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

FINAL FEASIBILITY STUDY REPORT WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E
ENVIRONMENTAL AND REGULATORY COMPLIANCE

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Appendix E1
Summary of Federal and State Regulatory Compliance

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Federal and State Regulatory Compliance

Following is a discussion of the various regulations and policies that are applicable to the Ala Wai Canal Project, and the status of compliance with each regulation and policy.

Federal Regulations and Policies

National Environmental Policy Act

The National Environmental Policy Act (NEPA) establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and provides a process for implementing these goals (42 United States Code [U.S.C.] 4321 *et seq*.). NEPA requires federal agencies to incorporate environmental considerations in their planning and decision-making process through a systematic interdisciplinary approach. Specifically, it requires full disclosure of the environmental effects, alternatives, potential mitigation, and environmental compliance procedures of the proposed action.

This draft Feasibility Study Report with integrated Environmental Impact Statement (EIS) has been prepared in compliance with NEPA and its implementing regulations (40 CFR Part 1500 through 1508). Pursuant to these regulations, the document describes the existing environmental conditions within the project site, the proposed action and alternatives, potential environmental impacts of the proposed project, and measures to minimize environmental impacts. Full compliance will be achieved when the Final EIS and Record of Decision (ROD) are filed with the EPA.

Clean Water Act

The purpose of the Clean Water Act (CWA; 33 U.S.C. 1251 *et seq*.) is to "restore and maintain the chemical, physical and biological integrity of the nation's waters." Section 404 of the CWA regulates the discharge of dredged or fill material into Waters of the U.S., which are defined to include rivers, streams, estuaries, the territorial seas, ponds, lakes, and wetlands; the USACE retains primary responsibility for this permit program (with oversight provided by EPA). USACE does not issue itself a permit under this program, but rather demonstrates compliance with the environmental criteria set forth in the Clean Water Act Section 404(b)(1) guidelines (40 CFR 230).[1] Section 404(b)(1) specifies that impacts to waters of the United States may only be permitted if there is no other practicable alternative that would have less adverse impact on the aquatic ecosystem and the action would not cause or contribute to significant degradation of the waters. As described in Section 5.4 of the Draft Feasibility Report/EIS, the project would result in discharge of fill material into Waters of the U.S. The Section 404(b)(1) evaluation for this project, which is contained in Appendix E, concludes that the proposed action is consistent with the specified guidelines, and that the tentatively selected plan is the least environmentally damaging alternative (LEDPA).

Under Section 401 of the CWA, applicants for a federal permit to conduct any activity that may result in a discharge of dredged or fill material to Waters of the U.S. must also obtain certification that any such discharge would comply with State water quality standards. The State of Hawai`i Department of Health

[1] If certain conditions are met, Clean Water Act Section 404(r) states that the discharge of dredged or fill material is not prohibited by or otherwise subject to regulation under Clean Water Act Section 404, Section 301(a), or Section 402 (except for effluent standards or prohibitions under Section 307). This applies only if information on the effects of such discharge, including consideration of the guidelines developed under Section 404(b)(1), is included in an EIS for such project pursuant to NEPA and such EIS has been submitted to Congress before (1) the actual discharge of dredged or fill material in connection with the construction of such project and (2) either authorization of such project or an appropriation of funds for each construction.

(DOH) administers the Section 401 water quality certification program, pursuant to HRS §342D, as discussed below.

Section 402 of the Clean Water Act regulates discharges of pollutants and stormwater to surface waters through the National Pollutant Discharge and Elimination System (NPDES) program; the program is administered by EPA, who has delegated oversight authority to the State of Hawaii DOH. The NPDES program is governed at the State level under HRS Chapter 342D, also discussed below.

Endangered Species Act

Section 7 of the Endangered Species Act (ESA; 16 U.S.C. 1536) prohibits Federal agencies from authorizing, funding, or carrying out activities that are likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat. The USFWS is the administering agency for this authority regarding non-marine species. Through consultation with USFWS, agencies review their actions prior to implementation to determine if these could adversely affect listed species or their habitat.

In compliance with ESA consultation requirements, USACE requested information from USFWS regarding threated and endangered species and designated critical habitat within the overall Ala Wai watershed in April 2008. The USFWS responded in May 2008, and provided a list of federal listed species and designed critical habitat that could occur within the watershed. Follow-up meetings were held with agency staff on October 14, 2014; January 23, 2015; April 14, 2015; May 26, 2015; June 5, 2015; June 29, 2015; and July 29, 2015. The purpose of these meetings was to update agency staff on the current project status, discuss the project features, and to obtain any additional input on ESA-related issues.

Consultation was also initiated with NMFS in 2008; in response to USACE's request, NMFS provided a complete list of ESA-listed species under their jurisdiction in the Hawaiian Archipelago on April 25, 2008. At the time of the original consultation, the project scope and objectives were more broadly defined, with the project area extending to include the nearshore marine waters. As the objectives and scope of the project were subsequently narrowed to focus on riverine-based flood risk management, the project is not expected to directly or indirectly affect the nearshore marine waters.

Based on this ongoing consultation, the USACE evaluated the potential impacts of the proposed project and summarized the results in a Draft Biological Assessment. As documented in the Draft Biological Assessment, USACE determined that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, O'ahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen), with no effect on all other Federally listed/candidate species or designated critical habitat. As the blackline Hawaiian damselfly was initially thought to be restricted to higher elevations of the watershed (and therefore have no potential to occur within the project area), the Draft Biological Assessment included a no effect determination for this species. However, on July 28, 2015, USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin (D. Polhemus, personal communication, July 29, 2015). Detailed information from USFWS regarding this species is still pending; however, USACE provided a letter to USFWS on August 5, 2015, with submittal of the Draft Biological Assessment, indicating USACE's intention to initiate formal Section 7 consultation on the endangered blackline Hawaiian damselfly upon receipt of the species information.

A copy of the Draft Biological Assessment and ESA Section 7 correspondence is contained in Appendix E5; documentation of the completed Section 7 consultation process will be included in the Final Feasibility Report/EIS.

Migratory Bird Treaty Act

Native migratory birds of the United States are protected under the MBTA of 1918, as amended (16 U.S.C. 703-712 et. seq.); the list of birds protected under MBTA implementing regulations is provided at 50 CFR 10.13. This Act states that it is unlawful to pursue, hunt, take, capture or kill; attempt to take, capture or kill; possess, offer to or sell, barter, purchase, deliver or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product. "Take" is defined as "to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect (16 U.S.C. 703-712)." Consistent with the analysis provided relative to the ESA, the project is not expected to adversely affect migratory species.

Magnuson-Stevens Fishery Conservation and Management Act

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. 1855(b)) establish provisions relative to Essential Fish Habitat (EFH), in order to identify and protect important habitats for federally managed marine and anadromous fish species. Federal agencies which fund, permit, or undertake activities that may adversely affect EFH are required to consult with the National Marine Fisheries Service (NMFS) regarding the potential effects of their actions on EFH, and respond to NMFS recommendations.

As described in the Draft Integrated Feasibility Report and Environmental Impact Statement (EIS), no portion of the project area has been designated as EFH, but the nearshore waters to which the streams and Canal drain (i.e. Mamala Bay) include EFH for various lifestages of bottomfish, pelagics, coral reef ecosystem, and crustaceans. An overview of the proposed project and a discussion of potential project-related impacts was the subject of a meeting with NMFS on June 29, 2015; based on this discussion and the analysis contained in the Draft Report, USACE has determined that there would be no adverse effect to EFH, such that consultation is not required.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) (16 U.S.C. 661) was established to provide for the protection of fish and wildlife as part of federal water resource development projects. It requires Federal agencies to coordinate with USFWS and State wildlife agencies during the planning of new projects or for modifications of existing projects so that wildlife conservation receives equal consideration with other features of such projects throughout the decision making process. Wildlife resources are conserved by minimizing adverse effects, compensating for wildlife resources losses, and enhancing wildlife resource values.

Coordination with USFWS and DLNR (including both the Division of Forestry and Wildlife (DOFAW) and Division of Aquatic Resources (DAR)) has been conducted under the FWCA throughout the planning process; specific meeting dates are summarized in Section 6.2 of the Draft Feasibility Report/EIS. Through this coordination, input has been requested from the agencies relative to the potential impacts to fish and wildlife species, and approaches to avoid, minimize and mitigate for those impacts (including compensatory mitigation). In addition to site visits to the proposed measure locations, discussions have included a detailed review of the proposed design drawings for both the flood risk management and the compensatory mitigation measures. Input received to date relates to: (1) consideration of potential impacts to Federally listed species and (2) consideration of water quality impacts due to flushing and mobilization of contaminants in multi-purpose detention basins. These considerations have been integrated into the planning process, as summarized throughout the Draft Feasibility Report/EIS. No high-risk issues or other significant concerns have been identified to date. A formal record of the agencies' recommendations will be documented in a FWCA Section 2(b) Report, which will be included in the Final Feasibility Report/EIS.

National Historic Preservation Act

The National Historic Preservation Act (NHPA; 16 U.S.C. 470f), as amended, governs the preservation of cultural and historic resources. Specific to the proposed project, NHPA Section 106 requires Federal agencies to consider the effects of a proposed undertaking on properties that have been listed (or determined to be eligible for listing) in the National Register of Historic Places; properties that are listed (or are eligible for listing) in the National Register are referred to as "historic properties."

As described in 36 CFR Part 800.1, which are the implementing regulations for the historic preservation review process, the Section 106 process seeks to accommodate historic preservation concerns with the needs of federal undertakings through consultation. The goal of consultation is to obtain input as needed to identify historic properties potentially affected by the undertaking, assess the potential effects and seek ways to avoid, minimize or mitigate any adverse effects on historic properties. Consulting parties that should be involved in the Section 106 process include the State Historic Preservation Officer (SHPO), Native Hawaiian Organizations (NHOs), jurisdictional agency representatives, and other interested parties. Additionally, federal agencies must give the Advisory Council on Historic Preservation (ACHP) an opportunity to comment on the undertaking.

Section 106 compliance for projects for which no historic properties are identified within the area of potential effects (APE), or for which adverse effects are either not anticipated or are easily resolved, can typically be achieved through a standard consultation process. In certain circumstances, including projects for which the effects cannot be fully determined prior to approval of the undertaking, a memorandum of agreement (MOA) or a programmatic agreement may be executed to guide the resolution of adverse effects and mitigation. Such agreements are negotiated between the Federal agency, the SHPO, and possibly the ACHP; other individuals or entities, such as NHOs, may be invited to participate as consulting parties. In addition, the federal agency must make information available to the public, and provide an opportunity for public input.

In compliance with NHPA Section 106, consultation with the SHPO was initiated in a letter dated August 21, 2014. Ongoing consultation has been conducted with SHPO and other consulting parties, with input sought relative to definition of the APE, identification of historic properties within the APE, and determination of potential effects to those properties; a copy of the Section 106 consultation documents is contained in Appendix F. Consistent with the summary of impacts and mitigation described in the consultation documents, the USACE determined that there would be an adverse effect to historic properties. Treatment recommendations have been proposed to reduce many of the impacts to no adverse effect with conditions. In addition, a Programmatic Agreement is being developed to further identify resources, determine effects and establish the process for resolving adverse effects that may arise throughout the remaining planning, design, and construction phases of the project. This determination, with a request for concurrence, was provided to the SHPO and other consulting parties in a letter dated June 29, 2015; responses from SHPO and other consulting parties are pending. Responses received, as well as the Final Programmatic Agreement will be included as part of the Final Feasibility Report/EIS.

Coastal Zone Management Act

In response to the increasing pressure of development on coastal resources, the United States Congress enacted the Coastal Zone Management Act (16 U.S.C 1451-1464; CZMA) in 1972 and the Coastal Zone Act Reauthorization Amendments in 1990. These laws make federal financial assistance available to any coastal state or territory that is willing to develop and implement a comprehensive coastal management program. Hawai`i's CZM program was approved as HRS Chapter 205A in 1977; compliance with the various components of the State's program is further described below.

Clean Air Act

Clean Air Act, as amended, authorizes the EPA to establish NAAQS for major air pollutants. Based on measurements of ambient criteria pollutant data, EPA designates areas of the United States as having air quality equal to or better than NAAQS (attainment) or worse than NAAQS (non-attainment). The general conformity rule requires Federal agencies to ensure that actions they undertake in nonattainment and maintenance areas are consistent with air quality management plans for those areas. Because Hawaiʻi is, and always has been, in attainment for all pollutants, conformity analysis procedures do not apply to this project.

Air quality in the State of Hawai`i is delegated to the Clean Air Branch of DOH, and is governed at the State level under HRS §342B (Air Pollution Control); compliance with these requirements is further discussed below.

Uniform Relocation Assistance and Real Property Acquisition Policies Act

Federal, state, local government agencies, and others receiving Federal financial assistance for public programs and projects that require the acquisition of real property must comply with the policies and provisions set forth in the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended in 1987 (42 USC 4601 et seq.), and implementing regulation, 49 C.F.R. Part 24. The act provides for relocation advisory services, moving costs reimbursement, replacement housing, and reimbursement for related expenses and rights of appeal.

While some land may need to be acquired to construct certain flood risk management measures, it is not anticipated that the project would require construction of new housing. However, if necessary, property acquisition and relocation services, compensation for living expenses for temporarily relocated residents, and negotiations regarding any compensation for temporary loss of business would be accomplished in accordance with this act.

Executive Orders

Executive Orders that are relevant to the proposed project and have been considered in the feasibility planning process include the following:

- **Executive Order 11514, Protection and Enhancement of Environmental Quality**: The objective of this executive order is to protect and enhance the quality of the Nation's environment to sustain and enrich human life. As summarized in this document, the potential effects of the project were assessed, in consultation with project stakeholders; compliance with all applicable environmental regulations is being obtained.
- **Executive Order 11988, Floodplain Management**: The objective of this executive order is to avoid, to the extent possible, long- and short-term adverse impacts associated with the occupancy and modification of the base floodplain, and avoid direct and indirect support of development in the base floodplain whenever there is a practicable alternative. Compliance with this executive order, based on the procedures outlined in ER 1165-2-26 (*Implementation of Executive Order 11988 on Flood Plain Management*; 30 March 1984), is discussed in Section 8.6 of the Draft Feasibility Report/EIS.
- **Executive Order 11990, Protection of Wetlands**: The objective of this executive order is to minimize the loss or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands. As discussed in Section 5.7 of the Draft Report, some small pockets of wetlands may exist within the limits of the channels, but no adjacent wetland features have been identified. Impacts to aquatic habitat within the stream channels will be mitigated so as to achieve no net loss of habitat function.

- **Executive Order 12898, Environmental Justice**: The objective of this executive order is to make it a high priority to identify and address, as appropriate, disproportionately high and adverse human health or environmental effects of programs, policies and activities on minority and low-income populations. As discussed in Section 5.18 of the Draft Feasibility Report/EIS, the project alternatives are not expected to have a disproportionate effect on minority or low-income populations in the project area.
- **Executive Order 13045, Protection of Children From Environmental Health Risks and Safety Risks**: The objective of this executive order is to make it a high priority to identify and assess environmental health risks and safety risks that may disproportionately affect children. As discussed in Section 5.18 of the Draft Feasibility Report/EIS, the project is not expected to involve risks that would disproportionately affect children.
- **Executive Order 13112, Invasive Species**: The objective of this executive order is to prevent the introduction of invasive species, provide restoration of native species and habitat conditions in ecosystems that have been invaded, and promote public education and the means to address invasive species. The proposed project would include BMPs intended to address the introduction or spread of invasive species, and would incorporate native species as part of revegetation and mitigation efforts, where practicable.

State Regulations and Policies

Hawaii Environmental Impact Review Law (HRS Chapter 343)

HRS Chapter 343 is designed to "establish a system of environmental review which will ensure that environmental concerns are given appropriate consideration in decision making along with economic and technical considerations." The regulations identify nine specific activities that trigger the need for compliance. The proposed action involves multiple activities that are triggers for compliance with HRS Chapter 343: (1) use of State or County lands or funds, (2) use within any land classified as Conservation District, (3) use within any historic site as designated in the National Register or Hawai`i Register, and (4) use within the Waikiki area. This Draft Feasibility Report/EIS has been prepared in compliance with HRS Chapter 343; DLNR is the proposing agency and the Governor will be the accepting authority. Full compliance will be achieved when the Final EIS is accepted by the Governor.

Hawaii State Environmental Policy (HRS Chapter 344)

The purpose of HRS Chapter 344 is to "establish a State policy which will encourage productive and enjoyable harmony between people and their environment, promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of humanity, and enrich the understanding of the ecological systems and natural resources important to the people of Hawai`i." It specifies that the programs, authorities, and resources of the State be used to conserve natural resources and improve the quality of life. Particular aspects of the policy that relate to the project includes a focus on encouraging "productive and enjoyable harmony between people and their environment" and "the health and welfare of humanity." Consistent with the policy and guidelines, the project seeks to balance protection of the environment and quality of life through protection against flood risks.

Coastal Zone Management (HRS Chapter 205A)

In response to the federal CZMA (16 U.S.C. §1451-1456), Hawai`i's CZM program was enacted as HRS Chapter 205A in 1977, and is administered by the State of Hawai`i Department of Business, Economic Development and Tourism (DBEDT) Office of Planning. The CZM area encompasses the entire state, including all marine waters seaward to the extent of the State's police power and management authority, including the 12-mile U.S. territorial sea and all archipelagic waters. The Hawai`i CZM program integrates decisions made by state and county agencies such as the Land Use Commission, DLNR, DOH, Department of Transportation, and Department of Agriculture to provide greater coordination and compliance with existing laws and rules. Specifically, the program focuses on ten policy objectives:

- Recreational Resources
- Historic Resources
- Scenic and Open Space Resources
- Coastal Ecosystems
- Economic Uses
- Coastal Hazards
- Managing Development
- Public Participation
- Beach Protection
- Marine Resources

Key components of Hawaii's CZM program include (1) regulation of development within the SMA, a designated area extending inland from the shoreline, (2) a Shoreline Setback Area, which serves as a buffer against coastal hazards and erosion, and protects view planes, and (3) a Federal Consistency provision, which requires that federal activities, permits, and financial assistance be consistent with the Hawai`i CZM program. The project would not involve any work within the Shoreline Setback Area or SMA. In compliance with the Federal Consistency provision, the USACE evaluated the proposed project for consistency with the policies of the Hawai`i CZM program. Based on this evaluation, the project was found to be consistent to the maximum extent practicable with the State coastal zone management program; the USACE's Federal Consistency determination was submitted to the Office of Planning for their certification on August 5, 2015 (see Appendix E4). Documentation of concurrence will be included in the Final Report.

Conservation District (HRS Chapter 183C)

The Conservation District was created to protect important natural resources essential to the preservation of the state's fragile natural ecosystems and the sustainability of the State's water supply. Land uses within the Conservation District are under the sole jurisdiction of the State and are governed by HRS Chapter 183C and HAR §13-5. The Conservation District is divided into five subzones: protective, limited, resource, and general, and a "special" subzone to accommodate unique projects (HRS §183C-1).

The DLNR Office of Conservation and Coastal Lands (OCCL) is responsible for regulating land uses within the Conservation District, in accordance with HAR §13-5-22. The project would involve work within the Conservation District at several of the measure locations in the upper portions of the watershed. A Conservation District Use Permit would be obtained from OCCL prior to construction.

Forest Reserve (HRS Chapter 183)

The State's Forest Reserve System was created by the Territorial Government of Hawai'i through Act 44 in 1903. It is managed by the State DLNR Division of Forestry and Wildlife (DOFAW) under HRS Chapter 183, and implementing rules (HAR Section 104). Through these directives, DOFAW focuses on protection, management, restoration, and monitoring of natural resources in the State's Forest Reserves. The proposed project would involve work within the Honolulu Watershed Forest Reserve. Consistent with the requirements of HAR Section 104, it is expected that a Forest Reserve Special Use Permit would be required; this permit would be obtained prior to construction.

State Water Code (HRS Chapter 174C)

HRS Chapter 174C, the State Water Code, was enacted into law by the 1987 Hawai`i State Legislature for the purpose of establishing a comprehensive water resource planning program to protect Hawai`i's water resources. It is intended to obtain maximum beneficial use of the waters of the State, while providing for protection of traditional and customary Hawaiian rights, protection and procreation of fish and wildlife, and other uses in the public interest.

As specified in the implementing rules (HAR Section 169), a Stream Channel Alteration Permit is required for any temporary or permanent activity within the stream bed or banks that may: 1) obstruct, diminish, destroy, modify, or relocate a stream channel; 2) change the direction of the flow of water in a stream channel; or 3) remove any material or structure from a stream channel. Routine streambed and drainageway maintenance activities and the repair of existing facilities are generally exempt from the SCAP requirements. As the project will involve channel alterations for construction of some of the measures, a SCAP will be obtained from CWRM prior to construction.

Conservation of Aquatic Life, Wildlife and Land Plants (HRS Chapter 195D)

HRS §195D, administered by DLNR, prohibits any taking, transport or commerce of aquatic, wildlife, or plant species deemed to be in need of conservation. It adopts the status of all species listed as threatened or endangered under the ESA, and allows further designation of additional species. For actions that may result in take of a State listed species, an incidental take license may be obtained as part of a habitat conservation plan, which includes consultation with the Endangered Species Recovery Committee. As described relative to the ESA, the USACE has determined that the project is not likely to adversely affect threatened or endangered species. The non-Federal sponsor is responsible for confirming compliance with HRS Chapter 195D.

Historic Preservation (HRS Chapter 6E)

HRS Chapter 6E establishes a comprehensive historic preservation program that is intended to preserve, restore and maintain historic and cultural properties. The regulations are implemented by SHPD, and require review of any project that is funded or permitted by the State. This process is the State counterpart to the Section 106 consultation requirement to identify historic properties potentially affected by a proposed project and can be an additional avenue of information gathering for fulfilling the Section 106 consultation mandate.

Specifically, HRS Chapter 6E (§6E-8 and §6E-42) requires that: "Before any agency or officer of the State or its political subdivisions commences any project which may affect historic property, aviation artifact, or a burial site, the agency or officer shall advise the department and allow the department an opportunity for review of the effect of the proposed project on historic properties, aviation artifacts, or burial sites, consistent with Chapter 6E-43, especially those listed on the Hawai`i register of historic places. The proposed project shall not be commenced, or in the event it has already begun, continued, until the department shall have given its written concurrence." HRS Chapter 6E-43 governs burial sites, and gives authority to the appropriate island burial council relative to treatment of burial sites.

The implementing rules for the historic property review process are contained in HAR Chapter 13-275; these rules apply to "all state or county agencies funding or directly undertaking a project, or having a project undertaken on lands under its ownership or control which may affect historic properties" (§13-275-1b). They address the specific requirements relative to conducting archaeological, ethnographic and/or architectural inventory surveys. Consistent with these requirements, HRS Chapter 343 includes a requirement to consider cultural practices as part of an environmental review of the effects of a proposed action; a cultural impact assessment has been completed in compliance with this requirement (see Appendix F2).

Project information, including archaeological studies and the cultural impact assessment have been provided to SHPD, in conjunction with the NHPA Section 106 process. The non-Federal sponsor is responsible for completing any requirements in compliance with HRS Chapter 6E.

Air Pollution Control (HRS Chapter 342B)

Air quality in the State of Hawai`i is regulated by the Clean Air Branch of DOH, as authorized under HRS §342B (Air Pollution Control). HAR Title 11, Chapter 59 (Ambient Air Quality Standards) establishes State ambient air quality standards, which in some cases are more stringent than the comparable Federal standards or address pollutants that are not covered by the Federal standards established under the Clean Air Act. These standards are monitored and enforced by the Clean Air Branch.

The implementing rules relating to air pollution control are set forth in HAR Section Chapter 60. Under these rules, an Air Pollution Control Permit is required before constructing, reconstructing, modifying, or operating a stationary air pollution source. Certain air pollution sources are exempt from these requirements including vehicles, trucks, cranes, graders, and loaders (HAR §11-60.1-62d). Stationary sources with potential emissions of less than 1.0 ton per year for each air pollutant are also exempt from Air Pollution Control Permit requirements. Because of the type of equipment anticipated for use during construction and operation of the project, and the low levels of emissions anticipated as described in Section 5.13 of the Draft Report, the project is not expected to require an Air Pollution Control Permit from the Clean Air Branch.

Water Pollution (HRS Chapter 342D)

The authority to administer both CWA Section 401 and Section 402 have been delegated to the State of Hawaii. The Department of Health (DOH) implements the State's Water Quality Certification Program and National Pollution Discharge Elimination System (NPDES) program, respectively, under HRS Chapter 342D.

As required by CWA Section 401, the objective of the Water Quality Certification Program is to ensure that any federally permitted activity will not adversely impact the existing uses, designated uses, and applicable water quality criteria of the receiving State waters. These requirements are based on the implementing rules contained in HAR 11-54. A Section 401 water quality certification will be obtained from the DOH prior to construction.[2]

Consistent with the requirements of CWA Section 402, Hawai`i's NPDES program regulates point source pollutant discharges and storm water. The implementing rules of the program are contained in HAR 11-55. Specifically, HAR 11-55-04 states that "before discharging any pollutant, or beginning construction activities that disturb one or more acres of land, or substantially altering the quality of any discharges, or substantially increasing the quantity of any discharges, a person shall submit a complete NDPES permit application…, submit a complete notice of intent…, or for certain storm water discharges, meet all requirements for a conditional "no exposure" exclusion." Issuance of an NPDES permit typically requires development and implementation of a Stormwater Pollution Prevention Plan (SWPPP), which should include measures to avoid or minimize adverse effects of sediment, erosion, and pollutants on surface waters. The specific requirements for the project will be determined in coordination with DOH and the permit will be obtained prior to construction.

[2] Prior to issuance of the Final Feasibility Report/EIS, USACE will seek reasonable assurance from DOH that Water Quality Certification can be obtained for this project.

Noise Pollution (HRS Chapter 342F)

The Noise Control Act of 1972, along with its subsequent amendments (Quiet Communities Act of 1978 [42 U.S.C. Parts 4901-4918]), delegates the authority to regulate environmental noise to each state. For Hawai`i, regulations to prevent, control, and abate noise pollution are set forth in HRS Chapter 342F. The implementing rules, which include statewide noise standards, are provided in HAR §11-46 ("Community Noise Control"); these are administered by HDOH. The stated purpose of the standards is to "provide for the prevention, control, and abatement of noise pollution in the State from the following noise sources: stationary noise sources (such as air-conditioning units, exhaust systems, generators, compressors, and pumps); and equipment related to agricultural, construction, and industrial activities" (HAR §11-46). The noise standards are the maximum permissible sound levels (as measured from the property line) and vary according to land use district. It is anticipated that noise levels during construction could exceed the maximum permissible sound levels; pursuant to HAR §11-46-7, a permit would be obtained from HDOH, as needed.

Appendix E2
Draft Mitigation and Monitoring Plan

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Final

Mitigation, Monitoring and Adaptive Management Plan

Ala Wai Canal Project; Oahu, Hawaii

U.S. Army Corps of Engineers, Honolulu District

August 2016

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Attachments

1.0 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR) and as authorized under Section 209 of the Flood Control Act of 1962, the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii[1] (hereafter referred to as "the project"). The purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding within the Ala Wai Watershed.

The Ala Wai Watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (mi^2) (12,064 acres) and extends from the ridge of the Ko`olau Mountains to the nearshore waters of Mamala Bay. It includes Maikiki, Manoa, and Palolo Streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki district.

The project is currently a feasibility study, considering a variety of non-structural and structural flood risk management measures. Plan formulation and evaluation resulted in tentative selection of an alternative plan for implementation (referred to as the tentatively selected plan). A detailed discussion of the plan formulation process and the components of the tentatively selected plan are provided in the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as "Feasibility Report/EIS."

As detailed in the Implementation Guidance for Section 2036(a) of the Water Resources Development Act (WRDA) of 2007– Mitigation for Fish and Wildlife and Wetland Losses, it is the policy of the USACE Civil Works program to demonstrate that damages to all significant ecological resources have been avoided and minimized to the extent practicable, and that any remaining unavoidable damages have been compensated to the extent possible. The mitigation planning process should seek to compensate for non-negligible impacts to the extent incrementally justified and ensure that the recommended project will not have more than negligible adverse impacts on ecological resources. Engineering Regulation (ER) 1105-2-100 ("Planning Guidance Notebook") requires the use of a habitat-based methodology, supplemented with other appropriate information to describe and evaluate the impacts of the alternatives plans, and to identify the mitigation need of the with-project condition as measured against the future without-project condition. Once a mitigation need has been identified, mitigation objectives must be developed to address the identified losses. Mitigation objectives are used to guide formulation of appropriate mitigation management features and to establish benchmarks for evaluating the performance of the mitigation plans.

The regulations require assessment of environmental impacts and associated mitigation actions in a manner that addresses changes in ecological resource quality. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and/or quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Mitigation actions also need to go through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Preparation of a mitigation plan is required, and should present the objectives, plan design, determination of success criteria and monitoring needs, all of which should be developed in

[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the Congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

coordination with Federal and State resource agencies to the extent practicable. The mitigation plan should include the following:

(1) a description of the physical action to be undertaken to achieve the mitigation objectives within the watershed in which such losses occur;

(2) the type, amount, and characteristics of the habitat being restored;

(3) ecological success criteria for mitigation based on replacement of lost functions and values of the habitat, including hydrologic and vegetative characteristics;

(4) a plan for monitoring to determine the success of the mitigation, including the cost and duration of any monitoring and the entities responsible for any monitoring;

(5) a contingency plan (i.e. adaptive management) for taking corrective actions in cases where monitoring demonstrates that mitigation measures are not achieving ecological success; and

(6) should land acquisition be proposed as part of the mitigation plan, a description of the lands or interests in lands to be acquired for mitigation and the basis for a determination that such lands are available for acquisition.

This mitigation and monitoring plan has been developed in compliance with these requirements. It includes a discussion of the quantification of habitat impacts, identification of mitigation objectives and proposed mitigation actions, and development of the proposed monitoring and adaptive management approach.

2.0 Assessment of Impacts to Aquatic Habitat

As described above, USACE regulations require the use of a habitat-based methodology to describe and evaluate the impacts of alternative plans, as well as to identify the need for mitigation to offset unavoidable ecological impacts of the with-project conditions as measured against the future without-project condition. As the outputs of ecosystem restoration are not readily convertible to actual monetary units (as is required for traditional benefit-cost analyses), ecosystem outputs must be clearly identified and quantified in appropriate units, preferably ones that measure change in ecosystem value and productivity. Measurable changes in ecosystem values are typically described in terms of suitability indices or habitat units, with an ecosystem output model used to quantify the changes over a 50-year period of analysis. Following is a description of the ecosystem output model selected for use on the project, and a summary of the modeling results for the existing (without-project) condition and with implementation of the tentatively selected plan.

2.1 Description of Ecosystem Model

Analogous with Habitat Evaluation Procedure (HEP) method and Habitat Suitability Index models developed by natural resource biologists elsewhere, the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) is a habitat-based model that was developed as a tool to support management of Hawaii’s streams and associated habitat for freshwater flora and fauna. Specifically, the model is intended to provide managers with the ability to quantify changes in habitat for native Hawaiian stream animals in response to actions such as channel alterations, flow modifications, land use change and watershed development, or construction of in-channel structures. It captures the major aspects of native stream animal ecology, the typical geomorphology of Hawaiian streams, and common modifications to the environment.

The HSHEP model is an outgrowth of a history of collaboration among biologists at the State of Hawaii Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. The collaborative effort focused on understanding the different aspects of the ecology and management of amphidromous stream animals, which have a life history involving downstream and upstream migration (Fitzsimons and Nishimoto, 2007). In recent years, efforts have focused on combining the information gained from the wide range of studies into an integrated model of Hawaiian streams that include the life history characteristics of amphidromous animals, island hydrology and geomorphology, and critical management issues.

The HSHEP model follows the overall Habitat Evaluation Procedure (HEP) model concepts developed by the U.S. Fish and Wildlife Service (USFWS) to evaluate the quantity and quality of habitat available for a species of concern (USFWS, 1980a,b; USFWS, 1981). In general, a Habitat Evaluation Procedure (HEP) model uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. This process may be used to assess changes associated with different management scenarios for a specific area, or to allow comparison across multiple sites. The HSHEP merges this traditional HEP approach with multi-spatial modeling capabilities for Hawaiian streams (Parham, 2002; Kuamo'o et al., 2006; Parham, 2008). The multi-spatial component addresses issues of scale in understanding differences in habitat availability and species distribution.

A detailed description of the HSHEP model development and design is provided in Attachment 1. The USACE Ecosystem Center of Expertise (ECO-PCX) reviewed this information, and granted approval for its use on the Ala Wai Canal Project on May 19, 2015 (Attachment 2).

2.2 Methodology

Detailed stream and fish surveys to support the HSHEP modeling effort were conducted by aquatic biologists, Dr. James Parham (Bishop Museum) and Glenn Higashi (DAR). As part of this effort, the streams in the Ala Wai Watershed were surveyed, including approximately 8.7 kilometers of Manoa Stream, 1.6 kilometers of Makiki Stream, and 3.7 kilometers of Palolo Stream. The stream surveys were recorded using high-definition video, and the survey data were subsequently processed according to the variables in the HSHEP model. Using the HSHEP model, the habitat suitability was then determined for each of the native aquatic species along approximately each meter of stream; the average suitability was then calculated for defined stream segments. A combination of the habitat suitability and the area of each segment were then used to calculate HUs for each individual species, as well as for the combination of all native species within each segment.

Despite the robust dataset available for native species in Hawaii's streams, there is still some degree of inherent uncertainty in the underlying assumptions used to model habitat quality. In particular, the extent to which in-stream structures restrict upstream migration (e.g., in response to varying flow regimes over time) has not previously been quantified, but has an important bearing on the modeling of upstream habitat quality. As such, the resource agencies requested consideration of different assumptions of species passage, in order to better understand the possible range of resulting habitat quality values. In response to this request, both the "expected scenario" and a "worst-case scenario" were modeled, as described below.

- The "expected scenario" reflects the project team's best professional judgement; it assumes that existing in-stream structures with an overhanging lip create a passage barrier for native species 50% of the time, and channelized reaches reduce passage by 10% for every 100 meters. These assumptions were used as the basis for calculation of the baseline impact and evaluation of mitigation requirements.
- The "worst-case scenario" reflects a more conservative set of assumptions that overhanging structures only allow for passage of native species approximately 35% of the time, and

channelized reaches reduce passage by 15% for every 100 meters. This scenario is intended to bound the range of possible conditions, thus providing a basic sensitivity analysis of the model results. It was used as a means to validate the outcomes of the mitigation development process (that is, to confirm that the mitigation would still adequately compensate for the habitat impacts even with a more conservative set of assumptions).

The model results for the existing and future-without project condition, as well as the conditions based on implementation of the tentatively selected plan are presented below. Application of the model for the mitigation measures is discussed in Section 3.3. Additional detail regarding model application is provided in Attachment 3.

2.3 Model Results

2.3.1 Existing and Future Without-Project Condition

Based on the methodology described above, the HSHEP model was used to determine existing quality of the streams and associated aquatic habitat within the Ala Wai Watershed. The analysis also considered the future without-project condition (i.e., the most likely condition expected to exist in the future in the absence of the proposed project), as this defines the benchmark against which alternative plans are evaluated.

Future changes in watershed and stream conditions have the potential to influence the amount and/or quality of freshwater stream habitat. For example, future watershed improvements could positively influence stream health, thus increasing habitat quality over time. Conversely, continued degradation could reduce the amount and/or quality of stream habitat. Based on the extent of existing urbanization and development within the Ala Wai Watershed, and more specifically along the streams, it is expected that further development will be minimal. Some degree of redevelopment may occur in the neighborhoods throughout the watershed, however this is not expected to substantially affect the physical or biological characteristics of the streams. While there may be some slight changes in localized conditions, the overall species composition and habitat structure is not expected to change dramatically over the period of analysis. Therefore, for the purposes of this analysis, it is assumed that habitat conditions will remain relatively constant over time, such that the HUs associated with the existing and future without-project conditions will be commensurate.

The HUs associated with the existing and future without-project conditions are summarized in Table 1; a detailed discussion of the results is provided in Attachment 3.

TABLE 1
Habitat Units Associated with the Existing and Future Without-Project Condition

Location	Habitat Units (HUs)	
	Expected Scenario	**Worst-Case Scenario**
Manoa Stream	36,713	35,391
Palolo Stream	1,377	834
Makiki Stream	7,800	7,495
Hausten Ditch	8,681	8,681
Total	**54,572**	**52,401**

2.3.2 Tentatively Selected Plan

The tentatively selected plan for the Ala Wai Canal Project is comprised of a series of flood risk management measures, including debris and detention basins, debris catchment structures, flood walls, and improvements to the flood warning system. A description of each measure and the estimated area of impact is provided in Table 2. A detailed discussion of the tentatively selected plan (and the plan formulation process) is provided in the Draft Feasibility Report/EIS.

The characteristics of the proposed measures were used to define changes in habitat quality using the HSHEP model, as needed to calculate HUs based on implementation of the tentatively selected plan. Changes in habitat quality associated with implementation of the tentatively selected plan include potential loss of aquatic habitat (e.g., due to placement of structures within the stream) and decreased passage for native aquatic species. As described in Section 3.6 of the Draft Feasibility Report/EIS, design features have been incorporated to avoid and minimize these impacts to the extent practicable (e.g., use of natural bottom arch culverts to maintain species passage); however, some degree of impact is unavoidable. The anticipated changes in habitat conditions were based on professional judgment of the project team, including input from the resource agencies.

Key assumptions that were made as part of the HSHEP modeling of the with-project condition are listed below. The assumptions were discussed and agreed upon with the resource agencies (as part of a meeting with USFWS and DAR on January 23, 2015), and were subsequently refined as part of the model application process.

- The area to be impacted by each measure was defined as the length of stream within the permanent structure footprint plus the area needed for O&M (generally the entire length of stream within the construction limits).
    - The aquatic habitat to be impacted by the Kanewai Detention Basin and the Ala Wai Golf Course Detention Basin is limited to the streambank within the notched spillway footprint.
    - The Ala Wai Canal floodwalls will not result in any impacts to the aquatic environment.
    - Improvements to the flood warning system will involve negligible work in the streams; as such, it is assumed there would be no impact to the aquatic environment.
- To be conservative, it has been assumed that habitat for aquatic species would be entirely eliminated within the permanent footprint of the debris catchment and detention structures (and stand-alone debris catchment structures), but that species passage would be maintained via a natural bottom arch culvert.
    - Within the area to be excavated behind the Waiomao Debris and Detention Basin, a low-flow channel will be reformed and the existing substrate will be replaced following construction. Recognizing that there could be some degree of long-term habitat degradation associated with the excavation (and ongoing vegetation management), it is assumed that there would be an approximately 50% decrease in habitat quality within this area. The “worst-case scenario” assumes 100% loss of habitat within the area to be excavated.
    - An in-stream structure associated with an abandoned USGS gaging station is located within the area to be excavated for the Waiomao Debris and Detention Basin, and will be removed as part of project construction. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat (thereby offsetting some of the habitat losses). This benefit is reflected in the with-project condition.
    - It is assumed that there would be an approximately 20% loss of habitat quality within the reach directly affected by the notched spillways for the Kanewai and Ala Wai Golf Course detention basins. The “worst-case scenario” assumes 100% loss of habitat within these reaches.

TABLE 2
Flood Risk Management Measures Included in the Tentatively Selected Plan

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements	Length of Stream Within Construction Limits (linear feet)	Length of Stream Within Permanent Structure Footprint (linear feet)	Length of Stream Within O&M Area (linear feet)
Waihi Debris and Detention Basin	Earthen dam, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	160	130	40
Waiakeakua Debris and Detention Basin	Earthen dam, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	190	110	40
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area.	120	60	40
Manoa In-Stream Debris Catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	48	8	40
Kanewai Field Multi-purpose Detention Basin	Earthen berm, approximately 7' high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Manoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.	70	70	0
Waiomao Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip rap on upstream and downstream side debris catchment feature located on upstream end of culvert. Excavation of approx. 2,015 cubic yards to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam and excavation area) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	455	130	40
Pukele Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	170	130	40
Makiki Debris and Detention Basin	Earthen dam, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.	175	130	40
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 5 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area. Periodically inspect drainage pipes and gates, and remove any impediments to movement. Paint and/or grease metal parts, as needed.	0	0	0
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (4.3' high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm and floodwalls) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for recreational use during non-flood conditions. Periodically inspect slide gates and actuators and remove any impediments to movement. Paint and/or grease metal parts, as needed.	70	35	35
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, up to approximately 7' high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Manoa Palolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of levee) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a golf course (with no woody vegetation in sediment basin) for recreational use during non-flood conditions. Periodically inspect floodgate and remove any impediments to movement. Paint and/or grease metal parts, as needed. Inspect, test, and maintain pump system annually. Paint and/or grease metal parts, as needed.	70	70	0
Floodwarning system	Improvements to existing flood warning system in Ala Wai Watershed, including installation of 3 real-time rain gages (Manoa, Makiki and Palolo Streams) and 1 real-time streamflow or stage gage (Ala Wai Canal); exact locations to be determined	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection.	0	0	0

- The debris and detention structures are not designed to trap sediment (except for the sediment basin at the Ala Wai golf course). Therefore, it has been assumed that there would be no substantial changes in substrate/embeddedness in downstream habitat.
- The inundation area behind each detention structures is not included as part of the impact area. Inundation of these areas would be infrequent and short in duration; for example, inundation resulting from the 1% annual chance exceedance (ACE) flood would last less than 12 hours. As such, there are expected to be little to no potential effects to stream habitat and aquatic species.

The results of the HSHEP modeling for the with-project condition are summarized in Table 3; a detailed discussion of the results is provided in Attachment 3. Based on a comparison of these results to those for the future without-project condition, implementation of the project is expected to result in a loss of 192 HUs as shown in Table 3.

As it is expected that the impacts would be immediately realized following construction of the project features (i.e., there would not be a delay or "compounding" effect on habitat quality over time), it is therefore assumed that habitat conditions would remain constant over the life of the project.

TABLE 3
Loss of Habitat Units Associated with Implementation of the Tentatively Selected Plan (As Compared to the Future Without-Project Condition)

Location	**Habitat Units (HUs)**				
	Existing Conditions	**With-Project Conditions**			**Net Loss**
		Lost	**Gained[a]**	**Total**	
EXPECTED SCENARIO					
Manoa Stream	36,713	191	0	36,522	**191**
Palolo Stream	1,377	11	118	1,484	**-107**
Makiki Stream	7,800	24	0	7,777	**24**
Hausten Ditch	8,681	84	0	8,597	**84**
Total	**54,572**	**310**	**118**	**54,380**	**192**
WORST-CASE SCENARIO					
Manoa Stream	35,391	808	0	34,584	**808**
Palolo Stream	834	3	32	863	**-29**
Makiki Stream	7,495	11	0	7,484	**11**
Hausten Ditch	8,681	420	0	8,261	**420**
Total	**52,401**	**1,242**	**32**	**51,192**	**1,210**

Note:
[a] The "expected scenario" reflects the project team's best professional judgement, and serves as the basis for calculation of the baseline impact and evaluation of mitigation requirements. The "worst-case scenario" reflects a more conservative set of assumptions and is intended to provide a basic sensitivity analysis of the model results (to help validate the outcomes of the mitigation development process).
[b] The anticipated gain of HUs for the with-project condition is associated with removal of an abandoned USGS gaging station within the area to be excavated for the Waiomao Debris and Detention Basin. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat.

3.0 Description of Proposed Mitigation

3.1 Mitigation Objectives

Based on the type of habitat to be impacted, and within the context of the habitat requirements for native Hawaiian aquatic species (as defined in the HSHEP model), the following objectives were developed to guide the mitigation development effort:

- Restore and/or enhance physical conditions to improve in-stream habitat for native Hawaiian aquatic species
- Improve passage for native Hawaiian aquatic species to increase access to upstream areas of high-quality habitat

In consultation with the resource agencies, it was determined that application of these mitigation objectives should not be limited to the specific habitat parameters or areas impacted by the project, but rather should be considered within the context of the overall watershed. In other words, the mitigation development process should entail a watershed approach, wherein the conditions throughout the watershed are assessed to identify those habitat parameters and locations where mitigation might provide the greatest benefit for native aquatic species as a whole.

3.2 Mitigation Development Approach

To support the mitigation development effort, a framework was developed based on a series of iterative tasks informed by the stream surveys and HSHEP modeling results. Each task was conducted within the context of the SMART planning approach employed for the overall flood risk management project, as described in the Draft Feasibility Report/EIS. First, as shown in Figure 1, the key stressors and primary factors limiting habitat quality for native aquatic species in the Ala Wai Watershed were broadly defined based on best professional judgment and the results of the stream surveys. This information was used as the basis for identifying potential mitigation concepts, or actions that could be implemented to address the various stressors. Using the HSHEP model results for the existing conditions, these concepts were further refined and applied to site-specific locations. A site visit was conducted for each of the potential mitigation locations to validate and refine the mitigation concept. In addition, other relevant information was gathered, including land ownership and existing channel maintenance activities. This information was then considered as part of a detailed screening process, which involved a comprehensive set of criteria (based on those used for the overall flood risk management project, and tailored to the mitigation effort). Those measures carried forward from the screening process were then combined into various mitigation alternatives that could be implemented to compensate for the habitat impacts associated with the overall flood risk management project. Conceptual design drawings were prepared for the range of mitigation measures/alternatives (to an approximately 10 percent level of design), based upon which cost estimates were developed. In addition, the habitat benefits associated with each alternative were quantified using the HSHEP model. The costs and benefits were then used as inputs to a CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The resource agencies were consulted throughout this process, and their input was incorporated as appropriate. The results of this process are described in the subsequent sections.

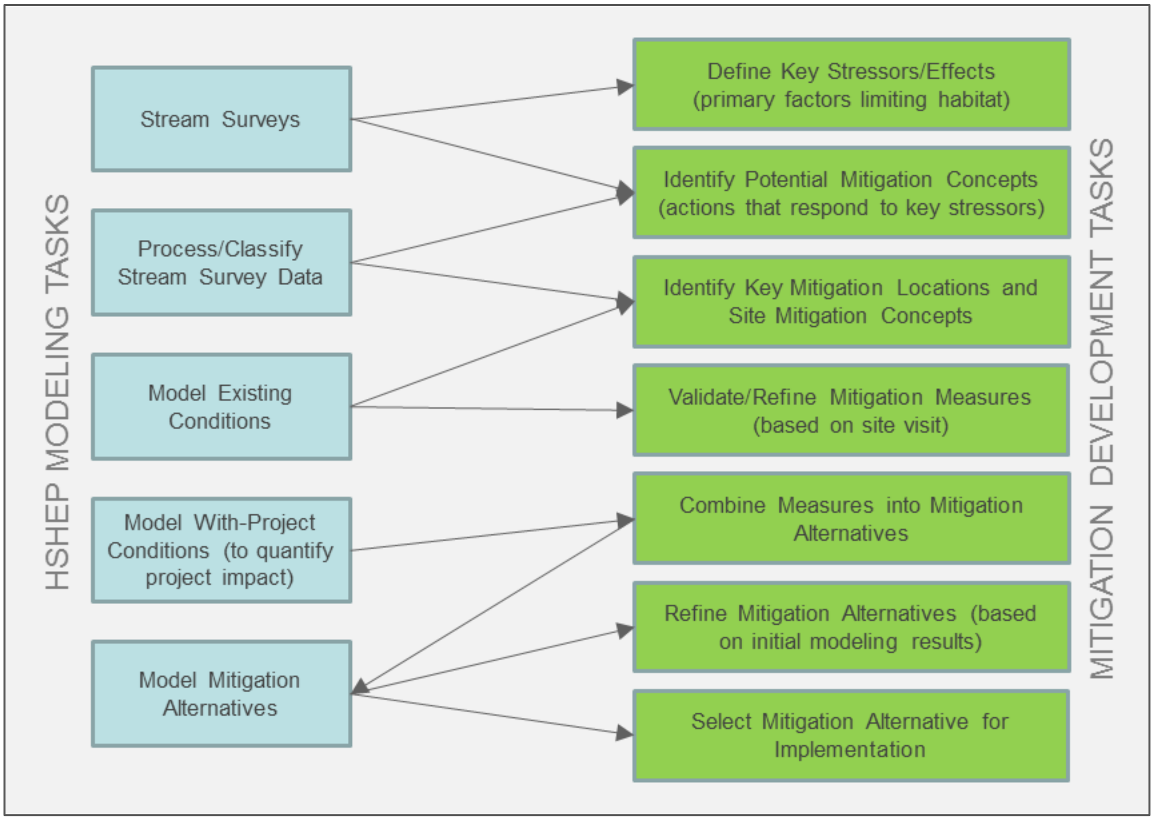


FIGURE 1
Overview of the HSHEP Modeling and Mitigation Development Process

3.3 Development of Mitigation Measures/Alternatives

3.3.1 Mitigation Concepts

As described above, the initial list of mitigation concepts was developed in response to the primary factors believed to be limiting habitat quality for native aquatic species in the Ala Wai Watershed; this effort was primarily based on best professional judgment and the results of the stream surveys. The list of initial mitigation concepts is provided in Table 4.

It is important to note that there are some stressors that are generally understood to be contributing to degradation of Hawaii’s stream habitat and faunal assemblage, but were determined to either be outside the scope of mitigation efforts for this project or are not considered key limiting factors in the Ala Wai Watershed (given other overriding conditions). These include prevalence of invasive aquatic species and inputs of stormwater runoff. Although both of these stressors are common throughout the Ala Wai Watershed, it was determined that the project could result in a limited response to these conditions, and as such, mitigation efforts should focus on key strssors related to physical habitat conditions.

TABLE 4
Initial Mitigation Concepts

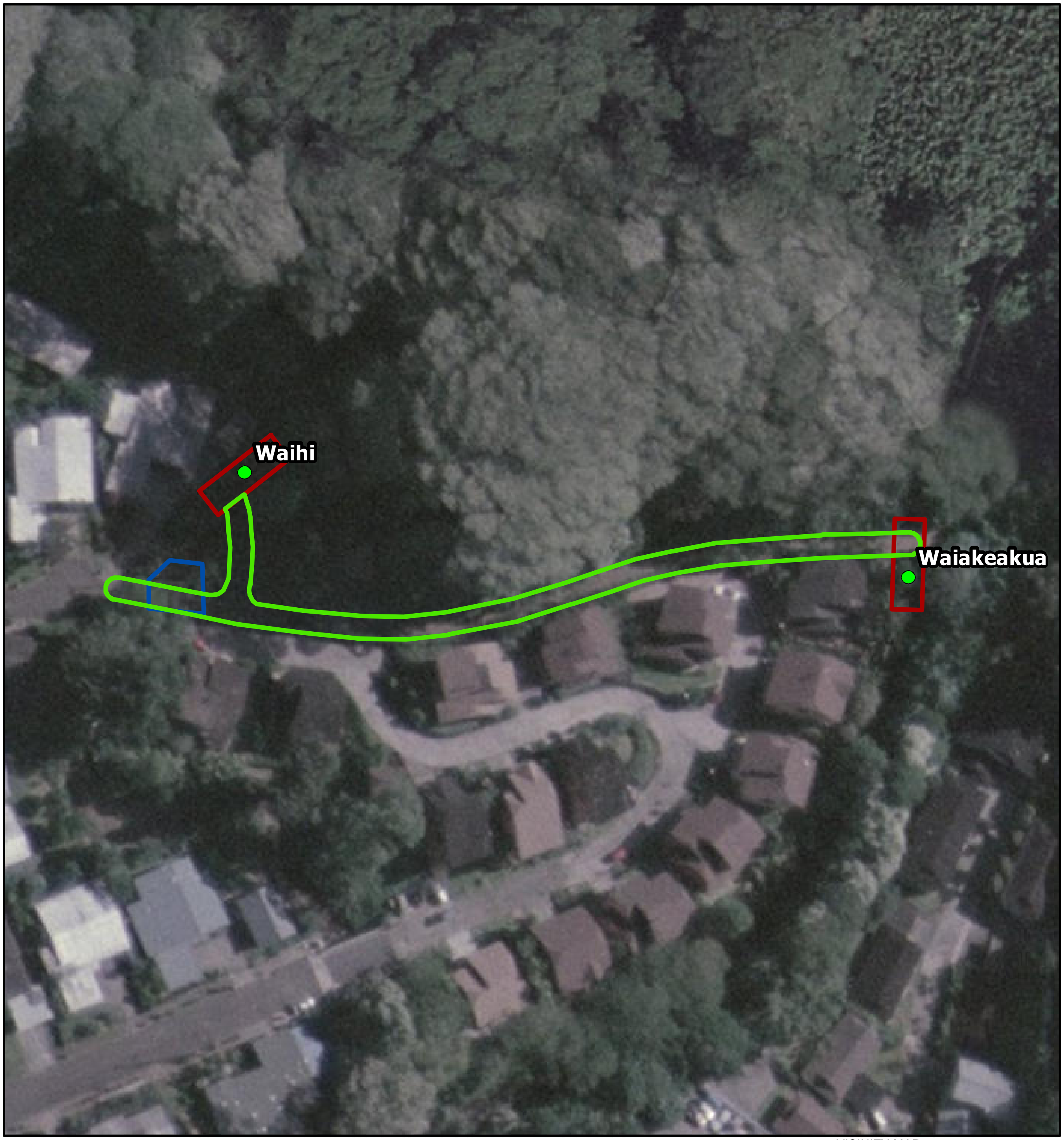
Response to Key Stressors	Mitigation Concept
Improve migratory pathway	Remove passage barrier (e.g., overhung structures)
	Install low-flow channel along channelized reach
	Install resting riffles along channelized reach
Improve in-stream habitat	Add new habitat pools in channelized reach
	Enhance existing in-stream habitat in unchannelized reach
Provide bank stabilization	Stabilize exposed/eroding banks
	Stabilize failing walls
Improve riparian habitat	Restore/enhance riparian habitat

The initial concepts were further reviewed and validated within the context of the HSHEP model source data and preliminary results for the existing habitat conditions. Through this effort, several of the concepts were eliminated from further consideration, as follows:

- **Enhance existing in-stream habitat in unchannelized reach:** Although there are reaches of unchannelized habitat with less than ideal conditions (e.g., degraded channel form, presence of trash, etc.), the results of the stream surveys indicate that these reaches still provide adequate habitat for native aquatic species, especially when compared to channelized reaches. As such, it was determined that enhancement of habitat in unchannelized reaches would not address a key stressor for native aquatic species in the Ala Wai Watershed.
- **Stabilize failing walls:** Although a wall failure could certainly affect in-stream habitat, should one occur, it was determined that stabilization of existing channel infrastructure is more of a channel maintenance issue than a habitat management issue. Therefore, this measure was eliminated from further consideration.
- **Restore/enhance riparian habitat:** Given the heavy urbanization and encroachment of development in the areas directly adjacent to the streams, there is very little opportunity for restoration of the riparian corridor in the Ala Wai Watershed without extensive land acquisition (which is beyond the scope of mitigation for this project). Although dominated by non-native species, the extant riparian habitat is not believed to be key limiting factor relative to in-stream habitat quality for native aquatic species (especially when considered in context with other factors, such as channelization). As such, this measure was also eliminated from further consideration.

3.3.2 Preliminary Mitigation Measures

The remaining mitigation concepts were carried forward for further consideration, and based on the review of the HSHEP model source data and preliminary results, key areas for habitat improvement were identified based on those concepts. This information was used as the basis for siting each of the mitigation concepts in locations where habitat benefits could be maximized. A site visit was conducted for each of the potential mitigation locations to validate and refine the various mitigation concepts. The resulting measures are summarized in Table 5, and the locations are shown in Figure 2.



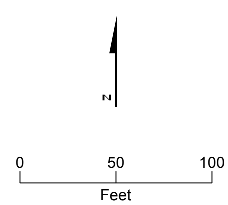
LEGEND

Impact Area Description

- **Construction Limits**
- **Access**
- **Staging**

Notes:

1. Area of interest subject to change.



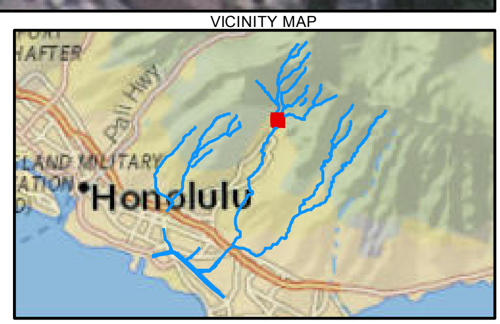
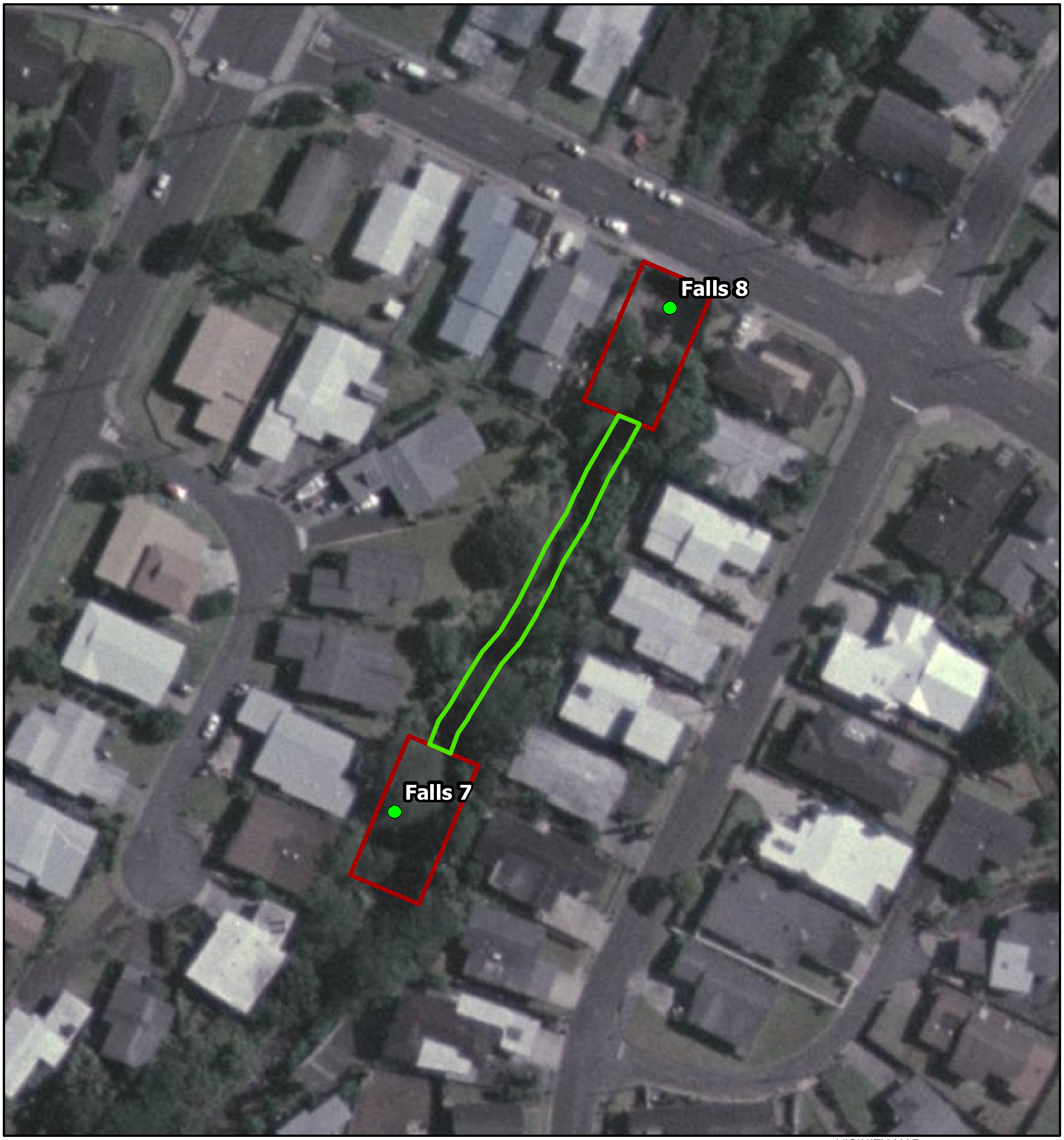


FIGURE 2a
Falls 11 and 12
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL.



LEGEND

Impact Area Description

- **Construction Limits**
- **Access**
- **Staging**

Notes:
1. Area of interest subject to change.

N

0 50 100
Feet

VICINITY MAP

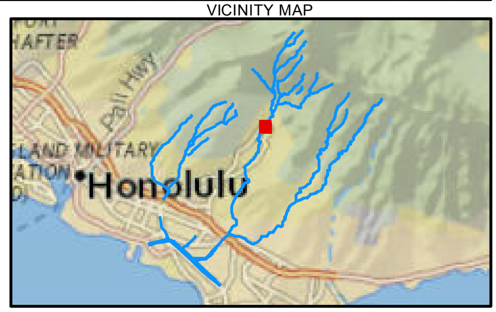


FIGURE 2b
Falls 7 and 8
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL

LEGEND

Impact Area Description

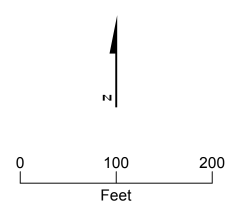
Construction Limits

Access

Staging

Notes:

1. Area of interest subject to change.



VICINITY MAP

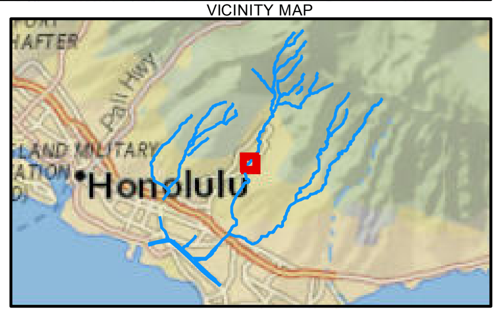


FIGURE 2c
Manoa Concrete Channel
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL

TABLE 5
Preliminary Mitigation Measures

Mitigation Measure	Location	Description
Remove Passage Barrier		
Falls 6	Manoa Stream, approximately 0.3 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing utility line crossing
Falls 7	Manoa Stream, approximately 0.6 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing in–stream structure
Falls 8	Manoa Stream, approximately 0.7 mile upstream of Manoa District Park	Remove overhanging lip associated with undercutting at existing in–stream structure
Falls 11	Waihi Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls 12	Waiakeakua Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls P5	Waiomao Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Install Low-flow Channel and/or Habitat Pools Along Channelized Reach[a]		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Palolo Stream	Approx. 1.5 miles of concrete channel through Palolo Valley	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Install Resting Riffles Along Channelized Reach[a]		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Palolo Stream	Approx. 1.5 miles of concrete channel through Palolo Valley	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Bank Stabillization		
Manoa Stream	Above Kahaloa Bridge near Manoa District Park	Reduce slope and install geotextile fabric and vegetation to stabilize ~300 feet of eroding bank

NOTE:
[a] Installation of a low-flow channel, habitat pools and/or resting riffles was initially considered for the channelized reach of Makiki Stream. However, it was determined that the extensive section of underground channel that is upstream of the channelized reach would severely limit the benefits gained by these measures. As such, these measures were eliminated from further consideration.

3.3.3 Screening and Refinement of Mitigation Measures

In order to ensure that the mitigation measures carried forward for further consideration meet a set of minimum standards, a detailed screening process was conducted. This process utilized a comprehensive set of criteria based on those used for the overall flood risk management project (which were defined within the context of the federal criteria specified in the Engineer Regulation [ER] 1105-2-100; "USACE Planning Guidance Notebook") and tailored to the mitigation effort. The screening criteria that were applied to the mitigation measures are summarized in Table 6.

TABLE 6
Criteria Used to Screen Mitigation Measures

Criteria	Description
Technical feasibility	Is it feasible/viable to construct measure?
Application in Hawaii	Has the measure been successfully applied in Hawaii?
Compatibility/Dependency	Is the measure dependent on another action to be functional?
Flood reduction	Does measure substantially increase potential for flooding?
Implementation cost[a]	What is the ROM cost to construct the measure?
Cost effectiveness[a]	Is the habitat gain worth the cost?
Land availability and ownership	Is there enough space to implement measure (including staging/access?)
	Is the land owned by State/C&C or a few private landowner?
	Can real estate rights be reasonably obtained?
O&M requirements	What is the estimated level of effort (need for new practice/equipment)?
	Would the measure conflict with existing O&M practices?
Acceptability	Will the measure displace people/activities? It is legally acceptable?
Biological resources	Would the measure adversely affect any known sensitive biological resources?
	Would the measure increase the potential for passage of non-native (invasive) species?
Historic/archaeological resources	Would the measure adversely affect any known historic/archaeological resources?
Sediment contamination	Would the measure be located in an area with known (or high potential for) sediment contamination?

NOTE:
[a] Recognizing that the purpose of the CE/ICA is to provide a quantifiable basis for evaluation of cost-effectiveness, the criteria related to implementation cost and cost-effectiveness were used to screen out measures that were considered to be excessively expensive or ineffective, so as to focus the mitigation development effort on reasonable and practicable mitigation solutions, consistent with the SMART planning approach.

The information required to complete the screening process was subsequently compiled, including consultation and coordination with State and County agencies, and other entities as needed. This effort resulted in the elimination of the measures listed below; the detailed screening results are contained in Attachment 4. In addition, based on additional information obtained through consultation, it was determined that two of the measures were no longer warranted, such that they were also eliminated from further consideration, as listed below.

- **Remove Passage Barrier at Falls 6:** Based on coordination with the City & County of Honolulu, it was determined that the Department of Facilities Maintenance (DFM) is in the process of resolving the erosion and undercutting associated with this structure. The design effort has been completed and the proposed design is expected to adequately address fish passage requirements; therefore, this measure was eliminated from further consideration (and instead is reflected in the future without-project conditions).
- **Remove Passage Barrier at Falls P5:** The specific location of this structure was verified based on the stream survey data, and was determined to be within the footprint of the excavation area for the Waiomao Debris and Detention Basin. It was confirmed that the

structure would be removed as part of construction of the debris and detention basin, such that the mitigation measure was eliminated from further consideration (and instead is reflected in the with-project condition).

- **Install Low-Flow Channel, Habitat Pools and/or Resting Riffles Along Channelized Portion of Palolo Stream:** Based on initial review of the real estate requirements, it was determined that this measure involved a multitude of property owners, and obtaining the real estate rights would require extensive coordination and would be cost-prohibitive. Therefore, these measures were eliminated from further consideration.

The remaining measures were carried forward for further consideration as part of the identification of mitigation alternatives.

3.3.4 Conceptual Design of Mitigation Measures

For the measures carried forward from the screening process, conceptual design drawings were developed to a 10-percent level of design. This effort incorporated the best available information and collective knowledge of the habitat requirements for native aquatic species; it also considered lessons learned from other past projects and input from the resource agencies. Key design considerations are discussed below.

The passage barrier removal design was based on previous passage barrier removal efforts completed by DAR (and others) on Waihe'e Stream (see Figure 3). Based on information gained from this successful effort, the measure would restore a near vertical surface to the face of the existing in-stream structure, which is expected to allow for native aquatic species passage, while deterring upstream passage of non-native species. It would be comprised of non-systematic placement of grouted stones that would mimic natural stream features and allow multiple pathways for water flow.

FIGURE 3
Previous Passage Barrier Removal Efforts on Waihe'e Stream (photos provided by Glenn Higashi [DAR])

The design for installation of in-stream habitat and passage within the channelized reach of Manoa Stream incorporates design features and dimensions based on best professional judgment regarding native species habitat requirements. Specifically, the conceptual designs assume that up to 6 inches of water is required to maintain passage (e.g., for the resting riffles), and at least 18 inches of water is needed to provide in-stream habitat (e.g., for the habitat pools and low-flow channel); the dimensions and spacing of these features reflects characteristics of natural stream habitat. Passage and/or habitat would be installed over the full 1,100 feet of the channelized reach in Manoa Stream; given the mitigation objectives, shorter increments were not considered.

The 10-percent design drawings for each of the mitigation measures carried forward from the screening process are contained in Attachment 5.

3.3.5 Identification of Mitigation Alternatives

Based upon the 10-percent design concepts, the mitigation measures were then combined into alternatives that could be implemented to adequately compensate for the habitat impacts associated with the overall flood risk management project. Specifically, this effort sought to identify alternatives comprised of measures that either alone or in combination would provide a gain of HUs equal to or greater than the loss of HUs anticipated from implementation of the tentatively selected plan, thus compensating for the loss of habitat quality associated with project implementation. Recognizing that there are many possible measure combinations, consistent with SMART planning principles, a focused number of alternatives were defined based on estimated habitat benefits and functionality, as discussed below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. As preliminary analyses indicated that the concrete channel improvements were not cost effective, they were not considered in combination with any other measures. Based on these concepts, the following alternatives were identified:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

Cost estimates were prepared for each alternative based on the conceptual design drawings. In addition, the habitat benefits were determined for each alternative, based on the HSHEP model outputs. The results of these efforts were then used to support the CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The results of this process are described in the subsequent sections.

3.4 Evaluation of Mitigation Alternatives

3.4.1 Habitat Benefits

Using the same methodology as described in Section 2, the HSHEP model was used to quantify the HUs associated with the various mitigation alternatives; the results are summarized in Table 7. As shown in Table 7, the mitigation alternatives involving removal of passage barriers provide a

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

significant increase in HUs relative to the concrete channel improvements. Despite the relatively small footprint of the barrier removal measures, the large gain of HUs reflects the overall extent of upstream habitat that would be made available to migrating native species. In contrast, the improvements along the channelized reach of Manoa Stream would only affect a relatively small, localized area.

However, in all cases, the mitigation alternatives would provide substantially more HUs than needed to offset the impacts of the flood risk management project. Because the flood risk management measures would only affect in-stream habitat within the footprint of the proposed flood risk management structures (with no anticipated impacts to species passage), a relatively small number of HUs are expected to be lost. Although the mitigation benefit would far exceed the impact of the proposed project, the mitigation alternatives reflect a reasonable range of options to improve instream habitat for native species, based on the best professional judgment of the project team. Despite the large number of HUs provided relative to the anticipated project impact, the estimated costs and level of effort of the mitigation alternatives is within the range that is appropriate for the scale and level of detail available for the proposed flood risk management project. Although different mitigation options or smaller-scale efforts that would result in fewer HUs (i.e. an increase in HUs more commensurate with the number of HUs lost) could certainly be identified, these would not address the key habitat needs identified for native aquatic species in the Ala Wai Watershed.

TABLE 7
Gain of Habitat Units Associated with Implementation of Mitigation Alternatives (As Compared to the With-Project Condition)

Location	With-Project (HUs Lost)	Mitigation Alternatives (HUs Gained)							
		Falls 7	Falls 7, 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11 and 12	Low-Flow Channel	Habitat Pools	Resting Riffles
EXPECTED SCENARIO									
Manoa Stream	191	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Palolo Stream	-107	0	0	0	0	0	0	0	0
Makiki Stream	24	0	0	0	0	0	0	0	0
Hausten Ditch	84	0	0	0	0	0	0	0	0
Total	**192**	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
WORST-CASE SCENARIO									
Manoa Stream	808	803	2,817	4,457	5,105	6,745	1,299	1,225	1,219
Palolo Stream	-29	0	0	0	0	0	0	0	0
Makiki Stream	11	0	0	0	0	0	0	0	0
Hausten Ditch	420	0	0	0	0	0	0	0	0
Total	**1,210**	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**

3.4.2 Cost Estimates

An estimate of the implementation costs was developed as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. In addition to the estimated costs, the CE/ICA also considers the O&M costs, as these are considered necessary to achieve the habitat benefits over the lifetime of the project. The estimated costs for each mitigation alternative is summarized in Table 8. Annualization of these costs, as needed to support the economic analysis is included in Attachment 6.

TABLE 8
Summary of Estimated Costs for Mitigation Alternatives (FY2014 Price Level)

Cost Component[1]	Falls 7	Falls 7 and 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11 and 12	Low-Flow Channel	Habitat Pools	Resting Riffles
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
Real Estate	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre-construction Monitoring	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250
Post-construction Monitoring	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250
O&M	$29,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction	$1,491	$2,918	$3,729	$3,746	$4,557	$17,526	$3,786	$3,916
Contingency[2]	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Total Estimated Cost	$240,526	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,264

NOTES:
[1] Based on FY2014 (October 2013) price levels) and 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS.
[2] Assumes contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, and OMRR&R costs

3.4.3 Cost Effectiveness and Incremental Cost Analysis (CE/ICA)

As specified in the USACE regulations, the outputs of ecosystem restoration are not monetized, as is required for traditional benefit-cost analyses. Rather, evaluation of alternative restoration plans considers the relationship of habitat benefits to project costs to identify the most cost-effective plans for various levels of restoration output and provide a basis for determining whether increasing levels of restoration output are worth the added cost.

The evaluation process includes two distinct analyses to identify cost-effective and incrementally justified plans. First, the cost effectiveness analysis is conducted to identify which alternative plans have output levels that cannot be produced more cost effectively by another plan. “Cost effective” means that, for a given level of output, no other plan costs less, and no other plan yields more output for less money. Subsequently, through the incremental cost analysis, the range of plans is evaluated to arrive at a “best” level of output. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of restoration benefits; these are referred to as “best buy plans.” They provide the greatest increase in output for the least increase in cost. That is, they have the lowest incremental cost per unit of output. The incremental analysis will not necessarily identify an optimal plan; rather, there may be a series of best buy plans. In this case, the results must be synthesized with other decision-making criteria (for example, acceptability, completeness, effectiveness, reasonableness of costs, risk and uncertainty) to provide the basis for selection of a particular plan.

