section 1.3 also described the reaches in greater detail).

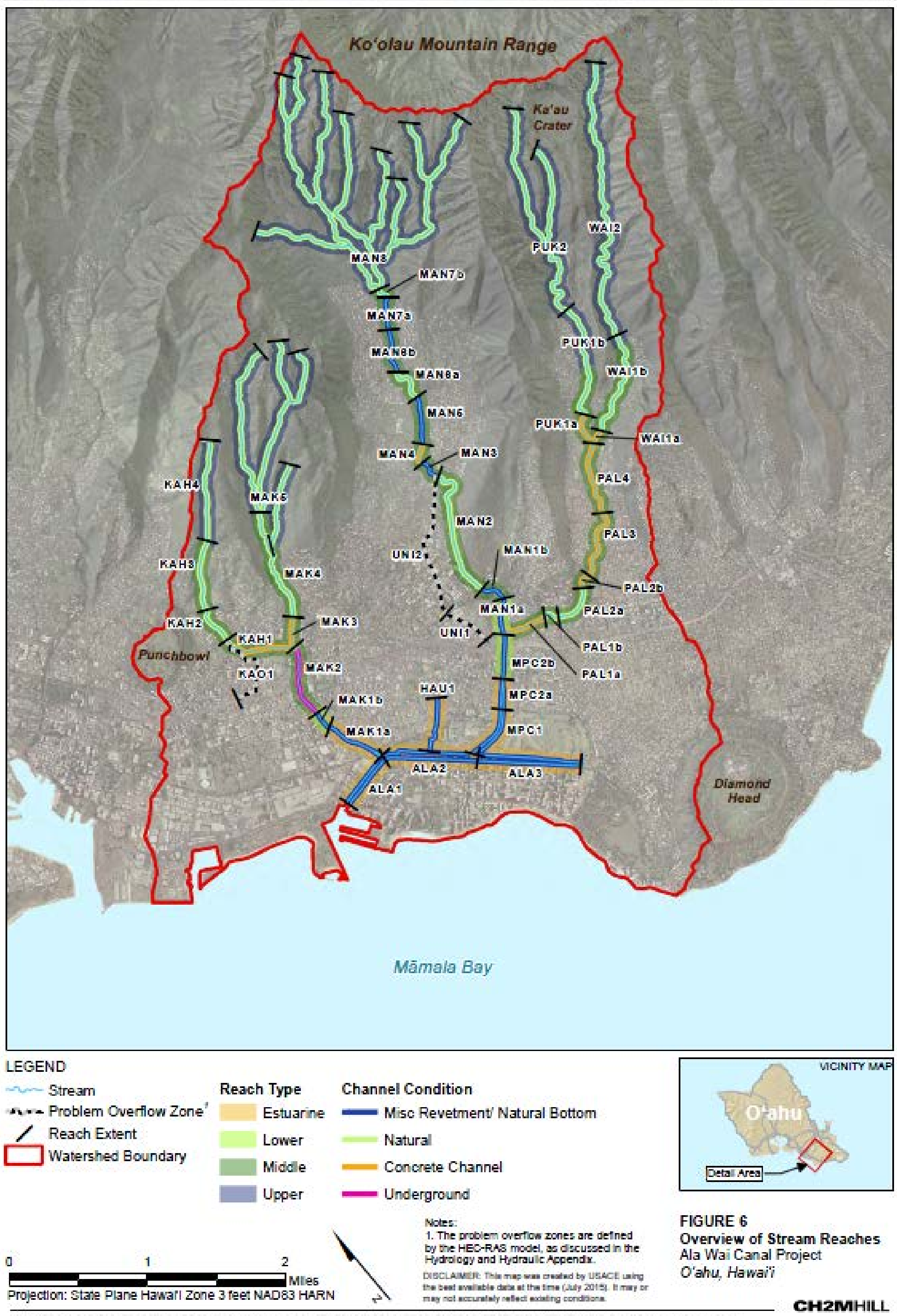
3.2.2. Structure Elevations. Ground and first-floor elevations for residential, commercial and public structures were estimated using 2008 LIDAR data obtained from GIS metadata and developed especially for the Ala Wai Canal Project. Ground elevations were estimated using a shapefile that included building footprints. The centroid point of each building polygon was calculated using ArcGIS and then the ground elevation of each centroid was extracted from the GIS data. ArcGIS was used to join the ground elevations to the TMK county tax data for each structure. First-floor elevations were then estimated by conducting a windshield survey of 10 percent of the total structures in the Ala Wai flood plain. This process resulted in an estimate of 2.0 feet for the average foundation height among study area structures. The foundation height was added to the ground elevation and rounded to the nearest tenth of a foot to obtain first-floor elevations for each structure. Street elevations were estimated following a similar process with the same mapping resources. It was estimated that the average structure in the study area has an average first finished floor elevation of 2.0 feet above its ground level.

Uncertainty was accounted for by assigning a standard deviation of 0.7 for all study area structures. This factor accounts for the separate and additive uncertainties inherent in estimating ground and first-floor elevations. Table 6-5 in EM 1110-2-1619 lists standard deviations to be used for different methods of estimation, and the LIDAR estimation of ground elevations in this study would be equivalent to the aerial survey with 2-foot contour intervals. The standard deviation recommended for this method is 0.3 feet, and this value is used to represent uncertainty in the ground elevation. Estimation of foundation heights entailed a larger degree of uncertainty

Table B-2. Economic Study Reaches

Sub-Basin and Stream	Reach	Index Point	Downstream end	Upstream end
ALA WAI				
Ala Wai	ALA1	1859	33	2400
Ala Wai	ALA2	4847	2401	6000
Ala Wai	ALA3	8015	6001	9724
Manoa-Palolo Canal	MPC1	1813	859	2300
Manoa-Palolo Canal	MPC2	3406	2301	5198
MAKIKI				
Makiki	MAK1	1719	200	3600
Makiki	MAK2	4325	3601	6300
Makiki	MAK3	6606	6301	7600
Makiki	MAK4	9666	7601	10768
Kanaha Split	KAO1	1393	809.96	3507.96
Kanaha Ditch	KAH1	1874	3	2800
Kanaha Ditch	KAH2	3005	2801	4372
MANOA				
Manoa	MAN1	948	84	2450
Manoa	MAN2	5461	2451	7900
Manoa	MAN3	8367	7901	8750
Manoa	MAN4	9032	8751	9520
Manoa	MAN5	10309	9521	11300
Manoa	MAN6	13136	11301	14650
Manoa	MAN7	15753	14651	16506
University	UNI1	1107	131	1900
University	UNI2	4606	1901	6929
PALOLO				
Palolo	PAL1	6376	5303	7500
Palolo	PAL2	8574	7501	9900
Palolo	PAL3	11649	9901	12600
Palolo	PAL4	14619	12601	15526
Pukele	PUK1	2184	146	5958
Waiomao	WAI1	1724	110	4900

Figure B-2. Overview of Stream Reaches



since it was done by visual inspection from a car during a windshield survey and involved only a 10 percent sample of the structure population. Based on professional judgment in performing surveys of this type, it is believed that the true range of a first-floor elevation would be on the order of plus or minus three-quarters of a foot. By assuming a range of 0.8 feet above and below the first floor value, or a total range of 1.6 feet representing the entire range of uncertainty beyond two standard deviations, and then dividing this figure by four, a standard deviation of 0.4 feet was arrived at to represent a single standard deviation. Adding this figure to the ground elevation uncertainty results in a first-floor elevation standard deviation of 0.7 feet which is applied to all buildings. For city streets, autos, and the golf course, only the 0.3 foot ground elevation standard deviation is applied.

3.2.3. Structure Values. Each parcel of land and improvements to the land is identified by a TMK (Tax Map Key), which is administered by the City and County of Honolulu. The City and County periodically appraises the properties and displays the assessed values on their website. ER 1105-2-100, the USACE Planning Guidance Notebook, warns against automatically equating county assessed values with the depreciated replacement values required in Corps economic analyses, but the appraised values often do present credible proxies for depreciated replacement value.

Most commercial, public, and residential property values used for this study are based on the values obtained from the tax appraisal data, which are available online. According to “Procedural Guidelines for Estimating Residential and Business Structure Value for Use in Flood Damage Estimations” (IWR report 95-R-9, April 1995), 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 and remaining life; (3) assesses land and improvements separately; and (4) is for properties without significant depreciation. These criteria are often met in Honolulu by the local appraisal values. The Revised Ordinances of Honolulu require 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, age and condition of the structure are accounted for in determining values, and depreciation is a much smaller factor than usual in this tourist-driven area where the appearance and functionality of properties needs to be up-to-date.

Still, although all the properties in the watershed have been appraised for taxation purposes and those values used as is in initial phases of the economic analysis, 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. Therefore, USACE economists prepared their own independent estimates of depreciated replacement structure value. These calculations were based on structure characteristics from the tax data such as area in square feet and age of structures. They utilized Marshall & Swift cost factors and were informed by input from local experts in Honolulu’s building costs and depreciation.

To estimate flood damages to structures and their contents, it was necessary to identify the following information for each structure in the flood plain:

- The watershed, and reach associated with the structure;

- The location or river station of each structure along the length of the watershed;
- The ground and first-floor elevations 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 GIS mapping that included layers for parcels, centroids (points) identifying structure locations, delineation of the 0.002 ACE flood plain, 2-foot contour intervals, LIDAR-based elevations and aerial photographs of the project area. The flood plain was divided into 27 reaches, as shown in Table B-4 and Figure B-2. Most of the structure characteristics of the structures in the flood plain were obtained from either field surveys performed by USACE economists or through the City and County of Honolulu Real Property Assessment Office. After identifying the initial structure inventory, a windshield survey of about 500 structures was performed by USACE economists to estimate the 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. These characteristics were entered into the Marshall & Swift estimation software program to obtain depreciated replacement costs for each structure in the inventory. The estimator software requires the user to enter essential data about the structure, including zip code, square footage, exterior wall type, foundation, roof type, number of stories and structure condition. The data are then processed within the software program and the depreciated replacement cost is calculated.

During the period since the beginning of the study, the HEC-FDA structure file for the Ala Wai Canal Project has undergone several major updates. Due to the vast structure inventory in the defined area, it was determined early on that it would be impractical to survey each structure. Therefore, a sampling technique was implemented to randomly reevaluate 10 percent of the properties. Marshall & Swift estimating software was again 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, regression analysis performed using the Microsoft Excel function indicated 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. Smaller 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 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 exceeding 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 became the final structure values used in the flood plain inventory.

A side note: valuation of structures in this analysis is focused on the first floor of the building. (Virtually none of the buildings here, commercial or residential, have basements.) Even in as large an event as the 0.002 ACE flood, floodwaters would not reach the second story of any structures in the flood plain. Therefore, a simplifying assumption was made early on in the data gathering and development phase of the economic analysis that the depreciated replacement costs of each building's first story would be based upon the total depreciated replacement value for the building divided by the number of stories in the building. Valuation of the many multi-storied buildings in this area is treated in this fashion.

3.2.3.1. Structure Value Uncertainty. Uncertainty in structure values was computed for residential, commercial and public structures based on Marshall and Swift square foot cost data for a range of construction classifications. The process assumed that the true rating of construction quality for any given structure could be one category higher or lower than our estimate. For example, if a home's construction quality was rated as fair in the field survey, for the uncertainty calculations it was assumed that the true rating could instead be low (one category below fair) if too optimistic, or average (one category above fair) if too pessimistic. Basic square foot values were identified for each condition for residential and commercial/public structures. Within each home type and typical size, the percentage change in square foot value from one construction quality rating to the next was calculated. Uncertainty was then accounted for by finding the maximum incremental change between quality ratings in any category or size. The maximum incremental change was approximately 39 percent for commercial structures and 35 percent for residential structures. These percentages imply that the true depreciated replacement value of a commercial structure could vary above and below the calculated value across a total uncertainty range of 78 percent. This value was divided by four to obtain a standard deviation of 19.5 percent for commercial and public structures. Similarly for residential structures, the estimated total uncertainty range of 70 percent was divided by four to obtain a standard deviation of 17.5 percent which is used for single-family homes. (Multi-family homes are assigned the commercial/public standard deviation.)

Other types of uncertainty also are inherent in estimating depreciated replacement value, and depreciation is one of the most important sources of uncertainty. A factor of 5 percent was added to the standard deviations discussed above to account for depreciation. The final standard deviations used in the economic analysis are 25 percent for commercial and public structures (including multi-family housing) and 23 percent for single-family housing.

3.2.3.2. 2016 Update of Structure Values. During the final stages of completion of this feasibility report in 2016, structure values were updated from 2014 to 2017 prices (2017, rather than 2016, on the assumption that final processing of the report will occur in FY 17). The 2014 to 2016 portion of the structure values update relied upon a sample of 10 percent of the properties in the county's tax assessment database, stratified to include all study reaches and to include a reasonable residential, commercial and public structures. The tax records broke out improvement values from land values, and the improvement values were the basis of the update; i.e., land value is not included anywhere in the calculations. For the 10 percent of properties sampled, each property's 2014 appraised structure value was compared with its 2016 appraised value, and a percentage increase or decrease was calculated. An average percentage increase was ultimately calculated for the residential, commercial and public categories, and the values of all structures in the study's structure inventory were updated to 2016 prices using one of these three factors. The 2014-2016 update factors were: residential, 1.20168; commercial, 1.12431; public, 1.20168. (In light of the ER 1105-2-100 guidance concerning appraised or assessed values vs. depreciated replacement values, it should be understood that that updated 2016 values do not represent a replacement of the original depreciated replacement valuations as calculated in the Marshall and Swift software. The change in appraised values is used only as an updating factor for price levels. It was deemed a better source for updating than such national price and cost indices as the Consumer Price Index and the ENR Construction Cost Index and Building Cost Index because it is site-specific and based on the county's most recent appraisal of values for structures within the study area. The depreciated replacement values used in the economic analysis represent the original Marshall and Swift-based values, updated from 2014 to 2016 using the factor based on growth in assessed values.)

Since 2017 appraised values were not yet available, the 2016 to 2017 portion of the price level adjustment had to be handled separately. The Marshall and Swift Comparative Cost Multiplier for Honolulu was used for this portion of the update. Available index numbers from the first three quarters of FY 16 for Class B and C structures were used to calculate an average quarterly percentage change in each case. Since the factors for the Class B and C structures were very similar (1.011 over the first three quarters of FY 16 for Class B, 1.013 for Class C), they were combined into one factor, 1.012, for convenience. This factor represented the first three quarters of FY 16; extending it to the final quarter of the year resulted in an update factor of 1.016 for the 2016-2017 portion of the update.

3.2.4. Other Values. Content value assumptions for residential, commercial and public buildings are discussed below in section 3.4.6. Valuation for city streets and residential autos is discussed in this section.

3.2.4.1. Street Values. Three types of city street are found in the county appraisal database for the study area. The values applied to the streets were based on average construction costs per mile for different classes of streets as obtained from five state and local transportation departments. These estimates were brought up to the current price level and averaged to obtain the values used in this analysis. The costs per mile were multiplied by the length of each street segment in the shapefile and within the 0.002 ACE flood plain to obtain a value for each segment. The three types of street and the cost per mile assigned to them are as follows:

Non-arterial (generally 2-lane):	$1,691,000
Arterial, divided (generally 2 lanes in each direction):	$6,705,000
Arterials, undivided (generally 2 lanes in each direction):	$6,495,000

None of the estimates available came from Hawaii. Previous surveys comparing road construction costs in the 50 states have found that these costs tend to be higher in Hawaii than in almost any other state due to such factors as topography (Washington State Department of Transportation, 2002), so the average values cited above can safely be considered understated.

Based broadly on the range of different estimates from the different transportation departments, a standard deviation of 15 percent is used to characterize uncertainty in street values. This percentage, too, is almost certainly somewhat conservative or understated.

3.2.4.2. Residential Auto Values. Damage to automobiles in this analysis is estimated only for residential properties. Estimates for businesses would almost certainly involve a lot of double-counting relative to the residential properties. A 2016 Edmunds report contained the most recent estimate for average used car values (Edmunds.com, 2016). The average value was $18,500. This value was updated to 2017 prices using the CPI-U, with a factor of 1.020266 representing the October 2015 to October 2016 increase in prices. (Monthly CPI-U index numbers were available only for the first eight months of FY 16, through June 2016, so an average monthly percentage increase was calculated based on the eight months to represent each of the remaining four months in the FY.) The value, updated to 2017 dollars, is $18,875.

Besides the average auto value, two other items are necessary to calculate the auto value to be used in the risk analysis. The average numbers of cars per household in Honolulu, according to a Governing magazine survey (quoting the American Community Survey of the U.S. Census Bureau), is 1.3. The average evacuation rate for storms with warning time of less than six hours (which would be the Ala Wai context) is 50.5 percent, according to EGM 09-04, meaning that 49.5 percent of vehicles would not be evacuated and would be subject to flood damage. Using these data, the value used in the analysis for each auto was $12,140:

$$\$18,875 \times 1.3 \times 49.5\% = \$12,140$$

The outcome of this process was to enter one auto into the structure inventory for each home (with the same ground elevation and station) and value it as above, accounting for autos per household and evacuation rates as well as current average used car values. Uncertainty for the value was assigned as a standard deviation of 10 percent.

3.2.5 Occupancies. Occupancy groups or occupancies are used to group structures with common characteristics pertaining to structure and contents value, elevation uncertainty and damage susceptibility. The occupancies used for this economic analysis include 18 classifications. Residential occupancies include 1 and 2-story single-family houses without basements, multi-family housing (apartments, town houses, condominiums), and residential autos. Commercial occupancies include convenience stores, restaurants, retail stores, garages, offices, banks, warehouses, hospitals, hotels, churches, golf courses, and a “commercial average” classification for properties where not enough information was available to narrow down the occupancy. Public occupancies include public structures and city streets.

Table B-3 displays the frequency with which each occupancy type appears in the study’s structure inventory, including the total, structure and content values of each occupancy. Table B-4 displays this information in a more detailed manner, by reach and by category (residential, commercial and public), allowing the reader to see, for example, which reaches are predominantly residential or commercial, how many single-family vs. multi-family homes are found in a particular reach, or how the industrial or business structure varies from reach to reach.

Table B-3. Breakdown of Structure Inventory by Occupancy Types

1 October 2016 Prices

Occupancy Type	Structures Quantity	Structure Value ($1000s)	Content Value ($1000s)	Total Value ($1000s)
Residential				
Single-Family 1-story no basement	2,910	$373,346	$373,346	$746,691
Single-Family 2-story no basement	1,291	$359,605	$359,605	$719,209
Multi-Family no basement	2,595	$1,359,291	$299,044	$1,658,335
Autos	--	$0	$82,220	$82,220
Total Residential	6,796	$2,092,241	$1,114,214	$3,206,455
Commercial				
Banks	13	$10,784	$8,412	$19,195
Churches	20	$11,056	$4,489	$15,545
Commercial average	14	$21,204	$16,115	$37,319
Convenience Stores	165	$28,497	$40,465	$68,962
Garages	11	$7,013	$4,348	$11,361
Golf Courses	1	$2,615	$9,153	$11,768
Hospitals	12	$50,825	$22,312	$73,137
Hotels	181	$735,288	$188,234	$923,522
Offices	660	$259,687	$236,315	$496,003
Restaurants	98	$72,416	$28,966	$101,382
Retail Stores	657	$631,291	$1,079,507	$1,710,798
Warehouses	84	$102,785	$69,894	$172,678
Total Commercial	1,916	$1,933,460	$1,708,210	$3,641,670
Public				
Public Facilities	249	$1,464,590	$551,806	$2,016,396
Streets	--	$64,161	$0	$64,161
Total Public	249	$1,528,751	$551,806	$2,080,557
Total	8,961	$5,554,452	$3,374,230	$8,928,681

Table B-4. Occupancy Groups by Reach (1 October 2016 Prices)
Ala Wai Subbasin

Ala Wai subbasin	ALA1		ALA2		ALA3		MPC1		MPC2	
Occupancy	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value
RESIDENTIAL										
Single-Family	13	$3,611.2	693	$239,285.2	125	$34,686.4	178	$56,072.4	322	$115,423.2
Multi-Family	119	$175,178.3	794	$486,755.2	311	$283,055.0	245	$126,960.5	192	$95,697.3
Autos	0	$1,585.1	0	$17,992.7	0	$5,275.6	0	$5,118.3	0	$6,219.4
Total Res.	132	$180,374.6	1,487	$744,033.1	436	$323,017.0	423	$188,151.2	514	$217,339.9
COMMERCIAL										
Banks	1	$702.4	5	$11,065.4	3	$2,612.7	3	$2,863.0	0	$0.0
Churches	0	$0.0	13	$5,006.2	1	$2,102.7	2	$1,116.5	0	$0.0
Commercial (gen.)	4	$15,955.8	8	$9,578.4	2	$11,784.4	0	$0.0	0	$0.0
Convenience Stores	3	$2,726.9	12	$20,696.1	5	$10,057.5	7	$3,946.3	70	$15,651.1
Garages	4	$8,562.3	4	$923.7	0	$0.0	2	$1,272.3	0	$0.0
Golf Courses	0	$0.0	0	$0.0	0	$0.0	1	$11,768.4	0	$0.0
Hospitals	0	$0.0	2	$2,932.8	2	$2,109.0	0	$0.0	2	$2,802.3
Hotels	36	$659,034.1	48	$97,277.5	92	$151,108.0	0	$0.0	0	$0.0
Offices	68	$230,413.2	70	$72,304.0	17	$6,264.0	15	$15,493.9	166	$20,897.3
Restaurants	34	$29,938.4	29	$21,663.5	30	$48,483.3	5	$1,297.0	0	$0.0
Retail Stores	98	$581,931.6	63	$183,501.4	61	$353,074.0	13	$10,909.6	76	$67,095.8
Warehouses	67	$107,359.9	13	$22,062.1	0	$0.0	1	$9,116.4	0	$0.0
Total Comm.	315	$1,636,624.6	267	$447,011.1	213	$587,595.6	49	$57,783.4	314	$106,446.5
PUBLIC										
Public structures	25	$361,255.7	22	$27,994.4	8	$31,378.9	0	$0.0	18	$12,127.2
Streets	0	$3,355.2	0	$17,808.5	0	$19,037.2	0	$2,474.4	0	$3,617.2
Total Pub.	25	$364,610.9	22	$45,802.9	8	$50,416.1	0	$2,474.4	18	$15,744.4
TOTAL	472	$2,181,610.1	1,776	$1,236,847.1	657	$961,028.7	472	$248,409.0	846	$339,530.8

Table B-4. Occupancy Groups by Reach (1 October 2016 Prices)
Makiki Subbasin

Makiki subbasin	MAK1		MAK2		MAK3		MAK4		KAH1		KAH2		KAO1	
Occupancy	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value
RESIDENTIAL														
Single-Family	266	$76,662.6	135	$44,110.4	61	$18,210.0	65	$21,914.4	72	$23,579.4	19	$6,502.6	147	$41,064.0
Multi-Family	330	$189,178.3	79	$117,424.6	30	$21,056.3	10	$5,535.6	32	$19,432.0	1	$546.6	60	$43,492.6
Autos	0	$7,211.6	0	$2,589.4	0	$1,101.1	0	$907.5	0	$1,258.4	0	$242.0	0	$2,504.7
Total Res.	596	$273,052.5	214	$164,124.4	91	$40,367.4	75	$28,357.5	104	$44,269.8	20	$7,291.2	207	$87,061.3
COMMERCIAL														
Banks	1	$1,951.9	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Churches	0	$0.0	1	$1,874.5	0	$0.0	0	$0.0	1	$3,776.9	0	$0.0	2	$1,667.8
Commercial (gen.)	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Convenience Stores	53	$9,450.6	11	$2,932.8	3	$619.0	0	$0.0	0	$0.0	0	$0.0	1	$2,881.5
Garages	1	$602.3	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Golf Courses	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Hospitals	0	$0.0	4	$57,903.1	0	$0.0	0	$0.0	0	$0.0	0	$0.0	2	$7,390.1
Hotels	5	$16,102.4	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Offices	294	$129,639.5	29	$19,576.9	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Restaurants	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Retail Stores	287	$430,890.8	33	$42,202.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	7	$3,045.5
Warehouses	0	$0.0	1	$20,175.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Total Comm.	641	$588,637.5	79	$144,664.3	3	$619.0	0	$0.0	1	$3,776.9	0	$0.0	12	$14,984.9
PUBLIC														
Public structures	0	$0.0	3	$17,802.1	0	$0.0	1	$1,562.1	0	$0.0	2	$5,609.6	3	$9,899.8
Streets	0	$3,600.0	0	$4,045.9	0	$2,236.2	0	$1,879.9	0	$266.1	0	$0.0	0	$882.7
Total Pub.	0	$3,600.0	3	$21,848.0	0	$2,236.2	1	$3,442.0	0	$266.1	2	$5,609.6	3	$10,782.5
TOTAL	1,237	$865,290.0	296	$330,636.7	94	$43,222.6	76	$31,799.5	105	$48,312.8	22	$12,900.8	222	$112,828.7