The IWR Planning Suite software (IWR Plan, version 1.0.11.0) was used to conduct the CE/ICA for this project. Inputs to the CE/ICA included average annual habitat units (AAHUs) and estimated average annual cost (AAC), which are calculated based on the benefits and costs (as presented in

Tables 7 and 8, respectively) averaged over the 50-year period of analysis. As previously noted, the analysis was based on the "expected scenario."

As listed in Table 9, the results of the CE/ICA indicate that the following mitigation alternatives are cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8 and 12; and Falls 7, 8, 11 and 12. Only Falls 7, 8, 11 and 12 and the No Action Alternative are considered best buy plans. A detailed discussion of the CE/ICA and the results are provided in Attachment 6.

TABLE 9
CE/ICA Results

Alternative	Estimated Cost for CE/ICA[1,2]	AAC	AAHUs	Cost-Effective	AAC/ AAHU	Best Buy?	Incremental Cost of BB Plan over Last BB Plan	Incremental Output of BB Plan over Last BB Plan	Incremental Cost/Output of Best Buy Plan
No Action	$0	$0	0	Yes	-	Yes	-	-	-
Resting Riffles	$403,264	$15,105	1,195	No	$12.64	No	N/A	N/A	N/A
Habitat Pools	$393,958	$14,753	1,202	No	$12.27	No	N/A	N/A	N/A
Low-Flow Channel	$1,236,900	$49,564	1,279	No	$38.75	No	N/A	N/A	N/A
Falls 7	$240,526	$9,014	1,340	Yes	$6.73	No	N/A	N/A	N/A
Falls 7 and 8	$354,197	$13,362	3,831	Yes	$3.49	No	N/A	N/A	N/A
Falls 7, 8 and 11	$433,070	$16,101	5,401	No	$2.98	No	N/A	N/A	N/A
Falls 7, 8 and 12	$430,841	$16,000	6,021	Yes	$2.66	No	N/A	N/A	N/A
Falls 7, 8, 11 and 12	$494,715	$18,440	7,591	Yes	$2.43	Yes	$19,102	7,783	$2.45

NOTES:

[1] The estimated costs utilized for CE/ICA are equal to the investment costs plus future costs, in present value terms. For each alternative, the investment costs include construction, real estate, PED, and construction management; future costs include post-construction monitoring, and O&M.

[2] The costs for the mitigation alternatives all fall within the estimated cost that is currently assumed for the tentatively selected plan, as described in the Cost Engineering Appendix.

3.5 Selection of Mitigation Plan

While the selected alternative need not be a best buy plan for the purposes of mitigation, it must be cost-effective; other decision-making criteria may include acceptability, completeness, effectiveness, reasonableness of costs, and risk and uncertainty. As summarized in Table 9, four of the passage barrier removal alternatives are cost-effective; only Falls 7, 8, 11 and 12 is a best buy plan (along with the No Action alternative).

Although Falls 7 alone is cost-effective, there is some degree of risk and uncertainty that this alternative would not adequately meet the required mitigation burden. Although there is assumed to be some degree of existing passage through Falls 8 (such that the habitat model indicates an adequate gain of HUs for removal of Falls 7 under the "expected scenario"), there is inherent risk in this assumption, such that it is possible that there is little to no existing passage through Falls 8. Based on this assumption, removal of Falls 7 alone would only measurably increase access to the approximately 100 meters of in-stream habitat between Falls 7 and Falls 8, and would not adequately meet the mitigation burden (as indicated by the "worst-case scenario").

Furthermore, the incremental cost per habitat unit (AAC/AAHU) drops significantly with the addition of Falls 8, such that substantially more benefits would be realized for a relatively small increase in cost. As shown in Table 9, the incremental cost of implementing Falls 7 is $6.73 per unit output, but is only $3.49 for Falls 7 and 8. Given the proximity of these features and the nature of the required work, the added cost of addressing Falls 8 is minimal, but the added benefit would be substantial (as a much greater extent of upstream habitat would be made available). Although the incremental cost of adding Falls 12 and/or Falls 11 and 12 is even lower ($2.66 and $2.43, respectively), these alternatives provide an excessive amount of habitat benefit relative to the project impacts, that the project team determined these were not worth the added cost.

These considerations, which are consistent with the USACE's Environmental Operating Principles[3] (USACE, 2012), were used the project team as the basis for selection of Falls 7 and 8 as the selected mitigation alternative for the project.

4.0 Monitoring and Adaptive Management

As specified in the guidance, monitoring includes the systematic collection and analysis of data that provides information needed to assess project performance, determine whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits. The monitoring plan should include a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring (recognizing that monitoring should continue until such time as the Secretary determines that the success criteria have been met).

A preliminary description of these items is provided below. It is expected that this information would continue to be refined as the detailed designs are further refined, and the monitoring plan would be finalized during the next phase of the project.

4.1 Monitoring Approach and Activities

In order to capitalize on the detailed baseline data and comprehensive approach to quantifying aquatic habitat quality, monitoring of the mitigation efforts would involve repeated stream and fish surveys, with analysis as part of the HSHEP model. The information gathered as part of these efforts directly relate to the mitigation objectives, which focus on the physical in-stream habitat conditions and passage for native species. Specifically, the stream surveys would record the physical in-stream conditions, with the HSHEP model outputs translating those conditions into habitat quality for native aquatic species. The fish surveys would directly measure the presence and abundance of native species along the stream gradient, particularly in reaches where passage has been restored. Consideration of these data relative to the HSHEP model results would help to correlate species presence/abundance with habitat quality and passage. Direct comparison with the baseline conditions data (and each subsequent year of monitoring data) would also allow for a clear understanding of the change in conditions over time.

4.2 Performance Criteria

Performance criteria represent the desired conditions to be achieved by the end of the performance monitoring period, as needed to determine project success. To the extent possible, performance criteria should be SMART (specific, measurable, achievable, relevant, and time-bound), and include target values and ranges, as appropriate, accounting for natural variability and management actions.

[3] In particular, the USACE's Environmental Operating Principles direct the USACE to "create mutually supporting economic and environmentally sustainable solutions," as well as to "consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs."

The proposed criteria are summarized in Table 10; specific quantities for these criteria would be developed as part of the final design phase.

TABLE 10
Performance Standards and Monitoring Requirements

Mitigation Objective	Performance Criteria	Monitoring Approach
Restore and/or enhance physical in-stream conditions to improve habitat for native Hawaiian aquatic species	Increased habitat units (HSHEP); specific quantification to be determined in final design phase	Stream surveys with HSHEP model
Improve passage for native Hawaiian aquatic species to upstream areas of high-quality habitat	Increased presence (either in total, or as a percentage) of native species in upper reaches; specific quantification to be determined in final design phase; specific species include o'opu nakea, o'opu alamo'o, o'opu nopili, o'opu naniha, and o'opu akupa	Fish surveys with species counts

4.3 Analysis and Reporting

To provide the basis for evaluating project performance, the data collected as part of the above-described monitoring efforts would be compiled and analyzed. The analysis would use the performance criteria to evaluate whether the mitigation measures are achieving restoration success. The results of the analysis would be presented in a report; a report would be produced annually for each year that monitoring is conducted (see Section 4.5 for a discussion of the monitoring schedule). After the final year of monitoring, assuming the performance criteria have been met, the project sponsors would be responsible for preparing a close-out report.

In the event that the evaluation indicates that the project has not met the performance criteria, the project sponsors would consider implementation of adaptive management actions as needed to attain the ecosystem objectives for the project. Considerations for the adaptive management approach are discussed below.

4.4 Adaptive Management

Adaptive management is a structured process of learning and using newly-acquired knowledge to adjust and improve project implementation. The adaptive management process promotes flexible decision-making as outcomes from management actions are better understood. This approach helps to reduce the risk of not achieving ecosystem restoration goals. Implementation guidance for WRDA 2007 specifies that an adaptive management plan should be developed for all ecosystem restoration projects. Specifically, the information generated by the performance monitoring, as described above should be used by the project sponsors to guide decisions relative to operational or structural changes that may be needed to ensure that the ecosystem restoration project meets the success criteria. This decision-making process may depend on a number of variables, including the timing and/or spatial scale of the performance issue, the urgency with which the issue must be addressed, and/or the type of adjustment that is needed to respond to the issue. The guidance specifies that if an adjustment is anticipated due to high uncertainty in achieving the desired outputs/results, the nature and cost of such actions should be explicitly described as part of the decision document and expressed in each of the monitoring reports as they are performed.

To evaluate the adaptive management measures that may be required for the proposed project, the potential risk and uncertainty relative to achieving the performance standards was assessed and potential adaptive management measures were identified. Specific measures that were considered included changes to project-related conditions, as well as external factors. As part of the assessment, the extent to which these adaptive management measures could address the potential deficiencies was considered.

In general, this assessment concluded that there is little risk that the structural components of the mitigation actions would require modification, such that the adaptive management does not need to account for physical changes to the in-stream structures. Similar efforts to eliminate passage barriers have been conducted on Oahu with high levels of success, and the proposed mitigation design would build upon these efforts. Structural repairs to address erosion and/or settlement that might occur over time would be covered as part of standard O&M. In terms of achieving the performance standards, the primary risk that was identified is associated with increased abundance and predation by non-native aquatic species. As previously described, prevalence of non-native species is not currently believed to be a key limiting factor for native aquatic species in the Ala Wai Watershed (given the overall habitat conditions); however, to the extent that the monitoring results indicate that this may be the case in the future, the adaptive management approach for the project incorporates non-native species removal. It is assumed that this effort would be similar to those previously conducted by the State of Hawaii DAR staff (assumed to cost approximately $30,000); any adaptive management costs incurred during the monitoring period would be cost-shared with the non-federal sponsor.

4.5 Monitoring Schedule

The implementation guidance for Section 2039 of WRDA 2007 specifies that monitoring would be initiated upon completion of construction, and should continue until ecological success has been documented; the law allows for but does not require a 10-year cost-shared monitoring plan. If monitoring is required beyond the 10-year period, it would be the responsibility of the non-federal sponsor. Based on the nature of the proposed mitigation measures, it is assumed that monitoring would be conducted annually over a 5-year period, which would start upon completion of construction.[4] The exact timing of monitoring would be determined in the final design phase.

4.6 Responsibilities and Cost

Consistent with the requirements of WRDA 2007, the cost of monitoring would be included as part of the total project costs and be cost-shared, with 65 percent of the costs paid by USACE and the other 35 percent paid by the State of Hawaii, as the non-federal sponsor. The estimated cost for the proposed monitoring activities is summarized in Table 11. Any additional post-construction monitoring past the designated monitoring period would be entirely the responsibility of the non-federal sponsor. As the non-federal sponsor, the State of Hawaii would also be responsible for O&M activities for the mitigation measures implemented as part of the tentatively selected plan.

TABLE 11
Estimated Monitoring Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Stream and fish surveys	Assumes a total of 20 person-days per monitoring event	$5,000

4 In many cases, pre-project monitoring is conducted, as needed to establish the basis for measuring restoration success. It is assumed that a single pre-monitoring event would be conducted prior to construction.

TABLE 11
Estimated Monitoring Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Data processing	Assumes a total of 5 person-days per monitoring event	$1,250
Analysis and reporting	Assumes a total of 10 person-days per monitoring event; assumes $500 in expenses per monitoring event	$3,000
Total (per monitoring event)		**$9,250**
Project Total (assuming 5 monitoring events)		**$46,250**

NOTE: Assumes $250 in labor charges per person-day.

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Attachment 1. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) Model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat

The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat

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Introduction:

In Hawaii, The Department of Land and Natural Resources (DLNR) is the lead agency in the state tasked with managing natural resources and the plants and animals that depend on them. In the case of Hawaiian streams, the waters that accumulate from rainfall on headwater slopes and flow downstream to the ocean provide essential habitat for Hawaii's unique freshwater flora and fauna. While the stream habitats are critical to native fish and macro-invertebrates, an open and direct link to the sea also is vital to their existence. Understanding and managing for the continuation of healthy instream habitats and suitable migratory pathways for native amphidromous stream animals is the responsibility of the Hawaii Division of Aquatic Resources (DAR), a division within the broader DLNR. Also within DLNR is the Commission on Water Resource Management (CWRM) which has the responsibility of balancing the benefits of current and future uses of water when rendering its decisions on specific water allocations. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model was created as a tool to support these management responsibilities. This model helps assess the impact of the stream diversions and other stream channel modifications on native stream animal habitat.

The presence of suitable habitat is considered fundamental to the sustained occurrence of an animal species. Changes to the naturally occurring habitat brought about by man's modification of the environment may have a positive or negative affect on the quantity or distribution of a species' suitable habitat. The HSHEP model is an attempt to quantify how various man-made changes affect native Hawaiian stream animals. While suitable habitat is fundamental for a species persistence and is the focus of the HSHEP model, it is not the only thing that may affect species populations. We fully realize that other factors, such as pollution, disease, or competition with introduced species may also greatly influence the observed distribution and densities of native animals, yet understanding the natural distribution of animals without the presence of these additional factors is still important. Providing managers the ability to assess change to native species habitat with respect to flow modifications, watershed development, or in channel structures is important in understanding the positive or negative implications of various actions. The HSHEP model is intended to capture the major aspects of native stream animal ecology, the typical geomorphology of Hawaiian streams, and common modifications to the environment within a single model. Additional factors outside of habitat can be modeled with the HSHEP approach, but need additional modeling steps that are best addressed on a case-by-case basis at this point.

The HSHEP model is an outgrowth of a history of collaboration among biologists at Hawaii Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. The collaborative effort focused on understanding the different aspects of the ecology and management of amphidromous stream animals (Fitzsimons and Nishimoto 2007). In recent years, efforts have focused on combining the information gained from the wide range of studies into an integrated model of Hawaiian streams that include the life history characteristics of amphidromous animals, island hydrology and geomorphology, and critical management issues. This report documents results of these efforts and describes the current version of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model.

The HSHEP model follows the overall Habitat Evaluation Procedure (HEP) model concepts developed by the U.S. Fish and Wildlife Service (USFWS) to evaluate the quantity and quality of habitat available for a species of concern (USFWS 1980 a,b, USFWS 1981). In general, a Habitat Evaluation Procedure (HEP) model has several characteristics:

1. It is a habitat-based assessment method.
2. It assumes that habitat quality and quantity are related to the number of animals using a habitat over the long term.
3. It uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density.
4. It converts suitability relationships into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions.
5. The HSI values range from 0 (unsuitable habitat) to 1 (most suitable habitat).
6. It multiplies the habitat quality (value from the HSI) with the habitat quantity (area) to determine overall Habitat Units (HU) within the area of concern.

As a result of the model design, HEP impact analyses are intended to allow the user to:

1. provide defined suitability-based estimates of HU within a study area,

2. provide impact assessments of the changes of HU within the study area under different management scenarios,
3. provide objective comparable unit measures for multi-site comparisons,
4. quantify changes in HU to be annualized and comparable with other cost/benefit analyses,
5. create plots of the distribution of HU in map-based formats (GIS analyses) to address issues of habitat fragmentation or connectivity.

The HEP user manual describes a HEP model like this, "HEP is a convenient means of documenting and displaying, in standard units, the predicted effects of proposed actions." USFWS designed HEP to be a legally defensible, standardized format for impact assessment in natural resource settings (USFWS 1980 a). While HEP models have been developed and used for impact assessment nationally for hundreds of species of birds, mammals, and fish, this was the first HEP model to assess changes in stream animal habitat in Hawaii.

Traditional HEP procedures have been joined with multi-spatial modeling efforts for Hawaiian streams (Parham 2002, Kuamo'o et al. 2006, Parham 2008). The multi-spatial models address issues of scale in understanding differences in habitat availability and species distributions. For example, the presence or density of amphidromous animals is influenced by the location of the sample site within a stream. Similar habitats found near the ocean may have different species assemblages than habitats found further inland. Additionally, characteristics of different watersheds and their streams influence the observed species assemblages. For example, streams with terminal waterfalls have different species assemblages than streams without terminal waterfalls. By assessing suitability at multiple spatial scales, different aspects of amphidromous animal ecology can be more appropriately modeled (Figure 1). As a result of the combination of the HEP method with multi-scale analysis, management issues can be addressed on a site, stream segment, whole stream, or region level. The HSHEP model is intended to be useful to assess the impacts of stream channel modification, flow alteration, land use change, climate change, stream restoration, and barrier modifications.

The general purpose of this report is three fold:

1. to explain the influence of stream modifications on the distribution and habitat availability of native stream animals;
2. to describe the HSHEP model's intent, design, and application, and
3. to document the source and use of data on habitat and fish occurrence.

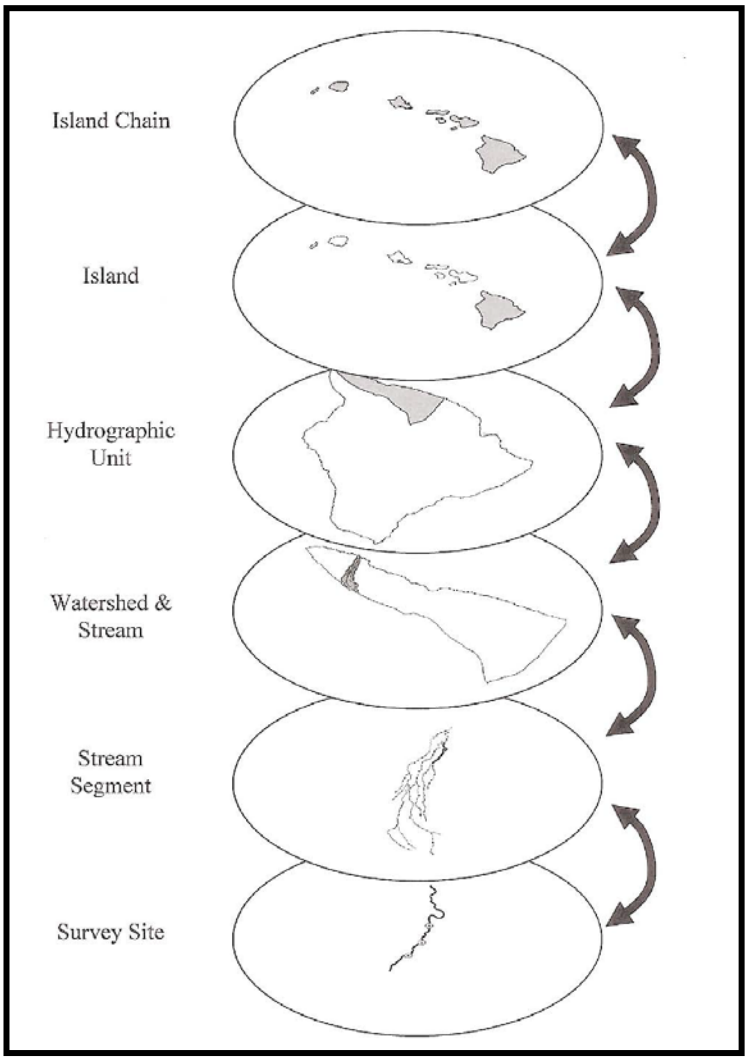

Figure 1: Spatially-nested hierarchy of the DAR Aquatic Surveys Database and predictive levels within the HSHEP model.

The Effect of Flow Diversion and Stream Channel Modifications on Native Amphidromous Stream Animals

From a management perspective, flow diversion and physical channel modifications have differing effects on the life history traits of native stream animals. While the HSHEP model attempts to capture many of the potential effects, not all can be adequately modeled at this time. Even though some of the potential issues caused by flow diversion and physical modifications are not addressed in the HSHEP model at this time, the design of the HSHEP model will allow for the inclusion of information on these issues as data become available. The following is a discussion of the potential affects that flow diversion and physical modifications may have on the different aspects of amphidromous animals' life history. The specifics regarding how the HSHEP addresses these issues are provided in the methods section.

Native amphidromous animals in Hawaiian streams share similar life history traits (McDowall 2007). In general, the animals have an oceanic larval phase during which they develop in the open ocean for up to six months. This is followed by recruitment to stream as the larvae metamorphose to postlarvae. The postlarve then migrate upstream to suitable habitat and complete their development into juvenile animals. Within the suitable stream habitat, the juveniles grow to adults and then reproduce. The newly hatched larvae drift downstream back to the ocean to undergo their oceanic larval phase. As a general model, the important phases can be separated into (1) oceanic larval phase, (2) recruitment, (3) upstream migration, (4) residence in local habitat, and (5) downstream migration and drift.

Oceanic Larval phase:

Amphidromous animal larvae living in the ocean as zooplankton during their oceanic larval phase are situated in full strength sea water (Radke et al. 1988). Whether the larvae drift widely offshore or stay near the islands in nearshore currents is unknown (Hobson et al. 2007, Murphy and Cowan 2007), but in either case there would be little or no influence of stream flow or stream habitat on this phase, and therefore no management actions related to instream structures would influence the species' oceanic larval phase.

While no direct management actions regarding flow diversion or stream channel modifications would influence the success of the oceanic larval phase, the oceanic larval phase has a role in the overall management philosophy of amphidromous animals. Murphy and Cowan (2007) discussed the possible patterns and implications of the oceanic larval phase. Although it is unknown at this time if the larvae drift passively on the ocean currents or show directed movement to stay near the islands, the larvae face many obstacles to complete their oceanic larval phase and successfully recruit to a stream. Larvae may be eaten, starve, or drift off into the open ocean. The chance for all necessary conditions lining up correctly for larvae to successfully complete this phase and recruit to suitable habitat has been likened to a winning a lottery (Sale 1978). As a result, a direct linear relationship between larvae spawned in a stream and larvae returning to a stream is highly unlikely. Given the unknowns and uncertainties associated with the oceanic larval phase, management strategies that maximize the production of larvae to the oceanic plankton pool and maximize the distribution of suitable habitat where larvae may recruit will improve the "odds of winning the recruitment lottery." While predicting the specific species, number, or time of recruitment to a specific stream may prove difficult, management actions that improve instream habitat and ultimately reproductive output are likely to result in more successful recruitment events and thus promote more stable populations among a group of streams.

In summary-

- Management actions that improve reproductive output will likely increase chances that some animals survive the oceanic larval phase.
- Management actions that improve instream habitat across a group of streams will increase the chance that suitable habitat will be encountered as the larvae end their oceanic phase and begin recruitment.

<u>Recruitment:</u>

There is some evidence that the freshwater plume created by stream discharge into the ocean draws recruiting animals to a stream (Nishimoto and Kuamoʻo 1997). It is theorized that larger freshwater plumes attract more recruiting animals. Amphidromous animals tend to recruit *en masse* (Nishimoto and Kuamoʻo 1997). As a result, the number of recruiting animals during a single recruitment event may not be tightly linked to the size of the freshwater plume, but the chance of the recruitment event occurring should be related to the ability of the animals to detect the stream (Figure 2 and Figure 3). In other words, if the mass of recruits is viewed as a single group or unit, the number of recruitment units that detect a stream's freshwater plume will be greater for a stream with a larger plume that occurs for a larger percentage of the time.

Figure 2: Two images of the mouth of Pi'ina'au Stream, Maui. The left image shows the amount of freshwater discharged into the ocean at low flows and the right image shows the amount of water discharged at high flows. Notice the color change in the ocean in the right image, where increased discharge (and increased sediment load) has a much larger area of influence in the ocean.

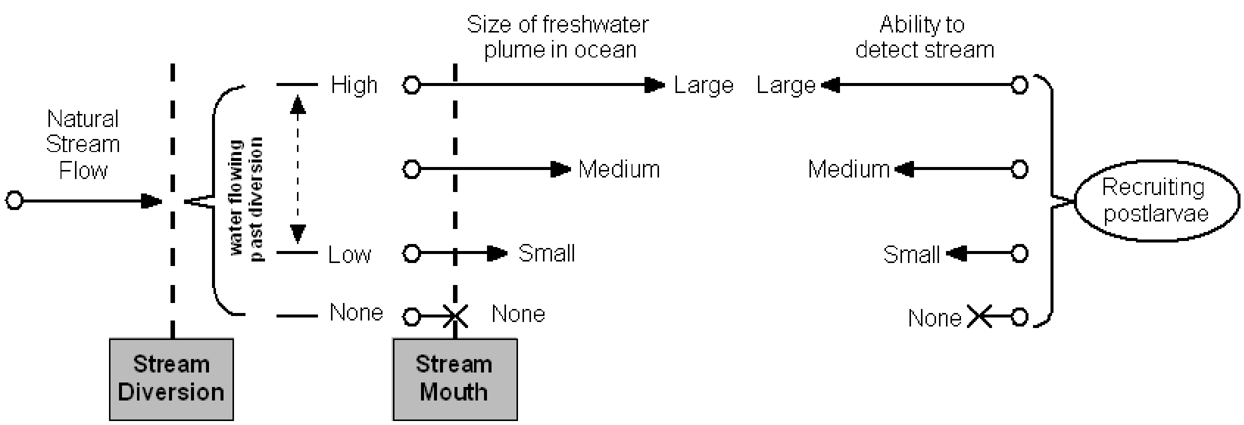

Figure 3: A conceptual model describing the role of streamflow into the ocean in attracting recruiting postlarval animals to the stream. Stream diversions decrease the size of the freshwater plume and therefore make it harder for recruiting animals to detect the freshwater from their offshore larval development areas.

In addition to the size of the freshwater plume, in many streams a stream mouth berm is created when deposition from wave action is greater than erosion by stream flow (Figure 4). The stream mouth berm acts as a barrier to recruitment. While the creation and destruction of a stream mouth berm is a natural phenomenon for many streams, decreases in stream flow as a result of stream diversion will decrease the erosive power of the stream water and increase the period of time that a berm may exist (Figure 5). Conversely, increased stream flow will decrease the amount of time that a stream remains closed by a berm and therefore blocked to recruitment. Changes in sediment quantity in the stream can also influence berm formation. Actions within the stream's watershed that increase the amount of sediment moving from the land into the stream channel likely will increase sediment deposition in stream mouths. Actions that restrict sediment input or downstream movement would likely decrease the size and thus period of time that a berm may exist.

Figure 4: Two photographs of the mouth of Kopiliÿula Stream, Maui. The image on the left shows a closed stream mouth berm and the image on the right show the berm open. Notice the

lower stream discharge on the left (i.e., more exposed rocks in stream and no white water in the upper riffle) as compared to the higher discharge on the right.

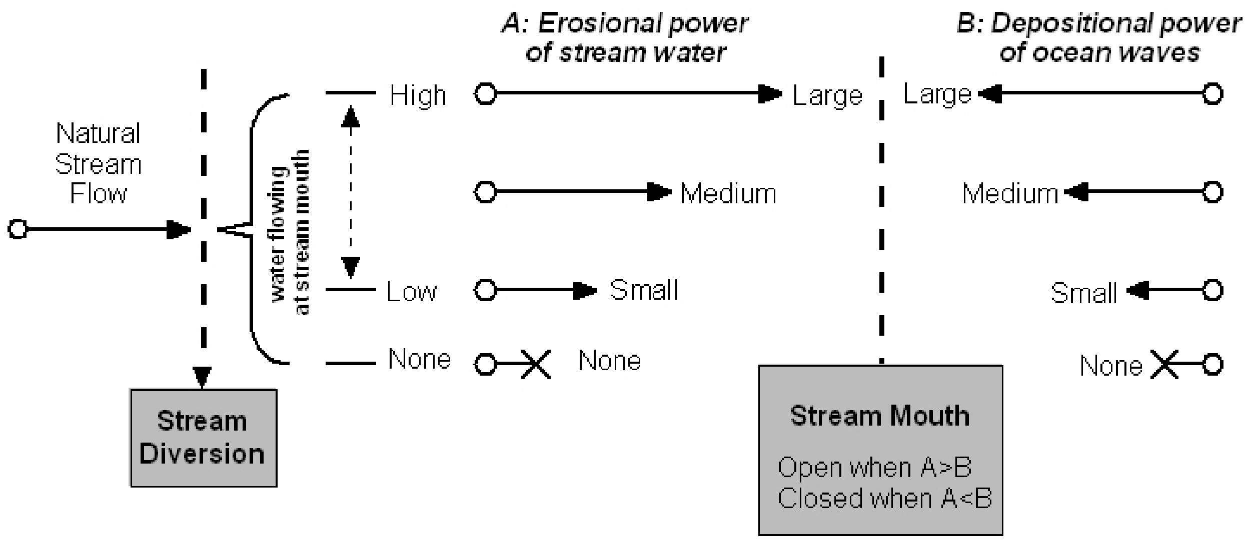

Figure 5: Conceptual model of the balance between stream power and ocean power in controlling the presence or absence of a berm at the stream mouth. When the stream mouth is open, recruiting stream animals can easily move upstream, while when a stream is closed by a berm, recruitment into the stream is highly restricted.

Management actions that increase freshwater discharge into the ocean are likely to improve recruitment by attracting more groups of recruiting animals and expanding the window of opportunity for recruits to enter an open stream mouth. Additionally, there is evidence that the presence of adult animals within a stream may draw recruiting individuals of the same species (Hobson et al. 2007). Therefore, management actions that improve adult populations in a stream may improve overall recruitment to the stream.

In summary-

- Management actions that increase the size of the freshwater plume will likely result in more recruitment events.
- Management actions that increase the time that the stream mouth is open will provide a longer window for recruitment events to occur.
- Management actions that increase instream adult population may attract more recruits.

Upstream migration:

Different species display different upstream migration capabilities (Schoenfuss and Blob 2007). Instream obstacles that prevent upstream movement for one species may be easily surmounted by different species (Figure 6). In general, differences in stream gradient or waterfalls height are measurable natural barriers to upstream migration for specific species.

Figure 6: Examples of potential natural barriers to upstream migration. Waterfalls are barriers to some species, while other species with the ability to climb may surmount the waterfall and continue moving upstream. The images show two different waterfalls in Maui streams. The left image (Honomanū Stream) shows a tall waterfall where the water is in contact with the face of the waterfall. Some species will be able to pass this type of waterfall. The right image (Honopou Stream) shows an undercut waterfall. An undercut waterfall will be a barrier to upstream migration for amphidromous species unless a wetted pathway exists for the animals to bypass the undercut.

Just as natural barriers exist in streams, some instream structures can act as barriers to upstream migration. A structure can be a physical barrier, while a stream diversion can create dry sections that prohibit movement by aquatic species, or entrain animals as they attempt to pass over the diversion structure. While the dry section is a direct result of water withdrawals, the other two factors (physical barrier or entrainment) are related to the design of the structure. As with natural barriers, species-specific differences in migratory ability influence whether or not an instream diversion structure is an actual barrier to a species.

Physical barriers that prevent the upstream migration of amphidromous animals are perhaps the most obvious barrier effect of stream diversions. Physical barriers can result from many different designs, but the major issues are height of the dam wall, inappropriate hydraulic conditions, or the creation of an overhanging drop-off in the stream channel (Figure 7 and Figure 9). Given the climbing ability of most amphidromous animals found in the middle reach to the headwaters of Hawaiian streams, as long as the height of structure is not substantially greater than natural waterfalls occurring downstream of the diversion location, then the vertical wall should have minimal impact on upstream migration. In cases where a structure is located in a relatively low gradient stream, blockage of upstream migration may be a problem.

Physical structures may also form hydraulic or behavioral barriers. If the structure creates a flow that is too fast or turbulent for animals to pass through then it can stop upstream migration. Additionally, some animals may have behavioral responses to the physical structure that prevent them from passing through the structure. For example, an animal may avoid passing through a pipe due to its darkness or its smooth sides. Currently, no studies address the hydraulic or behavioral aspects of barriers in Hawaiian streams, although preliminary studies suggest the larvae move mostly during the day and may avoid black plastic pipes (Burky et al. 1999).

In contrast to the height of the diversion, the creation of an overhanging drop-off is a problem for migrating animals wherever it is encountered in the stream. Amphidromous animals require a continuous wetted surface in order to climb an obstacle. If the water falls freely from the lip of the drop-off to the pool below then the animals cannot pass the structure (Figure 8). This situation typically occurs where a structure has been undercut by erosion on the downstream side or where a pipe is used to convey water downstream and the downstream pipe outlet is higher than the surface of the water below and extends out beyond the surface that supports it. Both of these situations can completely eliminate upstream migration, but are relatively easy to remedy by re-engineering the structure to remove the overhang.

Figure 7: Vertical drop as a barrier on ‘Īao Stream, Maui (left) and a pipe providing for water flow downstream over a diversion on Hanehoi Stream, Maui. While not actual stream diversions, the images show potential obstacles that animals migrating upstream may encounter. Notice the extent of the drop in comparison to the normal channel gradient in left image. In the right set of images, it is unknown if hydraulic conditions (too swift or turbulent flow) or the unsuitable substrate (smooth pipe may prevent animals from holding on to pipe sides) would prevent upstream migration. Additional behavioral issues may also be a factor in the extent of fish passage through the pipe (fish may avoid dark areas).

Figure 8: Over hanging diversions on Honopou Stream, Maui (left) and on the middle reach of Waihe‘e Stream, Maui (right). Notice how the water free falls and leaves no pathway for upstream migration.

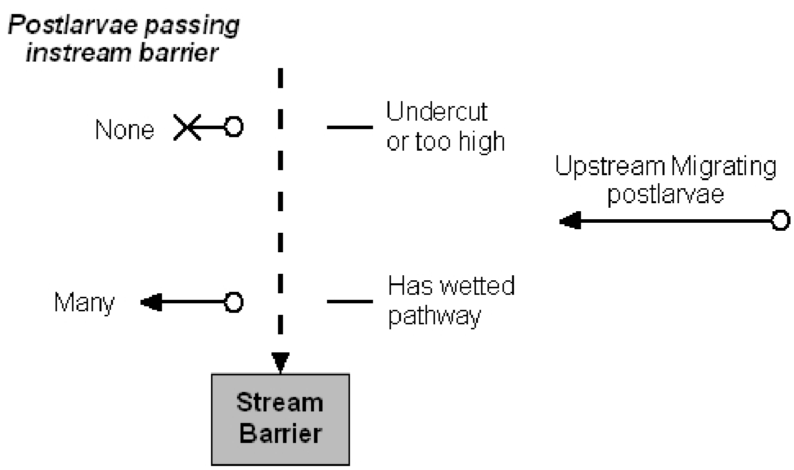

Figure 9: Conceptual model of the physical blockage of upstream migration instream structures.

Stream diversions may also result in the dewatering of a section of stream. This disruption of the physical connection between the upstream and downstream sections prevents the passage of migrating postlarvae to suitable adult habitats (Figure 11). In most native amphidromous fishes, the majority of upstream movement is accomplished prior to adulthood (Schoenfuss and Blob 2007). As the fish grow they become less capable climbers, therefore, the extent of time that a stream section is dewatered is critical to upstream migration of native stream animals. The issue of the time available for upstream movement is also important for the freshwater snail, *Neritina granosa*, as it moves slowly during migration and is susceptible to being stranded in dry sections (Hau 2007). A dewatered stream section can be viewed as a gate with respect to upstream migration (Figure 11). When water is present and flowing through the section, the section is open to upstream migration and when the stream section is dry, the section is closed to upstream migration. The following pictures show a stream bed closed and open to upstream migration as a result of stream diversion and rainfall (Figure 10). A different form of barrier may exist in channelized segments of streams. In these situations long stretches of shallow flow across open cement bottom channels can create a situation where no resting areas exist for migrating animals. Changes in flow can rapidly leave animals stranded. During sunny afternoons, water temperature can rise to very warm conditions resulting in stressful or lethal conditions for stream animals.

Figure 10: Two photographs of Kopiliʻula Stream, Maui.Both images are from stream sections downstream of the stream diversion. Notice how during periods of low stream discharge (left image) the stream pools are disconnected with dry streambed between the pools, while during periods of higher stream discharge (right image) the stream is fully connected and provides a migratory pathway for animals moving upstream.

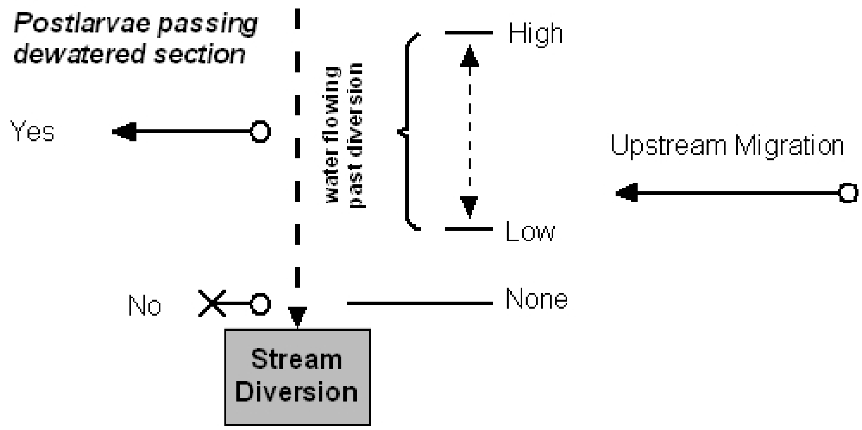

Figure 11: Conceptual model showing the probability of upstream passage by postlarvae of native amphidromous stream animals. Upstream movement would be possible when water is flowing past the diversion and provides a continuous pathway through previously dewatered stream section.

The final impact stream diversions may have on upstream migration is entrainment of individual postlarvae as they pass over the diversion structure. Depending on the design of the diversion structure, migrating animals may be entrained in the diversion and removed from the stream population (Figure 12 and Figure 13). Many diversion structures on Hawaiian streams divert water through a grate into a diversion ditch. Entrainment into the ditch would not only be possible, but likely with the typical diversion design.

Figure 12: Two images of Honopou Stream, Maui at low (left) and high (right) flows. At low flow the barrier is a complete blockage to upstream migration and at high flow most of the water flows through the diversion structure. As postlarvae move upstream through the structure, many would be entrained in the diverted waters and removed from the stream.

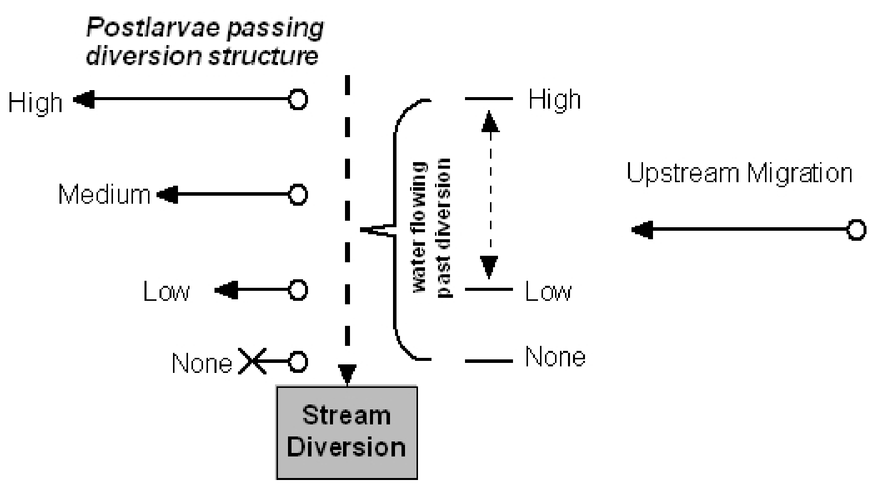

Figure 13: Conceptual model of the extent of upstream passage by postlarvae of native amphidromous stream animals. Entrainment of postlarvae would be a function of the proportion of amount of water passing the diversion and the amount flowing into the diversion.

From a management perspective, the maintenance of connectivity between the stream mouth and upstream habitats is critical for amphidromous animals. Given the vagaries of the timing of recruitment and the short developmental window for upstream movement, minimizing the time that barriers to upstream movement exist will increase the chance that suitable upstream habitat will be colonized by newly recruiting animals. The entrainment by diversion structures of migrating animals results in a direct loss of animals. After an animal has successfully survived the oceanic larval phase, found a suitable stream to recruit to, undergone substantial development changes, and moved upstream, the loss of an individual at this stage is costly to the adult population. Allowing for passage through stream diversion structures to suitable upstream habitat will likely result in greater upstream population densities of amphidromous animals.

In summary-

- Management actions that minimize barriers to upstream migration will increase settlement of juveniles in suitable upstream habitats.

- Management actions that increase the window of time that a pathway from the stream mouth upstream to suitable habitats is available will increase the chances that when a recruitment event occurs the postlarve will be able to move upstream to suitable habitats.

- Management actions that decrease entrainment of upstream migrating animals will increase the number of juveniles that settle in suitable upstream habitats.

Instream habitats:

Native Hawaiian stream animals move upstream to select suitable instream habitats for growth and reproduction. These habitats are typically described in terms of their physical characteristics (i.e. depth, velocities, substrates, water quality) or descriptive characteristics (i.e. riffle, run, pool). The instream habitats are influenced by the surrounding land cover and upstream conditions. From a hydraulic perspective, stream habitats observed at low discharge are created and maintained at high discharge. For example, while a stream pool is a slow, deep habitat at low discharge, at high discharge the pool is an erosional zone with swift scouring flow. A riffle is a depositional zone at high discharge and swift, shallow water at low discharge. Runs typically transport sediment over a range of discharge rates. It is important to remember that observed instream habitats are result of both high and low discharge events.

Stream diversions and other instream structures influence instream habitat in several ways. First, there is the physical structure that replaces the local instream habitat. In the case of stream diversions, this is generally a minor change to the overall stream habitat as most diversions act as a pool/riffle or pool/waterfall combination. In numerous places, native stream animals have been observed in the pool created by the diversion and in terms of total area of habitat, the stream diversion itself modifies a relatively small area. In contrast, channelized stream segments may result in the loss of habitat over the entire area they occupy. In some locations these channelized stream segments may be more than a kilometer in length. Thus the physical disruption of instream habitat by the instream structure is dependent on the size and construction of the particular structure.

In addition to the physical changes in stream habitat, stream diversions also decrease habitat area as a result of the removal of water from the downstream channel (Figure 14 and Figure 15). In the most extreme cases, the diverting of 100% of the water can result in the elimination of all habitats downstream of the diversion by dewatering the downstream sections. At lower percentages of diversion there is a decrease in wetted area, depths, and velocities (Kinzie et al. 1986). The exact relationship between the change in habitat area and discharge is controlled by the geomorphology of the site in question. Habitat models suggest that changes in wetted area are closely related to available habitat for native Hawaiian stream animals (Gingerich and Wolff 2005).

In addition to the loss of habitat area, water removal may result in a decrease of the suitability of the remaining habitat. While the amount of habitat available at low discharge levels is important, the timing and duration of these low discharge events are also important. Instream habitat is a balance between sediment transport dynamics at high and low discharge and holding a stream permanently at low discharge levels will result in a gradual change in the observed instream habitats. Lack of scouring flow generally leads to the infilling of deeper habitats and embedding of larger substrates with smaller sediment and these are not suitable characteristics of native animal habitat (Kido 2002). Lower discharge rates can also result in warmer water temperatures with the sun heating the slower, shallower water more quickly than the deeper and swifter waters. Warmer water holds less oxygen than cooler water and increases bioenergetic demands on the ecothermic stream animals.

Figure 14: Changes in instream habitat after stream diversion on Hononmanū Stream, Maui. The diversion, downstream of the surveyors, was diverting 100% of stream flow (left picture). Downstream of diversion (right picture) there is no water flow and no habitat for aquatic animals.

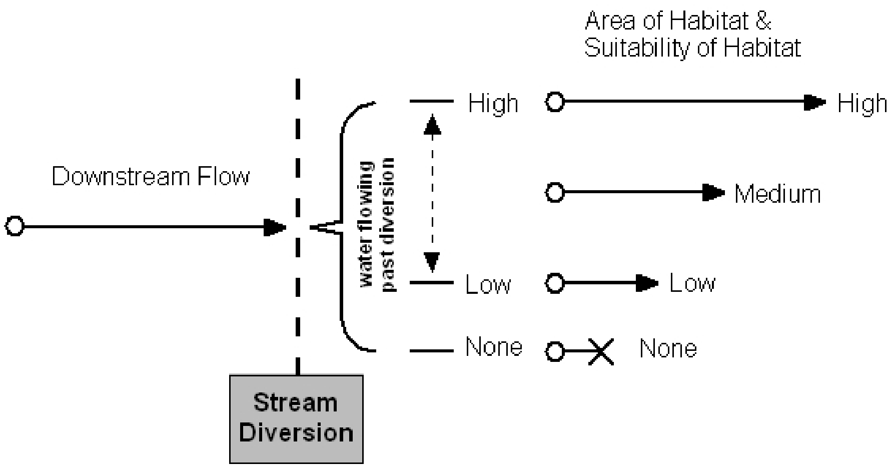

Figure 15: Conceptual model of the influence of stream diversion on instream habitat.

From a management perspective, instream habitat needs to provide adequate conditions for the animals to survive during drought conditions, provide cover to avoid predation and high flow events, supply enough food resources to grow, and provide suitable reproductive habitats. The presence of an animal in a site is not the only criteria needed to determine if the site has all characteristics necessary for the animal to complete its life cycle.

In summary-

- Management actions that provide stream discharge patterns in diverted streams that mimic natural discharge patterns with both high and low flows are likely to sustain suitable instream habitats and amphidromous animal populations.
- Management actions that avoid dewatering a streambed will provide substrate for algae (especially diatoms) and habitat for aquatic invertebrates which provide food sources for amphidromous animals
- Management actions that maintain water flow throughout the stream will minimize water quality problems, improve instream habitats, and allow movement of amphidromous animals among habitats.
- Instream structures that maintain suitable water depth in pools and runs, especially at low flows, will improve instream habitat conditions.
- Instream structures that maintain suitable water depth and appropriate substrates, especially at low flows, will provide for nest locations and assure the nests and eggs of amphidromous animals do not dry up.

Downstream movement (migration and drift):

Downstream movement in amphidromous animals may involve both adult and larval phases. In some species, adults may migrate from upstream locations to downstream locations to spawn (Kido and Heacock 1992, Fitzsimons et al. 2007). In all native amphidromous animals, downstream larval movement is accomplished by drifting with the stream current. The timing of the larval metamorphosis from a freshwater to saltwater larvae is measured in days and the larvae must reach saltwater to complete this transformation (Lindstrom 1998, Iguchi and Mizuno 1999, Iguchi 2007, McRae 2007). Therefore, travel time from hatching site to the ocean is critical to downstream migration of native stream animals (McRae 2007).

Similar to upstream migration issues, stream diversions and instream structures result in two separate mechanisms to prevent or reduce downstream migration and drift. Stream diversion may result in the dewatering of a section of stream. The dewatered stream section is a disruption of the physical connection of upstream sections with downstream sections preventing the passage of adults moving downstream or newly hatched larvae drifting to the ocean. Even if a stream diversion does not create a dewatered stream section, the diversion may decrease downstream water velocities as a result of the overall decrease in stream discharge. Average water velocity is a function of stream discharge and gradient. A decrease in the amount of water will result in slow stream flow velocities. As stream velocities decrease, fewer larvae can reach the ocean within an appropriate time to allow for metamorphosis into their larval phase (Figure 16) (Bell 2007). A diverted stream section can be viewed as a dial with respect to downstream drift (Figure 17). As one turns the dial upward, stream flow increases and a larger number of drifting larvae will successfully reach the ocean from their hatching sites upstream.

Figure 16: Three images of Hakalau Stream, Hawaii captured at different stream discharge rates. Notice the increased amount of swift water (i.e. white water) as stream discharge increases. The time for a drifting embryo to transit the distance of the image would decrease with increased stream discharge.

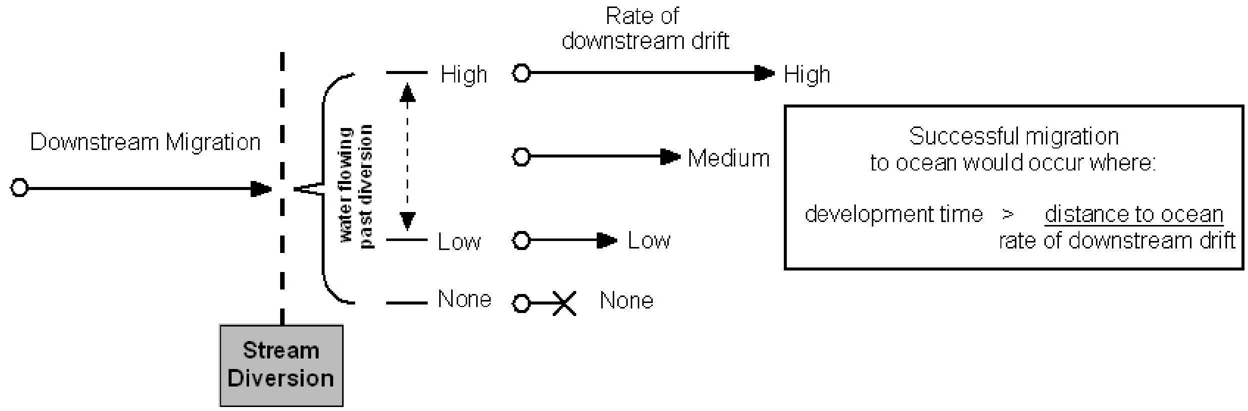

Figure 17: . Conceptual model of the influence of stream diversion on travel time and success of downstream drifting embryos reaching the ocean within a suitable development period. Successful downstream migration would be a function of rate of downstream drift and the distance to the ocean.

Stream diversions have a second effect on downstream movement. Depending on the design of the diversion structure, both adult and larval animals may be entrained in the diversion and removed from the stream population (Figure 18). Many diversion structures on Hawaiian streams divert water through a grate into a diversion ditch. Entrainment into the ditch would be possible and likely with the typical diversion design. Typical stream diversion structures divert 100% of the water at low to moderate flows. Under these conditions, 100% of downstream moving individuals would be entrained by the diversion. As stream flows overtop the diversion, a portion of the animals would likely pass the diversion and continue downstream (Figure 19).

Figure 18: Stream diversion intakes on Waiheʻe Stream (left) and Honopou Stream, Maui (right). Notice how 100% of the water flows into the diversion at the observed discharge. An animal moving downstream would be transported with the water and entrained in the diversion structure resulting in 100% mortality.

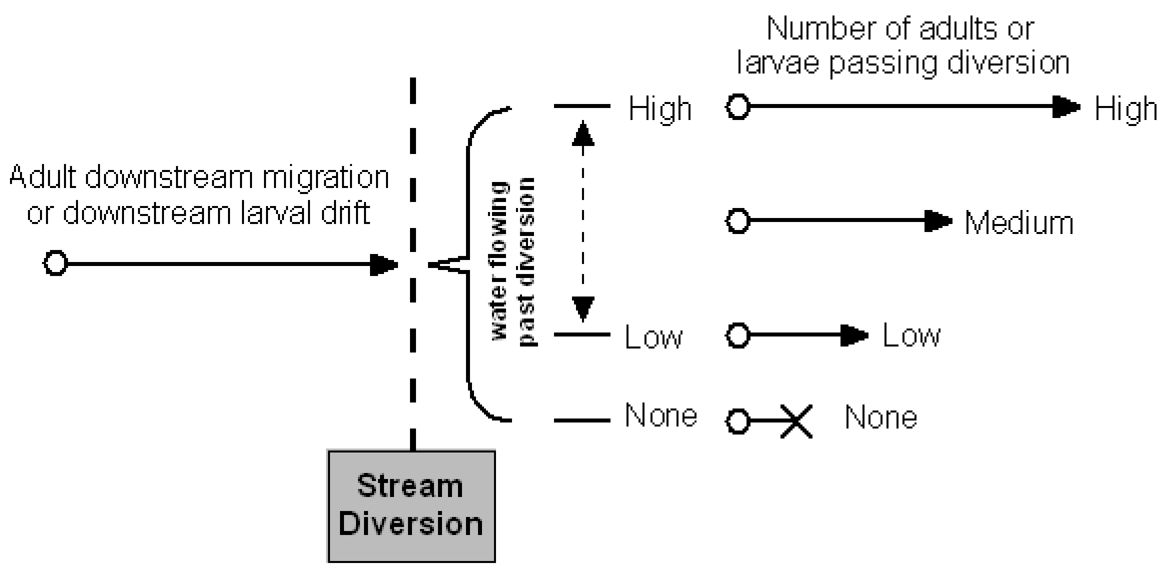

Figure 19: Conceptual model of the extent of diversion passage by downstream drifting larvae of native amphidromous stream animals. Entrainment of larvae would be related to the percent of water passing over the diversion compared to percent of water diverted.

From a management perspective, providing for adequate passage and timely transport of newly-hatched larvae to the ocean are important factors in successful downstream migration. In this respect, suitable stream habitat is more valuable if it is located near the ocean than if it is far inland or above a stream diversion site (McRae 2007). Assuring that newly hatched larval animals reach the ocean from the upstream nesting sites, coupled with successful completion of the other phases of the amphidromous animal's life history, results in ecological connectivity between ocean and stream habitats.

In summary-

- Management actions that decrease travel time from the nest site to the ocean for newly hatched larvae will increase the number of larvae that survive and successfully reach the ocean.

- Management actions that decrease entrainment of migrating adults and downstream drifting larvae will increase the number of adults that survive downstream migration to spawning sites and increase larvae that survive and successfully reach the ocean.

General Conceptual Summary

Overall, stream diversions and other instream structures interact with the native amphidromous animals found in Hawaiian stream in multiple ways. Fundamentally, aquatic animals live in the water. Diversions remove that water from the stream and instream structures remove habitat from the stream. Therefore, it is not a question of whether stream diversions and other instream structures have an impact on stream animals and their habitats, but rather of how can we minimize the impacts on native stream animals while still meeting other societal needs (such as drinking water or the minimization of flood impacts (Devick 2007)).

The following sections of this document outline the development and application of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP). The HSHEP model is a standardized way to assess flow or channel modification's impact on stream animal habitat and also help prioritizes restoration opportunities that would result in the most positive benefits to stream animal populations.

Hawaiian Stream Habitat Evaluation Procedure Model:

To quantify the current conditions of the stream and to estimate the effects of the stream diversions or other stream channel modifications in the Hawaiian streams on native stream animal habitat, a specific application of the HSHEP model follows a general modeling process. This modeling process was first used for the East Maui streams (Parham et al. 2009), and further refined on Wailoa River, Kauai (Parham 2014), the Nā Wai ʻEhā Streams, Maui (Parham 2013), and Waiheʻe Stream, Oahu (Parham and Higsahi 2012 an internal DAR working project). To document the modeling process, the following sections are covered:

- general modeling process,
- selection of evaluation species,
- description of model steps,
- scenarios modeled.

<u>General Modeling Process:</u>

To characterize habitat availability, the HSHEP model applies a nested spatial hierarchy (Figure 1). Depending on the scenario being modeled, various levels of the hierarchy may be applied. For completed models, the site, stream segment, and stream and its watershed scales have been used in assessing project impacts. The spatial levels of island chain, island, and region have not yet been used and although the modeling design supports these spatial levels if needed, they will not be discussed further in this document.

Using the previously reported HSHEP model (Parham et al. 2009), variables at the watershed level were stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. The ratings for these variables were presented in the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e) and the variables for all 430 streams included in the atlas were used to develop the model at this level. Inclusion of the watershed scale in the HSHEP model allows for comparisons of the results among streams in different watersheds.

To describe variation of instream habitat and animal distributions, variables included at the stream segment included elevation, distance inland from the ocean, and the presence of instream barriers. Native amphidromous animals are diadromous, requiring a connection between the freshwater streams and the ocean to complete their life cycle (McDowall 2007). Thus the ability of the animal to move upstream from the ocean will influence its observed distribution.

At the site level, more specific habitat characteristics are important. For the HSHEP analysis generalized suitability indices (depth, velocity, and substrate for flow studies) or (habitat type, depth, substrate, and temperature for habitat studies) are dependent on the data availability. In most cases, data is retrieved from the DAR point quadrat survey data within the DAR Aquatic Surveys Database as these surveys consistently used the same methodology to collect these habitat variables.

To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution. Categorical suitability criteria (e.g., habitat types or substrate types) were not smoothed. See Appendix 3 for the site scale data.

By combining HSHEP model results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable to all other streams in the Hawaiian Islands. The presence of suitable characteristics at a site is not the only important variable when determining site occupancy. A site can only be occupied by a species if that species can reach the habitat. For example, a deep stream pool with a mixture of cobble and boulder habitat may be highly suitable for a number of native species, yet if that pool is found far inland and above a high waterfall, only a few species would be expected to inhabit the pool. The HSHEP model's use of multiple spatial scales, accounts for local, network (up and downstream conditions), and watershed differences among sites.

Selection of Evaluation Species:

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Hawaiian Streams (Table 1). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 1: Species habitat evaluated within the Hawaiian Streams using the HSHEP model. *Identified as "Species of Greatest Conservation Need" in the Hawaii Statewide Aquatic Wildlife Conservation Strategy (Meadows et al. 2005).

Organism Type and Family	**Scientific name**	**Hawaiian name**
Freshwater fish (family Gobiidae)	*Awaous guamensis**	‘O‘opu nākea
	*Lentipes concolor**	‘O‘opu alamo‘o
	*Stenogobius hawaiiensis**	‘O‘opu naniha
	*Sicyopterus stimpsoni**	‘O‘opu nōpili
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	‘O‘opu akupa
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	‘Ōpae kala‘'ole
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	‘Ōpae ‘oeha‘a
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai

The selection of the complete set of amphidromous stream animals is appropriate in this case for several reasons.

- The DAR Aquatic Surveys Database has distribution and habitat use information for each of these species.
- All of these species have a diadromous life history, meaning that they migrate from the freshwater stream to the ocean and back again (McDowall 2007). This potentially exposes the migrating animals to barriers in the stream pathway, entrainment into water diversion systems, and elimination of suitable habitat resulting from water diversions or channel modifications.
- These species are characteristic of all reaches found in Hawaiian streams. Some are found in the lower reaches, a number in the middle reaches, and some even make it to the extreme upper ends of Hawaiian streams. This allows the HSHEP model to be applied to the appropriate species within any stream segment.
- The HSHEP model has habitat suitability indices developed for each of these species.

Description of HSHEP model steps:

To create the HSHEP models that compare the expected current distribution and habitat suitability in Hawaiian Streams for each species independently, a series of steps is followed. It is important to understand that the HSHEP model was designed to work closely with the DAR Aquatic Surveys Database and available geospatial data. As more data are collected and stored in the DAR Aquatic Surveys Database, the underlying relationships can be updated to reflect the new information. This is also true of available geospatial data. As higher resolution digital elevation models or improved flow models become available, the data could be recalculated using this improved data set. This document describes the current version of the data used for the HSHEP model.

Changes to the model are fully appropriate when developing a model to represent a specific location and address a specific management concern. These changes to the model generally occur for two separate reasons. First, the necessary spatial levels required for an individual model varies. For example, if one compares multiple watersheds then the watershed suitability scale is required, but when the management actions are fully contained within one watershed then the application of the watershed suitability scale is unnecessary. The watershed suitability values do not change within a watershed, therefore these values will not have a variable impact within watershed results. The second type of change likely to occur is the use of specific available data to describe local conditions. For example an instream flow study would be concerned with changes in discharge and its effect on habitat while a flood control project may be more concerned with the physical changes to the stream channel. As a result the specific data required to assess a specific project may vary, but overall, the steps described below are followed for each project.

<u>Watershed scale suitability:</u>

1. Watershed scale metrics were created from available GIS data for variables that covered all 430 perennial streams statewide. The creation of these metrics is detailed in the *Atlas of Hawaiian Watersheds and their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e and reproduced in Appendix 1). The watershed scale metrics included ratings for watershed size, wetness, stewardship, stream reach diversity, the amount of estuary and shallow nearshore marine habitat, and land cover. These metrics were intended to capture the range of the spatial variability for perennial streams in the state of Hawaii.

2. The complete set of 430 watershed suitability values was range standardized so that the range of all values had a minimum value of 0 and a maximum value of 1. This resulted in a comparable range of values for each species among the watersheds statewide.

3. For each species, the watershed scale suitability was determined by plotting the proportion of watersheds in which a species occurred against each watershed scale metric. The watersheds were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 5 of the 430 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples.

4. Multiple logistic regression was used to select the group of metrics that most appropriately predicted the occurrence of a species based on overall watershed characteristics.

5. The current modeled watershed scale suitability relationships are presented for each species in Appendix 1. It is important to realize that these relationships can be updated based on new collection information stored in the DAR aquatic surveys database.

6. There are several assumptions implicit in the watershed scale suitability metrics.
    a. That the set of metrics including watershed size, wetness, stewardship, stream reach diversity, the amount of estuary and shallow nearshore marine habitat, and land cover have any influence on the occurrence of native stream animals. From a general thought, the concept that larger, wetter and undisturbed watersheds with streams containing a wide variety of habitats may potentially contain a wider variety of native species is well supported in the general fisheries literature and has been observed in Hawaii. Also, the use of multiple logistic regression eliminated metrics that did not aid in predicting a species occurrence within a watershed.
    b. The relationship also assumes that there is even sampling within all watersheds. This is clearly not the case. A rating strength metric is reported within the *Atlas of Hawaiian Watersheds and their Aquatic Resources* (Parham et al. 2008 a,b,c,d,e). The rating strength metric reflects the number of surveys the type of surveys and the distribution of surveys within various stream reaches to estimate how confident we are with our underlying information. The rating strength metric is not currently used in the watershed suitability relationships but may be incorporated in subsequent versions of the HSHEP model.

<u>Instream distribution suitability:</u>

7. All native amphidromous stream animals share a common life history pattern and as a result migrate from the ocean to upstream habitats in each generation. As a result of differential climbing abilities among species, each species has its own characteristic instream distribution.

8. To account for this differential instream distribution within the HSHEP model, variables for site elevation, distance inland, and maximum downstream slope (a measure of waterfall or barrier height) are included.

9. The underlying data for these three variables comes from the USGS 10 m digital elevation model for each of the Hawaiian Islands. Digital flow models delineating watershed boundaries, stream channels, flow direction, and numerous other flow metrics were created for each Hawaiian island (Parham 2003a).

10. For each 10 m cell representing the path of the stream channel, each of the three variables was determined using ArcGIS software.

11. Elevation directly reflects the data from the underlying digital elevation model for each 10 m stream cell.

12. Distance inland is the reverse accumulation of distance against the downstream flow direction.

13. Maximum downstream slope is the reverse accumulation of the maximum change in

elevation between two adjacent cells. In some cases in specific HSHEP model applications, maximum downstream slope is replaced by actual measurements of barrier height or the extent at which a barrier is undercut from actual field measures.

14. Unlike in the watershed models, the variables used in the stream reach models were not linear; therefore, multiple logistic regressions could not be used to select the relationship between the instream distribution of the animals and the reach variables. To determine the suitability index based on the instream distribution for each species, the variables for elevation, distance inland, and downstream barrier height were combined with two different relationships and then the more appropriate relationship was selected for use. The two relationships were:

- Instream Distribution Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)
  where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

- Instream Distribution Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

15. Each relationship was range standardized with a minimum value of 0 and a maximum value of 1.

16. To select the more appropriate relationship, the results of each relationship for all sites with all data for each variable in the database were calculated. The sites were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 100 of the 8300 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples.

17. The results of the comparison of predicted suitability with the proportion of samples containing a species were plotted on a graph and analyzed using linear regression.

18. To select the more appropriate relationship, two criteria were used. First, the distribution of predicted results to observed proportions was visually compared. If predicted values between 0 and 1 resulted in a range of proportions between 0 and 1, the relationship was considered acceptable. If both relationships were acceptable to the first criteria, then the relationship with the higher r^2 value for the linear regression was chosen.

19. The selected instream suitability relationship for each species is shown in Appendix 2.

20. The selected relationship for each species was used to combine the three underlying source data grids within ArcGIS.

21. The instream suitability for all sites statewide was range standardized from a minimum of 0 and the maximum was 1 for each species. This resulted in a comparable range of values for each species among all stream segments statewide.

22. There are several assumptions implicit in the development of the instream distribution suitability metric:
    a. Probably the largest assumption in the instream distribution suitability metric results from the calculation of maximum downstream slope as a representation of downstream barrier height. A digital elevation model only contains a single elevation value for each 10 m cell. As a result, slope is calculated as the change between the two adjacent cells. It is impossible to tell whether the slope change is an even percent change or an abrupt drop off. To decrease this issue, if field verified data exists, it should replace the digitally derived metric. With that said, maximum downstream slope has proved effective at finding larger barriers within the stream channels throughout the state of Hawaii.
    b. Like the watershed metric, the relationships assume even sampling within all conditions. This is not true. Sampling is clearly uneven within stream reaches, but the large number of samples (8300+ for this report around the state) has helped decrease the impact of the uneven sampling effort.

<u>Combining Watershed and Instream Distribution Results:</u>

23. The resulting values for each of the relationships (watershed and stream segment suitability for each species) were appended to separate 10 m grids for each island in ArcGIS.

24. Each grid (watershed and stream segment suitability) was weighted by the r^2 value for the linear relationship developed for the species. The r^2 value was used as an estimator of the strength of the watershed or stream segment suitability model's results in predicting a species occurrence.

25. The grids for each scale were multiplied together in ArcGIS into a multi-scale habitat suitability grid.

26. The GIS layer for DAR streams was converted from vector to grid format and all non-stream cells were set to 0 and all stream cells were set to 1 in ArcGIS.

27. The multi-scale habitat suitability grid was multiplied by the stream grid to remove non-stream cells from the analysis in ArcGIS.

28. The resulting range of values for the multi-scale habitat suitability grid was again range standardized so that the minimum value for grid cells statewide was 0 and the maximum was 1 for each species.

At this point, we have combined and range-standardized the watershed and stream scale model with the stream segment scale model and have the values for habitat suitability for each 10 m cell of 430 streams statewide. For each species, the values for the habitat units range from 0 to 1 to reflect suitability. This step results in predictions of the non-locally corrected amount of suitable habitat for each species within each watershed statewide.

Adjusting the HSHEP model for local conditions:

To adjust the HSHEP model for local habitat conditions found in various segments of the stream, several different options are possible. The selection of the input data is usually dependent on two factors. The first factor is the availability and detail of site surveys and the second factor is the type of scenario being modeled. In general, site level measures will include variables such as depth, velocity, substrate, habitat type, and water temperature. There are numerous additional variables that may be useful in describing instream animal habitat, but may or may not be available for a specific project area. Traditionally, the field data used to describe local conditions comes from either point samples, small area transect samples, or possibly generalized reach scale estimates of conditions (Polhemus et al. 1992 , Parham 2003b). In all of these cases, we assume that un-surveyed areas are similar to the habitats observed in our survey areas. A newer survey technique, High Definition Stream Surveys (HDSS) may be used to document a wide range of variables for all or nearly all of the stream area under study. The HDSS approach is the preferred approach for HSHEP modeling when possible and is further described in Appendix 4.

With any of the local condition sampling approaches, the application of the information to the model is similar. The stream is segmented into areas with similar instream habitat characteristics. These segments begin or end in locations where there is a change in habitat, a barrier, or at the location of a potential modification. This results in a series of connected stream segments that are assumed to react to changes in a similar fashion. For example, we may have survey sites located in the lower, middle, and upper reaches of the stream. From the survey data, we know the distribution and average amount of various habitat types found in each reach. We then apply the results from the surveyed amounts of habitat types to the rest of the appropriate stream reaches. This, of course, assumes that our survey area is representative of the rest of the reach. As with any model, greater sampling and a wider variety of locations will result in a more accurate output. Depending on the size and importance of the project, the amount of fieldwork to characterize local habitat conditions will vary.

Specific local habitat steps:

29. From a vector (line) representation of the stream in ArcGIS, separate the stream into its appropriate segments based on reach breaks, barriers, project locations, or any other appropriate division.

30. Link a table containing average habitat characteristics to each segment.

31. Determine local habitat suitability for individual species by applying appropriate weighting factors to the description of locally available habitat. The species specific weighting factors are typically created from information contained in the DAR Aquatic Surveys Database. This database contains many thousands of samples and species observations from streams across the state of Hawaii and is considered the best source for this information.

32. Convert the stream segments (with their appropriate local habitat suitability score) into a grid of the same size and dimensions as used in the instream distribution portion of the model.

33. Multiply this local habitat suitability grid to the combined watershed and instream distribution suitability grid. This will result in a locally-corrected representation of habitat suitability for a species for each 10 m of stream. It also addresses its instream distribution and larger stream and watershed characteristics.

Scenario Models:

In general, the HSHEP model was designed to address the effects of two common instream modifications: the diversion or modification of stream flow and physical changes to the stream corridor. The impact of these two modification types can result in changes in a site's habitat suitability, changes to passage, and/or entrainment of animals during migratory events. The HSHEP model takes into account that not all actions will result in all possible impacts. Thus, the description and definition of the project impact must be clearly defined and related to available data describing local conditions.

To address specific project conditions and available local data, a graphical box model representing the modeling scenario features and their impacts is created. The following is a description of the box model process using an example from Iao Stream on Maui (Figure 20). Not all possibilities are shown in this example, but it highlights the conceptual approach well.

The box model for a stream contains the stream and its tributaries from the ocean upstream to the headwater reaches. The stream contains breaks at the various segments determined in the local habitat suitability section. It also contains representations for barriers or project modifications where appropriate. To the right of the stream representation are three additional columns. The first provides labels to each stream segment and is associated with available instream habitat. The second column describes impacts to downstream moving animals and the third column describes impacts to upstream moving animals. This box model provides a useful mechanism to track the label, type, location, and sequence for various possible scenario modifications.

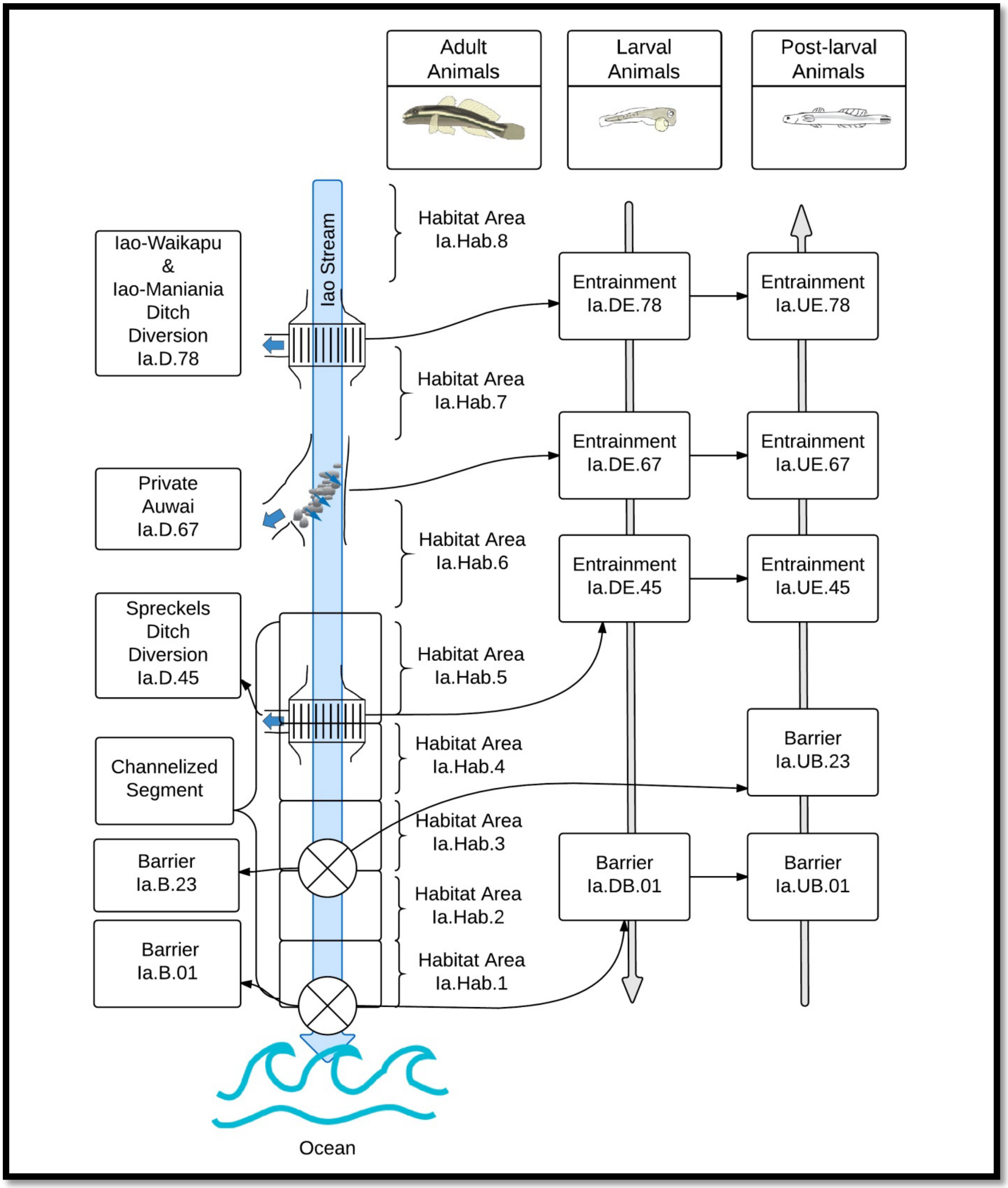

Figure 20: Example HSHEP graphic box model from Iao Stream, Maui. Box models are not to scale.

The impacts of stream diversions, barriers, and other instream modifications are estimated by describing a modification and then applying an impact factor based on the specific design criteria of the modification. In general, all of these potential modifications will share four possible impact factor criteria: (1) local habitat, (2) barrier, (3) upstream entrainment, and (4) downstream entrainment. An impact criterion can range from 0 to 1 with 0 representing the complete elimination of habitat and 1 representing no impact on habitat. In many cases, the specific modification will not influence a specific impact criterion and as a result will have that criterion set to one or no impact.

The description of the main modification types (Figure 21) are as follows:

> Side Diversion – This type of diversion removes water from the stream through a side intake structure (Figure 18). The water in natural stream channel flows downstream past the diversion and a portion is removed by the intake. These side diversions typically have a small dam to help increase the amount of water diverted. Both ditch and auwai diversion can fall into this group. Unless noted, there is no effect on instream habitat or as a barrier to upstream movement. Entrainment is directly related to the proportion of water removed by the diversion. When 100% of baseflow is diverted, the downstream entrainment is modeled at 80%. This would represent the entrainment of all animals drifting downstream in the baseflow and a portion of the animals that overtop the diversion at higher flows. At diversion rates lower than total baseflow removal, the entrainment value is a portion of baseflow (Q_{70}) remaining after the diversion compared to natural baseflow (Q_{70}), multiplied by the maximum entrainment rate. Upstream entrainment is modeled at a maximum of 50% of downstream entrainment. Upstream entrainment is lower because animals moving upstream are moving against the current and this will lead them upstream as opposed to downstream into the diversion. With that said, at high diversion rates, some animals will get entrained when moving upstream.

> Bottom Grate Diversion – This diversion type removes water from a grate covered channel that usually spans the stream channel bottom (Figure 18). Bottom grate diversions are usually found on larger stream diversions and are sized to remove 100% of baseflow. As with side diversions, unless noted there is no effect on instream habitat or as a barrier to upstream movement. Downstream and upstream entrainment rates are

modeled at a maximum of 80%. Upstream entrainment is higher than side diversion as upstream moving animals are easily trapped in the diversion as they try to pass over the bottom grate. At diversion rates lower than total baseflow removal, the entrainment value is a portion of baseflow (Q_{70}) remaining after the diversion, compared to natural baseflow (Q_{70}) multiplied by the maximum entrainment rate for both up and downstream entrainment.

Barriers – Barriers can be both natural (i.e. waterfalls) or man-made (i.e. dam). In a strict sense, barriers have two possible conditions, either open or closed. But when viewed over time and various flow conditions, the barrier may be open a percentage of the time. Therefore barrier impact value (% of time closed to migration) for each barrier is estimated from a combination of the barrier characteristics and flow characteristics at that site. Barriers usually have no local habitat or entrainment impact unless otherwise noted.

Undercut Barriers – Undercut barriers are considered a special type of barrier. Their impact is not correctly modeled from only height and flow conditions. Undercut barriers can transform an otherwise passable drop into a complete migratory barrier. From a modeling perspective the criteria are very similar, but the barriers impact value will be set to a much higher level than would be expected for similar non-undercut barrier.

Instream Structures - Instream structures can be anything built in the stream channel. Typical types of instream structures are those associated with flood control projects, bridges, or other development. The primary impact of these structures is to change in stream habitat. The structure may have differential impact within the project footprint as compared to above or below the project and therefore these extra regions are included where needed. An example of this is a debris basin. There may be little to no habitat where the debris trapping structure is located, while upstream the stream channel is occasionally cleared of debris. These two areas could be modeled with independent local habitat impact. Unless otherwise noted, instream structures will have no barrier or entrainment impact.

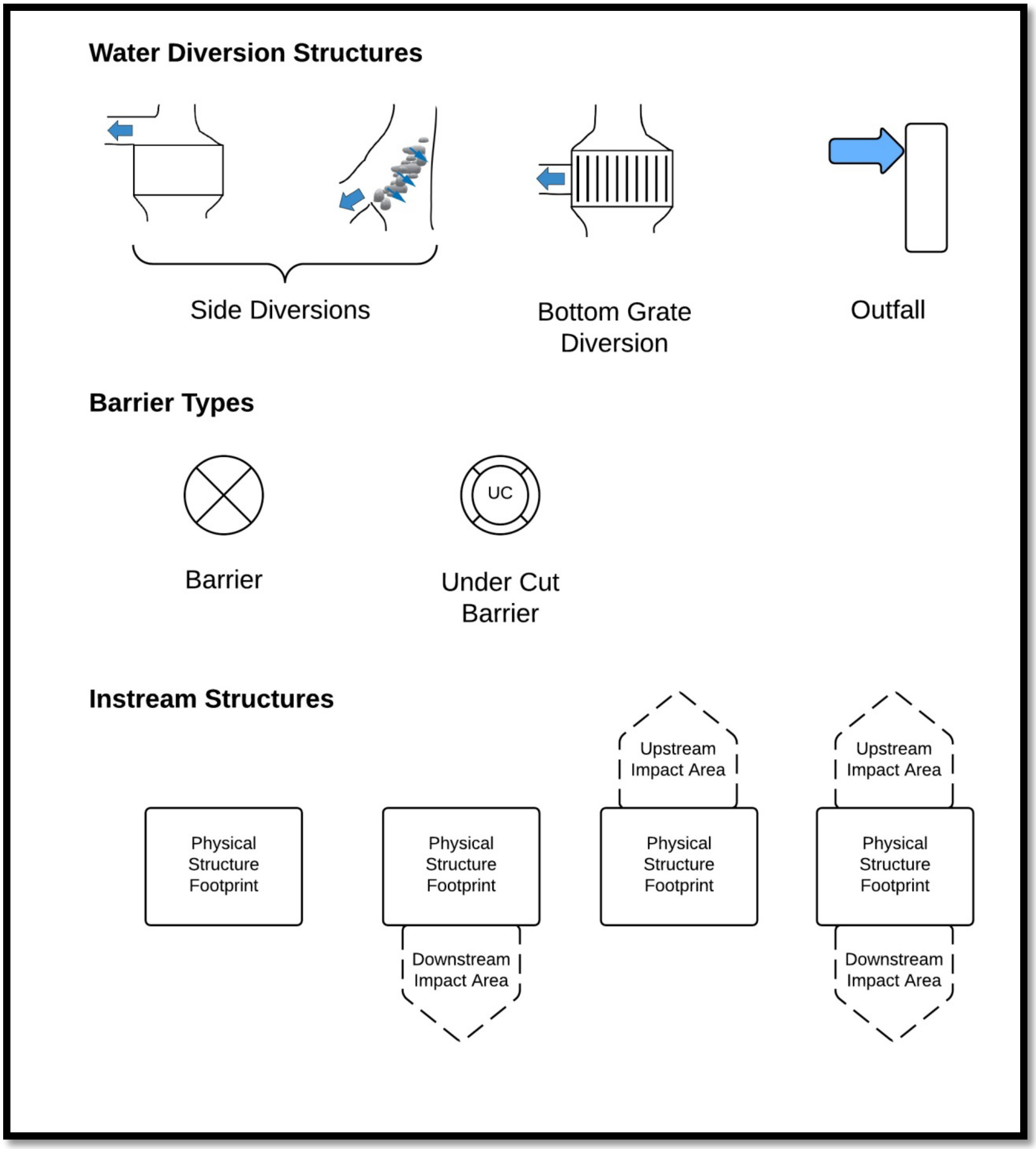

Figure 21: Modification graphics used in the HSHEP box models for each stream. Specifics used to model each type of modification would be project specific.

General Scenario Testing Steps:

34. Impact factors for the four criteria of instream habitat, barriers, downstream and upstream entrainment are determined for all potential impacted locations.
35. The barrier or entrainment impact value affects all upstream cells within the modeled stream network. For example, a barrier (A) that blocked 80% of fish passage would decrease suitable habitat in all cells above Barrier A by 80%. A second barrier (B), located upstream of Barrier A, may block an additional 50% of fish passage. Barrier B would decrease habitat suitability at sites upstream of Barrier B an additional 50%. The combination of passage impact values for both Barriers A (80%) and B (50%) would result in a total passage impact value of 90% at sites upstream of Barrier B. The inverse of the percent of fish blocked would be the percent of fish passing the barriers. In this case, 10% of fish would be expected to pass Barrier B (10% Fish pass = 20% fish pass Barrier A * 50% fish pass Barrier B).
36. If decreases in suitable habitat were the result of physical habitat modification, the estimated percent of lost habitat was multiplied with all habitat units within the affected area. This value did not impact upstream areas as described with passage impacts as it only affected the area where habitat was lost.
37. To address changes in habitat in response to changes in discharge (flow modification), the relationships between the baseflow (Q_{70}) remaining after diversion and natural baseflow (Q_{70}) typically applied. In general, the flow to habitat relationships account for changes in microhabitat variables (water depth, velocity, and substrate) with respect to changes in discharge. The microhabitat variables are weighted by their suitability to a species or species life stage, and as a result, changes in suitable habitat can be predicted from changes in discharge.
38. The amount of suitable habitat derived from the flow to habitat equations are intended to represent the average conditions for the area downstream of the diversion. There may be less available habitat immediately downstream of the diversion and more available habitat near the end of the stream segment after the stream has regained water. Therefore, the baseflow calculated at the start and end of the stream segment were averaged to provide an estimate of average baseflow within the whole segment.
39. The impacts associated with habitat loss due to water diversion (flow modification) were calculated within the specific area in which they occurred and did not impact areas up or downstream of the segment.
40. For each species in each area, the amount of habitat units lost due to changes in passage, entrainment, physical habitat modification, and flow modification were calculated. This approach allowed impacts associated with each type of impact to be considered separately as well as combined.
41. To assess the impact of the various modeled scenarios, the model was repeated with the appropriate scenario values changed.

42. Results for each scenario were created to show Habitat Units available to each species within each stream segment and the streams as a whole, as well as Habitat Units lost due to specific modifications within each scenario.

Conclusions

The HSHEP modeling approach was intended to account for the amphidromous life history strategy of native stream animals, differential instream habitat suitability, and a broad array of man-made changes to the environment. The approach is relatively straightforward yet still flexible enough to address the needs of migratory animals, changes in flow diversions, and different channel corridor construction impacts.

The strength of the HSHEP modeling approach is derived from several features. The first of these is its fundamental design which is derived from the widely used Habitat Evaluation Procedure framework. This framework allows for direct comparisons of different scenarios and supports a wide range of different impact assessments. Another strong feature of the approach is the incorporation of a multi-spatial structure. This provides the ability to differentiate local variances in habitat as well as the impact of network connectivity and watershed differences. Finally, the tight integration with the DAR Aquatic Surveys Database provides the HSHEP model a large and constantly growing source of information to better understand Hawaiian streams, available habitat, and species habitat suitability.

The HSHEP model has been used in multiple Instream Flow contested cases, in hydropower re-licensing, in barrier assessment and passage improvement, and in flood control projects. The range of projects has improved the HSHEP model as well as supported its underlying design. While the HSHEP model is specifically focused on Hawaiian streams, the underlying design should apply to oceanic islands worldwide where amphidromous and other diadromous animals are common.

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Appendix 1: Watershed and Stream Scale Metrics:

The watershed and stream scale metrics are intended to capture broad differences among the watersheds observed throughout Hawaii. Differences in stream size, the amount of rainfall, land management practices, the complexity of estuary and nearshore marine conditions, and land cover can result in differential suitability for native amphidromous stream animals. To capture these differences, standardized metrics were developed for each variable.

Size Rating:

This rating compares stream size. This rating combines the standardized overall length of a stream with the standardized stream order to estimate stream size. The length and stream order were determined from the DAR Streams GIS layer. Stream order followed the Strahler stream ordering system (Strahler, 1952). This rating assumes a larger stream with more tributaries has more habitat than a smaller stream.

Wetness Rating:

This rating compares the average annual rainfall within a watershed to estimate the wetness of a watershed. Rainfall was determined from gridded rainfall layers reported in:

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013: Online Rainfall Atlas of Hawai‘i. *Bull. Amer. Meteor. Soc.* 94, 313-316, doi: 10.1175/BAMS-D-11-00228.1.

The mean value for the average annual rainfall within the watershed is used for comparison with other watersheds. This rating assumes that a wetter watershed will have a larger stream with more stable flow than a drier watershed and less consistent flow.

Stewardship Rating:

Land stewardship information comes from the Hawaii Gap Analysis Program (GAP) (http://www.higap.org). Land Stewardship is not necessarily land ownership; instead, stewardship reflects who is taking care of the land.

This rating scores the stewardship categories as 1 = no biodiversity protection; 2 = protected but unmanaged; 3 = managed for multiple uses; and 4 = biodiversity protection. The percent of land in each category is multiplied by the weighting score, and the sum for the watershed is calculated. The overall sum is standardized to provide the rating.

Shallow Waters Rating:

This rating reflects the extent of estuarine and shallow marine waters associated with the stream. The estuary is the length of the stream from the coast inland to 1m elevation from the Digital Elevation Model for the Hawaiian Islands. Shallow water marine area was the distance from the stream mouth at the coast to the 60-ft contour line (10 fathoms) as digitize from bathymetric maps of the Hawaiian Islands. The length of the estuary and length from the stream mouth to the 60-ft contour line (10 fathoms) was measured and combined to estimate the amount of interaction the freshwater would have with the estuary and nearshore environments. Each category (estuary and shallow nearshore marine waters) was standardized prior to combining to weigh each category equally in the rating. This rating assumes that a stream with more associated shallow water would have greater habitat diversity than a stream that empties nearly directly into deep ocean waters.

Land Cover Rating:

Land use and land cover information was downloaded from National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center (http://www.csc.noaa.gov/crs/lca/hawaii). Data from the Costal Change Analysis Program (C-CAP) were used to classify land cover. The information is based on images collected in 2000 for all islands except Hawaii where the information was collected in 2001.

In general, this rating scores the amount of forested lands positively and the amount of developed lands negatively in a watershed, and other land cover types are assumed to have a neutral association with stream quality. Specifically, the percent of land cover type within the watershed was multiplied by a value to weight the land cover type with respect to its positive or negative value associated with a high quality stream. These values are:

- Evergreen Forest: +1
- Estuarine Forested Wetland: +1
- Palustrine Forested Wetland: +1
- Estuarine Forested Wetland: +1
- Palustrine Emergent Wetland: +1

- High Intensity Developed: -4
- Low Intensity Developed: -2
- Cultivated Land: -1
- Bare Land: -1
- Grassland: 0
- Palustrine Scrub/Shrub Wetland: 0
- Scrub/Shrub: 0
- Unconsolidated Shore: 0
- Unclassified: 0
- Water: 0

The higher negative values for High Intensity Developed and Low Intensity Developed lands reflect the typical increase in pollution, sedimentation, discharge modification, and habitat degradation in comparison with streams near cultivated lands.

Watershed and stream metric combination:

To develop a relationship between a species occurrence in the various watershed and stream metrics, several comparisons were made. First, the presence or absence of a species within an individual watershed was determined from all data within the DAR Aquatic Surveys Database. This resulted in a data set of 430 watersheds (those containing perennial streams) along with each of their watershed and stream metric scores (from 1 to 10) and the presence or absence of each of the eight native amphidromous stream animals.

Next, linear regressions were used to compare the proportional occurrence of a species against each watershed and stream metric score. For each species, the watershed scale suitability was determined by plotting the proportion of watersheds in which a species occurred against each watershed scale metric. The watersheds were grouped with the predicted results into bins from 1 to 10, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (fewer than 5 of the 430 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples. The combination of bins usually happened at the largest size categories. For example small watersheds occur much more frequently than the largest watersheds therefore the larger size classes were grouped into one bin. Thus the metric scale does not necessarily run from 1 to 10. The intent of these species by metric comparisons was to better understand the underlying relationships associated with these metrics that may be obscured in the results of the multiple linear regression described in the following section. Figure 22 to Figure 31 display these results and show the linear relationship, P value, r^2 statistic, and confidence intervals for these relationships. Multiple logistic regression was used to select the group of watershed and stream metrics that most appropriately predicted the occurrence of a species based on overall watershed characteristics. Multiple logistic regression was used as the dependent variable is nominal (either 0 or 1) based on a species presence or absence within a watershed and there are multiple (5) independent variables. The null hypothesis in these multiple logistic regressions is that there is no relationship between a species occurrence in a watershed and any of the watershed or stream metrics. The selection of independent variables used a stepwise selection approach. An objective selection approach was used so that the results could be rerun as new data is collected and added to the DAR Aquatic Surveys Database without having to examine the data and results independently with each new run. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of a species, the predicted watershed suitability value based on the multiple logistic regression was plotted against the proportion of watersheds in which the species occurred to the overall number of watersheds within an 0.1 sized suitability bin. Figure 32 to Figure 39 show the final multiple logistic regression for each species, the test statistics, and the graphical relationship.

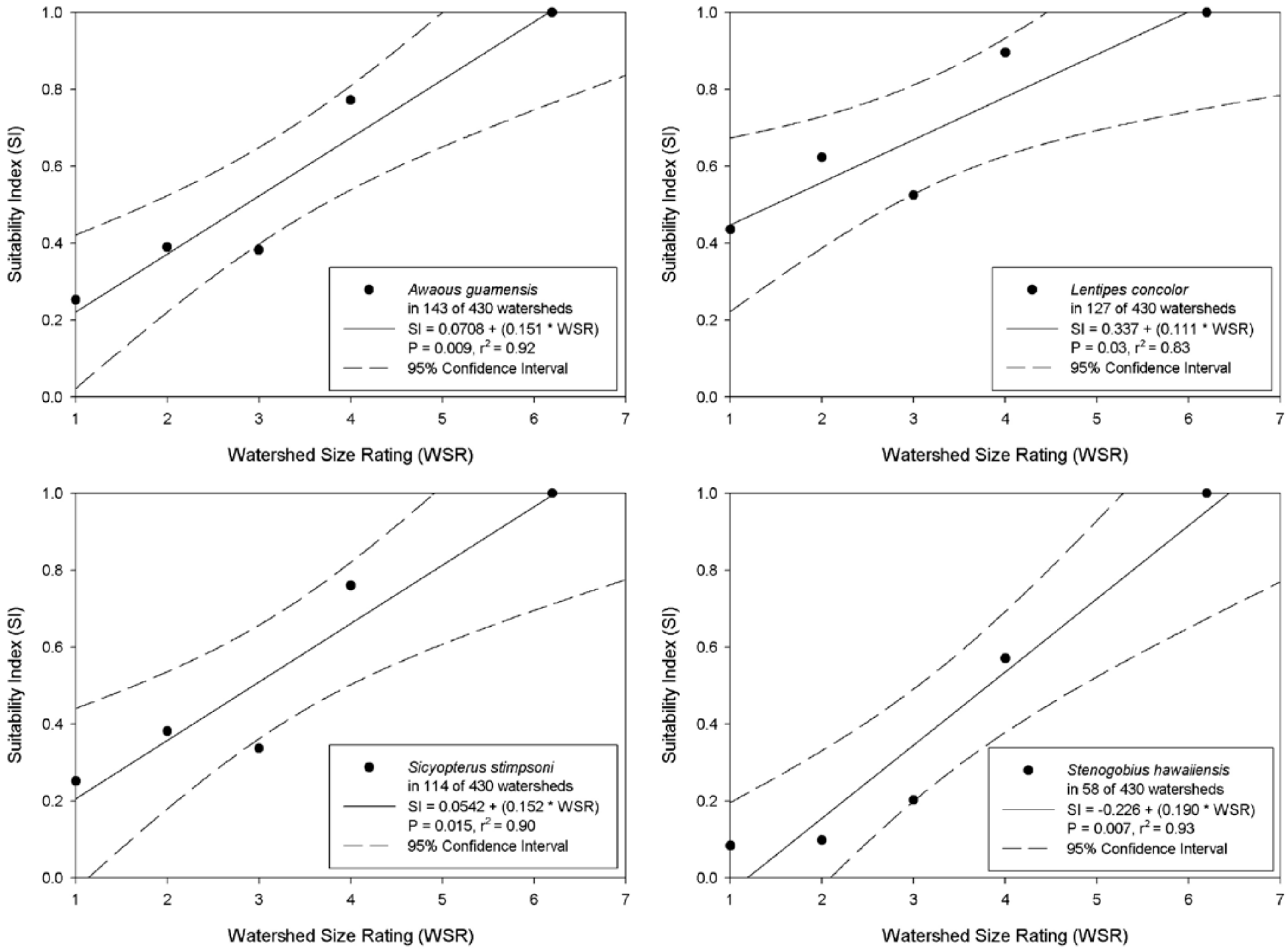

Figure 22: Suitability Indices for Watershed Size Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

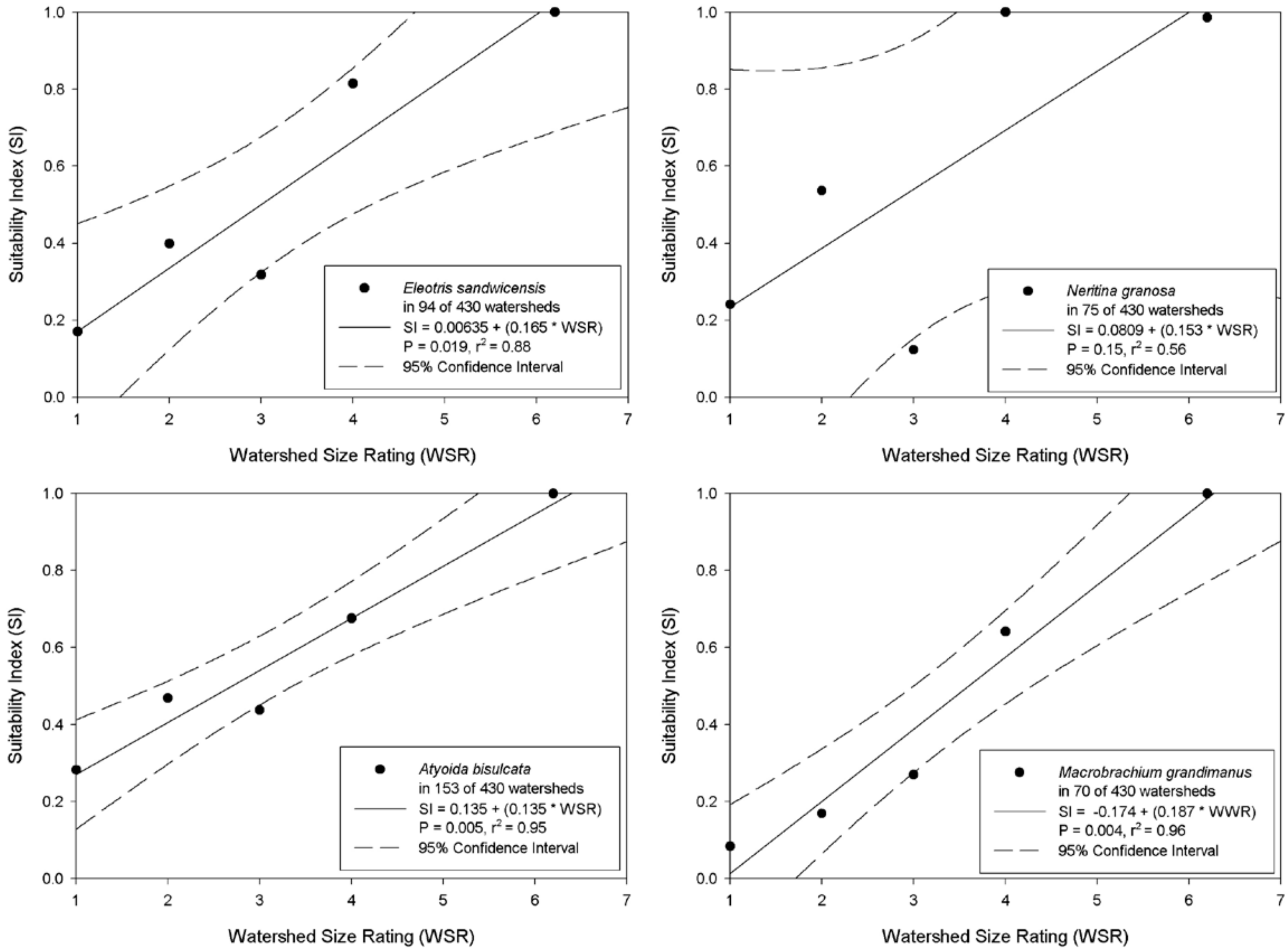

Figure 23: Suitability Indices for Watershed Size Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus*.

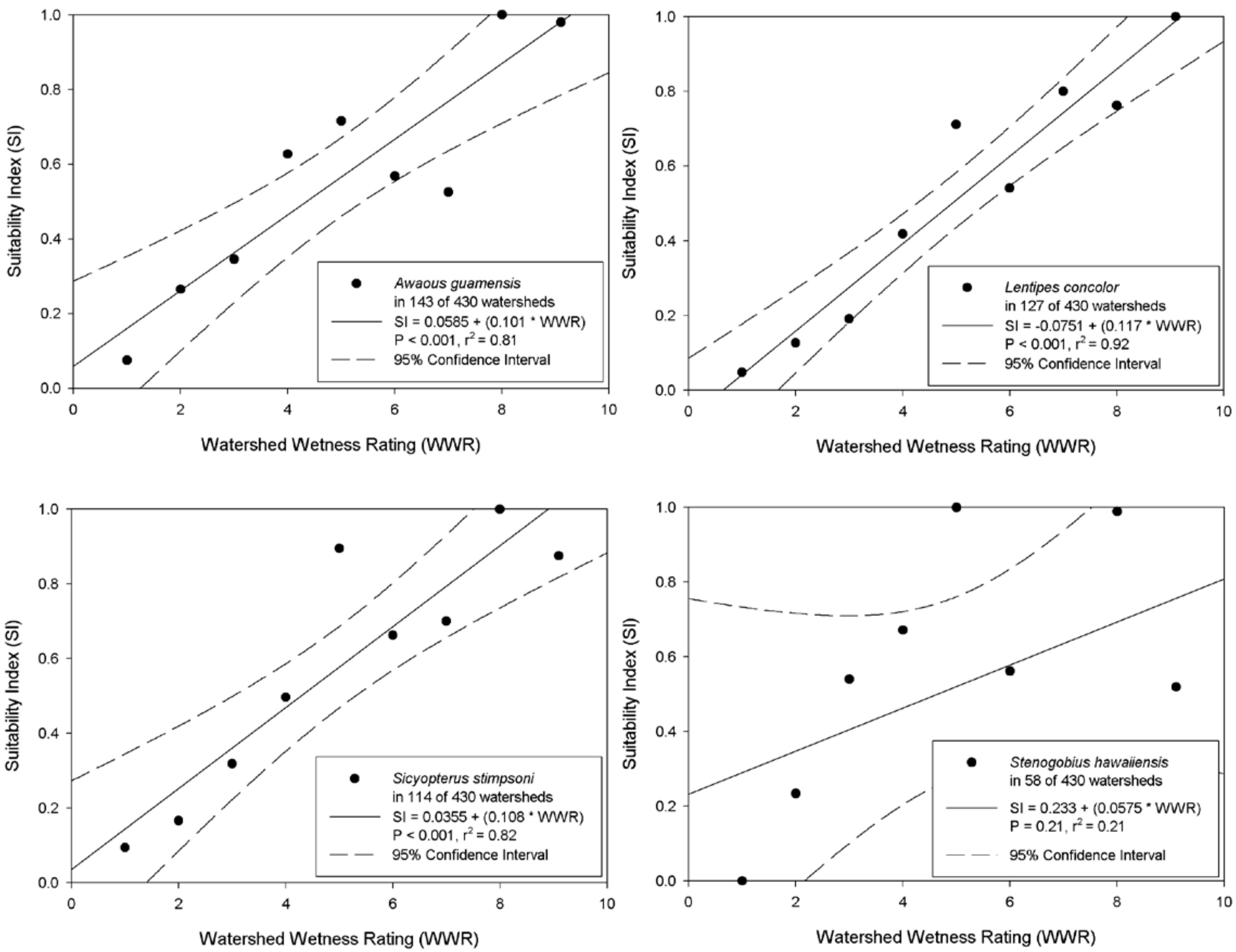

Figure 24: Suitability Indices for Watershed Wetness Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

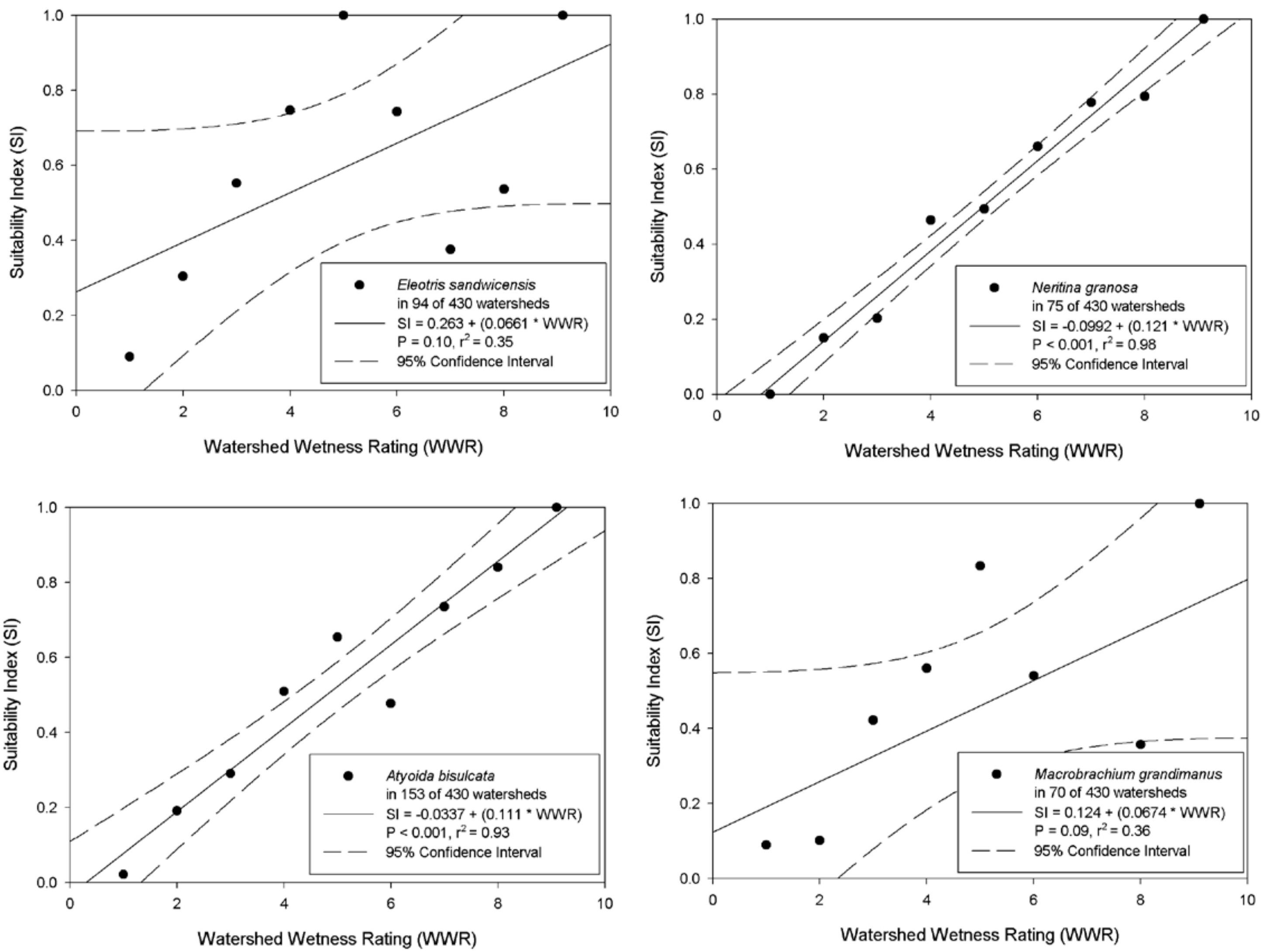

Figure 25: Suitability Indices for Watershed Wetness Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

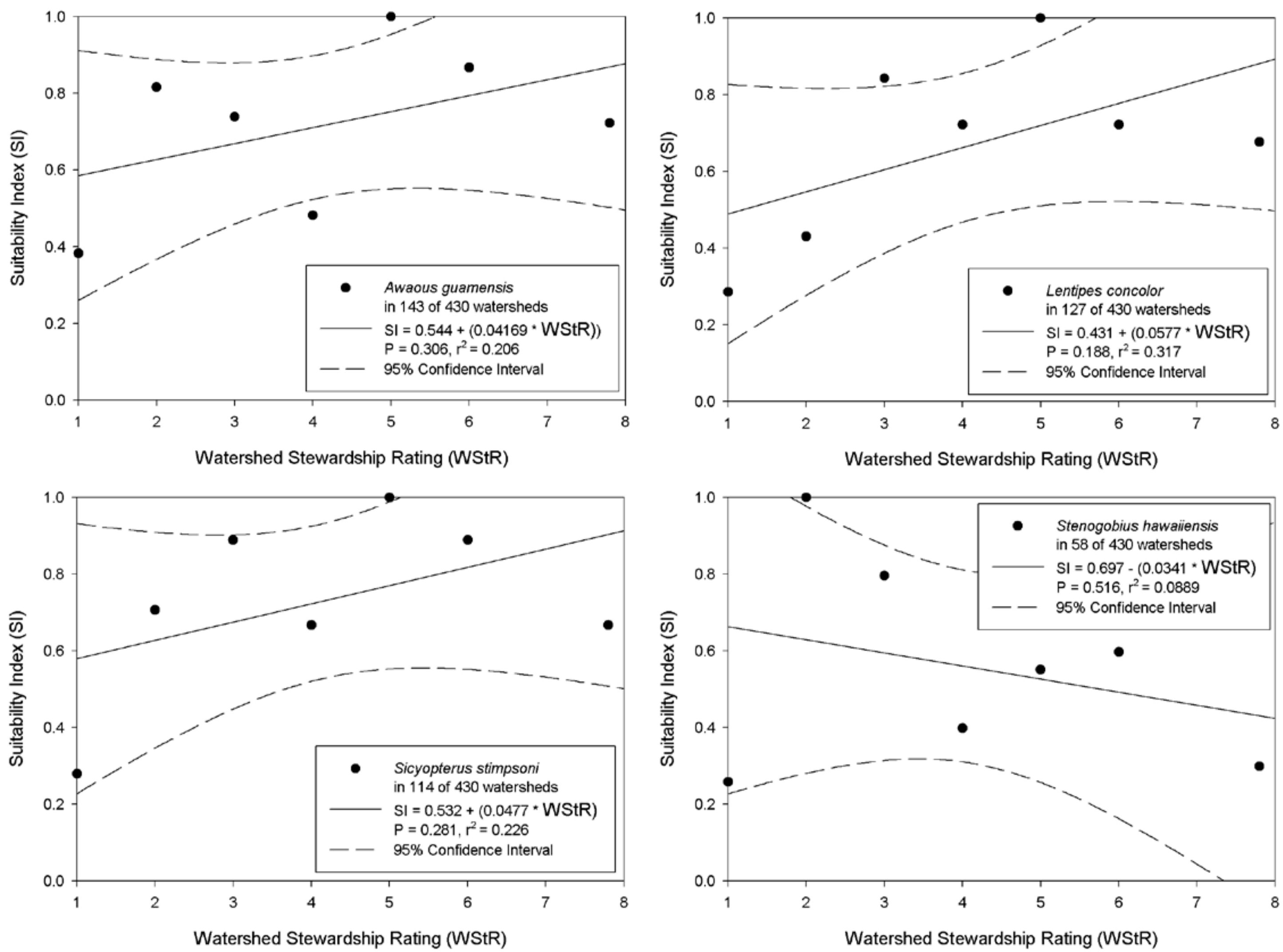

Figure 26: Suitability Indices for Watershed Stewardship Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

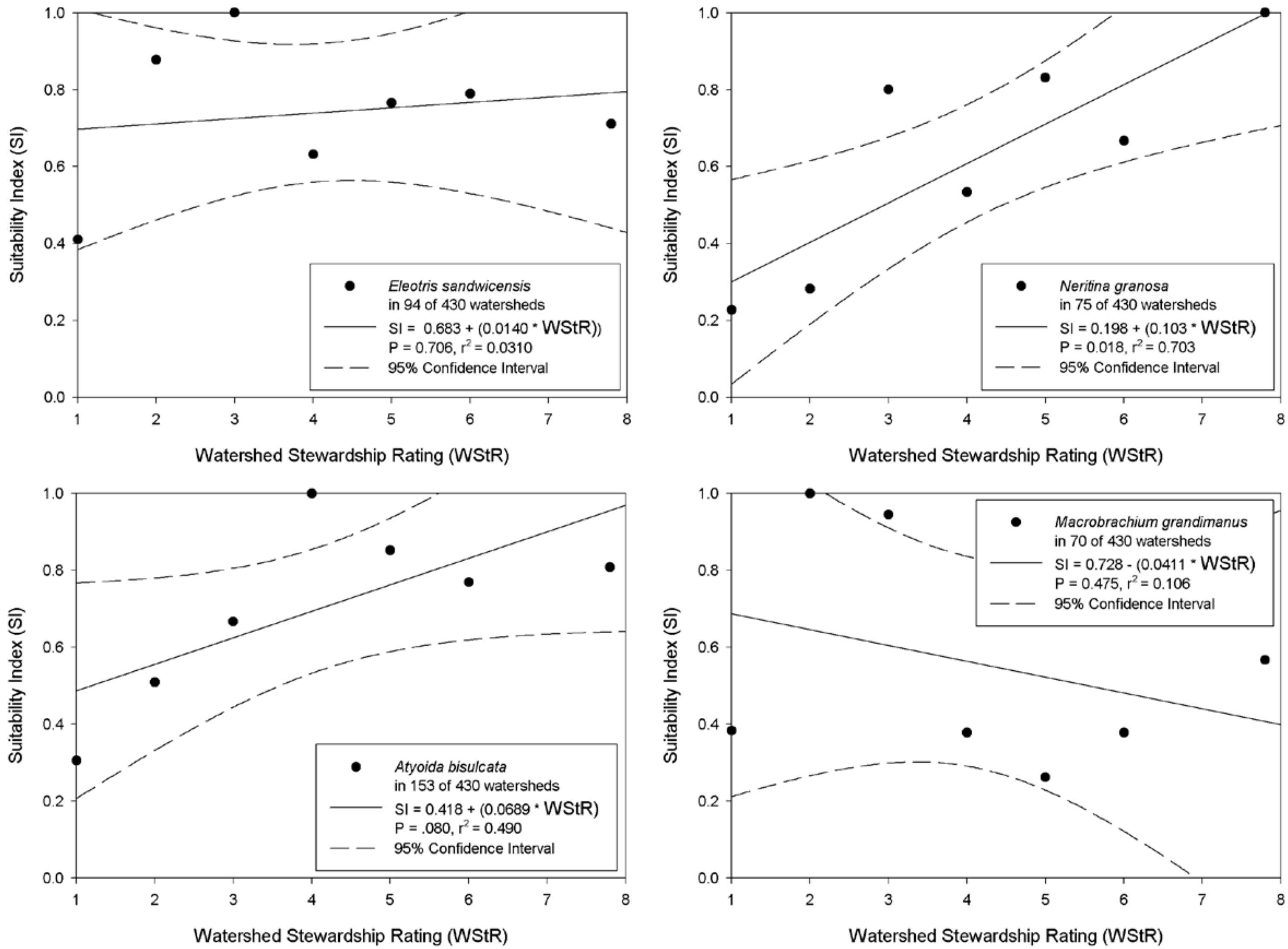

Figure 27: Suitability Indices for Watershed Stewardship Rating for *Eleotris sandwicensis, Neritina granosa*, *Atyoida bisulcata,* and *Macrobrachium grandimanus.*

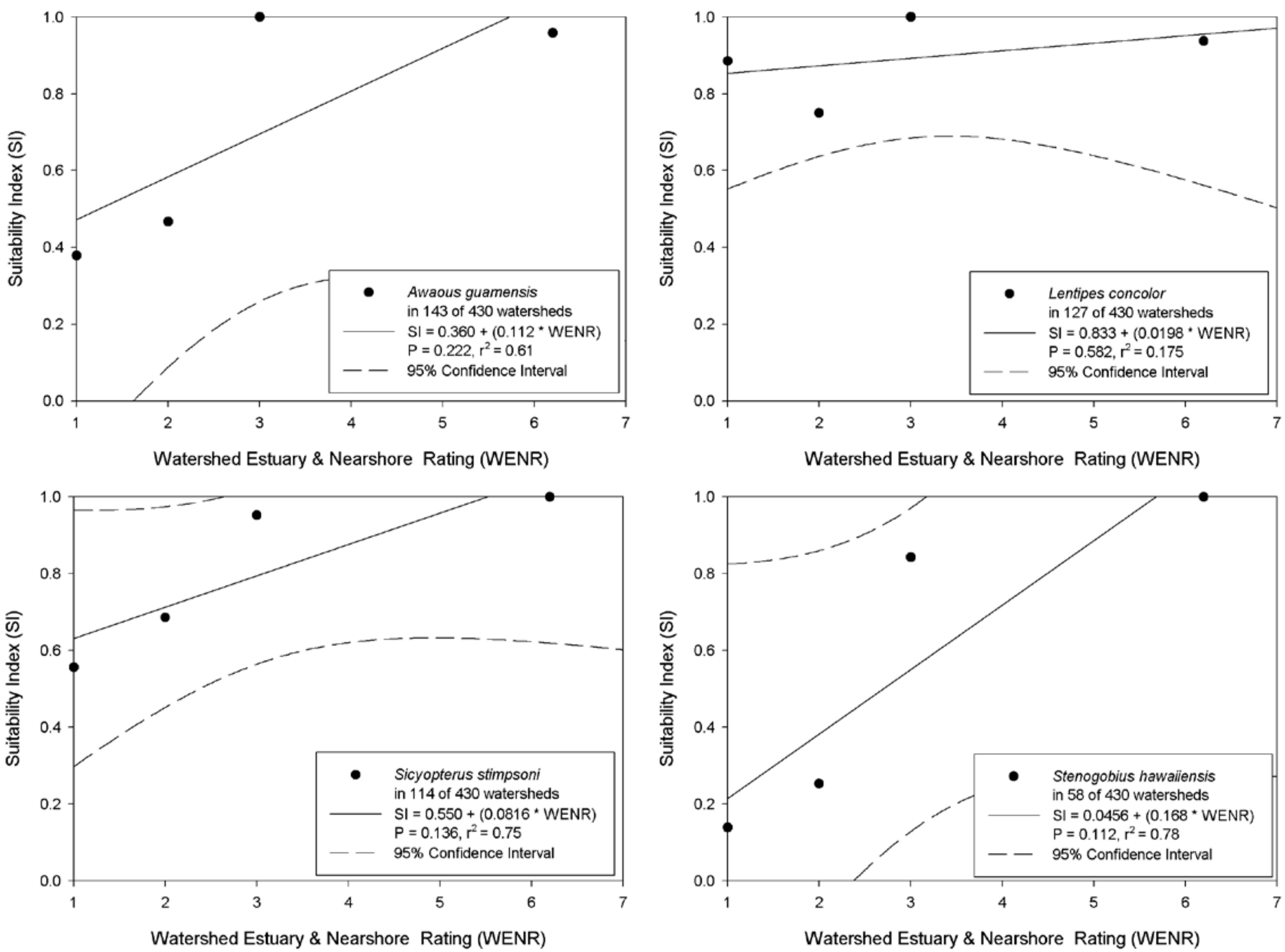

Figure 28: Suitability Indices for Watershed Estuary and Nearshore Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

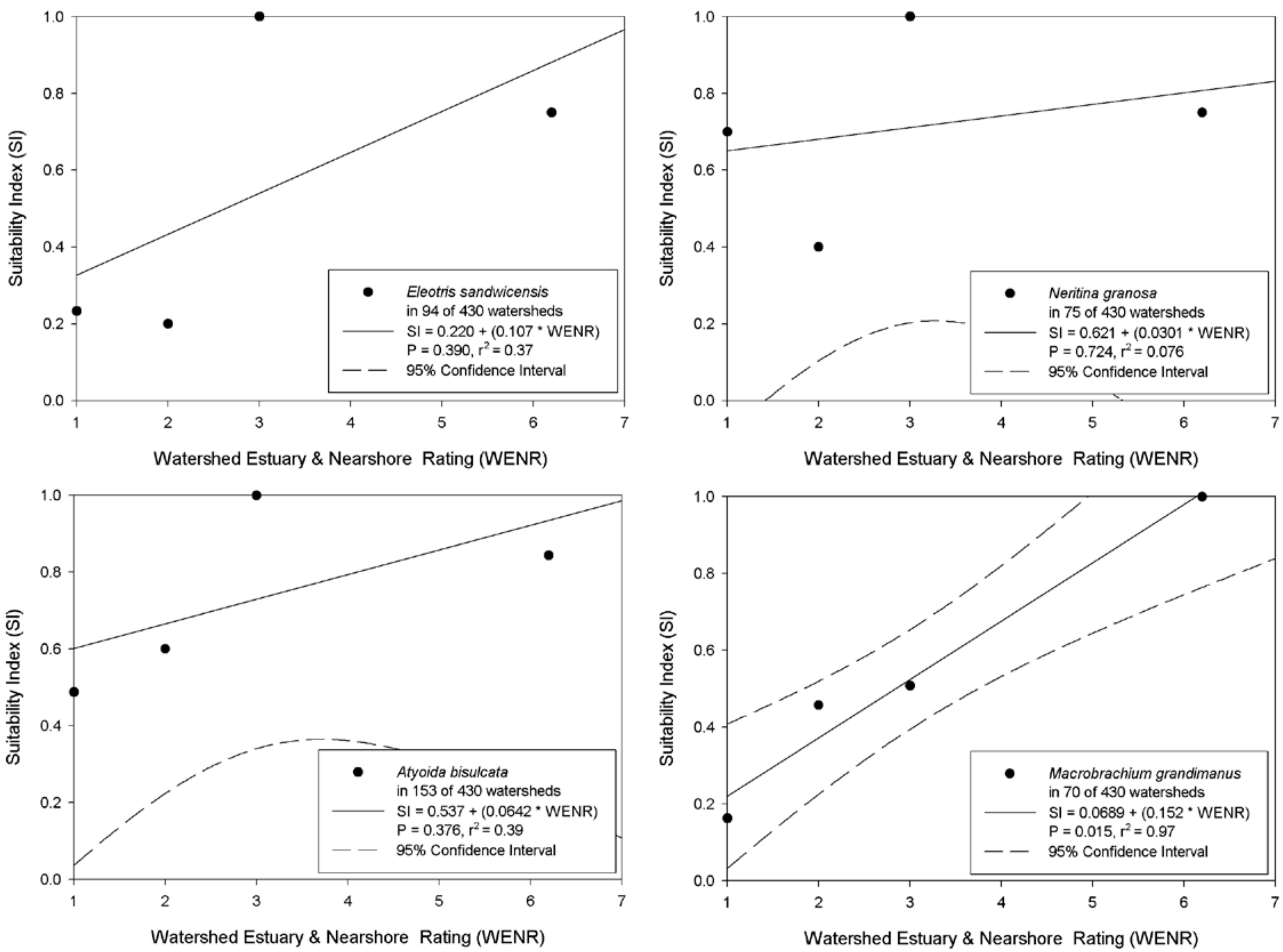

Figure 29: Suitability Indices for Watershed Estuary and Nearshore Rating for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

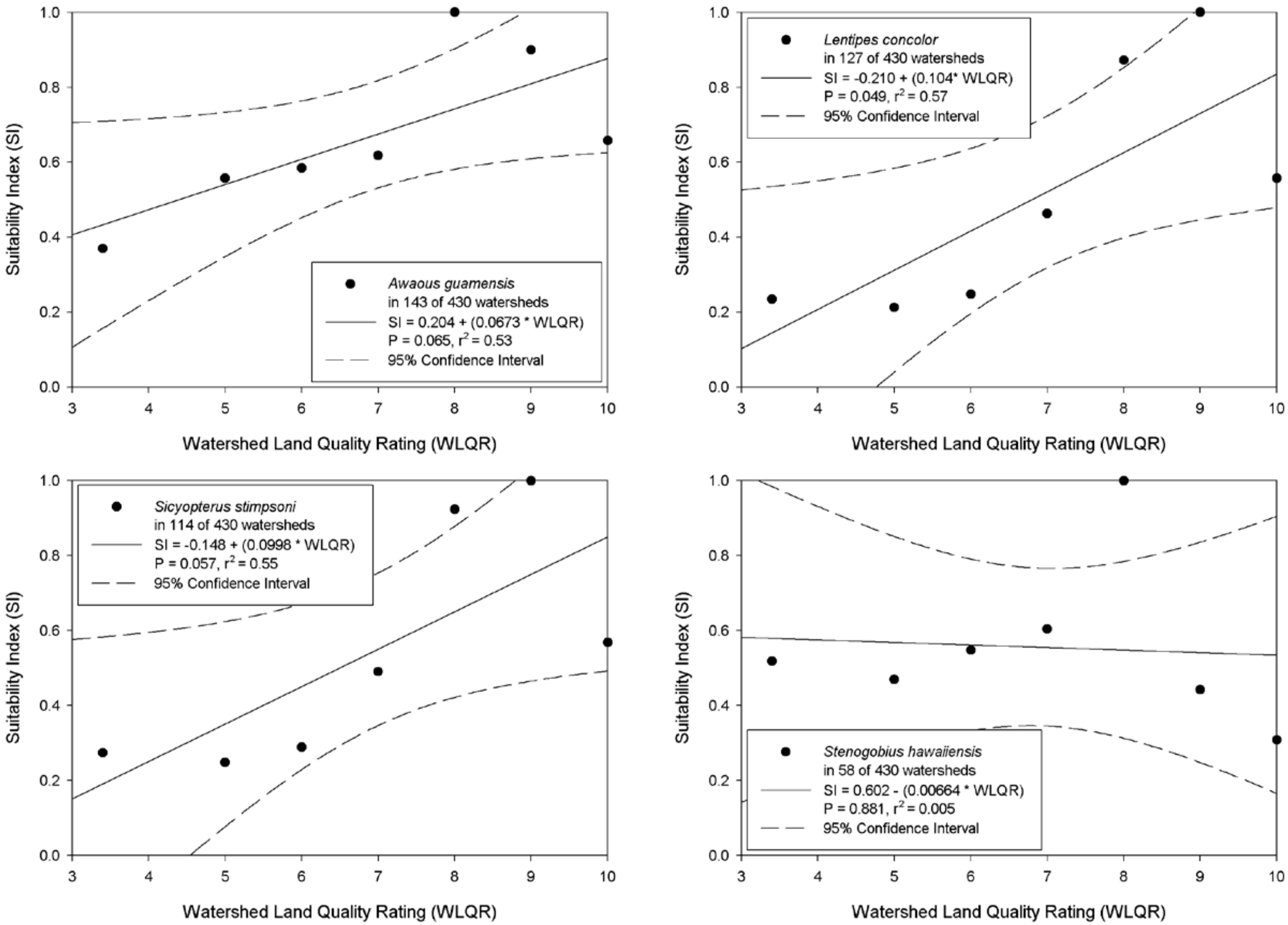

Figure 30: Suitability Indices for Watershed Land Quality Rating for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

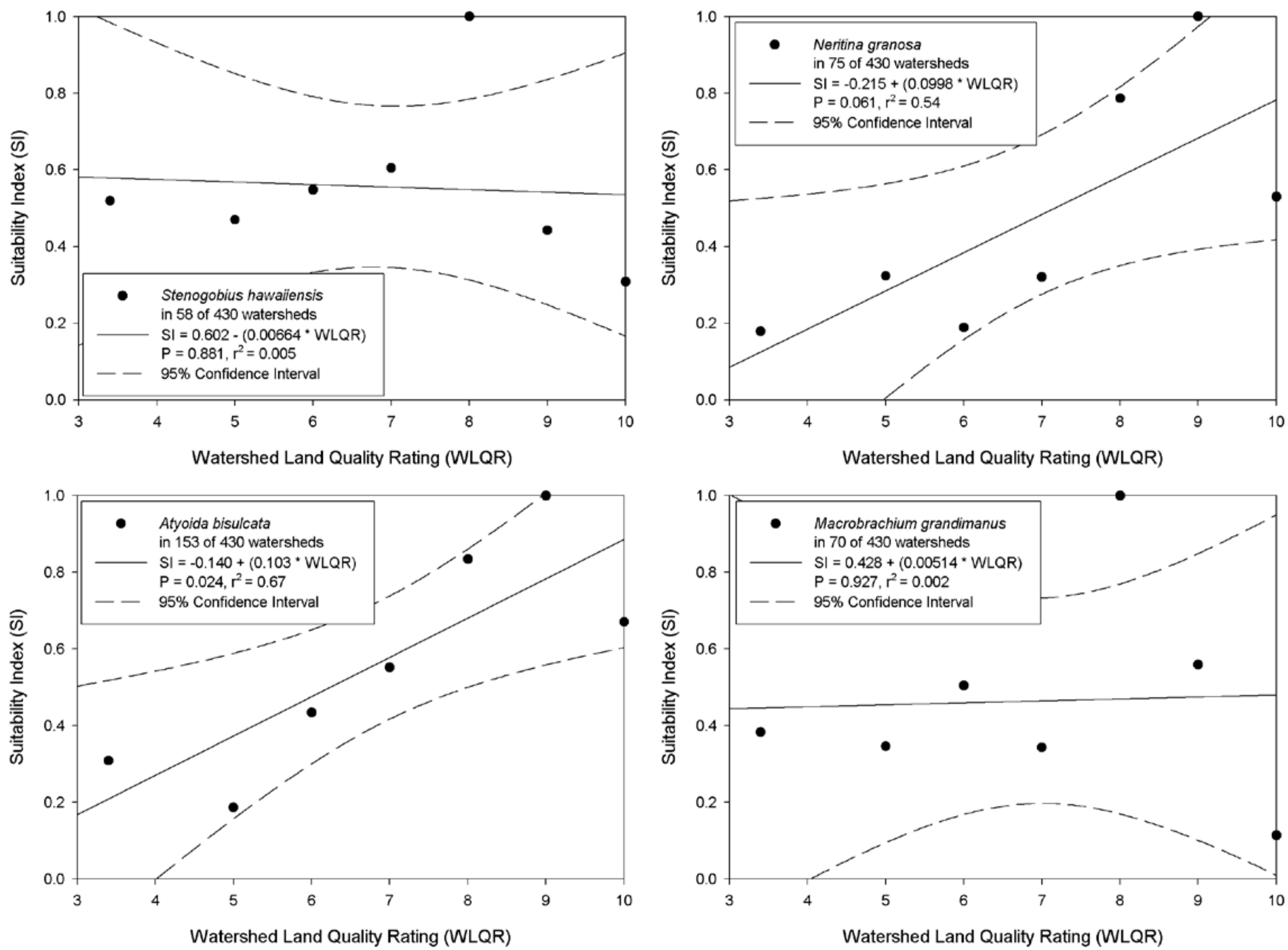

Figure 31: Suitability Indices for Watershed Land Quality Rating for *Eleotris sandwicensis, Neritina granosa*, *Atyoida bisulcata,* and *Macrobrachium grandimanus.*

Watershed Suitability Models for each species

Awaous guamensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-4.043} + (0.425 * \text{WWR}) + (0.543 * \text{WSR}) + (0.280 * \text{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 120.7 (P = <0.001), and correctly predicted the presence or absence of *Awaous guamensis* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Awaous guamensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Awaous guamensis* occurred (Figure 32).

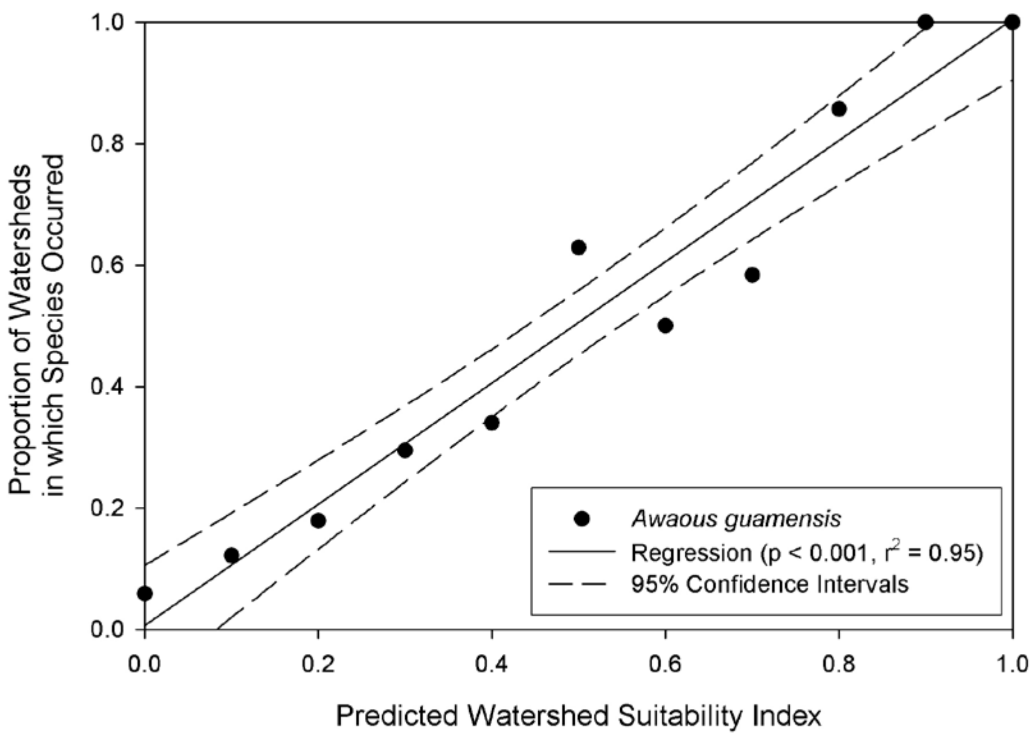

Figure 32: Proportion of the total watersheds where *Awaous guamensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-4.164} + (0.493 * \text{WWR}) + (0.362 * \text{WSR}) + (0.121 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WStR = Watershed Stewardship Rating, ($p = 0.025$).

This equation had a Likelihood Ratio Test Statistic of 117.8 (P = <0.001), and correctly predicted the presence or absence of *Lentipes concolor* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Lentipes concolor*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Lentipes concolor* occurred (Figure 33).

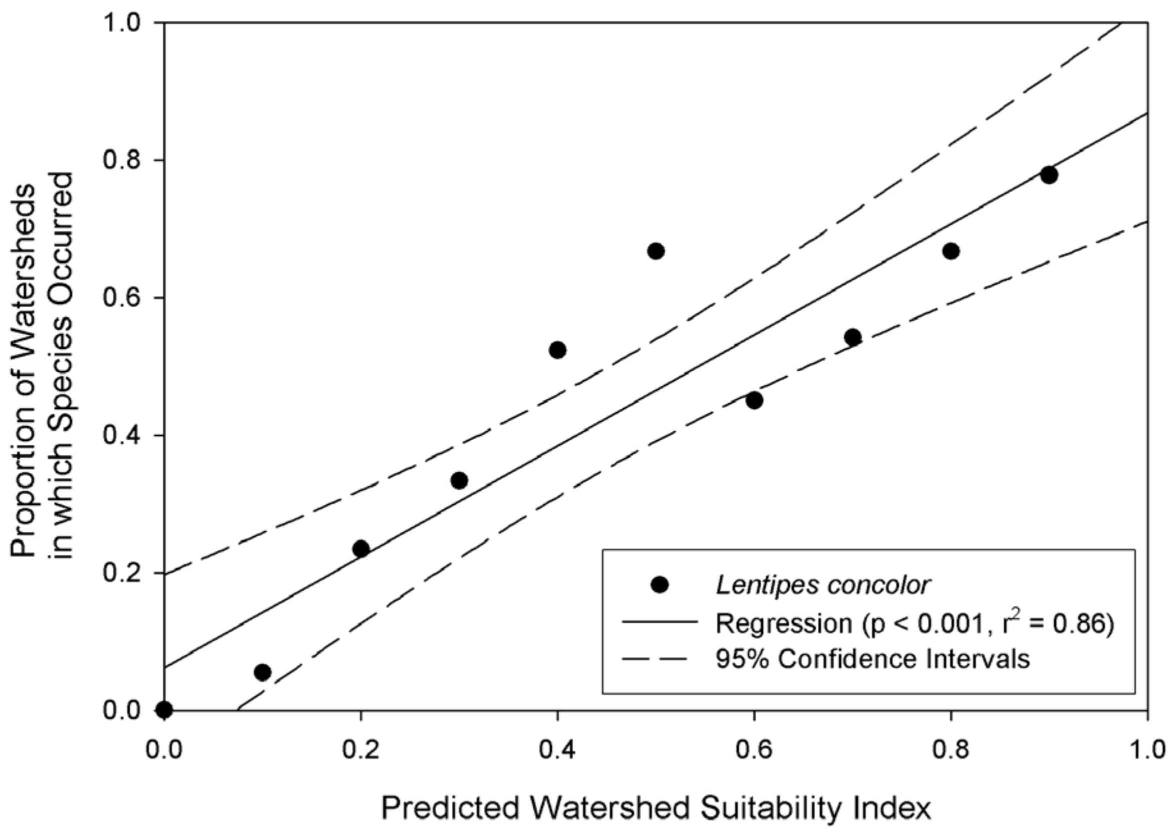

Figure 33: Proportion of the total watersheds where *Lentipes concolor* was observed within each 0.1 group of the Watershed Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-4.195} + (0.358 * \text{WWR}) + (0.539 * \text{WSR}) + (0.135 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, (p < 0.001)

WSR = Watershed Size Rating, (p < 0.001)

WENR = Watershed Stewardship Rating, (p = 0.012).

This equation had a Likelihood Ratio Test Statistic of 97.1 (P = <0.001), and correctly predicted the presence or absence of *Sicyopterus stimpsoni* in 340 of 430 watersheds (79.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Sicyopterus stimpsoni*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Sicyopterus stimpsoni* occurred (Figure 34).

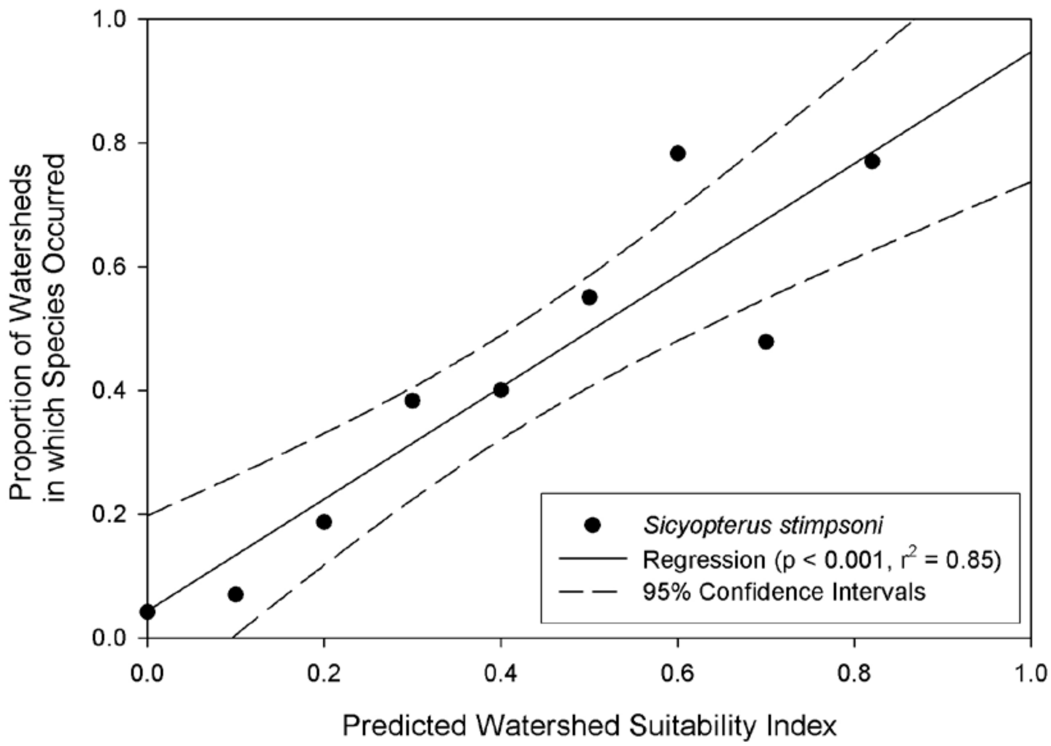

Figure 34: Proportion of the total watersheds where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Watershed Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.923 + (0.206 * \mathrm{WWR}) + (0.796 * \mathrm{WSR}))}}$$

where: WWR = Watershed Wetness Rating, ($p = 0.003$)

WSR = Watershed Size Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 73.4 (P = <0.001), and correctly predicted the presence or absence of *Stenogobius hawaiiensis* in 375 of 430 watersheds (87.2% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Stenogobius hawaiiensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Stenogobius hawaiiensis* occurred (Figure 35).

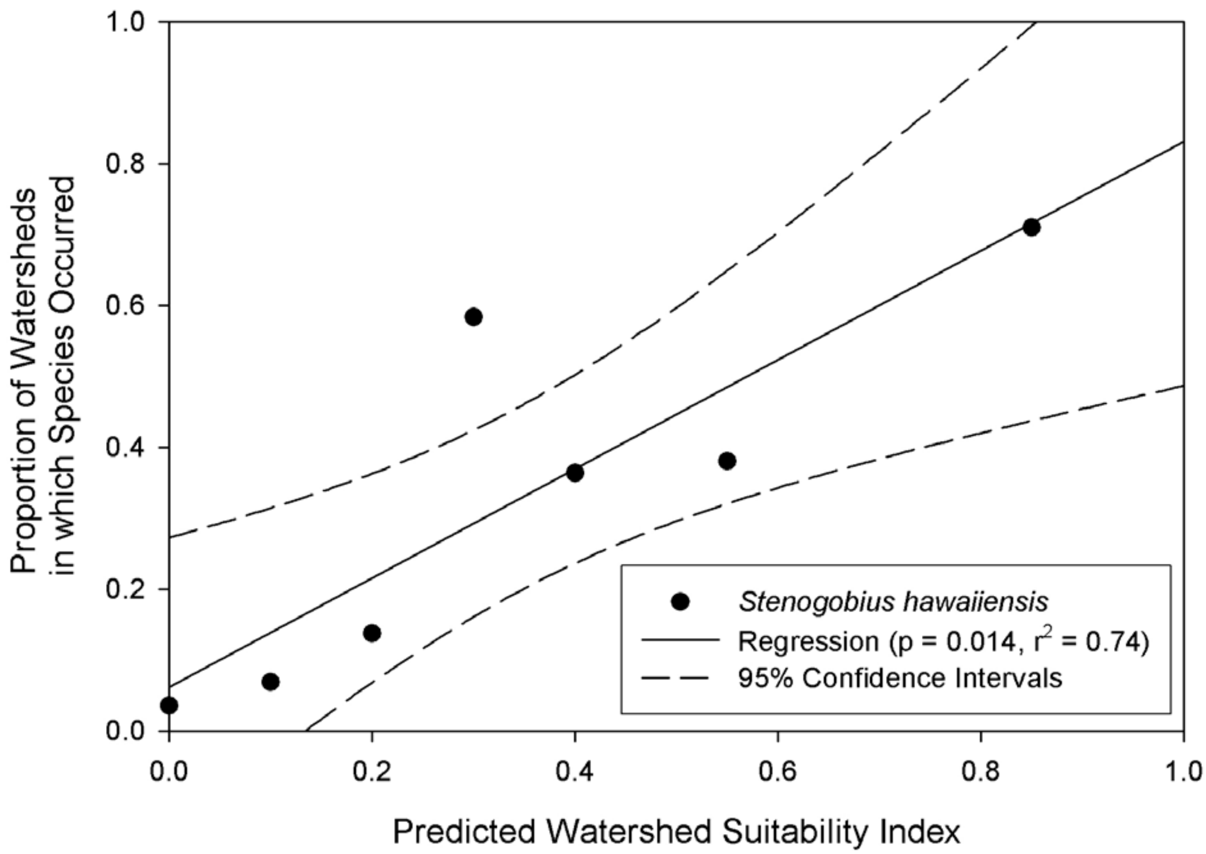

Figure 35: Proportion of the total watersheds where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-3.552 + (0.245 * \text{WWR}) + (0.376 * \text{WSR}) + (0.278 * \text{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 65.4 (P = <0.001), and correctly predicted the presence or absence of *Eleotris sandwicensis* in 343 of 430 watersheds (79.8% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Eleotris sandwicensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Eleotris sandwicensis* occurred (Figure 36).

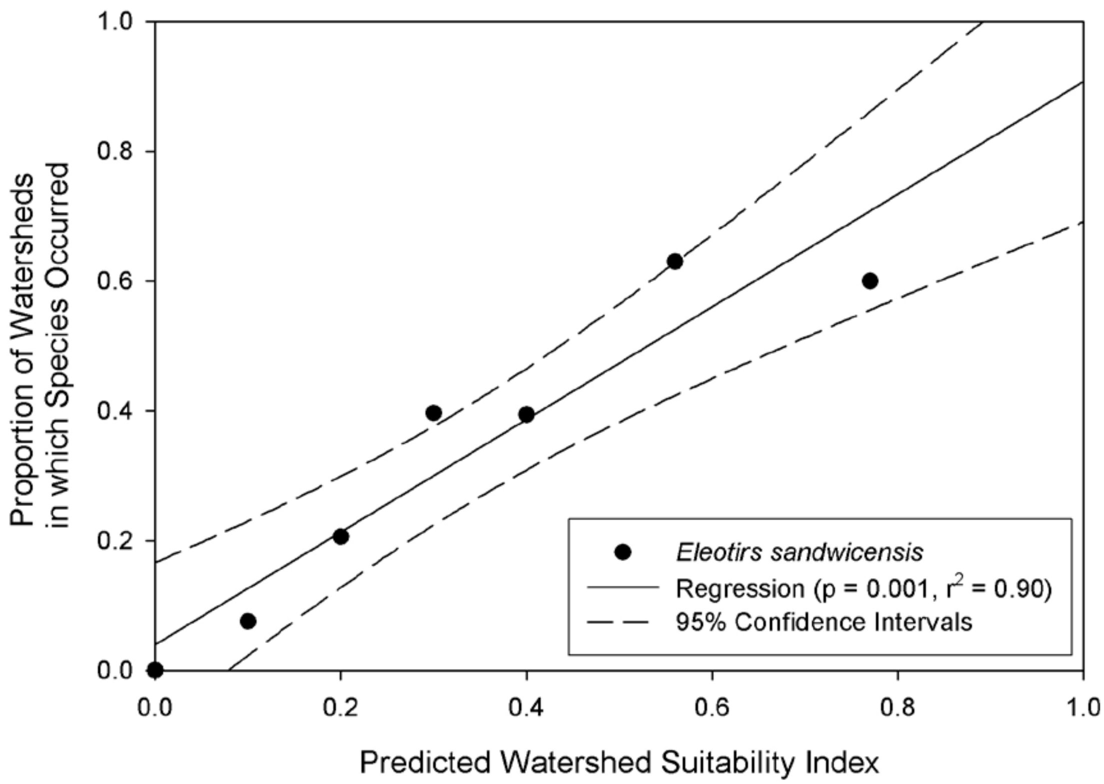

Figure 36: Proportion of the total watersheds where *Eleotris sandwicensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.806 + (0.375 * \text{WWR}) + (0.435 * \text{WSR}) + (0.177 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, (p < 0.001)

WSR = Watershed Size Rating, (p < 0.001)

WENR = Watershed Stewardship Rating, (p = 0.003).

This equation had a Likelihood Ratio Test Statistic of 77.5 (P = <0.001), and correctly predicted the presence or absence of *Neritina granosa* in 357 of 430 watersheds (83.0% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Neritina granosa*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Neritina granosa* occurred (Figure 37).

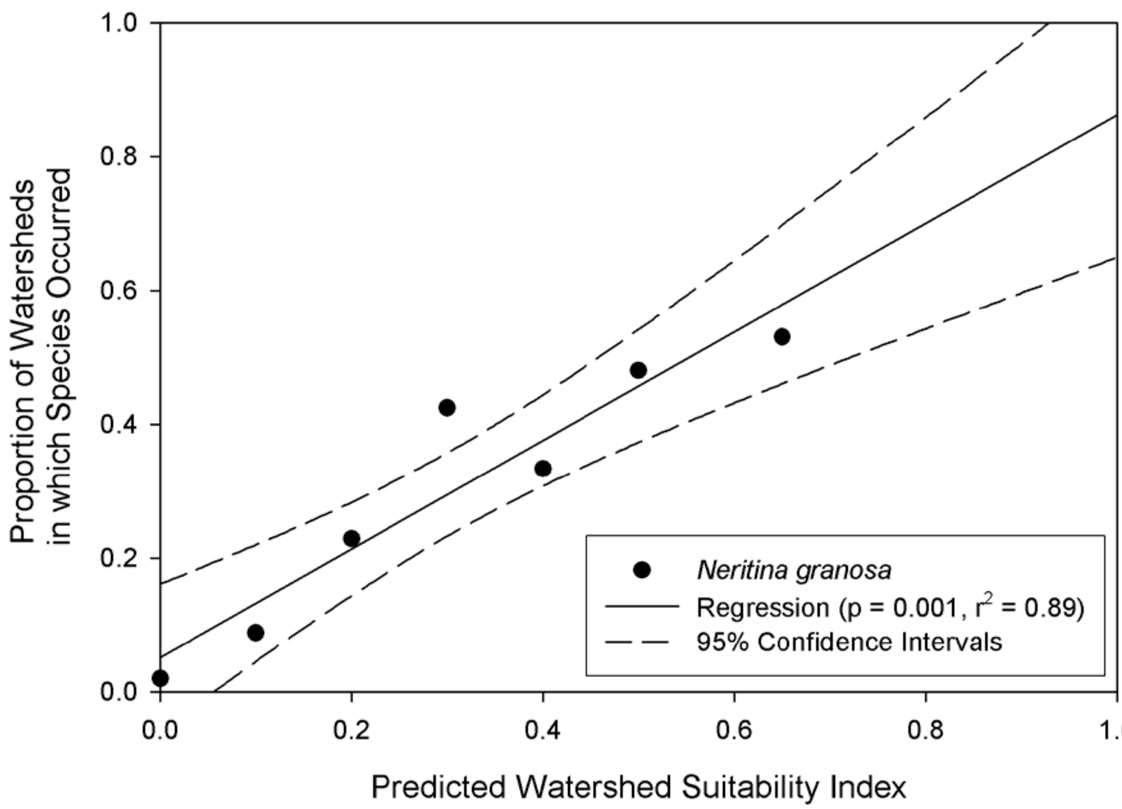

Figure 37: Proportion of the total watersheds where *Neritina granosa* was observed within each 0.1 group of the Watershed Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-4.458} + (0.508 * \text{WWR}) + (0.497 * \text{WSR}) + (0.179 * \text{WStR}) + (0.165 * \text{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$)

WStR = Watershed Stewardship Rating, ($p = 0.001$)

WENR = Watershed Estuary and Nearshore Rating, ($p = 0.04$).