Table B-4. Occupancy Groups by Reach (1 October 2016 Prices)
Manoa Subbasin

Manoa subbasin	MAN1		MAN2		MAN3 & 4		MAN5		MAN6 & 7		UNI1		UNI2	
Occupancy	**quantity**	**total value**	**quantity**	**total value**	**quantity**	**total value**	**quantity**	**total value**	**quantity**	**total value**	**quantity**	**total value**	**quantity**	**total value**
RESIDENTIAL														
Single-Family	106	$33,652.2	25	$10,584.0	224	$101,238.4	244	$99,545.4	146	$273,303.8	0	$0.0	0	$0.0
Multi-Family	5	$5,316.6	106	$1,889.7	62	$21,178.7	22	$18,931.8	100	$32,335.5	0	$0.0	0	$0.0
Autos	0	$1,343.1	0	$1,585.1	0	$3,460.6	0	$3,218.6	0	$8,131.2	0	$0.0	0	$0.0
Total Res.	111	$40,311.9	131	$14,058.8	286	$125,877.7	266	$121,695.8	246	$313,770.5	0	$0.0	0	$0.0
COMMERCIAL					0	$0.0			0	$0.0				
Banks	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Churches	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Commercial (gen.)	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Convenience Stores	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Garages	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Golf Courses	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Hospitals	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Hotels	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Offices	0	$0.0	0	$0.0	0	$0.0	1	$1,414.0	0	$0.0	0	$0.0	0	$0.0
Restaurants	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Retail Stores	0	$0.0	6	$0.0	2	$30,749.3	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Warehouses	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Total Comm.	0	$0.0	6	$0.0	2	$30,749.3	1	$1,414.0	0	$0.0	0	$0.0	0	$0.0
PUBLIC					0	$0.0			0	$0.0				
Public structures	12	$53,065.7	42	$55,688.6	8	$23,753.5	3	$2,194.3	2	$702.5	21	$322,182.2	54	$1,079,345.9
Streets	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Total Pub.	12	$53,065.7	42	$55,688.6	8	$23,753.5	3	$2,194.3	2	$702.5	21	$322,182.2	54	$1,079,345.9
TOTAL	123	$93,377.6	179	$69,747.4	296	$180,380.5	270	$125,304.1	248	$314,473.0	21	$322,182.2	54	$1,079,345.9

Table B-4. Occupancy Groups by Reach (1 October 2016 Prices)
Palolo Subbasin

Palolo subbasin	PAL1		PAL2		PAL3		PAL4		PUK1		WAI1	
Occupancy	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value	quantity	total value
RESIDENTIAL												
Single-Family	52	$14,831.6	70	$20,259.6	293	$83,844.8	220	$57,256.2	191	$55,179.6	108	$35,082.6
Multi-Family	8	$3,001.8	9	$4,201.8	24	$1,745.8	1	$707.6	38	$2,470.1	17	$2,243.0
Autos	0	$726.0	0	$955.9	0	$3,835.7	0	$2,674.1	0	$2,770.9	0	$1,512.5
Total Res.	60	$18,559.4	79	$25,417.3	317	$89,426.3	221	$60,637.9	229	$60,420.6	125	$38,838.1
COMMERCIAL												
Banks	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Churches	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Commercial (gen.)	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Convenience Stores	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Garages	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Golf Courses	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Hospitals	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Hotels	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Offices	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Restaurants	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Retail Stores	7	$5,518.6	4	$1,879.1	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Warehouses	2	$13,964.8	0	$0.0	0	$0.0	0	$0.0	0	$0.0	0	$0.0
Total Comm.	9	$19,483.4	4	$1,879.1	0	$0.0	0	$0.0	0	$0.0	0	$0.0
PUBLIC												
Public structures	0	$0.0	5	$6,967.7	0	$0.0	16	$3,922.0	4	$943.7	0	$0.0
Streets	0	$2,362.1	0	$1,307.4	0	$732.3	0	$449.7	0	$93.9	0	$12.5
Total Pub.	0	$2,362.1	5	$8,275.1	0	$732.3	16	$4,371.7	4	$1,037.6	0	$12.5
TOTAL	69	$40,404.9	88	$35,571.5	317	$90,158.6	237	$65,009.6	233	$61,458.2	125	$38,850.6

3.2.6. Generic Content Values and Depth-Damage Functions. The nearly 2,200 commercial and public buildings included in the structure inventory for the Ala Wai economic analysis range from small shops and businesses to 40-plus story hotels and large public institutional buildings like hospitals and college classroom buildings. An economic analysis with a structure inventory of thousands of structures with a very diverse range of types does not as a practical matter allow for development of individual contents value and damage susceptibility estimates for each structure. Generic estimates of contents-to-structure value ratio (CSVR) and damage per foot of inundation (depth-damage functions or curves) generally are used in such cases. Few such data sets exist, and the accuracy, reliability and usefulness is highly variable between different sources. But while not ideal, the generic estimates are really the only tools available for estimating economic damages for large studies such as the Ala Wai Canal study. Tables B-5 and B-6 display the main depth-damage functions and content value ratios used in this study along with their sources, which are discussed below, including their applicability to the Ala Wai context.

IWR residential functions -- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures, published semi-official depth-damage functions for single-family homes researched and developed by the Institute for Water Resources (IWR). These curves, which are used in this study for 1 and 2-story homes without basements, were based on thousands of cases of FEMA post-flood insurance claims data and are intended for national use in USACE flood damage analyses. To facilitate risk and uncertainty-based estimation of damages, the curves are also equipped with standard deviations for each foot of flooding. As for contents values for these classes of residential property, the EGM also recommends that a CSVR of 100 be used with these curves in the HEC-FDA calculation, and this guidance has been followed.

\In addition to the IWR residential structure and content curves, IWR-developed depth-damage functions for autos also have been released in EGM 09-04. These are used for residential autos in this analysis. A weighted average curve derived from the EGM is used since a breakdown of vehicles into the five types analyzed in the EGM is not available. This curve weights the five vehicle curves according to how many of each type were included in the sample summarized in Table 2 of the EGM and used in the analysis of vehicle damages contained there.

New Orleans District data **–** The New Orleans District of USACE has, over three major studies, conducted separate expert elicitations to develop depth-damage and content value data. For the Ala Wai study, data are used from the May 1997 New Orleans District report "Depth-Damage Relationships for Structures, Contents and Vehicles and Content-to-Structure Value Ratios (CSVR) in Support of the Lower Atchafalaya Reevaluation and Morganza to the Gulf, Louisiana Feasibility Studies." For this and other studies, New Orleans District brought together experts in areas such as construction, post-flood restoration and insurance adjusting to collectively estimate depth-damage relationships and content values for a group of prototype structures.

While the New Orleans context is in some important respects admittedly different from Hawaii, the prototypes evaluated (which include eating and recreation places, grocers and gas stations, professional offices, warehouses and contractors, repair and home use businesses, retail and personal services, public and semi-public facilities, and multi-family housing, as well as structure damage curves for masonry, metal or wood commercial/public structures) are broadly enough defined to be relevant in most study environments if the flooding context is similar. The commercial and public structure functions used in the economic analysis are the curves for masonry on slab structures since the great majority of the commercial and public buildings in the Ala Wai basin are of that type. There is no apparent reason why commercial and public structures should be built much differently in New Orleans than in Hawaii, or at least, not in any way relevant to flood damages. (Residential structures, on the other hand, could be significantly different.) In terms of the flooding context, one especially helpful feature of the New Orleans data is that separate estimates are provided for short and long-term flooding, and also for saltwater vs. freshwater flooding. The set of short-term inundation curves with a freshwater context is reasonably applicable to the flooding context in Hawaii, which also is characterized by inland flash flooding. Another desirable feature is that the curves include maximum and minimum percentage values along with the most likely values for each inundation depth. This feature facilitates damage estimation in a risk-based environment.

CSVRs were estimated by a second expert panel, and these estimates do not include uncertainty estimates, but an additional data set included in this report is taken from post-flood interviews of business owner/operators, and the owner/operator data do include estimated CSVRs along with standard deviations. The New Orleans expert elicitation data were used to provide most of the depth-damage functions in this study, including content functions and CSVRs for convenience stores, restaurants, retail, garages, warehouses, offices, public buildings and multi-family housing, and also structure depth-damage functions for commercial/public buildings. The expert elicitation CSVRs also were used in many cases, while the owner/operator-estimated CSVRs were paired with the expert estimates as minimum or maximum values.

***IWR non-residential functions* –** IWR has developed more than one draft set of generic nonresidential structure and content depth-damage functions with CSVRs included, most recently in 2011. These unofficial draft data have been announced for official release but have never been released despite extensive research, development and review. The curves and CSVRs use structure prototypes for a group of business types that would be representative almost anywhere in the U.S.and were developed with the intention of being provided for national use. The depth-damage functions also are equipped with minimum and maximum percentage values to accommodate risk and uncertainty requirements. In the Ala Wai study, the IWR non-residential data set is used to provide contents depth-damage functions and CSVRs for hotels and hospitals, important categories in the Ala Wai area which are not sufficiently isolated in the more broadly-defined New Orleans categories. Other CSVRs from this data set also are used in a few cases as maximum or minimum values for content value.

***HAZUS data* –** The Federal Emergency Management Agency (FEMA), in cooperation with other agencies including the Corps of Engineers, has released a large, comprehensive set of data supporting quick damage estimates for hazards such as floods at a low level of detail for almost any type of property, anywhere in the U.S. Included in the data are depth-damage functions. Many of these were developed using older Flood Insurance Administration post-flood claims data, and others were taken from Corps sources, including a data set developed by Galveston District. In this study, the HAZUS data are used only for a hospital structure depth-damage function. This is a specialized type of structure that needs to be isolated in estimating damages rather than subsumed in broad categories of office buildings or the like.

***IWR Wyoming Valley report* –** In May 1996, IWR published "Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies" (IWR report 96-R-12). This report was based upon Baltimore District post-flood data from the Wyoming Valley region of the Susquehanna River basin. The long duration, low velocity flooding pattern that served as a basis for the data is not an ideal match for the Ala Wai study; on the other hand, the freshwater, inland flooding context is applicable. This data set is particularly valuable because it is based on larger (often much larger) sample sizes than other available data sets, and it also includes some categories that are not found elsewhere. The depth-damage functions in the report do not include uncertainty data, and professional judgment has to be relied upon to fill in minimum and maximum values. The CSVRs also do not include uncertainty data, but there is enough detailed raw data in the report that standard deviations can be deduced. The Wyoming Valley data are used in this report only for religious institutions – a fairly important category that is not well covered by other data sets – and "commercial average," a generic nonresidential category covering properties where there is not enough information available to further narrow down the type of occupancy involved. In addition, in cases where CSVRs from other sources do not include uncertainty data, Wyoming Valley CSVRs are sometimes used as minimum or maximum values.

In some occupancy categories where generic depth-damage functions or CSVRs are not available, professional judgment was used. The two main cases in the present study are golf courses and city streets. For golf courses, some information on typical construction costs was available from internet sources, and additional internet research also yielded a modest amount of data on flood damage impacts to golf courses which were used to estimate a depth-damage function for the course itself (buildings on the course are evaluated using the New Orleans nonresidential structure curve and the Wyoming Valley commercial average contents curve). Street damage functions were estimated by examining data on typical costs available from several state transportation departments. These cost data are available for relatively minor repairs, such as resurfacing, that might be needed in the aftermath of a smaller flood event, as well as reconstruction costs that would be more representative of more severe events. When these costs are compared to average construction costs on a percentage basis, they provide a reasonable basis for a depth-damage function.

Damage uncertainty for the depth-damage functions used in this analysis, in all but two cases, is expressed as a triangular distribution with a most likely value for the damage percentage for each foot, bracketed by minimum and maximum damage percentages for each foot. The two exceptions are the IWR residential curves for single-family homes, where standard deviations are used to characterize damage uncertainty rather than minimum and maximum values. Content value uncertainty is expressed as standard deviations in some cases and triangular distributions in others; Table B-6 shows how uncertainty is treated for each CSVR.

3.3. The Economic Model. Upon completion of the data development and formatting of the data for HEC-FDA, construction of the FDA risk analysis model commenced.

3.3.1. Software Version. Version 1.4.1 of HEC-FDA (May 2016), the current nationally certified version of the program, was used for the latest version of the economic analysis.

3.3.2. Model Configuration. Step one in building the model was configuration, which involved loading the stream names (10 streams); the 27 reaches with index points, boundaries and left/right bank specification; analysis years or index years; and plans. The plans entered included without-project conditions under existing and future conditions (the latter reflecting intermediate and high scenarios pertaining to sea-level rise) as well as with-project conditions that individually include either the recommended plan or one of three variations of the recommended plan with higher or lower floodwalls along the Ala Wai Canal. These with-project conditions also were analyzed in the context of intermediate and high sea-level rise scenarios. Other alternatives considered earlier during the alternative formulation and evaluation phase of the study were not included in the most recent HEC-FDA model or otherwise reevaluated.

3.3.3. Engineering Data Inputs. Step two was entering the hydrologic and hydraulic engineering data, a four-part process:

(a) The water surface profiles were imported for each stream, plan and analysis year. The profiles provided from HEC-RAS were the 0.5, 0.2, 0.1, 0.05, 0.02, 0.01, 0.005 and 0.002 ACE events, plus the 0.999 ACE event and the invert elevation. Profiles were provided for four conditions:

- Existing without-project condition – indexed to existing conditions of 2015, but also used to represent the base year (2025) without-project condition; no change in the hydrologic/hydraulic variables is projected between 2015 and 2025, so the existing and base year conditions are identical.
- Future without-project condition intermediate – indexed to future without project conditions of 2075 and based on an intermediate or medium scenario pertaining to sea level rise (a low scenario was not evaluated for this analysis).
- Future without-project condition high – indexed to 2075 and representing high or pessimistic sea level rise assumptions; the starting backwater rises from 1.89 feet in the intermediate case to 3.52 feet in the high case.
- Future with-project condition – used for analysis of the four floodwall alternatives, including the recommended plan, and applied to both the base year (2025) and future year (2075) without change.

(b) Exceedance probability functions with uncertainty were constructed, joining probabilities or frequencies with discharges for each of the eight events, with uncertainty specified. These functions were constructed for all ten streams using the graphical, in which ordered pairs of discharges and exceedance frequencies are used to define the functions, with equivalent years of record defining the uncertainty in the function. The graphical functions were constructed by pulling in the water surface profiles at the index point of each reach and inserting a 0.999 ACE event as recommended in the HEC-FDA user manual. The equivalent periods of record for the 10 streams in the model ranged from 18 to 44 years.

c) Stage-discharge functions were then constructed by importing the discharges and stages for the eight events from the profiles and manually inserting the 0.999 ACE event. A normal distribution was selected to represent uncertainty, and a standard deviation of 0.7 feet was applied to the stages for all streams, reaches, events and conditions except for the 0.999 ACE event and the zero discharge, which were characterized with a standard deviation of zero. In addition, in order to better encompass the range of uncertainty introduced by the proposed floodwall heights in the recommended plan, the functions for the Ala Wai Canal reaches (ALA1, ALA2 and ALA3) and the downstream Manoa-Palolo Canal reach (MPC1) also were lengthened beyond the 0.002 ACE event to include the stage-discharge relationship for the 0.001 event.

(d) The levee feature was used to define plans and regulate without-project damage calculations. Top of levee elevations were specified for the three Ala Wai Canal reaches, where the floodwall would be constructed, for four scales of floodwall. These floodwalls initially were set to be 2 feet above the 0.01 ACE water surface elevation, then the top of wall elevations were varied in intervals of one foot until floodwall heights were identified that were estimated to have at least a 90 percent chance of containing a 0.01 ACE flood in addition to optimizing net benefits. The levee feature was also used for without-project condition and for with-project conditions in the non-project reaches (all reaches except the Ala Wai reaches). In these cases, the levees are "false" levees intended to, literally, put sideboards on the program's damage calculations by specifying the top of stream bank elevation at each index point/reach. These elevations were taken from a top of stream bank profile used in the HEC-RAS modeling. The program otherwise would not know if a stream elevation sampled in the Monte Carlo analysis for a simulated event was contained within bank and would calculate damages as though overbank flooding was occurring for any water surface elevations above the channel bottom (invert).

3.3.4. Economic Data Inputs. Following the configuration of the model and its structuring with hydrologic/hydraulic functions, economic data is added to the model. This process can be broken down into four aspects:

(a) Five categories are used in the economic analysis: commercial, public-structures, public-streets, residential-structures and residential-autos. Outputs from these five categories are eventually combined into three categories for reporting: commercial, public and residential. But the five categories allow the separation of streets from public buildings and of autos from homes, if need be.

(b) Occupancy groups, as summarized in Tables B-3 and B-4, were imported into the model. The 18 occupancies include depth-damage functions with uncertainty (see Table B-5), content-to-structure value ratios (CSVRs – see Table B-6), structure and contents value uncertainty factors, and first-floor elevation uncertainty factors for each group. Note that the IWR residential depth-damage functions for single-family homes, which begin at minus eight feet, are truncated to begin at minus one foot since residential structures in the study area rarely have basements of any kind, much less the walk-out basements apparently envisioned by these damage curves.

(c) The economic structure inventory was imported into the model, containing 16,616 homes, autos, businesses, public structures and street segments. Autos are treated as structures, separate from the homes with which they are associated, so that calculation of their values and damages can be isolated. Each item is characterized by identification number, stream, station, bank, reach, occupancy group, first-floor elevation (or ground elevation for streets and autos), value and module. Only one module, the base module, is used in this analysis – meaning the same structure inventory is applied to all plans, years and conditions.

3.3.5. Model Calibration. Efforts were made to ensure model outputs corresponded reasonably to known flood history. However, research has uncovered very little “known” flood history, in terms of recorded, itemized and quantified damages of the type that would be required to calibrate against. In addition, as discussed in Section 1.4, there is no historical record of any event in the Ala Wai Canal watershed that would be considered extremely rare, such as a 0.01 ACE flood. Where historical flood data were available, as was the case with the University of Hawaii’s 2004 flood experience and its subsequent flood proofing effort that has sharply reduced the campus’s flood exposure, model inputs were adjusted to bring results in line with these records. But there is a dearth of reliable and complete information on historical flood consequences that would be useful in the modeling. The damages produced by the model may seem large in light of the lack of historical information that could verify them, but based on the large urban investment value found in the flood plain and the vulnerability of many properties to inundation damage, and also on flood risk in similar densely developed urban areas in other areas of the county, the results of the model should be reasonably accurate.

Table B-5. Depth-Damage Functions Used in the Economic Analysis

Occupancy	Type	-1	0	1	2	3	4	6	8	12	15	Source
Residential, Single-Family 1 story	Struc	2.5	13.4	23.3	32.1	40.1	47.1	58.6	67.2	77.2	80.2	1
	Cont	2.4	8.1	13.3	17.9	22.0	25.7	31.5	35.7	39.7	40.0	1
Residential, Single-Family 2 story	Struc	3.0	9.3	15.2	20.9	26.3	31.4	40.7	48.8	61.4	67.7	1
	Cont	1.0	5.0	8.7	12.2	15.5	18.5	23.9	28.4	34.7	36.9	1
Residential, Multi-Family	Struc	0.0	0.0	13.2	20.9	23.6	27.1	28.8	41.3	41.3	41.3	4a
	Cont	0.0	0.0	14.6	22.3	37.8	43.1	45.0	45.0	82.7	89.9	4a
Residential Autos	Auto	0.0	0.0	25.1	42.9	58.6	72.3	93.2	99.5	100.0	100.0	2
Commercial/Public Structure - Masonry	Struc	0.0	1.6	12.0	17.4	22.4	26.3	29.5	31.9	52.4	41.3	4a
Bank	Cont	0.0	0.0	16.2	34.0	64.8	80.2	89.5	91.8	91.8	91.8	4a
Church	Cont	0.0	0.0	22.1	37.4	47.9	55.1	63.5	67.4	70.2	70.8	6
Commercial average	Cont	0.0	0.0	21.6	36.6	47.1	54.4	63.0	67.2	70.4	70.9	6
Convenience store	Cont	0.0	0.0	26.9	79.3	86.6	89.8	95.9	95.9	95.9	95.9	3a
Garage	Cont	0.0	0.0	19.6	31.2	47.1	62.9	64.2	65.6	76.1	76.1	3a
Golf course	Struc	0.0	1.6	12.0	17.4	22.4	26.3	29.5	31.9	52.4	41.3	4a
	Cont	0.0	0.0	75.0	76.4	86.8	97.2	100.0	100.0	100.0	100.0	7
	Other	0.0	1.0	5.0	10.0	20.0	30.0	50.0	70.0	75.0	75.0	7
Hospital	Struc	0.0	0.0	0.0	0.0	20.0	25.0	35.0	43.0	55.0	60.0	5
	Cont	0.0	0.0	14.6	27.0	37.0	53.4	79.1	92.5	96.3	96.3	3
Hotel	Cont	0.0	0.0	11.8	18.6	26.3	34.1	48.7	58.4	64.9	64.9	3
Office	Cont	0.0	0.0	16.2	34.0	64.8	80.2	89.5	91.8	91.8	91.8	4a
Public facility	Cont	0.0	0.0	65.0	65.0	90.0	100.0	100.0	100.0	100.0	100.0	4a
Restaurant	Cont	0.0	0.0	23.9	47.8	76.5	91.3	94.4	96.7	96.7	96.7	4a
Retail store	Cont	0.0	0.0	23.0	55.0	68.5	77.4	94.4	94.4	97.0	97.0	4a
Warehouse	Cont	0.0	0.0	12.0	20.1	26.6	30.9	46.2	60.6	72.5	72.5	4a
Streets	Struc	0.0	0.01	0.05	0.50	1.0	4.0	8.0	14.0	33.0	50.0	7

Sources: (1) IWR residential, from EGM 04-01; (2) IWR vehicle curves, from EGM 09-04; (3) IWR non-residential (unofficial, 2011 draft); (4a) New Orleans District Atchafalaya/Morganza report expert elicitation; (4b) New Orleans District Atchafalaya/Morganza report owner/operator data; (5) HAZUS data; (6) IWR report 96-R-12, Wyoming Valley data; (7) professional judgment.

Notes:

1. All residential structures are assumed to be without basements.
2. All commercial and public structures are assumed to be one-story, since valuation of these buildings for this analysis was done based only on first-floor value and excluding value for floors above the first.
3. All depth-damage functions are expressed as triangular distributions, with most likely, maximum and minimum values. The only exceptions are the two single-family homes curves from IWR, which use standard deviation values instead of maximum and minimum.
4. For the golf course, the contents function refers to buildings on the course, while the "other" function refers to the course itself (i.e., the land).