This equation had a Likelihood Ratio Test Statistic of 153.3 (P = <0.001), and correctly predicted the presence or absence of *Atyoida bisulcata* in 336 of 430 watersheds (78.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Atyoida bisulcata*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Atyoida bisulcata* occurred (Figure 38).

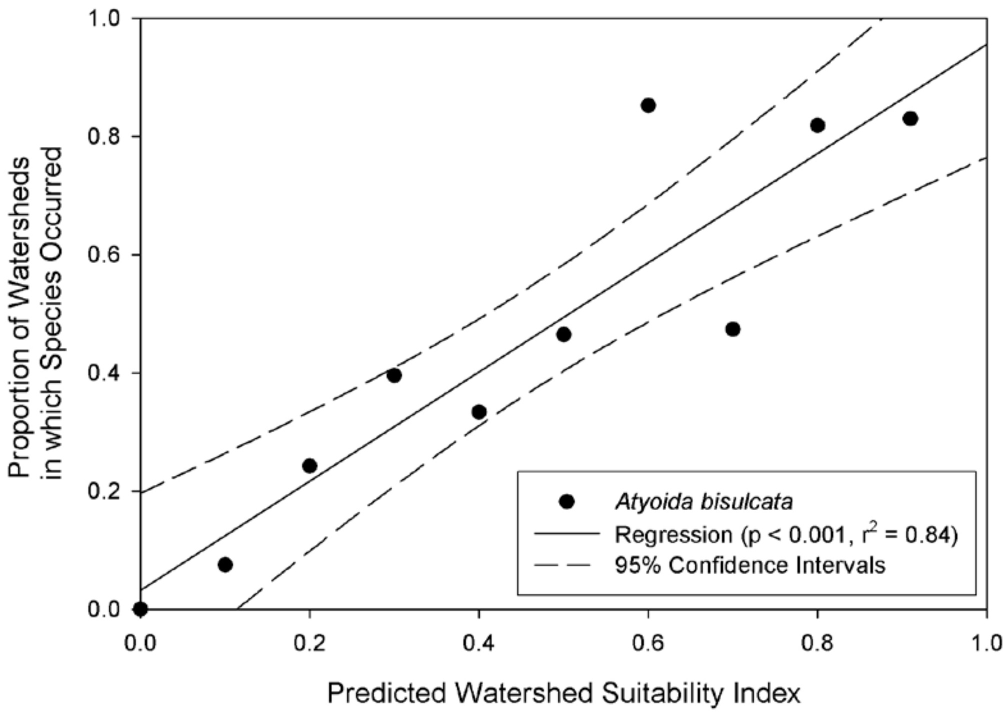

Figure 38: Proportion of the total watersheds where *Atyoida bisulcata* was observed within each 0.1 group of the Watershed Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.942 + (0.286 * \text{WWR}) + (0.775 * \text{WSR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)

WSR = Watershed Size Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 82.4 (P = <0.001), and correctly predicted the presence or absence of *Macrobrachium grandimanus* in 366 of 430 watersheds (85.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Macrobrachium grandimanus*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Macrobrachium grandimanus* occurred (Figure 39).

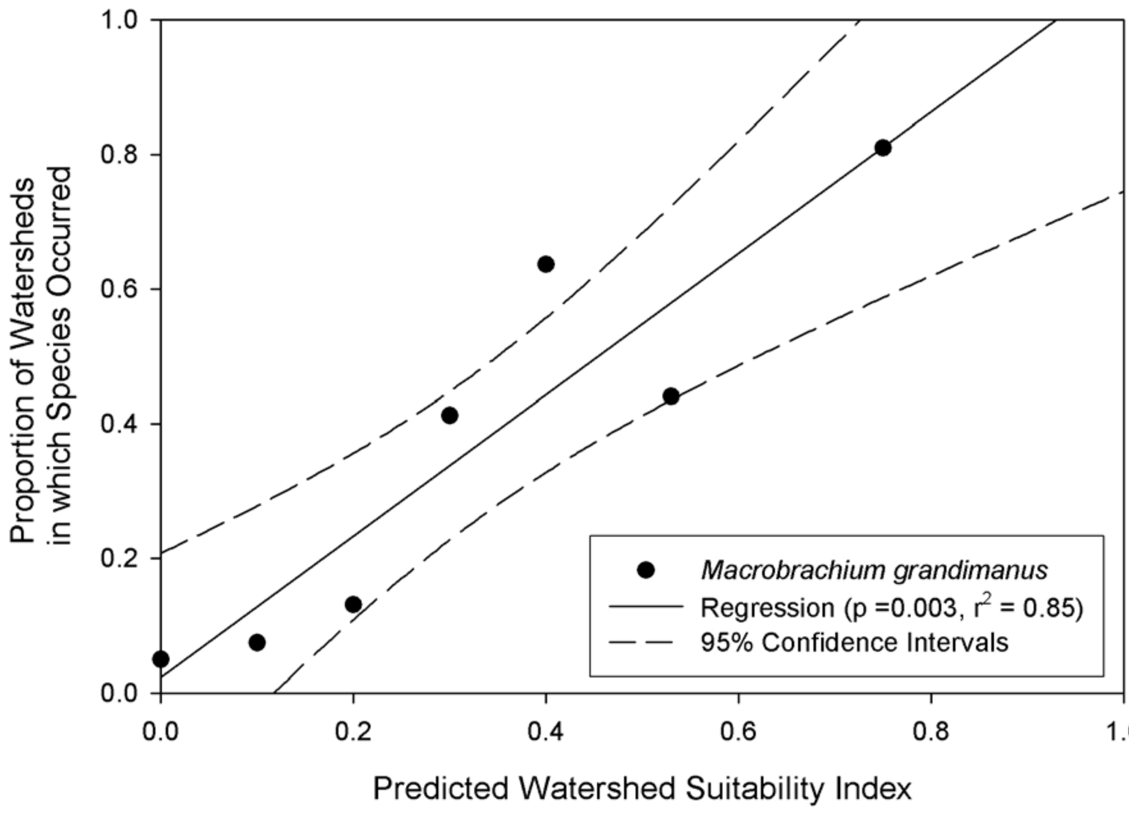

Figure 39: Proportion of the total watersheds where *Macrobrachium grandimanus* was observed within each 0.1 group of the Watershed Suitability Index equation for *Macrobrachium grandimanus*.

Appendix 2: Instream Distribution Scale:

Unlike the watershed and stream metric relationships, the instream distribution model is more of a GIS construct than a statistical construct. The data that underlies the prediction of instream distribution for the native amphidromous species comes primarily from DARs point quadrat surveys. In general, these standardized surveys have been conducted by state biologists and technicians in a wide variety of locations in many different streams across all of the lower Hawaiian Islands. The point quadrat survey is a visual survey in which both habitat and species information are recorded within a defined point in a stream. As a result, at a defined location we have a record of species occurrence. This survey location can be mapped and the co-occurring elevation, distance inland, and maximum downstream slope can be extracted from gridded GIS data. This results in a data set in which all survey points have a location, the values for the instream distribution variables, and the presence or absence of each species.

To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977) and as reported for Hawaiian stream animals (Parham 2008). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution.

The decision on the bin sizes for the various continuous variables was set subjectively to balance several factors. First, the number of samples in each bin attempted to have at least 200 observations from the total number of samples. Next, the bin sizes were adjusted to make the number of samples in each bin as consistent as possible, and finally, the bins were distributed to cover a range of biologically meaningful values. For example, the native amphidromous animals migrate upstream from the ocean. As the elevation increases different species are less likely to be observed, therefore, the elevation bins are more closely spaced at lower elevations and more widely spaced at higher elevations to see changes that occur as the animals move upstream.

The selection of animals included in this analysis was based on the overall number of sites in which the animals were observed. In most cases, at least 50 independent site observations were needed to include the animal in development of specific suitability criteria, although in some cases smaller sample sizes were accepted if the species had consistently been observed in other suitability criteria variables. In a perfect database, all observations of the animals would have all of the information included, but in many cases, the information for certain variables were not recorded so sample size varies among criteria. The database and spreadsheets are designed to allow changes in bin distribution or species to allow user adjustment to account for specific project needs.

<u>GIS Suitability Modeling</u>

The use of table based suitability criteria was in part based on the desire to allow rapid integration of the results with the GIS map-based analyses. The spreadsheet results were multiplied by 100 and then converted to integer values to fit the GIS reclassification requirements. The bins were split into a “from value” and “to value” with the integer suitability for each species in the subsequent columns. For example using elevation, the “from value” may be 0 and the “to value” was 2, the next “from value” would be 3 to 5, etc. No overlap of subsequent “from” and “to” values are allowed, although the “from” and “to” value on an individual line can be the same value.

After converting the suitability table to the reclassification format, the spreadsheet was converted to a database table (dbf). Next, the dbf table was imported into ArcGIS. In ArcGIS, the distributional layers were added to the map. Each layer was developed in previous work from the

USGS 10 meter digital elevation model. The distribution layers of elevation, distance inland, and maximum downstream slope were used to predict instream distribution of the native amphidromous animals. Prediction of the instream distribution of introduced animals is difficult as most of their locations are based on proximity to the place of introduction in the stream and not migration.

The instream distributional variables were combined by using map algebra where the results of each of the suitability criteria layers were multiplied together to describe a range of conditions from most to least suitable in a stream. Within the stream sections that a species is expected to occur, the habitat suitability criteria describe the suitable habitat for the species. To determine the appropriate combination method within the ArcGIS map algebra, two of the most commonly used methods were tried. These combination methods were an additive model and a multiplicative model.

- Instream Distribution Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)
  where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0
- Instream Distribution Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

To determine which of these combination methods were more appropriate for an individual species, the variables for elevation, distance inland, and downstream barrier height were combined using two different relationships. Next, each relationship was range standardized with a minimum value of 0 and a maximum value of 1. Then, the results of each relationship for all sites with all data for each variable in the database were calculated. The sites were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 100 of the 8300 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples. The results of the comparison of predicted suitability with the proportion of samples containing a species were plotted on a graph and analyzed using linear regression.

To select the more appropriate relationship, two criteria were used. First, the distribution of predicted results to observed proportions was visually compared. If predicted values between 0 and 1 resulted in a range of proportions between 0 and 1, the relationship was considered acceptable. If both relationships were acceptable to the first criteria, then the relationship with the higher r^2 value for the linear regression was chosen.

Figure 40 to Figure 45 graphically show the suitability for the native amphidromous stream animals. While Table 2 to Table 25 show the bins, frequency, utilization, suitability, and smooth suitability for the species. Finally, Figure 46 to Figure 53 show the selected combination method and its associated linear regression with statistics for each species.

Elevation Suitability Indices

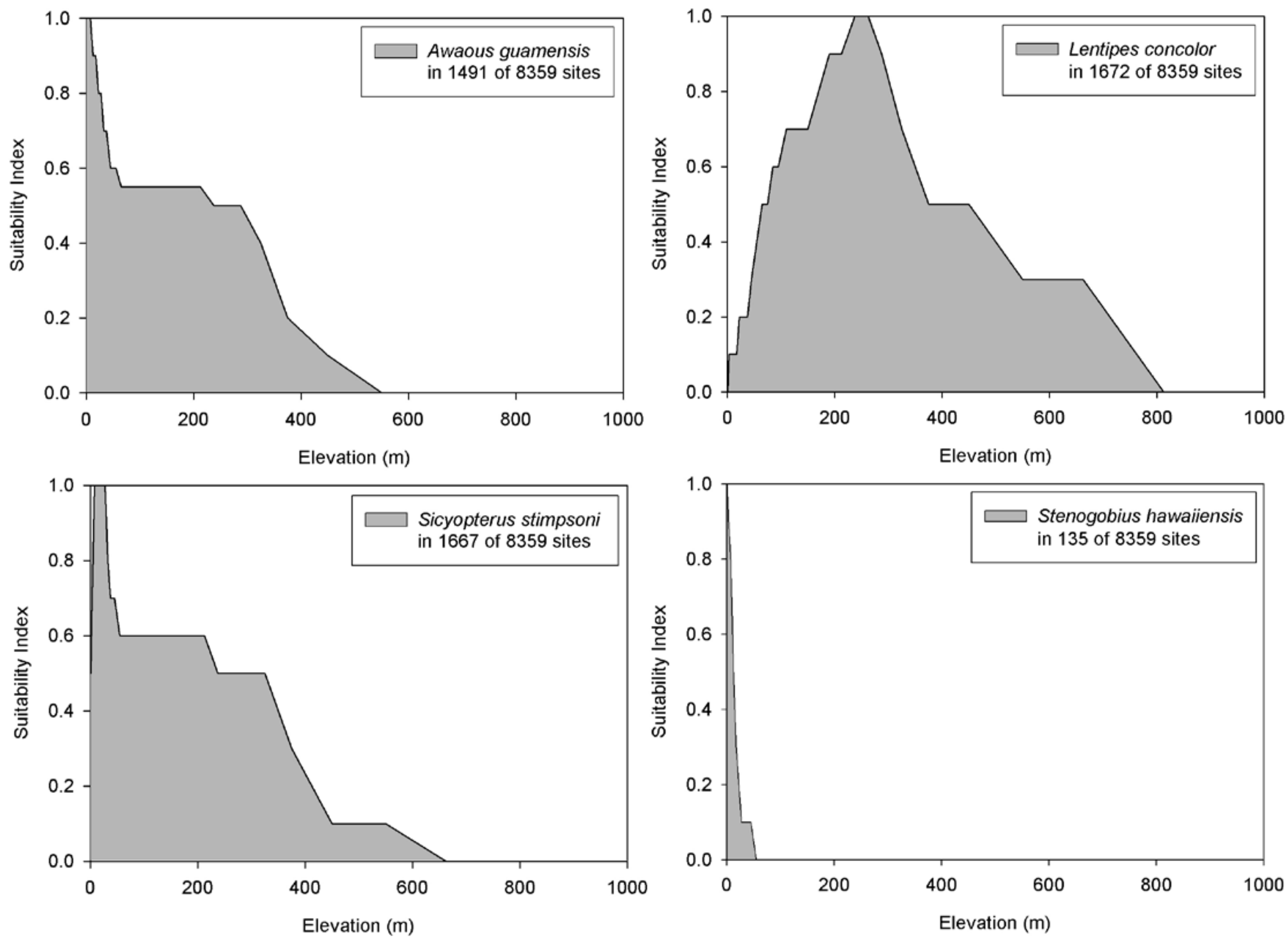

Figure 40: Suitability Indices for Elevation for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

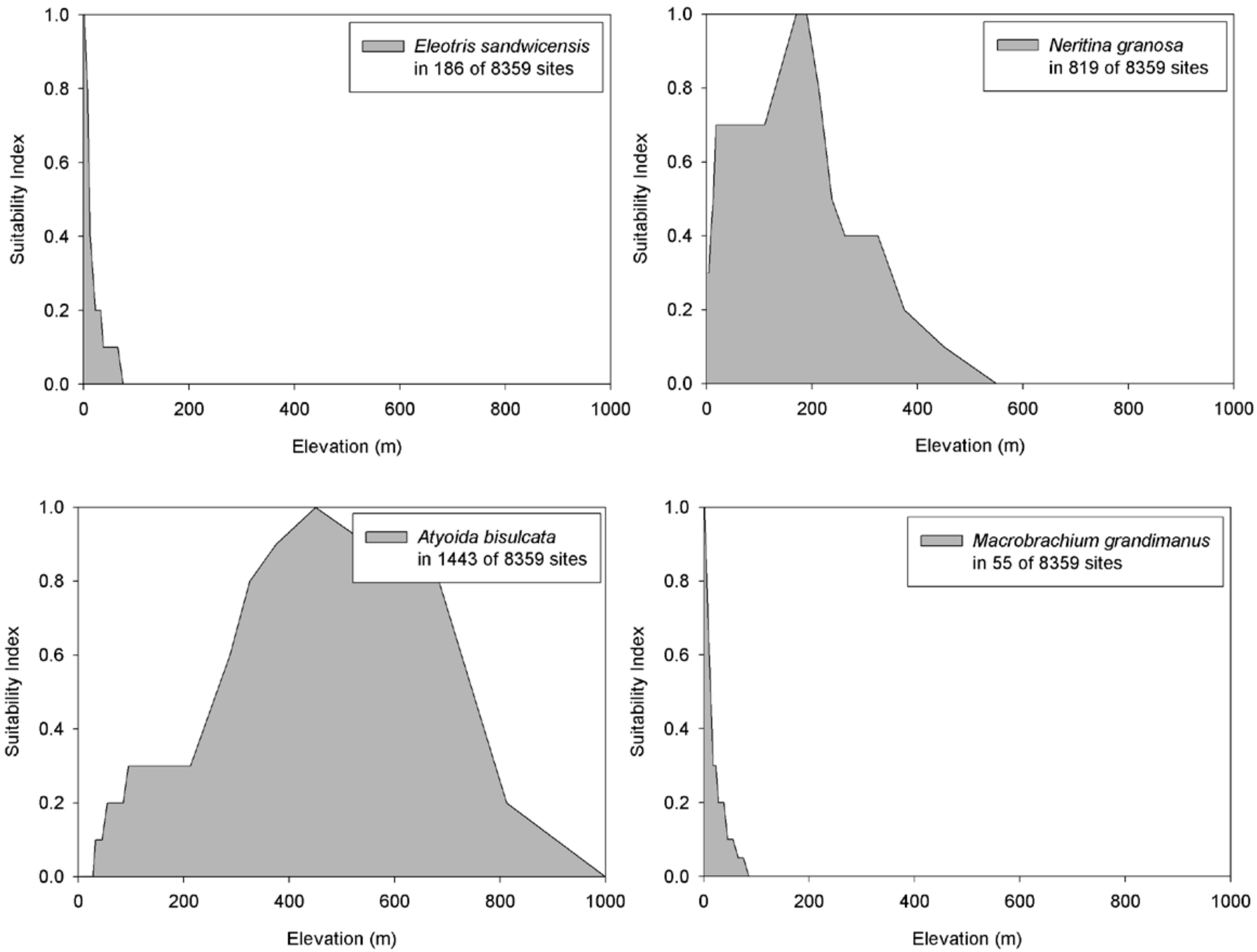

Figure 41: Suitability Indices for Elevation for *Eleotris sandwicensis*, *Neritina granosa*, *Atyoida bisulcata*, and *Macrobrachium grandimanus.*

Distance Inland Suitability Indices

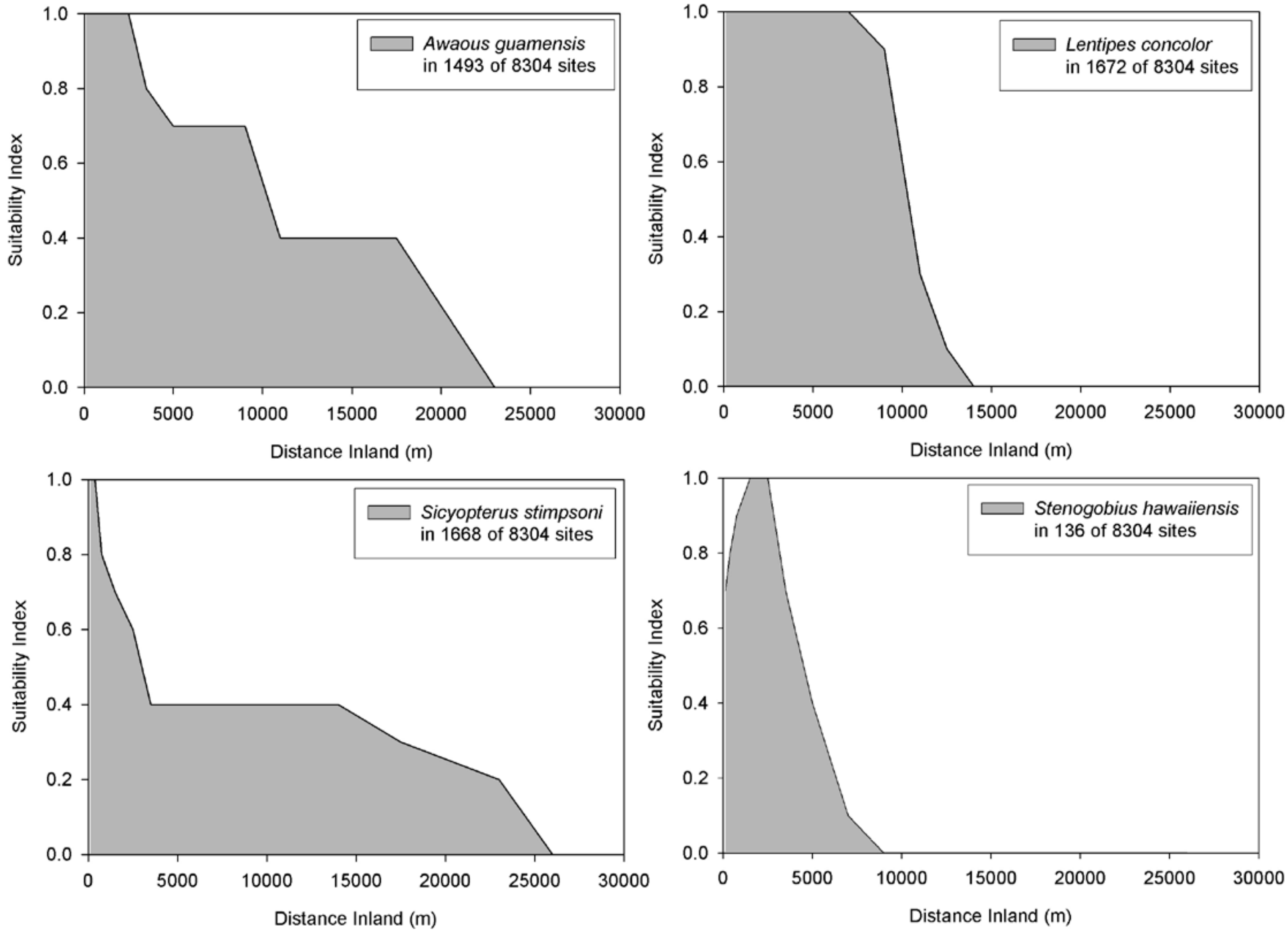

Figure 42: Suitability Indices for Distance Inland for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Stenogobius hawaiiensis.*

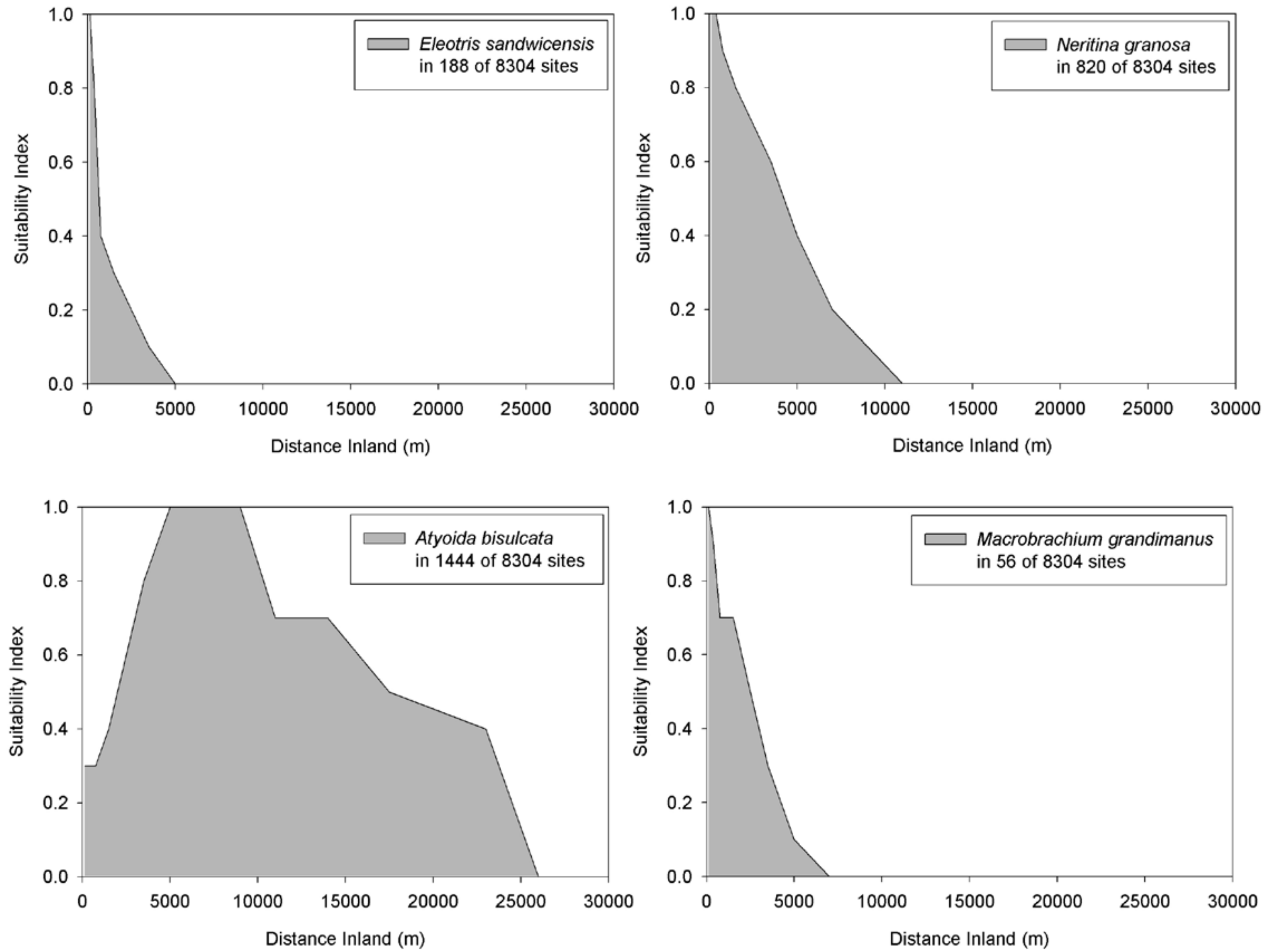

Figure 43: Suitability Indices for Distance Inland for *Eleotris sandwicensis, Neritina granosa, Atyoida bisulcata,* and *Macrobrachium grandimanus.*

Barrier Height Suitability Indices

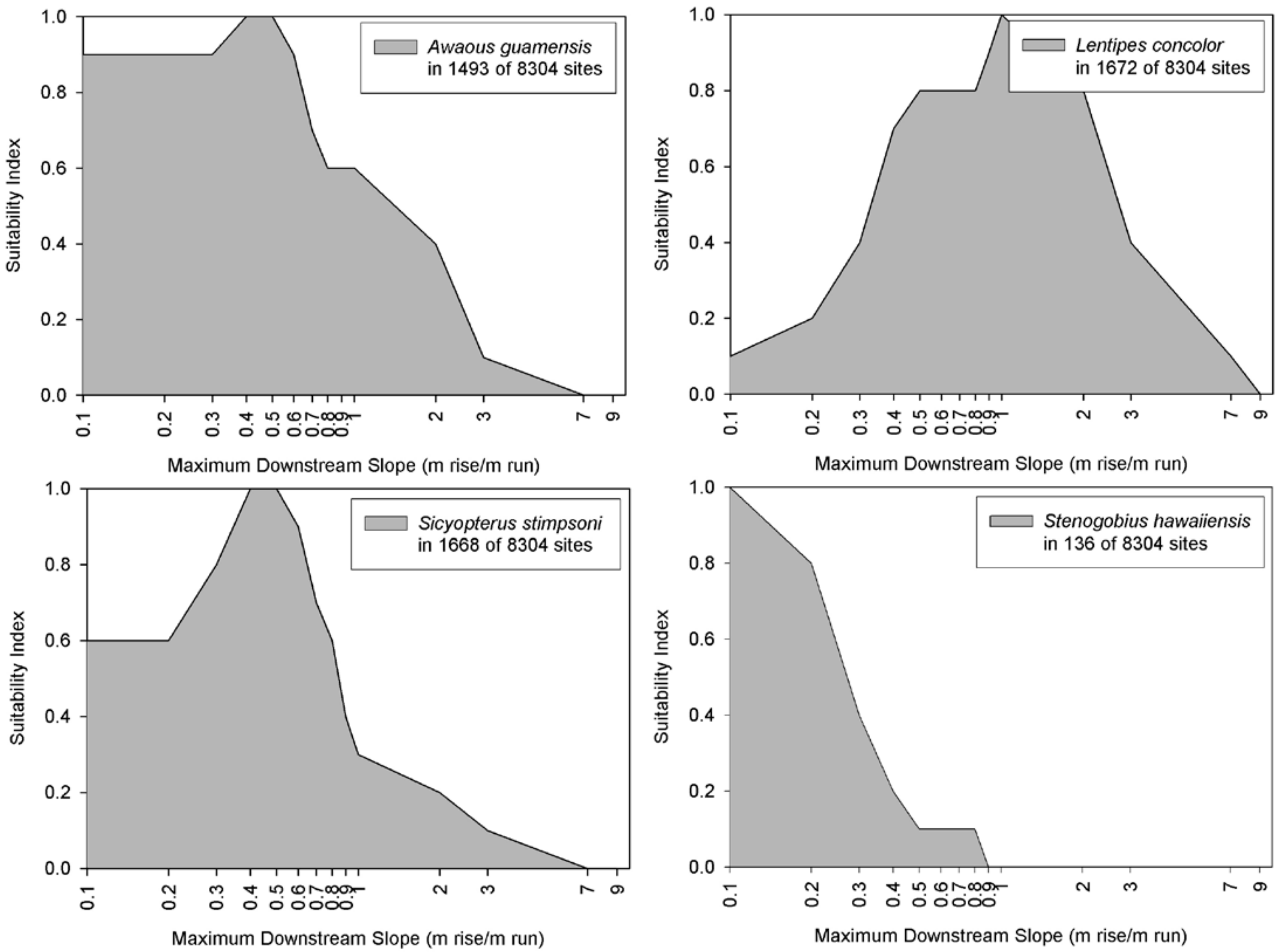

Figure 44: Suitability Indices for Barriers (maximum downstream slope over 10m distance) for *Awaous guamensis, Lentipes concolor, Sicyopterus stimpsoni,* and *Stenogobius hawaiiensis.*

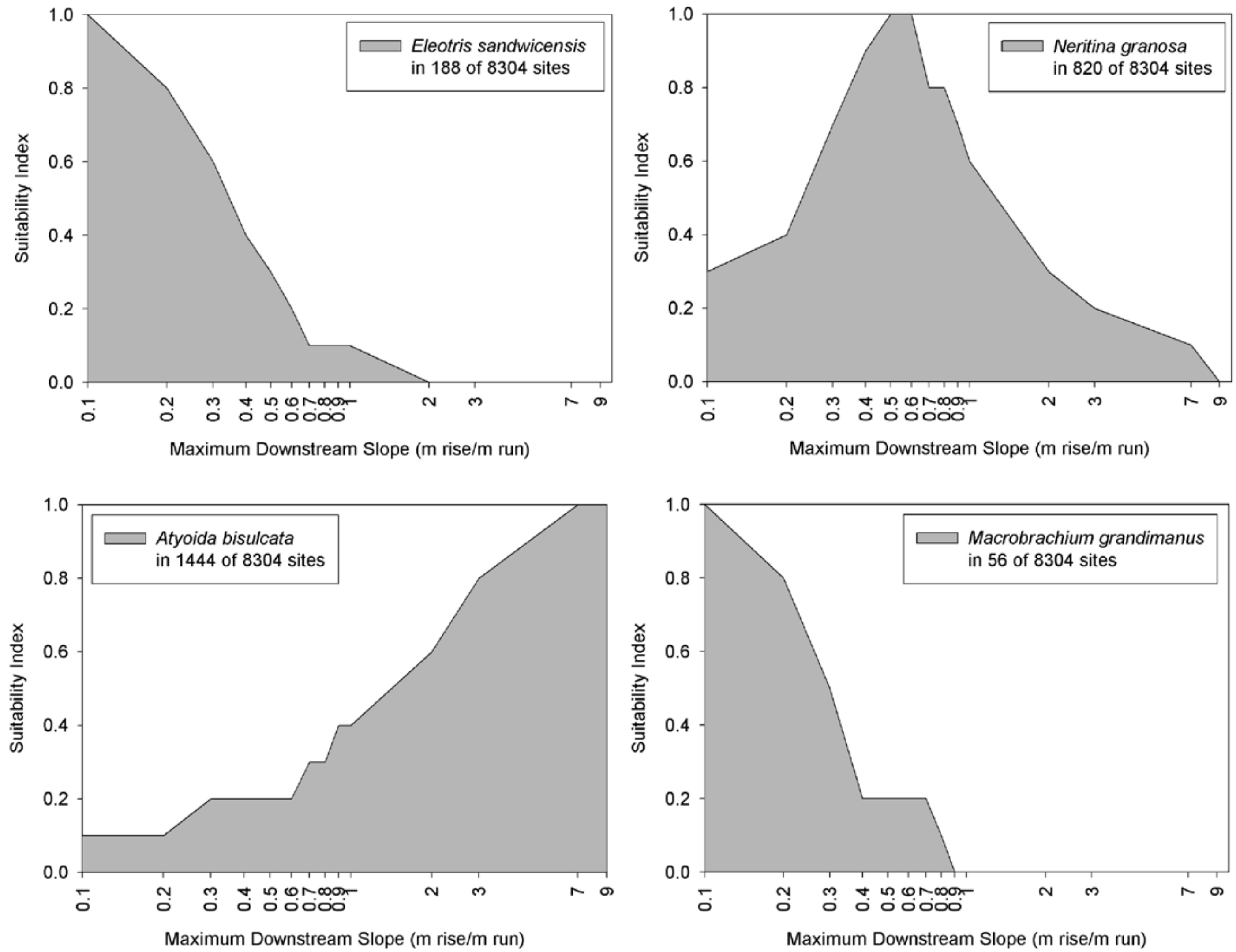

Figure 45: Suitability Indices for Barriers (maximum downstream slope over 10m distance) for *Eleotris sandwicensis, Neritina granosa, Atyoida bisulcata,* and *Macrobrachium grandimanus.*

Table 2: Frequency of occurrence for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	111	1	29	12	1	27	1	5	9	2	33	3	4	6	12	5	8
5	331	5	109	56	2	71	11	11	47	35	70	1	2	87	38	4	7
10	470	12	136	46	12	63	15	14	105	31	100	13	3	162	36	6	33
15	333	5	93	18	9	20	12	7	61	20	89	12	9	111	20	8	20
20	274	9	73	5	6	10	14	3	51	41	77	9	3	78	8	6	23
25	315	4	76	14	3	29	18	2	60	53	84	11	2	100	6	6	27
30	243	7	55	9	3	6	34	3	60	34	74	7	1	83	6	2	17
35	306	10	78	5	2	9	22	3	81	40	84	15	3	79	1	4	37
40	186	10	34	8	2	2	18	0	53	26	57	7	1	40	2	3	22
50	355	23	71	1	6	2	41	3	66	28	130	25	4	70	1	6	45
60	414	44	71	6	4	4	82	0	85	50	144	11	15	91	3	9	31
70	284	38	53	2	2	1	58	1	76	19	90	4	5	55	1	2	23
80	393	46	51	1	1	5	94	0	81	31	151	3	7	59	0	4	8
90	245	30	24	0	1	0	47	1	51	15	111	5	4	34	0	8	6
100	174	30	26	0	0	2	47	0	36	16	62	5	2	40	0	3	5
120	319	59	68	1	2	1	106	2	74	43	86	11	7	57	1	17	8
140	324	53	46	0	2	0	101	0	81	51	87	9	5	53	0	14	4
160	296	42	70	0	2	0	88	0	69	46	87	16	5	68	0	3	13
180	311	41	55	1	2	0	102	0	56	60	86	13	5	89	0	4	4
200	220	41	52	0	3	0	83	0	27	45	60	10	2	48	0	4	8
225	288	43	49	0	1	0	110	0	42	46	88	9	2	48	0	9	4
250	287	50	44	1	3	0	102	0	28	19	100	8	3	43	0	7	3
275	215	55	24	0	1	1	114	0	21	10	46	1	1	29	0	4	4
300	189	64	41	0	0	0	71	0	2	22	47	0	1	41	0	0	1
350	298	122	37	0	2	0	69	0	15	17	81	4	1	52	0	6	2
400	278	147	17	0	2	0	71	0	2	8	99	1	6	16	0	2	1
500	406	192	5	0	2	0	77	0	2	10	173	0	1	21	0	0	2
600	320	209	0	0	6	0	50	0	1	1	76	0	26	5	0	0	41
700	126	45	4	0	1	0	8	0	0	0	69	2	5	2	0	0	7
1000	44	6	0	0	0	0	6	0	0	0	31	0	0	0	0	0	0
1000+	4	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Total	8359	1443	1491	186	83	253	1672	55	1342	819	2576	215	135	1667	135	146	414

Table 3: Percent Utilization for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1.3	0.1	1.9	6.5	1.2	10.7	0.1	9.1	0.7	0.2	1.3	1.4	3.0	0.4	8.9	3.4	1.9
5	4.0	0.3	7.3	30.1	2.4	28.1	0.7	20.0	3.5	4.3	2.7	0.5	1.5	5.2	28.1	2.7	1.7
10	5.6	0.8	9.1	24.7	14.5	24.9	0.9	25.5	7.8	3.8	3.9	6.0	2.2	9.7	26.7	4.1	8.0
15	4.0	0.3	6.2	9.7	10.8	7.9	0.7	12.7	4.5	2.4	3.5	5.6	6.7	6.7	14.8	5.5	4.8
20	3.3	0.6	4.9	2.7	7.2	4.0	0.8	5.5	3.8	5.0	3.0	4.2	2.2	4.7	5.9	4.1	5.6
25	3.8	0.3	5.1	7.5	3.6	11.5	1.1	3.6	4.5	6.5	3.3	5.1	1.5	6.0	4.4	4.1	6.5
30	2.9	0.5	3.7	4.8	3.6	2.4	2.0	5.5	4.5	4.2	2.9	3.3	0.7	5.0	4.4	1.4	4.1
35	3.7	0.7	5.2	2.7	2.4	3.6	1.3	5.5	6.0	4.9	3.3	7.0	2.2	4.7	0.7	2.7	8.9
40	2.2	0.7	2.3	4.3	2.4	0.8	1.1	0.0	3.9	3.2	2.2	3.3	0.7	2.4	1.5	2.1	5.3
50	4.2	1.6	4.8	0.5	7.2	0.8	2.5	5.5	4.9	3.4	5.0	11.6	3.0	4.2	0.7	4.1	10.9
60	5.0	3.0	4.8	3.2	4.8	1.6	4.9	0.0	6.3	6.1	5.6	5.1	11.1	5.5	2.2	6.2	7.5
70	3.4	2.6	3.6	1.1	2.4	0.4	3.5	1.8	5.7	2.3	3.5	1.9	3.7	3.3	0.7	1.4	5.6
80	4.7	3.2	3.4	0.5	1.2	2.0	5.6	0.0	6.0	3.8	5.9	1.4	5.2	3.5	0.0	2.7	1.9
90	2.9	2.1	1.6	0.0	1.2	0.0	2.8	1.8	3.8	1.8	4.3	2.3	3.0	2.0	0.0	5.5	1.4
100	2.1	2.1	1.7	0.0	0.0	0.8	2.8	0.0	2.7	2.0	2.4	2.3	1.5	2.4	0.0	2.1	1.2
120	3.8	4.1	4.6	0.5	2.4	0.4	6.3	3.6	5.5	5.3	3.3	5.1	5.2	3.4	0.7	11.6	1.9
140	3.9	3.7	3.1	0.0	2.4	0.0	6.0	0.0	6.0	6.2	3.4	4.2	3.7	3.2	0.0	9.6	1.0
160	3.5	2.9	4.7	0.0	2.4	0.0	5.3	0.0	5.1	5.6	3.4	7.4	3.7	4.1	0.0	2.1	3.1
180	3.7	2.8	3.7	0.5	2.4	0.0	6.1	0.0	4.2	7.3	3.3	6.0	3.7	5.3	0.0	2.7	1.0
200	2.6	2.8	3.5	0.0	3.6	0.0	5.0	0.0	2.0	5.5	2.3	4.7	1.5	2.9	0.0	2.7	1.9
225	3.4	3.0	3.3	0.0	1.2	0.0	6.6	0.0	3.1	5.6	3.4	4.2	1.5	2.9	0.0	6.2	1.0
250	3.4	3.5	3.0	0.5	3.6	0.0	6.1	0.0	2.1	2.3	3.9	3.7	2.2	2.6	0.0	4.8	0.7
275	2.6	3.8	1.6	0.0	1.2	0.4	6.8	0.0	1.6	1.2	1.8	0.5	0.7	1.7	0.0	2.7	1.0
300	2.3	4.4	2.7	0.0	0.0	0.0	4.2	0.0	0.1	2.7	1.8	0.0	0.7	2.5	0.0	0.0	0.2
350	3.6	8.5	2.5	0.0	2.4	0.0	4.1	0.0	1.1	2.1	3.1	1.9	0.7	3.1	0.0	4.1	0.5
400	3.3	10.2	1.1	0.0	2.4	0.0	4.2	0.0	0.1	1.0	3.8	0.5	4.4	1.0	0.0	1.4	0.2
500	4.9	13.3	0.3	0.0	2.4	0.0	4.6	0.0	0.1	1.2	6.7	0.0	0.7	1.3	0.0	0.0	0.5
600	3.8	14.5	0.0	0.0	7.2	0.0	3.0	0.0	0.1	0.1	3.0	0.0	19.3	0.3	0.0	0.0	9.9
700	1.5	3.1	0.3	0.0	1.2	0.0	0.5	0.0	0.0	0.0	2.7	0.9	3.7	0.1	0.0	0.0	1.7
1000	0.5	0.4	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0
1000+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0

Table 4: Standardized suitability for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1	0.01	0.79	0.64	0.33	1.00	0.02	1.00	0.28	0.09	0.30	0.38	0.44	0.16	0.94	0.85	0.56
5	1	0.02	1.00	1.00	0.22	0.88	0.06	0.74	0.50	0.52	0.21	0.04	0.07	0.76	1.00	0.23	0.17
10	1	0.04	0.88	0.58	0.94	0.55	0.06	0.66	0.78	0.32	0.21	0.39	0.08	1.00	0.67	0.24	0.55
15	1	0.02	0.85	0.32	1.00	0.25	0.07	0.47	0.64	0.29	0.27	0.51	0.33	0.97	0.52	0.45	0.47
20	1	0.05	0.81	0.11	0.81	0.15	0.10	0.24	0.65	0.73	0.28	0.47	0.13	0.83	0.25	0.41	0.66
25	1	0.02	0.73	0.26	0.35	0.38	0.11	0.14	0.67	0.82	0.27	0.50	0.08	0.92	0.17	0.36	0.67
30	1	0.04	0.69	0.22	0.46	0.10	0.26	0.27	0.87	0.68	0.30	0.41	0.05	0.99	0.22	0.15	0.55
35	1	0.05	0.77	0.10	0.24	0.12	0.14	0.22	0.93	0.64	0.27	0.70	0.12	0.75	0.03	0.25	0.94
40	1	0.08	0.56	0.25	0.40	0.04	0.18	0.00	1.00	0.68	0.31	0.53	0.07	0.62	0.09	0.30	0.92
50	1	0.10	0.61	0.02	0.63	0.02	0.22	0.19	0.65	0.39	0.37	1.00	0.14	0.57	0.02	0.32	0.99
60	1	0.16	0.52	0.09	0.36	0.04	0.37	0.00	0.72	0.59	0.35	0.38	0.45	0.64	0.06	0.41	0.58
70	1	0.20	0.57	0.04	0.26	0.01	0.39	0.08	0.94	0.33	0.32	0.20	0.22	0.56	0.03	0.13	0.63
80	1	0.18	0.39	0.02	0.09	0.05	0.45	0.00	0.72	0.39	0.38	0.11	0.22	0.44	0.00	0.19	0.16
90	1	0.19	0.30	0.00	0.15	0.00	0.36	0.09	0.73	0.30	0.45	0.29	0.20	0.40	0.00	0.61	0.19
100	1	0.26	0.45	0.00	0.00	0.05	0.51	0.00	0.73	0.45	0.36	0.41	0.14	0.67	0.00	0.32	0.22
120	1	0.28	0.65	0.02	0.23	0.01	0.63	0.14	0.81	0.66	0.27	0.49	0.27	0.52	0.03	1.00	0.20
140	1	0.25	0.43	0.00	0.23	0.00	0.59	0.00	0.88	0.77	0.27	0.39	0.19	0.47	0.00	0.81	0.10
160	1	0.22	0.72	0.00	0.25	0.00	0.56	0.00	0.82	0.76	0.29	0.77	0.21	0.67	0.00	0.19	0.34
180	1	0.20	0.54	0.02	0.24	0.00	0.62	0.00	0.63	0.94	0.28	0.59	0.20	0.83	0.00	0.24	0.10
200	1	0.29	0.72	0.00	0.50	0.00	0.71	0.00	0.43	1.00	0.27	0.65	0.11	0.63	0.00	0.34	0.28
225	1	0.23	0.52	0.00	0.13	0.00	0.72	0.00	0.51	0.78	0.31	0.44	0.09	0.48	0.00	0.59	0.11
250	1	0.27	0.47	0.02	0.39	0.00	0.67	0.00	0.34	0.32	0.35	0.40	0.13	0.43	0.00	0.46	0.08
275	1	0.39	0.34	0.00	0.17	0.02	1.00	0.00	0.34	0.23	0.21	0.07	0.06	0.39	0.00	0.35	0.15
300	1	0.52	0.66	0.00	0.00	0.00	0.71	0.00	0.04	0.57	0.25	0.00	0.07	0.63	0.00	0.00	0.04
350	1	0.63	0.38	0.00	0.25	0.00	0.44	0.00	0.18	0.28	0.27	0.19	0.04	0.51	0.00	0.38	0.05
400	1	0.81	0.19	0.00	0.27	0.00	0.48	0.00	0.03	0.14	0.36	0.05	0.27	0.17	0.00	0.13	0.03
500	1	0.72	0.04	0.00	0.18	0.00	0.36	0.00	0.02	0.12	0.43	0.00	0.03	0.15	0.00	0.00	0.04
600	1	1.00	0.00	0.00	0.69	0.00	0.29	0.00	0.01	0.02	0.24	0.00	1.00	0.05	0.00	0.00	1.00
700	1	0.55	0.10	0.00	0.29	0.00	0.12	0.00	0.00	0.00	0.55	0.23	0.49	0.05	0.00	0.00	0.43
1000	1	0.21	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00
1000+	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 5: Smoothed standardized suitability for site elevation (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Elevation Bin	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
2	1	0.02	0.90	0.82	0.28	0.94	0.04	0.87	0.39	0.30	0.25	0.21	0.26	0.46	0.97	0.54	0.36
5	1	0.03	0.89	0.74	0.50	0.81	0.05	0.80	0.52	0.31	0.24	0.27	0.20	0.64	0.87	0.44	0.43
10	1	0.03	0.91	0.63	0.72	0.56	0.06	0.62	0.64	0.38	0.23	0.32	0.16	0.91	0.73	0.31	0.39
15	1	0.04	0.85	0.34	0.92	0.32	0.07	0.46	0.69	0.45	0.25	0.46	0.18	0.93	0.48	0.37	0.56
20	1	0.03	0.80	0.23	0.72	0.26	0.09	0.28	0.65	0.62	0.27	0.49	0.18	0.90	0.31	0.41	0.60
25	1	0.04	0.74	0.20	0.54	0.21	0.16	0.22	0.73	0.75	0.28	0.46	0.09	0.91	0.21	0.31	0.62
30	1	0.04	0.73	0.19	0.35	0.20	0.17	0.21	0.82	0.72	0.28	0.53	0.08	0.89	0.14	0.25	0.72
35	1	0.06	0.67	0.19	0.37	0.09	0.19	0.16	0.93	0.67	0.30	0.55	0.08	0.79	0.11	0.23	0.80
40	1	0.08	0.65	0.12	0.42	0.06	0.18	0.14	0.86	0.57	0.32	0.74	0.11	0.65	0.05	0.29	0.95
50	1	0.11	0.56	0.12	0.46	0.04	0.26	0.06	0.79	0.55	0.34	0.64	0.22	0.61	0.06	0.34	0.83
60	1	0.16	0.56	0.05	0.41	0.03	0.33	0.09	0.77	0.43	0.34	0.53	0.27	0.59	0.04	0.29	0.74
70	1	0.18	0.49	0.05	0.24	0.04	0.40	0.03	0.79	0.43	0.35	0.23	0.29	0.55	0.03	0.24	0.46
80	1	0.19	0.42	0.02	0.17	0.02	0.40	0.06	0.80	0.34	0.38	0.20	0.21	0.47	0.01	0.31	0.33
90	1	0.21	0.38	0.01	0.08	0.03	0.44	0.03	0.73	0.38	0.40	0.27	0.19	0.50	0.00	0.38	0.19
100	1	0.24	0.47	0.01	0.13	0.02	0.50	0.08	0.76	0.47	0.36	0.40	0.20	0.53	0.01	0.65	0.20
120	1	0.27	0.51	0.01	0.15	0.02	0.57	0.05	0.81	0.63	0.30	0.43	0.20	0.55	0.01	0.71	0.17
140	1	0.25	0.60	0.01	0.24	0.00	0.59	0.05	0.84	0.73	0.28	0.55	0.22	0.55	0.01	0.67	0.21
160	1	0.22	0.56	0.01	0.24	0.00	0.59	0.00	0.78	0.82	0.28	0.59	0.20	0.66	0.00	0.41	0.18
180	1	0.23	0.66	0.01	0.33	0.00	0.63	0.00	0.63	0.90	0.28	0.67	0.17	0.71	0.00	0.26	0.24
200	1	0.24	0.59	0.01	0.29	0.00	0.68	0.00	0.52	0.91	0.28	0.56	0.13	0.65	0.00	0.39	0.16
225	1	0.26	0.57	0.01	0.34	0.00	0.70	0.00	0.43	0.70	0.31	0.50	0.11	0.52	0.00	0.46	0.16
250	1	0.30	0.44	0.01	0.23	0.01	0.80	0.00	0.40	0.44	0.29	0.30	0.09	0.44	0.00	0.46	0.11
275	1	0.39	0.49	0.01	0.19	0.01	0.79	0.00	0.24	0.37	0.27	0.15	0.08	0.49	0.00	0.27	0.09
300	1	0.51	0.46	0.00	0.14	0.01	0.72	0.00	0.19	0.36	0.24	0.09	0.05	0.51	0.00	0.24	0.08
350	1	0.65	0.41	0.00	0.17	0.00	0.54	0.00	0.08	0.33	0.29	0.08	0.12	0.43	0.00	0.17	0.04
400	1	0.72	0.20	0.00	0.23	0.00	0.43	0.00	0.07	0.18	0.35	0.08	0.11	0.27	0.00	0.17	0.04
500	1	0.84	0.07	0.00	0.38	0.00	0.38	0.00	0.02	0.09	0.34	0.02	0.43	0.12	0.00	0.04	0.36
600	1	0.76	0.04	0.00	0.39	0.00	0.26	0.00	0.01	0.05	0.40	0.08	0.51	0.08	0.00	0.00	0.49
700	1	0.59	0.03	0.00	0.33	0.00	0.22	0.00	0.00	0.01	0.50	0.08	0.50	0.03	0.00	0.00	0.48
1000	1	0.25	0.03	0.00	0.10	0.00	0.13	0.00	0.00	0.00	0.75	0.08	0.16	0.02	0.00	0.00	0.14
1000+	1	0.10	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00

Table 6: Frequency of occurrence for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	763	53	182	86	9	115	134	18	193	100	10	110	16	7	270	15	2	8
500	653	55	105	24	9	40	154	1	150	115	0	167	9	7	184	9	1	13
1,000	1050	101	191	24	13	34	250	10	220	150	1	267	24	12	301	24	6	42
2,000	1256	112	283	37	15	37	195	15	252	116	2	389	28	14	290	33	31	62
3,000	1136	183	217	10	7	18	158	8	223	140	0	378	50	21	187	22	25	104
4,000	1190	309	198	6	4	6	250	2	181	110	0	377	15	38	170	24	19	93
6,000	1116	319	132	0	12	2	339	2	86	59	0	362	34	14	135	8	31	48
8,000	528	161	48	1	5	1	141	0	30	28	0	218	14	7	65	1	18	18
12,000	396	112	55	0	6	1	48	0	6	2	0	170	13	6	44	0	12	11
17,000	136	23	42	0	3	0	3	0	2	0	0	63	8	5	16	0	1	7
17,000+	80	16	40	0	0	0	0	0	0	0	0	18	4	4	6	0	0	8
Total	8304	1444	1493	188	83	254	1672	56	1343	820	13	2519	215	135	1668	136	146	414

Table 7: Percent Utilization for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	9.2	3.7	12.2	45.7	10.8	45.3	8.0	32.1	14.4	12.2	76.9	4.4	7.4	5.2	16.2	11.0	1.4	1.9
500	7.9	3.8	7.0	12.8	10.8	15.7	9.2	1.8	11.2	14.0	0.0	6.6	4.2	5.2	11.0	6.6	0.7	3.1
1,000	12.6	7.0	12.8	12.8	15.7	13.4	15.0	17.9	16.4	18.3	7.7	10.6	11.2	8.9	18.0	17.6	4.1	10.1
2,000	15.1	7.8	19.0	19.7	18.1	14.6	11.7	26.8	18.8	14.1	15.4	15.4	13.0	10.4	17.4	24.3	21.2	15.0
3,000	13.7	12.7	14.5	5.3	8.4	7.1	9.4	14.3	16.6	17.1	0.0	15.0	23.3	15.6	11.2	16.2	17.1	25.1
4,000	14.3	21.4	13.3	3.2	4.8	2.4	15.0	3.6	13.5	13.4	0.0	15.0	7.0	28.1	10.2	17.6	13.0	22.5
6,000	13.4	22.1	8.8	0.0	14.5	0.8	20.3	3.6	6.4	7.2	0.0	14.4	15.8	10.4	8.1	5.9	21.2	11.6
8,000	6.4	11.1	3.2	0.5	6.0	0.4	8.4	0.0	2.2	3.4	0.0	8.7	6.5	5.2	3.9	0.7	12.3	4.3
12,000	4.8	7.8	3.7	0.0	7.2	0.4	2.9	0.0	0.4	0.2	0.0	6.7	6.0	4.4	2.6	0.0	8.2	2.7
17,000	1.6	1.6	2.8	0.0	3.6	0.0	0.2	0.0	0.1	0.0	0.0	2.5	3.7	3.7	1.0	0.0	0.7	1.7
17,000+	1.0	1.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.9	3.0	0.4	0.0	0.0	1.9

Table 8: Standardized suitability for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	1	0.23	0.48	1.00	0.53	1.00	0.58	1.00	1.00	0.74	1.00	0.31	0.36	0.18	1.00	0.75	0.08	0.10
500	1	0.28	0.32	0.33	0.62	0.41	0.78	0.06	0.91	1.00	0.00	0.55	0.23	0.21	0.80	0.52	0.04	0.20
1,000	1	0.32	0.36	0.20	0.56	0.21	0.78	0.40	0.83	0.81	0.07	0.55	0.39	0.23	0.81	0.87	0.17	0.40
2,000	1	0.29	0.45	0.26	0.54	0.20	0.51	0.51	0.79	0.52	0.12	0.67	0.38	0.22	0.65	1.00	0.72	0.49
3,000	1	0.53	0.38	0.08	0.28	0.11	0.46	0.30	0.78	0.70	0.00	0.72	0.75	0.37	0.47	0.74	0.65	0.92
4,000	1	0.85	0.33	0.04	0.15	0.03	0.69	0.07	0.60	0.52	0.00	0.68	0.21	0.64	0.40	0.77	0.47	0.78
6,000	1	0.94	0.24	0.00	0.49	0.01	1.00	0.08	0.30	0.30	0.00	0.70	0.52	0.25	0.34	0.27	0.81	0.43
8,000	1	1.00	0.18	0.02	0.43	0.01	0.88	0.00	0.22	0.30	0.00	0.89	0.45	0.27	0.35	0.07	1.00	0.34
12,000	1	0.93	0.28	0.00	0.69	0.02	0.40	0.00	0.06	0.03	0.00	0.93	0.56	0.30	0.31	0.00	0.89	0.28
17,000	1	0.55	0.62	0.00	1.00	0.00	0.07	0.00	0.06	0.00	0.00	1.00	1.00	0.74	0.33	0.00	0.22	0.51
17,000+	1	0.66	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.85	1.00	0.21	0.00	0.00	1.00

Table 9: Smoothed standardized suitability for distance inland (m) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Distance Inland (m)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	*Neritina vespertina*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
250	1	0.25	0.40	0.66	0.58	0.70	0.68	0.53	0.95	0.87	0.50	0.43	0.30	0.20	0.90	0.64	0.06	0.15
500	1	0.27	0.39	0.51	0.57	0.54	0.71	0.49	0.91	0.85	0.36	0.47	0.33	0.21	0.87	0.71	0.10	0.23
1,000	1	0.29	0.38	0.26	0.58	0.27	0.69	0.32	0.84	0.78	0.06	0.59	0.33	0.22	0.75	0.80	0.31	0.36
2,000	1	0.38	0.40	0.18	0.46	0.17	0.58	0.40	0.80	0.68	0.06	0.65	0.51	0.27	0.64	0.87	0.51	0.60
3,000	1	0.56	0.39	0.13	0.32	0.11	0.55	0.29	0.72	0.58	0.04	0.69	0.45	0.41	0.51	0.83	0.61	0.73
4,000	1	0.77	0.32	0.04	0.31	0.05	0.72	0.15	0.56	0.51	0.00	0.70	0.49	0.42	0.40	0.59	0.64	0.71
6,000	1	0.93	0.25	0.02	0.36	0.02	0.86	0.05	0.38	0.38	0.00	0.76	0.39	0.38	0.36	0.37	0.76	0.52
8,000	1	0.95	0.23	0.01	0.53	0.01	0.76	0.03	0.20	0.21	0.00	0.84	0.51	0.27	0.33	0.11	0.90	0.35
12,000	1	0.83	0.36	0.01	0.71	0.01	0.45	0.00	0.11	0.11	0.00	0.94	0.67	0.43	0.33	0.02	0.70	0.38
17,000	1	0.71	0.63	0.00	0.56	0.01	0.16	0.00	0.04	0.01	0.00	0.80	0.80	0.68	0.29	0.00	0.37	0.60
17,000+	1	0.61	0.81	0.00	0.50	0.00	0.04	0.00	0.03	0.00	0.00	0.74	0.93	0.87	0.27	0.00	0.11	0.76

Table 10: Frequency of occurrence for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1177	44	237	59	21	99	15	24	205	37	459	55	25	140	75	35	142
0.2	1189	81	263	63	15	83	50	17	195	78	399	38	16	293	25	32	103
0.3	941	175	200	20	6	29	140	6	168	102	265	29	8	173	21	29	28
0.4	728	98	145	13	12	13	119	2	130	99	249	26	6	197	2	15	28
0.5	1160	96	298	22	16	15	447	2	201	230	263	15	7	490	6	13	16
0.6	442	79	93	3	2	7	110	2	58	59	170	14	8	89	3	1	17
0.7	259	32	40	3	1	5	58	1	46	33	91	3	3	57	3	3	10
0.8	283	69	21	1	0	1	75	0	48	27	81	20	9	47	0	9	3
0.9	254	46	34	2	0	1	68	0	75	44	76	3	2	28	0	3	0
1	421	148	75	2	1	1	157	0	30	23	98	3	1	31	1	3	3
2	1171	379	85	0	3	0	425	2	166	86	301	5	15	121	0	2	10
3	242	170	2	0	3	0	7	0	7	1	60	4	35	2	0	1	54
3+	37	27	0	0	3	0	1	0	14	1	7	0	0	0	0	0	0
Total	8304	1444	1493	188	83	254	1672	56	1343	820	2519	215	135	1668	136	146	414

Table 11: Percent Utilization for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	14.2	3.0	15.9	31.4	25.3	39.0	0.9	42.9	15.3	4.5	18.2	25.6	18.5	8.4	55.1	24.0	34.3
0.2	14.3	5.6	17.6	33.5	18.1	32.7	3.0	30.4	14.5	9.5	15.8	17.7	11.9	17.6	18.4	21.9	24.9
0.3	11.3	12.1	13.4	10.6	7.2	11.4	8.4	10.7	12.5	12.4	10.5	13.5	5.9	10.4	15.4	19.9	6.8
0.4	8.8	6.8	9.7	6.9	14.5	5.1	7.1	3.6	9.7	12.1	9.9	12.1	4.4	11.8	1.5	10.3	6.8
0.5	14.0	6.6	20.0	11.7	19.3	5.9	26.7	3.6	15.0	28.0	10.4	7.0	5.2	29.4	4.4	8.9	3.9
0.6	5.3	5.5	6.2	1.6	2.4	2.8	6.6	3.6	4.3	7.2	6.7	6.5	5.9	5.3	2.2	0.7	4.1
0.7	3.1	2.2	2.7	1.6	1.2	2.0	3.5	1.8	3.4	4.0	3.6	1.4	2.2	3.4	2.2	2.1	2.4
0.8	3.4	4.8	1.4	0.5	0.0	0.4	4.5	0.0	3.6	3.3	3.2	9.3	6.7	2.8	0.0	6.2	0.7
0.9	3.1	3.2	2.3	1.1	0.0	0.4	4.1	0.0	5.6	5.4	3.0	1.4	1.5	1.7	0.0	2.1	0.0
1	5.1	10.2	5.0	1.1	1.2	0.4	9.4	0.0	2.2	2.8	3.9	1.4	0.7	1.9	0.7	2.1	0.7
2	14.1	26.2	5.7	0.0	3.6	0.0	25.4	3.6	12.4	10.5	11.9	2.3	11.1	7.3	0.0	1.4	2.4
3	2.9	11.8	0.1	0.0	3.6	0.0	0.4	0.0	0.5	0.1	2.4	1.9	25.9	0.1	0.0	0.7	13.0
3+	0.4	1.9	0.0	0.0	3.6	0.0	0.1	0.0	1.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Table 12: Standardized suitability for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1.00	0.05	0.78	0.95	0.22	1.00	0.03	1.00	0.46	0.16	1.00	0.66	0.15	0.28	1.00	0.94	0.54
0.2	1.00	0.09	0.86	1.00	0.16	0.83	0.11	0.70	0.43	0.33	0.86	0.45	0.09	0.58	0.33	0.85	0.39
0.3	1.00	0.25	0.83	0.40	0.08	0.37	0.39	0.31	0.47	0.55	0.72	0.44	0.06	0.44	0.35	0.97	0.13
0.4	1.00	0.18	0.78	0.34	0.20	0.21	0.42	0.13	0.47	0.69	0.88	0.51	0.06	0.64	0.04	0.65	0.17
0.5	1.00	0.11	1.00	0.36	0.17	0.15	1.00	0.08	0.46	1.00	0.58	0.18	0.04	1.00	0.08	0.35	0.06
0.6	1.00	0.24	0.82	0.13	0.06	0.19	0.65	0.22	0.35	0.67	0.99	0.45	0.13	0.48	0.11	0.07	0.17
0.7	1.00	0.17	0.60	0.22	0.05	0.23	0.58	0.19	0.47	0.64	0.90	0.16	0.08	0.52	0.18	0.36	0.17
0.8	1.00	0.33	0.29	0.07	0.00	0.04	0.69	0.00	0.45	0.48	0.73	1.00	0.22	0.39	0.00	1.00	0.05
0.9	1.00	0.25	0.52	0.15	0.00	0.05	0.69	0.00	0.78	0.87	0.77	0.17	0.05	0.26	0.00	0.37	0.00
1	1.00	0.48	0.69	0.09	0.03	0.03	0.97	0.00	0.19	0.28	0.60	0.10	0.02	0.17	0.04	0.22	0.03
2	1.00	0.44	0.28	0.00	0.03	0.00	0.94	0.08	0.37	0.37	0.66	0.06	0.09	0.24	0.00	0.05	0.04
3	1.00	0.96	0.03	0.00	0.15	0.00	0.08	0.00	0.08	0.02	0.64	0.23	1.00	0.02	0.00	0.13	1.00
3+	1.00	1.00	0.00	0.00	1.00	0.00	0.07	0.00	1.00	0.14	0.49	0.00	0.00	0.00	0.00	0.00	0.00

Table 13: Smoothed standardized suitability for maximum downstream slope (m rise /m run) by the species that occurred in at least 50 different survey sites within the DAR Aquatic Surveys Database. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Maximum Downstream Slope	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Tilapia sp.*	*Xiphophorus helleri*
0.1	1.00	0.07	0.82	0.97	0.19	0.91	0.07	0.85	0.45	0.24	0.93	0.56	0.12	0.43	0.66	0.89	0.46
0.2	1.00	0.13	0.82	0.78	0.15	0.73	0.18	0.67	0.46	0.35	0.86	0.52	0.10	0.43	0.56	0.92	0.35
0.3	1.00	0.18	0.82	0.58	0.15	0.47	0.31	0.38	0.46	0.52	0.82	0.46	0.07	0.55	0.24	0.82	0.23
0.4	1.00	0.18	0.87	0.37	0.15	0.24	0.60	0.18	0.47	0.74	0.73	0.37	0.05	0.69	0.16	0.66	0.12
0.5	1.00	0.18	0.86	0.27	0.14	0.18	0.69	0.15	0.43	0.79	0.81	0.38	0.07	0.71	0.08	0.36	0.14
0.6	1.00	0.18	0.81	0.23	0.09	0.19	0.74	0.17	0.42	0.77	0.82	0.27	0.08	0.67	0.12	0.26	0.14
0.7	1.00	0.25	0.57	0.14	0.03	0.15	0.64	0.14	0.42	0.60	0.87	0.54	0.14	0.46	0.10	0.48	0.13
0.8	1.00	0.25	0.47	0.14	0.02	0.11	0.65	0.06	0.57	0.67	0.80	0.44	0.12	0.39	0.06	0.58	0.07
0.9	1.00	0.35	0.50	0.10	0.01	0.04	0.78	0.00	0.47	0.54	0.70	0.42	0.10	0.28	0.01	0.53	0.03
1	1.00	0.39	0.50	0.08	0.02	0.03	0.87	0.03	0.45	0.51	0.67	0.11	0.05	0.23	0.01	0.22	0.02
2	1.00	0.63	0.34	0.03	0.07	0.01	0.66	0.03	0.21	0.22	0.63	0.13	0.37	0.15	0.01	0.14	0.36
3	1.00	0.80	0.10	0.00	0.39	0.00	0.36	0.03	0.48	0.18	0.59	0.10	0.36	0.09	0.00	0.06	0.35
3+	1.00	0.98	0.02	0.00	0.58	0.00	0.07	0.00	0.54	0.08	0.56	0.12	0.50	0.01	0.00	0.06	0.50

Awaous guamensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

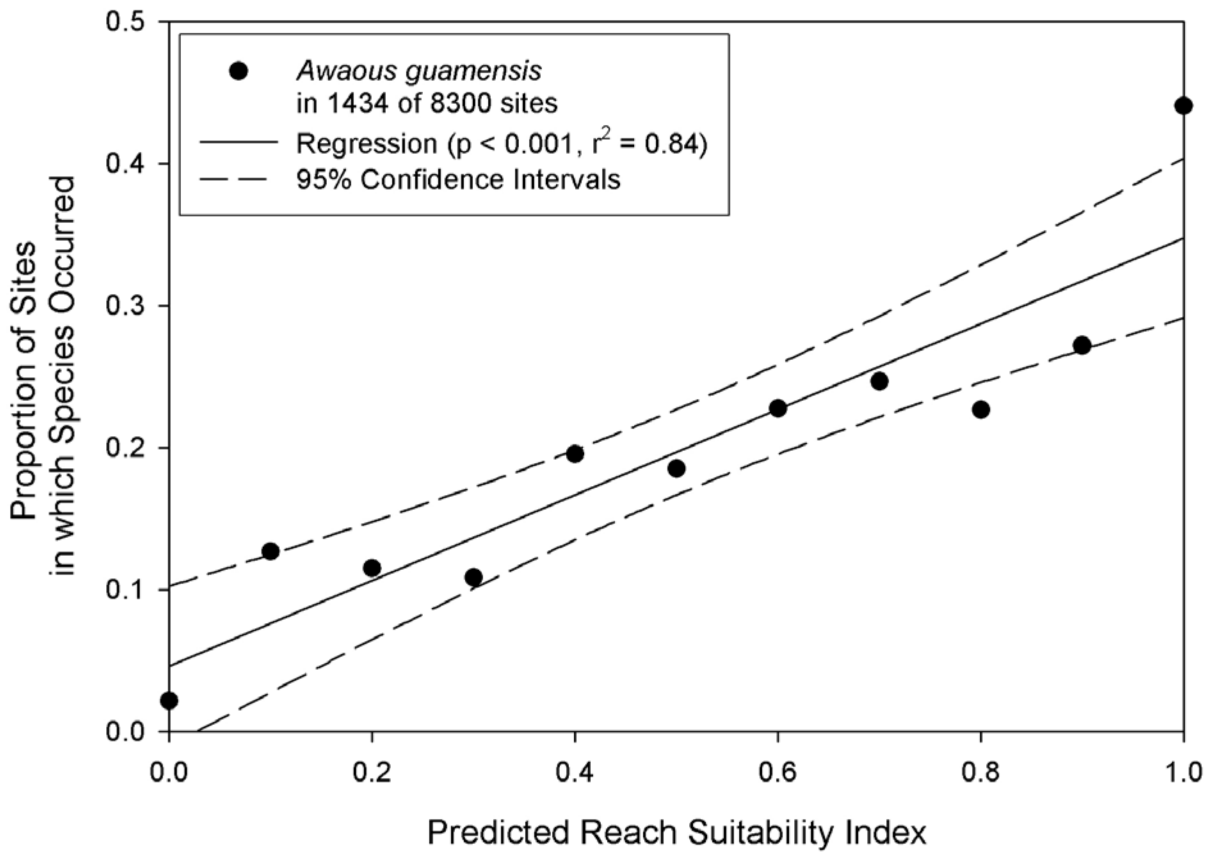

Figure 46: Proportion of the total sites where *Awaous guamensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

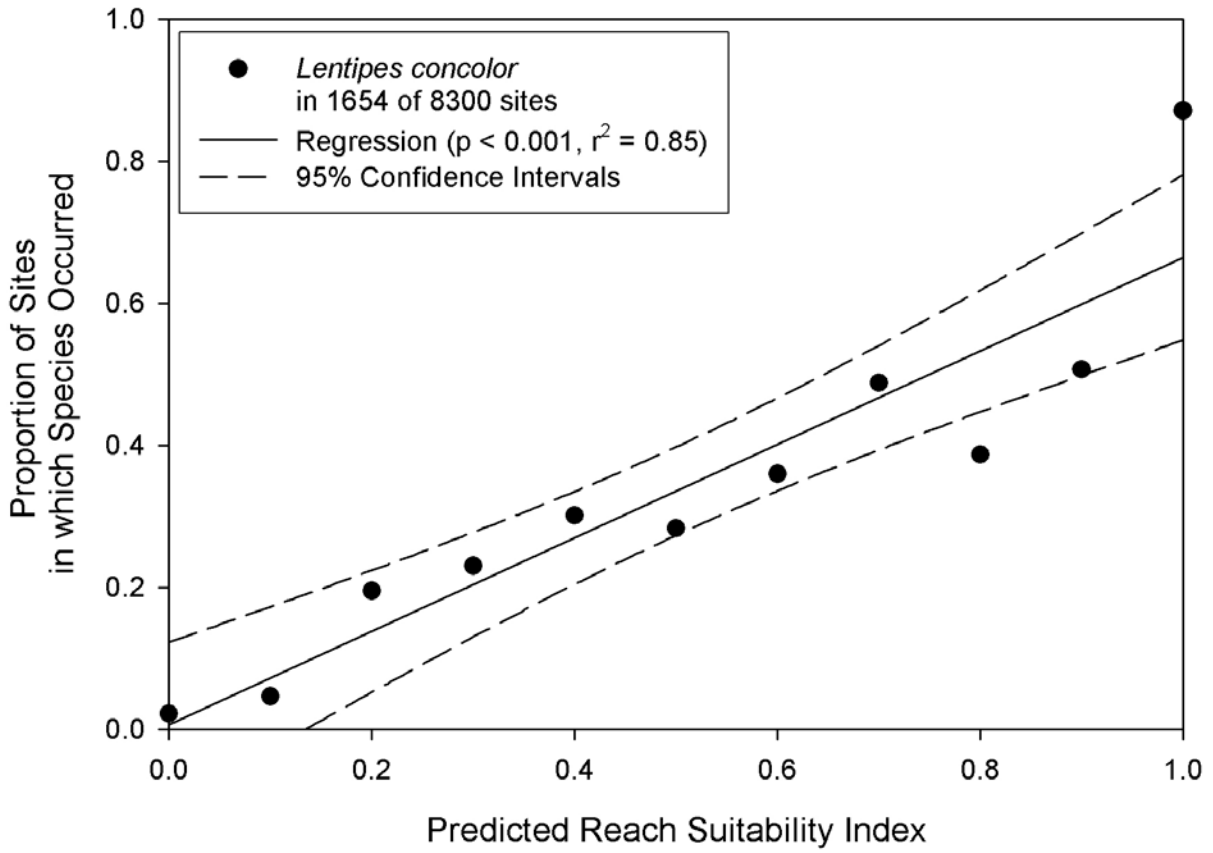

Figure 47: Proportion of the total sites where *Lentipes concolor* was observed within each 0.1 group of the Reach Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