Table B-6. Content-to-Structure Value Ratios Used in the Economic Analysis

Occupancy	CSVR	Std Dev	Minimum %	Maximum %	Source
Residential, Single-Family	100.0	---	---	---	1
Residential, Multi-Family	22.0	---	4.0	48.0	4a (4b)
Bank	78.0	101.3	---	---	4b
Church	34.0	82.1	---	---	6
Commercial average	245.0	73.0	---	---	6
Convenience store	142.0	---	128.0	168.2	4a (4b, 6)
Garage	62.0	---	50.0	251.0	4a (4b, 7)
Golf course (contents)*	50.0	10.0	---	---	7
Golf course (other)*	300.0	10.0	---	---	7
Hospital	43.9	---	13.9	150.0	3
Hotel	25.6	---	21.9	27.0	3
Office	91.0	---	78.0	150.0	4a
Public facility	37.0	---	30.0	82.0	4a
Restaurant	40.0	---	22.9	306.0	4a
Retail store	171.0	---	148.0	180.0	4a
Warehouse	68.0	---	37.4	372.0	4a

Sources: (1) IWR residential, from EGM 04-01; (2) IWR vehicle curves, from EGM 09-04; (3) IWR non-residential (unofficial, 2011 draft); (4a) New Orleans District Atchafalaya/Morganza report expert elicitation; (4b) New Orleans District Atchafalaya/Morganza report owner/operator data; (5) HAZUS data; (6) IWR report 96-R-12, Wyoming Valley data; (7) professional judgment. Source numbers in parentheses refer to the uncertainty factors used for the category.

Notes:
1. All residential structures are assumed to be without basements.
2. All commercial and public structures are assumed to be one-story, since valuation of these buildings for this analysis was done based only on first-floor value and excluding value for floors above the first.
3. All depth-damage functions are expressed as triangular distributions, with most likely, maximum and minimum values. The only exceptions are the two single-family homes curves from IWR, which use standard deviation values instead of maximum and minimum.
4. For the golf course, the contents function refers to buildings on the course, while the "other" function refers to the course itself (i.e., the land).

4.0. EXISTING WITHOUT-PROJECT DAMAGE ANALYSIS RESULTS

The analysis of existing conditions in the study area is indexed to hydrologic/hydraulic and economic conditions of 2015, while the analysis of base year without-project conditions is indexed to 2025. However, the economic damage analysis results and the project performance results are identical since there are no differences whatsoever between the two years in terms of hydrologic, hydraulic or economic factors. (There could be a bit of a rise in water surface elevations from 2015 to 2025 due to sea level rise, but it was not considered significant.)

4.1. Investment. Total investment for the study area by reach, as calculated using the procedures described in section 3, is summarized in Table B-7. Investment in the study area totals $8,928,681,000 (2017 prices). Of the four subbasins, the Ala Wai subbasin accounts for 56 percent of total investment, while the Manoa subbasin accounts for 24 percent, the Makiki for 16 percent and the Palolo for 4 percent. Of the 27 individual reaches, the five with the highest investment are ALA1 ($2.18 billion), ALA2 ($1.24 billion), UNI2 ($1.08 billion), ALA3 ($961,000) AND MAK1 ($865,000). Residential, commercial and public categories respectively account for 36, 41 and 23 percent of total investment.

4.2. Single-Event Damages. Table B-8 displays existing/ without-project total inundation damages for each of the eight events used in the analysis, plus the 0.001 event. These totals do not represent annualized impacts (EAD). Each total is the estimated total of damages that would occur in each event evaluated, without being discounted according to how frequently the event would be expected to occur as in the annualization process. The totals shown account for physical damages to homes, businesses, public structures, streets and residential autos and include damages both for buildings and their contents. They do not include other impacts of flooding such as emergency costs, clean-up costs or travel delay costs. There is also the point made earlier in this appendix that total damages and NED impacts probably are understated because of negative impacts from flooding to other than domestic spending sources. Thus, these damage totals could be much larger if all known impacts could be quantified.

A 0.002 ACE flood would be expected to result in $2.07 billion in damages, while a 0.01 ACE flood, as shown in Table B-8, would cause estimated property and infrastructure damage of more than $1.41 billion. Figure B-3 shows by color-coded reaches the range of total damages under without-project conditions for the 0.01 ACE flood. The three Ala Wai Canal reaches, which are home to many of Waikiki's landmark hotels, are by far the largest contributors to the 0.01 event total damages, accounting for two-thirds of the total. The Ala Wai subbasin accounts for three-fourths of the total. The UNI2 reach also contributes heavily to the total.

4.3. Expected Annual Damages (EAD). Table B-9 presents total without-project EAD under existing conditions for each damage category and reach, while Figure B-4 gives a color-coded overview of flood risk in each reach. EAD by reach for the entire watershed totals $53,719,000. The Ala Wai subbasin accounts for 84 percent of the total EAD. This area surrounding the Ala Wai Canal is clearly where most of the greater watershed's flood risk is highest. As for the remainder of the study area, the Manoa subbasin is the next largest contributor to the total EAD with 12 percent of the total, while the Makiki and Palolo areas account for almost 4 percent and less than 1 percent respectively. The reaches with the highest

EAD are, in order, ALA2, ALA3, ALA1 and UNI2. The commercial category, including large hotels, accounts for 48 percent, and the public category, which includes the University of Hawaii campus, accounts for 13 percent. About 39 percent of the total EAD for the study area is residential, including large condominiums. The latter result emphasizes the fact that, while 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.

4.4. Beginning Damage Elevations. Table B-10 shows a reach by reach account of the beginning damage frequency. Use of false levees forces many of these beginning frequencies to be lower and thus more accurate than they would be with no indication of stream bank top elevation in the model.

4.5. Annual, Long-Term and Conditional Exceedance Performance. USACE guidelines on risk-based analysis for flood damage reduction studies direct the assignment of accuracy to flood frequency estimates based on 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 is assigned an accuracy value, depending on which hydrologic methodology was used to determine the peak flow discharge magnitudes, and this can be determined using guidance in EM 1110-2-1619 (Department of the Army, 1996). 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 is 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-11 displays the "project performance" statistics for the existing/base year without-project condition. Target stage is the stage where significant damage from flooding begins. In leveed reaches, it is the same as the specified top of levee elevations; in unleveed reaches, it is the stage at the location in the reach where the stream initially goes over bank. Annual exceedance probability (AEP), which is keyed to the target stage, is the chance that a damaging flood will occur in any given year, regardless of magnitude. AEP is the probability that in a given year the water surface elevation will exceed the target stage and result in economic damages. There are two versions of AEP: a median version, based solely on nominal values as entered into the FDA program, and an expected version. Long-term risk is the probability that the target stage would be exceeded over a 10-, 30-, or 50-year period. Conditional nonexceedance probability is the chance that a given flood event will be successfully contained at or below the target stage, preventing significant economic damage.

Calculated expected annual exceedance probability under without-project conditions of 2015 are approximately 18.9 percent for reach ALA1, 64 percent for ALA2 and 91.8 percent for ALA3. The Manoa subbasin also has three reaches with fairly high expected annual exceedance probabilities: MAN1 (29.4 percent), MAN4 (24.3 percent) and MAN5 (16.6 percent). The expected AEP in all other reaches is less than 10 percent.

Table B-7. Total Investment in Ala Wai Study Area - By Reach and Category
1 October 2016 Prices

Reach	RESIDENTIAL STRUCTURES				COMMERCIAL STRUCTURES				PUBLIC						GRAND TOTAL	
	Total # res. bldgs	Total struc value ($000s)	Total cont value ($000s)	Total residential value ($000s)	Total # comm. bldgs.	Total struc value ($000s)	Total cont value ($000s)	Total commercial value ($000s)	Total # pub. bldgs	Total struc value ($000s)	Total cont value ($000s)	Total bldg value ($000s)	Streets value ($000s)	Total public value ($000s)	# bldgs	Total value ($000s)
ALA WAI SUBBASIN																
ALA1	132	$145,394	$34,980	$180,375	315	$961,241	$675,384	$1,636,625	25	$261,431	$99,825	$361,256	$3,355	$364,611	472	$2,181,610
ALA2	1,487	$518,622	$225,411	$744,033	267	$238,004	$209,007	$447,011	22	$17,286	$10,708	$27,994	$17,809	$45,803	1,776	$1,236,847
ALA3	436	$249,356	$73,662	$323,017	213	$303,786	$283,810	$587,596	8	$21,079	$10,300	$31,379	$19,037	$50,416	657	$961,029
MPC1	423	$132,102	$56,049	$188,151	49	$25,924	$31,859	$57,783	0	$0	$0	$0	$2,474	$2,474	472	$248,409
MPC2	514	$136,152	$81,188	$217,340	314	$44,114	$62,332	$106,447	18	$8,852	$3,275	$12,127	$3,617	$15,744	846	$339,531
TOTAL	2,992	$1,181,626	$471,289	$1,652,916	1,158	$1,573,069	$1,262,392	$2,835,461	73	$308,648	$124,108	$432,756	$46,293	$479,049	4,223	$4,967,426
MAKIKI SUBBASIN																
MAK1	596	$193,396	$79,657	$273,053	641	$245,068	$343,569	$588,638	0	$0	$0	$0	$3,600	$3,600	1,237	$865,290
MAK2	214	$118,305	$45,820	$164,124	79	$80,615	$64,050	$144,664	3	$12,994	$4,808	$17,802	$4,046	$21,848	296	$330,637
MAK3	91	$26,364	$14,003	$40,367	3	$256	$363	$619	0	$0	$0	$0	$2,236	$2,236	94	$43,223
MAK4	75	$15,495	$12,863	$28,358	0	$0	$0	$0	1	$1,140	$422	$1,562	$1,880	$3,442	76	$31,800
KAH1	104	$27,718	$16,552	$44,270	1	$2,686	$1,091	$3,777	0	$0	$0	$0	$266	$266	105	$48,313
KAH2	20	$3,699	$3,592	$7,291	0	$0	$0	$0	2	$4,095	$1,515	$5,610	$0	$5,610	22	$12,901
KAO1	207	$56,182	$30,880	$87,061	12	$8,636	$6,349	$14,985	3	$7,226	$2,674	$9,900	$883	$10,783	222	$112,829
TOTAL	1,307	$441,158	$203,366	$644,524	736	$337,262	$415,421	$752,683	9	$25,455	$9,419	$34,874	$12,911	$47,784	2,062	$1,444,991
MANOA SUBBASIN																
MAN1	111	$21,184	$19,128	$40,312	0	$0	$0	$0	12	$38,734	$14,332	$53,066	$0	$53,066	123	$93,378
MAN2	131	$6,841	$7,218	$14,059	6	$0	$0	$0	42	$40,649	$15,040	$55,689	$0	$55,689	179	$69,747
MAN3	92	$22,223	$17,523	$39,746	0	$10,489	$17,936	$28,424	8	$17,338	$6,415	$23,754	$0	$23,754	100	$91,924
MAN4	194	$45,756	$40,376	$86,132	2	$858	$1,467	$2,325	0	$0	$0	$0	$0	$0	196	$88,457
MAN5	266	$65,291	$56,405	$121,696	1	$740	$674	$1,414	3	$1,602	$593	$2,194	$0	$2,194	270	$125,304
MAN6	461	$122,280	$113,102	$235,382	0	$0	$0	$0	2	$513	$190	$703	$0	$703	463	$236,084
MAN7	211	$40,877	$37,512	$78,389	0	$0	$0	$0	0	$0	$0	$0	$0	$0	211	$78,389
UNI1	0	$0	$0	$0	0	$0	$0	$0	21	$235,170	$87,013	$322,182	$0	$322,182	21	$322,182
UNI2	0	$0	$0	$0	0	$0	$0	$0	54	$787,844	$291,502	$1,079,346	$0	$1,079,346	54	$1,079,346
TOTAL	1,466	$324,451	$291,264	$615,715	9	$12,087	$20,076	$32,163	142	$1,121,849	$415,084	$1,536,933	$0	$1,536,933	1,617	$2,184,811
PALOLO SUBBASIN																
PAL1	60	$9,876	$8,683	$18,559	9	$10,349	$9,135	$19,483	0	$0	$0	$0	$2,362	$2,362	69	$40,405
PAL2	79	$13,574	$11,843	$25,417	4	$693	$1,186	$1,879	5	$5,086	$1,882	$6,968	$1,307	$8,275	88	$35,572
PAL3	317	$43,353	$46,073	$89,426	0	$0	$0	$0	0	$0	$0	$0	$732	$732	317	$90,159
PAL4	221	$29,208	$31,430	$60,638	0	$0	$0	$0	16	$2,863	$1,059	$3,922	$450	$4,372	237	$65,010
PUK1	229	$29,615	$30,806	$60,421	0	$0	$0	$0	4	$689	$255	$944	$94	$1,038	233	$61,458
WAI1	125	$19,380	$19,458	$38,838	0	$0	$0	$0	0	$0	$0	$0	$13	$13	125	$38,851
TOTAL	1,031	$145,006	$148,294	$293,300	13	$11,042	$10,320	$21,363	25	$8,638	$3,196	$11,833	$4,958	$16,791	1,069	$331,453
GRAND TOTAL	6,796	$2,092,241	$1,114,213	$3,206,454	1,916	$1,933,460	$1,708,210	$3,641,670	249	$1,464,590	$551,806	$2,016,396	$64,161	$2,080,557	8,961	$8,928,681

Table B-8. Existing Condition Single-Event Damages

1 Oct 2016 Prices ($000s); Index Year: 2015

Reach	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
ALA1	$0	$0	$32,033	$55,685	$98,044	$299,809	$464,886	$563,932
ALA2	$1,786	$21,768	$56,827	$101,139	$166,007	$214,029	$255,098	$334,810
ALA3	$170	$10,820	$37,957	$79,067	$158,907	$223,309	$264,326	$351,575
MPC1	$0	$0	$3,836	$7,481	$23,944	$43,945	$56,761	$76,808
MPC2	$0	$0	$0	$0	$9,505	$25,388	$39,516	$48,923
Ala Wai subtotal	$1,956	$32,587	$130,653	$243,371	$456,406	$806,480	$1,080,587	$1,376,048
Kah1	$0	$0	$0	$0	$0	$0	$0	$0
Kah2	$0	$0	$0	$61	$213	$349	$443	$643
Kao1	$0	$0	$0	$2,020	$4,416	$8,009	$9,806	$10,884
Mak1	$0	$0	$1,066	$3,447	$8,697	$12,814	$26,576	$98,376
Mak2	$0	$0	$0	$3,349	$28,650	$42,965	$58,485	$73,393
Mak3	$0	$0	$0	$0	$0	$0	$0	$0
Mak4	$0	$0	$0	$1,737	$2,289	$2,675	$3,030	$3,243
Makiki subtotal	$0	$0	$1,066	$10,614	$44,265	$66,811	$98,339	$186,540
Man1	$0	$9	$230	$1,018	$2,966	$9,656	$16,286	$24,194
Man2	$0	$0	$0	$0	$0	$0	$0	$0
Man3	$0	$0	$0	$0	$0	$0	$0	$3,570
Man4	$0	$0	$17	$703	$3,202	$4,960	$6,823	$17,583
Man5	$0	$0	$180	$600	$2,126	$3,602	$4,746	$9,092
Man6	$0	$0	$0	$186	$1,193	$2,257	$3,152	$5,403
Man7	$0	$0	$0	$0	$0	$0	$366	$789
Uni1	$0	$0	$0	$230	$21,736	$43,242	$63,871	$104,176
Uni2	$0	$0	$0	$0	$59,189	$201,089	$277,085	$322,683
Manoa subtotal	$0	$9	$426	$2,737	$90,411	$264,805	$372,329	$487,489
Pal1	$0	$0	$0	$0	$2,064	$2,957	$3,989	$4,980
Pal2	$0	$0	$0	$0	$0	$0	$0	$3,026
Pal3	$0	$0	$0	$0	$0	$0	$3,667	$6,039
Pal4	$0	$0	$0	$0	$0	$0	$2,015	$3,319
Puk1	$0	$0	$0	$0	$0	$7	$115	$263
Wai1	$0	$0	$0	$0	$0	$0	$2	$53
Palolo subtotal	$0	$0	$0	$0	$2,064	$2,964	$9,788	$17,680
STUDY AREA TOTAL	**$1,956**	**$32,596**	**$132,145**	**$256,722**	**$593,146**	**$1,141,059**	**$1,561,044**	**$2,067,756**

Figure B-3. Existing Condition 0.01 ACE Flood Damages by Reach
1 October 2016 Prices

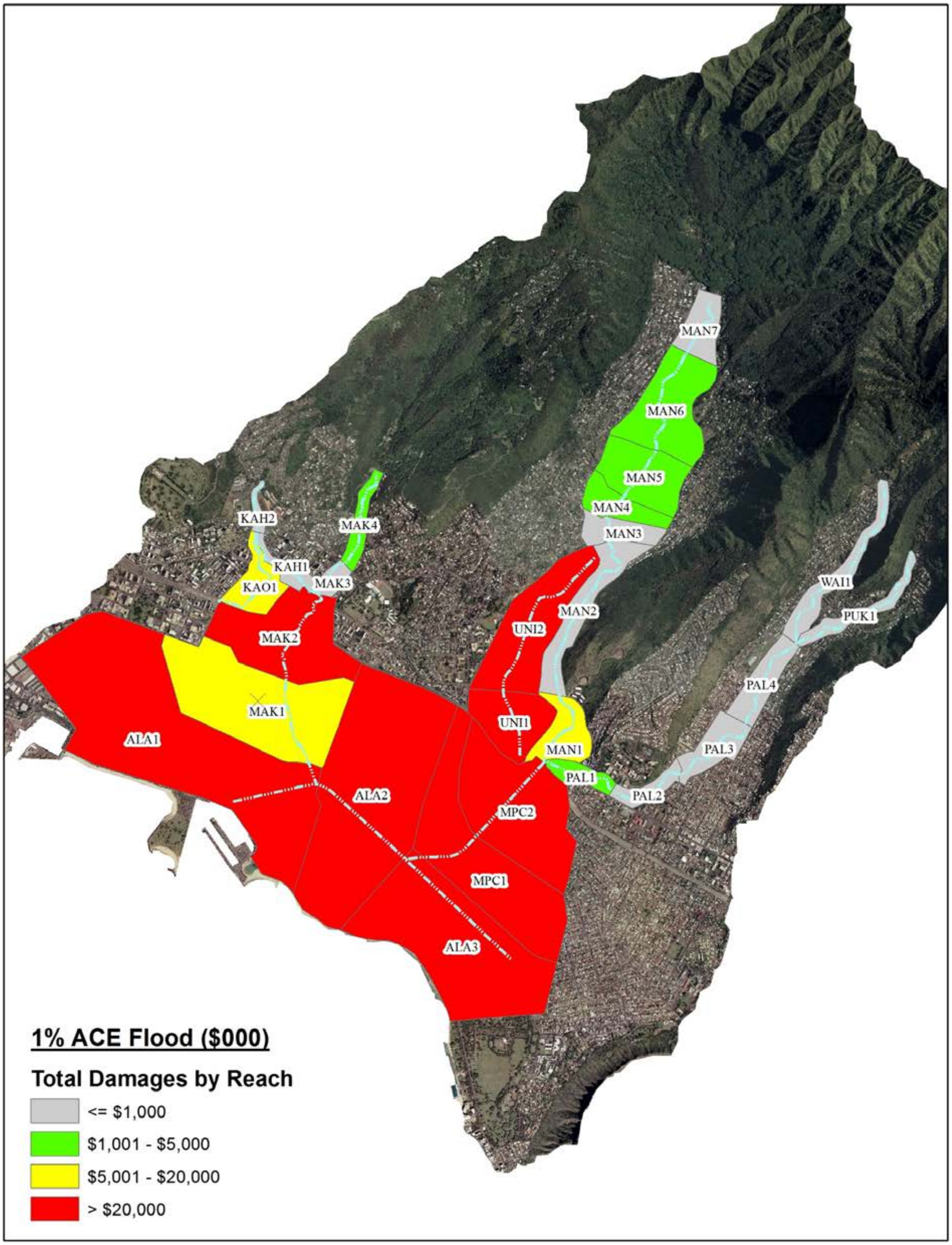


Figure B-4. Existing Condition Expected Annual Damages
2015 Conditions
1 Oct 2016 Prices ($$$)

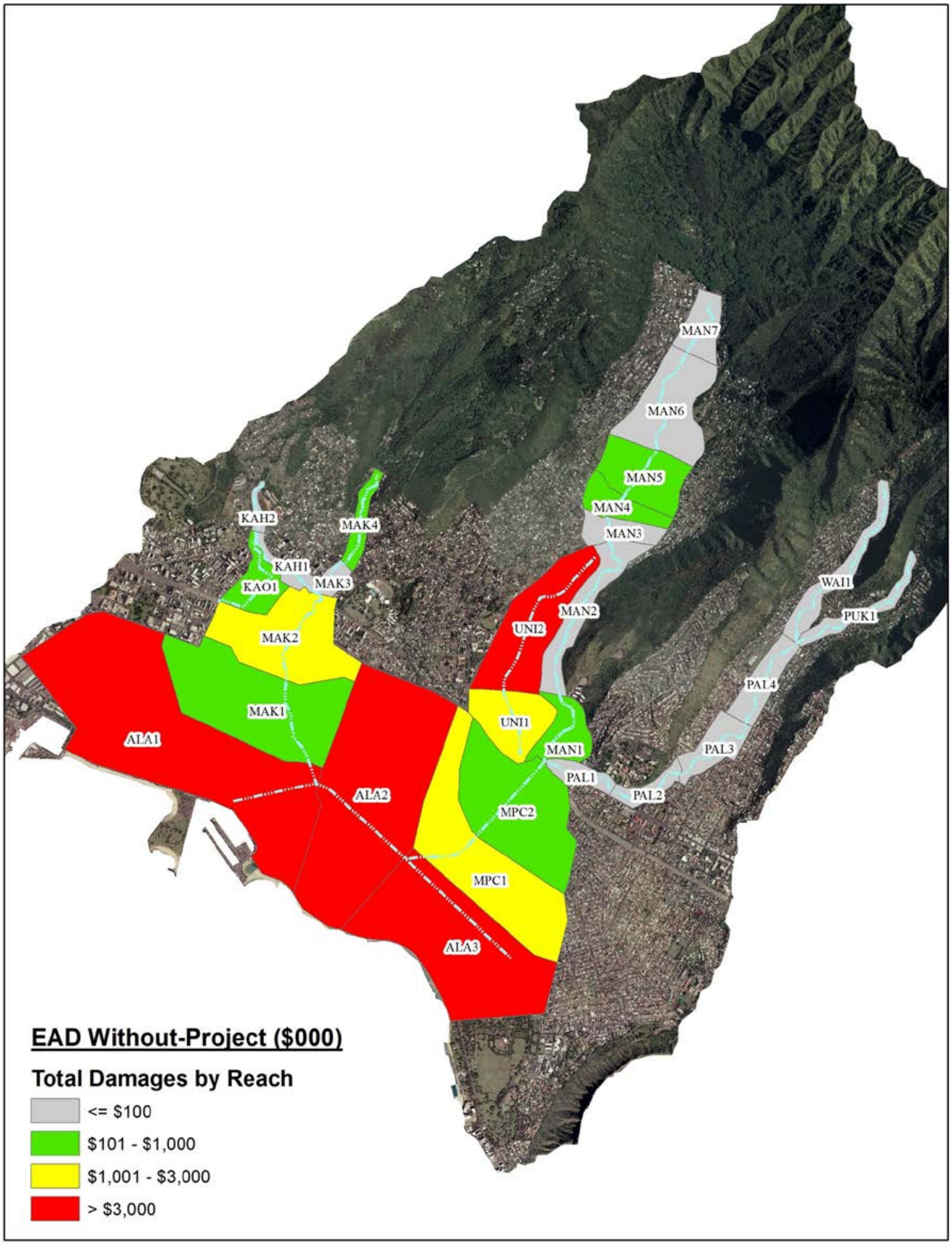


Table B-9. Existing Condition EAD (Expected Annual Damages) by Reach and Category
Index Year: 2015
1 October 2016 Prices ($000s); 2.875% Interest Rate

Reach	Residential	Commercial	Public	Total
Ala Wai subbasin				
ALA1	$325	$10,567	$219	$11,110
ALA2	$12,448	$5,375	$408	$18,231
ALA3	$5,629	$7,797	$166	$13,591
MPC1	$781	$841	$4	$1,626
MPC2	$373	$165	$25	$563
TOTAL	$19,554	$24,744	$822	$45,121
Makiki subbasin				
MAK1	$202	$398	$0	$599
MAK2	$373	$581	$314	$1,267
MAK3	$0	$0	$0	$0
MAK4	$44	$0	$93	$137
KAH1	$2	$0	$0	$2
KAH2	$11	$0	$0	$11
KAO1	$145	$66	$5	$217
TOTAL	$777	$1,045	$413	$2,234
Manoa subbasin				
MAN1	$131	$0	$173	$304
MAN2	$0	$0	$0	$0
MAN3	$6	$2	$2	$11
MAN4	$168	$2	$0	$170
MAN5	$141	$0	$0	$141
MAN6	$68	$0	$0	$68
MAN7	$3	$0	$0	$3
UNI1	$0	$0	$1,304	$1,304
UNI2	$0	$0	$4,204	$4,204
TOTAL	$517	$4	$5,683	$6,205
Palolo subbasin				
PAL1	$33	$0	$56	$89
PAL2	$6	$0	$2	$8
PAL3	$39	$0	$1	$39
PAL4	$18	$0	$3	$21
PUK1	$1	$0	$1	$2
WAI1	$0	$0	$0	$0
TOTAL	$97	$0	$62	$159
STUDY AREA TOTAL	**$20,945**	**$25,793**	**$6,981**	**$53,719**

Table B-10. Beginning Damage Frequency by Reach

Stream	Index Point	Beginning Damage Event Prob.
ALA WAI SUBBASN		
ALA1	1859	> 0.2
ALA2	4847	< 0.5
ALA3	8015	< 0.5
MPC1	1813	0.1
MPC2	3406	0.02
MAKIKI SUBBASIN		
MAK1	1719	0.1
MAK2	4325	0.05
MAK3	6606	> 0.002
MAK4	9666	0.05
KAO1	1393	0.05
KAH1	1874	> 0.002
KAH2	3005	0.05
MANOA SUBBASIN		
MAN1	948	< 0.5
MAN2	5461	>0.002
MAN3	8367	0.002
MAN4	9032	< 0.1
MAN5	10309	< 0.1
MAN6	13136	0.05
MAN7	15753	0.005
UNI1	1107	0.05
UNI2	4606	0.04
PALOLO SUBBASIN		
PAL1	6376	< 0.2
PAL2	8574	0.002
PAL3	11649	< 0.005
PAL4	14619	< 0.005
PUK1	2184	0.02
WAI1	1724	< 0.02

Table B-11. Existing Condition Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability

Index Year: 2015

Reach Name	Target Stage	Annual Exceedance Probability		Long Term Risk (years)			Conditional Non-Exceedance Probability by Event					
		Median	Expected	10	30	50	10%	4%	2%	1%	0.4%	0.2%
Ala Wai subbasin												
ALA1	4.71	0.1549	0.1888	87.67%	99.81%	100.00%	39.45%	22.50%	11.76%	8.08%	5.10%	2.66%
ALA2	4.44	0.6384	0.6398	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
ALA3	3.5	0.9841	0.9180	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MPC1	8.5	0.0949	0.1085	68.27%	96.81%	99.68%	52.09%	11.48%	3.70%	1.63%	0.21%	0.11%
MPC2	14.74	0.0152	0.0206	18.80%	46.46%	64.70%	99.81%	85.59%	59.12%	36.77%	12.94%	8.21%
Makiki subbasin												
MAK1	7.43	0.0461	0.1104	68.97%	97.01%	99.71%	69.48%	44.42%	28.40%	17.52%	9.41%	6.81%
MAK2	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.76%	13.54%	2.89%	0.80%	0.11%
MAK3	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
MAK4	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
KAH1	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
KAH2	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
KAO1	42.92	0.0140	0.0566	44.16%	82.59%	94.57%	79.26%	62.51%	53.52%	46.70%	39.63%	35.25%
Manoa subbasin												
MAN1	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
MAN2	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
MAN3	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
MAN4	156.84	0.2358	0.2430	93.82%	99.98%	100.00%	5.38%	0.54%	0.13%	0.07%	0.01%	0.00%
MAN5	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.63%	11.94%	6.27%	3.31%	1.50%	0.67%
MAN6	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
MAN7	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
UNI1	12.77	0.0256	0.0513	40.92%	79.38%	92.80%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
UNI2	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
Palolo subbasin												
PAL1	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
PAL2	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
PAL3	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
PAL4	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
PUK1	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
WAI1	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%

5.0. FUTURE WITHOUT-PROJECT CONDITION DAMAGE ANALYSIS RESULTS

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 reduce flood risk. Given the great degree of uncertainty, the future condition represents a best guess of conditions in the watershed over the 50-year planning horizon. This forecast becomes the basis for evaluation of project alternatives. For the Ala Wai Canal Project, the base year assumed for the economic analysis is 2025, when the project is expected to become operational. Thus, the 50-year forecast period starts at 2025 and ends in 2075. The index year chosen to represent the future condition is 2075.

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 change (SLC). The selection of 2075 as the index year for the future condition was primarily in order to forecast the economic effects of sea-level change to the maximum extent possible within the period of analysis. Intermediate and low SLC scenarios were evaluated in the damage analysis, but the benefit-cost analysis is based on the intermediate scenario. (A high SLC scenario and an additional year of analysis, 2125, were also evaluated in the analysis, but for project performance only, not economics.)

5.1. Expected Annual Damages. Expected annual damages were calculated in HEC-FDA for the 2025 base year and the 2075 future year based on the current Federal interest rate of 2.875 percent and a 1 October 2016 price level. Assuming an intermediate SLC case, the EAD for 2025 totals $51,597,000. This total increases about 11 percent to $57,244,000 for 2075. The reach-by-reach totals for both years are displayed in Table B-12. Nearly all of the growth in EAD to 2075 is accounted for by the Ala Wai subbasin ($5,593,000 of $5,647,000), where the growth is about 13 percent. If a low SLC case is assumed, EAD totals $49,913,000 for 2025 and $54,470,000 for 2075.

5.2. Equivalent Annual Damages. Future without-project equivalent annual damages essentially combine expected annual damages for the base year and future year conditions into one value representing damages over the entire 50-year period of analysis, given any operative changes in hydrology, hydraulics or economic development. Expected annual damages are computed for base year and future year conditions, discounted to a present worth value and annualized. In addition to displaying the expected annual damages for 2025 and 2075 conditions, Table B-12 also shows the total equivalent annual damages by reach. Equivalent annual damages for the study area for the future without-project condition, assuming the intermediate SLC case, total $53,719,000. The price level is 1 October 2016 and the interest rate is the current rate of 2.875 percent, with a 50-year period of analysis.

5.3. Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability. Table B-13 summarizes project performance for each reach in the 2025 base year and 2075 future year conditions, assuming both intermediate and low SLC cases. In ALA1, expected annual exceedance probability (AEP) is about 18.9 percent in both 2025 and 2075 in the intermediate case, but in the low case, there is an increase from 17.8 to 20.3 over the 50-year period. In ALA 2, expected AEP is 64 percent in both the intermediate and low SLC cases, while in the low case, there is a rise from 62.3 to 66.1 percent. ALA3, where the AEP of 91.8 percent in the intermediate scenario for both 2025 and 2075 is by far the largest of any of the 27 reaches, sees a rise in the low case from 91.1 percent or 92.9 percent. Other reaches with relatively high expected AEPs (defined here as more than 0.1 or 10 percent) include MPC1, MAN1, MAN4 and MAN5. AEPs in the other reaches are less than 0.1. Using the conditional nonexceedance probability in a 0.01 ACE event as an index, reaches ALA2 and ALA3 are estimated to have essentially zero probability of containing this event, which is unsurprising in light of the AEPs for those reaches. ALA1 would have only about an eight percent chance of containing the 0.01 event.

Table B-12. Future Without-Project Expected and Equivalent Annual Damages 2025 vs. 2075 (Intermediate SLC)

1 October 2016 Prices – 2.875% Interest Rate

Reach	2025 Expected Annual Damages ($000s)	2075 Expected Annual Damages ($000s)	Growth	% Growth	Equivalent Annual Damages ($000s)
Ala Wai subbasin					
ALA1	$9,098	$14,455	$5,357	58.9%	$11,110
ALA2	$18,181	$18,313	$132	0.7%	$18,231
ALA3	$13,589	$13,595	$6	0.0%	$13,591
MPC1	$1,589	$1,687	$98	6.2%	$1,626
MPC2	$563	$563	$0	0.1%	$563
TOTAL	$43,019	$48,612	$5,593	13.0%	$45,121
Makiki subbasin					
MAK1	$595	$606	$11	1.9%	$599
MAK2	$1,262	$1,277	$15	1.2%	$1,267
MAK3	$0	$0	$0	0.0%	$0
MAK4	$137	$137	$0	0.0%	$137
KAH1	$2	$2	$0	0.0%	$2
KAH2	$11	$11	$0	0.0%	$11
KAO1	$217	$217	$0	0.0%	$217
TOTAL	$2,224	$2,250	$26	1.2%	$2,234
Manoa subbasin					
MAN1	$303	$306	$4	1.2%	$304
MAN2	$0	$0	$0	0.0%	$0
MAN3	$11	$11	$0	0.0%	$11
MAN4	$169	$171	$2	1.1%	$170
MAN5	$134	$152	$17	12.8%	$141
MAN6	$68	$68	$0	0.5%	$68
MAN7	$3	$4	$0	14.2%	$3
UNI1	$1,302	$1,307	$5	0.4%	$1,304
UNI2	$4,204	$4,204	$0	0.0%	$4,204
TOTAL	$6,194	$6,223	$28	0.5%	$6,205
Palolo subbasin					
PAL1	$89	$89	$0	0.0%	$89
PAL2	$8	$8	$0	0.0%	$8
PAL3	$39	$39	$0	0.0%	$39
PAL4	$21	$21	$0	0.0%	$21
PUK1	$2	$2	$0	0.0%	$2
WAI1	$0	$0	$0	0.0%	$0
TOTAL	$159	$159	$0	0.0%	$159
STUDY AREA TOTAL	**$51,597**	**$57,244**	**$5,647**	10.9%	**$53,719**

Table B-13. Future Without-Project Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability
2025 and 2075 Low and Intermediate SLC

Reach	Year & SLC	Target Stage	Annual Exceedance Probability		Long-Term Risk			Conditional Non-exceedance Probability					
			Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
ALA1	WO Low 2025	4.71	0.1405	0.1782	85.95%	99.72%	99.99%	41.49%	23.58%	12.26%	8.30%	5.20%	2.70%
	WO Low 2075	4.71	0.1757	0.2031	89.67%	99.89%	100.00%	36.79%	20.91%	11.13%	7.74%	5.04%	2.61%
	WO Intermed 2025	4.71	0.1549	0.1888	87.67%	99.81%	100.00%	39.45%	22.50%	11.76%	8.08%	5.10%	2.66%
	WO Intermed 2075	4.71	0.1549	0.1885	87.62%	99.81%	100.00%	39.53%	22.51%	11.78%	8.07%	5.07%	2.64%
ALA2	WO Low 2025	4.44	0.6107	0.6233	99.99%	100.00%	100.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Low 2075	4.44	0.6744	0.6613	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Intermed 2025	4.44	0.6384	0.6398	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Intermed 2075	4.44	0.6384	0.6398	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
ALA3	WO Low 2025	3.5	0.9799	0.9106	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Low 2075	3.5	0.9898	0.9294	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Intermed 2025	3.5	0.9841	0.9180	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	WO Intermed 2075	3.5	0.9841	0.9180	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MPC1	WO Low 2025	8.5	0.0944	0.1075	67.92%	96.70%	99.66%	52.66%	11.62%	3.84%	1.68%	0.20%	0.10%
	WO Low 2075	8.5	0.0954	0.1092	68.55%	96.89%	99.69%	51.77%	11.44%	3.75%	1.66%	0.21%	0.11%
	WO Intermed 2025	8.5	0.0949	0.1084	68.26%	96.80%	99.68%	52.20%	11.51%	3.79%	1.66%	0.20%	0.10%
	WO Intermed 2075	8.5	0.0982	0.1136	70.05%	97.31%	99.76%	49.68%	10.95%	3.61%	1.62%	0.20%	0.10%
MPC2	WO Low 2025	14.74	0.0152	0.0206	18.81%	46.47%	64.71%	99.81%	85.58%	59.10%	36.76%	12.94%	8.21%
	WO Low 2075	14.74	0.0152	0.0206	18.80%	46.47%	64.71%	99.81%	85.58%	59.10%	36.76%	12.94%	8.21%
	WO Intermed 2025	14.74	0.0152	0.0206	18.80%	46.46%	64.70%	99.81%	85.59%	59.12%	36.77%	12.94%	8.21%
	WO Intermed 2075	14.74	0.0152	0.0206	18.81%	46.48%	64.72%	99.81%	85.61%	59.14%	36.77%	12.94%	8.21%

Table B-13 (continued). Future Without-Project Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability

2025 and 2075 Low and Intermediate SLC

Reach	Year & SLC	Target Stage	Annual Exceedance Probability		Long-Term Risk			Conditional Non-exceedance Probability					
			Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAK1	WO Low 2025	7.43	0.0455	0.1095	68.63%	96.91%	99.70%	69.96%	44.74%	28.55%	17.57%	9.39%	6.77%
	WO Low 2075	7.43	0.0476	0.1132	69.92%	97.28%	99.75%	68.44%	43.65%	27.89%	17.20%	9.27%	6.71%
	WO Intermed 2025	7.43	0.0461	0.1104	68.97%	97.01%	99.71%	69.48%	44.42%	28.40%	17.52%	9.41%	6.81%
	WO Intermed 2075	7.43	0.0461	0.1104	68.96%	97.01%	99.71%	69.49%	44.40%	28.40%	17.54%	9.43%	6.82%
MAK2	WO Low 2025	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.76%	13.54%	2.89%	0.80%	0.11%
	WO Low 2075	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.79%	13.55%	2.91%	0.79%	0.11%
	WO Intermed 2025	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.76%	13.54%	2.89%	0.80%	0.11%
	WO Intermed 2075	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.77%	13.57%	2.92%	0.79%	0.11%
MAK3	WO Low 2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
	WO Low 2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
	WO Intermed 2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
	WO Intermed 2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
MAK4	WO Low 2025	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
	WO Low 2075	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
	WO Intermed 2025	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
	WO Intermed 2075	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
KAH1	WO Low 2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
	WO Low 2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
	WO Intermed 2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
	WO Intermed 2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
KAH2	WO Low 2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
	WO Low 2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
	WO Intermed 2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
	WO Intermed 2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
KAO1	WO Low 2025	42.92	0.0140	0.0566	44.16%	82.59%	94.57%	79.26%	62.51%	53.52%	46.70%	39.63%	35.25%
	WO Low 2075	42.92	0.0137	0.0566	44.17%	82.60%	94.58%	79.19%	62.50%	53.73%	47.08%	39.23%	34.73%
	WO Intermed 2025	42.92	0.0140	0.0566	44.16%	82.59%	94.57%	79.26%	62.51%	53.52%	46.70%	39.63%	35.25%
	WO Intermed 2075	42.92	0.0137	0.0566	44.17%	82.60%	94.58%	79.19%	62.50%	53.73%	47.08%	39.23%	34.73%

Table B-13 (continued). Future Without-Project Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability
2025 and 2075 Low and Intermediate SLC

Reach	Year & SLC	Target Stage	Annual Exceedance Probability		Long-Term Risk			Conditional Non-exceedance Probability					
			Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAN1	WO Low 2025	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
	WO Low 2075	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
	WO Intermed 2025	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
	WO Intermed 2075	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
MAN2	WO Low 2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
	WO Low 2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
	WO Intermed 2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
	WO Intermed 2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
MAN3	WO Low 2025	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
	WO Low 2075	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
	WO Intermed 2025	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
	WO Intermed 2075	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
MAN4	WO Low 2025	156.84	0.2358	0.2430	93.82%	99.98%	100.00%	5.38%	0.54%	0.13%	0.07%	0.01%	0.00%
	WO Low 2075	156.84	0.2376	0.2454	94.01%	99.98%	100.00%	5.28%	0.53%	0.13%	0.07%	0.01%	0.00%
	WO Intermed 2025	156.84	0.2358	0.2430	93.82%	99.98%	100.00%	5.38%	0.54%	0.13%	0.07%	0.01%	0.00%
	WO Intermed 2075	156.84	0.2376	0.2454	94.01%	99.98%	100.00%	5.28%	0.53%	0.13%	0.07%	0.01%	0.00%
MAN5	WO Low 2025	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.63%	11.94%	6.27%	3.31%	1.50%	0.67%
	WO Low 2075	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.65%	11.94%	6.27%	3.33%	1.51%	0.68%
	WO Intermed 2025	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.63%	11.94%	6.27%	3.31%	1.50%	0.67%
	WO Intermed 2075	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.65%	11.94%	6.27%	3.33%	1.51%	0.68%
MAN6	WO Low 2025	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
	WO Low 2075	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
	WO Intermed 2025	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
	WO Intermed 2075	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
MAN7	WO Low 2025	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
	WO Low 2075	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
	WO Intermed 2025	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
	WO Intermed 2075	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
UNI1	WO Low 2025	12.77	0.0256	0.0513	40.92%	79.38%	92.80%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
	WO Low 2075	12.77	0.0256	0.0514	40.99%	79.46%	92.85%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
	WO Intermed 2025	12.77	0.0256	0.0513	40.92%	79.38%	92.80%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
	WO Intermed 2075	12.77	0.0256	0.0514	40.99%	79.46%	92.85%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
UNI2	WO Low 2025	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
	WO Low 2075	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
	WO Intermed 2025	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
	WO Intermed 2075	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%

Table B-13 (continued). Future Without-Project Annual Exceedance Probability, Long-Term Risk and Conditional Nonexceedance Probability

Reach	Year & SLC	Target Stage	Annual Exceedance Probability		Long-Term Risk			Conditional Non-exceedance Probability					
			Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
PAL1	WO Low 2025	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
	WO Low 2075	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
	WO Intermed 2025	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
	WO Intermed 2075	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
PAL2	WO Low 2025	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
	WO Low 2075	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
	WO Intermed 2025	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
	WO Intermed 2075	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
PAL3	WO Low 2025	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
	WO Low 2075	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
	WO Intermed 2025	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
	WO Intermed 2075	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
PAL4	WO Low 2025	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
	WO Low 2075	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
	WO Intermed 2025	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
	WO Intermed 2075	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
PUL1	WO Low 2025	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
	WO Low 2075	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
	WO Intermed 2025	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
	WO Intermed 2075	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
WAI1	WO Low 2025	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
	WO Low 2075	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
	WO Intermed 2025	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
	WO Intermed 2075	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%

Table B-14. 2025 vs. 2075 Water Surface Profile Changes for Ala Wai Canal Reaches Without-Project Conditions

Reach	Index	SLC & Year	0.5	0.2	0.1	0.05	0.02	0.01	0.005	0.002
ALA1	1859	Low 2025	3.40	4.53	4.87	5.14	5.62	5.73	5.79	6.10
		Low 2075	3.54	4.65	4.95	5.21	5.66	5.73	5.80	6.10
		2025-2075 change (ft.)	0.14	0.12	0.08	0.07	0.04	0.00	0.01	0.00
		Intermediate 2025	3.46	4.59	4.90	5.17	5.63	5.74	5.80	6.10
		Intermediate 2075	3.92	4.90	5.17	5.42	5.70	5.79	5.84	6.10
		2025-2075 change (ft.)	0.46	0.31	0.27	0.25	0.07	0.05	0.04	0.00
ALA2	4847	Low 2025	4.65	6.43	6.99	7.48	8.4	8.73	9.05	9.71
		Low 2075	4.76	6.51	7.04	7.53	8.4	8.69	9.01	9.66
		2025-2075 change (ft.)	0.11	0.08	0.05	0.05	0	-0.04	-0.04	-0.05
		Intermediate 2025	4.70	6.47	7.01	7.50	8.40	8.72	9.03	9.69
		Intermediate 2075	5.05	6.68	7.2	7.67	8.40	8.72	9.03	9.69
		2025-2075 change (ft.)	0.35	0.21	0.19	0.17	0.00	0.00	0.00	0.00
ALA3	8015	Low 2025	4.80	6.67	7.32	7.90	8.89	9.33	9.79	10.5
		Low 2075	4.90	6.75	7.37	7.95	8.9	9.33	9.79	10.5
		2025-2075 change (ft.)	0.1	0.08	0.05	0.05	0.01	0.00	0.00	0.00
		Intermediate 2025	4.84	6.71	7.34	7.92	8.90	9.32	9.77	10.50
		Intermediate 2075	5.18	6.91	7.51	8.08	8.90	9.32	9.77	10.50
		2025-2075 change (ft.)	0.34	0.20	0.17	0.16	0.00	0.00	0.00	0.00

5.4. Economic Context for Future Conditions. There is little room for new development without redevelopment in the Ala Wai Canal watershed. In other words, for something new to go in, something must come out. In spite of relatively recent recession, growth has continued in some areas of the watershed, albeit much slower than in 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. 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 residential structures with greater population density; i.e., condominiums and multi-story 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 existing condition and 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 2075; it is just that the exact nature of these changes cannot be projected with any degree of certainty.

5.5. Sea-Level Change. In order to account for the uncertainty in sea-level change (SLC) over the life of the project in accordance with USACE guidance (Department of the Army, 2009; EC 1165-2-211), the HEC-FDA risk and uncertainty analysis evaluated without-project conditions in 2025 and 2075 under low and intermediate SLC scenarios. Table B-13 shows "project performance" estimates for the 2025 and 2075 intermediate and low SLC cases without project, while Table B-14 shows changes in the water surface profiles for the three key Ala Wai Canal reaches for the eight events analyzed under 2025 and 2075 intermediate and low SLC scenarios. In the context of the intermediate SLC scenario, these reaches experience increases of up to about a half-foot in ALA1 and up to about a third of a foot in ALA2 and ALA3. Most of the change is in the most frequent floods, particularly the 0.5 ACE event.

As sea level rise continues over the coming decades, tidal and backwater impacts during periods of rainfall induced flooding will cause water surface elevations to rise slightly in the lower reaches of the flood plain, primarily reaches ALA1, ALA2, and ALA3 (i.e., Waikiki and the neighborhoods bordering the Ala Wai Canal). Sea level rise is not expected to reach the majority of the study reaches and neighborhoods as the slight increase in water surface elevation over time will be nullified by the gradual to steep sloped flood plain rising upstream. Yet development that was on the cusp of the existing flood plain in ALA1, ALA2, and ALA3 could be considered inside its boundaries in the future. Likewise, development in these lower flood plain reaches that was on the fringe of, for instance, the 0.5 or 0.2 ACE flood plains during the early years of the period of analysis, could be squarely in these flood plains toward the end of the period.

5.6. Flood Plain Management. The City and County of Honolulu (CCH) has addressed county-wide flood plain management and flood mitigation in their Multi-Hazard Pre-Disaster Mitigation Plan. The plan defines flood hazard districts and their appropriate uses, such as public parks, conservation, agriculture, wetlands, and planned developments that keep buildings out of the flood plain; intensive development is not permitted. The plan was further amended in 2004 to require new pre-construction and post-construction certification standards for new structures built within a flood zone. Other sections of the plan relating to the flood hazard districts were also modified to conform to the language of the NFIP. CCH participates in the NFIP (National Flood Insurance Program), although it does not participate in the NFIP Community Rating System (CRS), a voluntary program of the NFIP. To participate in the NFIP, a community must adopt and enforce a flood plain management ordinance to reduce future flood risks to new construction and improvements in flood hazard areas.

The FIRMs (Flood Insurance Rate Maps) that are the foundation of the NFIP were last updated for Oahu in 2014 to reflect new coastal surge analyses. However, the flood plain reflected in the Oahu FIRMs does not extend as far outward as the flood plain modeled for the current feasibility study, partly because the USACE model incorporates impacts from increased urbanization in the upper Ala Wai watershed. As such, the Corps analysis reflects a somewhat greater level of future risk than the FIRMs. Efforts by local government to implement responsible flood plain management policies and procedures will undoubtedly be ongoing during the 50-year period of analysis but will struggle with issues such as sea-level rise and upstream urbanization as well as the sheer extent of population at risk, infrastructure and property within the 0.01 ACE flood plain.