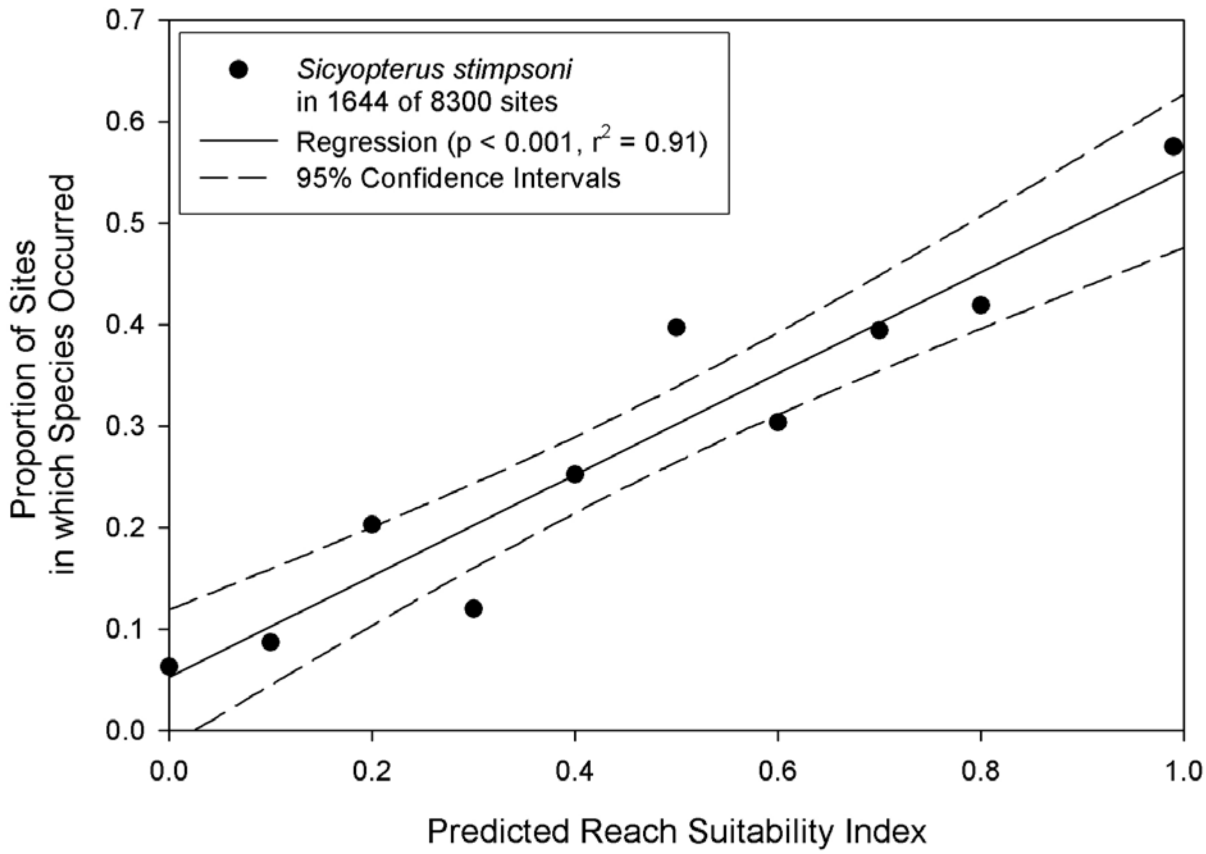

Figure 48: Proportion of the total sites where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Reach Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

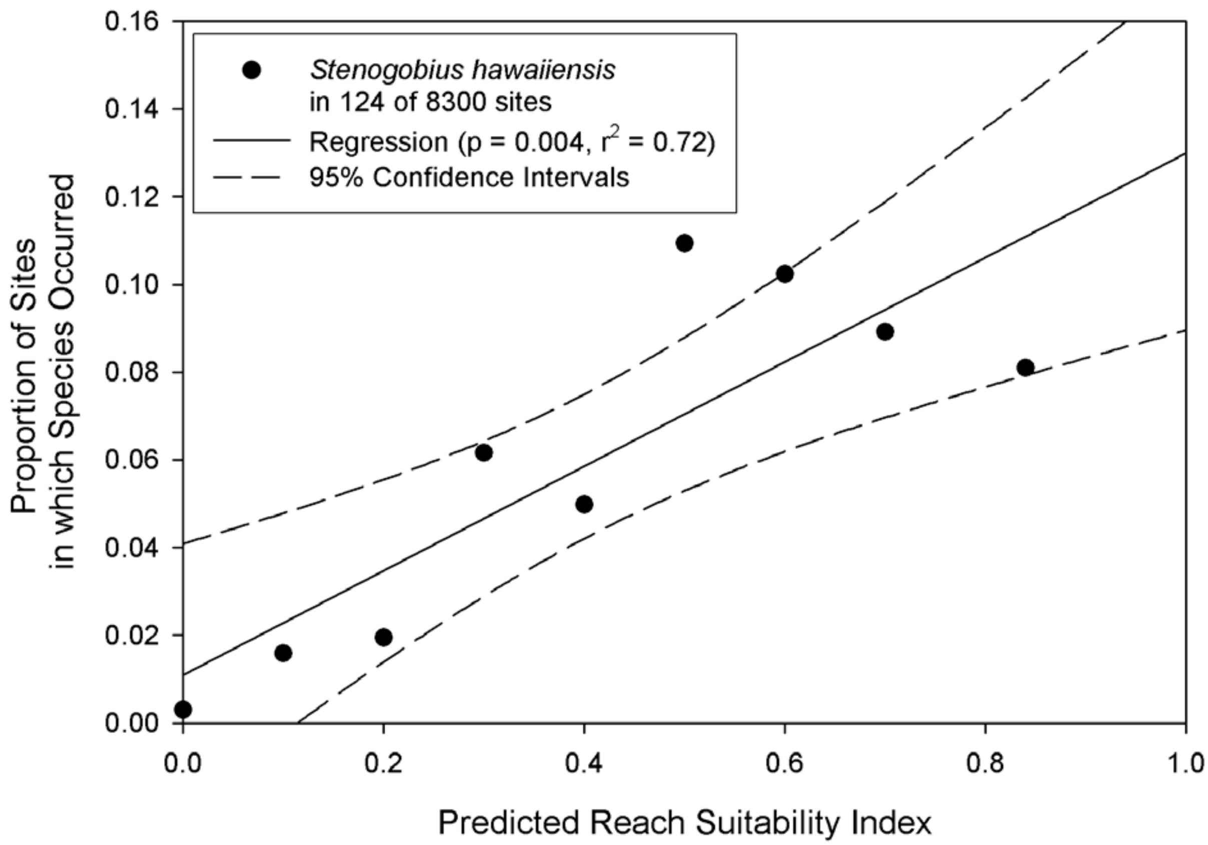

Figure 49: Proportion of the total sites where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

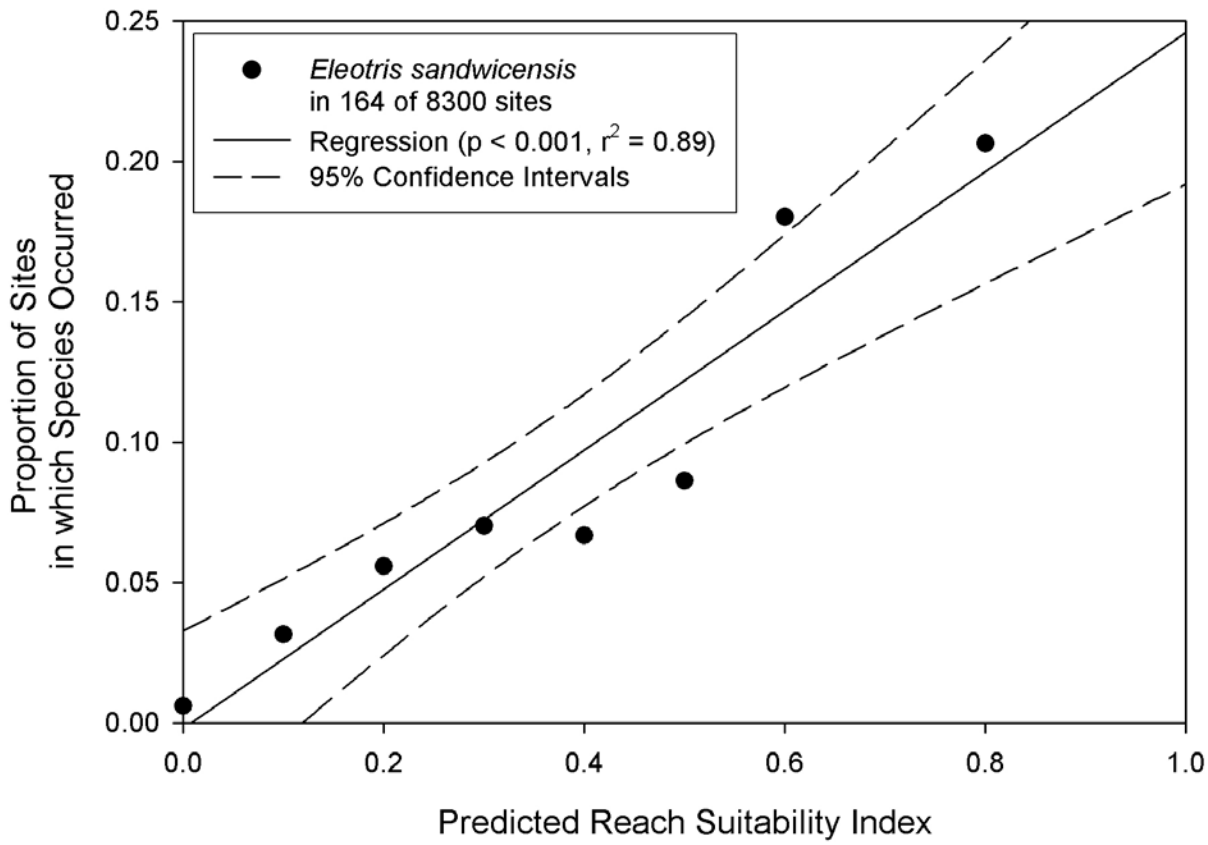

Figure 50: Proportion of the total sites where *Eleotris sandwicensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

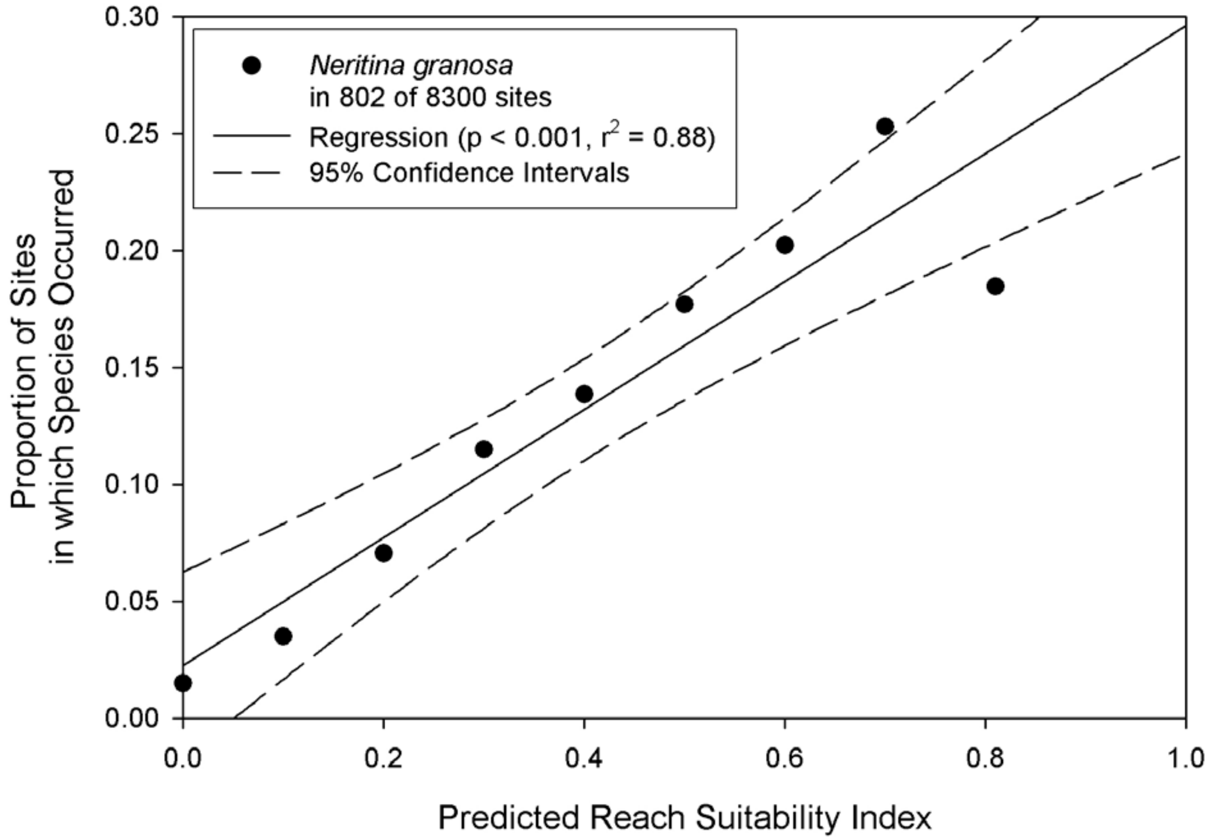

Figure 51: Proportion of the total sites where *Neritina granosa* was observed within each 0.1 group of the Reach Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability)

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

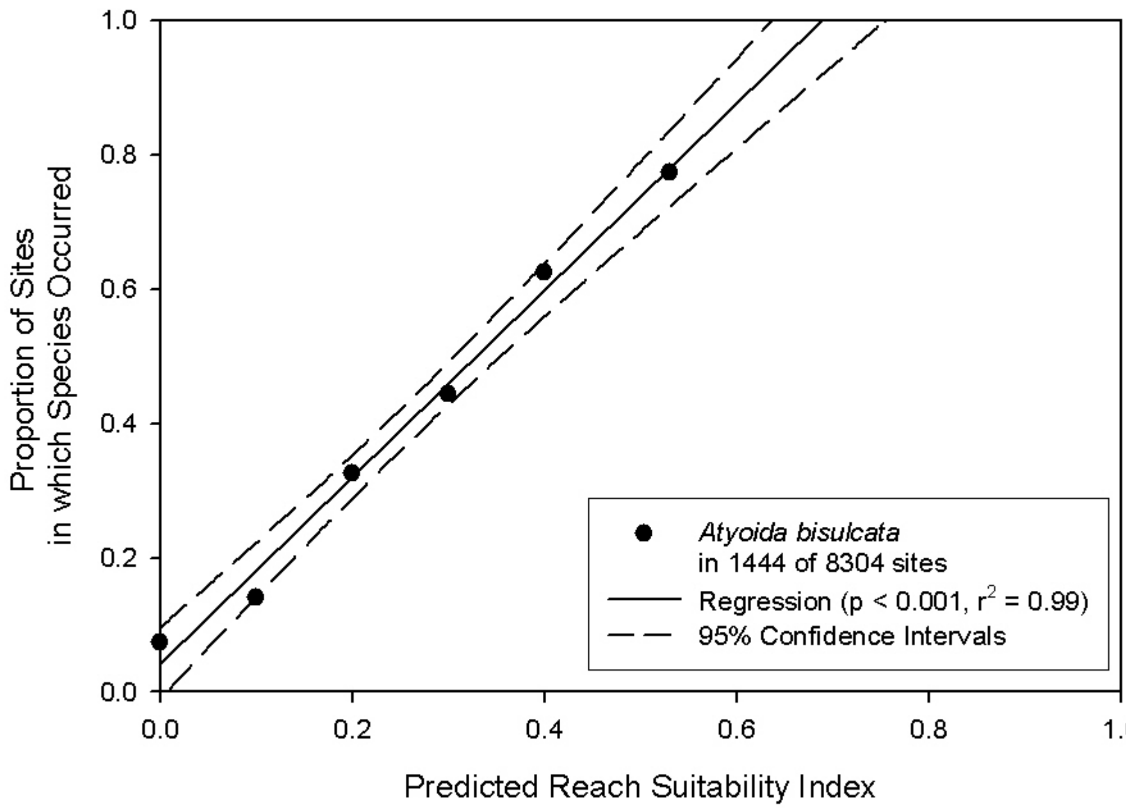

Figure 52: Proportion of the total sites where *Atyoida bisulcata* was observed within each 0.1 group of the Reach Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)

where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

Both relationships had adequate distributions and the equation with the higher r^2 was selected.

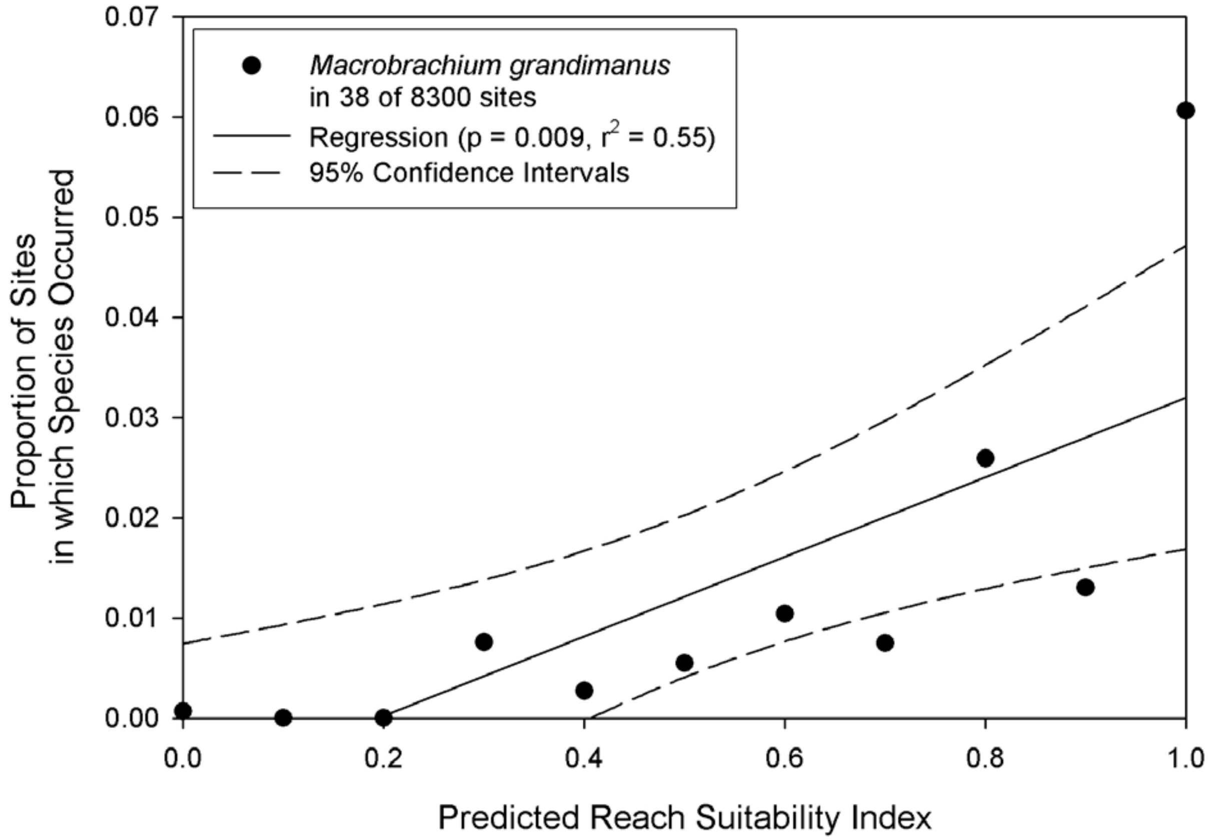

Figure 53: Proportion of the total sites where *Macrobrachium grandimanus* was observed within each 0.1 group of the Reach Suitability Index equation for *Macrobrachium grandimanus*.

Appendix 3: Site Scale Metrics

All data reflected in this report came from the DAR Aquatic Surveys Database. The data for the habitat level variables of habitat type, depth, substrate, and temperature were gathered from DAR point quadrat survey data within the DAR Aquatic Surveys Database as these surveys consistently used the same methodology to collect these habitat variables.

Following an identical process to developing suitability criteria for the instream distribution variables, suitability was determined for site scale metrics. To compare the suitability for the stream animals, availability, utilization, and suitability criteria were developed following standardized procedures (Bovee and Cochnauer 1977). In general, this method bases habitat utilization on the presence/absence data and does not take into account site density. Habitat availability is the frequency of each habitat category and is based on the distribution of habitats observed in the field survey. Percent availability is calculated by dividing the number of observations for a habitat category by the total number of observations and multiplying by 100. Utilization is the frequency of occurrence for an individual species in each habitat category. Percent utilization is calculated by dividing the number of sites with a species observed for a habitat category by the total number of sites with a species observed and multiplying by 100. Suitability is developed by dividing the percent utilization for each habitat category with the percent availability for each habitat category. The standardized suitability has the range adjusted so that the largest value for each species equals 1 (highly suitable) and the lowest value equals 0 (unsuitable). The smoothed standardized suitability was created by averaging the value for the bin with its two nearest neighbors. In the case of the first and last bin values, they were only averaged with the single bin next to them. The smoothed suitability was used to decrease the variation between adjacent bins as a result of same size or sample distribution. Non-ordinal categorical suitability criteria (e.g., habitat types) were not smoothed.

The decision on the bin sizes for the various continuous variables was set subjectively to balance several factors. First, the number of samples in each bin attempted to have at least 200 observations from the total number of samples. Next, the bin sizes were adjusted to make the number of samples in each bin as consistent as possible, and finally, the bins were distributed to fit the field survey data. For example, the HDSS technique classified depth into specific depth categories. In this case, the field depth categories were used to most closely match survey information.

To combine the various site scale variables into an overall suitability score for the site the following process is followed. Data from field surveys are used to characterize local habitat. Typical data collected during field surveys can be divided into two broad categories. First are those descriptive variables that differentiate natural habitat into more or less suitable units. For example, habitat type classifications into riffle runs or pools or depth classification from shallow to deep are good examples of differentiation of natural habitat into different units. The second type of descriptive variables is those variables that describe some level of human modification to natural habitats. For example, the extent of channelization or presence of flood control structures occurring at a site modifies what natural habitat would be normally expected to be found at the location. So in general, first we calculate the natural conditions at a site and then score for the natural condition is modified by downward by extent of human modification at the site.

For native amphidromous animals found in Hawaiian streams, we typically describe habitat with respect to variables associated with habitat type, depth, substrate, water velocity, water quality, bank and riparian condition to describe the natural stream habitats. Not all surveys of stream habitat record all of these variables. Habitat type, depth, substrate, water quality, bank and riparian conditions form the core descriptors stream animal habitat using the HDSS techniques. At a single location a linear combination of the suitability for each of the five variables is used to provide an overall suitability score. The combination would be the suitability for each score added together and divided by the total number of variables. This approach allows some flexibility to utilize the variables are collected during field sampling.

The next set of variables are associated with human modification of the environment include channel type, substrate embeddedness, or other human modifications of the environment that may be recorded during surveys. These variables modify the natural habitat variables described above. For example, cobble may be the primary substrate, but if it is highly embedded with fine sediment than it is less suitable than non-embedded cobble substrate. Not all variables will have a modifier variable.

The overall site impact score calculation is defined in advance and is applied identically to all sites within the HSHEP model. So while some variables may or may not occur in a specific application of an HSHEP model, within a specific application of the model all variables will be consistently applied.

For the application of the HSHEP model within the Ala Wai watershed streams, the variable combination calculations are as follows:

Site Suitability Equation for each species is –

$$(HV_1 * MV_1 + HV_2 * MV_2 + \cdots HV_n * MV_n)/n$$

where habitat variables (HV) and associated Modifier Variables (MV) are shown below:

Area	Habitat Variable	Modifier Variable
Habitat Type	Habitat Type	Channel Condition
Substrate	Substrate	Embeddedness
Depth	Depth	
Water Quality	Threshold limits for Temperature, Dissolved Oxygen, pH, Conductivity	
Bank & Riparian Condition	(Bank Height + Bank Angle + Surface Protection + Riparian Condition)/4	

Change as a result of an instream alteration (either negative or positive) in physical habitat, water quantity or water quality that will need to be able to be measured by one of the habitat or modifier variables to be able to quantify habitat changes in a HSHEP model.

Note to reviewer: The data for the site variables shown below are being updated to reflect the latest information within the DAR Aquatic Surveys Database but provide a good example of the data and the approach.

Table 14: Frequency, percent utilization, and standardized suitability for the use of habitat types by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Colors in the standardized suitability reflect three groups to aid in interpreting the data. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green. No smoothed standardized suitability values are presented as the habitat types are categorical variables.

	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Gambusia affinis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
Frequency															
Cascade	84	11	7	0	0	0	17	12	18	35	0	0	13	0	1
Riffle	1076	162	138	13	1	18	223	131	170	354	10	2	307	7	14
Run	3216	505	587	66	15	134	734	486	359	863	57	23	780	75	158
Pool	1605	279	320	28	28	43	374	358	127	429	55	23	209	21	105
Plunge Pool	213	67	33	6	1	1	64	40	42	37	0	5	44	0	6
Side Pool	649	97	111	14	10	20	101	132	43	217	21	2	99	9	33
Total	6843	1121	1196	127	55	216	1513	1159	759	1935	143	55	1452	112	317
Percent Utilization															
Cascade	1.2	1.0	0.6	0.0	0.0	0.0	1.1	1.0	2.4	1.8	0.0	0.0	0.9	0.0	0.3
Riffle	15.7	14.5	11.5	10.2	1.8	8.3	14.7	11.3	22.4	18.3	7.0	3.6	21.1	6.3	4.4
Run	47.0	45.0	49.1	52.0	27.3	62.0	48.5	41.9	47.3	44.6	39.9	41.8	53.7	67.0	49.8
Pool	23.5	24.9	26.8	22.0	50.9	19.9	24.7	30.9	16.7	22.2	38.5	41.8	14.4	18.8	33.1
Plunge Pool	3.1	6.0	2.8	4.7	1.8	0.5	4.2	3.5	5.5	1.9	0.0	9.1	3.0	0.0	1.9
Side Pool	9.5	8.7	9.3	11.0	18.2	9.3	6.7	11.4	5.7	11.2	14.7	3.6	6.8	8.0	10.4
Standardized Suitability															
Cascade	1	0.42	0.42	0.00	0.00	0.00	0.67	0.64	1.00	1.00	0.00	0.00	0.54	0.00	0.18
Riffle	1	0.48	0.64	0.43	0.05	0.40	0.69	0.55	0.74	0.79	0.27	0.08	1.00	0.28	0.20
Run	1	0.50	0.92	0.73	0.27	1.00	0.76	0.68	0.52	0.64	0.52	0.30	0.85	1.00	0.75
Pool	1	0.55	1.00	0.62	1.00	0.64	0.78	1.00	0.37	0.64	1.00	0.61	0.46	0.56	1.00
Plunge Pool	1	1.00	0.78	1.00	0.27	0.11	1.00	0.84	0.92	0.42	0.00	1.00	0.72	0.00	0.43
Side Pool	1	0.48	0.86	0.77	0.88	0.74	0.52	0.91	0.31	0.80	0.94	0.13	0.53	0.59	0.78

Table 15: Frequency of occurrence, percent utilization, standardized suitability, and adjusted smoothed standardized suitability for site depth (in.) for native amphidromous animals in different survey sites within the DAR Point Quadrat Surveys. The *values were adjusted to further smooth the results with unadjusted smoothed results in parentheses.

Depth Bin (in)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Lentipes concolor*	*Macrobrachium grandimanus*	*Neritina granosa*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*
Frequency									
0	27	0	0	0	0	0	0	0	0
3	210	9	9	1	11	0	3	6	4
6	500	50	32	4	20	3	8	16	9
12	1742	273	216	19	275	5	152	296	29
24	2503	442	500	46	584	13	295	629	48
36	786	123	191	27	226	2	85	203	10
>36	315	51	71	14	74	3	33	46	11
Total	6083	948	1019	111	1190	26	576	1196	111
Percent Utilization									
0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3.5	0.9	0.9	0.9	0.9	0.0	0.5	0.5	3.6
6	8.2	5.3	3.1	3.6	1.7	11.5	1.4	1.3	8.1
12	28.6	28.8	21.2	17.1	23.1	19.2	26.4	24.7	26.1
24	41.1	46.6	49.1	41.4	49.1	50.0	51.2	52.6	43.2
36	12.9	13.0	18.7	24.3	19.0	7.7	14.8	17.0	9.0
>36	5.2	5.4	7.0	12.6	6.2	11.5	5.7	3.8	9.9
Total	100	100	100	100	100	100	100	100	100
Standardized Suitability									
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0.3	0.3	0.3	0.3	0.0	0.2	0.1	1.0
6	1	0.6	0.4	0.4	0.2	1.4	0.2	0.2	1.0
12	1	1.0	0.7	0.6	0.8	0.7	0.9	0.9	0.9
24	1	1.1	1.2	1.0	1.2	1.2	1.2	1.3	1.1
36	1	1.0	1.5	1.9	1.5	0.6	1.1	1.3	0.7
>36	1	1.0	1.3	2.4	1.2	2.2	1.1	0.7	1.9
Max	1	1.1	1.5	2.4	1.5	2.2	1.2	1.3	1.9
Adjusted Smoothed Standardized Suitability									
0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	1	0.2	0.2	0.1	0.2	0.0	0.1	0.1	0.5
6	1	0.6	0.3	0.2	0.1	0.5*(0.6)	0.1	0.1	0.5
12	1	0.9	0.5	0.2	0.5	0.5*(0.3)	0.7	0.7	0.5
24	1	1.0	0.8	0.4	0.8	0.5	1.0	1.0	0.5
36	1	0.9	1.0	0.8	1.0	0.5*(0.3)	0.9	1.0	0.5*(0.4)
>36	1	0.9	0.9	1.0	0.8	1.0	0.9	0.6	1.0

Table 16: Percent Utilization for site substrate and total samples by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1.2	1.5	0.2	0.2	1.8	0.6	0.5	0.3	2.7	1.4	3.6	2.8	2.6	2.5	1.9
Fine Sediment	6.5	5.8	8.4	7.2	7.4	9.3	4.3	4.4	5.1	6.2	11.5	6.4	7.6	6.0	2.9
Sand	3.5	3.5	1.1	2.0	3.8	5.7	0.9	1.7	6.4	6.0	6.0	6.1	23.6	8.4	3.6
Gravel	12.2	14.8	7.0	7.8	12.8	12.3	7.4	8.0	23.7	13.8	19.3	13.9	14.9	12.2	20.5
Cobble	29.5	29.0	30.7	35.5	28.1	30.2	29.4	28.6	29.3	33.4	18.5	35.7	31.4	30.0	32.7
Boulder	32.8	29.6	35.5	39.1	34.8	34.3	33.9	42.6	28.0	36.5	29.0	31.0	19.9	19.1	32.3
Bedrock	14.3	15.9	17.0	8.1	11.3	7.7	23.5	14.4	4.9	2.7	12.1	4.1	0.0	21.8	6.2
Total Samples	6999	2156	1445	1438	1156	1156	1087	757	315	187	146	123	111	56	52

Table 17: Standardized suitability for site substrate by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1	1.00	0.13	0.13	1.00	0.30	0.27	0.22	1.00	0.70	1.00	1.00	0.32	0.88	0.97
Fine Sediment	1	0.69	1.00	0.92	0.75	0.87	0.40	0.51	0.34	0.55	0.58	0.42	0.17	0.38	0.26
Sand	1	0.80	0.25	0.48	0.73	1.00	0.16	0.38	0.80	1.00	0.57	0.74	1.00	1.00	0.61
Gravel	1	0.95	0.45	0.53	0.69	0.61	0.37	0.50	0.84	0.65	0.53	0.48	0.18	0.41	1.00
Cobble	1	0.77	0.81	1.00	0.63	0.63	0.61	0.74	0.43	0.66	0.21	0.51	0.16	0.42	0.66
Boulder	1	0.71	0.84	0.99	0.71	0.64	0.63	1.00	0.37	0.65	0.29	0.40	0.09	0.24	0.59
Bedrock	1	0.87	0.92	0.47	0.53	0.33	1.00	0.78	0.15	0.11	0.28	0.12	0.00	0.63	0.26

Table 18: Smoothed standardized suitability for site substrate by the species that occurred in at least 50 different survey sites within the DAR Point Quadrat Surveys. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

	all sites	no species observed	*Lentipes concolor*	*Sicyopterus stimpsoni*	*Macrobrachium lar*	*Awaous guamensis*	*Atyoida bisulcata*	*Neritina granosa*	*Xiphophorus helleri*	*Kuhlia xenura*	*Poecilia reticulata*	*Eleotris sandwicensis*	*Stenogobius hawaiiensis*	*Gambusia affinis*	*Procambarus clarkii*
Detritus	1	0.85	0.56	0.52	0.88	0.59	0.34	0.37	0.67	0.62	0.79	0.71	0.25	0.63	0.62
Fine Sediment	1	0.83	0.46	0.51	0.83	0.72	0.28	0.37	0.71	0.75	0.72	0.72	0.50	0.75	0.62
Sand	1	0.81	0.57	0.64	0.73	0.83	0.31	0.46	0.66	0.74	0.56	0.54	0.45	0.60	0.63
Gravel	1	0.84	0.50	0.67	0.69	0.75	0.38	0.54	0.69	0.77	0.44	0.57	0.45	0.61	0.76
Cobble	1	0.81	0.70	0.84	0.68	0.63	0.54	0.75	0.55	0.65	0.34	0.46	0.14	0.36	0.75
Boulder	1	0.78	0.86	0.82	0.62	0.53	0.75	0.84	0.32	0.47	0.26	0.34	0.08	0.43	0.50
Bedrock	1	0.79	0.88	0.73	0.62	0.48	0.82	0.89	0.26	0.38	0.29	0.26	0.04	0.44	0.42

Table 19: Frequency of occurrence for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	57	39	0	0	0	2	1	1	16	0	0	1	0	0
17	66	19	7	0	0	23	15	23	11	0	1	19	0	1
18	99	27	11	0	0	12	6	9	46	0	4	5	0	9
19	391	105	53	10	15	18	29	8	159	2	16	37	4	33
20	521	49	40	7	10	33	41	18	253	19	1	37	1	57
21	737	101	73	13	28	104	159	94	278	19	6	66	3	51
22	850	73	121	11	31	81	177	91	299	17	6	146	23	71
23	380	15	59	8	23	56	102	45	114	25	1	39	15	23
24	206	4	32	6	11	18	48	31	52	16	1	38	16	10
25	169	0	44	6	7	28	39	18	43	7	0	48	12	5
26	114	0	35	1	3	23	25	17	29	3	0	46	6	1
26+	81	0	35	10	6	13	15	9	10	1	0	26	10	0
Total	3671	432	510	72	134	411	657	364	1310	109	36	508	90	261

Table 20: Percent Utilization for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1.6	9.0	0.0	0.0	0.0	0.5	0.2	0.3	1.2	0.0	0.0	0.2	0.0	0.0
17	1.8	4.4	1.4	0.0	0.0	5.6	2.3	6.3	0.8	0.0	2.8	3.7	0.0	0.4
18	2.7	6.3	2.2	0.0	0.0	2.9	0.9	2.5	3.5	0.0	11.1	1.0	0.0	3.4
19	10.7	24.3	10.4	13.9	11.2	4.4	4.4	2.2	12.1	1.8	44.4	7.3	4.4	12.6
20	14.2	11.3	7.8	9.7	7.5	8.0	6.2	4.9	19.3	17.4	2.8	7.3	1.1	21.8
21	20.1	23.4	14.3	18.1	20.9	25.3	24.2	25.8	21.2	17.4	16.7	13.0	3.3	19.5
22	23.2	16.9	23.7	15.3	23.1	19.7	26.9	25.0	22.8	15.6	16.7	28.7	25.6	27.2
23	10.4	3.5	11.6	11.1	17.2	13.6	15.5	12.4	8.7	22.9	2.8	7.7	16.7	8.8
24	5.6	0.9	6.3	8.3	8.2	4.4	7.3	8.5	4.0	14.7	2.8	7.5	17.8	3.8
25	4.6	0.0	8.6	8.3	5.2	6.8	5.9	4.9	3.3	6.4	0.0	9.4	13.3	1.9
26	3.1	0.0	6.9	1.4	2.2	5.6	3.8	4.7	2.2	2.8	0.0	9.1	6.7	0.4
26+	2.2	0.0	6.9	13.9	4.5	3.2	2.3	2.5	0.8	0.9	0.0	5.1	11.1	0.0

Table 21: Standardized suitability for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys. Standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1	1.00	0.00	0.00	0.00	0.10	0.07	0.05	0.58	0.00	0.00	0.04	0.00	0.00
17	1	0.42	0.25	0.00	0.00	1.00	0.85	1.00	0.34	0.00	0.37	0.71	0.00	0.14
18	1	0.40	0.26	0.00	0.00	0.35	0.23	0.26	0.96	0.00	0.99	0.13	0.00	0.83
19	1	0.39	0.31	0.21	0.52	0.13	0.28	0.06	0.84	0.07	1.00	0.23	0.08	0.77
20	1	0.14	0.18	0.11	0.26	0.18	0.29	0.10	1.00	0.47	0.05	0.18	0.02	1.00
21	1	0.20	0.23	0.14	0.51	0.40	0.80	0.37	0.78	0.33	0.20	0.22	0.03	0.63
22	1	0.13	0.33	0.10	0.49	0.27	0.78	0.31	0.72	0.26	0.17	0.43	0.22	0.76
23	1	0.06	0.36	0.17	0.82	0.42	1.00	0.34	0.62	0.85	0.06	0.25	0.32	0.55
24	1	0.03	0.36	0.24	0.72	0.25	0.87	0.43	0.52	1.00	0.12	0.46	0.63	0.44
25	1	0.00	0.60	0.29	0.56	0.48	0.86	0.31	0.52	0.53	0.00	0.70	0.58	0.27
26	1	0.00	0.71	0.07	0.36	0.58	0.82	0.43	0.52	0.34	0.00	1.00	0.43	0.08
26+	1	0.00	1.00	1.00	1.00	0.46	0.69	0.32	0.25	0.16	0.00	0.80	1.00	0.00

Table 22: Smoothed standardized suitability for site temperature (°C) by the species that occurred in at least 36 different survey sites within the DAR Point Quadrat Surveys. Smoothed standardized suitability values that were less than or equal to 0.33 were colored orange, those from 0.33 to less than or equal to 0.66 were colored yellow, and values greater than 0.66 were colored green.

Temp Bin (°C)	All Sites	*Atyoida bisulcata*	*Awaous guamensis*	*Eleotris sandwicensis*	*Kuhlia xenura*	*Lentipes concolor*	*Macrobrachium lar*	*Neritina granosa*	no species observed	*Poecilia reticulata*	*Procambarus clarkii*	*Sicyopterus stimpsoni*	*Stenogobius hawaiiensis*	*Xiphophorus helleri*
16	1	0.71	0.12	0.00	0.00	0.55	0.46	0.53	0.46	0.00	0.19	0.38	0.00	0.07
17	1	0.61	0.17	0.00	0.00	0.48	0.38	0.44	0.63	0.00	0.45	0.29	0.00	0.32
18	1	0.40	0.27	0.07	0.17	0.49	0.45	0.44	0.71	0.02	0.79	0.36	0.03	0.58
19	1	0.31	0.25	0.11	0.26	0.22	0.27	0.14	0.93	0.18	0.68	0.18	0.03	0.87
20	1	0.24	0.24	0.15	0.43	0.24	0.46	0.17	0.87	0.29	0.42	0.21	0.04	0.80
21	1	0.15	0.25	0.12	0.42	0.29	0.62	0.26	0.83	0.35	0.14	0.27	0.09	0.80
22	1	0.13	0.31	0.14	0.61	0.37	0.86	0.34	0.71	0.48	0.15	0.30	0.19	0.65
23	1	0.07	0.35	0.17	0.68	0.32	0.88	0.36	0.62	0.70	0.12	0.38	0.39	0.59
24	1	0.03	0.44	0.23	0.70	0.38	0.91	0.36	0.55	0.79	0.06	0.47	0.51	0.42
25	1	0.01	0.56	0.20	0.55	0.44	0.85	0.39	0.52	0.62	0.04	0.72	0.54	0.26
26	1	0.00	0.77	0.45	0.64	0.50	0.79	0.35	0.43	0.34	0.00	0.83	0.67	0.12
26+	1	0.00	0.86	0.54	0.68	0.52	0.75	0.37	0.39	0.25	0.00	0.90	0.71	0.04

Appendix 4: HDSS data collection

Introduction:

This report documents the results of the High Definition Stream Surveys (HDSS) data collection on Manoa Stream, Oahu. The Department of Land and Natural Resources, Engineering Division requested Parham & Associates Environmental Consulting, LLC to collect data on Manoa Stream. The request for these data was to better understand the environmental impact of flood control structures proposed within Manoa Stream. Specifically, the Engineering Division is planning to construct the Woodlawn Chute Flood Control Structure. The Woodlawn Chute project focuses on channel improvements under and downstream of the bridge on Woodlawn Drive. In general, the channel improvements can be described as: (1) widening and stabilizing the stream banks and (2) grading the stream channel to allow water to flow more swiftly through this channel segment, thus lowering the overall flood risk at the site. In addition to the Woodlawn Chute structure, the U.S. Army Corps of Engineers are planned to add nine additional flood control structures within the Ala Wai Watershed (Manoa Stream) and this data will be used to support this effort as well.

This HDSS data collection effort is part of a larger project. The data collected in this project is to be incorporated into a Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model to assess three different conditions: the current conditions within the site, the conditions with the flood control project, and the mitigation burden as a result of the project. This larger project includes fish surveys collected by the Department of Land and Natural Resources, Division of Aquatic Resources (DAR) and the overall model integration by researchers at Bishop Museum. This report will focus on the results of the HDSS effort within Manoa Stream and not on the larger results of the HSHEP model or overall mitigation effort.

In general, the HDSS approach is a multi-attribute, high resolution sampling technique that collects data of both streambanks and the stream channel bottom at approximately 1 m intervals. This approach is an improvement over traditional transect methods because the data collection is continuous over the survey area as opposed to being limited to small survey areas. For this project we collected data throughout Manoa Stream, including all of the Palolo and Makiki tributaries, to better understand conditions within and outside all of the project footprints. The HDSS technique integrates GPS, video, depth, and water quality sensors in a single pass. These results can be easily mapped to better understand conditions at the survey site. The following is a description of the HDSS methodology.

Methods:

Field Data Collection:

During the HDSS data collection process, two primary methods were used. A backpack-mounted HDSS system accounted for the majority of the data collected. A bodyboard-mounted HDSS system was used in deeper sections of the stream. The two systems shared many features. All video collected was geo-referenced to a GPS data stream so that an X,Y locational coordinate was associated with each second of video collected. Water quality was collected using a YSI EXO1 sonde will at point locations throughout the stream. When using the backpack HDSS system, depth was classified from the video collected, while when using the bodyboard-mounted HDSS system, depth was collected from a hull-mounted transducer.

The backpack-mounted HDSS system featured four different high definition video cameras with image stabilization (Figure 1). One camera was faced forward, one camera was faced downward, and a single camera was faced at the right and left banks. When using the backpack-mounted HDSS system, the surveyor moved in an upstream direction attempting to follow the thalweg of the stream. The bodyboard-mounted HDSS system included two additional cameras (Figure 2). These cameras were faced at a 45° angle downward towards the stream bottom. When using the bodyboard-mounted HDSS system, the bodyboard was drifted downstream under control of a long extension pole.

The GPS signal was collected using a Garmin 64C handheld GPS and a Garmin 19X GPS receiver. In both of these cases, the GPS NMEA data string was recorded at 1 Hz (approximately 1 sec interval). All data including the video and GPS track logs were saved to multiple external hard drives at the end of each day in the field. The track log for the GPS signal was exported in GPX format and the data was stored in a Microsoft Access database. The video was further post-processed in Adobe Premiere software to create a single view that encompassed all four video streams.

Figure 54: The author wearing the backpack-mounted HDSS system.

Figure 55: The bodyboard-mounted HDSS system.

<u>Video Classification:</u>

The HDSS video was classified by applying a standard classification system for each variable under consideration. The individual classes within each category are described below, but in general the process for each classification pass was similar. Prior to classification, the technician was trained on a subset of the videos under supervision of the principal investigator. Each video was watched by a technician and the category under consideration was scored. The HDSS Video Coder software version 2 (Parham 2014) was used to facilitate the classification process (Figure X). This software allows the human classifier to select the appropriate class and have it tied to the second it occurs in the video. In addition to the appropriate category classes, several additional classes were included in most categories. Unknown class was reserved for areas where the appropriate category was not visible to or otherwise noted by the surveyors. Other 1 and Other 2 classes were reserved for classes not accounted for in the above classification or for areas where the classifier had trouble determining class membership. These areas were then revisited with the field surveyors to decide on the appropriate class.

Once the classification was completed for the entire group of videos, an overall spreadsheet containing the video file name, the second at which the category occurred, the class name, and the class code was created. Given the unique combination of video name and second, we were able to link the classified spreadsheet with the GPS coordinates contained within the database.

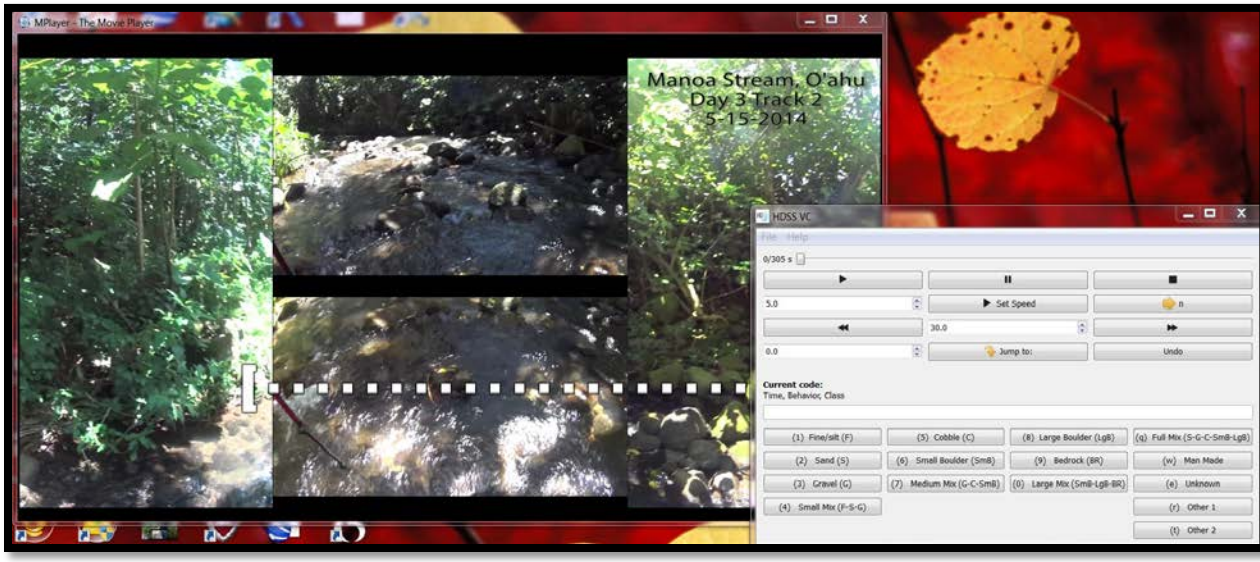

Figure 56: A computer screen image of the HDSS Video Coder Version 2 software and associated HDSS video of Manoa stream. In actual application, multiple computer monitors are used so that the HDSS video is displayed at high resolution on one monitor and the HDSS Video Coder software is displayed on a different monitor.

<u>Classification Categories:</u>

At each point, data for the following variables were estimated from the HDSS video:

- Habitat Type
- Depth
- Substrate
- Embeddedness
- Channel Condition
- Channel Width
- Percent Wetted Width
- Right and Left Streambank Height
- Right and Left Streambank Angle

- Right and Left Streambank Surface Protection
- Right and Left Riparian Zone Condition

The following describe each classification category.

Habitat Type

1. Pool
2. Run
3. Riffle
4. Cascade
5. Falls
6. Pocket Water
7. Sheet Flow
8. Unknown

Habitat type is one of the primary measures in describing instream habitat. Habitat types represent the classic riffle-run-pool combinations found in most streams. In general, the habitat types classified from the HDSS videos are compatible with those habitat types used by DAR in their habitat and fish surveys. Two additional classes were added. Pocket water represents a mix of riffle, run, and small pool habitat commonly found in the mid to upper reaches of the stream. Sheet flow is characteristic of the habitat found in man-made channelized stream sections. Transitions from one habitat type to the other were visually determined from experience by the primary investigator.

The following are examples of some of the more common habitat types found in the stream:

Figure 57: Habitat Types of Pool and Falls are shown in the image.

Figure 58: Run Habitat Type. The water is moving, but not broken on the surface.

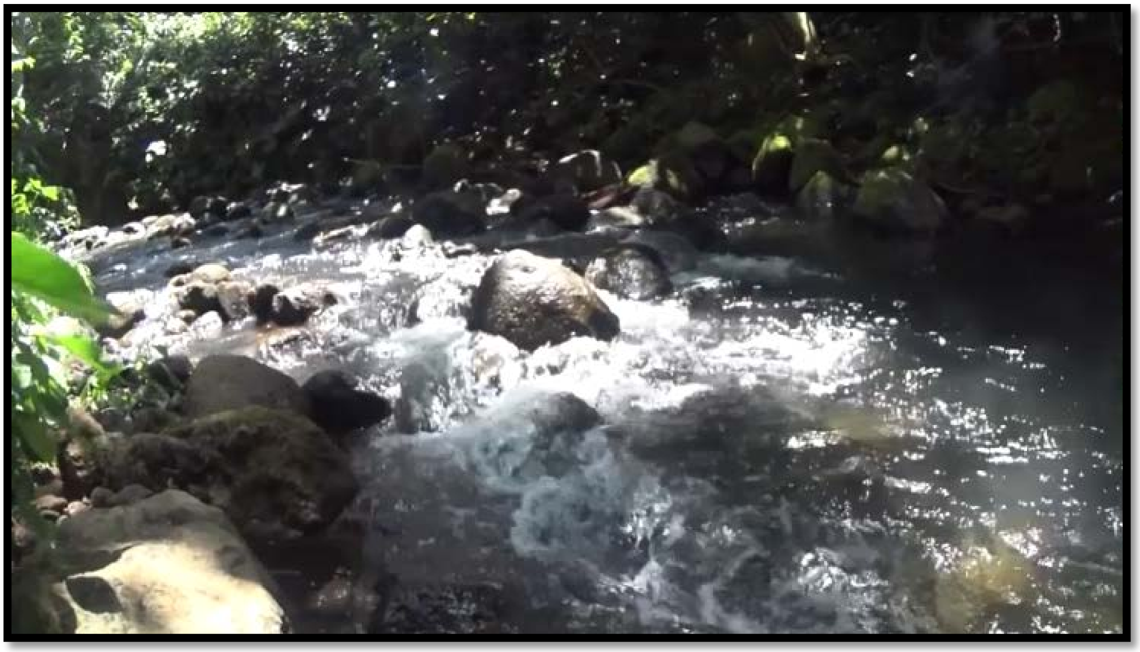

Figure 59: Riffle Habitat Type. Swiftly flowing water with broken surface.

Figure 60: Cascade Habitat Type. Note the high velocity, highly mixed flow in center of the image.

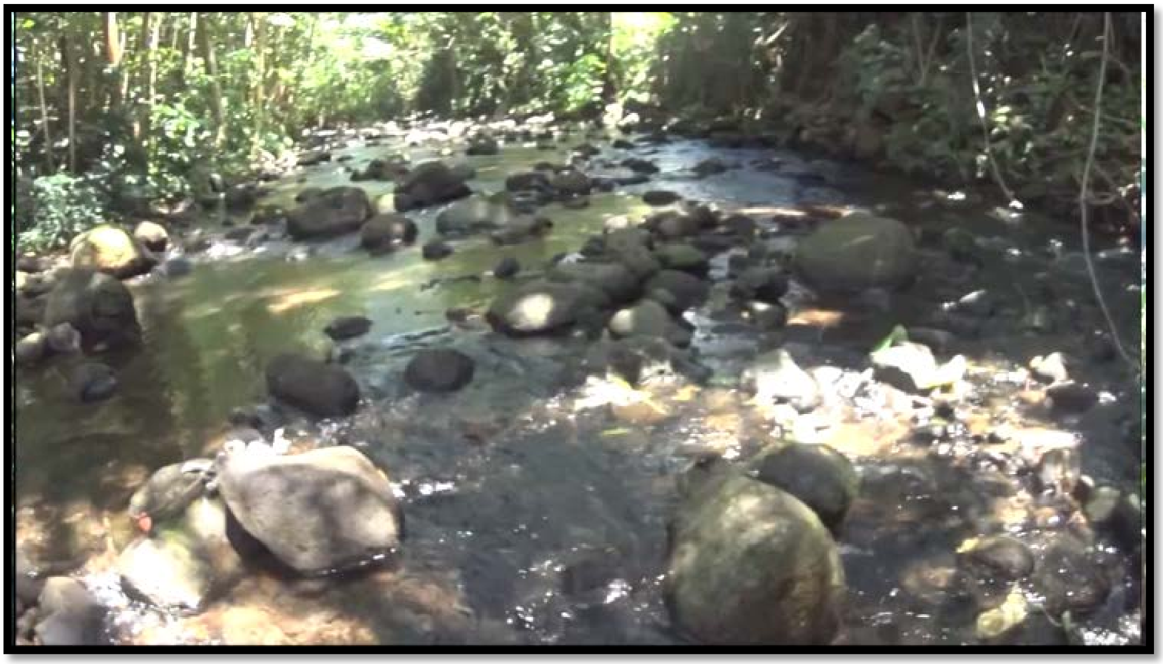

Figure 61: Pocket Water Habitat Type. Note the mixture of riffles, runs and small pools intermixed across the channel.

Figure 62: Sheet Flow Habitat Type is swift, shallow and uniform and is characteristic of fully channelized stream sections.

Depth:

1. Dry
2. 1-3 inches
3. 3-6 inches
4. 6-12 inches
5. 12-24 inches (1-2 ft deep)
6. 24-36 inches (2-3 ft deep)
7. 36+ inches (>3ft deep)
8. Unknown

The Depth category was intended to capture the thalweg depth for the main flow of the stream channel. The thalweg can be considered the center of the main flow and usually the deepest depth across the stream channel. The wading poles (as seen in the down-looking video) are set at 1 ft at the first black joint and 2 ft at the second joint for reference. In deeper sections, verbal documentation of depths by the surveyors may have been noted for reference.

The following are some example of depth classes observed in the surveys:

Figure 63: Depth class of 1 to 3 inches deep. This class was common in the fully channelized stream sections.

Figure 64: Depth class of 3 to 6 inches.

Figure 65: Depth class of 6 to 12 inches. Note the first clasp of the wading staff is above the water surface.

Figure 66: Depth class of 1 to 2 feet deep. Note second black clasp on wading staff denoting 2 ft deep is just above the water surface.

Figure 67: Depth class of 2 to 3 ft deep. Note the second clasp on the wading staff is fully underwater.

Figure 68: Depth class of greater than 3 ft deep. Note the right wading staff fully underwater.

Substrate:

1. Detritus (D): Dead particulate organic matter. Typically woody or leafy plant debris.
2. Fine/silt (F): All sediments finer than sand. Covers the Mud and Silt categories in the Wentworth Particle Classification Scale. Visually it is difficult to see individual grains of the sediment and if disturbed it easily clouds the water.
3. Sand (S): Observable small grains of sand ranging up to 2 mm in diameter. The covers all of the Sand category in the Wentworth Particle Classification Scale.
4. Gravel (G): From 2 mm to 64 mm in diameter. Visually this can be observed as small pebbles to rocks a little larger than a golf ball.
5. Small Mix (F-S-G)
6. Cobble (C): From 64 mm to 256 mm in diameter. Visually these can be observed as rocks from little larger than a golf ball to a volley ball size.
7. Small Boulder (SmB): From 256 to 610 mm or large rocks from 1 to 2 ft in diameter.
8. Medium Mix (G-C-SmB)
9. Large Boulder (LgB): Boulder greater than 610 mm (approximately 2 ft) in diameter
10. Bedrock (BR): Large areas of unbroken rock. Bedrock is typically smooth with some small cracks.
11. Large Mix (SmB-LgB-BR)
12. Full Mix (S-G-C-SmB-LgB)
13. Man-made: Any man-made substrate. Typically concrete.
14. Unknown

The classification is primarily based on the center (down-looking) video track where possible. The side-looking video was used for substrate classification when surveyor was not following the thalweg of the channel. Basing the substrate classification on the primary substrate in the channel thalweg is intended to achieve two things: (1) substrate type will vary with the thalweg depth criteria and thus will be more consistent among stream segments, and (2) may allow us to classify left and right channel substrate if necessary. For this habitat classification project, only the center (thalweg) channel substrate was scored.

Substrate classification is based on the substrate classification commonly applied by DAR in stream habitat surveys and can be considered a modification of the Wentworth particle scale (Higashi and Nishimoto 2007). The standard classes used in DAR surveys were modified to include several substrate mix classes as the visual assessment averages substrate type across several meters of the channel bottom. Man-made bottom type was generally concrete and found in channelized sections, but could include any non-natural bottom type.

The rules for determining specific substrate classes were as follows: if approximately 75% or more of the bottom is in a single class (i.e. gravel or cobble) then place it in the single substrate class. If it is mixed, pick the majority as small, medium, or large mix. Only use the full mix if the site contains a mix of everything small to large. In general, the mixes will be considered 33%, 33%, 33% of each substrate class. If it is 50/50% in two classes use the appropriate mix class as opposed to one or the other class. If you have a 50/50 mix of gravel and large boulder, go with the larger substrate class.

The following are examples of some of the more common substrate classes:

Figure 69: Small Mix substrate class. This is a mix of fine, sand, and gravel substrate classes.

Figure 70: Medium Mix substrate class. This is a mix of gravel, cobble and small boulder substrates classes.

Figure 71: Cobble substrate class. A few small boulders and some gravel were present, but the majority of the substrate is in the cobble class.

Figure 72: Large Boulder substrate class.

Figure 73: Full Mix substrate class. A wide range of substrate classes are visible from gravel to large boulder.

Figure 74: Bedrock substrate class

Figure 75: Man-made substrate class.

Embeddedness:

1. Optimal (0-25%)
2. Suboptimal (25-50%)
3. Marginal (50-75%)
4. Poor (75-100%)

The Embeddedness category refers to the extent at which rocks gravel cobble are covered or sunken in fine or sand substrates. We followed the EPA classification for high gradient streams with embeddedness ranging from optimal to poor depending on the extent that the large substrate is surrounded by fine substrate. Embeddedness is rated as the average of the most common condition and not reflective of a single boulder or cobble within the video frame. As with substrate, the embeddedness classification focused on the down-looking video where possible associated with the thalweg of the stream.

The following are examples of some of the more common embeddedness classes:

Figure 76: Optimal Embeddedness class. While some of the larger boulders are surrounded by smaller gravel or cobble, there is almost no fine or sand substrate surrounding the gravel and small cobbles.

Figure 77: Sub-optimal Embeddedness class. The larger cobbles are surrounded between 25% and 50% by fine or sand substrates.

Figure 78: Marginal Embeddness class. Note how the boulder and larger cobble are surrounded between 50% and 75% by fine or sand substrate.

Figure 79: Poor Embeddedness class. Most boulders are surrounded by greater than 75% by fine substrate.

Channel Condition:

1. Natural Channel
2. Natural Bottom – Walls far back
3. Natural Bottom – Left wall close
4. Natural Bottom – Right wall close
5. Natural Bottom – Both walls close
6. Fully channelized – low flow channel
7. Fully channelized – flat bottom
8. Unknown

The channel condition category is intended to capture the extent of channel modification at an individual location. In general, this category differentiates a natural stream channel from a channel with hardened walls from a fully channelized segment. The location of a man-made wall on either right or left bank and its proximity to the stream channel (close or far) was documented to aid in understanding available habitat and stream function within an area. The difference between close or far wall positions is if the wall is closer or further than 10 feet of the active channel. A low flow channel in a fully channelized segment was defined as an area of confined flow that constrains the majority of the low flow.

The following are examples of some of the more common channel condition classes:

Figure 80: Natural Channel class.

Figure 81: Natural Bottom: Left Wall Close class.

Figure 82: Natural Bottom - Both Walls Close class.

Figure 83: Fully Channelized - Flat Bottom

Channel Width:

1. Less than 10 ft. wide
2. Between 10 and 20 ft. wide
3. Between 20 and 30 ft. wide
4. Between 30 and 40 ft. wide
5. Greater than 40 ft. wide

The channel width metric categorically describes the stream's active channel. This category is intended to help determine the potential habitat area of a stream segment. The longitudinal HDSS approach can determine channel length effectively. The combination of length and width provides a measure of total habitat area within the active channel. When channel width is used in combination with percent wetted width, a measure of wetted habitat area can be determined.

The following examples are some of the channel width classes:

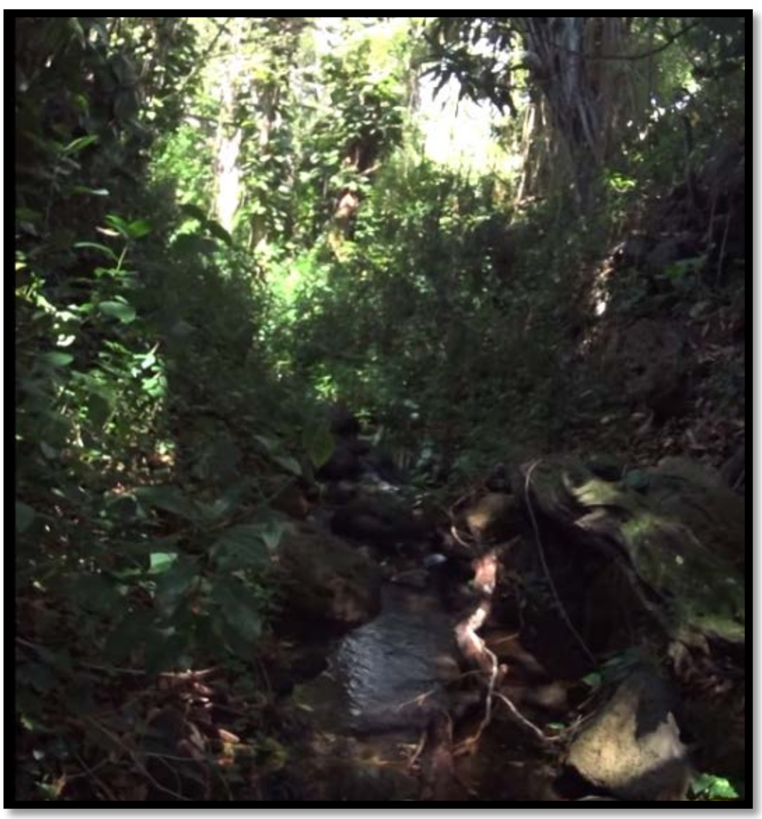

Figure 84: Channel width less than 10 ft wide.

Figure 85: Channel width between 10 and 20 ft wide.

Figure 86: Channel width between 20 to 30 ft wide.

Figure 87: Channel width between 30 and 40 ft wide.

Figure 88: Channel width greater than 40 ft wide.

Percent Wetted Width:

1. Dry
2. 1 -10%
3. 10-20%
4. 20-40%
5. 40-60%
6. 60-80%
7. 80-100%
8. Unknown

The category Percent Wetted Width is a descriptor of the extent at which the active channel is filled with water during the survey. Longitudinal changes in Percent Wetted Width can reflect changes in the base flow in the stream due to stream diversion, a losing or gaining reach, differences in channel morphology, or sections of unstable streams (i.e., incising or aggrading streams). There are more classes in the lower range of this category due to the critical nature of the amount of water found in the stream at very low flows.

The following are examples of some classes within the Percent Wetted Width category:

Figure 89: Percent Wetted Width class of 20 to 40%.

Figure 90: Percent Wetted Width class of 40 to 60%. Note that the active channel width includes the exposed rocks to the left of the image.

Figure 91: Percent Wetted Width class 80 to 100%.

Right and Left Streambank Height:

1. 0 to 1 ft
2. 1 to 3 ft
3. 3 to 6 ft
4. 6 to 9 ft
5. 9 to 12 ft
6. 12 to 18 ft
7. Greater than 18 ft
8. Unknown

Streambank height is relatively self-explanatory as it is the height of either the left or right streambank. The confusion comes and in determining where the streambank ends and the floodplain begins. This is further compounded in Manoa Stream as much of the stream is channelized or has setback flood control walls. For Manoa Stream, we define streambank height as the height of the wall if the walls were close to the active channel. At locations where there was no flood wall or the flood wall was far back from the active channel, streambank height was considered the height to the first bench.

Documenting streambank height is important in understanding channel volume, flow characteristics, and the stability of the streambank. Streambank height and bank angle may also indicate areas of channel incision or aggradation.

The following are examples of some classes within the Streambank Height category:

Figure 92: Streambank Height class for 3 - 6 ft.

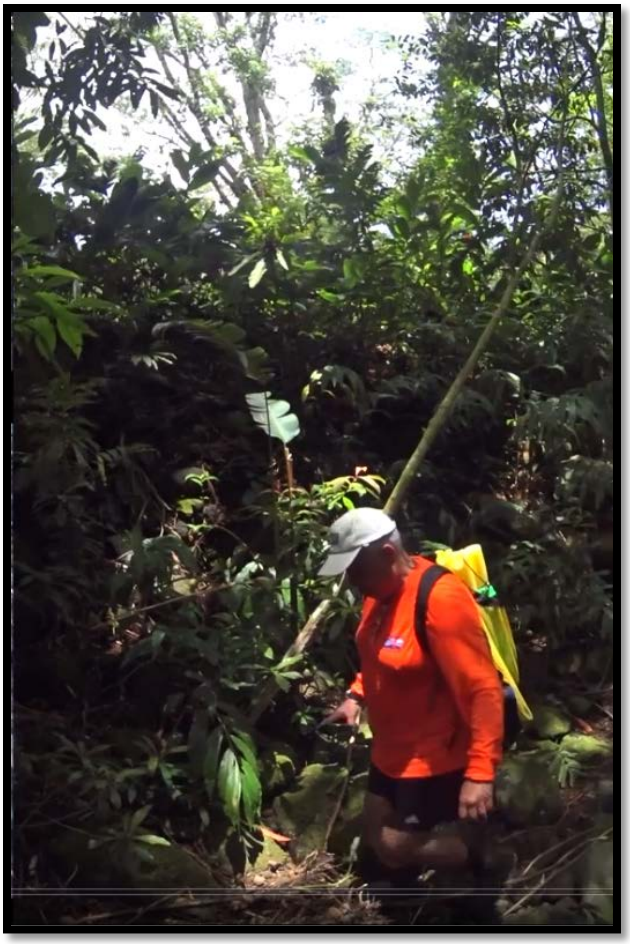

Figure 93: Streambank Height class for 6 - 9 ft.

Figure 94: Streambank Height class for greater than 18 ft. This image highlights the scoring when a flood wall is close to the streambank. Where the wall is close, the bank height equals the height of the wall. If the wall had been set further back, then height would equal the first bench in the front.

Right and Left Streambank Angle:

1. Low (0 - 60°)
2. Medium (61 - 80°)
3. High (81 - 90°)
4. Extreme (>90°)
5. Unknown

Streambank angle documents how steep or shallow the bank is where it enters the water. Streambank angle must be considered in combination with streambank height as the overall angle should be determined from the water level to the top of the streambank. In locations with near vertical or overhung bank angles there is greater potential for bank failure or streambank erosion.

The following are examples of some classes within the Streambank Angle category:

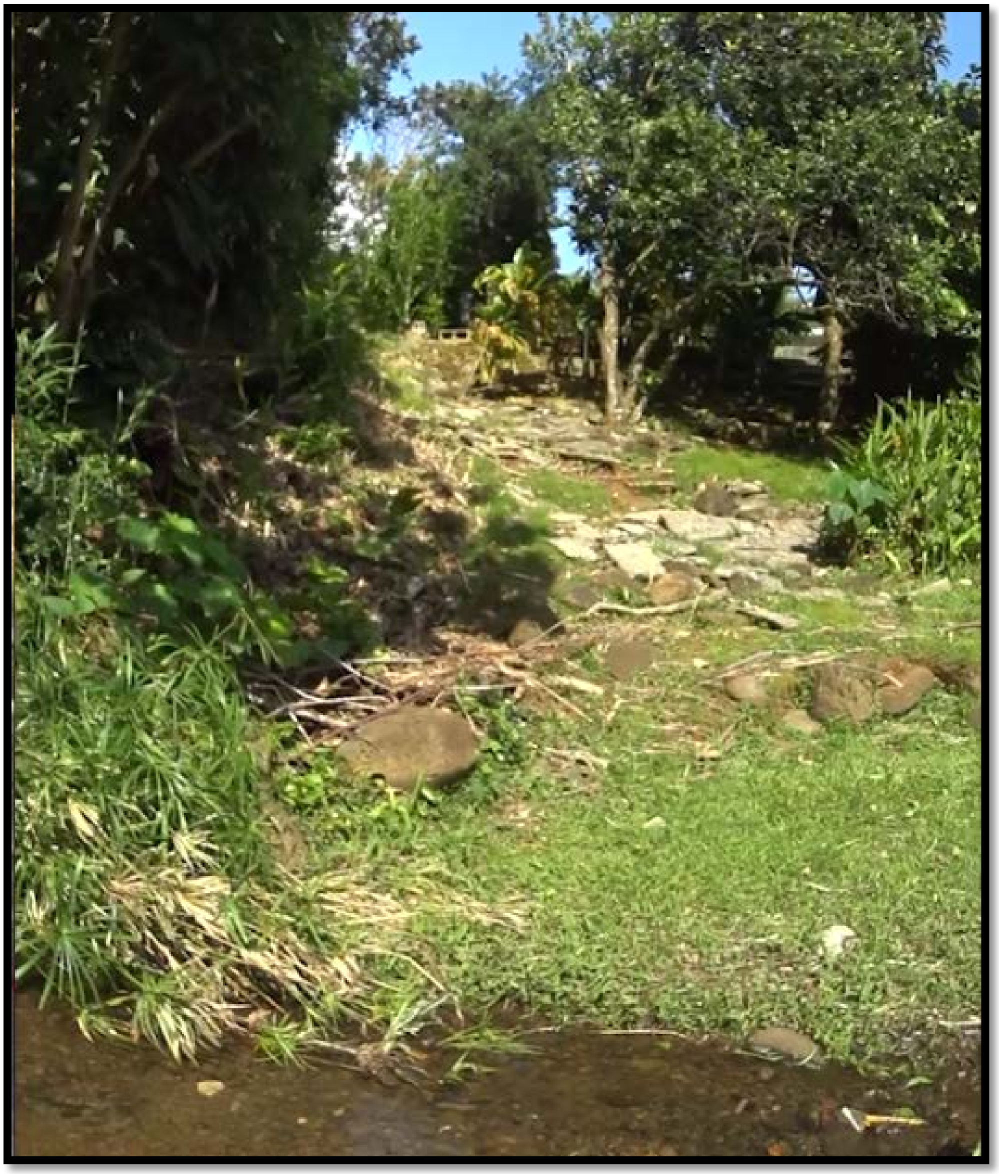

Figure 95: Low streambank angle (<60°).

Figure 96: High streambank angle (near 90°).

Figure 97: Extreme streambank angle (>90°, or undercut).

Right and Left Streambank Surface Protection:

1. Optimal (greater than 56% protected)
2. Sub-optimal (30 to 55% protected)
3. Marginal (15 to 29% protected)
4. Poor (less than 15% protected)
5. Unknown

Surface protection class is related to the percentage of the stream bank covered and protected from erosion by plant roots, downed logs and branches, and rocks. This metric is scored independently for both the left and right streambank. These classes follow the classes described by Connell (2012) as a modification of those of Rosgen (2001). Surface protection can be an important variable in and of itself, yet is more commonly combined with other variables to aid in determining overall streambank erosion potential.

The following are examples of streambank surface protection classes:

Figure 98: Optimal streambank surface protection. The banks are fully covered by vegetation minimizing possible surface erosion.