The feasibility analysis has estimated, based on modeling for the project, that approximately 1,358 acres of the Ala Wai Watershed are within the 0.01 ACE flood plain. This 0.01 flood plain area contains at least 3,000 properties; the 0.002 flood plain includes a much higher number of structures. (The structure inventory developed for the economic analysis includes more than 6,800 homes, businesses and public facilites, although many of these structures included in the survey did not prove to be within the flood plain after all.) In addition, the location of some of the critical infrastructure as well as main streets and highways in the watershed within the 0.01 ACE flood plain will be a challenge, as will the continued presence of an estimated 54,000 residents, 79,000 visitors on any given day, 48,000 students and 65,000 jobs.

6.0. ALTERNATIVES ANALYSIS

As described in Chapters 3 and 4 of the main Feasibility Report, alternative 3A was identified as the NED plan and selected as the Tentative Selected Plan (TSP) prior to eventually becoming the recommended 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.

6.1. The Plan Selection Process. The plan formulation for this project follows the recent USACE guidelines for implementing the SMART Planning paradigm (Department of the Army, 2014). For a general description of SMART Planning and a complete account of how the PDT screened various project alternatives and arrived at the TSP, consult chapters 3 and 4 of the main Feasibility Report. 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, a 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 multiple measures of alternative 3A were incrementally justified;
- How alternative 3A was optimized to emerge as the NED Plan;
- How the NED plan also proved to be the TSP; and
- How the TSP/NED Plan had a greater than 95 percent confidence level of passing the 0.01 ACE event.

6.2. The Nonstructural Alternative (Alternative 5). Early in the formulation stages of the Ala Wai Canal Project, the PDT settled on reducing riverine flood hazards to property and life safety in the Ala Wai Canal watershed as the study's main flood risk management-related objective. 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.

6.2.1. 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 1960s 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 new idea was that in order to reduce flood damage from an economic perspective, the focus had to be on reducing not only the frequency 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 flood plain and the behavior of people living within the flood plain (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 from support for merely reducing property damage due to flooding to overall flood risk reduction and flood risk management. The nation has recognized that the adverse effects of flooding were manifested comprehensively across many categories including loss of life, rather than simply economic damage. In the flood risk reduction/flood risk management environment, flood plain/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, and the 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 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 flood plains. Today, nonstructural measures are required to have equal consideration to structural measures in USACE studies, and in many cases, they have been shown to provide justifiable benefits.

The 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 flood plains. In general, nonstructural alternatives do not modify the characteristics of floods nor induce development in flood plains in such a way as to be 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 flood plain. Because structural alternatives reduce the frequency of flooding within a particular flood plain, they can affect the behavior of people living in or near the flood plain by allowing them to think that the flood plain 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 flood plain that is inconsistent with reducing flood risk (USACE, 2011).

A particular advantage of nonstructural measures when compared to structural measures is often 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 participation is always preferred but can 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 management (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 flood plain 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, nonstructural 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 flood plain and reducing the risks to people living or working in the flood plain (Adams, 2014).

Nonstructural measures, which are cost shared at 65 percent Federal /35 percent non-Federal just like structural measures, include raising, relocating and acquiring or buying-out structures, implementing flood warning and preparedness systems, flood plain 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 flood plain or accommodate existing uses in the flood plain, without changing the extent 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.

6.2.2. 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 solely of nonstructural measures that could be used to provide location-specific flood risk reduction to specific structures. The nonstructural analysis began with the formulation of a purely nonstructural plan by screening for structures that sustained enough expected annual damage to economically justify some kind of nonstructural solution. This was a daunting task considering the time constraints and the availability and specificity of data relative to individuals structures with the structure inventory containing several thousand homes, businesses and public facilities. Data needed in order to correctly and thoroughly analyze each structure and apply a nonstructural measure were not available. Some examples of this lack of specific data were 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 and the building's construction materials.

With this many unknowns, the PDT had to make many assumptions in order to accomplish the task of developing standalone nonstructural alternatives with cost estimates and benefits. For example, the PDT assumed that there are few homes with basements and, therefore, no depth-damage curves calculating basement damages were used. Another assumption was that, if susceptible to 12 feet of flooding or greater, a structure had to be relocated or bought out. Elevating a residential structure would potentially be technically feasible for depths up to 12 feet. Non-residential structures were not considered for raising. Dry flood proofing, or water proofing of a 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) have a magnitude of net benefits comparable to those derived from a structural plan. A more refined nonstructural analysis would only be conducted if both (a) and (b) were found to be true through the initial analysis. The results of the hydrologic/hydraulic 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. An additional consideration that was kept in sight during the analysis was that if USACE's benefit-cost ratio (BCR) methodology proved to be too restrictive, other programs in collaboration with the other partners might produce further opportunities for implementing nonstructural solutions.

6.2.3. The 3-Step Process for Evaluation of Nonstructural Measures. The basic 3-step screening process followed by USACE economics for inclusion of nonstructural alternatives **is** summarized below:

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, the 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 further reduce flood damages.

As for Alternative 5 -- the purely nonstructural alternative -- the process consisted 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 water proofing 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 (classified as high, medium or low) for nonstructural alternative formulation and identification of a TSP, hydrologic/hydraulic 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 0.1 to 0.02 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 0.02 to 0.08 ACE exposure; this medium-level of risk tends to yield potential flood reduction benefits that are insufficient to justify large expenditures for individual flood protection. For the most part, those structures that were not in harm's way even with a 0.01 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 flood plain 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 further investigation.

6.2.4. The First Screening. The results of the initial nonstructural screening suggested that about 340 structures within the flood plain could contribute positive net benefits to a purely nonstructural alternative and comprise an economically justifiable plan. Breaking down these structures further, about 115 residential and 225 commercial and institutional buildings were potentially justifiable. The construction cost was estimated at $31.3 million, expected annual costs 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 was decided upon and is summarized below:

Manoa

- There were approximately 45 homes, businesses and public buildings along the Manoa reaches MAN1 through MAN6, along with MPC1 and MPC2, that experienced enough damages under existing conditions to economically justify some type of nonstructural measure.
- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding. Other structures would have had to be elevated, protected with a ring wall or relocated or purchased.
- One nonstructural measure or another appeared to be feasible for 15 large classroom and multipurpose buildings on the main campus of the University of Hawaii.

Palolo

- There were approximately 10 homes, businesses and churches along the Palolo reaches PAL3 and PAL4 that experienced enough damages under existing conditions to economically justify some kind of flood proofing measure.
- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding. Other structures would have had to be elevated, protected with a ring wall or relocated or purchased.

Makiki

- There were approximately 90 homes, businesses, churches and public buildings along the Makiki reaches MAK1 through MAK4, KAH1 and KAO1 that experienced enough damages under existing conditions to economically justify some type of nonstructural measure. About two-thirds of these structures were homes.
- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding. Other structures would have had to be protected by a ring wall, elevated, relocated or purchased.

Ala Wai Canal

- There were approximately 180 structures along the Ala Wai Canal reaches ALA2 and ALA3 that experienced enough damages under existing conditions to economically justify some type of nonstructural measure, typically individual ring walls. About 90 percent of these were businesses and condominiums.
- Potential economic justification existed for water proofing or protection by 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 flood plain) 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. Water proofing or elevating to mitigate flood damages, on the other hand, is generally technically feasible for most single-family residences and was 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 water proofing. 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 distinction between the two concepts is that 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 flood plain or floodway could be changed. As nonstructural measures, 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.

6.2.5. 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 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 0.5 to 0.05 ACE flood events. After the second screening, the breakdown of these potential candidates to comprise a purely nonstructural alternative stood as follows:

Manoa

- There were approximately 50 homes, businesses and public buildings along the Manoa Valley reaches MAN1, MAN4, MAN 5 and MPC2 that experienced enough damages under existing conditions to economically justify some type of nonstructural measure.

- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding.

Palolo

- There were approximately 20 homes, businesses and public buildings along the Palolo reaches PAL3 and PAL4 that experienced enough damages under existing conditions to economically justify some kind of nonstructural flood proofing measure.
- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding.

Makiki

- There were approximately 40 homes, businesses and public buildings along the Makiki reaches MAK2, KAH1 and KAO1 that experienced 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.
- Potential economic justification existed for water proofing of many structures to withstand up to 3 feet of flooding.

6.2.6. The Third Screening. Those structures that passed the 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 the most likely nonstructural solution, and a rough cost estimate for that solution. Consideration was also given to the fact that some structures, if examined on an individual basis, might not show economic feasibility but the larger group of structures containing these individually infeasible structures might be economically feasible. The determination of economic feasibility was not based on individual structure feasibility; 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 no 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 so 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 were not 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. The 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 estimated to cost about $400/linear foot in Hawaii. A typical Waikiki condominium might require about 600 linear feet to completely surround the ground floor footprint. Therefore, the assumption was that for the large high-rise condominiums, a construction cost of $240,000 would be required for a nonstructural solution to mitigate the 0.01 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 USACE 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.

6.2.7. The Outcome. One of the disadvantages 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. A structural alternative, on the other hand, can reduce flood damages by reducing water surface elevation throughout an entire flood plain. 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 economic analysis that very few structures would be economically justified and the PDT's conclusion that reducing flood risks to so 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 of 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. It also 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 were carried into the ultimate cost estimate for alternative 3A.

6.3. Choosing Alternative 3A over Alternative 2A in the Final Array Stage. Table B-15 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 were refined to risk-based cost and benefit estimates as shown in Table B-16. 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 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 detailed both in the Feasibility Report and throughout the rest of the Economic Appendix.

Table B-15. Early Relative Order of Magnitude (ROM) Cost and Benefit Estimates Screening for National Economic Development (NED) Plan

1 October 2013 Prices ($000s); 3.75% Interest Rate; 50-Year Period of Analysis

	Alternative 2A	Alternative 3A	Alternative 5A
Project Cost (First Cost)*	$272,885	$223,917	78691
Estimated Average Annual Cost	$14,045	$10,752	3508
Total Annual Benefit	$24,801	$32,727	9843
Annual Net Benefits	$10,756	$21,520	6335
Benefit-Cost Ratio (BCR)	1.8	3.0	2.81

* Project Cost includes Real Estate, PED, CM and 25% contingencies

Table B-16. 10% Design - Cost and Benefit Estimates, February 2014 Screening for NED Plan

1 October 2013 Prices; 3.5% Interest Rate; 50-Year Period of Analysis

	Alternative 2A	Alternative 3A
Project Cost (First Cost)	$221,231	$178,096
Estimated Average Annual Cost	$11,097	$8,923
Total Annual Benefit	$24,814	$32,272
Annual Net Benefits	$13,717	$23,349
Benefit-Cost Ratio (BCR)	2.2	3.6

From the beginning, and confirmed by the refinement later in the process, Alternative 3A, with almost $10 million more in net benefits than Alternative 2A, proved to be the best choice. Basically, Alternative 2A had too many less economically efficient 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 did a much better job protecting Waikiki properties where the bulk of the benefits came from lead to it emerging as a clearly better plan than Alternative 2A.

6.3.1. 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 gain economic justification. In addition, if there were competing measures proposed for a single area, the one with the most net benefits was chosen for the project.

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 plan possible. The focus of the incremental analysis was to confirm that each measure in Alternative 3A was economically justified for addition to net benefits. 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 its contribution to benefits. The increments or measures that were analyzed are listed in Table B-17. They were added sequentially to increment 0, testing whether they added to net benefits for each step of the process as shown in Table B-18. 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-17. 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

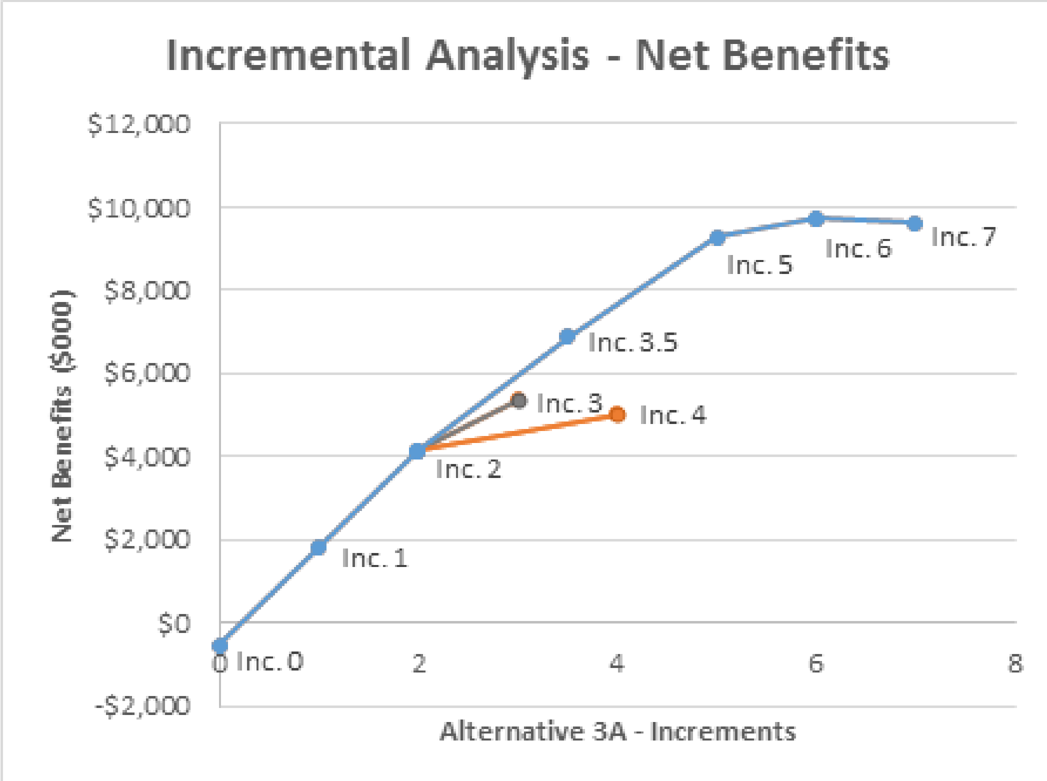
Table B-18 shows the detailed results of the incremental cost analysis, and Figure B-5 shows the net benefits curve as measures were added to the project. Due to the potentially devastating effect in Waikiki, flood protection measures along the Ala Wai Canal, i.e., increment 0, provided the foundation for the overall plan. However, increment 0 by itself, as shown in Table B-13, was not economically justified (0.87 BCR). To achieve a level of protection similar to the TSP/NED Plan, the Ala Wai Canal floodwalls would have to be built too high, with too many huge pumps to be economically justified (i.e., there was no economically feasible plan with floodwalls and pumps as the only measures). The floodwall economics improved dramatically as the other incremental measures were added and effectively reduced peak flows. The most potentially effective measures were added to increment 0 in order of their effectiveness 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-18. Incremental Cost Analysis, May 2014

1 October 2013 Prices; 3.5% Interest Rate; 50-Year Period of Analysis

	Incremental 0	Incremental 1	Incremental 2	Incremental 3	Incremental 3.5	Incremental 4	Incremental 5	Incremental 6	Incremental 7
Expected Annual Costs (EAC)									
Plans & Specs	$15,513	$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	$0	$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 Costs	$75,030	$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 Costs	$3,193	$4,577	$5,778	$6,219	$6,408	$7,057	$7,217	$7,387	$7,456
Annual O&M Costs	$761	$834	$875	$916	$903	$944	$942	$982	$982
Total Annual Costs	$3,954	$5,411	$6,652	$7,135	$7,311	$8,001	$8,159	$8,369	$8,438
Expected Annual Benefits (EAB)									
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
Total Annual Benefits	$3,428	$7,242	$10,794	$12,493	$14,187	$13,010	$17,430	$18,098	$18,056
Benefit-Cost Data									
Benefit/Cost Ratio	0.87	1.34	1.62	1.75	1.94	1.63	2.14	2.16	2.14
Net Benefits	-$526	$1,830	$4,142	$5,385	$6,876	$5,009	$9,271	$9,728	$9,618

Figure B-5. 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-5, 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 less in net benefits than the Makiki Debris and Detention Basin alone (increment 3.5); thus, the most cost effective Alternative 3A included 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 to add to net benefits. With the addition of increment 7, [1] 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, where the associated BCR was 2.16. Accordingly, the most cost effective version of Alternative 3A leading to selection as the NED Plan was determined to include the measures in increments 0, 1, 2, 3.5, 5, and 6.

6.3.2 Possible Trade-Offs in Measures to Improve Alternative 3A. Nonstructural measures as a stand-alone plan were 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 (the sixth incremental measure), further analysis was conducted to determine whether equal or greater net benefits could be attained if the height of the Ala Wai Canal floodwalls were increased by approximately 0.5 feet in lieu of adding Kanewai Field detention to the optimal mix.

At the time of the non-Federal sponsor's request to investigate this variation of Alternative 3A, the plan thought to maximize net benefits was increment 6 with +2 feet, or an average floodwall height of 6 feet. However, the non-Federal sponsor was interested in finding out 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 nonstructural 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 6.5-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) floodwall;
> Total cost = $173,117,000;
> Original increment 6 with +0 total cost = $168,135,000;
> Difference was refined cost for stairs at the floodwall and other miscellaneous details added to design drawings = $4,982,000.
>
> Increment 5 (+0) total cost = $163,588,000;
> Plus refined cost change above of $4,982,000 = $168,570,000;
> This is new increment 5 (+0) cost = $168,570,000.

[1] 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 between increment 6 (+2) revised versus increment 6 (+0) revised;

Total cost was $180,675,000 - $173,117,000 = $7,558,000;
Added to increment 5 (+0), refined 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 need 6.5-foot height of floodwall;
Based on increment 6 (+1) revised, difference with increment 6 (+2) revised, which was $2,668,000; split in half = $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 floodwall.

This cost of $177,462,000 is obviously less than the increment 6 (+2) revised total cost of $180,675,000, and would make increment 5 (lower by $3,213,000) the NED plan rather than 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) costs, thus converting these first construction costs into expected annual costs. The resulting net benefits for increment 5 (+2-1/2) equaled $11,923,000, and yielded a BCR of 2.35. As shown in Table B-19, this compared to net benefits of $11,740,000 and a BCR of 2.31 for increment 6 with the 6-foot high floodwall:

Table B-19. Last Increment Added - Check on Validity

	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 assumed 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, confirming 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 that of increment 6 (+2) and could not have higher net benefits, nor could it be the NED plan. In fact, in no instance was the economic analysis able to show that the addition of nonstructural features for the protection of individual structures would be economically feasible and a justifiable additional feature to be included in any of the alternative plans; these measures simply did not improve the economic efficiency of any structural alternative. The structural alternative normally accounts for the lion's share of the benefits and the residual damages prove to be insufficient to offset the incremental cost of additional nonstructural components. Based on this example and other similar attempts, the economic analysis verified that increment 6 with +2 or 6-foot average height of the floodwall 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.

6.3.3. 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. 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 0.002 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 0.01 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 it was not considered as part of the optimization process.

Therefore, the optimization efforts focused on the height of the floodwall along the Ala Wai Canal; that is, the only project feature that varied within Alternative 3A was the average height of the floodwall. As costs and benefits were refined throughout FY 2014, so was the optimal average height of the floodwall 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 floodwall. For each HEC-FDA run, the floodwall average height was changed in one-foot increments until the height that maximized net benefits was found. Then, floodwall performance was assessed to ensure it provided a 95 percent or greater assurance that it would not be overtopped by a 0.01 ACE flood; this was an important planning objective for the local sponsors. In addition, since the Ala Wai Canal itself is divided into three reaches, each reach needed to demonstrate the 95 percent assurance objective.

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-20, 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 average heights of both 5 feet and 6 feet. Although the difference in net benefits is small, the average floodwall height of 4 feet maximized net benefits and was identified as the NED Plan.

Table B-20. Ala Wai NED Plan Optimization Analysis – EAC

1 October 2014 Prices ($000); 3.5% Interest Rate

Plan	Floodwall (3 foot)	Floodwall (4 foot)	Floodwall (5 foot)	Floodwall (6 foot)
Costs				
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 Investment	$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
Benefits				
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
Benefit-Cost Data				
Benefit/Cost Ratio	**2.34**	**2.38**	**2.25**	**2.21**
Net Benefits	**$11,401**	**$11,752**	**$11,258**	**$11,120**

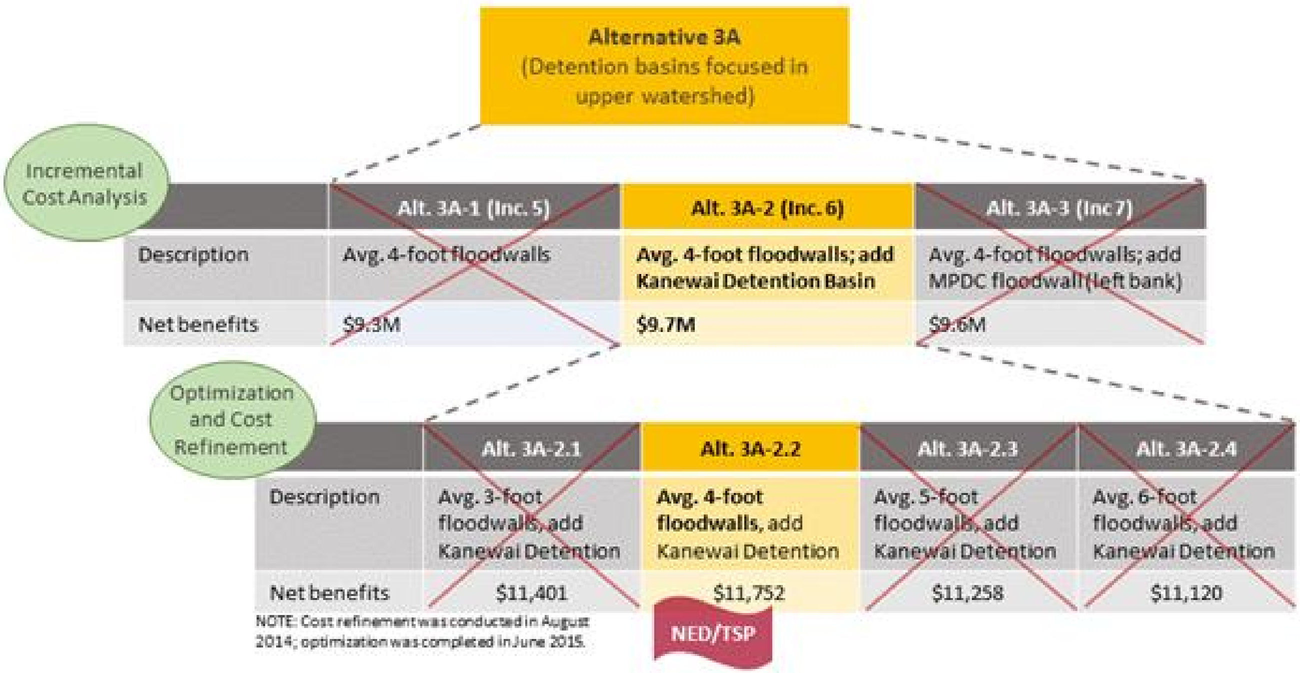
The difference in net benefits between the 3 and 4-foot average floodwall heights was small, and when the difference is judged to be statistically insignificant, USACE regulations suggest the smaller plan should be selected. Therefore, plan selection received additional consideration prior to declaring the 4-foot average floodwall height the NED plan. Advantages of the 4-foot average height floodwall (relative to the 3-foot) include:

- Maximization of net benefits, although the difference was minor; it provided an additional $354,000 in expected annual benefits, while costing only about $60,000 more than the 3-foot floodwall;
- Met the local planning objective of a 95 percent level of assurance of passing the 0.01 ACE event, while the 3-foot floodwall did not;
- Less risk of overtopping;
- Lower residual damages;
- Provided a more resilient and robust project;
- Better reflection of 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.

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 are summarized in Table B-20 and shown in Figure B-6, illustrating how the costs and benefits were used to bracket Alternative 3A-2.2 as the NED plan. Ultimately, this plan was also the TSP.