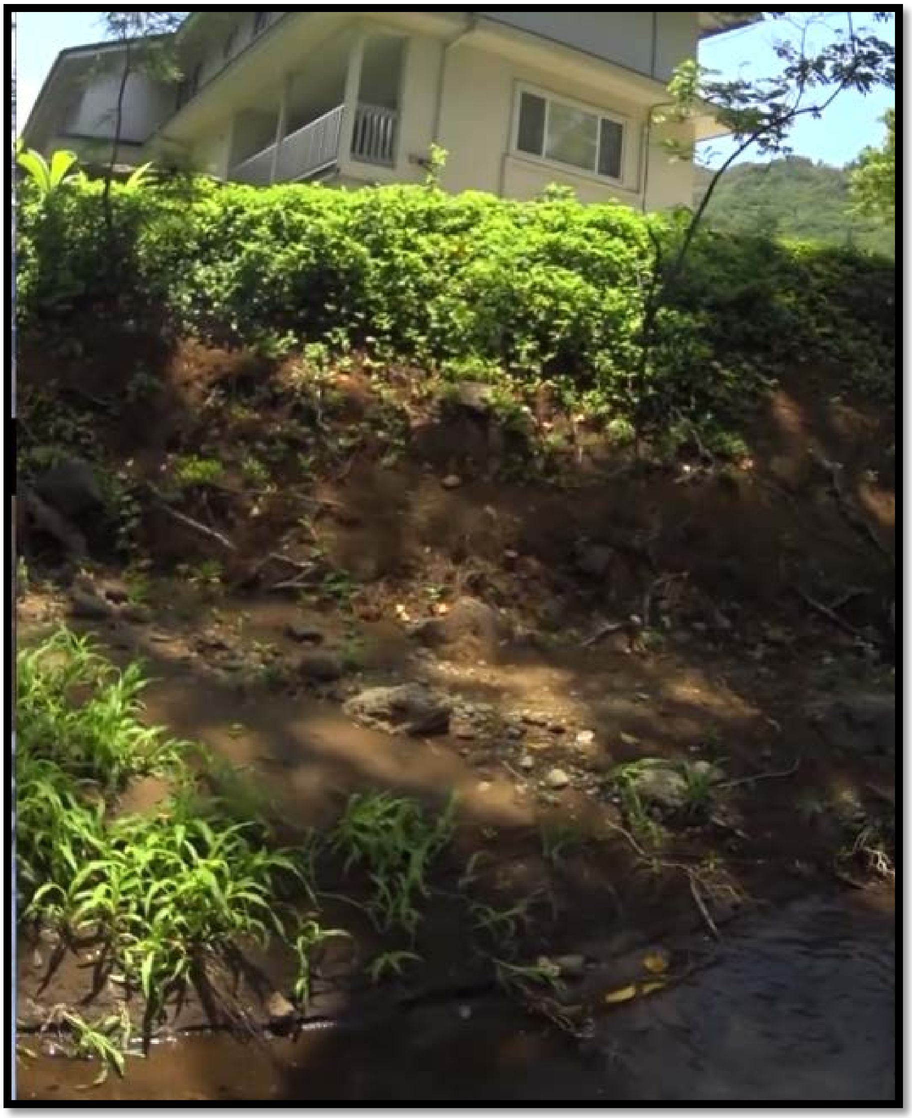

Figure 99: Poor and Marginal streambank surface protection. Here the bank is transitioning from an area of poor surface protection (right) to marginal surface protection (left). Note the high potential for surface erosion at this location.

Right and Left Riparian Zone Condition:

1. Optimal (presence of large trees or a wide variety of plant diameters)
2. Sub-optimal (mostly small trees or shrubs)
3. Marginal (mostly tall grasses)
4. Poor (lawn grass, pavement, or bare soil)
5. Unknown

For the purposes of this study, riparian zone condition refers to the extent at which the streambank or floodplain is vegetated by various sized trees. At one extreme there may be no riparian zone vegetation and at the other large trees can dominate the area near the banks of the stream. Where large trees exist, the stream is more likely to be shaded and thus have lower average stream temperatures. The root structures on the trees also stabilize the bank and prevent lateral in-cutting during flooding events. Much of Manoa Stream lacks a true riparian area thus this measure was adjusted to consider any vegetation within the stream channel corridor.

The following are a few examples of the Riparian Zone Condition classes:

Figure 100: Poor Riparian Zone Condition. No trees, shrubs or tall grasses to provide shading.

Figure 101: Marginal Riparian Zone Condition. Here large grasses are the primary cover and the trees are relatively far off the stream channel.

Figure 102: Optimal Riparian Zone Condition. There is a dense stand of moderate sized trees. If the trees were all small it would likely fall into the sub-optimal class.

Figure 103: Optimal Riparian Zone Condition. This location has very large tree that provide bank stability as well as stream shading.

Streambank Erosion Potential:

Streambank Erosion Potential is a derived metric that is formed from a combination of bank height, bank angle, and bank surface protection. Streambank erosion potential was modified from the calculation and scoring system described in Connell (2012). The modification involved the removal of the riparian zone condition score from the overall metric. This change was made to better represent the majority of the conditions observed in Manoa Stream. The streambanks of Manoa Stream are highly modified. In most places the stream channel is constrained by flood control walls and the riparian zone is highly urbanized. As a result the riparian metric represents the extent at which trees grow inside the flood walls and is used to represent the extent of stream shading not root depth as the riparian metric is traditionally used for. A further modification involved scoring where flood walls occurred near the stream. In this case, the concrete or grouted-rock walls had low erosion potential under any flow condition, therefore, where flood walls existed close to the stream channel, streambank erosion potential was low.

After determining the final streambank erosion potential score, the values were range standardized between 0 and 1. The range standardized value was inverted so that high bank erosion potential scores were near zero and low bank erosion potential scores were near one. This was done to allow this metric to be combined with other habitat modification metrics in an appropriate scale. Additionally, a combined metric for right and left bank scores was created by selecting the maximum value of the two scores. This single score represents the estimated likelihood of sediment entering into the adjacent instream habitat.

The Streambank Erosion Potential metric is calculated independently for each bank as follows:

$$Streambank\ Erosion\ Potential\ (for\ each\ bank) = Bank\ Height\ score + Bank\ Angle\ Score + Surface\ Protection\ Score$$

$$where: if\ [channel\ condition] indicates\ presence\ of\ flood\ wall\ close\ to\ channel,$$

$$then\ Streambank\ Erosion\ Potential\ is\ low$$

The following are a few examples of the component and overall Streambank Erosion Potential scores:

Figure 104: Low Potential for Bank Erosion. Bank Angle is just under vertical and the Bank Surface Protection is highly protected due to gabion baskets. There is no riparian diversity which means no root structure to hold together the rocks, but this has been functionally replaced by the braided wire fence.

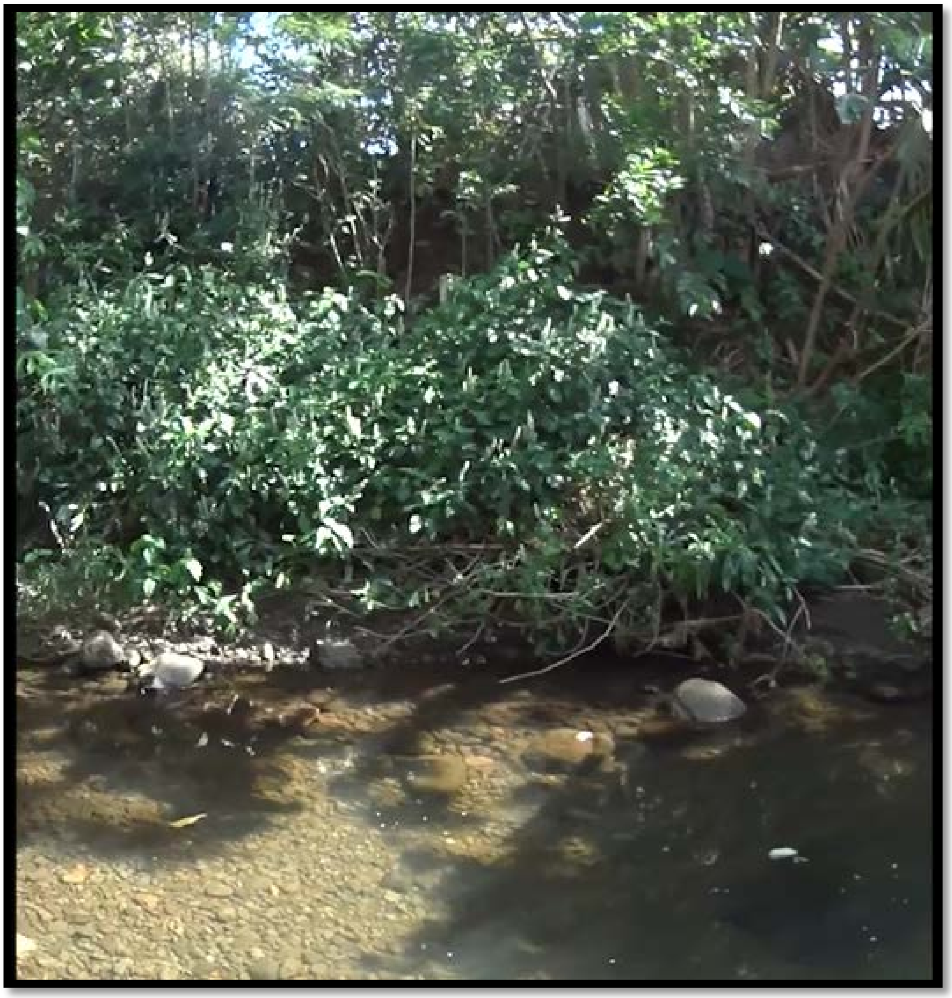

Figure 105: Moderate Potential for Bank Erosion. Bank angle is relatively steep (between 60-80°), Surface Protection is good, but there is some exposed bank. The Bank Height is rather tall (9 to 12 ft) and the Riparian Zone displays a lack of larger diameter vegetation.

Figure 106: High potential for Bank Erosion. The bank shows an almost undercut bank angle with marginal surface protection due to limited vegetation on the top part of bank and poor riparian diversity due to the complete lack of roots. Bank erosion is likely during high water events.

Fish Classification:

Native Fishes: O'opu nakea (*Awaous stamenius*), O'opu naniha (*Stenogobious hawaiiensis*), O'opu nopili (*Sicyotperus stimponi*), O'opu alamo'o (*Lentipes concolor*) O'opu akupa (*Eleotris sandvicensis*), Aholehole (*Kuhlia zenura*), Mullet (*Mugil cephalus)*

Native Crustaceans and Mollusks: Opae oeha'a (*Macrobrachium grandimanus*), Opae kala'ole (*Atyoida bisulcata*), Hihiwai *(Neritina granosa*), Hapawai (*Neritina vespertina*)

Introduced Fishes: Armored Catfish (*Hypostomus c.f. watawata)*, Bristlenose Catfish (*Ancistrus c.f. temmincki*), Bronze Corydoras (*Corydoras aeneus)*, Liberty Molly (*Poecilia sp. hybrid complex)*, Green Swordtail (*Xiphophorus hellerii)*, Guppy (*Poecilia reticulata)*, Mosquitofish (*Gambusia affinis*), Blackchin Tilapia (*Sarotherodon melanotheron)*, Convict Cichlid (*Amatitlania nigrofasciata)*, Smallmouth Bass (*Micropterus dolomieu)*, Carp (*Cyprinus carpio)*, Goldfish *(Carassius auratus)*

Introduced Crustaceans, Mollusks, and Amphibians: Tahitian prawn (*Macrobrachium lar*), Grass Shrimp (*Neocaridina denticulata sinensis*), Crayfish (*Procambarus clarkii*), Cane Toad (*Bufo marinus*)

Fish and other stream animal surveys were accomplished using two methods. The first method was visual surveys completed as the HDSS habitat surveys were underway. The visual surveys were further confirmed with net samples conducted by DAR biologists and technicians. While the visual surveys were widespread and covered all the habitat areas, these surveys likely missed some small or cryptic animals.

Figure 107: An example of a large Koi (Cyprinus carpio) captured during the net surveys.

Figure 108: Native mollusk, *Neritina vespertina*, on rock from in the lower reach of a stream.

The second and more extensive fish and aquatic animal survey involved the use of the High Definition Fish Survey (HDFS) approach. The HDFS approach utilized pole-mounted, high-definition, underwater video cameras to capture images of fish or other aquatic animals at a specific location. The underwater cameras were also geo-referenced so that specific time and place information was recorded for all video observations. By logging GPS data with underwater video, the HDFS results can easily be integrated with the HDSS habitat information gathered at the same location.

Figure 109: Underwater geo-referenced video camera used during the HDFS observations.

In general, the HDFS sample could be considered a point sample. The cameras are moved into position, slowly lowered to the bottom, and then remain in position for approximately 15 seconds to capture a sample of animals at that location. This process is repeated at sites distributed evenly throughout the available habitat. To document the animals observed in the videos, the HDSS video coder software with a list of potential animal species was used. During classification, a start code was inserted when the camera was in position. Next, all species were recorded, and then a stop code was recorded. This process allowed only high-quality underwater video samples to be used and to link the appropriate GPS data for that location. Habitat data associated with the fish samples was linked from the HDSS data collection.

The following are some examples of stream animals observed during the HDFS sample collection from various Hawaiian streams:

Figure 110: Native fish, *Awaous steminus*, in a stream pool.

Figure 111: Native fish, *Sicyopterus stimpsoni*, on boulder substrate.

Figure 112: Native species, *Kuhlia zenura*, in the lower reach of a stream.

Figure 113: Introduced swordtails, *Xiphophorus hellerii*, observed at high density.

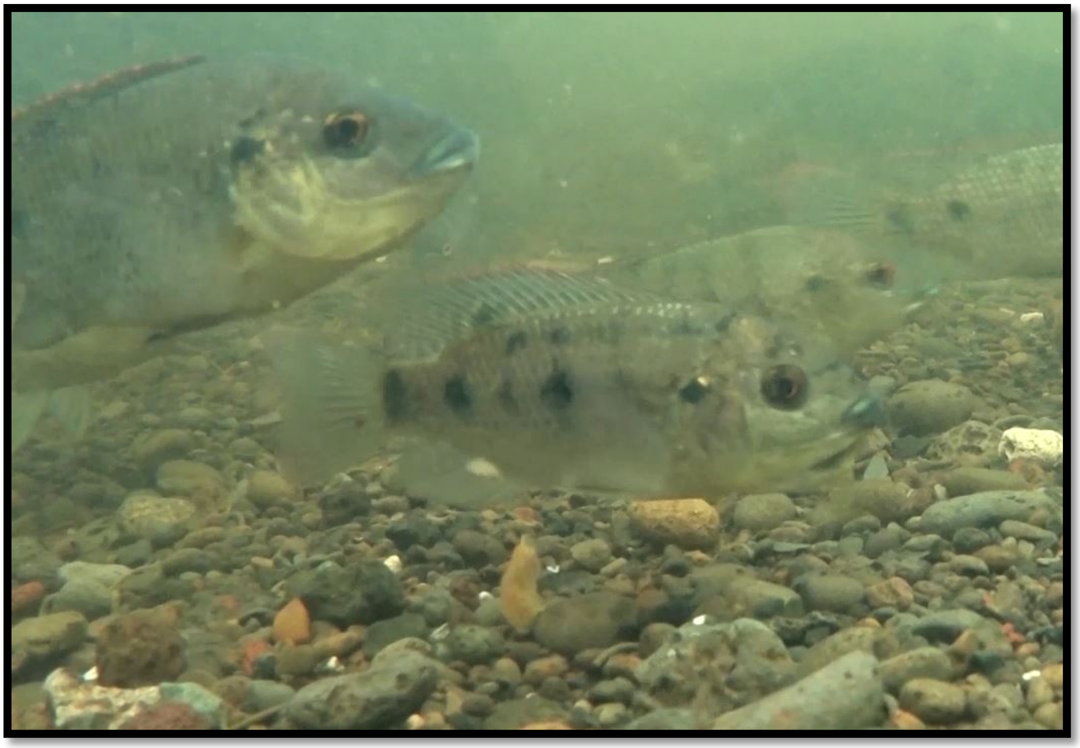

Figure 114: Introduced Blackchin tilapia, *Sarotherodon melanotheron*, over gravel substrate.

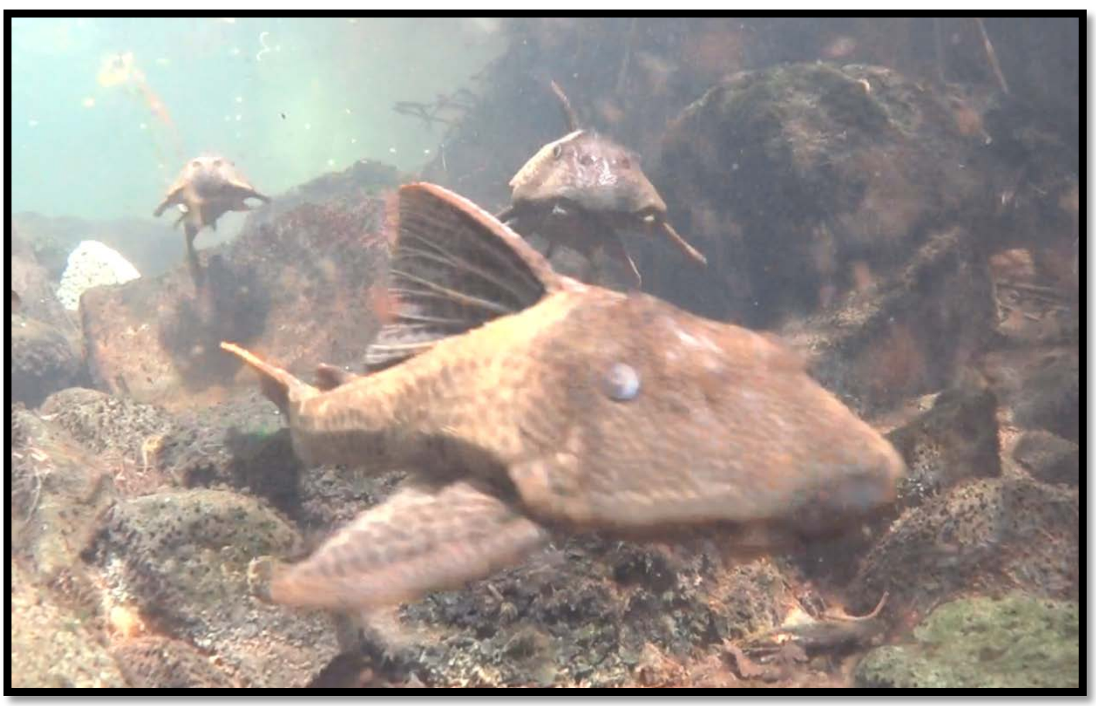

Figure 115: Introduced armored catfish, *Hypostomus c.f. watawata*, were found in large aggregations.

Attachment 2. Single-Use Approval of the Hawaiian Stream Habitat Evaluation Procedure for the Ala Wai Canal Flood Risk Management Project

CECW-P 28 May 2015

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: Single-Use Approval of the Hawaiian Stream Habitat Evaluation Procedure for the Ala Wai Canal Flood Risk Management Project, Hawaii

1. The HQUSACE Model Certification Panel has reviewed the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) in accordance with EC 1105-2-412 and has determined that the model and its accompanying documentation are sufficient to approve its use for the Ala Wai Canal flood risk managament study, Oahu, Hawaii. Adequate technical reviews have been accomplished and the Panel considered the assessments of the ECO-PCX and the Agency Technical Review in making this determination.

2. The HSHEP model was developed through collaboration between the Hawaii Division of Aquatic Resources and researchers at universities, state agencies, museums, and private entities. The model follows the Habitat Evaluation Procedure concepts and methodology to capture the major aspects of native stream animal ecology, geomorphology of Hawaiian streams, and common modifications to the environment. The intent of the model is to be useful in assessing the potential impacts of stream channel modification, flow alteration, land use change, climate change, stream restoration, and barrier modifications on native stream animal habitat quality and quantity. The HSHEP is designed to be used at site, stream segment, and stream and watershed scales depending on the scenario and level of detail required. Variables at the watershed scale include stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. Variables in the model describe instream habitat and animal distributions include factors such as elevation, distance from the ocean, and the presence of instream barriers. Finally, at the site level, more specific characteristics are included as suitability indices for six instream flow assessment (e.g., depth, velocity, and substrate) or habitat assessment (e.g., habitat type, depth, substrate, and temperature for habitat assessment) depending on the project objectives. Habitat suitability for eight species of native stream animals (i.e., five fish, two crustaceans, and one mollusk) was determined using presence/absence data as the basis for habitat utilization. Habitat utilization is the frequency of occurrence for an individual species in each habitat category. Suitability is developed by dividing the percent utilization for each habitat category with the percent available. The resulting suitability curve ranges from 0 (unsuitable) to 1.0 (highly suitable). By combining HSHEP results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable.

3. The HSHEP model has been reviewed by the Hawaii Division of Aquatic Resources, the USFWS and private consultants utilizing the model for hydroelectric licensing applications. Additionally, the ECO-PCX managed a review of the HSHEP model. The review was conducted by an ecologist with expertise in tropical island flora and fauna, associated habitat requirements, and extensive ecological modeling expertise, Dr. Kyle McKay, ERDC Environmental Laboratory. Comments received pursuant to this review recommended actions to clarify and improve model documentation and improve the overall usability of the model. The model documentation and inherent user's guide was

updated to more explicitly describe the intended use and appropriate documentation for variables, use of scales, and addition of variables. Documentation was improved to further detail application methodology, assumptions and limitations of the model, and address statistical model development issues.

4. The HSHEP has sufficient technical quality, is computationally correct, meets usability criteria and is policy compliant.

APPLICABILITY: The HSHEP is approved for single use on the Ala Wai Canal flood risk management study, Oahu, Hawaii.

BRUCE D. CARLSON
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

Attachment 3. Ala Wai Flood Control Project Impact to Native Stream Animal Habitat and Possible Habitat Mitigation Options

Ala Wai Flood Risk Management Project Impact to Native Stream Animal Habitat and Possible Habitat Mitigation Options

August 5, 2015

Submitted to:

CH2MHill
1132 Bishop Street, Suite 1100
Honolulu, Hawaii 96813

Submitted by:

James E. Parham, Ph.D.
Bishop Museum

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Introduction:

The purpose of the Ala Wai Canal Project is to reduce the risk of flooding within the Ala Wai watershed. In general, the flood risk management project is focused on holding back or diverting peak flood flows to lessen the impact of a flooding event. The infrastructure needed to do this is expected to have an impact on aquatic habitat and native Hawaiian stream animals. This report is an accounting of the impacts of the flood risk management project on aquatic habitat and native Hawaiian stream animals, and potential mitigation plans to offset these impacts. The Hawaiian Stream Habitat Assessment Procedure (HSHEP) model was used to determine the impact and quantify mitigation scenarios. In addition to supporting the HSHEP model, long stretches of Manoa, Palolo and Makiki streams were surveyed to better understand instream conditions both at the impact sites and throughout the stream in general.

Data Collection and HSHEP Methodology:

The overall HSHEP approach and methodology was reviewed by the USACE and approved for use on the Ala Wai Flood Risk Management Project. The HSHEP for the Ala Wai Flood Risk Management Project followed the accepted approach and methods can be found in the document:

Parham, J.E. 2015. The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model: Intent, Design, and Methods for Project Impact Assessment to Native Amphidromous Stream Animal Habitat. Submitted to Civil and Public Works Branch, U.S. Army Corps of Engineers, Honolulu District, HI. 178 pages.

Associated Data:

Also provided with this report are associated data tables and field videos. An Excel spreadsheet of the information associated with the stream segment results from the HSHEP model is named:

Parham, J.E. 2015. Ala Wai HSHEP Impact and Mitigation Worksheet: Spreadsheet of model outputs. Final Output.

There are also a number of video files from the High Definition Stream Surveys (HDSS) for the Ala Wai watershed streams (Table 1). The video files may be referred to as:

Parham J.E. and G.R. Higashi. 2015. High Definition Stream Surveys Video for the Ala Wai Watershed Streams: Video Name: *insert_name_here*.

The video names are as follows:

Table 1: HDSS Video Names for Ala Wai Watershed Streams.

HDSS_Video_Name
02_LowerManoa1
03_LowerManoa2
06_MaonaF2UH_final
07_UHupstreamT11_final
08_UHupstreamT12_final
09_UHupstreamT2_final
11_Track23_combined_final
13_ManoaDVpark_Up1Final
14_Manoa_D3T1a
15_Manoa_D3T2a
16_Manoa_D3T3a
17_Manoa_D3T3ba
18_Manoa_D3T4a
20_Upper_Trib
51_lowerPalolo1
54_PaloloMid1
55_PaloloMid2
58_UpperPaloloHDSS
80_Makiki1

Not all of the data could be presented effectively in this report. There were approximately 23,000 lines of data generated for the sites in the HSHEP model. This report summarizes the results in a segment by segment approach. All data will be made available with this report.

Geographic Area of Concern:

The overall HSHEP Model included Manoa Stream and its tributary Palolo Stream as well as Makiki Stream and Hausten Ditch which also flow into the Ala Wai Canal (Figure 1). These streams are all within the Ala Wai Watershed. The Ala Wai Flood Risk Management Project impacts various locations within Ala Wai Watershed streams. The stream segments are broadly numbered with lower numbers closer to the stream mouth and higher numbers toward the headwaters. Manoa Stream is numbered from 1 to 120, Palolo Stream 200 to 225, Makiki Stream 300 to 306, Hausten Ditch from 500 to 502. Table 1 shows the Segment IDs, Stream Name, and Flood Risk Management Site (Table 2).

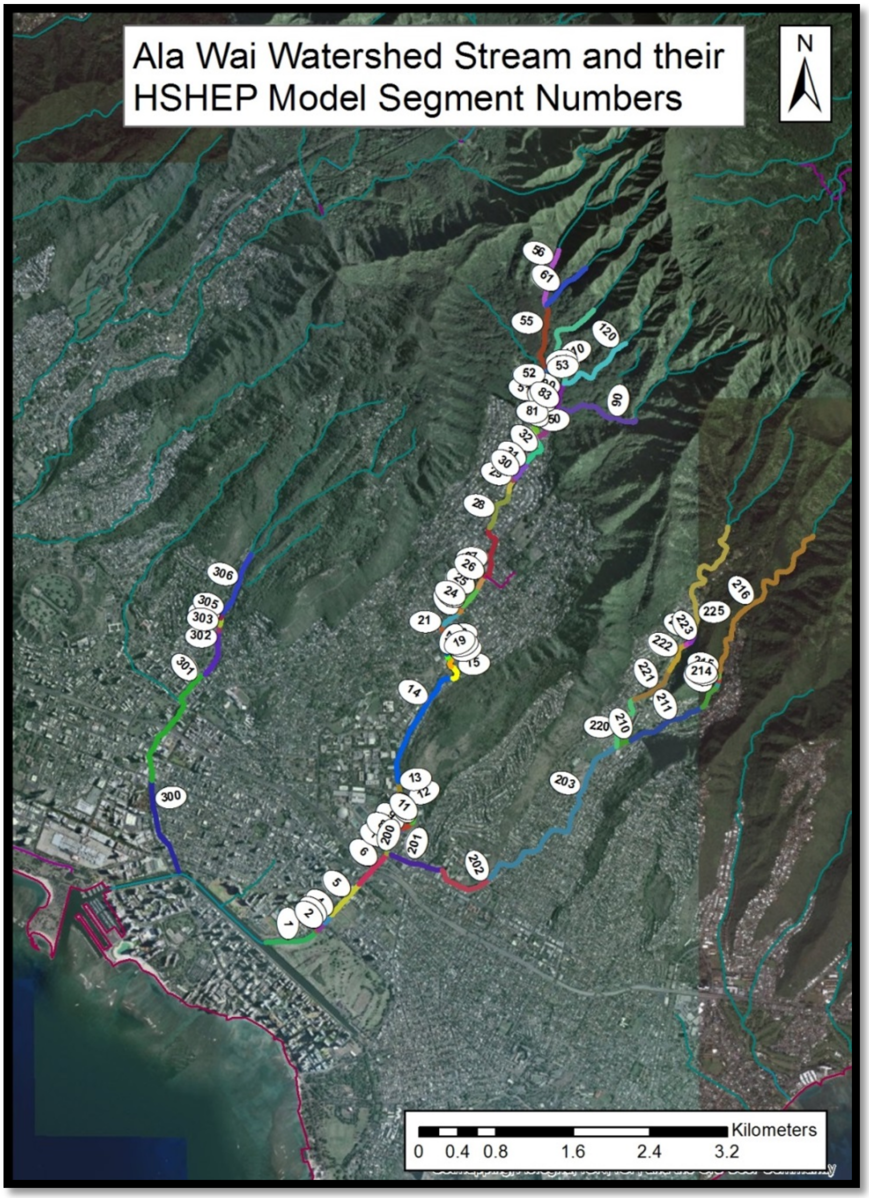


Figure 1: The Ala Wai Watershed Streams and the segment numbering used in the HSHEP model. Manoa Stream numbering goes from 1 at the stream mouth upstream to 120 in the upper reaches, Palolo Stream from 200 to 225, and Makiki Stream from 300 to 306.

Table 2: HSHEP Stream Segment ID, Name, and other information.

Segment ID	Stream Name	Tributary Name[1]	Key Site Description	Barriers: Falls Number (at start of segment)	Length[3] (m)	Width Class (ft)	Wetted Width (%)	Width (m)	Area (m^2)
1	Manoa	Manoa			520	80	90%	22	11,410
2	Manoa	Manoa	Ala Wai Golf Course Basin		22	80	90%	22	476
3	Manoa	Manoa			96	80	90%	22	2,115
4	Manoa	Manoa	Channel Maintenance Area		99	60	90%	16	1,638
5	Manoa	Manoa	Channel Maintenance Area		394	49	90%	13	5,304
6	Manoa	Manoa	Channel Maintenance Area		404	49	90%	13	5,407
7	Manoa	Manoa			108	36	90%	10	1,066
8	Manoa	Manoa			69	30	90%	8	569
9	Manoa	Manoa		Lower Falls	111	33	90%	9	1,004
10	Manoa	Manoa			96	33	90%	9	882
11	Manoa	Manoa	Kanewai Detention Basin		19	40	90%	11	212
12	Manoa	Manoa			320	35	90%	10	3,057
13	Manoa	Manoa			122	35	90%	10	1,171
14	Manoa	Manoa			1208	39	89%	11	12,714
15	Manoa	Manoa	State Woodlawn Chute Project		170	39	56%	7	1,132
16	Manoa	Manoa	State Woodlawn Chute Project		106	32	90%	9	942
17	Manoa	Manoa	State Woodlawn Chute Project		11	40	86%	10	116
18	Manoa	Manoa	State Woodlawn Chute Project		19	40	48%	6	111
19	Manoa	Manoa	State Woodlawn Chute Project		10	40	30%	4	36
20	Manoa	Manoa			228	33	30%	3	684
21	Manoa	Manoa	Channelized	Chan Barrier	74	50	30%	5	338
22	Manoa	Manoa	Channelized	Chan Barrier	199	50	30%	5	912
23	Manoa	Manoa	Channelized	Chan Barrier	55	50	30%	5	253
24	Manoa	Manoa	Manoa Instream Debris Catchment		13	44	68%	9	120
25	Manoa	Manoa			234	32	90%	9	2,078
26	Manoa	Manoa	Streambank Restoration Area		124	40	90%	11	1,362
27	Manoa	Manoa			564	35	89%	9	5,298

28	Manoa	Manoa		Barrier: Falls 6[4]	428	39	90%	11	4,567
29	Manoa	Manoa		Barrier: Falls 7	116	50	90%	14	1,597
30	Manoa	Manoa		Barrier: Falls 8	36	50	90%	14	498
31	Manoa	Manoa			197	50	90%	14	2,704
32	Manoa	Manoa			318	43	90%	12	3,784
50	Manoa	Waiahi			190	34	90%	9	1,759
51	Manoa	Waiahi		Barrier: Falls 11	366	30	75%	7	2,518
52	Manoa	Waiahi			73	30	75%	7	503
53	Manoa	Waiahi	Waiahi Detention Basin		37	30	75%	7	255
54	Manoa	Waiahi			60	30	75%	7	415
55	Manoa	Waiahi			617	20	90%	5	3,383
56	Manoa	Waiahi			567	15	90%	4	2,333
61	Manoa	Unnamed			531	15	90%	4	2,184
80	Manoa	Luaalaea			191	34	90%	9	1,768
81	Manoa	Luaalaea		Barrier: Falls 12	58	24	90%	7	387
82	Manoa	Luaalaea	Waiakeakua Detention Basin		63	27	90%	8	474
83	Manoa	Luaalaea			36	25	90%	7	247
90	Manoa	Waiakeakua			864	15	90%	4	3,557
100	Manoa	Luaalaea			257	20	90%	5	1,413
110	Manoa	Luaalaea			960	15	90%	4	3,949
120	Manoa	Naniuapo			815	15	90%	4	3,354
200	Palolo	Palolo			44	30	85%	8	344
201	Palolo	Palolo	Channelized	Chan Barrier	528	40	33%	4	2,086
202	Palolo	Palolo			570	30	86%	8	4,522
203	Palolo	Palolo	Channelized	Chan Barrier	2003	38	45%	5	10,451
210	Palolo	Waiomao	Channelized	Chan Barrier	154	35	45%	5	739
211	Palolo	Waiomao			789	35	45%	5	3,788
212	Palolo	Waiomao			275	22	83%	6	1,522
213	Palolo	Waiomao			40	25	90%	7	279
214	Palolo	Waiomao	Waiomao Detention Basin		34	20	90%	5	185
215	Palolo	Waiomao	Waiomao Detention Basin Excavation	Barrier: P_Falls 5	66	35	89%	9	620

216	Palolo	Waiomao			1852	15	90%	4	7,623
220	Palolo	Pukele	Channelized	Chan Barrier	566	40	50%	6	3,447
221	Palolo	Pukele			459	30	90%	8	3,777
222	Palolo	Pukele			308	30	90%	8	2,535
223	Palolo	Pukele	Pukele Detention Basin		54	30	90%	8	443
224	Palolo	Pukele			114	25	90%	7	785
225	Palolo	Pukele			1373	15	90%	4	5,648
300	Makiki	Makiki			940	40	90%	11	10,312
301	Makiki	Makiki	Channelized	Chan Barrier	1272	30	50%	5	5,814
302	Makiki	Makiki			454	18	84%	5	2,126
303	Makiki	Makiki			56	14	90%	4	220
304	Makiki	Makiki	Makiki Detention Basin		74	20	90%	5	404
305	Makiki	Makiki			57	16	90%	4	255
306	Makiki	Makiki			634	15	90%	4	2,607
500	Hausten	Hausten	Hausten Detention Intake		10	66	90%	18	181
501	Hausten	Hausten			150	66	90%	18	2,716
502	Hausten	Hausten	above Marco Polo Apts		560	44	90%	12	6,759

Description of Flood Risk Management Impact Areas:

Site 1, Manoa Stream: Ala Wai Golf Course Basin Intake

Segment ID: 2

Area Map:

Figure 2: HSHEP segment numbers associated with the Ala Wai Golf Course Detention Basin

Site Description: Manoa Stream is relatively wide at this location and the banks are covered with mangrove trees. The channel is constrained by man-made streambanks. The water is relatively slow moving and deep with fine substrates most common. This area is tidally influenced and what hard substrates do exist appear to be highly embedded with fine sediment.

The detention basin intake would be on the right hand shore looking upstream and would be a concrete structure that would fully harden a small section of the streambank. Instream habitat is unlikely to be greatly affected, as no plans for modification of the stream bottom are in the designs. The Expected Condition based on best professional judgment was a reduction in 20% of the habitat at the location due to the armoring of the streambank. The Worst-Case Condition reflected the maximum impact and was modeled at 100% loss of habitat as a result of the intake construction. The Worst-Case Condition likely far overstates the potential changes to instream habitat and its effects on native stream animals.

Figure 3: Looking upstream toward the Date Street Bridge. The golf course basin intake would be on the right.

Figure 4: Left bank looking upstream of lower Manoa Stream near the Date Street Bridge.

Figure 5: Right bank looking upstream of lower Manoa Stream near the Date Street Bridge. This is typical of the streambank condition at the basin intake site.

Site 2, Manoa Stream: Kanewai Field Multi-Purpose Detention Basin Intake

Segment ID: 11

Area Map:

Figure 6: HSHEP segment numbers associated with the Kanewai Field Detention Basin

Site Description: Manoa Stream is moderately wide and varies between riffles, runs, and pools in this area. The right bank looking upstream is already hardened with the majority of the riparian vegetation being found on the left-hand side. The site is a mix of substrates ranging from gravel to small boulders with cobble being the most common substrate type. The stream in this area has relatively decent instream habitat typical of mid-reaches in Hawaiian streams. There is some embeddedness from fine substrates due to upstream erosion.

Similar to the Ala Wai golf course basin intake, the detention basin intake at the Kanewai Field would be on the right hand shore looking upstream and would be a concrete structure that would fully harden a small section of the streambank. Instream habitat is unlikely to be greatly affected as no plans for modification of the stream bottom are in the designs. In the Expected Condition, our best professional judgment was a reduction in 20% of the habitat at the location due to the armoring of the streambank. The Worst-Case Condition was 100% loss of habitat as a result of the intake construction. The Worst-Case Condition likely far overstates the potential changes to instream habitat and its effects on native stream animals.

Figure 7: Below the Kanewai Field Intake Site looking upstream. This image shows instream conditions typical downstream of the impact site. Note the USGS gage site on the right bank.

Figure 8: Immediately below the Kanewai Field Intake Site. The large box culvert in upper center image is a reference to the site location.

Figure 9: Streambank and in-channel conditions at the Kanewai Field Intake site.

Figure 10: Looking upstream of the Kanewai Field Intake site.

Site 3, Manoa Stream: Manoa Instream Debris Catchment Site near Manoa Valley District Park

Segment ID: 24

Area Map:

Figure 11: HSHEP segment numbers associated with the Manoa In-Stream Debris Catchment Site.

Site Description: The site for the instream debris catchment is just upstream of a long channelized segment of Manoa Stream. This site is adjacent to the Manoa Valley District Park in the channel appears to have been straightened and widened in the past. Cobble and gravel are the primary substrates available with a small amount of fine sediment embedding of larger substrate types. The area is primarily a run habitat type mostly a foot or less in depth.

The impact at this location is expected to remove all instream habitat for native stream animals as the bottom will be entirely made of cement with the debris catchers rising up from it. Thus, the Expected Condition is in line with the Worst-Case Condition modeled as a total removal of the habitat.

Figure 12: Downstream of Debris Catchment site. Note that the stream is fully channelized here.

Figure 13: At the end of the channelized section immediately downstream of the Debris Catchment site.

Figure 14: Debris Catchment site. Manoa Valley District Park is on the left side of the image.

Figure 15: Upstream of the Debris Catchment Site. Instream habitat is similar from the end of the channelized segment to the bridge above.

Site 4, Manoa Stream: Woodlawn Ditch Detention Basin

Segment ID: no ID number (not perennial stream at Detention Basin site)

Area Map:

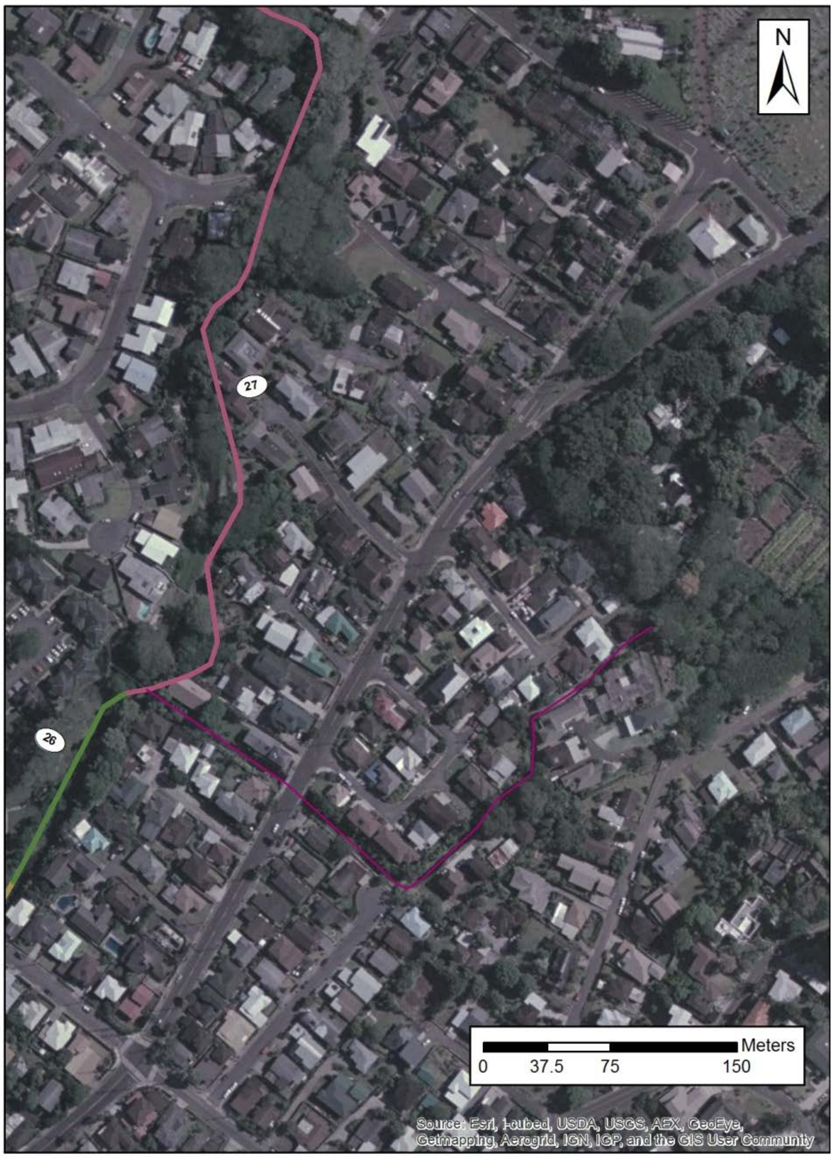


Figure 16: Map of the Woodlawn Ditch stream segments downstream of detention basin site.

Site Description: The Woodlawn Ditch was surveyed by state biologists and technicians. The ditch appears to have perennial flow in the lower end and becomes intermittent in the area of the planned detention basin. The stream was not surveyed directly in the impact area, but it was dry above it and was very small below it. Under best of conditions, the amount and quality of instream habitat for native amphidromous stream animals would be limited, but with its designation as an intermittent stream, we did not include it in the model as by definition it would not support the stream animals of concern.

Figure 17: Mouth of the Woodlawn Ditch entering Manoa Stream. Ditch is entering on the right side of stream.

Figure 18: Downstream view of Woodlawn Ditch from East Manoa Road Bridge. (G. Higashi, DAR photo)

Figure 19: View straight down from East Manoa Road Bridge into Woodlawn Ditch. (G. Higashi, DAR photo)

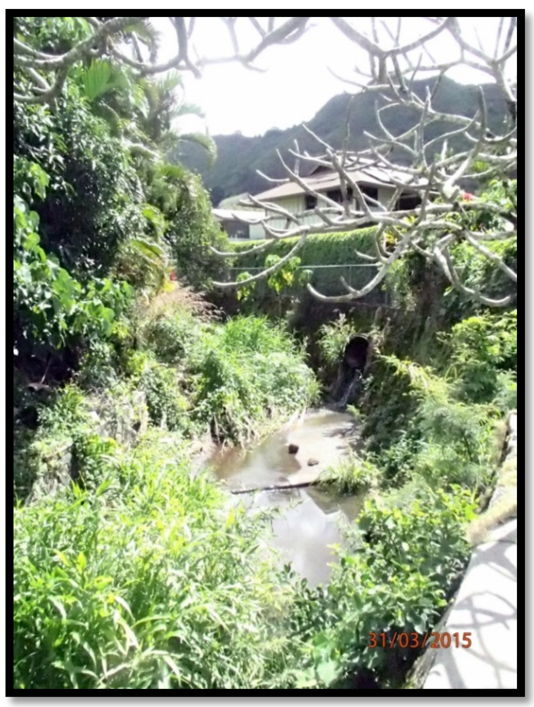


Figure 20: Looking upstream on Woodlawn Ditch from end of Kahiwa Place. Channelized section begins here. (G. Higashi, DAR photo)

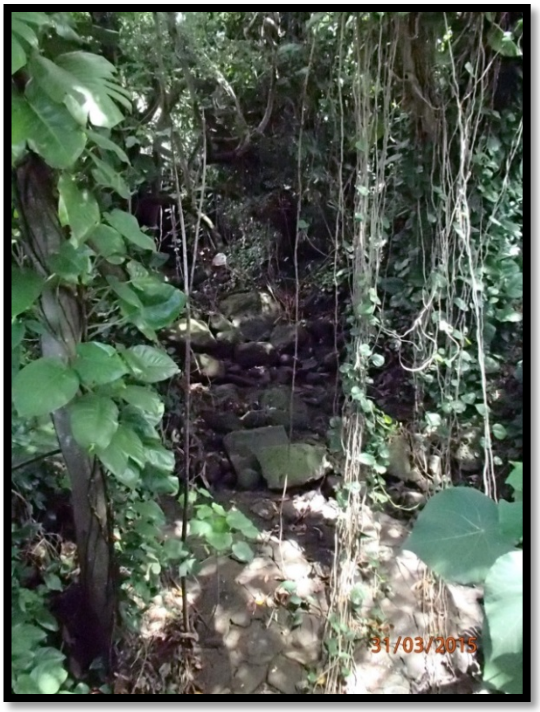


Figure 21: Looking upstream from the East Manoa Road and Akaka Place intersection. Stream is dry here. This is just above the Detention Basin site. (G. Higashi, DAR photo)

Figure 22: Looking upstream from the East Manoa Road and Akaka Place intersection. Stream is dry here. This is just above the Detention Basin site. (G. Higashi, DAR photo)

Site 5, Manoa Stream: Waihi Debris and Detention Basin

Segment ID: 53

Area Map:

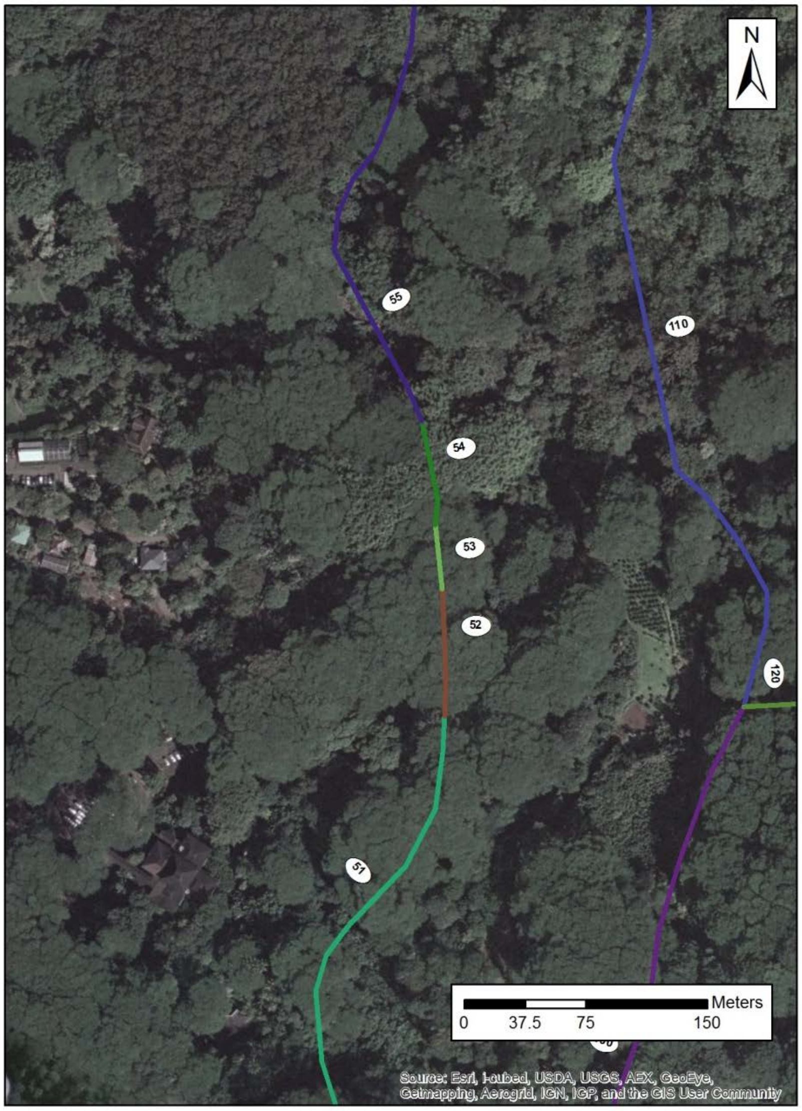


Figure 23: HSHEP segment numbers associated with the Waihi Debris and Detention Basin Site.

Site Description: Manoa Stream, in the vicinity of the Waihi Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site is above the majority of the development found lower in the watershed and has large trees throughout its riparian zone. There is evidence of erosion scars from past flooding events and numerous large logs are found in the stream channel but in general the instream habitat would be considered good in comparison to much of the rest of Manoa Stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and the Worst-Case Condition scenarios.

Figure 24: Downstream of the Waihi Detention Basin Site.

Figure 25: A plunge pool in the area of the Waihi Detention Basin Site.

Figure 26: Looking upstream toward Waihi Detention Basin Site. Much of the area ahead was impassable due to flood debris, with many logs across the stream.

Site 6, Manoa Stream: Waiakeakua Debris and Detention Basin

Segment ID: 82

Area Map:

Figure 27: HSHEP segment numbers associated with Waiakeakua Debris and Detention Basin Site.

Site Description: The tributary of Manoa Stream, in the vicinity of the Waiakeakua Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site is above the majority of the development found lower in the watershed and has large trees throughout its riparian zone.

There is evidence of erosion scars from past flooding events and hau and bamboo are growing in the stream channel, but in general the instream habitat would be considered good in comparison to much of the rest of Manoa Stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and the Worst-Case Condition scenarios.

Figure 28: Lower end of Waiakeakua Debris Basin. Note that much of the area is overgrown by Hau trees.

Figure 29: Upper end of Waiakeakua Debris basin.

Site 7, Palolo Stream: Waiomao Debris and Detention Basin

Segment ID: 214 and 215

Area Map:

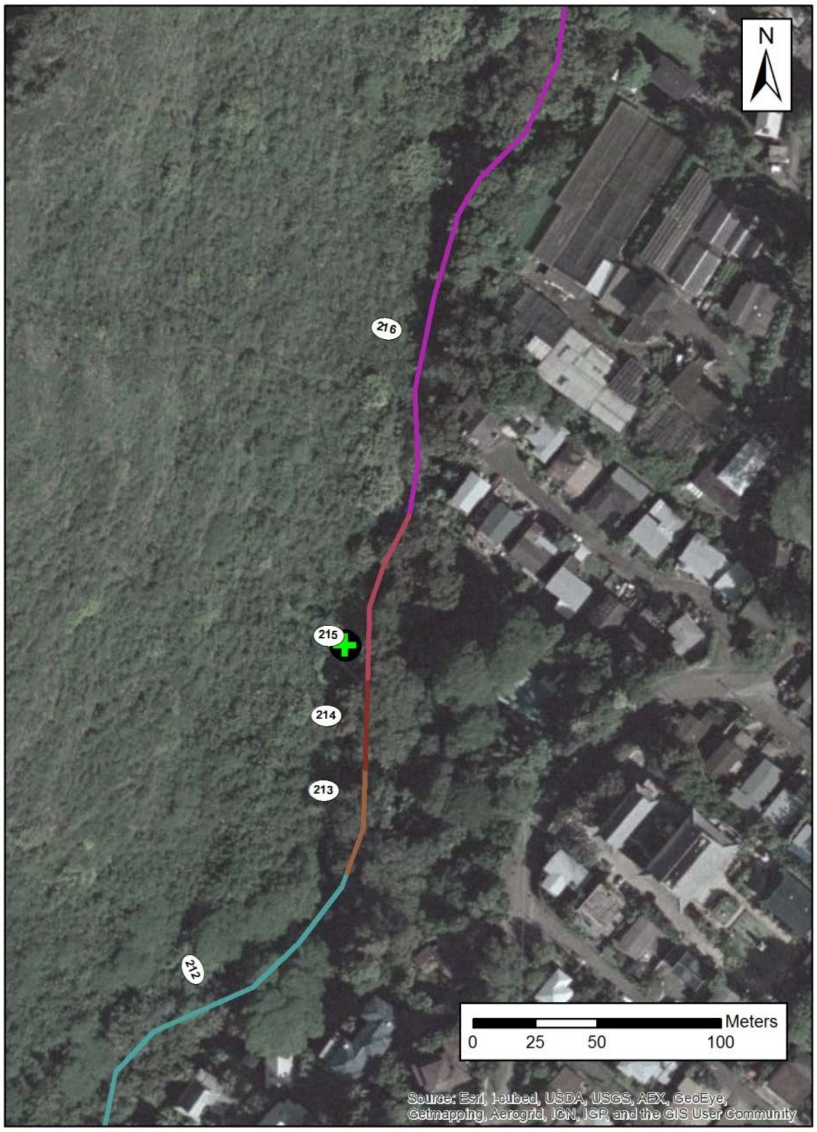


Figure 30: HSHEP segment numbers associated with Waiomao Debris and Detention Basin Site.

Site Description: The Waiomao tributary of Palolo stream, in the vicinity of the Waiomao Debris and Detention basin, is a relatively natural stream. We observed a range of substrate types from fine sand to large boulder, with run, riffle and pool habitats all present. This site has housing developments on its right bank looking upstream but still has large trees and bushes in much of its riparian zone. There is evidence of erosion scars from past flooding events and an old USGS gage is located in the stream channel at the site. Overall, the instream habitat would be considered good in comparison to much of the rest of Palolo stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the best professional judgment and the maximum impact scenarios. At this location, the area above the berm will be excavated to increase the detention volume of the basin and thus some habitat will be lost in this area also. Expected Condition expected a loss of approximately 50% of the habitat with the Worst-Case Condition scenario at 100% loss of habitat in the excavation area.

The old USGS gage will be removed during the construction of this project and as a result upstream passage will be improved for native migratory stream animals. Thus, there are both positive and negative impacts associated with the flood risk management project at this location.

Figure 31: Downstream of the Waiomao Tributary Detention Basin site.

Figure 32: Looking upstream into the Waiomao Tributary Detention Basin site.

Figure 33: The USGS gage in the Waiomao Tributary Detention Basin site. This old gage will be removed with the project and will no longer be a barrier to upstream animal passage.

Site 8, Palolo Stream: Pukele Debris and Detention Basin

Segment ID: 223

Area Map:

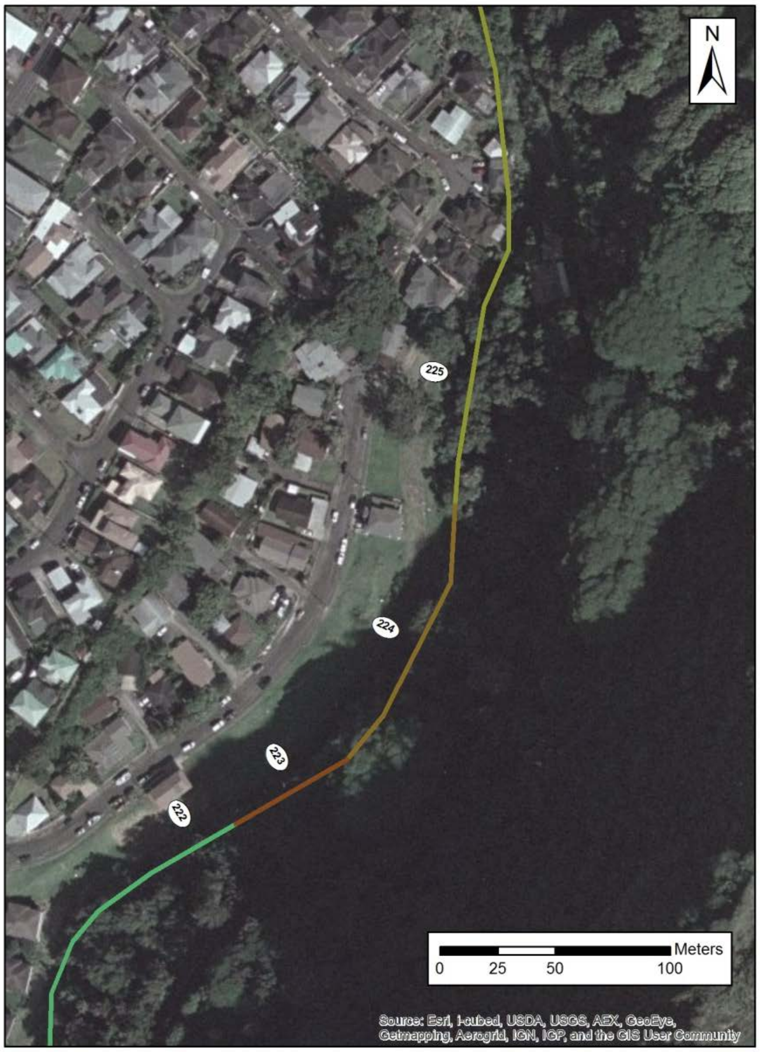


Figure 34: HSHEP segment numbers associated with Pukele Debris and Detention Basin Site.

No pictures available as we were unable to gain access to this site. It is modeled to be similar to the Waiomao Tributary site.

<u>Site 9, Makiki Stream: Makiki Debris and Detention Basin</u>

Segment ID: 304

Area Map:

Figure 35: HSHEP segment numbers associated with Makiki Debris and Detention Basin Site.

Site Description: Makiki stream, in the vicinity of the Makiki Debris and Detention basin, is a relatively natural stream. It is narrow with steep walls and we observed a range of substrate types from gravel to large boulder, with run, riffle and pool habitats all present. This site has large trees and bushes in much of its riparian zone. There is evidence of erosion scars from past flooding events. Overall, the instream habitat would be considered good in comparison to much of the rest of Makiki stream. We began our survey after the stream reemerged from being underground for a long section under Honolulu. Interestingly, we observed amphidromous animals as well as numerous introduced fishes in the area. This confirms that some native animals are able to travel underneath the city to reach the upper reaches of the stream.

The debris and detention basin here will change instream habitat and likely capture substantial amounts of woody debris. The footprint of the detention berm will be expected to eliminate all instream habitats under both the Expected Condition and Worst-Case Condition scenarios.

Figure 36: Downstream of Makiki Detention Basin Site.

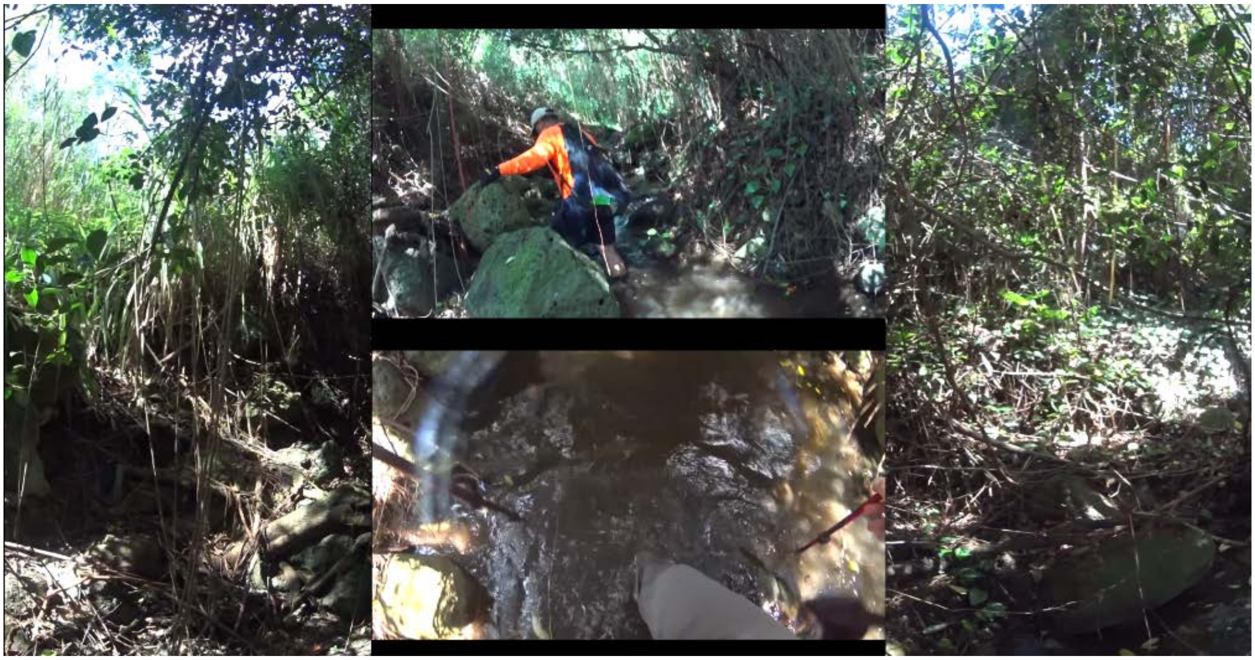


Figure 37: Near downstream end of Makiki Detention Basin Site.

Figure 38: Makiki Stream in the area of Makiki Detention Basin Site.

Site 10, Hausten Ditch: Hausten Ditch Detention Basin Intake

Segment ID: 500

Area Map:

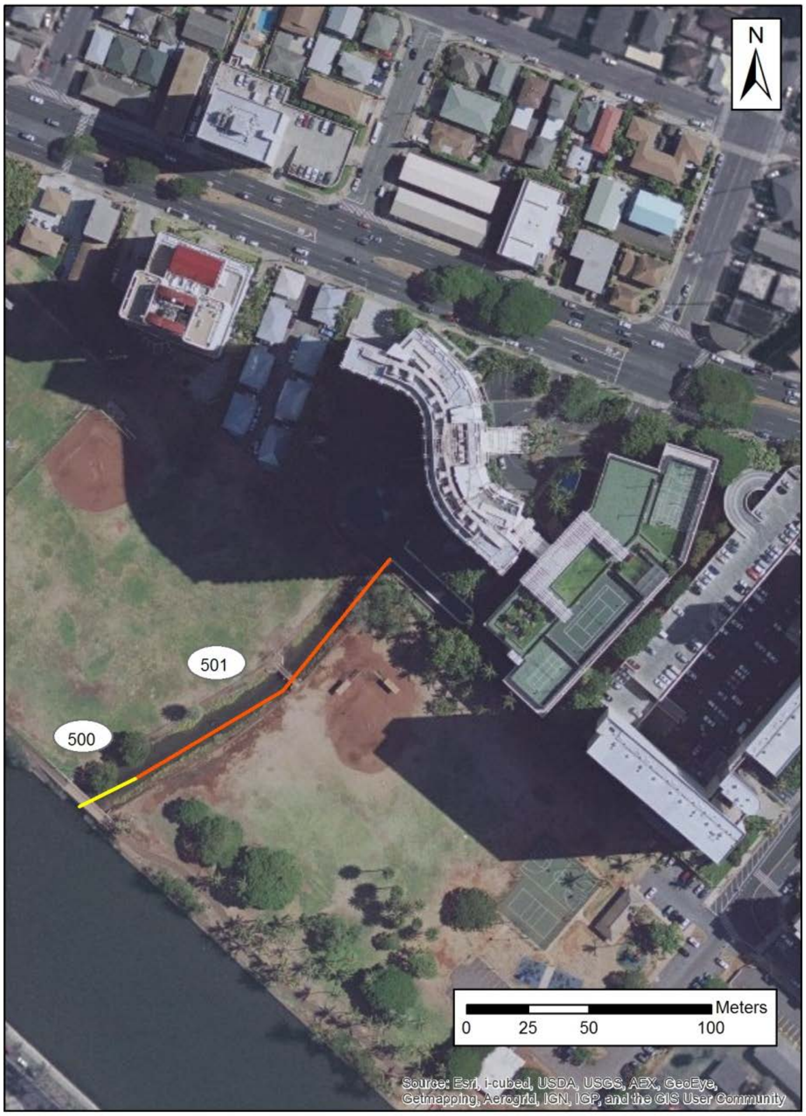


Figure 39: HSHEP segment numbers associated with Hausten Ditch Detention Basin Intake Site.

Site Description: Hausten Ditch is moderately wide at this location and the banks are covered with mangrove trees. The channel is constrained by man-made streambanks. The water is relatively slow moving and deep with mostly fine substrates. This area is tidally influenced and what hard substrates do exist appear to be highly embedded with fine sediment.

The Hausten Ditch detention basin intake would cross the entire channel and would likely eliminate instream habitat within its footprint. As a result, the Expected Condition and the Worst-Case Condition were modeled with a 100% loss of habitat as a result of the intake construction. The detention basin intake would not affect passage for stream animals and flow impacts would only be at very high flood flows.

Figure 40: Looking downstream toward the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch.

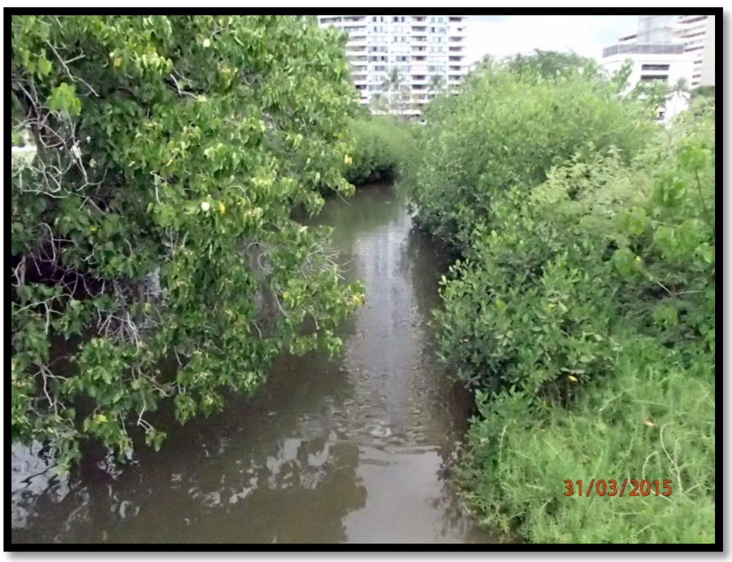


Figure 41: Looking upstream away from the Ala Wai Canal from the first pedestrian bridge over Hausten Ditch. The intake will be on the right bank in this area.

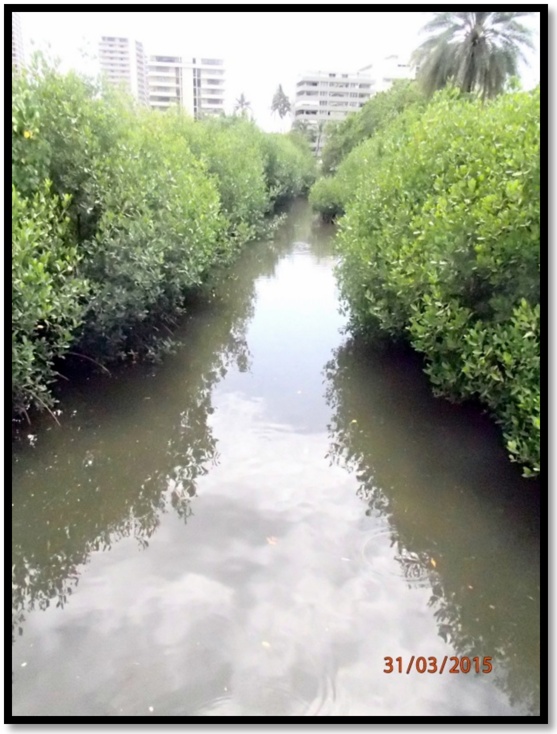


Figure 42: Downstream view from the second pedestrian bridge upstream of the intake site on Hausten Ditch.

Figure 43: The boundary fence for the Marco Polo Apartments on Hausten Ditch.

Figure 44: Looking upstream from Kapiolani Blvd. across from Marco Polo by bus stop.

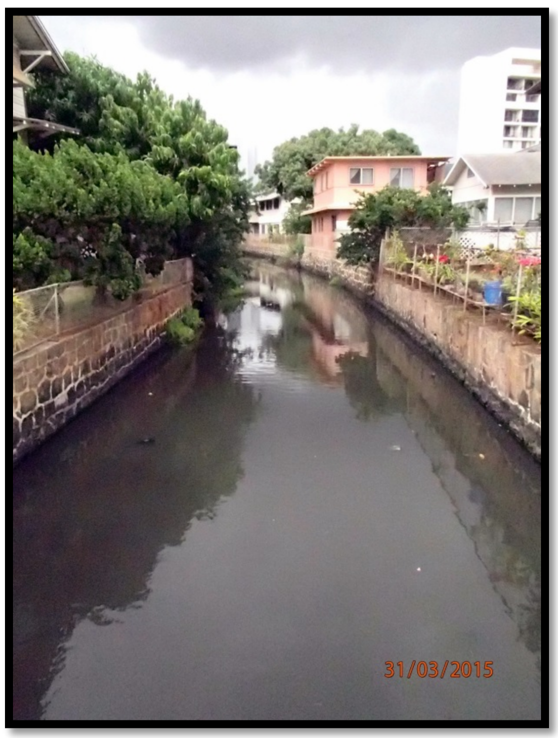


Figure 45: Upstream view from Date St. Bridge into Hausten Ditch.

Mitigation Scenario 1, Manoa Stream: Mitigation of Channelized segment in Manoa Stream

Segment ID: 22 and 23

Area Map:

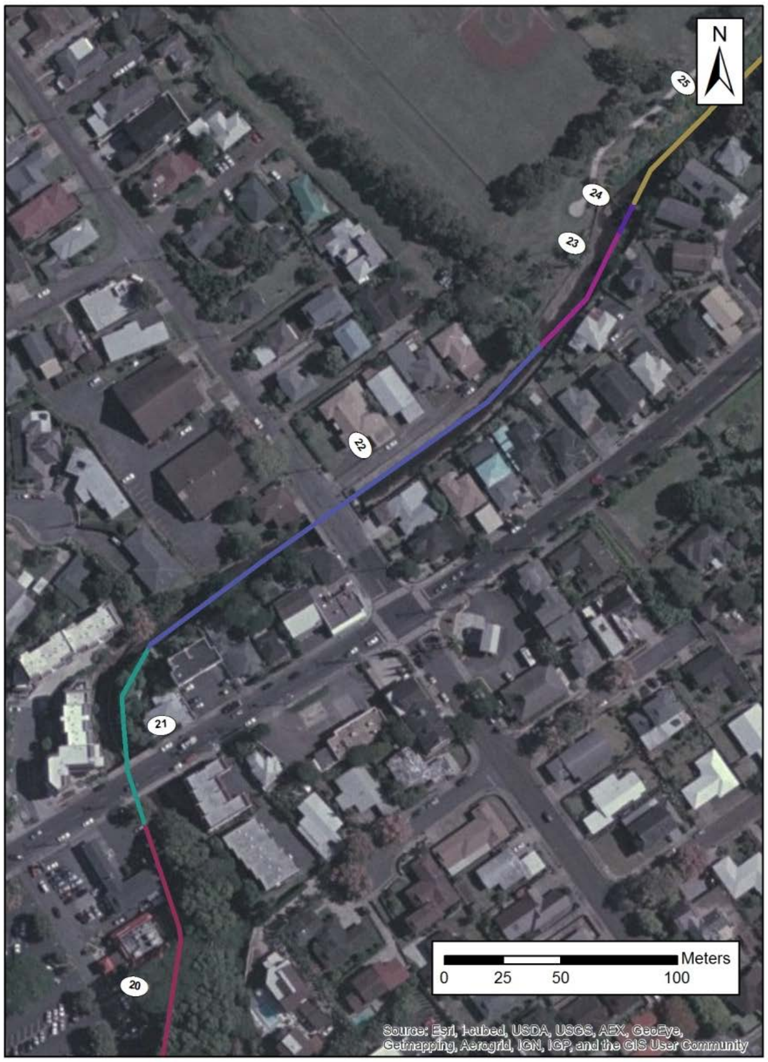


Figure 46: HSHEP segment numbers associated with Channelized section of Manoa Stream.

Mitigation Description: Improvements to the channelized section are intended to accomplish two separate goals. First, the improvements will allow easier passage across the long flat concrete bottom for migratory animals. The improvements will add some roughness and increase water depth to provide holding pools during passage. Second, the habitat pool and low flow channel designs would also provide suitable instream habitat within the channelized section. The plans would place the channel improvements starting above the curve in segment 21 and going upstream to the end of the channelized section. The drop found in the middle of this section is not currently a barrier to native stream species that could reach this location so improvements are not focused on this particular instream feature.

The three instream improvements are:

1. Resting riffles - these are small speedbump-like features that provide shallow pools on the upstream side and concentrate flow on the downstream side. This is intended to allow migratory animals places to rest as they move through the channelized segment. It is not primarily for the improvement of instream habitat with the intent of animals living within the shallow features.
2. Habitat Pools - these are small pools cut into the existing bottom of the channel. These would be deep enough to provide some instream habitat under all flow conditions. The pools would be disconnected by the otherwise flat channel bottom. They would also improve passage by providing resting pools during migratory events.
3. Low-Flow Channel - the low-flow channel would be cut into the existing bottom of the channel. The low-flow channel would constrain flow to a much narrower channel with rocks embedded in the channel to provide complex flow, a variety of depths, and more natural substrate. This feature would be continuous through the channelized segment. The low-flow channel would provide instream habitat and improve passage.

From a modeling perspective, channelized sections of the stream are a barrier to passage, affecting the availability of habitat in all upstream segments. The longer the channelized section, the more difficult it will be for fish to pass without ending up in unsuitable habitat conditions (for example overly hot water due to its shallow and fully exposed channel shape). For short distances the majority of fish would likely pass, but if distances reach more than a kilometer or two, it is likely to cause some problems for passage. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 10% of the animals for each 100 m of channelized stream and the greater impact was modeled at a barrier to passage 15% of the animals for each 100 m of channelized stream. These provided a range of impacts to address passage uncertainty at the site.

For improvements to fish habitat, the estimates change in suitable habitat for the two instream habitat improvement is based on the designs of the structures and reflect the area of the new structure with respect to the overall channel dimension. The habitat pools were thought to add approximately 8% more suitable habitat area to the channel than without the features and the low-flow channel would add about 62% more suitable habitat area to the channel. The habitat pools are much smaller features than the continuous low flow channel. Both of these actions are improvements over the flat concrete bottom currently found in the channelized section, but neither option is a return to a natural stream bottom with complex instream habitat, therefore neither option returns 100% of potential habitat.

Figure 47: Channelized segment in Manoa Stream. Low-flow channel would begin just above wall in middle of stream.

Figure 48: Channelized segment of Manoa Stream

Figure 49: Drop in the channelized segment of Manoa Stream.

Figure 50: Above the drop in the Channelized segment of Manoa Stream.