Figure B-6. Identification of the NED Plan and 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 incorporated lower floodwalls (average height of 3 feet) with only a slight reduction in net benefits. Based on this evaluation, the PDT identified several important distinctions which underscored the designation of the NED plan as the tentatively selected plan. First, the NED plan had lower residual damages (approximately $354,000 less EAD than Alternative 3A-2.1) for only a minimal increase in construction cost (going from 3 to 4-foot average floodwall height increased project first cost by $59,000). In addition, it provided a high level of assurance relative to a 0.01 ACE flood event, actually surpassing 99 percent assurance and allowing for 2 feet of freeboard (a requirement for FEMA accreditation), which is consistent with the performance levels desired by the non-Federal sponsor. The NED plan also provided for greater resiliency, as further discussed in Section 6.2.

It is true that, in terms of the potential visual impacts associated with floodwalls along the Ala Wai Canal, Alternative 3A-2.1 had the benefit of being a foot lower than the NED plan. However, the degree of visual impact between these two heights was considered to be relatively minimal (i.e. they would both impact aesthetics, but would both 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.

6.3.4. 2017 Re-check of NED Plan Determination. The four alternative Ala Wai Canal floodwall heights were reconsidered during the final phases of this feasibility study in 2016 and 2017 in order to make sure that more current economic and cost data did not undermine the previous plan selection. But the outcome was the same as before. The 4-foot floodwall again had the highest net benefits of the four alternatives, as can be seen in Table B-21. The NED plan selection was thus reaffirmed and final planning was continued for the recommended plan.

Table B-21. Ala Wai NED Plan Optimization Analysis – EAC (2017)
1 October 2016 Prices ($000s); 2.875% Interest Rate; 50-Year Period of Analysis

Plan	Floodwall (3 foot)	Floodwall (4 foot)	Floodwall (5 foot)	Floodwall (6 foot)
Costs				
PED	$55,736	$56,627	$57,608	$58,624
Construction Management	$26,795	$27,224	$27,696	$28,183
Lands	$7,309	$7,309	$7,309	$7,309
Construction Contract	$211,545	$214,935	$218,649	$222,511
Total First Cost	$301,385	$306,095	$311,262	$316,627
Interest During Construction	$13,511	$13,602	$13,701	$13,805
Total Investment	$314,896	$319,697	$324,963	$330,432
Annualized Total Investment	$11,950	$12,132	$12,332	$12,539
Annual O&M	$985	$985	$985	$985
Expected Annual Cost (EAC)	$12,935	$13,117	$13,317	$13,524
Benefits				
Residential	$19,656	$19,803	$19,811	$19,811
Commercial	$24,841	$24,953	$24,962	$24,962
Public	$3,568	$3,575	$3,575	$3,575
Expected Annual Benefits (EAB)	$48,065	$48,331	$48,348	$48,348
Benefit-Cost Data				
Benefit/Cost Ratio	**3.72**	**3.68**	**3.63**	**3.57**
Net Benefits	**$35,130**	**$35,214**	**$35,031**	**$34,824**

7.0. RECOMMENDED PLAN.

7.1. Plan Summary. The recommended plan is multi-faceted, basin-wide plan that includes the following measures or features:

- 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;
- Flood warning system.

7.2. Project Costs.

7.2.1. Total Project Costs. The total project cost for the recommended plan, in 1 October 2016 dollars, is $306,095,000. Table B-22 summarizes the costs by account.

Table B-22. Total Project Costs for Recommended Plan
1 October 2016 Prices ($000s)

Account	Item	Cost
30	PED	$56,627
01	Lands & Damages	$7,309
	Construction	
02	Relocation	$9,885
04	Dams	$71,288
11	Levees & Floodwalls	$58,912
15	Floodway Control & Diversion	$6,470
13	Pumping Plant	$67,009
19	Buildings, Grounds & Utilities	$356
06	Fish &Wildlife	$229
18	Cultural Resources	$786
	Total Construction	$214,935
31	Construction Management	$27,224
	TOTAL	**$306,095**

7.2.2. Annual Costs. The total annual cost for the recommended plan, in 1 October 2016 prices and at the 2.875 percent interest rate, is $13,117,000. The annual cost calculation is summarized in Table B-23.

Included in the annual cost calculations is an estimated annual OMRR&R cost of $982,000. The annual cost computation also includes IDC (interest during construction) of $13,602,000. The IDC computation, shown in Table B-24, is based on an expected project completion date of 2024. PED (preconstruction engineering and design) is initially slated to be done in FY 2018 and 2019, followed by real estate actions and then a three-year construction period expected to be handled as a single contract.

Table B-23. Annual Costs
1 October 2016 Prices ($000s); 2.875% Interest Rate; 50-Year Period of Analysis

First Costs	**$306,095**
IDC (Interest During Construction)	$13,602
Total Investment Cost	$319,697
Interest & Amortization Factor	0.03795
Annual Costs subtotal	$12,132
Annual OMRR&R Costs	$985
Total Annual Costs	**$13,117**

Table B-24. Interest During Construction (IDC)
1 October 2016 Prices; 2.875% Interest Rate

Year	Years to completion	Total annual expenditure ($000s)	Interest factor	IDC ($000s)	Total payment ($000s)
2018	5.5	$27,483.0	0.1687	$4,636.5	$32,119.5
2019	4.5	$27,483.0	0.1360	$3,738.8	$31,221.8
2020	3.5	$0.0	0.1043	$0.0	$0.0
2021	2.5	$7,309.0	0.0734	$536.7	$7,845.7
2022	1.5	$81,273.3	0.0434	$3,530.0	$84,803.3
2023	0.5	$81,273.3	0.0143	$1,160.0	$82,433.4
2024	0.0	$81,273.3	0.0000	$0.0	$81,273.3
Total		**$306,095.0**		**$13,602.0**	**$319,697.0**

7.3. Project Benefits.

7.3.1. NED Benefits. Annual benefits for the Ala Wai recommended plan are 48,331,000 in 1 October 2016 prices and at the current Federal interest rate of 2.875 percent. Table B-25 also shows probabilistic estimates of the benefits; to wit, there is a 25 percent chance that the true benefits total would exceed $65,604,000, a 50 percent chance it would exceed $34,823,000 and a 75 percent chance it would exceed $17,018,000.

Table B-26 gives a more detailed breakdown of benefits by category and by reach. The commercial category accounts for 52 percent of total benefits, while residential accounts for 41 percent and public for 7 percent. The three Ala Wai Canal reaches, as might be expected, account for a large share of the benefits – 89 percent. The Ala Wai subbasin, including the Manoa-Palolo Canal, accounts for 92 percent of benefits.

Table B-25. Annual Benefits with Probabilistic Values

1 October 2016 Prices; 2.875% Interest Rate; 50-Year Period of Analysis

WO Proj EAD	Residual EAD	Benefits (EAD Reduced)	75% Probability that Benefits Exceed:	50% Probability that Benefits Exceed:	25% Probability that Benefits Exceed:
$53,719	$5,388	$48,331	$17,018	$34,823	$65,604

7.3.2. NED Benefits vs. RED Effects. 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.

Approximately 30,000 hotel rooms - one-half of the total hotel rooms in the state - are in Waikiki, and about one-half of tourists 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 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-27, Waikiki directly or indirectly contributes about 7.4 percent of

Table B-26. Annual Benefits by Category and Reach

1 October 2016 Prices; 2.875% Interest Rate; 50-Year Period of Analysis

Reach	Without Project				With Project (Residual)				EAD Reduced (Benefits)				
	Res.	Comm.	Pub.	Total	Res.	Comm.	Pub.	Total	Res.	Comm.	Pub.	Total	% of Total
Ala Wai subbasin													
ALA1	$325	$10,567	$219	$11,110	$0	$0	$0	$0	$325	$10,567	$219	$11,110	23.0%
ALA2	$12,448	$5,375	$408	$18,231	$4	$3	$0	$7	$12,444	$5,372	$408	$18,223	37.7%
ALA3	$5,629	$7,797	$166	$13,591	$3	$7	$0	$10	$5,625	$7,790	$165	$13,581	28.1%
MPC1	$781	$841	$4	$1,626	$127	$235	$1	$363	$653	$606	$3	$1,263	2.6%
MPC2	$373	$165	$25	$563	$75	$24	$7	$106	$298	$141	$18	$457	0.9%
TOTAL	$19,554	$24,744	$822	$45,121	$210	$269	$8	$486	$19,345	$24,475	$814	$44,634	92.4%
Makiki subbasin													
MAK1	$202	$398	$0	$599	$246	$303	$0	$549	-$44	$94	$0	$50	0.1%
MAK2	$373	$581	$314	$1,267	$149	$208	$198	$555	$224	$373	$116	$712	1.5%
MAK3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	0.0%
MAK4	$44	$0	$93	$137	$22	$0	$91	$113	$22	$0	$3	$24	0.0%
KAH1	$2	$0	$0	$2	$2	$0	$0	$2	$0	$0	$0	$0	0.0%
KAH2	$11	$0	$0	$11	$11	$0	$0	$11	$0	$0	$0	$0	0.0%
KAO1	$145	$66	$5	$217	$129	$59	$5	$193	$16	$7	$0	$24	0.0%
TOTAL	$777	$1,045	$413	$2,234	$559	$570	$294	$1,423	$217	$474	$119	$811	1.7%
Manoa subbasin													
MAN1	$131	$0	$173	$304	$82	$0	$69	$151	$49	$0	$104	$154	0.3%
MAN2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	0.0%
MAN3	$6	$2	$2	$11	$0	$0	$0	$0	$6	$2	$2	$11	0.0%
MAN4	$168	$2	$0	$170	$92	$1	$0	$93	$76	$1	$0	$77	0.2%
MAN5	$141	$0	$0	$141	$154	$0	$0	$154	-$13	$0	$0	-$13	0.0%
MAN6	$68	$0	$0	$68	$26	$0	$0	$26	$42	$0	$0	$42	0.1%
MAN7	$3	$0	$0	$3	$1	$0	$0	$1	$3	$0	$0	$3	0.0%
UNI1	$0	$0	$1,304	$1,304	$0	$0	$751	$751	$0	$0	$553	$553	1.1%
UNI2	$0	$0	$4,204	$4,204	$0	$0	$2,272	$2,272	$0	$0	$1,932	$1,932	4.0%
TOTAL	$517	$4	$5,683	$6,205	$354	$1	$3,091	$3,446	$163	$4	$2,592	$2,759	5.7%
Palolo subbasin													
PAL1	$33	$0	$56	$89	$6	$0	$12	$18	$27	$0	$44	$71	0.1%
PAL2	$6	$0	$2	$8	$1	$0	$0	$1	$5	$0	$2	$7	0.0%
PAL3	$39	$0	$1	$39	$9	$0	$0	$9	$30	$0	$0	$30	0.1%
PAL4	$18	$0	$3	$21	$2	$0	$0	$3	$16	$0	$3	$19	0.0%
PUK1	$1	$0	$1	$2	$1	$0	$0	$1	$0	$0	$0	$1	0.0%
WAI1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	0.0%
TOTAL	$97	$0	$62	$159	$19	$0	$13	$32	$78	$0	$49	$127	0.3%
STUDY AREA TOTAL	**$20,945**	**$25,793**	**$6,981**	**$53,719**	**$1,142**	**$840**	**$3,406**	**$5,388**	**$19,803**	**$24,953**	**$3,575**	**$48,331**	100.0%
% of Total	39.0%	48.0%	13.0%	100.0%	21.2%	15.6%	63.2%	100.0%	41.0%	51.6%	7.4%	100.0%	

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 about one-half of the hotel rooms in Hawaii and more than 85 percent of the hotel rooms on Oahu. Economic impacts from flood events, or flood events avoided, are not limited to physical property damages. Although not quantified for this study, 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 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 impossible. 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-27. Contribution to the State's Economy by Statewide Visitor Industry and 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	$444	7
Direct and indirect impact 4/				
Gross domestic product ($ 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 visit
Source: Hawaii State Department of Business, Economic Development & Tourism, records.

In most areas, many of the economic impacts of flooding would be primarily Regional Economic Development (RED) in nature and thus would not be included in an NED analysis. Typically in most areas of the country, if flooding forces 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 flood plain of the Ala Wai Canal Project, and for this they spend an average of more than $14 million per day in Waikiki alone. 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.

The contention that money moving between state economies generated from Federal expenditures (e.g., a harbor improvement) is simply a regional transfer with no net national economic impact is diluted in Hawaii, because a disproportional amount of money spent and invested there comes from outside the U.S. What would normally appear to be purely a regional benefit in other states is often an NED benefit in Hawaii. Most international econometric models analyze expenditures or monetary injections from foreign sources separately from domestic expenditures. Statistics show that international visitors account for 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 in 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. Furthermore, such an experience would likely discourage these tourists from ever coming back to Hawaii or spending money on U.S. soil.

International tourists willing to spend the money to come to Hawaii have made a conscious decision to seek a particular kind of tropical vacation, and they are unlikely to find another location in the U.S. that would meet their expectations. Most of these tourists book their 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 these visitors account for 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 to 85 percent 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 when expressed on 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. The main purpose of this discussion is to suggest that the NED benefits claimed for the project and included in the benefit-cost analysis almost certainly are significantly understated.

Severe flooding in Waikiki would 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 could take away some of Waikiki's allure in the minds of potential visitors. Reducing the level of flooding that might occur would help minimize these long-term impacts.

The businesses in areas surrounding Waikiki also stand to lose during a major flood event. Several thousand businesses are found in and adjacent to the flood plain 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 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 show that a majority of these establishments are small businesses with fewer than 10 employees. These are the types of businesses that tend to have the least resources for recovering from a natural disaster. Under with-project conditions, many of these small business operators would stand to be spared the hardships related to recovering from a major flood.

7.3.3. Benefits in Low Flow Reaches (ER 1165-2-21)

Local governments – not the Corps – are responsible for providing adequate drainage in areas with small streams and ditches with carrying capacities typical of storm sewer pipes. Consequently, Corps participation generally is excluded by ER 1165-2-21 (Flood Damage Reduction Measures in Urban Areas, 30 October 1980) in cases and areas where the 0.1 ACE flood is associated with a flow of less than 800 cfs. The intent of the regulation is to prevent Corps participation in flood risk management projects that amount to local storm sewer drainage improvements for handling local runoff. Such locations exist in the Ala Wai Watershed, and the project-related ones are summarized in Table B-28 and shown in Figures B-7 to B-9. For the Makiki Stream detention basin, no benefits are taken until the stream reaches an urban area downstream of the 800 cfs point (Figure B-8). There are 24 residential structures between the detention basin and the start of the 0.1 ACE flow of 800 cfs. Benefits cannot be taken from these structures between cross-sections 7674 and 9175. The Woodlawn ditch detention measure is located on a tributary to Manoa Stream, upstream of a point (800 cfs) that is economically justified by benefits derived within the Manoa Stream reach which does qualify for flood control improvements (Figure B-9). The Woodlawn ditch tributary was not a separate damage reach, so no benefits are taken due to the detention feature until a point is reached downstream of this tributary along Manoa Stream where the 0.1 ACE flow is much greater than 800 cfs. The remaining features are located at points where the 0.1 ACE exceeds 800 cfs.

Table B-28. Ala Wai Watershed Project-Related Locations of 10% ACE Flows (Existing Conditions)

Stream	10% flow (ft^3/s)	Damage Reach	Notes
Makiki Subbasin			
Makiki Stream upstream of urban area at detention feature location	560	MAK4	Feature provides benefits downstream; location at RAS XSEC 9175.
Makiki Stream at start of urban area	800	MAK3	Location at RAS XSEC 7674.
Manoa Subbbasin			
Waihi Stream Tributary to Manoa Stream at location of detention basin	1,600	Above MAN7b	Feature provides benefits downstream in urban area
Waiakeakua Stream Tributary to Manoa Stream at location of detention basin	1,080	Above MAN7b	Feature provides benefits downstream in urban area
Woodlawn Ditch tributary to Manoa Stream at location of detention basin feature.	530	Above MAN5	Feature provides downstream benefits to Manoa Stream
Manoa Stream downstream of junction with Woodlawn Ditch	4,600	MAN5	Start of benefits from Woodlawn Ditch detention basin
Manoa Stream at Kanewai Field detention basin location	5,990	MAN1a	
Palolo Subbasin			
Pukele Stream, Tributary to Palolo Stream, at location of detention basin	1,120	PUK1b	Feature provides benefits downstream
Waiamao Stream, Tributary to Palolo Steam, at location of detention basin	1,300	WAI1b	Feature provides benefits downstream

Figure B-7. Ala Wai Stream Reaches and Detention Basin Feature Locations

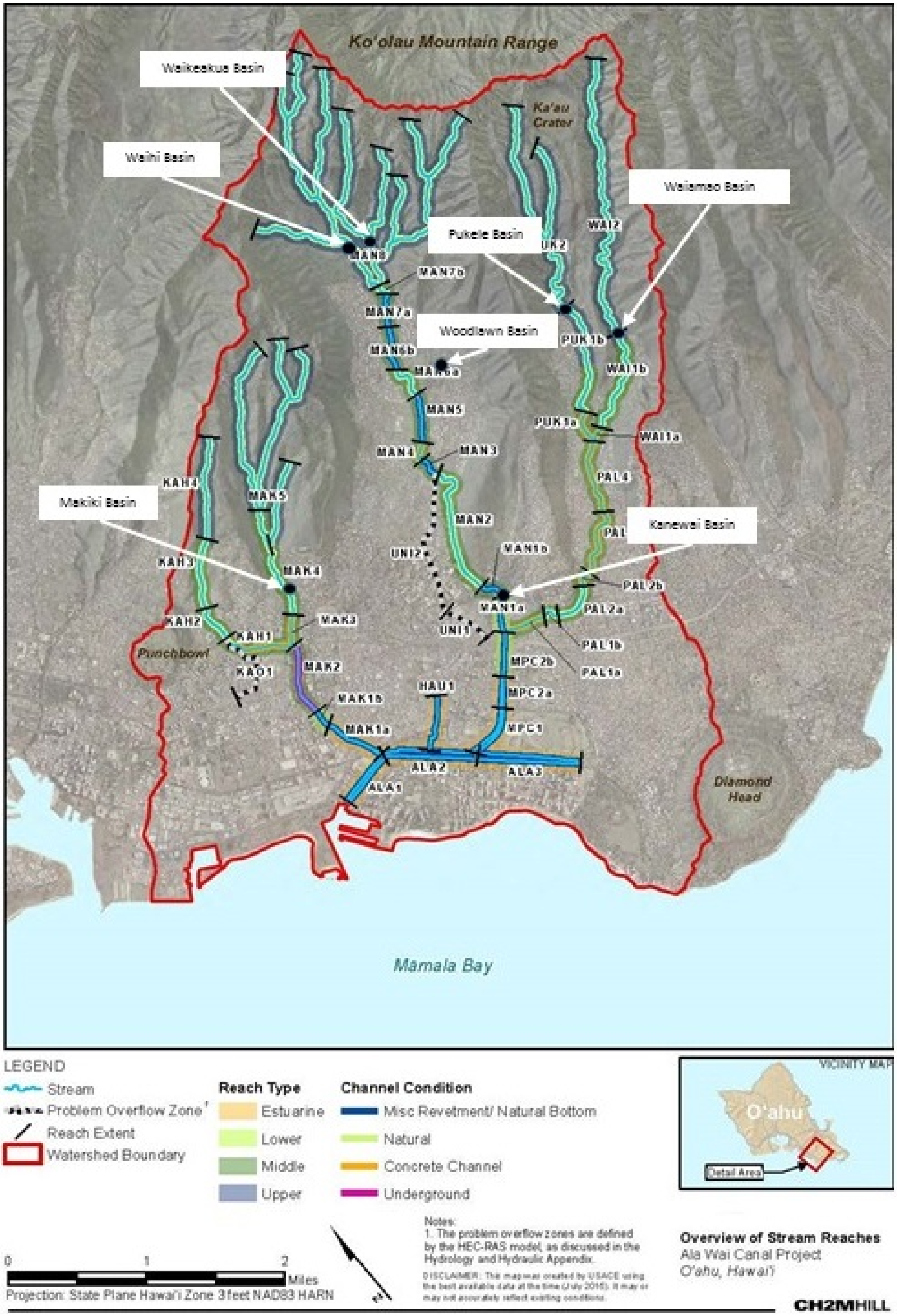
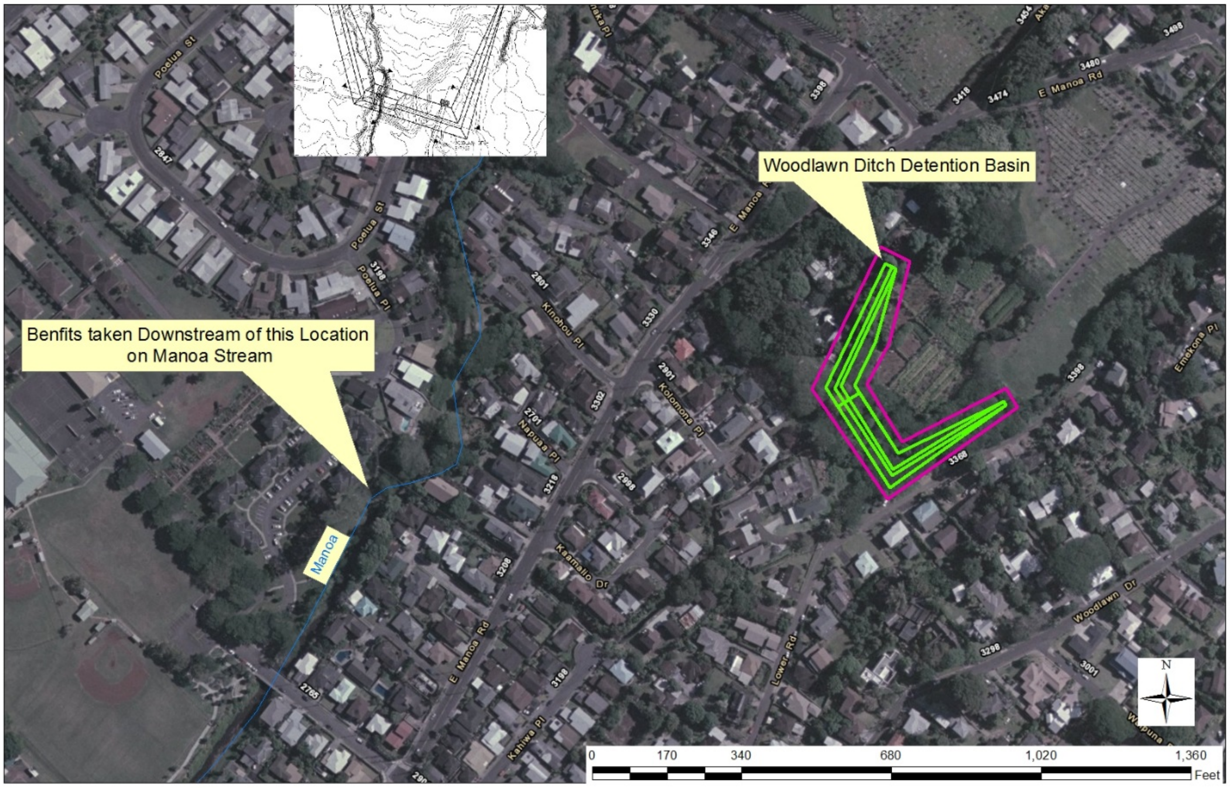


Figure B-8. Location of Makiki Stream Detention Basin and 800 cfs Location Point

Figure B-9. Location of Woodlawn Detention Basin and Beginning Benefits Location Downstream



7.4. Benefit-Cost Analysis. With annual benefits of $48,331,000 and annual costs of $13,117,000 for the $306,095,000 project, the benefit cost ratio is 3.7, as shown in Table B-29. Net benefits are $35,214,000. These figures are based on a price level of 1 October 2016, the current Federal interest rate of 2.875 percent, and a 50-year period of analysis.

The benefit-cost ratio is based on damages and damage reduction reflecting the intermediate SLC scenario for 2025 and 2075. It should be noted, however, that even under the low SLC scenario, the project is still strongly justified. Under the low scenario, annual benefits would total $46,208,000 and the benefit-cost ratio would be 3.5.