Mitigation Scenario 2, Mitigation of overhanging barriers

Segment ID: multiple segments depending on barriers selected

Area Map:

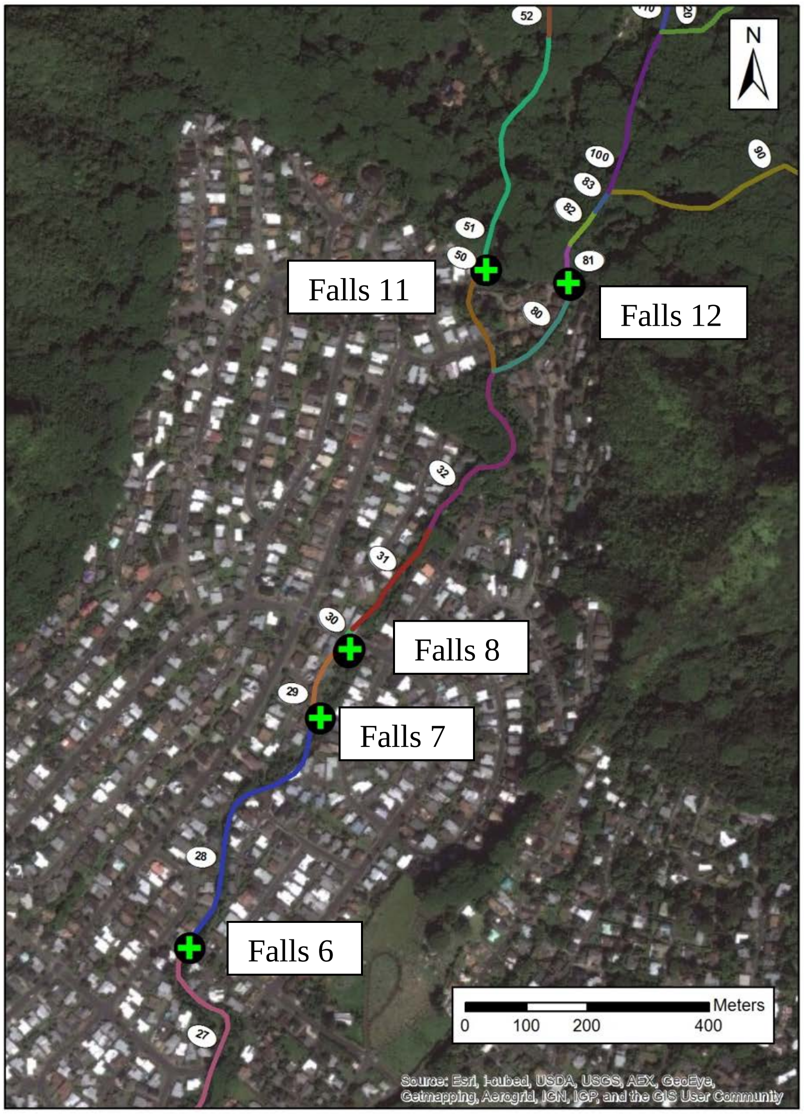


Figure 51: HSHEP segment numbers associated with overhanging falls on Manoa Stream. Falls are represented by the green cross in the black circle.

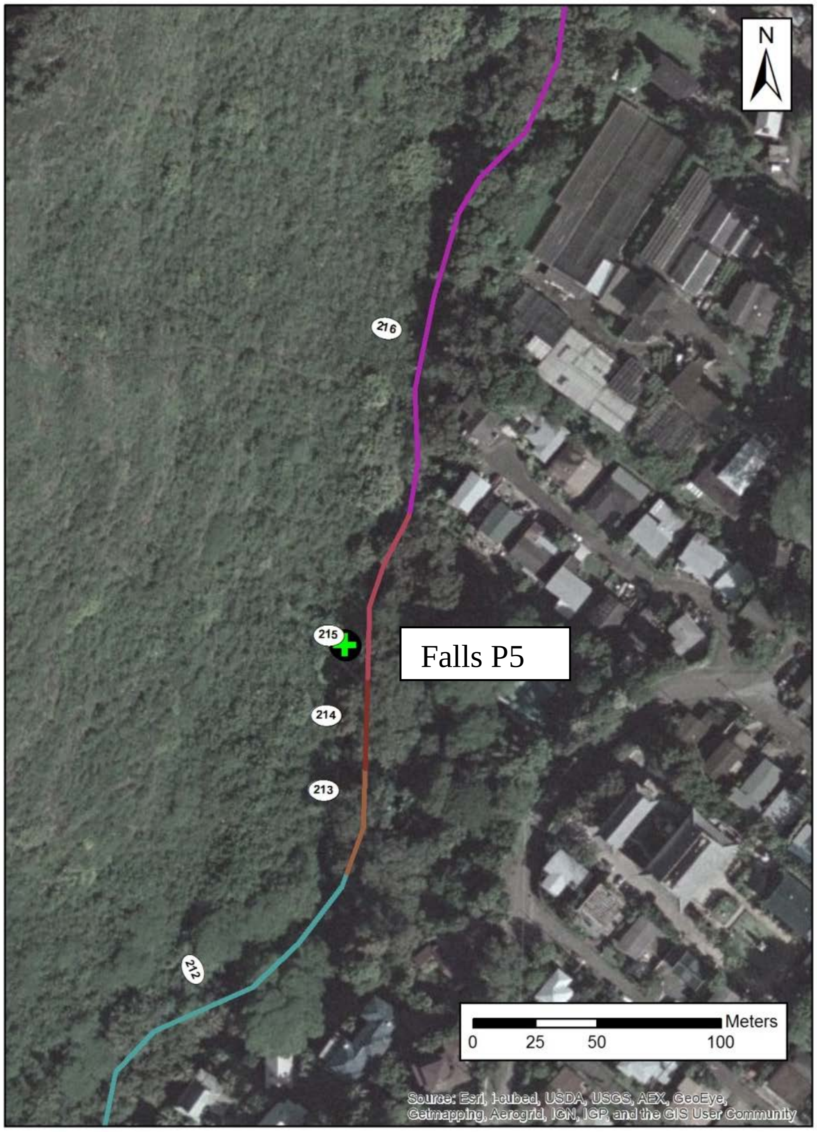


Figure 52: HSHEP segment numbers associated with overhanging falls on Palolo Stream. Falls are represented by the green cross in the black circle.

Mitigation Description: Waterfalls, either natural or man-made, which feature an overhanging lip that does not allow water to flow down the face of the waterfall with continuous contact, have been found to limit the ability of migratory animals to pass. During the surveys in the Ala Wai watershed streams, we observed a number of man-made structures that had the overhanging feature. In most cases, the overhanging feature was the result of erosion and undermining of the structure by the stream flow. These overhanging features were unlikely to be complete barriers to passage as at higher flows they may be completely underwater. At lower flows, migratory stream animals would need to wait below the feature until suitable flows aloud upstream passage. As a result each barrier would increase the time that it would take for an animal to reach suitable upstream habitats and decrease the temporal window in which passage would be available.

The mitigation action proposed to improve the structures would be to fill in the area under the structure with grouted riprap to provide a continuous wetted surface at all discharges to allow fish passage. As a secondary benefit, these improvements would also extend the life of the features and decrease the probability of their failure in the stream.

From a modeling perspective, these barriers to passage affect the suitability of habitat in all upstream segments above the barrier. Additionally, the cumulative effect of multiple barriers can greatly reduce the suitability of upstream habitats by limiting the probability that fish could reach these locations. In the Ala Wai watershed streams, this is a problem because high-quality habitat can be found in the forested upstream reaches and these barriers decrease the availability of these habitats to native stream animals. Given the uncertainty in determining the proportion of time in which these features act as barriers to instream movement, two different barrier impact values were considered. The lesser impact was modeled at a barrier to passage 50% of the time and the greater impact was modeled at a barrier to passage 65% of the time. These provided a range of impacts to address passage uncertainty at the site.

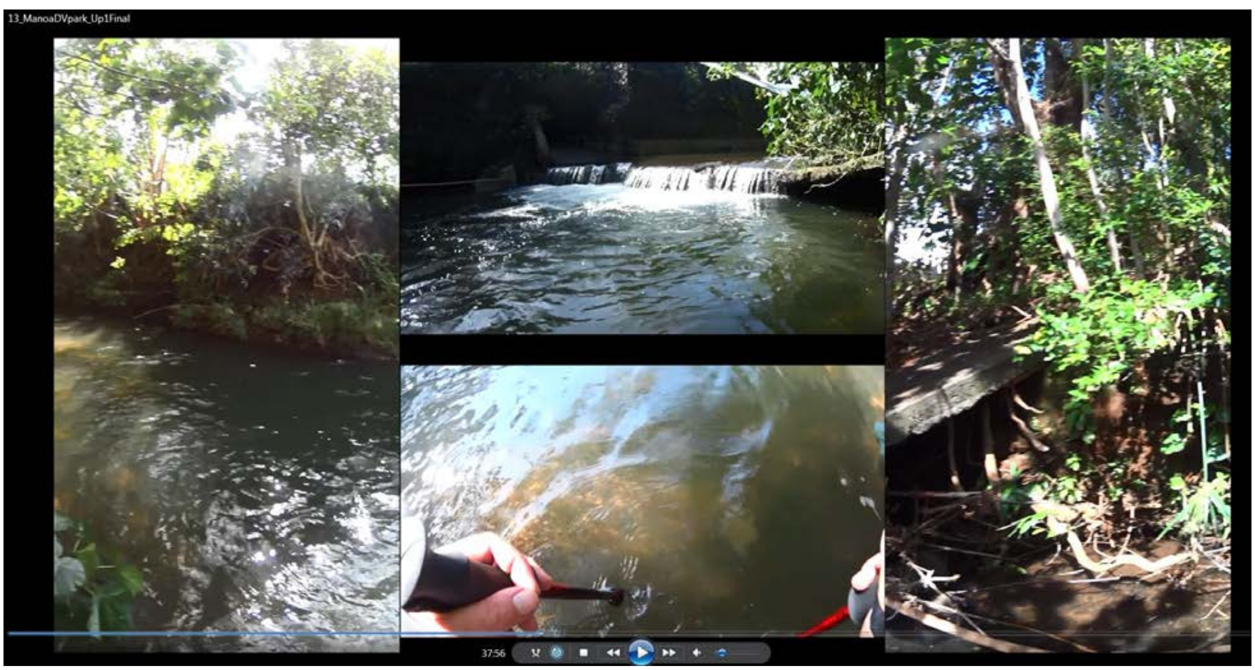


Figure 53: Overhanging barrier on the main channel of Manoa Stream (named as Falls 6).

Figure 54: Overhanging barrier on the main channel of Manoa Stream (named as Falls 7).

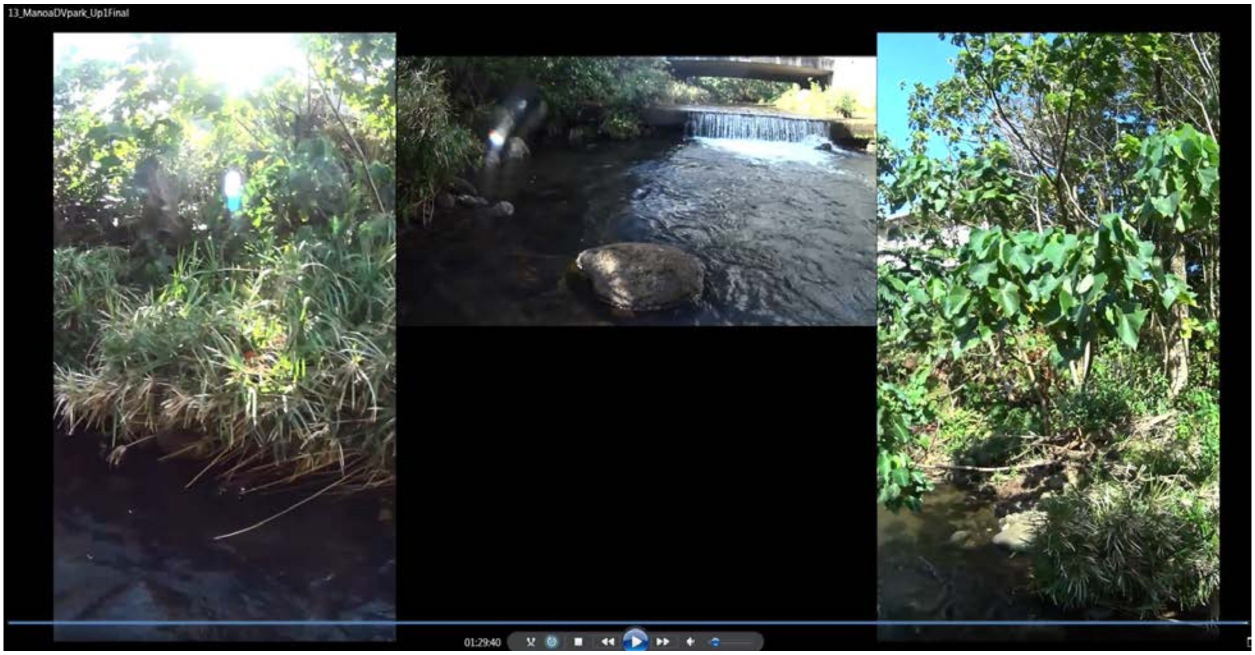


Figure 55: Overhanging barrier on the main channel of Manoa Stream (named as Falls 9).

Figure 56: Overhanging barrier on Manoa Stream tributary Waihi (named as Falls 11). This is a USGS gage that is failing.

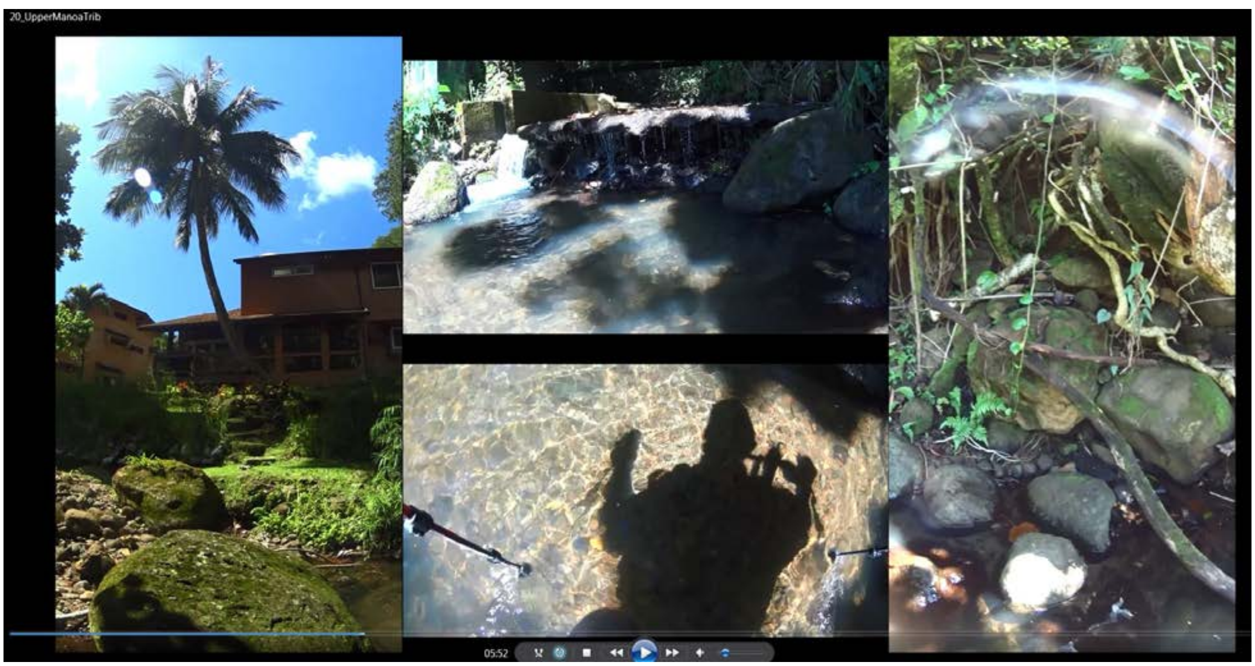


Figure 57: Overhanging barrier on Manoa Stream (named as Falls 12). This is another USGS gage that is being undermined. This is on the Waiakeakua tributary of Manoa Stream just below the Waiakeakua Debris and Detention Basin site.

Figure 58: Overhanging barrier on Palolo Stream tributary Waiomao. (named as Falls P5). This is a USGS gage that is in the footprint of the Waiomao Debris and Detention Basin.

Determination of current instream habitat availability:

<u>Selection of Evaluation Species:</u>

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Hawaiian streams (Table 2). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 3: Species habitat evaluated within the Hawaiian Streams using the HSHEP model. *Identified as "Species of Greatest Conservation Need" in the Hawaii Statewide Aquatic Wildlife Conservation Strategy.

Organism Type and Family	**Scientific name**	**Hawaiian name**	**Climbing Species**
Freshwater fish (family Gobiidae)	*Awaous guamensis**	ʻOʻopu nākea	Yes
	*Lentipes concolor**	ʻOʻopu alamoʻo	Yes
	*Stenogobius hawaiiensis**	ʻOʻopu naniha	No
	*Sicyopterus stimpsoni**	ʻOʻopu nōpili	Yes
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	ʻOʻopu akupa	No
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	ʻŌpae kalaʻ'ole	Yes
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	ʻŌpae ʻoehaʻa	No
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai	Yes

Determination of Habitat Availability, Impact, and Mitigation:

Following the HSHEP methods approved by the USACE, the habitat suitability was determined for approximately each meter of the project area and then the average suitability within the segment was applied to each segment. A combination of habitat suitability and the length and width of the segment were used to determine the habitat units (HU) within the segment. The HU were calculated for each species and also the combination of all native species within the segment.

The current (or without project conditions) are based on the observed field conditions within the stream segments. The project impact (or with project conditions) was determined for loss of habitat and potential for restriction of passage for the native species. As discussed earlier, two impact possibilities were considered: (1) the Expect Condition based on best professional judgement (BPJ) of the impact, and (2) Worst-Case Condition with the complete elimination of habitat in the segment. The Expected Condition was based on discussions with state biologists, consulting hydrologic engineers and my professional opinion. We had a number of meetings and phone discussions to determine the extent of impacts and the potential mitigation benefits. The Worst-Case Condition provides an estimate of the upper bounds of the impact to habitat in the project area.

Table 4: Expected Condition results in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	36713	36,522	36,522	0
Palolo Stream	1377	1,484	1,366	118
Makiki Stream	7800	7,777	7,777	0
Hausten Ditch	8681	8,597	8,597	0
Total	**54572**	**54,380**	54,262	118
Overall HU Change		**-192**	-310	118
Net HU Change				

Table 5: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the current conditions and with-project conditions in the Ala Wai watershed streams.

	Existing Conditions	With-Project Conditions	With Project Negative	With Project Positive
Manoa Stream	35,391	34,584	34,584	0
Palolo Stream	834	863	831	32
Makiki Stream	7,495	7,484	7,484	0
Hausten Ditch	8,681	8,261	8,261	0
Total	**52,401**	**51,192**	**51,160**	**32**
Overall HU Change		**-1,210**	**-1,242**	**32**

The mitigation potential was determined for different potential mitigation efforts: (1) the improvement of passage barriers in the upstream reaches, and (2) the installation of a low-flow channel with various levels of instream habitat. Each of these mitigation efforts had different design applications and results are shown for the options below.

Table 6: Expected Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options in the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	37,875	40,392	41,978	42,604	44,190	37,814	37,736	37,729
Palolo Stream	1,484	1,484	1,484	1,484	1,484	1,484	1,484	1,484
Makiki Stream	7,777	7,777	7,777	7,777	7,777	7,777	7,777	7,777
Hausten Ditch	8,597	8,597	8,597	8,597	8,597	8,597	8,597	8,597
Total	**55,733**	**58,250**	**59,836**	**60,462**	**62,048**	**55,672**	**55,594**	**55,587**
Overall HU Change	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
Net HU Change	**1,161**	**3,678**	**5,264**	**5,891**	**7,477**	**1,100**	**1,022**	**1,016**

Table 7: Worst-Case Condition results for in Habitat Units (m^2) for all species combined associated with the mitigation options for the Ala Wai watershed streams.

	Falls 7	Falls 7 & 8	Falls 7, 8 & 11	Falls 7, 8 & 12	Falls 7, 8, 11, & 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Manoa Stream	35,386	37,401	39,041	39,689	41,329	35,882	35,809	35,803
Palolo Stream	863	863	863	863	863	863	863	863
Makiki Stream	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484
Hausten Ditch	8,261	8,261	8,261	8,261	8,261	8,261	8,261	8,261
Total	**51,994**	**54,009**	**55,649**	**56,297**	**57,937**	**52,490**	**52,417**	**52,411**
Overall HU Change	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**
Net HU Change	**-407**	**1,607**	**3,248**	**3,895**	**5,536**	**89**	**16**	**9**

It is important to remember that these summary tables provide the results for all of the native amphidromous species combined and are summarized at the stream level. The results of the model are far more specific than this but it is difficult to present very large spreadsheets in document form. The underlying data were collected at approximately 1 m resolution for both streambanks and the stream channel and then was summarized for the segments of concern throughout the watersheds. Next, changes for uncertainty in impact (Expected Condition and Worst-Case Condition), mitigation options, and species-specific distribution and habitat were all calculated. Changes to any one of these variables affects all the other results, and while this is an effective way to view the results in an active spreadsheet, it is difficult to reproduce in printed form.

Conclusion:

The application of the HSHEP model and High Definition Stream Surveys (HDSS) approach to habitat quantification for the assessment of current conditions with project impacts, and mitigation scenarios for the Ala Wai watershed streams in response to the USACE flood risk management project proved very successful. HDSS habitat availability data were collected broadly throughout the streams. This allowed very detailed understanding of where and what type of habitat was present in different stream segments. Prior to the HDSS fieldwork, the presence of over-hanging drops within Manoa and Palolo Streams were unknown. Covering extensive stream reaches also allowed us to see that the upper reaches of all of the streams still have suitable habitat for native amphidromous species and in many locations in the highly developed lower and middle reaches suitable habitat still exists.

The HSHEP model provides a standardized approach to assess both instream distribution and habitat suitability for the native amphidromous stream animals. It was able to address issues of fish passage as well as changes to local instream habitat. For all of the streams in the system, allowing migratory animals a pathway to reach their favorite habitats should allow for more native species to be found in the streams. Local improvement of habitat will also improve instream conditions. In many places, decent habitat existed but few native species were observed at the sites. Instead of native species, numerous introduced species were observed suggesting that habitat and water quality conditions were acceptable to stream fish.

To assess project impacts, the available habitat was multiplied by the percent of habitat likely left after the construction of the project given its design. Some loss of habitat was expected given the design criteria of the various Ala Wai Flood risk management structures. Determining exactly how habitat for native amphidromous species is changed by these construction activities is not always well understood. As a result, we combined our best professional judgment (Expected Condition) with a maximum impact (Worst-Case Condition) to provide a range of possibilities. The effect of the construction activities combined with variability instream conditions, as well as differences in species habitat use, result in a complicated matrix of outputs.

In general, Manoa Stream had the majority of the habitat units for native amphidromous species within the streams of concern. Palolo Stream had small amounts of habitat as a result of the long channelized segments of its downstream reaches. Makiki Stream had habitat for native species in both the upper and lower reaches even though it is a highly developed and impacted stream. We did observe native species in areas the model predicted they would occur although their densities were very low in comparison to introduced animals. Hausten Ditch, somewhat surprisingly, was predicted to have relatively large amounts of native stream animal habitat even though it is also highly developed. The majority of the habitat for the lower reach species was found in the lower end just upstream from the Ala Wai canal.

When viewing the with-project conditions, it is apparent that many of these flood risk management measures will not have a large impact on the overall native species habitat within the streams. The footprint of these measures is relatively small in comparison to the total length streams and the overall impacts to water quality, flow patterns, sediment movement, and fish passage are limited. There are also some positive benefits from the location of the flood risk management measures. In the Waiomao detention basin, a legacy barrier in the form of an old USGS gage will be removed during construction and will improve this passage as a result. The native fish, *Awaous stamineus*, was observed below the USGS gage and improved passage will provide more habitat for this and other native species. The use of the Expected and Worst-Case Conditions allowed a range of potential impacts to be assessed for the flood risk management measures and in both cases we expect an overall loss of habitat as a result of the construction activities.

When viewing the mitigation options, the effect of barriers to upstream movement for native species is clearly of primary concern. The majority of the gains to habitat units as result of the mitigation measures can be attributed to improving the availability of the high quality habitat in the upper ends of the streams to native species. In contrast, the impacts are high in the lower end of the streams as the streams are large and multiple native species use the available habitat. When improving fish passage, it is most beneficial to do so in a downstream-to-upstream order. The native Hawaiian stream animals are migratory and require a pathway from the ocean to instream habitats. In other words, fish and other animals need to surmount the first barrier prior to reaching any others upstream. This pattern is also true when looking at the benefits associated with habitat improvements in the channelized section of Manoa Stream. The majority of the benefits come from the improvement in fish passage and not from the construction of suitable habitat within the channelized section. This does not suggest that improving habitat is not an important goal, but it does suggest that allowing the native species to access currently suitable habitat may result in large increases in habitat units in the streams.

By design, the focus of the HSHEP model was to look at physical habitat remediation efforts (either building habitat or allowing passage primarily) as opposed to management of introduced species or water quality gains with off-channel improvements. In these urban streams, flood runoff and the potential pollutions contained in it may pose a significant threat to native stream animals. While this is surely possible, there are high densities of fish throughout the streams suggesting water quality conditions are at least marginal.

The issue of introduced species is more difficult to address. We observed large numbers of introduced species many of which may be competitive with or predatory on native amphidromous stream animals. Where native species were observed we did see many other introduced species with the exception of smallmouth bass. Throughout much of the best habitat in the middle reaches of Manoa stream smallmouth bass were common and we did not see native fishes at all in these areas. Further surveys by DAR may clarify this relationship but for now it appears that smallmouth bass limit the presence of native stream animals. Limiting the spread of introduced species should be a priority when improving fish passage for native species. The native amphidromous species observed at these upper barriers can all climb near vertical surfaces and thus fixing of these barriers can still include quite steep faces to help prevent the upstream movement of introduced species. With that said we observed introduce species throughout the streams all the way to the upper waterfalls.

When attempting to understand how the potential mitigation options will improve instream conditions over time, both adding habitat and improving fish passage will likely see benefits for years to come. From an accounting perspective the habitat opened by improving fish passage should be available at all times into the future. The actual presence of native species in these habitats may take some time to be realized as new recruits need to make it to the stream and moved to these newly opened habitats. A similar accounting could be done for the improvements to instream habitat within the channelized section. These habitats will be available as soon as they are completed and should be suitable long into the future.

Overall the combination of the HSHEP model and HDSS data collection proved very useful in determining instream habitat and passage barriers in the Ala Wai watershed streams. Improvements to this passage may be very beneficial to increasing populations of native amphidromous stream fish while continued protection of water quality and management of introduced species may also be necessary.

Attachment 4. Results of Mitigation Measure Screening

Ala Wai Canal Project, Screening of Mitigation Measures

Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
Remove Existing Passage Barriers	**Manoa**	**Falls 6**	Approximately 0.3 miles above Manoa District Park	Yes; except that passage barrier is expected to be addressed by City & County	Yes, Waihee Stream	**Box culvert to be stabilized by the City & County; assumes fish passage will be addressed as part of this effort**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	**Eliminate measure, as structure improvements are planned by City & County**
		Falls 7	Approximately 0.6 miles above Manoa District Park	Yes	Yes, Waihee Stream	No, assumes downstream barriers (Falls 6) to be addressed by City & County	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 8	Approximately 0.7 miles above Manoa District Park (just below Pawaina St. Bridge)	Yes	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes; assumes work to be done by hand (no heavy equipment) to minimize staging and access requirements	Multiple private landowners	Yes; assumes real estate rights can be reasonably obtained with easements	Low (none)	No	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	No archaeological/ historic structures identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would not involve substantial movement of stream sediments	Retain measure for further consideration
		Falls 11	USGS gaging station on Waihi Stream	Yes; can either riprap undercutting portion of structure, or remove/replace entire structure	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Privately owned	Yes; assumes real estate rights can be reasonably obtained with easement	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	Native damselfly population located upstream; measure not expected to affect this species.	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
		Falls 12	USGS gaging station on Waiakeakua Stream	Yes; existing structure needs to stay in place (to support bridge), but grouted riprap can be added to eliminate undercutting	Yes, Waihee Stream	Yes, downstream barriers need to also be addressed to maximize habitat benefits (Falls 7 and 8)	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, staging and access available via existing BWS road	Primarily BWS, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measure supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur); however, non-natives are already present above measure location	Yes, gaging station and dam both eligible as historic property; assume these can be addressed through USACE Sec. 106 process	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would be located above urban area where inputs occur	Retain measure for further consideration
	Palolo	**Falls P5**	USGS gaging station on Waiomao Stream	Yes; except structure to be removed for construction of Waiomao Detention Basin	Yes, Waihee Stream	**Structure is expected to be removed as part of construction for Waiomao Detention Basin**	No	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be obtained for detention basin	Low (none)	No	No, not expected to displace people/activities or raise significant concerns; measures supported by USGS	No sensitive biological resources identified to date	Measure would be designed to minimize potential for increased passage of non-natives (but assumes some passage would still occur)	No archaeological/historic structures identified to date	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as structure will be removed as part of construction of the detention basin**
Improve Passage Corridor and/or Habitat in Channelized Reach	**Manoa**	**Install low-flow channel (with embedded habitat pools)**	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Excavate habitat pools	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	Med-High	Possibly, may be relatively high cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
		Install resting pockets	Extending from lower edge of Manoa District Park (approximately 1100 feet long)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Low	Yes, assumed to be relatively low cost relative to habitat gain	Yes, assumes staging and access via Manoa District Park	Primarily City & County, with some private land ownership	Yes; assumes real estate rights can be reasonably obtained with easement and ROE	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Non-native (invasive) species are already profilic throughout this section of Manoa Stream	Manoa Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Manoa Stream; therefore minimal potential for the presence of contaminated sediment	Retain measure for further consideration
	Palolo	**Install low-flow channel (with embedded habitat pools)**	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate low-flow channel and reinforce channel to maintain structural integrity; add natural substrate	Low-flow channel on Kahaluu Stream; issue with water temperature, capture of fine sediment; low-flow channel needs more depth and complexity	No	Channel modifications could increase roughness, trap debris and/or change sediment transport; but channel would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**

Mitigation Measures			Location	Technical feasibility	Successful Application in Hawaii?	Compatibility - Dependency	Flood Damage Reduction	Implementation Cost	Cost-effectiveness	Availability of Land			O&M Requirements (new)	Conflict with Existing O&M Approach	Acceptability – Public Sentiment	Biological Resources		Archaeological/ Historic Structures	Potential for Contaminated Sediment?	Screening Results
				Can the mitigation measure be accomplished or not? Is it constructible?		Is the measure dependent upon another action to be functional? Does it conflict with any other action?	Does measure substantially increase flood risk within watershed?	Rough Order Magnitude (ROM) of construction cost (excluding land cost)	Is the habitat gain worth the cost?	Is there enough space for implementation of the measure? Is there access and room for staging?	Is the land owned by State/C&C (or a few private landowners)?	Can real estate rights be reasonably obtained?	Estimate level of effort for O&M (consider need for changes in practice/ equipment/etc.)	Would the measure conflict or otherwise preclude existing O&M practices?	Will the measure displace people or activities? Will the measure raise significant concerns?	Would the measure adversely affect any known sensitive biological resource?	Would the measure increase the potential for passage of non-native (invasive) species?	Would the measure adversely affect any known archaeological/ historic structures?	Would the measure be located in an area with known (or high potential for) contaminated sediments?	
		Excavate habitat pools	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; excavate pool (>18" water depth) and reinforce channel to maintain integrity; add natural substrate	None known	Could be stand-alone measure or combined with resting curbs	Channel modifications could increase roughness, trap debris and/or change sediment transport; but pool would be excavated down so not expected to decrease flood capacity	High	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
		Install resting pockets	Extending through most of urbanized Palolo Valley (approximately 1.5 miles)	Yes; install low-profile, raised curbs to create small pools (<6" water depth) for resting on existing concrete surface	None known	Could be stand-alone measure or combined with habitat pools	Channel modifications could increase roughness, trap debris and/or change sediment transport; curbs would be low-profile, but could still reduce flood conveyance. To be confirmed based on HEC-RAS model.	Med	Possibly, assumed to be extremely high cost relative to habitat gain (based on channel length)	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Channel is owned by a multitude of private land owners	**No; real estate requirements expected to be onerous given number of land owners**	Low; possibly some sediment/debris removal	Not expected; assume measure would provide adequate space for standard-sized vehicle to conduct ongoing O&M	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Palolo Stream	Palolo Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Palolo Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure based on land ownership and real estate requirements**
	Makiki	**Add passage/ habitat improvements**	Extending through most of urbanized Makiki (including 0.75-mile of underground channel)	**Channel modifications to improve passage/habitat are not feasible in underground section of stream**	None known	No	Channel modifications could increase roughness, trap debris and/or change sediment transport	**Extremely high**	**No; channel improvements in above-ground section would not provide much benefit without improvements to underground section; improvements to underground section would be extremely expensive relative to habitat gain**	Staging and access is limited, but assumed to be available via the existing routes used for O&M	Patchwork of public and private land	Unknown; specific requirements not investigated as measure was eliminated	Low; possibly some sediment/debris removal	Unknown; not investigated as measure was eliminated	No, not expected to displace people/activities or raise significant concerns	No sensitive biological resources identified to date	Possibly; but non-native (invasive) species are already known to transit this section of Makiki Stream	Makiki Stream Channel is eligible as historic property; assume structure can be addressed through USACE Sec. 106 process	Measure would be located in channelized portion of Makiki Stream; therefore minimal potential for the presence of contaminated sediment	**Eliminate measure as improvements would be needed to underground section, which would be extremely expensive relative to habitat gain**
Bank Stabilization	**Manoa**	**Stabilize Eroding Banks**	Above Kahaloa Bridge (Manoa Gardens Retirement Community)	Yes	Yes, successful bank replanting downstream of Kahaloa Bridge (but previous bank condition unknown)	No	No; assume little to no effect on channel capacity	**High**	**No; channel bank improvements would be extremely expensive, with only very minimal improvements to aquatic species habitat**	Yes, staging and access available via Manoa District Park	City & County land (but they are considering selling property)	Yes; assumes real estate rights can be reasonably obtained with ROE (or quit-claim deed to State if C&C sells property)	Low; temporary vegetation maintenance during plant establishment	Not expected	Could affect use of property (views; pedestrian walkway)	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	None identified to date	Stream sediments in urban Manoa are known to contain contaminants (e.g., termiticides); however, measure would primarily involve the stream bank, with minimal movement of streambed sediments	**Eliminate measure as improvements would be extremely expensive relative to very minimal habitat gain**
Other	**Palolo**	**Waiomao Excavation Area**	Adjacent to residences on Waiomao Road	Yes; assumes channel form and substrate would be replaced within area excavated for detention basin	None known	**Dependent on Waiomao Detention Basin; construction of detention basin will include replacement of channel form and substrate**	Assumes these factors were considered in modeling for detention basin; not further addressed for mitigation as measure was eliminated	Med	Possibly	Yes, assumes use of staging and access for Waiomao Detention Basin	Single private landowner	Yes; assumes real estate rights will be addressed as part of detention basin	Low; assumes debris removal and already being conducted for detention basin	No	No, not expected to displace people/ activities or raise significant concerns	No sensitive biological resources identified to date	No; assumes measure would not substantially affect species passage	USGS gaging station may be within excavation area, but assumes it will be removed as part of project construction	Measure would be located in upper watershed; no known input of contaminants	**Eliminate measure, as channel form and substrate will be replaced as part of detention basin measure (therefore, minimal habitat improvements available for mitigation)**

Attachment 5. Conceptual Designs for Potential Mitigation Measures

ALA WAI CANAL PROJECT

MITIGATION MEASURES
HONOLULU, OAHU, HI

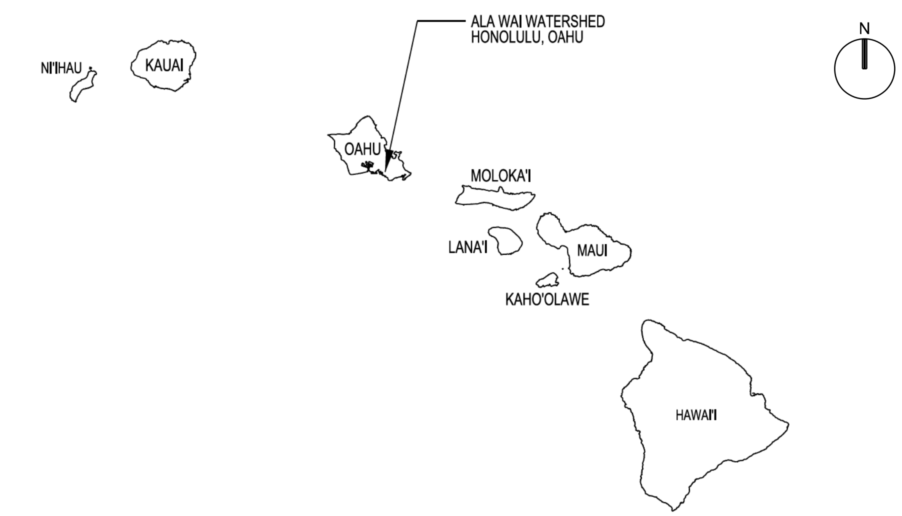
PROJECT TITLE

SITE LOCATIONS

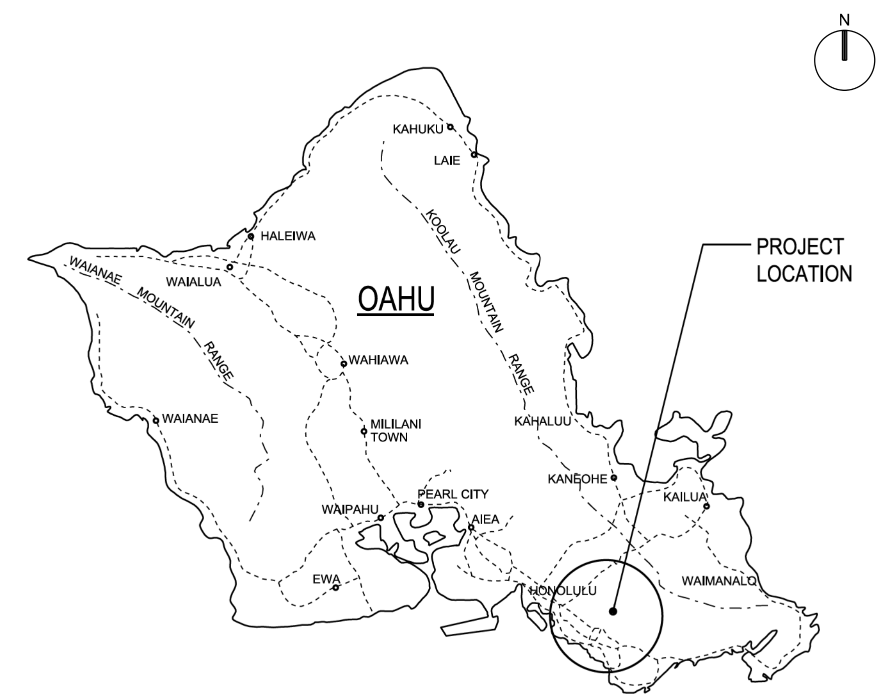
NOT TO SCALE

INDEX OF DRAWINGS

DWG	TITLE
G-001	SITE LOCATIONS, PROJECT LOCATION, VICINITY MAP, AND DRAWING INDEX
G-002	CIVIL GENERAL NOTES AND LEGEND
C-001	MANOA CONCRETE CHANNEL EXISTING CONDITIONS
C-101	MANOA CONCRETE CHANNEL ACCESS AND STAGING PLAN
C-102	MANOA CONCRETE CHANNEL LOW FLOW CHANNEL CONCEPT PLAN AND PROFILE
C-103	MANOA CONCRETE CHANNEL HABITAT POOL CONCEPT PLAN AND PROFILE
C-104	MANOA CONCRETE CHANNEL RESTING RIFFLE CONCEPT PLAN AND PROFILE
C-105	MANOA CONCRETE CHANNEL TYPICAL SECTIONS
C-106	MANOA STREAM FALLS 7 AND 8 ACCESS AND STAGING PLAN
C-107	MANOA STREAM FALLS 7 REHABILITATION CONCEPT
C-108	MANOA STREAM FALLS 8 REHABILITATION CONCEPT
C-109	MANOA STREAM FALLS 11 AND 12 ACCESS AND STAGING PLAN
C-110	MANOA STREAM FALLS 11 REHABILITATION CONCEPT
C-111	MANOA STREAM FALLS 12 REHABILITATION CONCEPT



VICINITY MAP — NOT TO SCALE



PROJECT LOCATION — NOT TO SCALE

US Army Corps of Engineers

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: L HAYS | DATE: 5/XX/2015 | REVISION:
DRAWN BY: T STIMPSON | CHECKED BY: J YOUNG | SOLICIT / CONTRACT NO.: 481684
SUBMITTED BY: J YOUNG | LOCATION CODE
PLOT SCALE: AS NOTED | PLOT DATE: 2015/05/12 | DRAWING NUMBER:
SIZE: ANSI D | FILE NAME: FILENAME

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES

SITE LOCATIONS, PROJECT LOCATIONS, VICINITY MAP, AND DRAWING INDEX

SHEET IDENTIFICATION
G-001
SHEET 01 OF 14

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

FILE: $FILEL$ MODEL NAME: $MODELNAME$ DATE & TIME: $DATE$ $TIME$ LAST SAVED BY:

GENERAL SITE NOTES:

1. SOURCE OF TOPOGRAPHY SHOWN ON THE CIVIL PLANS ARE BASE MAPS PROVIDED BY THE US ARMY CORP OF ENGINEERS HONOLULU DISTRICT. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. EXISTING TOPOGRAPHY, STRUCTURES, AND SITE FEATURES ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW FINISH GRADE, STRUCTURES, AND SITE FEATURES ARE SHOWN HEAVY-LINED.

   HORIZONTAL DATUM: NAD 1983, HAWAII STATE PLANE ZONE 3, US SURVEY FEET
   VERTICAL DATUM: NAVD 1988, US SURVEY FEET
3. MAINTAIN, RELOCATE, OR REPLACE EXISTING SURVEY MONUMENTS, CONTROL POINTS, AND STAKES WHICH ARE DISTURBED OR DESTROYED. PERFORM THE WORK TO PRODUCE THE SAME LEVEL OF ACCURACY AS THE ORIGINAL MONUMENT(S) IN A TIMELY MANNER, AND AT THE CONTRACTOR'S EXPENSE.
4. STAGING AREA SHALL BE FOR CONTRACTOR'S EMPLOYEE OVERFLOW PARKING AND ON-SITE STORAGE OF MATERIALS.
5. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
6. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
7. CONTRACTOR SHALL PREPARE AND SUBMIT DEWATERING AND CREEK BYPASS PLAN FOR CONTRACTING OFFICER APPROVAL.
8. IN-WATER CONSTRUCTION WORK IS EXPECTED TO BE CONDUCTED DURING DRY SEASON FROM APPROXIMATELY MAY TO SEPTEMBER.

GENERAL YARD PIPING AND UTILITIES NOTES:

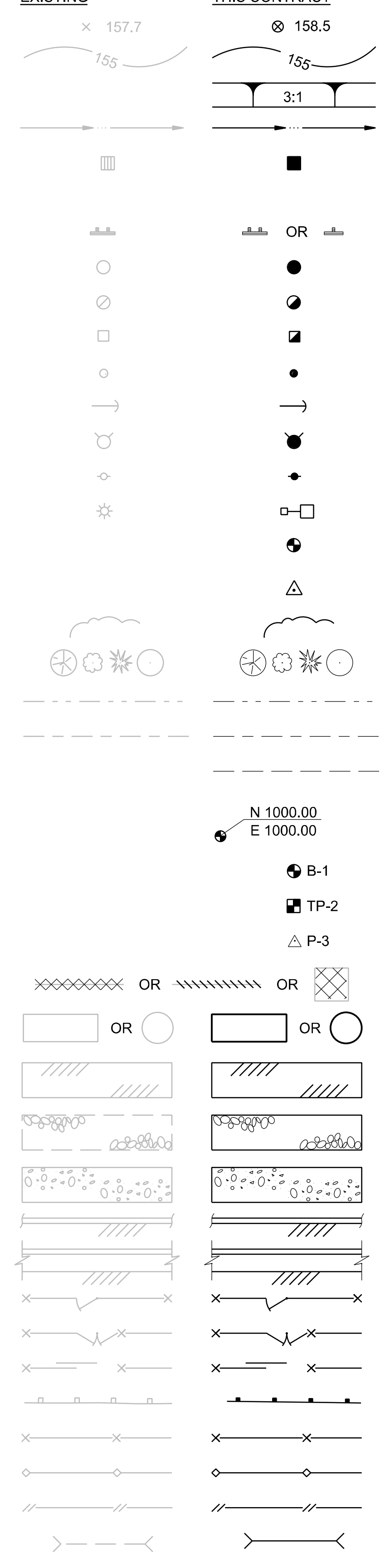
1. EXISTING UNDERGROUND UTILITIES HAVE NOT BEEN IDENTIFIED BUT IS EXPECTED TO OCCUR IN A FUTURE DESIGN PHASE. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION. PROTECT ALL EXISTING UTILITIES TO REMAIN DURING CONSTRUCTION.
2. EXISTING PIPING AND EQUIPMENT ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW PIPING AND EQUIPMENT ARE SHOWN HEAVY-LINED.
3. UNLESS OTHERWISE SHOWN ALL PIPING SHALL HAVE A MINIMUM OF 3' COVER.
4. ALL PIPES SHALL HAVE A CONSTANT SLOPE BETWEEN INVERT ELEVATIONS UNLESS A FITTING IS SHOWN.
5. FOR SURFACE RESTORATION OF ASPHALT CONCRETE MATCH EXISTING PAVEMENT.
6. MINIMUM ALLOWABLE CLEARANCE BETWEEN PIPES AT CROSSINGS SHALL BE 3".

GENERAL NOTE:

1. THIS IS A STANDARD LEGEND SHEET. THEREFORE, NOT ALL OF THE INFORMATION SHOWN MAY BE USED ON THIS PROJECT.

CIVIL LEGEND

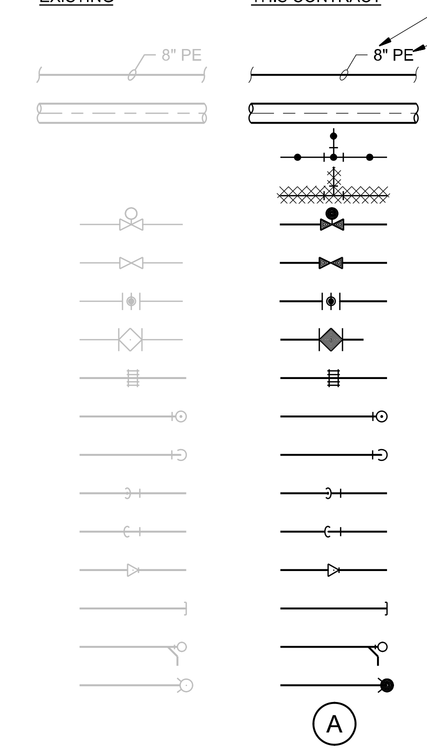
EXISTING / THIS CONTRACT



SPOT ELEVATION
CONTOUR LINE
EMBANKMENT AND SLOPE
DRAINAGEWAY OR DITCH
CATCH BASIN OR INLET
TRENCH DRAIN
SIGN
MANHOLE
ELECTRICAL MANHOLE
ELECTRIC HANDHOLE
POST OR GUARD POST
GUY ANCHOR
FIRE HYDRANT
UTILITY POLE
LIGHT POLE
BENCH MARK
SURVEY CONTROL POINT OR POINT OF INTERSECTION
BRUSH/TREE LINE
TREE
PROPERTY LINE
CENTER LINE, BUILDING, ROAD, ETC.
FEATURE LINES AND AVERAGE SEASONAL WATER LEVELS
STRUCTURE, BUILDING OR FACILITY LOCATION POINT - COORDINATES
BORING LOCATION AND NUMBER
TEST PIT LOCATION AND NUMBER
PIEZOMETER LOCATION AND NUMBER
DEMOLITION
STRUCTURE, BUILDING OR FACILITY
ASPHALT CONCRETE PAVEMENT
GRAVEL SURFACING
CONCRETE PAVEMENT
CURB
CURB AND GUTTER
SINGLE SWING GATE
DOUBLE SWING GATE
SLIDING GATE
GUARD RAIL
CHAIN LINK FENCE
ARCHITECTURAL FENCE
WIRE FENCE
CULVERT
FLOW DIRECTION

YARD PIPING LEGEND

EXISTING / THIS CONTRACT



NOMINAL PIPE DIAMETER
PIPE USE IDENTIFICATION
PIPING < 30" DIAMETER
PIPING ≧ 30" DIAMETER
EXISTING PIPE TO BE ABANDONED
EXISTING PIPE TO BE REMOVED
INDICATOR POST VALVE
GATE VALVE AND VALVE BOX
BUTTERFLY VALVE AND VALVE BOX
PLUG VALVE AND VALVE BOX
FLEXIBLE COUPLING
90° ELBOW UP
90° ELBOW DOWN
BEND < 90° UP
BEND < 90° DOWN
CONCENTRIC REDUCER
CAP OR PLUG
CLEANOUT
FIRE HYDRANT
BACKFILL CLASS

ABBREVIATIONS

APPROX	APPROXIMATE
AVG	AVERAGE
B.F.	BUTTERFLY
°	DIAMETER
DIA	DIAMETER
EL	ELEVATION
ELEV	ELEVATION
EXST	EXISTING
FT	FOOT / FEET
GAL	GALLON
HDPE	HIGH DENSITY POLYETHYLENE
HP	HORSE POWER
N	NORTH
NTS	NOT TO SCALE
O.C.	ON-CENTER
PE	POLYETHYLENE
PVC	POLYVINL CHLORIDE
SQ FT	SQUARE FOOT
TYP	TYPICAL
W/	WITH

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HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: 2015\05\12
SIZE: ANSI D
FILE NAME: FILENAME
DATE: 5/XX/2015
REVISION:
SOLICIT./ CONTRACT NO.: 481684
LOCATION CODE
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES
CIVIL GENERAL NOTES AND LEGEND

SHEET IDENTIFICATION
G-002
SHEET 02 OF 14

N

PLAN
1"=40'

0 40 80 120
Scale In Feet

PHOTO 1
NTS

PHOTO 2
NTS

PHOTO 3
NTS

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ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
EXISTING CONDITIONS

SHEET IDENTIFICATION
C-001
SHEET 03 OF 14

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PEN TABLE: $PENTBL$$
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ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

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DATE: 5/XX/2015
SOLICIT / CONTRACT NO.: 481684
REVISION:
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-101
SHEET 04 OF 14

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DATE & TIME: $DATE$ $TIME$
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PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

NOTES:

1. CUT AND REMOVE EXISTING CONCRETE WITHIN LOW FLOW CHANNEL EXTENTS.
2. SEE LOW FLOW CHANNEL TYPICAL SECTIONS - SHEET C-105 .
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.

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1"=40'

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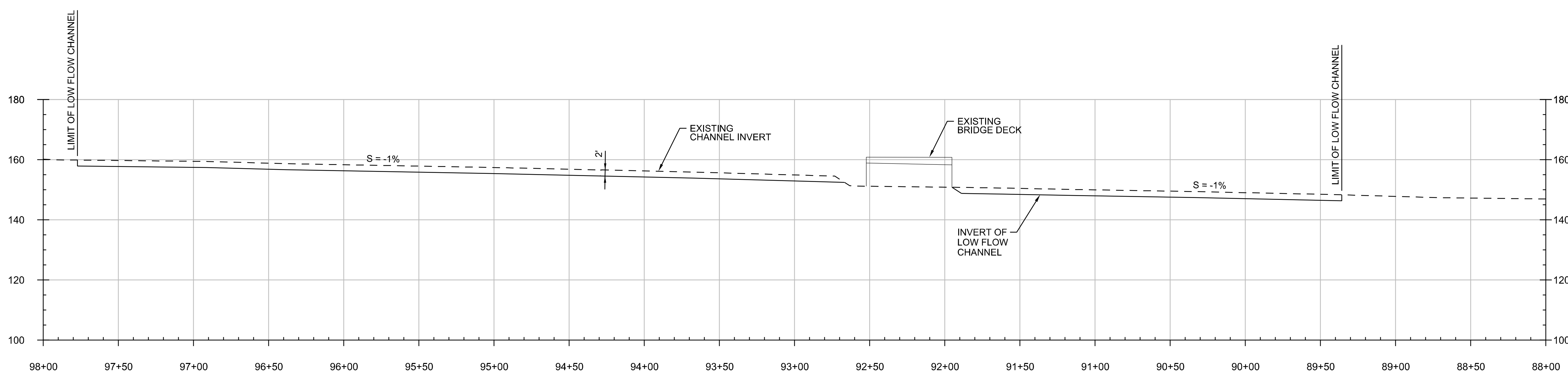
Scale In Feet



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DATE & TIME: $DATE$ $TIME$
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SUBMITTED BY: J YOUNG
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SOLICIT / CONTRACT NO.: 481684
REVISION:
LOCATION CODE
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/13
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

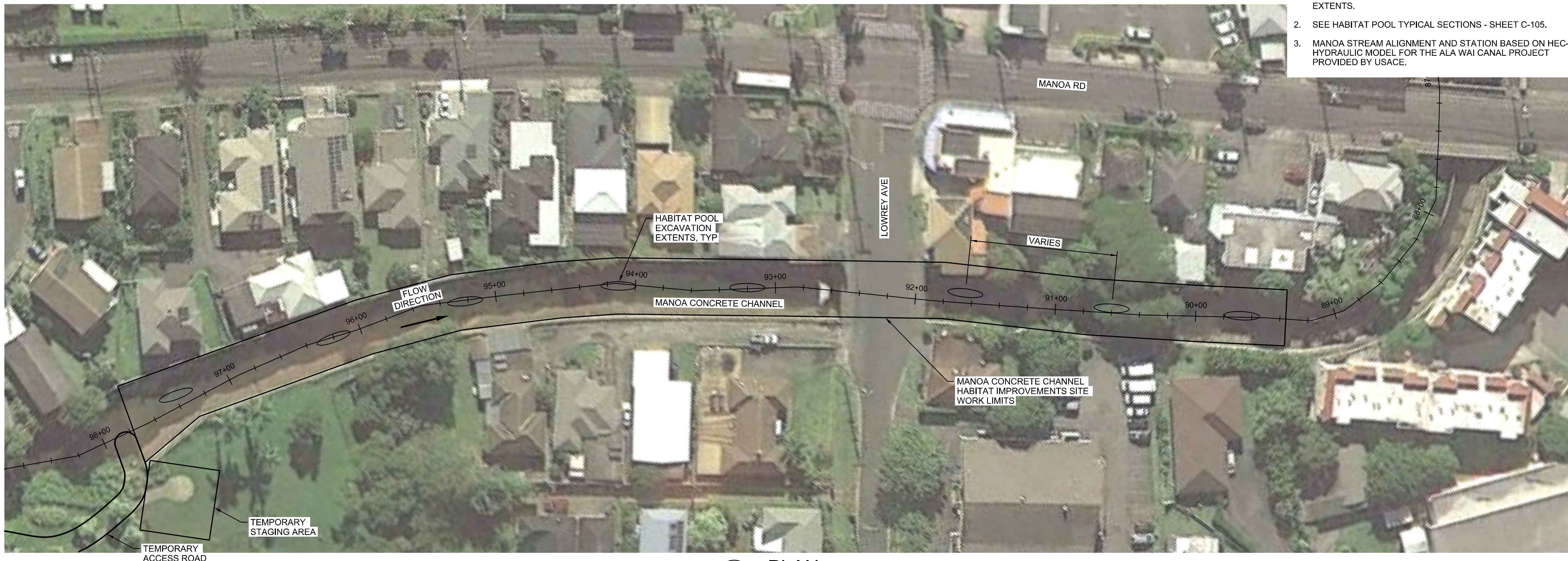
ALA WAI CANAL PROJECT
MITIGATION MEASURES

MANOA CONCRETE CHANNEL
LOW FLOW CHANNEL CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-102
SHEET 05 OF 14

NOTES:

1. CUT AND REMOVE EXISTING CONCRETE WITHIN HABITAT POOL EXTENTS.
2. SEE HABITAT POOL TYPICAL SECTIONS - SHEET C-105.
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



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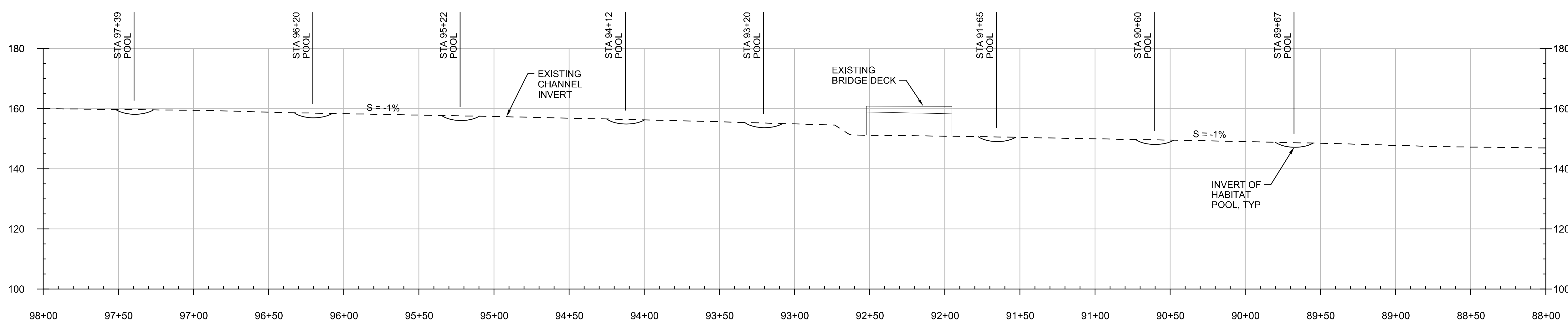

PROFILE

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VERT: 1"=20'

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PRINTED BY: $USER$

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MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

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HONOLULU, HI 96813

DESIGNED BY: L HAYS		DATE: 5/XX/2015	REVISION:
DRAWN BY: T STIMPSON	CHECKED BY: J YOUNG	SOLICIT./ CONTRACT NO.: 481684	
SUBMITTED BY: J YOUNG		LOCATION CODE	
PLOT SCALE: AS NOTED	PLOT DATE: 2015\05\13	DRAWING NUMBER:	
SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT

MITIGATION MEASURES

MANOA CONCRETE CHANNEL
HABITAT POOL CONCEPT
PLAN AND PROFILE

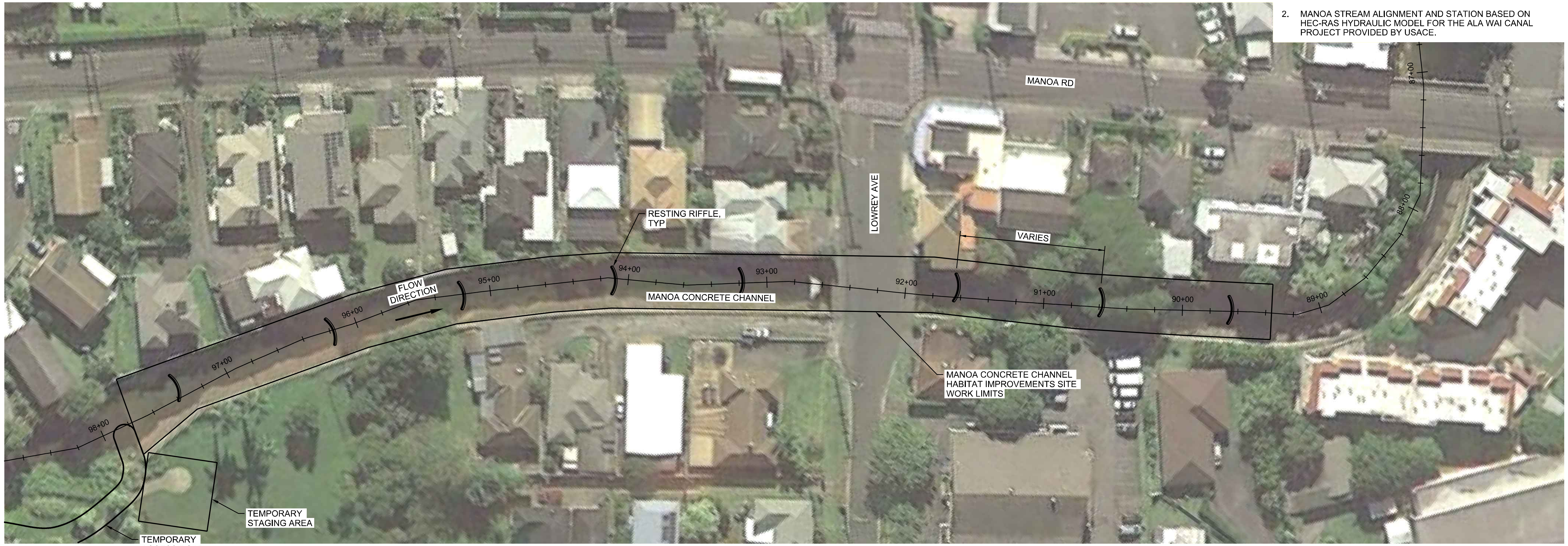
SHEET IDENTIFICATION

C-103

SHEET 06 OF 14

NOTES:

1. SEE RESTING RIFFLE TYPICAL SECTIONS - SHEET C-105.
2. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.



PLAN
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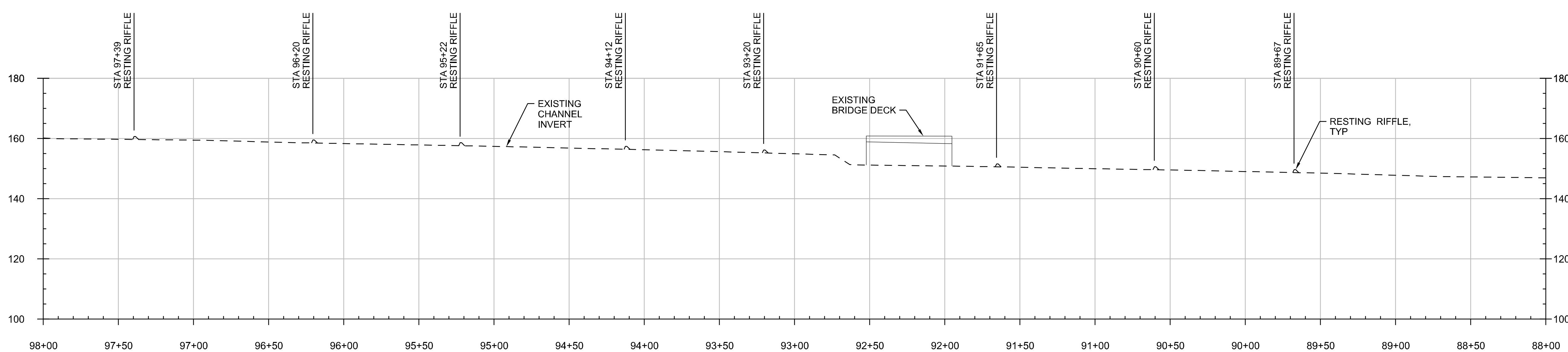
0 40 80 120
Scale In Feet



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

FILE: $FILEL$
MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
LAST SAVED BY:

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MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

DATE: 5/XX/2015
REVISION:
SOLICIT./ CONTRACT NO.: 481684
LOCATION CODE
DRAWING NUMBER:
DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: 20150513
SIZE: ANSI D
FILE NAME: FILENAME

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HONOLULU DISTRICT
HONOLULU, HAWAII

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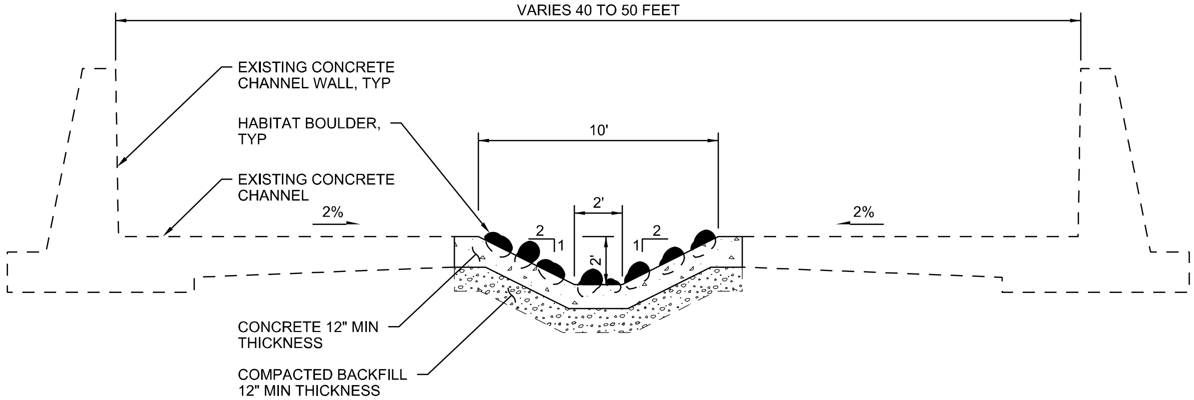
HONOLULU, HI 96813

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
RESTING RIFFLE CONCEPT
PLAN AND PROFILE

SHEET IDENTIFICATION
C-104
SHEET 07 OF 14

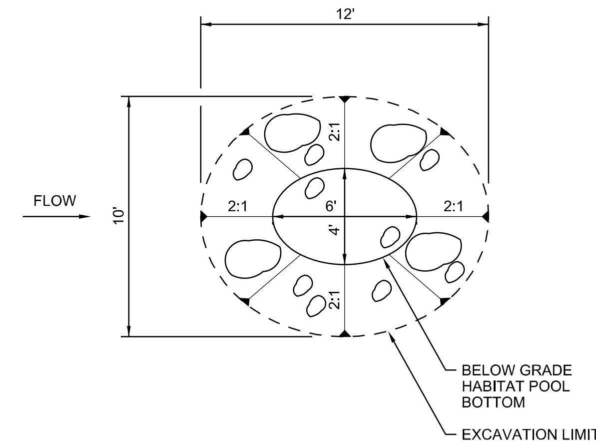
GENERAL SHEET NOTES:

1. ALL DIMENSIONS APPROXIMATE
2. REINFORCING STEEL DOWELS MAY BE INCORPORATED IN A FUTURE DESIGN PHASE.



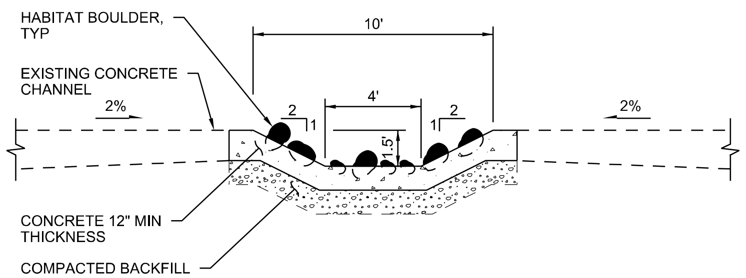
LOW FLOW CHANNEL TYPICAL SECTION

1"=4'



HABITAT POOL PARTIAL PLAN

1"=4'



HABITAT POOL TYPICAL SECTION

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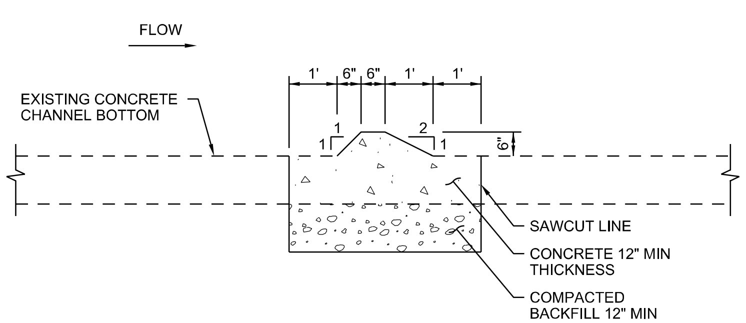

RESTING RIFFLE CROSS SECTION

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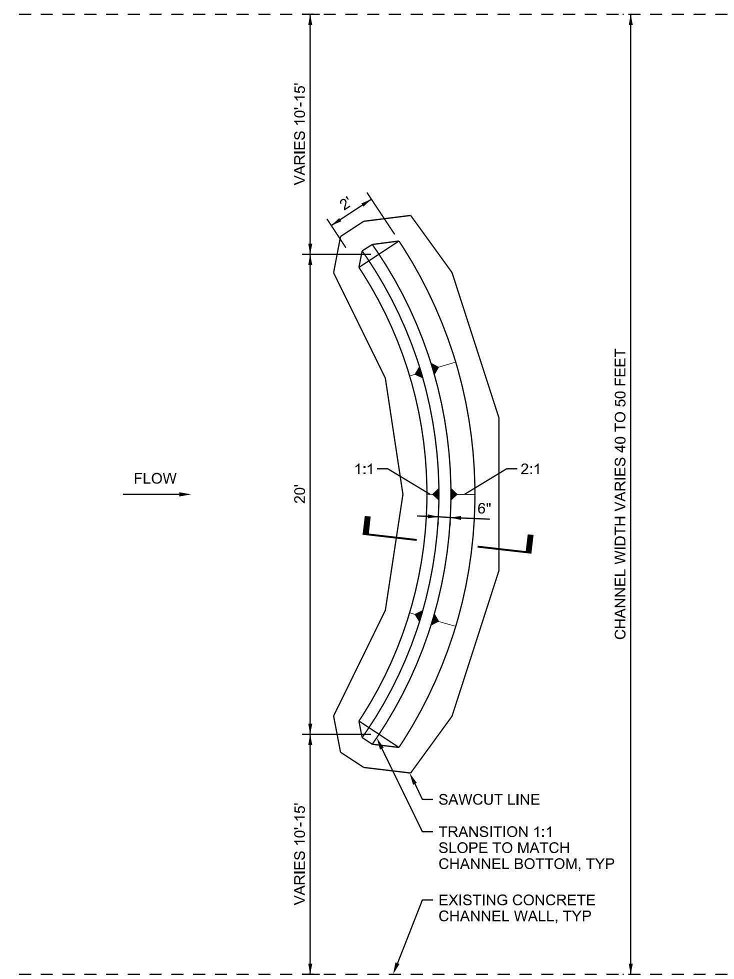

RESTING RIFFLE PARTIAL PLAN

NTS

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HONOLULU, HAWAII

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1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813

DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
SIZE: ANSI D
FILE NAME: FILENAME
DATE: 5/XX/2015
REVISION:
SOLICIT / CONTRACT NO.: 481684
LOCATION CODE
DRAWING NUMBER:

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
TYPICAL SECTIONS

SHEET IDENTIFICATION
C-105
SHEET 08 OF 14

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NOTES:

1. LOCATION OF A STAGING AREA WILL BE DETERMINED, IF NEEDED.
2. IF EQUIPMENT, MATERIALS AND/OR ACCESS IS PROVIDED VIA THE BRIDGE, THEN A PARTIAL LANE CLOSURE AND TRAFFIC CONTRL MAY BE REQUIRED.