Table B-29. Benefit-Cost Ratio
1 October 2016 Prices; 2.875% Interest Rate; 50-Year Period of Analysis

First Costs ($000s)	$306,095
Annual Benefits ($000s)	$48,331
Annual Costs ($000s)	$13,117
Benefit-Cost Ratio	3.7
Net Benefits ($000s)	$35,214

7.5. Project Performance and Sea-Level Rise Considerations. Table B-30 presents the three measures of project performance -annual exceedance probability, long-term risk analysis and conditional non-exceedance probability – for the four subbasins. These statistics have already been summarized for existing and base year without-project conditions in Table B-11 and for future without-project conditions in Table B-13, and are repeated here along with the recommended plan performance ratings. Although the economic benefit-cost analysis was based on an evaluation of intermediate and low SLC scenarios for 2025 and 2075, a broader range of scenarios was used to evaluate project performance, as listed below:

- Without-condition, low SLC, for 2025 and 2075;
- Without-condition, intermediate SLC, for 2025 and 2075;
- Recommended plan, low SLC, for 2025 and 2075;
- Recommended plan, intermediate SLC, for 2025, 2075 and 2125;
- Recommended plan, high SLC, for 2025, 2075 and 2125;
- Recommended plan, high SLC with surge from coincident storm, for 2075 and 2125.

Results for the three sea level rise scenarios, as detailed in the Climate Change Scenarios Appendix, range from 0.41 to 2.96 feet in 2075. The sea level rise impacts were incorporated into the starting backwater conditions of the Ala Wai Canal Project HEC-RAS model, which currently assumes a mean high high water (MHHW) of 1.08 feet. In addition to the sea level values, the interannual variability of the tidal data of 0.40 feet was also added to the MHHW value to determine the starting backwater conditions. The starting water surface elevations for the low, intermediate, and high 2075 scenarios were 1.89, 2.50, and 4.44 feet, respectively.

The expected (i.e., risk-based) annual exceedance probability (AEP) in the 2025 and 2075 without-project intermediate SLC case range from 18.9 percent in ALA1 to 64 in ALA2 and 91.8 percent in ALA3. Project implementation reduces the expected AEP in 2075 to 0.01 percent in ALA1 and ALA2 and to 0.02 percent in ALA3. More modest reductions in AEP also occur in MPC1 and MPC2. As can be seen in Table B-30, these reductions in flood risk extend even to the high SLC case, with or without coincident storm, in 2075. They also extend to 2125 in the intermediate and low SLC cases. Only in the 2125 high SLC scenarios does project performance drop significantly – and it is a major reduction in these limited cases.

In terms of long-term risk, over a 10-year period and assuming the intermediate SLC scenario, reach ALA1 would have about an 88 percent chance of at least one damaging flood occurring and would have a greater than 99 percent chance over 30 and 50 years. Reaches ALA2 and ALA3 would have greater than 99 percent chances over 10, 30 or 50-year periods. In all three reaches, the risk of a damaging flood over any of the three time periods with project implementation would be reduced to less than 1 percent.

Flood risk management project performance is often evaluated in relation to the 0.01 ACE (1 percent) event. Within that context, the conditional nonexceedance probabilities calculated by the HEC-FDA program indicate that the recommended plan would give the Ala Wai Canal reaches greater than 99 percent confidence in successfully containing this flood event under intermediate SLC case assumptions. But even under the high SLC scenarios, the conditional nonexceedance probability in the 0.01 ACE event in 2075 remains above 99 percent in all three reaches. These figures represent a major reduction in flood risk along the Ala Wai Canal, where, under future without-project conditions, reaches ALA2 and ALA3 have essentially no chance whatsoever of containing this flood event and ALA1 has only an 8 percent chance.

7.6   Residual Risk. The recommended plan is expected to dramatically reduce flood risk in the oceanfront areas along the Ala Wai Canal, where thousands upon thousands of tourists congregate daily. Flood risk would also be reduced to a lesser extent in many other portions of the watershed. However, no flood risk management project will completely eliminate flood risk. No project is large enough to withstand every conceivable storm that nature can devise. Moreover, when structural flood risk projects such as this one have their capacity exceeded in a storm, it can be very dangerous.

7.6.1   EAD and Project Performance.   The residual economic damages in each of the 27 reaches with the project in place can be seen in the middle columns of Table B-26. In economic terms, equivalent annual damage is reduced from $53,719,000 under without-project conditions to $5,388,000 with implementation of the recommended plan, thus removing about 90 percent of the economic flood risk while leaving 10 percent. Figure B-10 portrays the residual flood risk by reach; this figure can be compared to its without-project equivalent in Figure B-4. Of the residual damages, 21 percent would be residential, 63 percent public, and 15 percent commercial. Certain reaches in the Manoa and Makiki subbasins, as well as the Manoa-Palolo Canal reaches, would continue to experience significant residual flooding with the project in place. (For the Makiki area, the built-out nature of these reaches, combined with dense development leaving little space between the structures and stream banks, restricted space for detention basin development and underground conveyance systems, and limited opportunities for nonstructural measures made it difficult to further address flood risk in the Makiki Stream watershed.)

The project performance aspects of residual risk can be seen in Tables B-30, which indicate that flood risk is sharply reduced in the Ala Wai area reaches, but hardly eliminated, and that there is no reduction at all in some areas of the watershed. Yet in these area with no improvement, residents may be fooled into believing that the project has also addressed their flood risk.

7.6.2.   Public Safety.   Effects of the project on life safety are not as easily measured as projecting property damage or capacity exceedance. For the most part, the risk of life loss during flood events in the study area is not high. That is not, of course, to say that lives would not be endangered in the event of a major flood. About 21 percent of the residual flooding expected with the project in place would be residential. In addition, flooding can be flashy and come with little warning. However, these conditions exist primarily in the steeply sloped, less populated hillside communities with relatively narrow flood plains. In the lower flood plain, it is much flatter and floodwater would rise more slowly. The project will include a new, basin-wide flood warning system to ensure that periods of intense and long duration rainfalls are highly monitored and occupants are given as much warning as possible. People should generally have adequate warning and time to move to higher ground or upper floors and out of harm's way. But 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 flood plain as high-rise buildings replace older, lower profile ones.

7.6.3 Iolani School. One area of significance and concern that does not stand to benefit from the project, as it is currently 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 0.01 ACE event with the project in place, flood waters would rise almost to the floor levels of several classrooms and/or administration buildings and also flood as much as one-half of the campus, although 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. Both hydrologic/hydraulic 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 specifically for the Iolani School site also 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. A flood warning system, however, is included in the recommended plan for the benefit of all residual risk areas within the study area.

7.6.4. Ala Wai Golf Course. Similarly, initial evaluation of adding a nonstructural solution to the project 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.

7.6.5. Resiliency and Superiority. Under the risk based concept, the system is expected to protect the project area up to the top of containment - in this case, the top of floodwall 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 in terms of 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. (Floodwall failure apart from overtopping is unlikely, and the left bank floodwall is designed to not fail even with overtopping. Splash protection in the form of a concrete slab is integrated into the design on the landward side of the floodwalls throughout each reach. The splash protection will reduce the risk scour and erosion in an overtopping event and add to the resiliency of the feature.

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 0.01 ACE event would be between 30 minutes to 1 hour. This would limit the amount of discharge that would overtop the floodwalls 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 inundate a few buildings but would mostly impact 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 street 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 down Ala Wai Blvd towards the ocean in ALA 1 and through Waikiki in 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. The public safety risk here is low since 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 comparable to those from two feet of inundation in those overtopping areas.

Recovery for the community in the aftermath of any overtopping event along the Ala Wai floodwall certainly should not be minimized given the large population at risk and the numerous businesses in the area, but certain aspects of the scenario would limit the risk. Only a few critical facilities are located in the oceanfront areas likely to be affected, so an inundation event would not shut down the ability of emergency personnel to respond from other portions of Honolulu outside the Waikiki area and to function in the wake of such an event. A consequence of the flashy nature of flooding in this watershed is that flooding would not remain inside buildings and on streets for a very long period of time, and the depths would not be extreme even while the water is up. This pattern of flooding would greatly help clean-up operations and facilitate a swift return to normal operations for businesses and public facilities as well as residents.

Related to resilience is superiority. Superiority simply means constructing the levee/floodwall so that it has a low section at a point 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.

8.0. CONCLUSION.

Implementation of the recommended plan for the Ala Wai Canal project, including detention basins and a floodwall along the canal itself, would cost $306,095,000 (FY17 prices). The project would have strong economic justification, with a benefit-cost ratio of 3.7 and net annual benefits of $35,214,000. Annual benefits would total $48,331,000 and annual costs $13,117,000. About 90 percent of the economic flood risk would be eliminated. The project would be expected to perform well under all assumed sea-level change scenarios through 2075.

Figure B-10. Residual Expected Annual Damages for the Recommended Plan

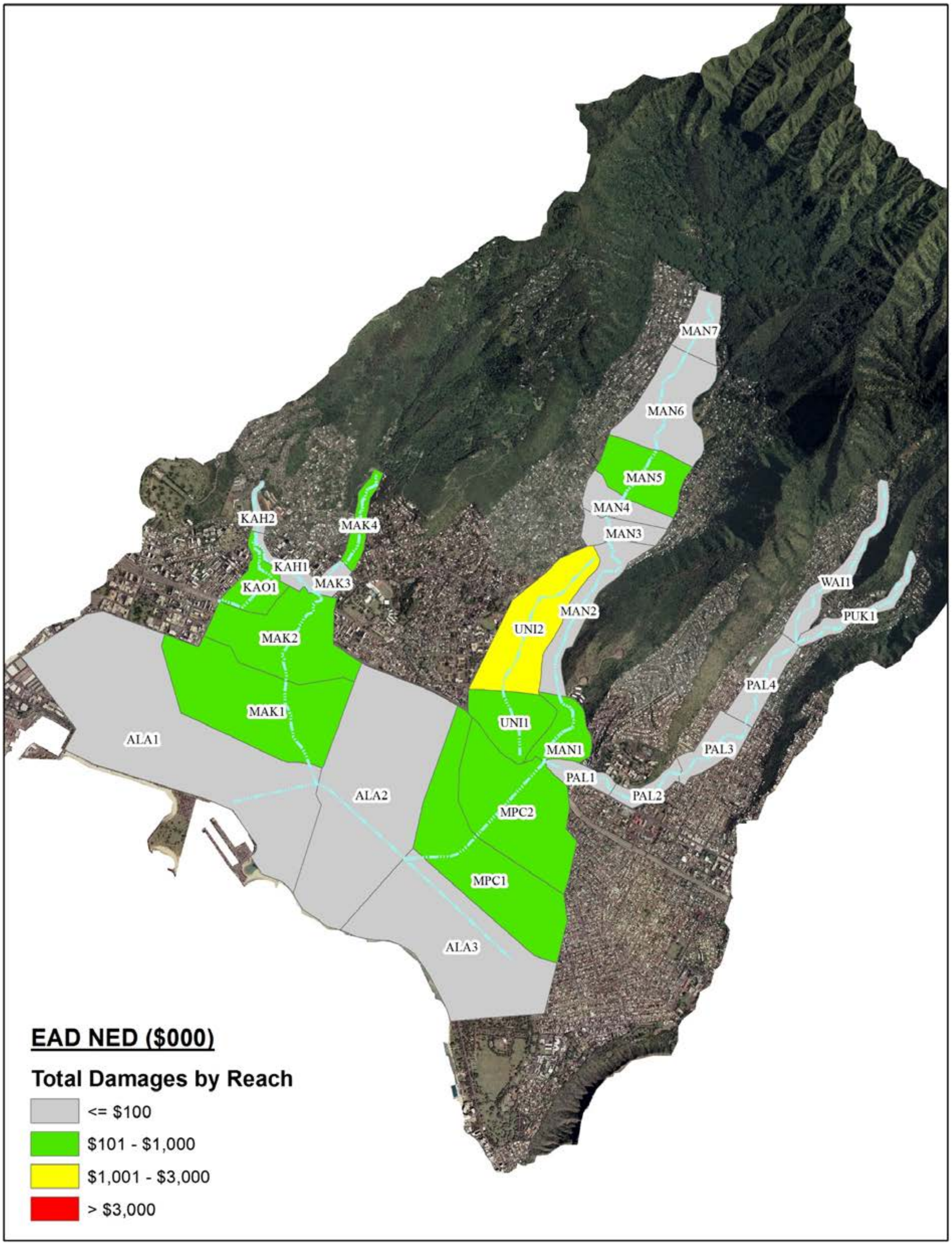


Table B-30 – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
ALA1	WO	Low	2025	4.71	0.1405	0.1782	85.95%	99.72%	99.99%	41.49%	23.58%	12.26%	8.30%	5.20%	2.70%
		Low	2075	4.71	0.1757	0.2031	89.67%	99.89%	100.00%	36.79%	20.91%	11.13%	7.74%	5.04%	2.61%
		Intermed	2025	4.71	0.1549	0.1888	87.67%	99.81%	100.00%	39.45%	22.50%	11.76%	8.08%	5.10%	2.66%
		Intermed	2075	4.71	0.1549	0.1885	87.62%	99.81%	100.00%	39.53%	22.51%	11.78%	8.07%	5.07%	2.64%
	NED	Low	2025	7.9	0.0001	0.0001	0.10%	0.30%	0.50%	99.99%	99.99%	99.99%	99.99%	99.98%	99.98%
		Low	2075	7.9	0.0001	0.0001	0.10%	0.30%	0.50%	99.99%	99.98%	99.98%	99.98%	99.98%	99.98%
		Intermed	2025	7.9	0.0001	0.0001	0.10%	0.30%	0.50%	99.99%	99.96%	99.96%	99.96%	99.96%	99.95%
		Intermed	2075	7.9	0.0001	0.0001	0.10%	0.30%	0.50%	99.98%	99.96%	99.96%	99.96%	99.96%	99.95%
		Intermed	2125	7.9	0.0001	0.0001	0.14%	0.43%	0.71%	99.98%	99.98%	99.96%	99.96%	99.96%	99.95%
		High	2025	7.9	0.0001	0.0001	0.10%	0.30%	0.50%	99.99%	99.99%	99.99%	99.99%	99.99%	99.99%
		High	2075	7.9	0.0001	0.0003	0.33%	0.99%	1.64%	99.93%	99.87%	99.86%	99.86%	99.85%	99.85%
		High	2125	7.9	0.9990	0.8768	100.00%	100.00%	100.00%	11.30%	10.88%	10.72%	10.51%	10.32%	10.18%
		Coincident Storm	2075	7.9	0.0001	0.0040	3.98%	11.46%	18.37%	99.25%	98.99%	98.94%	98.90%	98.87%	98.86%
		Coincident Storm	2125	7.9	0.9990	0.9970	100.00%	100.00%	100.00%	0.14%	0.14%	0.12%	0.12%	0.12%	0.12%
ALA2	WO	Low	2025	4.44	0.6107	0.6233	99.99%	100.00%	100.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
		Low	2075	4.44	0.6744	0.6613	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
		Intermed	2025	4.44	0.6384	0.6398	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
		Intermed	2075	4.44	0.6384	0.6398	100.00%	100.00%	100.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.00%
	NED	Low	2025	8.75	0.0001	0.0001	0.12%	0.35%	0.59%	99.99%	99.99%	99.99%	99.99%	99.89%	99.72%
		Low	2075	8.75	0.0001	0.0001	0.14%	0.40%	0.67%	99.99%	99.99%	99.98%	99.98%	99.94%	99.81%
		Intermed	2025	8.75	0.0001	0.0001	0.13%	0.38%	0.63%	99.99%	99.99%	99.99%	99.99%	99.92%	99.73%
		Intermed	2075	8.75	0.0001	0.0001	0.15%	0.46%	0.77%	99.99%	99.97%	99.96%	99.96%	99.83%	99.54%
		Intermed	2125	8.75	0.0001	0.0005	0.50%	1.49%	2.47%	99.90%	99.75%	99.64%	99.63%	99.18%	96.82%
		High	2025	8.75	0.0001	0.0001	0.12%	0.36%	0.61%	99.99%	99.99%	99.98%	99.98%	99.95%	99.86%
		High	2075	8.75	0.0001	0.0016	1.60%	4.74%	7.77%	99.52%	98.79%	98.55%	98.53%	97.62%	96.06%
		High	2125	8.75	0.5829	0.5131	99.93%	100.00%	100.00%	42.85%	40.90%	39.27%	38.52%	37.63%	37.25%
		Coincident Storm	2075	8.75	0.0001	0.0075	7.26%	20.23%	31.39%	97.47%	95.31%	94.61%	94.55%	93.24%	91.27%
		Coincident Storm	2125	8.75	0.9990	0.9418	100.00%	100.00%	100.00%	4.56%	4.20%	3.73%	3.57%	3.44%	3.36%
ALA3	WO	Low	2025	3.5	0.9799	0.9106	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Low	2075	3.5	0.9898	0.9294	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Intermed	2025	3.5	0.9841	0.9180	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Intermed	2075	3.5	0.9841	0.9180	100.00%	100.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	NED	Low	2025	9.3	0.0001	0.0001	0.13%	0.38%	0.64%	99.99%	100.00%	99.96%	99.90%	99.81%	99.74%
		Low	2075	9.3	0.0001	0.0001	0.12%	0.36%	0.60%	99.99%	100.00%	99.97%	99.93%	99.86%	99.81%
		Intermed	2025	9.3	0.0001	0.0001	0.11%	0.33%	0.56%	99.99%	100.00%	99.99%	99.96%	99.92%	99.90%
		Intermed	2075	9.3	0.0001	0.0002	0.23%	0.70%	1.16%	99.97%	99.99%	99.94%	99.84%	99.69%	99.58%
		Intermed	2125	9.3	0.0001	0.0003	0.27%	0.81%	1.35%	99.98%	99.94%	99.72%	99.53%	99.21%	98.85%
		High	2025	9.3	0.0001	0.0001	0.12%	0.35%	0.58%	99.99%	99.99%	99.98%	99.94%	99.89%	99.85%
		High	2075	9.3	0.0001	0.0006	0.64%	1.91%	3.17%	99.89%	99.73%	99.36%	98.69%	97.77%	97.15%
		High	2125	9.3	0.0001	0.2535	94.62%	99.98%	100.00%	69.07%	65.65%	62.31%	60.11%	58.62%	57.46%
		Coincident Storm	2075	9.3	0.0001	0.0014	1.43%	4.24%	6.96%	99.84%	98.90%	98.29%	97.60%	96.82%	96.33%
		Coincident Storm	2125	9.3	0.9990	0.8025	100.00%	100.00%	100.00%	17.34%	15.55%	13.24%	11.91%	11.20%	10.55%

Table B-30 – Project Performance (continued)

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MPC1	WO	Low	2025	8.5	0.0944	0.1075	67.93%	96.70%	99.66%	52.57%	11.59%	3.75%	1.66%	0.21%	0.11%
		Low	2075	8.5	0.0954	0.1093	68.56%	96.89%	99.69%	51.65%	11.39%	3.66%	1.65%	0.22%	0.12%
		Intermed	2025	8.5	0.0949	0.1085	68.27%	96.81%	99.68%	52.09%	11.48%	3.70%	1.63%	0.21%	0.11%
		Intermed	2075	8.5	0.0982	0.1137	70.11%	97.33%	99.76%	49.63%	10.91%	3.52%	1.60%	0.21%	0.12%
	NED	Low	2025	8.5	0.0407	0.0485	39.16%	77.48%	91.66%	89.48%	51.16%	27.47%	17.29%	4.88%	2.91%
		Low	2075	8.5	0.0407	0.0486	39.26%	77.59%	91.73%	89.36%	51.07%	27.44%	17.30%	4.88%	2.91%
		Intermed	2025	8.5	0.0403	0.0484	39.11%	77.43%	91.63%	89.47%	51.28%	27.61%	17.30%	4.84%	2.85%
		Intermed	2075	8.5	0.0400	0.0490	39.48%	77.84%	91.88%	89.09%	51.30%	27.64%	17.36%	4.87%	2.85%
		Intermed	2125	8.5	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		High	2025	8.5	0.0400	0.0484	39.13%	77.45%	91.64%	89.41%	51.41%	27.68%	17.43%	4.87%	2.93%
		High	2075	8.5	0.0418	0.0592	45.68%	83.97%	95.27%	83.22%	48.28%	26.66%	17.01%	4.83%	2.88%
		High	2125	8.5	0.9990	0.6755	100.00%	100.00%	100.00%	25.45%	19.64%	13.66%	10.52%	4.42%	2.37%
		Coincident Storm	2075	8.5	0.0456	0.0782	55.72%	91.32%	98.30%	75.20%	46.68%	28.50%	19.20%	5.43%	3.15%
		Coincident Storm	2125	8.5	0.9990	0.9712	100.00%	100.00%	100.00%	2.53%	1.99%	1.48%	1.22%	0.84%	0.63%
MPC2	WO	Low	2025	14.74	0.0152	0.0206	18.81%	46.47%	64.71%	99.81%	85.58%	59.10%	36.76%	12.94%	8.21%
		Low	2075	14.74	0.0152	0.0206	18.80%	46.47%	64.71%	99.81%	85.58%	59.10%	36.76%	12.94%	8.21%
		Intermed	2025	14.74	0.0152	0.0206	18.80%	46.46%	64.70%	99.81%	85.59%	59.12%	36.77%	12.94%	8.21%
		Intermed	2075	14.74	0.0152	0.0206	18.81%	46.48%	64.72%	99.81%	85.61%	59.14%	36.77%	12.94%	8.21%
	NED	Low	2025	14.74	0.0067	0.0099	9.49%	25.86%	39.27%	99.99%	96.26%	84.70%	69.75%	34.31%	23.42%
		Low	2075	14.74	0.0067	0.0099	9.50%	25.87%	39.28%	99.99%	96.26%	84.71%	69.76%	34.38%	23.47%
		Intermed	2025	14.74	0.0067	0.0098	9.37%	25.55%	38.84%	99.99%	96.26%	84.69%	69.99%	35.19%	24.70%
		Intermed	2075	14.74	0.0067	0.0099	9.46%	25.78%	39.16%	99.99%	96.29%	84.69%	69.84%	34.58%	23.66%
		Intermed	2125	14.74	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		High	2025	14.74	0.0067	0.0099	9.50%	25.87%	39.28%	99.99%	96.26%	84.71%	69.76%	34.38%	23.47%
		High	2075	14.74	0.0067	0.0099	9.50%	25.87%	39.28%	99.99%	96.25%	84.72%	69.80%	34.39%	23.47%
		High	2125	14.74	0.0061	0.0103	9.81%	26.63%	40.31%	100.00%	96.38%	81.07%	69.13%	36.91%	21.77%
		Coincident Storm	2075	14.74	0.0067	0.0099	9.46%	25.79%	39.17%	99.99%	96.29%	84.69%	69.88%	34.69%	23.83%
		Coincident Storm	2125	14.74	0.0059	0.0097	9.24%	25.24%	38.41%	99.98%	96.44%	82.10%	71.09%	42.63%	30.49%
MAK1	WO	Low	2025	7.43	0.0455	0.1095	68.63%	96.91%	99.70%	69.96%	44.74%	28.55%	17.57%	9.39%	6.77%
		Low	2075	7.43	0.0476	0.1132	69.92%	97.28%	99.75%	68.44%	43.65%	27.89%	17.20%	9.27%	6.71%
		Intermed	2025	7.43	0.0461	0.1104	68.97%	97.01%	99.71%	69.48%	44.42%	28.40%	17.52%	9.41%	6.81%
		Intermed	2075	7.43	0.0461	0.1104	68.96%	97.01%	99.71%	69.49%	44.40%	28.40%	17.54%	9.43%	6.82%
	NED	Low	2025	7.43	0.0073	0.0709	52.06%	88.98%	97.47%	81.69%	72.34%	64.45%	55.92%	49.36%	48.14%
		Low	2075	7.43	0.0073	0.0710	52.14%	89.04%	97.49%	81.69%	72.34%	64.45%	55.92%	49.36%	48.14%
		Intermed	2025	7.43	0.0073	0.0709	52.05%	88.97%	97.46%	81.69%	72.34%	64.43%	55.87%	49.29%	48.06%
		Intermed	2075	7.43	0.0073	0.0710	52.14%	89.04%	97.49%	81.60%	72.15%	64.30%	55.81%	49.26%	48.04%
		Intermed	2125	7.43	0.0067	0.0771	55.18%	91.00%	98.19%	78.67%	70.31%	62.78%	55.13%	49.25%	47.64%
		High	2025	7.43	0.0073	0.0709	52.06%	88.98%	97.47%	81.69%	72.34%	64.45%	55.92%	49.36%	48.14%
		High	2075	7.43	0.0073	0.0982	64.42%	95.49%	99.43%	72.00%	62.48%	57.71%	52.23%	47.61%	46.67%
		High	2125	7.43	0.9990	0.9722	100.00%	100.00%	100.00%	2.06%	1.90%	1.82%	1.76%	1.69%	1.67%
		Coincident Storm	2075	7.43	0.0718	0.1955	88.64%	99.85%	100.00%	54.98%	46.42%	44.35%	43.24%	41.89%	41.62%
		Coincident Storm	2125	7.43	0.9990	0.9990	100.00%	100.00%	100.00%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%

Table B-30 – Project Performance (continued)

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAK2	WO	Low	2025	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.76%	13.54%	2.89%	0.80%	0.11%
		Low	2075	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.79%	13.55%	2.91%	0.79%	0.11%
		Intermed	2025	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.76%	13.54%	2.89%	0.80%	0.11%
		Intermed	2075	30.87	0.0493	0.0557	43.62%	82.08%	94.30%	88.52%	39.77%	13.57%	2.92%	0.79%	0.11%
	NED	Low	2025	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.34%	21.56%	8.39%	3.95%	0.61%
		Low	2075	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.34%	21.56%	8.39%	3.95%	0.61%
		Intermed	2025	30.87	0.0434	0.0498	39.98%	78.38%	92.21%	91.42%	44.31%	21.50%	8.41%	3.96%	0.59%
		Intermed	2075	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.32%	21.57%	8.34%	3.94%	0.59%
		Intermed	2125	30.87	0.0359	0.0425	35.21%	72.80%	88.58%	93.21%	54.78%	24.87%	8.27%	6.42%	0.57%
		High	2025	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.46%	21.66%	8.38%	3.94%	0.60%
		High	2075	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.46%	21.66%	8.38%	3.94%	0.60%
		High	2125	30.87	0.0359	0.0425	35.21%	72.80%	88.58%	93.21%	54.71%	24.82%	8.29%	6.40%	0.57%
		Coincident Storm	2075	30.87	0.0434	0.0494	39.75%	78.13%	92.06%	91.40%	44.29%	21.51%	8.37%	3.95%	0.59%
		Coincident Storm	2125	30.87	0.0359	0.0425	35.21%	72.80%	88.58%	93.21%	54.69%	24.93%	8.26%	6.38%	0.57%
MAK3	WO	Low	2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
		Low	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
		Intermed	2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
		Intermed	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.98%	99.95%	99.95%
	NED	Low	2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Low	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Intermed	2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Intermed	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Intermed	2125	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		High	2025	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		High	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		High	2125	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Coincident Storm	2075	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
		Coincident Storm	2125	78.68	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	99.99%	99.98%	99.98%	99.97%
MAK4	WO	Low	2025	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
		Low	2075	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
		Intermed	2025	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
		Intermed	2075	178.15	0.0168	0.0668	49.90%	87.43%	96.84%	79.82%	62.02%	51.23%	44.59%	32.42%	23.55%
	NED	Low	2025	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		Low	2075	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		Intermed	2025	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		Intermed	2075	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		Intermed	2125	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		High	2025	178.15	0.0168	0.0651	48.98%	86.72%	96.54%	80.44%	63.49%	52.30%	44.60%	35.74%	23.76%
		High	2075	178.15	0.0168	0.0651	48.98%	86.72%	96.54%	80.44%	63.49%	52.30%	44.60%	35.74%	23.76%
		High	2125	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%
		Coincident Storm	2075	178.15	0.0168	0.0651	48.98%	86.72%	96.54%	80.44%	63.49%	52.30%	44.60%	35.74%	23.76%
		Coincident Storm	2125	178.15	0.0168	0.0647	48.76%	86.55%	96.47%	80.60%	63.78%	52.41%	44.65%	35.81%	23.51%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
KAH1	WO	Low	2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Low	2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Intermed	2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Intermed	2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
	NED	Low	2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Low	2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Intermed	2025	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Intermed	2075	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Intermed	2125	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		High	2025	72.13	0.0001	0.0009	0.92%	2.74%	4.52%	99.63%	99.48%	99.39%	99.39%	99.36%	99.35%
		High	2075	72.13	0.0001	0.0009	0.92%	2.74%	4.52%	99.63%	99.48%	99.39%	99.39%	99.36%	99.35%
		High	2125	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
		Coincident Storm	2075	72.13	0.0001	0.0009	0.92%	2.74%	4.52%	99.63%	99.48%	99.39%	99.39%	99.36%	99.35%
		Coincident Storm	2125	72.13	0.0001	0.0008	0.82%	2.44%	4.03%	99.70%	99.50%	99.42%	99.42%	99.41%	99.41%
KAH2	WO	Low	2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Low	2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Intermed	2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Intermed	2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
	NED	Low	2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Low	2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Intermed	2025	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Intermed	2075	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Intermed	2125	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		High	2025	76.68	0.0512	0.0631	47.87%	85.83%	96.15%	77.38%	44.82%	27.41%	15.71%	8.65%	4.12%
		High	2075	76.68	0.0512	0.0631	47.87%	85.83%	96.15%	77.38%	44.82%	27.41%	15.71%	8.65%	4.12%
		High	2125	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
		Coincident Storm	2075	76.68	0.0512	0.0631	47.87%	85.83%	96.15%	77.38%	44.82%	27.41%	15.71%	8.65%	4.12%
		Coincident Storm	2125	76.68	0.0512	0.0628	47.73%	85.72%	96.10%	77.35%	44.78%	27.20%	15.29%	8.50%	3.97%
KAO1	WO	Low	2025	42.92	0.0140	0.0566	44.16%	82.59%	94.57%	79.26%	62.51%	53.52%	46.70%	39.63%	35.25%
		Low	2075	42.92	0.0137	0.0566	44.17%	82.60%	94.58%	79.19%	62.50%	53.73%	47.08%	39.23%	34.73%
		Intermed	2025	42.92	0.0140	0.0566	44.16%	82.59%	94.57%	79.26%	62.51%	53.52%	46.70%	39.63%	35.25%
		Intermed	2075	42.92	0.0137	0.0566	44.17%	82.60%	94.58%	79.19%	62.50%	53.73%	47.08%	39.23%	34.73%
	NED	Low	2025	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		Low	2075	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		Intermed	2025	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		Intermed	2075	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		Intermed	2125	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		High	2025	42.92	0.0138	0.0527	41.78%	80.27%	93.31%	80.86%	65.23%	54.32%	47.22%	40.92%	34.60%
		High	2075	42.92	0.0138	0.0527	41.78%	80.27%	93.31%	80.86%	65.23%	54.32%	47.22%	40.92%	34.60%
		High	2125	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%
		Coincident Storm	2075	42.92	0.0138	0.0527	41.78%	80.27%	93.31%	80.86%	65.23%	54.32%	47.22%	40.92%	34.60%
		Coincident Storm	2125	42.92	0.0137	0.0523	41.55%	80.03%	93.18%	81.05%	65.51%	54.37%	47.21%	40.83%	34.50%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAN1	WO	Low	2025	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
		Low	2075	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
		Intermed	2025	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
		Intermed	2075	35.58	0.2874	0.2935	96.90%	100.00%	100.00%	3.15%	0.28%	0.07%	0.06%	0.02%	0.00%
	NED	Low	2025	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		Low	2075	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		Intermed	2025	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		Intermed	2075	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		Intermed	2125	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		High	2025	35.58	0.2874	0.2934	96.90%	100.00%	100.00%	3.23%	0.29%	0.09%	0.11%	0.04%	0.01%
		High	2075	35.58	0.2874	0.2934	96.90%	100.00%	100.00%	3.23%	0.29%	0.09%	0.11%	0.04%	0.01%
		High	2125	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
		Coincident Storm	2075	35.58	0.2874	0.2934	96.90%	100.00%	100.00%	3.23%	0.29%	0.09%	0.11%	0.04%	0.01%
		Coincident Storm	2125	35.58	0.2873	0.2935	96.90%	100.00%	100.00%	3.20%	0.26%	0.07%	0.07%	0.03%	0.00%
MAN2	WO	Low	2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
		Low	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
		Intermed	2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
		Intermed	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	99.99%	99.98%	99.98%
	NED	Low	2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Low	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Intermed	2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Intermed	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Intermed	2125	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		High	2025	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		High	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		High	2125	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Coincident Storm	2075	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
		Coincident Storm	2125	122.93	0.0001	0.0001	0.10%	0.30%	0.50%	100.00%	100.00%	100.00%	100.00%	99.98%	99.97%
MAN3	WO	Low	2025	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
		Low	2075	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
		Intermed	2025	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
		Intermed	2075	156.95	0.0011	0.0029	2.85%	8.30%	13.44%	99.98%	99.18%	95.99%	91.71%	83.45%	74.83%
	NED	Low	2025	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		Low	2075	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		Intermed	2025	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		Intermed	2075	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		Intermed	2125	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		High	2025	156.95	0.0001	0.0001	0.11%	0.32%	0.54%	100.00%	100.00%	99.99%	99.99%	99.95%	99.88%
		High	2075	156.95	0.0001	0.0001	0.11%	0.32%	0.54%	100.00%	100.00%	99.99%	99.99%	99.95%	99.88%
		High	2125	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%
		Coincident Storm	2075	156.95	0.0001	0.0001	0.11%	0.32%	0.54%	100.00%	100.00%	99.99%	99.99%	99.95%	99.88%
		Coincident Storm	2125	156.95	0.0001	0.0001	0.11%	0.33%	0.55%	100.00%	100.00%	99.98%	99.97%	99.95%	99.89%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAN4	WO	Low	2025	156.84	0.2358	0.2430	93.82%	99.98%	100.00%	5.38%	0.54%	0.13%	0.07%	0.01%	0.00%
		Low	2075	156.84	0.2376	0.2454	94.01%	99.98%	100.00%	5.28%	0.53%	0.13%	0.07%	0.01%	0.00%
		Intermed	2025	156.84	0.2358	0.2430	93.82%	99.98%	100.00%	5.38%	0.54%	0.13%	0.07%	0.01%	0.00%
		Intermed	2075	156.84	0.2376	0.2454	94.01%	99.98%	100.00%	5.28%	0.53%	0.13%	0.07%	0.01%	0.00%
	NED	Low	2025	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		Low	2075	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		Intermed	2025	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		Intermed	2075	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		Intermed	2125	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		High	2025	156.84	0.2151	0.2255	92.23%	99.95%	100.00%	6.11%	0.66%	0.65%	0.47%	0.27%	0.04%
		High	2075	156.84	0.2151	0.2255	92.23%	99.95%	100.00%	6.11%	0.66%	0.65%	0.47%	0.27%	0.04%
		High	2125	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
		Coincident Storm	2075	156.84	0.2151	0.2255	92.23%	99.95%	100.00%	6.11%	0.66%	0.65%	0.47%	0.27%	0.04%
		Coincident Storm	2125	156.84	0.2150	0.2251	92.19%	99.95%	100.00%	6.08%	0.64%	0.62%	0.45%	0.21%	0.02%
MAN5	WO	Low	2025	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.63%	11.94%	6.27%	3.31%	1.50%	0.67%
		Low	2075	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.65%	11.94%	6.27%	3.33%	1.51%	0.68%
		Intermed	2025	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.63%	11.94%	6.27%	3.31%	1.50%	0.67%
		Intermed	2075	171.01	0.1525	0.1654	83.60%	99.56%	99.99%	30.65%	11.94%	6.27%	3.33%	1.51%	0.68%
	NED	Low	2025	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		Low	2075	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		Intermed	2025	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		Intermed	2075	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		Intermed	2125	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		High	2025	171.01	0.1259	0.1396	77.76%	98.90%	99.95%	40.32%	20.88%	13.19%	9.12%	4.61%	2.05%
		High	2075	171.01	0.1259	0.1396	77.76%	98.90%	99.95%	40.32%	20.88%	13.19%	9.12%	4.61%	2.05%
		High	2125	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
		Coincident Storm	2075	171.01	0.1259	0.1396	77.76%	98.90%	99.95%	40.32%	20.88%	13.19%	9.12%	4.61%	2.05%
		Coincident Storm	2125	171.01	0.1259	0.1389	77.57%	98.87%	99.94%	40.26%	20.89%	13.14%	9.02%	4.63%	2.01%
MAN6	WO	Low	2025	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
		Low	2075	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
		Intermed	2025	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
		Intermed	2075	210.35	0.0487	0.0568	44.28%	82.70%	94.63%	81.09%	46.74%	30.29%	19.83%	11.34%	6.71%
	NED	Low	2025	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		Low	2075	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		Intermed	2025	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		Intermed	2075	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		Intermed	2125	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		High	2025	210.35	0.0139	0.0231	20.87%	50.45%	68.97%	96.61%	81.57%	58.79%	42.77%	29.87%	10.98%
		High	2075	210.35	0.0139	0.0231	20.87%	50.45%	68.97%	96.61%	81.57%	58.79%	42.77%	29.87%	10.98%
		High	2125	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%
		Coincident Storm	2075	210.35	0.0139	0.0231	20.87%	50.45%	68.97%	96.61%	81.57%	58.79%	42.77%	29.87%	10.98%
		Coincident Storm	2125	210.35	0.0138	0.0231	20.81%	50.34%	68.86%	96.60%	81.59%	58.95%	42.87%	29.76%	10.65%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
MAN7	WO	Low	2025	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
		Low	2075	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
		Intermed	2025	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
		Intermed	2075	262.83	0.0018	0.0056	5.49%	15.57%	24.59%	99.99%	98.50%	90.83%	79.92%	68.27%	57.87%
	NED	Low	2025	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		Low	2075	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		Intermed	2025	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		Intermed	2075	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		Intermed	2125	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		High	2025	262.83	0.0001	0.0011	1.13%	3.35%	5.53%	100.00%	100.00%	98.82%	97.18%	94.87%	87.10%
		High	2075	262.83	0.0001	0.0011	1.13%	3.35%	5.53%	100.00%	100.00%	98.82%	97.18%	94.87%	87.10%
		High	2125	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
		Coincident Storm	2075	262.83	0.0001	0.0011	1.13%	3.35%	5.53%	100.00%	100.00%	98.82%	97.18%	94.87%	87.10%
		Coincident Storm	2125	262.83	0.0001	0.0012	1.15%	3.40%	5.60%	100.00%	99.96%	98.90%	97.24%	94.95%	87.18%
UNI1	WO	Low	2025	12.77	0.0256	0.0513	40.92%	79.38%	92.80%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
		Low	2075	12.77	0.0256	0.0514	40.99%	79.46%	92.85%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
		Intermed	2025	12.77	0.0256	0.0513	40.92%	79.38%	92.80%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
		Intermed	2075	12.77	0.0256	0.0514	40.99%	79.46%	92.85%	89.32%	62.03%	45.02%	33.09%	18.36%	11.01%
	NED	Low	2025	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		Low	2075	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		Intermed	2025	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		Intermed	2075	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		Intermed	2125	12.77	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		High	2025	12.77	0.0126	0.0384	32.36%	69.06%	85.85%	93.94%	76.61%	61.11%	48.53%	29.28%	10.40%
		High	2075	12.77	0.0126	0.0384	32.36%	69.06%	85.85%	93.94%	76.61%	61.11%	48.53%	29.28%	10.40%
		High	2125	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
		Coincident Storm	2075	12.77	0.0126	0.0384	32.36%	69.06%	85.85%	93.94%	76.61%	61.11%	48.53%	29.28%	10.40%
		Coincident Storm	2125	12.77	0.0124	0.0384	32.38%	69.08%	85.86%	93.94%	76.69%	61.21%	48.64%	29.40%	10.43%
UNI2	WO	Low	2025	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
		Low	2075	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
		Intermed	2025	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
		Intermed	2075	101.16	0.0280	0.0480	38.85%	77.13%	91.45%	89.46%	60.55%	44.42%	33.71%	20.84%	14.87%
	NED	Low	2025	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		Low	2075	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		Intermed	2025	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		Intermed	2075	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		Intermed	2125	101.16	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		High	2025	101.16	0.0161	0.0365	31.08%	67.26%	84.45%	93.64%	73.14%	58.04%	46.92%	30.33%	15.34%
		High	2075	101.16	0.0161	0.0365	31.08%	67.26%	84.45%	93.64%	73.14%	58.04%	46.92%	30.33%	15.34%
		High	2125	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%
		Coincident Storm	2075	101.16	0.0161	0.0365	31.08%	67.26%	84.45%	93.64%	73.14%	58.04%	46.92%	30.33%	15.34%
		Coincident Storm	2125	101.16	0.0160	0.0366	31.11%	67.31%	84.49%	93.65%	73.20%	58.15%	46.98%	30.37%	15.37%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
PAL1	WO	Low	2025	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
		Low	2075	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
		Intermed	2025	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
		Intermed	2075	39.54	0.0234	0.0331	28.55%	63.53%	81.38%	97.21%	66.72%	44.07%	28.59%	11.91%	5.54%
	NED	Low	2025	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		Low	2075	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		Intermed	2025	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		Intermed	2075	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		Intermed	2125	39.54	0.0335	0.0483	39.03%	77.34%	91.57%	87.97%	57.33%	29.75%	17.04%	5.40%	2.67%
		High	2025	39.54	0.0048	0.0075	7.22%	20.13%	31.25%	99.99%	98.85%	95.00%	81.30%	41.35%	4.23%
		High	2075	39.54	0.0048	0.0075	7.22%	20.13%	31.25%	99.99%	98.85%	95.00%	81.30%	41.35%	4.23%
		High	2125	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		Coincident Storm	2075	39.54	0.0048	0.0075	7.22%	20.13%	31.25%	99.99%	98.85%	95.00%	81.30%	41.35%	4.23%
		Coincident Storm	2125	39.54	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
PAL2	WO	Low	2025	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
		Low	2075	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
		Intermed	2025	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
		Intermed	2075	91.41	0.0011	0.0026	2.52%	7.38%	12.00%	100.00%	99.60%	97.07%	92.51%	83.19%	75.11%
	NED	Low	2025	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		Low	2075	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		Intermed	2025	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		Intermed	2075	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		Intermed	2125	91.41	0.0059	0.0099	9.45%	25.74%	39.11%	100.00%	96.67%	82.02%	70.59%	38.77%	23.59%
		High	2025	91.41	0.0001	0.0004	0.38%	1.14%	1.90%	100.00%	100.00%	100.00%	100.00%	100.00%	97.77%
		High	2075	91.41	0.0001	0.0004	0.38%	1.14%	1.90%	100.00%	100.00%	100.00%	100.00%	100.00%	97.77%
		High	2125	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		Coincident Storm	2075	91.41	0.0001	0.0004	0.38%	1.14%	1.90%	100.00%	100.00%	100.00%	100.00%	100.00%	97.77%
		Coincident Storm	2125	91.41	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
PAL3	WO	Low	2025	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
		Low	2075	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
		Intermed	2025	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
		Intermed	2075	139.47	0.0041	0.0088	8.46%	23.28%	35.71%	99.93%	96.81%	86.18%	71.85%	48.59%	35.82%
	NED	Low	2025	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		Low	2075	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		Intermed	2025	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		Intermed	2075	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		Intermed	2125	139.47	0.0048	0.0073	7.12%	19.86%	30.86%	99.96%	98.91%	95.05%	81.26%	41.27%	4.11%
		High	2025	139.47	0.0017	0.0019	1.83%	5.39%	8.83%	100.00%	100.00%	100.00%	100.00%	98.76%	67.04%
		High	2075	139.47	0.0017	0.0019	1.83%	5.39%	8.83%	100.00%	100.00%	100.00%	100.00%	98.76%	67.04%
		High	2125	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		Coincident Storm	2075	139.47	0.0017	0.0019	1.83%	5.39%	8.83%	100.00%	100.00%	100.00%	100.00%	98.76%	67.04%
		Coincident Storm	2125	139.47	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%

Table B-30 (continued) – Project Performance

Reach	Condition	SLC	Year	Target Stage	Ann. Exceedance Prob.		Long-Term Risk			Conditional Non-exceedance Probability					
					Median	Expected	10 yrs	30 yrs	50 yrs	10%	4%	2%	1%	0.4%	0.2%
PAL4	WO	Low	2025	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
		Low	2075	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
		Intermed	2025	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
		Intermed	2075	187.93	0.0047	0.0089	8.60%	23.65%	36.22%	99.96%	96.84%	85.66%	70.89%	47.14%	34.33%
	NED	Low	2025	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		Low	2075	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		Intermed	2025	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		Intermed	2075	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		Intermed	2125	187.93	0.0001	0.0004	0.42%	1.26%	2.09%	100.00%	100.00%	100.00%	100.00%	99.99%	97.80%
		High	2025	187.93	0.0015	0.0014	1.36%	4.03%	6.62%	100.00%	100.00%	100.00%	100.00%	99.21%	74.58%
		High	2075	187.93	0.0015	0.0014	1.36%	4.03%	6.62%	100.00%	100.00%	100.00%	100.00%	99.21%	74.58%
		High	2125	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
		Coincident Storm	2075	187.93	0.0015	0.0014	1.36%	4.03%	6.62%	100.00%	100.00%	100.00%	100.00%	99.21%	74.58%
		Coincident Storm	2125	187.93	0.0014	0.0014	1.41%	4.17%	6.85%	100.00%	100.00%	100.00%	100.00%	99.24%	74.73%
PUK1	WO	Low	2025	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
		Low	2075	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
		Intermed	2025	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
		Intermed	2075	285.76	0.0225	0.0283	24.94%	57.71%	76.17%	98.30%	73.58%	45.79%	26.07%	8.84%	2.32%
	NED	Low	2025	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		Low	2075	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		Intermed	2025	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		Intermed	2075	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		Intermed	2125	285.76	0.0017	0.0018	1.80%	5.31%	8.69%	100.00%	100.00%	100.00%	100.00%	98.75%	67.21%
		High	2025	285.76	0.0072	0.0110	10.44%	28.16%	42.38%	100.00%	97.77%	82.80%	63.37%	27.63%	5.36%
		High	2075	285.76	0.0072	0.0110	10.44%	28.16%	42.38%	100.00%	97.77%	82.80%	63.37%	27.63%	5.36%
		High	2125	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
		Coincident Storm	2075	285.76	0.0072	0.0110	10.44%	28.16%	42.38%	100.00%	97.77%	82.80%	63.37%	27.63%	5.36%
		Coincident Storm	2125	285.76	0.0072	0.0108	10.32%	27.88%	42.00%	100.00%	97.86%	82.89%	63.48%	27.47%	5.17%
WAI1	WO	Low	2025	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
		Low	2075	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
		Intermed	2025	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
		Intermed	2075	265.81	0.0264	0.0470	38.19%	76.39%	90.98%	86.19%	60.48%	41.13%	27.22%	12.19%	4.29%
	NED	Low	2025	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		Low	2075	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		Intermed	2025	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		Intermed	2075	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		Intermed	2125	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		High	2025	265.81	0.0054	0.0225	20.36%	49.49%	67.96%	93.51%	86.29%	81.17%	72.63%	36.36%	7.16%
		High	2075	265.81	0.0054	0.0225	20.36%	49.49%	67.96%	93.51%	86.29%	81.17%	72.63%	36.36%	7.16%
		High	2125	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%
		Coincident Storm	2075	265.81	0.0054	0.0225	20.36%	49.49%	67.96%	93.51%	86.29%	81.17%	72.63%	36.36%	7.16%
		Coincident Storm	2125	265.81	0.0054	0.0222	20.12%	49.03%	67.48%	93.49%	86.48%	81.35%	72.88%	36.24%	7.04%

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