N

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

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SUBMITTED BY: J YOUNG		LOCATION CODE	
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SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 7 AND 8
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-106
SHEET 09 OF 14

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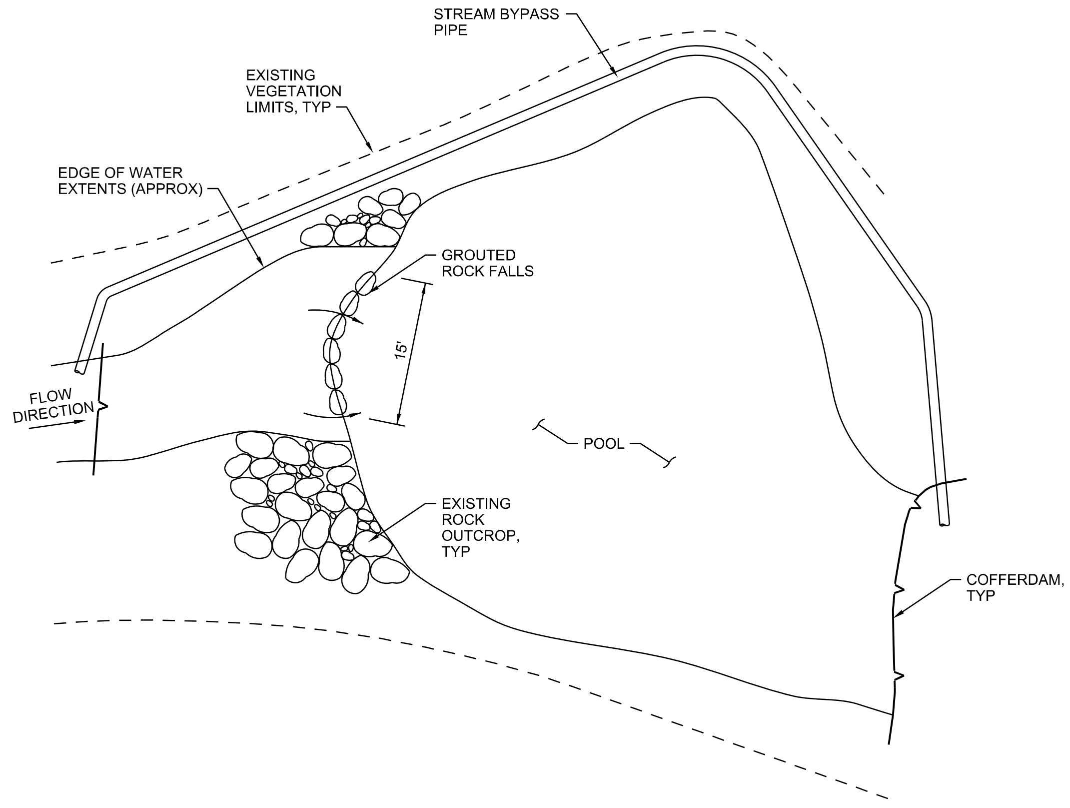

PLAN
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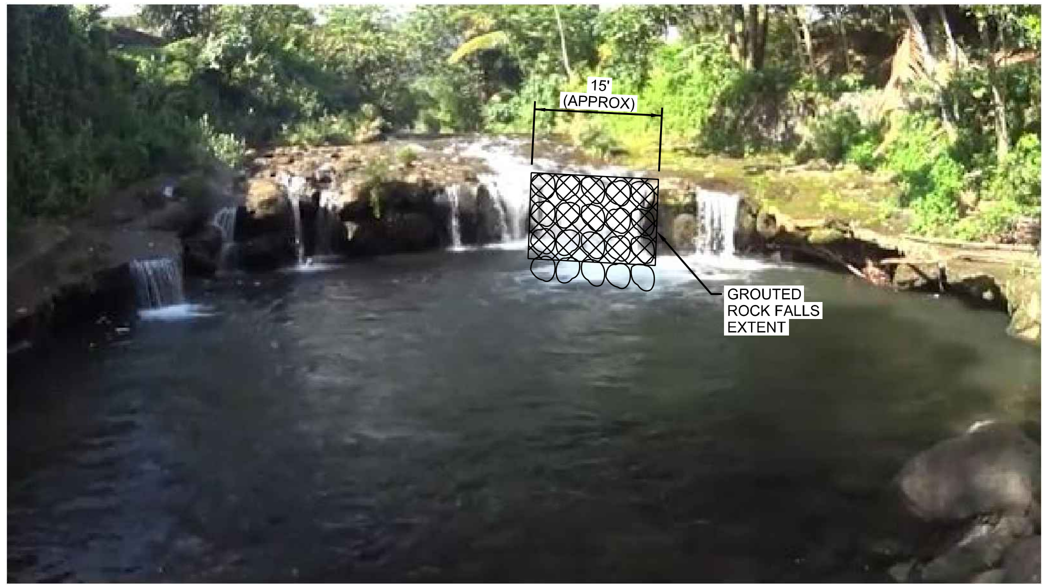

NOTE:

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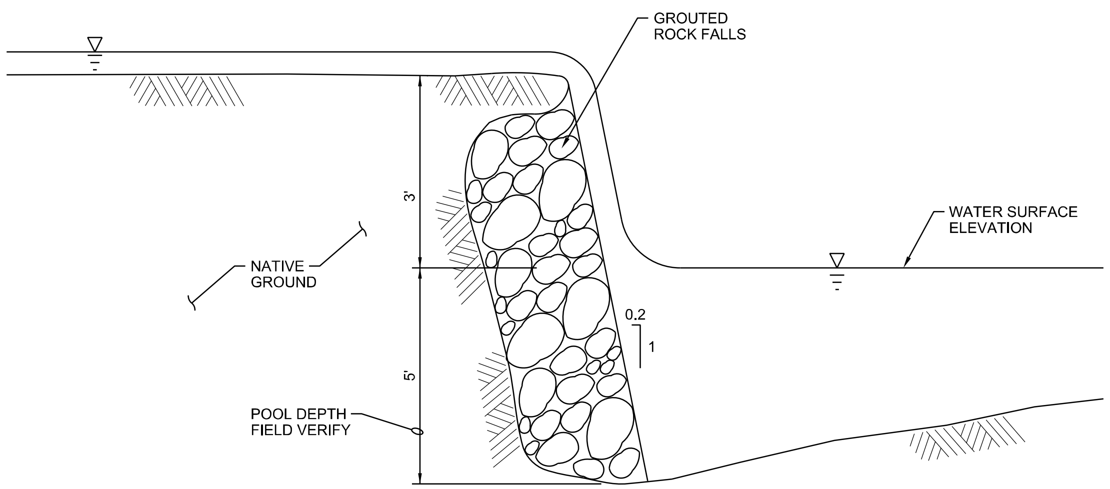
SITE PHOTO
NTS



NOTE:

DIMENSIONS ARE APPROXIMATED BASED ON FIELD PHOTO.

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DATE: 5/XX/2015
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PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
DRAWING NUMBER:
SIZE: ANSI D
FILE NAME: FILENAME

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 7
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-107
SHEET 10 OF 14

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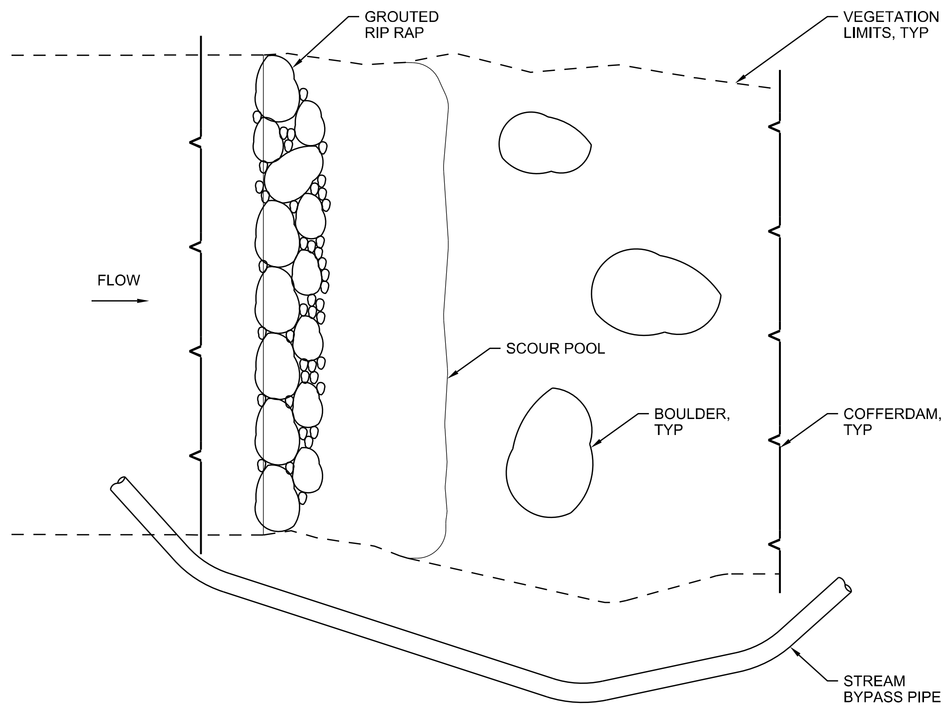
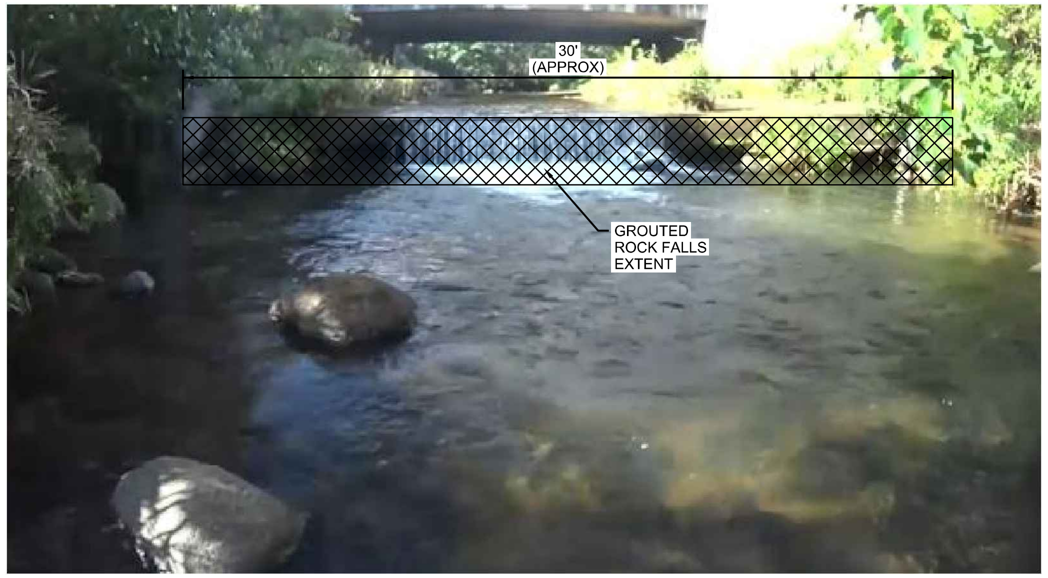


PLAN
1"=5'



NOTE:

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SITE PHOTO
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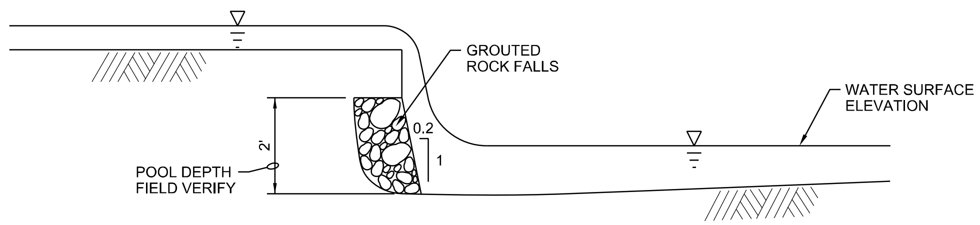

NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON FIELD PHOTO.

SECTION
1"=2'

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DATE: 5/XX/2015
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ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 8
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-108
SHEET 11 OF 14

ACCESS AND STAGING PLAN

1"=50'

0 50 100 150
Scale In Feet

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SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 11 AND 12
ACCESS AND STAGING PLAN

SHEET IDENTIFICATION
C-109
SHEET 12 OF 14

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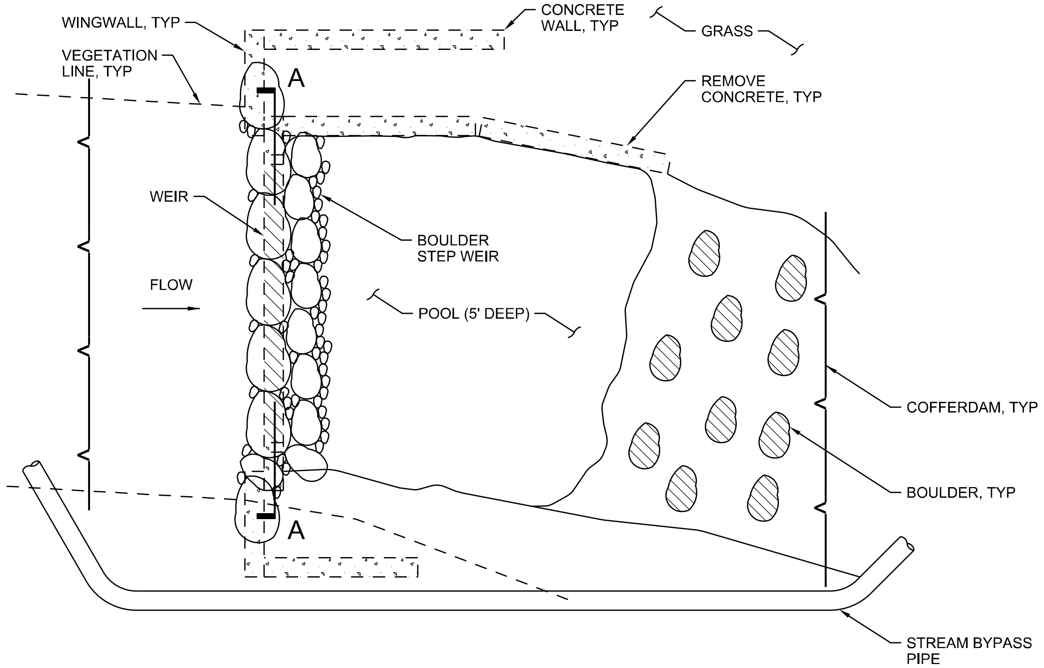
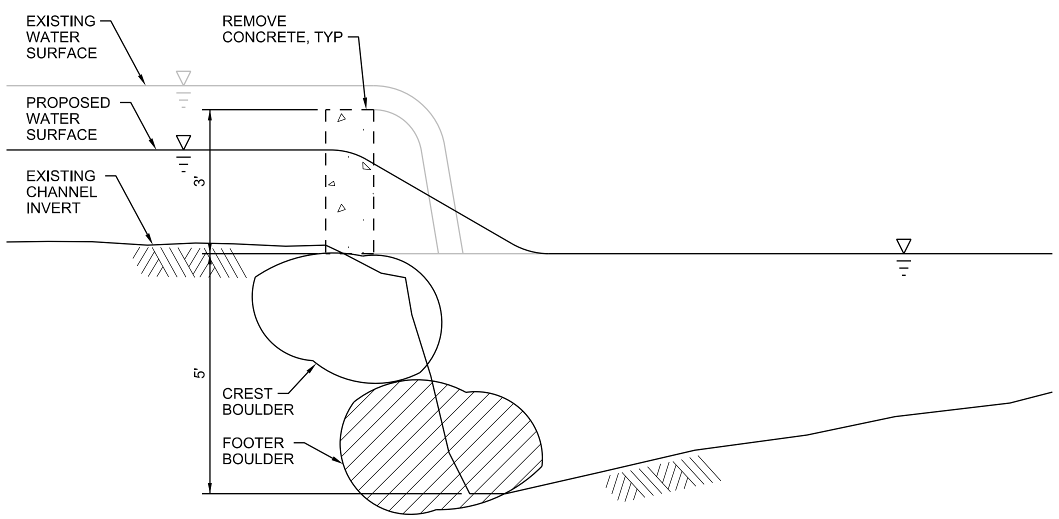


PLAN
1"=5'

NOTES:

1. REMOVE ALL EXISTING CONCRETE FROM CHANNEL.
2. DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.
3. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

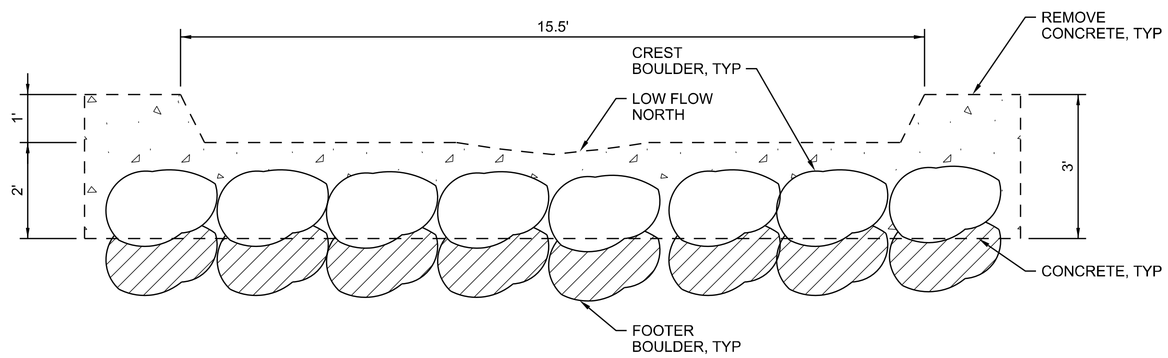
SITE PHOTO
NTS



NOTES:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

PROFILE
1"=2'



NOTE:

DIMENSIONS ARE APPROXIMATE BASED ON LIMITED FIELD MEASUREMENTS.

SECTION A-A
1"=2'

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DATE: 5/XX/2015
SOLICIT / CONTRACT NO.: 481684
REVISION:
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PLOT SCALE: AS NOTED
PLOT DATE: 2015/05/12
SIZE: ANSI D
FILE NAME: FILENAME
DRAWING NUMBER:

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HONOLULU, HAWAII

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ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA STREAM FALLS 11
REHABILITATION CONCEPT

SHEET IDENTIFICATION
C-110
SHEET 13 OF 14

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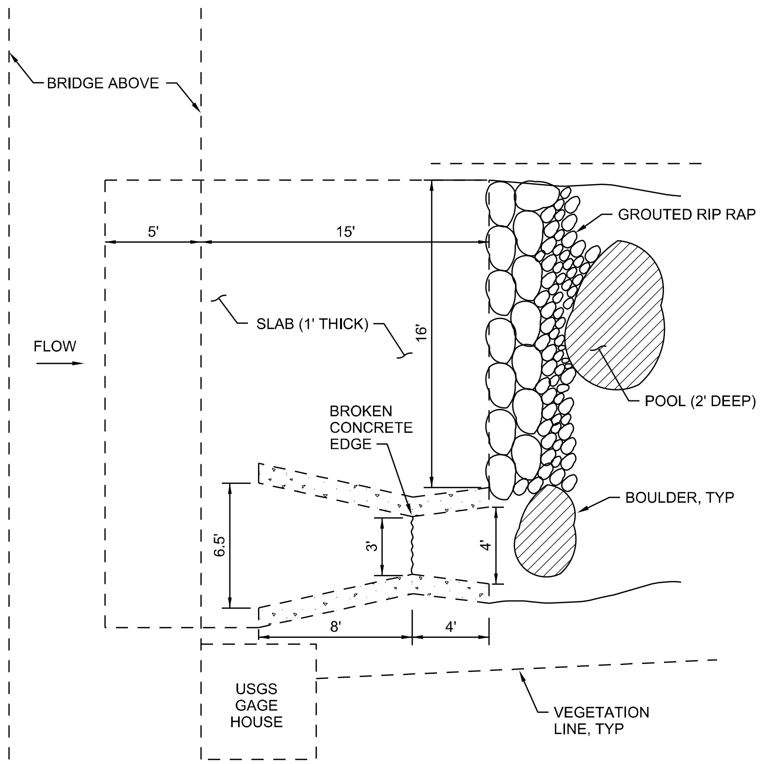


PLAN

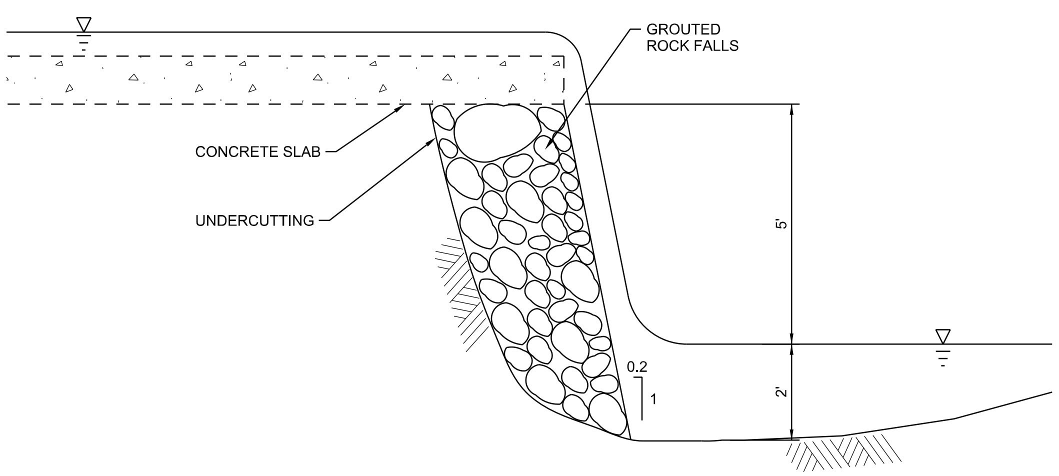
1"=5'

NOTES:

1. EXISTING SITE IS AN ACTIVE US GEOLOGICAL SURVEY (USGS) STREAM GAGING STATION. ALL WORK AT THE SITE WILL BE COORDINATED WITH USGS.

SITE PHOTO

NTS



PROFILE

1"=2'

US Army Corps of Engineers

10% DESIGN

MARK	DESCRIPTION	DATE	APPR.

MARK	DESCRIPTION	DATE	APPR.

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HONOLULU, HAWAII

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DESIGNED BY: L HAYS		DATE: 5/XX/2015	REVISION:
DRAWN BY: T STIMPSON	CHECKED BY: J YOUNG	SOLICIT./ CONTRACT NO.: 481684	
SUBMITTED BY: J YOUNG		LOCATION CODE	
PLOT SCALE: AS NOTED	PLOT DATE: 2015\05\12	DRAWING NUMBER:	
SIZE: ANSI D	FILE NAME: FILENAME		

ALA WAI CANAL PROJECT

MITIGATION MEASURES

MANOA STREAM FALLS 12
REHABILITATION CONCEPT

SHEET IDENTIFICATION

C-111

SHEET 10 OF 14

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MODEL NAME: $MODELNAME$
DATE & TIME: $DATE$ $TIME$
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PLOTDRIVER: $PLTDRV$$
PEN TABLE: $PENTBL$$
PRINTED BY: $USER$

Attachment 6. Cost Effectiveness and Incremental Cost Analysis

Cost Effectiveness and Incremental Cost Analysis
Ala Wai Canal Project

July 2015

Contents

1.0 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii[1] (hereafter referred to as "the project"). As project implementation is expected to result in impacts to aquatic habitat, compensatory mitigation will be required to offset these impacts. The USACE planning process requires that compensatory mitigation plans be developed, evaluated and selected consistent with the requirements of their overall planning process. A detailed discussion of the mitigation development process for the project is provided in the Mitigation and Monitoring Plan; this document presents the economic analysis used to support evaluation and selection of the compensatory mitigation plan.

As outlined in Engineering Regulation (ER) 1105-2-100 "USACE Planning Guidance Notebook" (USACE, 2000), alternative plans should be evaluated based on four primary criteria: completeness, effectiveness, efficiency, and acceptability. Economic analyses are important primarily in the evaluation of efficiency. Economic analyses also play a role in the evaluation of the acceptability of an alternative, based on its estimated implementation cost, and the completeness of an alternative, based on identifying all potential costs that could result from implementation.

The USACE Institute for Water Resources (IWR) Planning Suite tool was developed in response to the intricacies of ecosystem restoration planning studies (including mitigation) and performs cost-effectiveness and incremental cost analyses (CE/ICA) on combinations of water resources alternatives. The CE analysis is employed to eliminate "production inefficient" solutions, or alternatives plans with the same level of output that can be provided at a lesser cost than another plan, and "production ineffective" solutions, or alternative plans with less output than a plan that has a lesser or equal cost. The ICA evaluates the incremental cost of cost-effective alternatives to determine which are "best buy" plans, or plans which provide the greatest increase in output for the least increase in cost.

To identify the mitigation alternative(s) that would provide the greatest benefit compared to cost for the project, CE/ICA were conducted to compare predicted future benefits (quantified by average annual habitat units) to estimated average annual costs for each of the mitigation alternatives identified for the project. This analysis is based on and follows guidance from the USACE IWR publication, *Evaluation of Environmental Investment Procedures Manual, Interim: Cost Effectiveness and Incremental Analyses*, May 1995, IWR Report #95-R-1 and *Cost Effectiveness Analysis for Environmental Planning: Nine Easy Steps*, October 1994, IWR Report 94-PS-2. The organization of this appendix follows the steps outlined in IWR Report #95-R-1k:

Plan Formulation Steps

- **Step 1:** Display Outputs and Costs of Management Measures
- **Step 2:** Identify Management Measure Relationships
- **Step 3:** Add Costs and Outputs of Combinations

Cost Effectiveness Analysis Steps

- **Step 4:** Identify "Production Inefficient" Solutions
- **Step 5:** Identify "Production Ineffective" Solutions

Incremental Cost Analysis Step

- **Step 6:** Calculate and Display Incremental Costs

Additional Analytical Steps to Assist in Scale Selection

- **Step 7:** Calculate Change in Unit Cost from No-Action Plan to All Other Plans
- **Step 8:** Recalculate Change in Unit Cost from Last Selected Plan
- **Step 9:** Tabulate and Display Incremental Costs of Selected Plans

---

[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

2.0 Plan Formulation

Steps 1 through 3 are related to plan formulation and, in the case of this project, include an analysis of the possible management measures identified for compensatory mitigation. In the context of the USACE planning process, management measures are defined as actions that can be implemented to cause a desirable change relative to the planning objective; they are individual features or activities that serve as the building blocks of alternative plans. Formulation of mitigation measures is detailed in Section 3 of the Mitigation and Monitoring Plan and is summarized below.

2.1 Step 1: Display Outputs and Costs of Management Measures

The first step of plan formulation, as it relates to analysis of cost-effectiveness and incremental cost, is to identify the mitigation measures and their output and cost. The mitigation measures that were considered as part of the evaluation, based on the results of the mitigation development process (as described in the Mitigation and Monitoring Plan) are summarized in Table 1. Given that the mitigation effort is focused on restoring passage or habitat to stream channels based on the conditions known to favor native species, it was determined that different scales or increments of each measure would not meet the objectives of the mitigation effort, and therefore were not considered. Additional detail on the mitigation identification and screening process is provided in the Mitigation and Monitoring Plan.

TABLE 1
Conceptual Mitigation Measures

Mitigation Measure/Alternative	Description
Falls 7	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.6 mile above Manoa District Park
Falls 8	Remove overhanging lip associated with undercutting at in–stream structures located approximately 0.7 mile above Manoa District Park
Falls 11	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waihi Stream
Falls 12	Remove overhanging lip associated with undercutting at in–stream structures associated with USGS gaging stations on Waiakeakua Stream
Manoa Low-Flow Channel	Notch low-flow channel into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Habitat Pools	Notch habitat pools (<18” of water depth) into concrete and add natural substrate along approximately 1,100 feet of concrete channel below Manoa District Park
Manoa Resting Riffles	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat (>6” of water depth) along approximately 1,100 feet of concrete channel below Manoa District Park

2.2 Step 2: Identify Management Measure Relationships

Step 2 of plan formulation and evaluation is to identify potential groupings of management measures, based on their dependency to each other. In the case of this project, each of the mitigation measures considered as part of the CE/ICA are mutually exclusive (meaning, they could be implemented as stand-alone actions). However, recognizing that there are many possible measure combinations, it was determined that a focused set of alternatives should be defined based on estimated habitat benefits and functionality, according to the rationale summarized below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. The barrier removal measures were not considered in combination with the concrete channel improvements, because individually, they are expected to provide adequate benefits to offset the habitat impacts associated with the flood risk management project.

2.3 Step 3: Derive Combinations and Calculate Costs and Outputs

Based on the concepts described above, a total of eight mitigation alternatives were identified, as follows:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

The costs and outputs were then developed, as detailed below.

2.3.1 Estimate Alternative Costs

Planning level cost estimates are used in CE/ICA, and are comprised of two main cost elements: (1) implementation costs (explicit costs) and (2) opportunity costs of foregone National Economic Development (NED) benefits (implicit costs). For the purposes of this project, it is assumed that there are no implicit costs (as no NED benefits would be foregone), such that the total project cost is equal to the implementation cost. An estimate of the implementation costs was developed by the USACE as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. The cost estimate for each mitigation alternative is summarized in Table 2.

As part of CE/ICA, environmental outputs and cost estimates should be annualized across the period of analysis. To annualize the project costs, an implementation timeline must be developed to identify initial costs, investment costs, and future costs. So that project costs can be evaluated in present value, the implementation timeline is used to categorize cost components as investment costs or future costs. For each alternative, the total project cost is equal to the investment cost plus future costs, in present value terms.

In the case of this project, all costs with the exception of those for monitoring and operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) are assumed to be incurred in Year 0. The IWR Planning Suite Annualizer was used to calculate the average annual cost of each alternative. The average annual cost assumes a 50-year period of analysis and a federal discount rate of 3.5%, which is the federal discount rate established for the evaluation of water resources development projects in fiscal year (FY) 2014. Table 2 shows the total

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

estimated cost and the average annual cost of the mitigation alternatives. A detailed breakdown of the present value cost for each of the 50 years of analysis is provided as an attachment to this document.

TABLE 2
Summary of Estimated Costs (FY2014 Price Level)

Implementation Cost Component	Falls 7	Falls 7 and 8	Falls 7, 8, 11	Falls 7, 8, 12	Falls 7, 8, 11, 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
LERRDs[1]	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre-construction Monitoring	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250	$9,250
Post-construction Monitoring[2]	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250	$76,250
OMRR&R[3]	$29,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction[4]	$1,491	$2,918	$3,729	$3,746	$4,557	$17,526	$3,786	$3,916
Contingency[5]	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Estimated Cost for CE/ICA	$240,526	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,264
Average Annual Cost[6]	$9,014	$13,362	$16,101	$16,000	$18,440	$49,564	$14,753	$15,105

[1] Lands, Easements, Rights-of-way, Relocations, and Dredge Disposal areas
[2] Includes 5 monitoring events during Years 1, 2, 3, 4, and 5
[3] Includes 50 years of OMRR&R
[4] Assumes a 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS
[5] Assumes contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, and OMRR&R costs
[6] Calculated using IWR Planning Suite annualizer: discount rate = 3.5% and period of analysis = 50 years

2.3.2 Estimate Alternative Outputs

The benefits of ecosystem mitigation are non-monetary, and therefore outputs must be quantified based on a unit of habitat improvement (that is, habitat units). In the case of this project, the Hawaii Stream Habitat Evaluation Procedure (HSHEP) was used to quantify the habitat benefits associated with each of the mitigation alternatives. A detailed discussion of the HSHEP model and its application to the project is provided in the Mitigation and Monitoring Plan (specifically including Attachments 1 and 2).

In order for proper comparison of costs and benefits, habitat units must be annualized over the period of analysis. Average annual habitat units were calculated using the IWR Planning Suite annualizer. It is expected that all habitat benefits would be realized in Year 1 and remain stable over the 50-year planning period, as shown in Figure 1. The total habitat units and average annual habitat units for the mitigation alternatives are listed in Table 3.

TABLE 3
Total Habitat Units and Average Annual Habitat Units for Mitigation Alternatives

Metric	No Action	Falls 7	Falls 7 and 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11 and 12	Manoa Low-Flow Channel	Manoa Habitat Pools	Manoa Resting Riffles
Total Habitat Units	0	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Average Annual Habitat Units[a]	0	1,340	3,831	5,401	6,021	7,591	1,279	1,202	1,195

[a] Assumes that all benefits would be realized in Year 1 and remain stable over the 50-year planning period; calculated using the IWR Planning Suite annualizer.

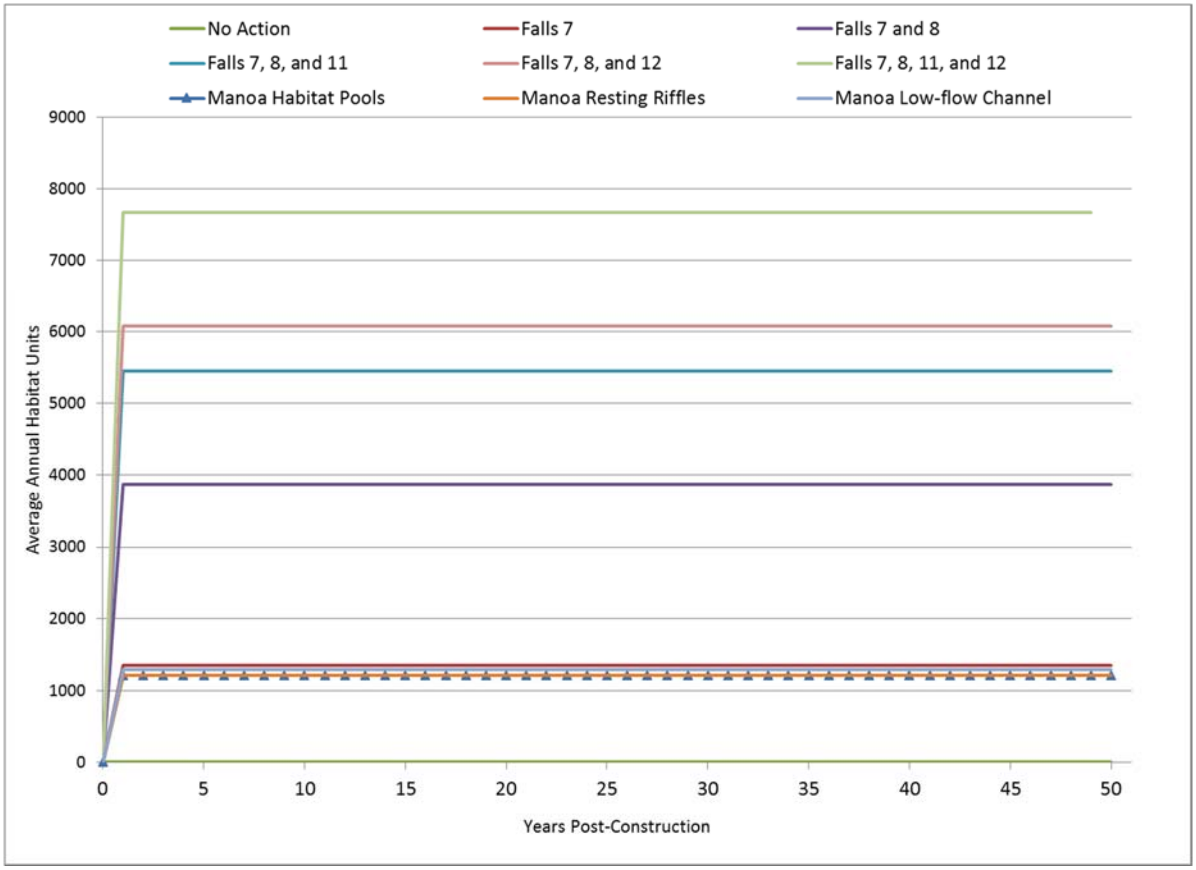

FIGURE 1
Projected Habitat Units over Period of Analysis

2.3.3 Summary of Alternative Outputs and Costs

Table 4 and Figure 2 summarize the outputs and costs of the alternatives. Costs are displayed in average annual costs, and outputs are displayed in average annual habitat units. These values are used in CE/ICA, as detailed in the remainder of this document.

TABLE 4
Summary of Alternative Outputs and Costs

Alternative	Output (Average Annual Habitat Units)	Cost (Average Annual Cost)
No Action	0	$ -
Falls 7	1,340	$ 9,014
Falls 7 and 8	3,831	$ 13,362
Falls 7, 8, 11	5,401	$ 16,101
Falls 7, 8, 12	6,021	$ 16,000
Falls 7, 8, 11, and 12	7,591	$ 18,440
Manoa Habitat Pools	1,202	$ 14,753
Manoa Resting Riffles	1,195	$ 15,105
Manoa Low-Flow Channel	1,279	$ 49,564

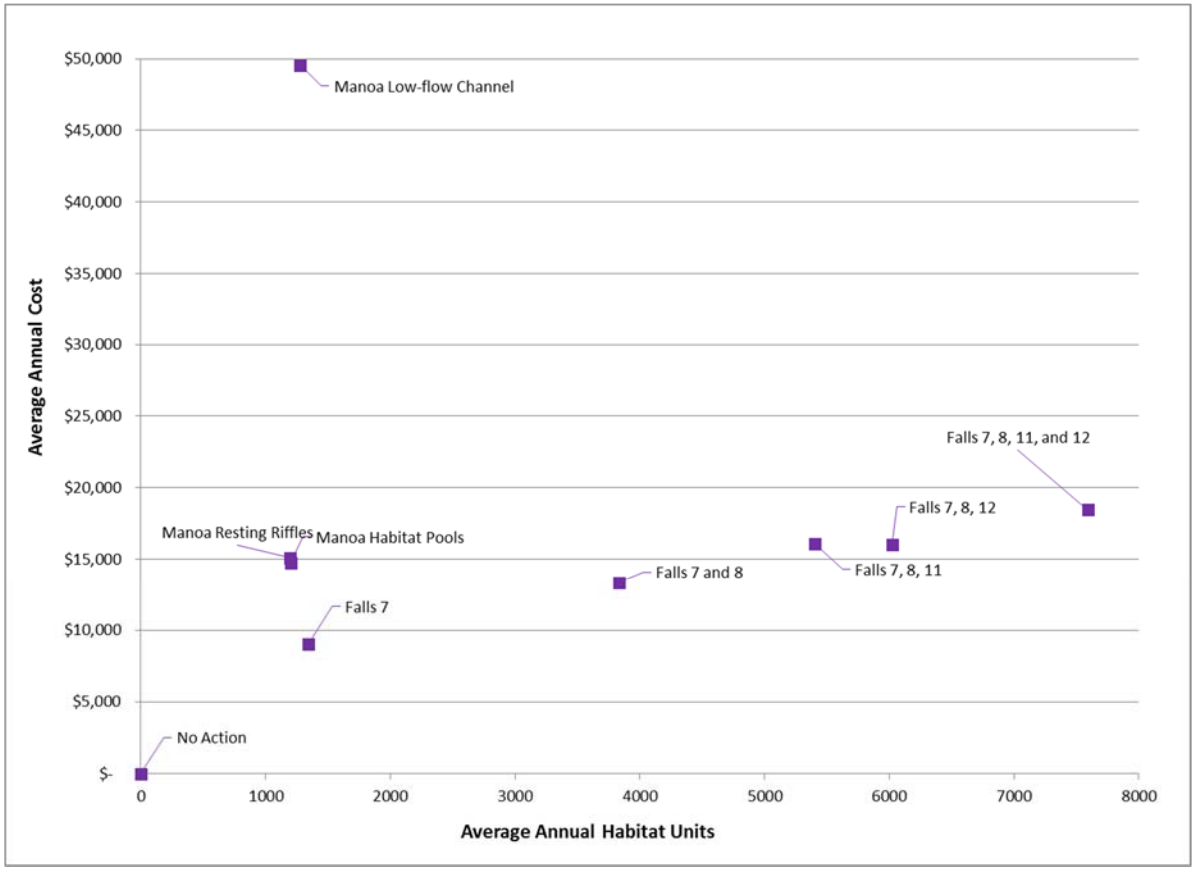

FIGURE 2
Cost and Output of Alternative Plans

3.0 Cost Effectiveness Analysis

The following section details the CE analysis, which is conducted to eliminate the least economically effective restoration alternatives. The inputs to the IWR Planning Suite include the predicted average annual habitat units (output) and the average annual cost for each alternative, each based on a 50-year period of analysis. For each level of output, only the least expensive alternative is cost-effective. As demonstrated in the following section, five of the nine alternatives were considered cost-effective and were carried forward to the ICA.

3.1 Step 4: Identify "Production Inefficient" Solutions

In Step 4, "production inefficient" solutions are identified. Production inefficient solutions are defined as alternative plans with the same level of output that can be provided at a lesser cost than another plan. Since none of the alternatives have the exact same level of output (or, average annual habitat units), there are no production inefficient solutions. These results are shown in Table 5.

TABLE 5
Identification of Production Inefficient Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of Alternative with Same Output?
No Action	0	$ -	N/A
Manoa Resting Riffles	1,195	$ 15,105	N/A
Manoa Habitat Pools	1,202	$ 14,753	N/A
Manoa Low-flow Channel	1,279	$ 49,564	N/A
Falls 7	1,340	$ 9,014	N/A
Falls 7 and 8	3,831	$ 13,362	N/A
Falls 7, 8, 11	5,401	$ 16,101	N/A
Falls 7, 8, 12	6,021	$ 16,000	N/A
Falls 7, 8, 11, and 12	7,591	$ 18,440	N/A

3.2 Step 5: Identify "Production Ineffective" Solutions

In Step 5, "production ineffective" solutions are identified. Production ineffective solutions are defined as plans with less output than a plan that has a lesser or equal cost. To demonstrate analysis conducted to identify these plans, the alternatives are ordered by increasing output, and a plan is removed from further consideration if its cost is more than a plan with greater output. As shown in Table 6, there are four plans (Manoa Resting Riffles, Manoa Habitat Pools, and Manoa Low-flow Channel, and Falls 7, 8, and 11) that have a lesser output but greater cost than at least one other plan, and are therefore production ineffective solutions. Figure 3 demonstrates the results of the CE analysis (Steps 4 and 5). Five alternatives are considered cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8, and 12; and Falls 7, 8, 11 and 12.

TABLE 6
Identification of Production Ineffective Solutions

Alternative	Average Annual Habitat Units	Average Annual Cost	Less than Cost of all Alternatives in Subsequent Rows?
No Action	0	$ 0	Yes
Manoa Resting Riffles	1,195	$ 15,105	No
Manoa Habitat Pools	1,202	$ 14,753	No
Manoa Low-flow Channel	1,279	$ 49,564	No
Falls 7	1,340	$ 9,014	Yes
Falls 7 and 8	3,831	$ 13,362	Yes
Falls 7, 8, 11	5,401	$ 16,101	No
Falls 7, 8, 12	6,021	$ 16,000	Yes
Falls 7, 8, 11, and 12	7,591	$ 18,440	Yes

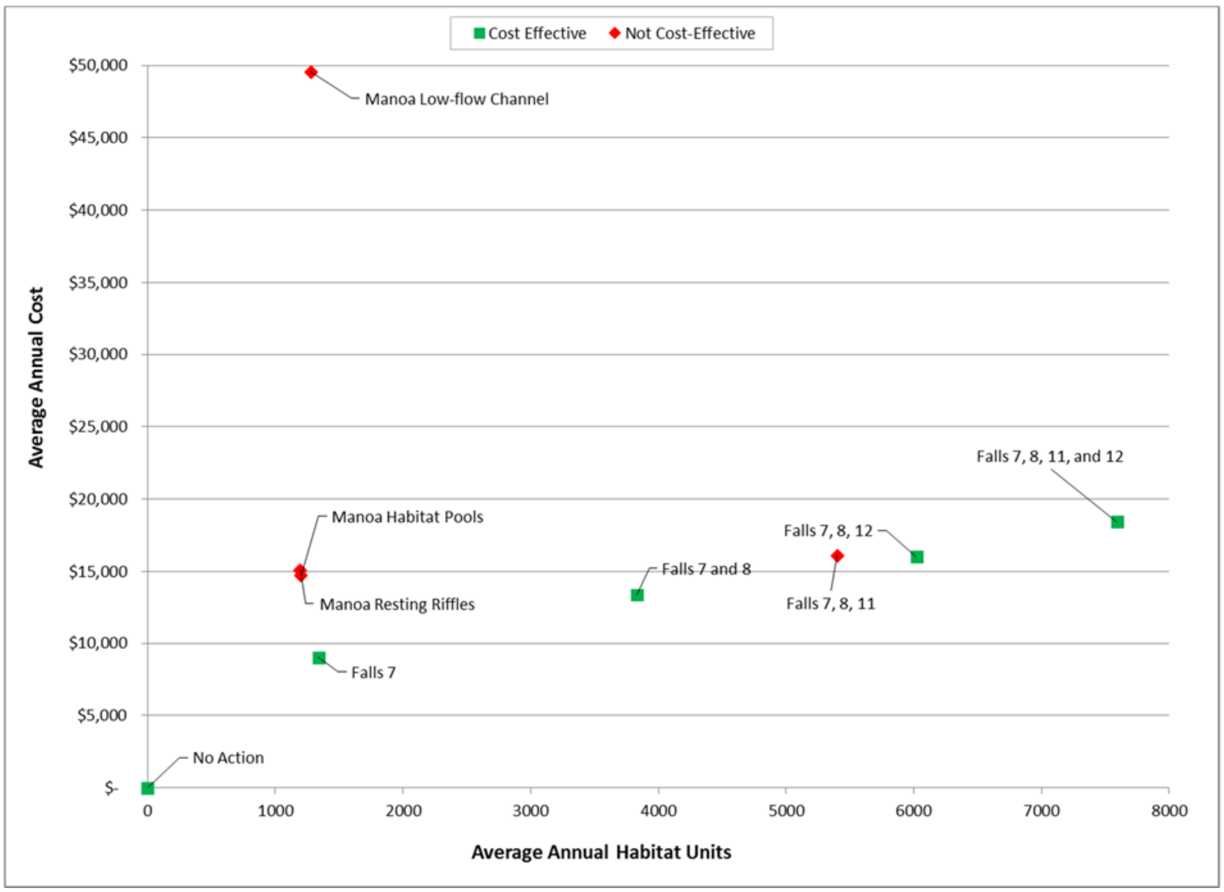

FIGURE 3
Costs and Outputs of Cost Effective Plans

4.0 Incremental Cost Analysis

The following section outlines the ICA conducted for the project. ICA is conducted on the cost-effective alternatives to determine which alternatives provide the greatest increase in output for the least increase in average annual cost. ICA serves to eliminate less economically effective solutions and determine which are best buy alternatives, or which provide the greatest increase in output for the least increase in cost. ICA is used to compare increases in average annual cost to increases in benefits, which are quantified in habitat units, among the alternatives being considered. The No Action Alternative does not have an associated cost and is therefore always considered a best buy plan. As demonstrated in the following section, of the five cost-effective alternatives, two were considered best buy plans.

4.1 Step 6: Calculate and Display Incremental Costs for Cost-Effective Plans

As previously mentioned, ICA is conducted on only the cost-effective plans identified in Steps 4 and 5. In Step 6, the incremental cost of implementing each successive cost-effective plan is calculated. While this step is not conducted to remove any alternatives, it identifies whether Steps 7 through 9 need to be completed. If the results of Step 6 show that the incremental cost per unit increases as the level of output increases, for all alternatives, the remainder of the steps do not need to be completed. However, this ideal situation is often not the case in planning studies. For the cost-effective alternatives identified in Section 3, the incremental cost per unit does not increase with increasing output (Table 7); therefore, Steps 7 through 9 must be employed.

TABLE 7
Summary of Incremental Costs per Unit (Step 6)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	2,491	$4,348	$1.75	No
Falls 7, 8, 12	6,021	$16,000	2,190	$2,638	$1.20	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	1,570	$2,440	$1.55	Yes

4.2 Step 7: Calculate and Display Incremental Costs per Unit from No Action Plan

In Step 7, alternative plans that have a higher incremental cost of implementation over the No Action Plan than an alternative with a higher output level are removed. For example, Falls 7 and 8 has a higher incremental cost per unit over the No Action Plan than does an alternative with a greater output (e.g, Falls 7, 8, and 12); therefore, Falls 7 and 8 is not considered a best buy plan (Table 8). After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 8). In Step 7, three alternatives were removed: Falls 7; Falls 7 and 8; and Falls 7, 8, 11, and 12.

TABLE 8
Summary of Incremental Costs per Unit (Step 7)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from No Action	Incremental Cost from No Action	Incremental Cost Per Unit Output from No Action	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7	1,340	$9,014	1,340	$9,014	$6.73	No
Falls 7 and 8	3,831	$13,362	3,831	$13,362	$3.49	No
Falls 7, 8, 12	6,021	$16,000	6,021	$16,000	$2.66	No
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

Note: Shaded alternatives were removed as potential best buy plan.

4.3 Step 8: Recalculate Incremental Cost from Last Selected Plan

In Step 8, the two remaining alternatives (No Action and Falls 7, 8, 11, and 12) are evaluated. The incremental cost of implementing each plan over the plan with the next lower output is calculated (Table 9). Any alternative plan that has higher incremental cost of implementation over the previous plan than an alternative with a higher output level is removed. After alternatives are removed based on this analysis, the incremental cost of remaining alternatives should increase with increasing cost (Table 9). In Step 8, no alternatives were removed. Therefore, the No Action Plan and Falls 7, 8, 11, and 12 are both considered best buy plans.

TABLE 9
Summary of Incremental Costs per Unit (Step 8)

Cost-Effective Alternatives	Average Annual Habitat Units	Average Annual Cost	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan	Less than Incremental Cost of Alternative in All Subsequent Rows?
No Action	0	$0	0	$0	$0	Yes
Falls 7, 8, 11, and 12	7,591	$18,440	7,591	$18,440	$2.43	Yes

4.4 Step 9: Tabulate and Graph Incremental Costs

In Step 9, the incremental costs of implementing each alternative over the No Action Plan are tabulated and graphed. The purpose of Step 9 is to clearly display the CE/ICA results to be used for alternative selection. Since no alternatives were removed in Step 8, the incremental costs do not change (Table 10). Table 10 also provides the average cost per habitat unit, which is often an additional consideration in the decision-making process.

TABLE 10
Summary of Incremental Costs per Unit (Step 9)

Alternative (Cost-Effective Solutions)	Average Annual Habitat Units	Average Annual Cost	Average Cost per Output	Incremental Output from Last Selected Plan	Incremental Cost from Last Selected Plan	Incremental Cost Per Unit Output from Last Selected Plan
No Action	0	$0	$ 0	0	$0	$0
Falls 7, 8, 11, and 12	7,591	$18,440	$2.43	7,591	$18,440	$2.43

Figure 4 displays the average annual cost and average annual habitat units of the alternatives. Figure 5 shows the incremental cost of implementing each successive best buy alternative (in this case only one alternative, Falls 7, 8, 11, and 12, is a successive best buy alternative), and the average annual cost of each best buy alternative. As shown, the average annual cost of Falls 7, 8, 11, and 12 is $18,440, and the incremental cost of implementing Falls 7, 8, 11, and 12 over the No Action Alternative is $2.43 per unit output. This information provides one decision factor for selection of mitigation alternative for the project.

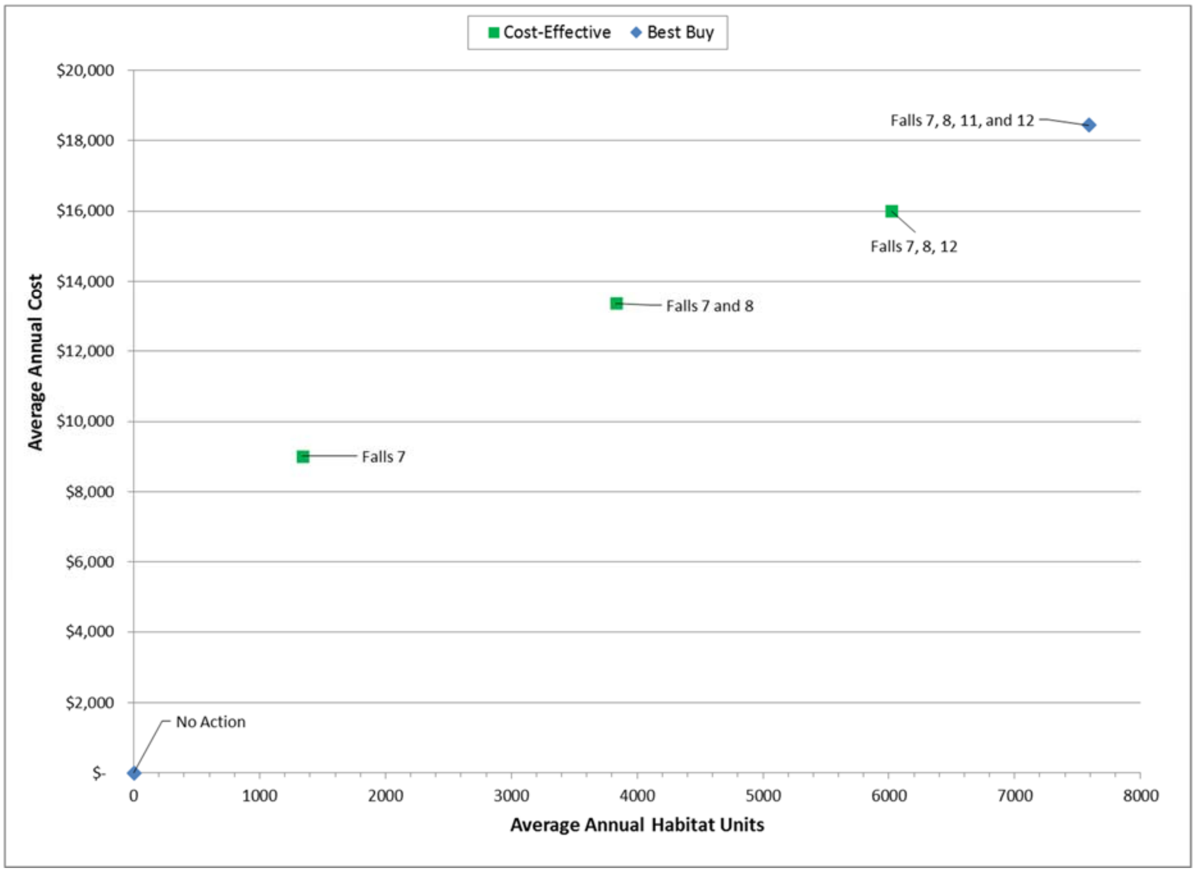

FIGURE 4
Costs and Outputs of Cost Effective and Best Buy Plans

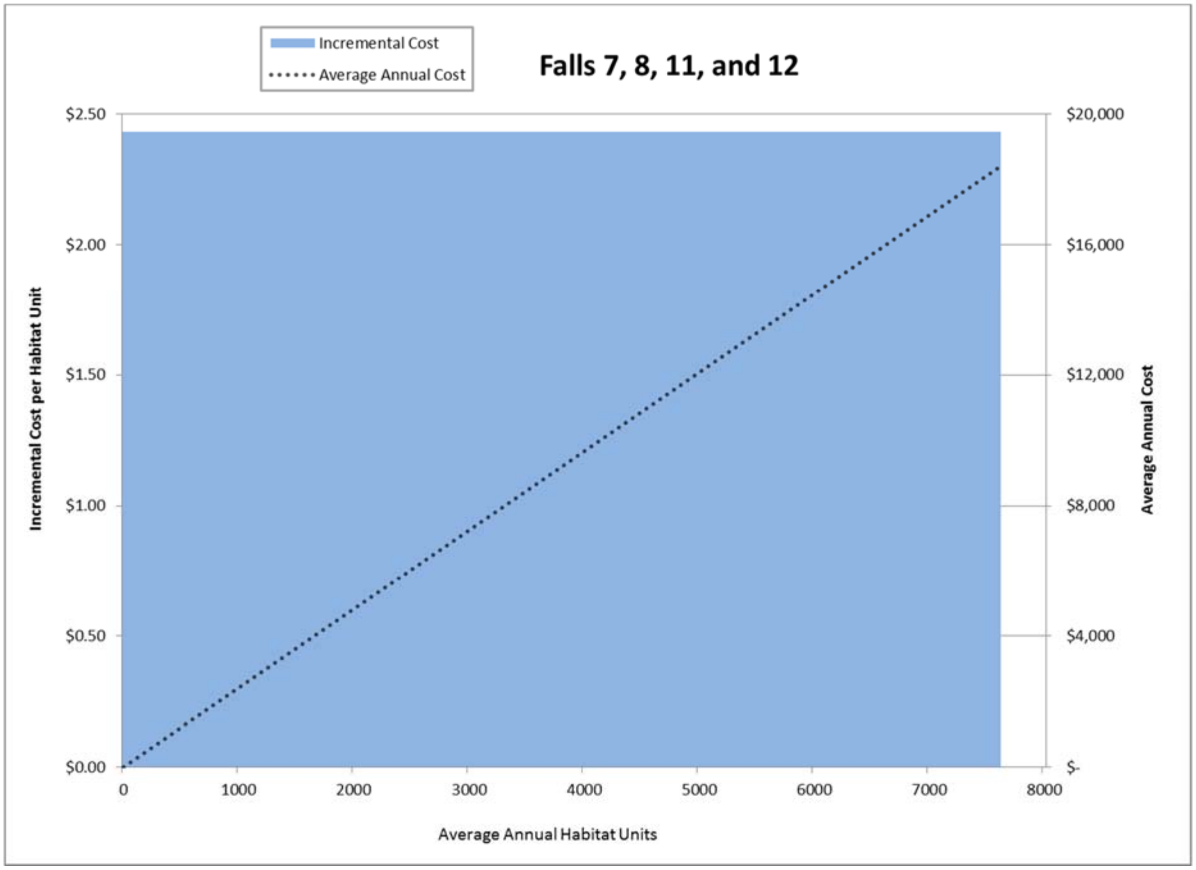

FIGURE 5
Incremental Cost of Best Buy Plans

5.0 References

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U.S. Water Resources Council. 1983. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.*

Attachment 1

IWR Planning Suite Detailed Cost Output

Annualized Cost for Falls 7, 8, 11, and 12

7/30/2015 9:05:02AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $18,439.89

Total initial cost:
Construction $260,409.00 + Real Estate $34,900.00 + Monitoring $11,100.00 + Other $0.00 = $306,409.00

Total Investment cost:
Total Initial Cost $306,409.00 + PED $0.00 + IDC $4,557.16 = $310,966.16

Initial investment:
Total Investment Cost $310,966.16 PV Factor 1.000000 Present Value = $310,966.16

Year	Cost	PV Factor	Present Value
0	$310,966.16	1.0000	$310,966.16
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$13,050.00	0.7089	$9,251.39
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$13,050.00	0.5026	$6,558.48
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$13,050.00	0.3563	$4,649.43
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$13,050.00	0.2526	$3,296.07
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$13,050.00	0.1791	$2,336.65

Net Totals: Cost: $494,716.16 Present Value: $432,518.94 Avg Annual Cost: $18,439.89

Annualized Cost for Falls 7, 8, and 11

7/30/2015 8:54:34AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $16,101.07

Total initial cost:
Construction $213,101.00 + Real Estate $32,700.00 + Monitoring $11,100.00 + Other $0.00 = $256,901.00

Total Investment cost:
Total Initial Cost $256,901.00 + PED $0.00 + IDC $3,729.27 = $260,630.27

Initial investment:
Total Investment Cost $260,630.27 PV Factor 1.000000 Present Value = $260,630.27

Year	Cost	PV Factor	Present Value
0	$260,630.27	1.0000	$260,630.27
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,788.00	0.7089	$7,647.82
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,788.00	0.5026	$5,421.68
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,788.00	0.3563	$3,843.53
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,788.00	0.2526	$2,724.75
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,788.00	0.1791	$1,931.63

Net Totals: Cost: $433,070.27 Present Value: $377,660.43 Avg Annual Cost: $16,101.07

Annualized Cost for Falls 7, 8, and 12

7/30/2015 9:00:46AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $16,000.38

Total initial cost:
Construction $214,033.00 + Real Estate $29,300.00 + Monitoring $11,100.00 + Other $0.00 = $254,433.00

Total Investment cost:
Total Initial Cost $254,433.00 + PED $0.00 + IDC $3,745.58 = $258,178.58

Initial investment:
Total Investment Cost $258,178.58 PV Factor 1.000000 Present Value = $258,178.58

Year	Cost	PV Factor	Present Value
0	$258,178.58	1.0000	$258,178.58
1	$11,700.00	0.9662	$11,304.35
2	$11,700.00	0.9335	$10,922.08
3	$47,700.00	0.9019	$43,022.67
4	$11,700.00	0.8714	$10,195.87
5	$11,700.00	0.8420	$9,851.09
6	$600.00	0.8135	$488.10
7	$600.00	0.7860	$471.59
8	$600.00	0.7594	$455.65
9	$600.00	0.7337	$440.24
10	$10,833.00	0.7089	$7,679.72
11	$600.00	0.6849	$410.97
12	$600.00	0.6618	$397.07
13	$600.00	0.6394	$383.64
14	$600.00	0.6178	$370.67
15	$600.00	0.5969	$358.13
16	$600.00	0.5767	$346.02
17	$600.00	0.5572	$334.32
18	$600.00	0.5384	$323.02
19	$600.00	0.5202	$312.09
20	$10,833.00	0.5026	$5,444.30
21	$600.00	0.4856	$291.34
22	$600.00	0.4692	$281.49
23	$600.00	0.4533	$271.97
24	$600.00	0.4380	$262.77
25	$600.00	0.4231	$253.89
26	$600.00	0.4088	$245.30
27	$600.00	0.3950	$237.01
28	$600.00	0.3817	$228.99
29	$600.00	0.3687	$221.25
30	$10,833.00	0.3563	$3,859.56
31	$600.00	0.3442	$206.54
32	$600.00	0.3326	$199.55
33	$600.00	0.3213	$192.81
34	$600.00	0.3105	$186.29
35	$600.00	0.3000	$179.99
36	$600.00	0.2898	$173.90
37	$600.00	0.2800	$168.02
38	$600.00	0.2706	$162.34
39	$600.00	0.2614	$156.85
40	$10,833.00	0.2526	$2,736.12
41	$600.00	0.2440	$146.42
42	$600.00	0.2358	$141.47
43	$600.00	0.2278	$136.68
44	$600.00	0.2201	$132.06
45	$600.00	0.2127	$127.60
46	$600.00	0.2055	$123.28
47	$600.00	0.1985	$119.11
48	$600.00	0.1918	$115.08
49	$600.00	0.1853	$111.19
50	$10,833.00	0.1791	$1,939.69

Net Totals: Cost: $430,843.58 Present Value: $375,298.71 Avg Annual Cost: $16,000.38

Annualized Cost for Falls 7 and 8

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $13,361.51

Total initial cost:
Construction $166,724.00 + Real Estate $27,100.00 + Monitoring $11,100.00 + Other $0.00 = $204,924.00

Total Investment cost:
Total Initial Cost $204,924.00 + PED $0.00 + IDC $2,917.67 = $207,841.67

Initial investment:
Total Investment Cost $207,841.67 PV Factor 1.000000 Present Value = $207,841.67

Year	Cost	PV Factor	Present Value
0	$207,841.67	1.0000	$207,841.67
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$8,271.00	0.7089	$5,863.47
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$8,271.00	0.5026	$4,156.72
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$8,271.00	0.3563	$2,946.78
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$8,271.00	0.2526	$2,089.03
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$8,271.00	0.1791	$1,480.95

Net Totals: Cost: $354,196.67 Present Value: $313,402.50 Avg Annual Cost: $13,361.51

Annualized Cost for Falls 7

7/30/2015 8:44:15AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $9,014.08

Total initial cost:
Construction $85,175.00 + Real Estate $15,900.00 + Monitoring $11,100.00 + Other $0.00 = $112,175.00

Total Investment cost:
Total Initial Cost $112,175.00 + PED $ 0.00 + IDC $1,490.56 = $113,665.56

Initial investment:
Total Investment Cost $113,665.56 PV Factor 1.000000 Present Value = $113,665.56

Year	Cost	PV Factor	Present Value
0	$113,665.56	1.0000	$113,665.56
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$4,372.00	0.7089	$3,099.39
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$4,372.00	0.5026	$2,197.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$4,372.00	0.3563	$1,557.65
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$4,372.00	0.2526	$1,104.25
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$4,372.00	0.1791	$782.82

Net Totals: Cost: $240,525.56 Present Value: $211,430.78 Avg Annual Cost: $9,014.08

Annualized Cost for Manoa Habitat Pools

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $14,753.16

Total initial cost:
Construction $216,353.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $231,953.00

Total Investment cost:
Total Initial Cost $231,953.00 + PED $0.00 + IDC $3,786.18 = $235,739.18

Initial investment:
Total Investment Cost $235,739.18 PV Factor 1.000000 Present Value = $235,739.18

Year	Cost	PV Factor	Present Value
0	$235,739.18	1.0000	$235,739.18
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,644.00	0.7089	$7,545.73
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,644.00	0.5026	$5,349.31
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,644.00	0.3563	$3,792.23
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,644.00	0.2526	$2,688.38
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,644.00	0.1791	$1,905.84

Net Totals: Cost: $393,959.18 Present Value: $346,044.56 Avg Annual Cost: $14,753.16

Annualized Cost for Manoa Low-Flow Channel

7/30/2015 9:15:05AM

Initial terms:

Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $49,564.05

Total initial cost:

Construction $1,001,513.0 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $1,017,113.00

Total Investment cost:

Total Initial Cost $1,017,113.00 + PED $0.00 + IDC $17,526.48 = $1,034,639.48

Initial investment:

Total Investment Cost $1,034,639.4 PV Factor 1.000000 Present Value = $1,034,639.48

Year	Cost	PV Factor	Present Value
0	$1,034,639.48	1.0000	$1,034,639.48
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$19,452.00	0.7089	$13,789.89
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$19,452.00	0.5026	$9,775.91
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$19,452.00	0.3563	$6,930.33
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$19,452.00	0.2526	$4,913.04
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$19,452.00	0.1791	$3,482.95

Net Totals: Cost: $1,236,899.48 Present Value: $1,162,555.48 Avg Annual Cost: $49,564.05

Annualized Cost for Manoa Resting Riffles

7/30/2015 9:08:36AM

Initial terms:
Discount rate %: 3.5 Period of analysis: 50 Capital recovery factor: 0.042633709 Avg annual cost: $15,104.61

Total initial cost:
Construction $223,759.00 + Real Estate $4,500.00 + Monitoring $11,100.00 + Other $0.00 = $239,359.00

Total Investment cost:
Total Initial Cost $239,359.00 + PED $0.00 + IDC $3,915.78 = $243,274.78

Initial investment:
Total Investment Cost $243,274.78 PV Factor 1.000000 Present Value = $243,274.78

Year	Cost	PV Factor	Present Value
0	$243,274.78	1.0000	$243,274.78
1	$11,400.00	0.9662	$11,014.49
2	$11,400.00	0.9335	$10,642.02
3	$47,400.00	0.9019	$42,752.08
4	$11,400.00	0.8714	$9,934.44
5	$11,400.00	0.8420	$9,598.49
6	$300.00	0.8135	$244.05
7	$300.00	0.7860	$235.80
8	$300.00	0.7594	$227.82
9	$300.00	0.7337	$220.12
10	$10,998.00	0.7089	$7,796.69
11	$300.00	0.6849	$205.48
12	$300.00	0.6618	$198.53
13	$300.00	0.6394	$191.82
14	$300.00	0.6178	$185.33
15	$300.00	0.5969	$179.07
16	$300.00	0.5767	$173.01
17	$300.00	0.5572	$167.16
18	$300.00	0.5384	$161.51
19	$300.00	0.5202	$156.05
20	$10,998.00	0.5026	$5,527.22
21	$300.00	0.4856	$145.67
22	$300.00	0.4692	$140.75
23	$300.00	0.4533	$135.99
24	$300.00	0.4380	$131.39
25	$300.00	0.4231	$126.94
26	$300.00	0.4088	$122.65
27	$300.00	0.3950	$118.50
28	$300.00	0.3817	$114.50
29	$300.00	0.3687	$110.62
30	$10,998.00	0.3563	$3,918.35
31	$300.00	0.3442	$103.27
32	$300.00	0.3326	$99.78
33	$300.00	0.3213	$96.40
34	$300.00	0.3105	$93.14
35	$300.00	0.3000	$89.99
36	$300.00	0.2898	$86.95
37	$300.00	0.2800	$84.01
38	$300.00	0.2706	$81.17
39	$300.00	0.2614	$78.42
40	$10,998.00	0.2526	$2,777.79
41	$300.00	0.2440	$73.21
42	$300.00	0.2358	$70.73
43	$300.00	0.2278	$68.34
44	$300.00	0.2201	$66.03
45	$300.00	0.2127	$63.80
46	$300.00	0.2055	$61.64
47	$300.00	0.1985	$59.56
48	$300.00	0.1918	$57.54
49	$300.00	0.1853	$55.60
50	$10,998.00	0.1791	$1,969.23

Net Totals: Cost: $403,264.78 Present Value: $354,287.95 Avg Annual Cost: $15,104.61

Attachment 7

Addendum to

Mitigation, Monitoring and Adaptive Management Plan

Ala Wai Canal Project

U.S. Army Corps of Engineers, Honolulu District

14 July 2016

1. The draft Mitigation, Monitoring, and Adaptive Management Plan (MMAMP; USACE 2015) and its attachments describe the use of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) to evaluate the impacts of the Ala Wai Canal project on aquatic habitat, and summarize the results of the HSHEP modeling effort. As with other Habitat Evaluation Procedure (HEP) models, the HSHEP uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. Adverse impacts to stream habitat can then be expressed as HUs lost, while mitigation efforts that improve stream habitat can be quantified as HUs gained.

2. When the HSHEP was applied to the Ala Wai Canal project, following the methodology and assumptions detailed in the MMAMP, the resulting total HUs lost within the Ala Wai watershed due to project impacts was calculated as 192 under the "expected scenario" (described in Section 2.2 of the MMAMP) and 1,210 under the "worst-case scenario". When these HU losses were compared against the HU gains calculated for an array of mitigation alternatives developed for the project, it was apparent that the mitigation alternative involving the removal of migration barriers at "Falls 7" and "Falls 8" would provide a sufficient gain in HUs to offset the HU losses from project impacts (Table 7 of the MMAMP).

3. In May 2016, the Corps' internal review of the project revealed that several of the project elements would need to be redesigned to provide sufficient stormwater retention and management capacity. Some of the design changes, such as additional excavation within the detention basins and riprap scour protection downstream of the detention structures, represented additional impacts to stream habitat beyond what had been modeled by the HSHEP.

4. The Corps contracted James Parham of Parham and Associates Environmental Consulting, LLC, to update and rerun the HSHEP model to reflect the changes to project design (Parham 2016a). Dr. Parham's update of the HSHEP spreadsheet included creating new model stream segments to reflect the updated plans, reviewing the impacts of the project changes and determining criteria for them. The most relevant design changes included in the updated model included:

- The addition or expansion of an upstream excavation area at three sites;
- The replacement of the open bottom arch culverts with box culverts at three sites; and
- The addition of downstream riprap scour protection areas at five sites.

Dr. Parham consulted with Glenn Higashi at the Hawaiian Division of Aquatic Resources in determining the impacts of the design changes. They followed a similar impact criteria methodology as had been developed for the first model, as much as possible. For the upstream excavation areas, they applied the expected and maximum impact criteria values as had been previously determined for the first model; similar criteria values were applied to the new downstream riprap scour protection areas. In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, they applied the same values as the determined for channelized stream segments in the first model. Each box culvert was assigned the barrier impact value of 100 meters of channelized stream, although the box culverts will range in length from roughly 49 to 62 meters, providing some conservatism to the assessment of impact of the box culverts (Parham 2016b).

5. Table 1 below updates Table 7 from the MMAMP, comparing the calculated HUs lost with the redesigned project ("2016 Scope") with those calculated for the original scope, and with the net HU gained from an abbreviated set of mitigation alternatives. Despite the additional impacts to stream habitat inherent in the project design changes, the benefit from the "Falls 7 and 8" mitigation alternative remains sufficient to offset the total project impacts.

Table 1. Comparison of HUs Lost/Gained between Original and Expanded Project Scope

Location	*2015 Scope With-Project HUs Lost*	2016 Scope With-Project HUs Lost	Mitigation Alternatives – Net HUs Gained		
			"Falls 7"	"Falls 7, 8"	"Falls 7, 8, 11"
EXPECTED SCENARIO					
Manoa Stream	*191*	233	1,308	3,736	5,147
Palolo Stream	*-107*	-59	0	0	0
Makiki Stream	*24*	38	0	0	0
Hausten Ditch	*84*	84	0	0	0
Total	***192***	**295**	**1,308**	**3,736**	**5,147**
WORST CASE SCENARIO					
Manoa Stream	*808*	825	796	2,688	4,065
Palolo Stream	*-29*	-15	0	0	0
Makiki Stream	*11*	29	0	0	0
Hausten Ditch	*420*	420	0	0	0
Total	***1,210***	**1,259**	**796**	**2,688**	**4,065**

References:

U.S. Army Corps of Engineers, Honolulu District (USACE). 2015. Mitigation, Monitoring, and Adaptive Management Plan (draft), Ala Wai Canal Project, Oahu, Hawaii. August 2015.

Parham, James E. 2016a. Ala Wai HSHEP Impact Worksheet Final 07/07/2016 with updated plans. 7 July 2016.

Parham. 2016b. Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study. 12 July 2016.

Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study.

7/12/2016

Submitted to:

Michael D. Wyatt, POH

US Army Corps of Engineers

Honolulu, Hawaii

Submitted by:

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Introduction:

The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) was used to estimate current conditions and project impacts for proposed actions in Manoa, Makiki, and Palolo Streams associated with the Ala Wai Canal Flood Mitigation Project. The application of the model was based on extensive field surveys within the streams as well as stream surveys statewide. To estimate project impacts, the designs of the flood mitigation projects were used as defined at the time. As the project has advanced, changes to the design specification occurred in response to overall project review. This report documents changes to the original HSHEP model which reflect the new project design specifications.

In addition to this report, an updated spreadsheet of the results and GIS shapefiles of the newly defined segments has been provided to the US Army Corps of Engineers (USACE).

Methods:

Several steps needed to be completed to update the spreadsheet to allow the new changes to be reflected in the results:

1. New stream segments associated with the updated plans were created in ArcGIS 10.2.
2. The new segments had their instream habitat conditions associated with them from the prior model.
3. The new segments had the habitat suitability for the native instream biota associated with them from the prior model.
4. The impacts of the new design specification changes were reviewed and criteria were determined for them.
5. All of these changes were updated into the HSHEP spreadsheet and new impacts were determined for the current conditions and eight different mitigation scenarios.

The following further describes the steps:

<u>Development of New Stream Segments:</u>

The USACE provided PDF copies of the new flood mitigation projects sites (Appendix 1) and associated GIS shapefiles. In addition to the drawings, a spreadsheet of the changes was also provided (Appendix 2). Some additional guidance to understanding the changes was also provided by USACE in an email discussion.

Primarily, there were three changes associated with the new plans:

1. The addition or expansion of an upstream excavation area,
2. the replacement of the open bottom arch culverts with box culverts, and
3. the addition of downstream riprap scour protection areas.

These changes were not found at all sites and impacted different amounts of the stream channel. To create the new stream segments, the old stream segments were split and redefined based on the GIS shapefiles to reflect the new designs. At all five sites, all three types of plan changes were included within the model (Figure 1). When the project did not call for one of the changed types, a segment with zero length was included in the model. This was done for consistency of approach and for flexibility in modeling possible future changes to the plans. Stream segment code numbers were modified to clearly identify the site changes.

30	28	Manoa	Manoa	
31	29	Manoa	Manoa	
32	30	Manoa	Manoa	
33	31	Manoa	Manoa	
34	32	Manoa	Manoa	
35	50	Manoa	Waiahi	
36	51	Manoa	Waiahi	
37	52	Manoa	Waiahi	
38	53	Manoa	Waiahi	Waiahi Detention Basin
39	54	Manoa	Waiahi	
40	55	Manoa	Waiahi	
41	56	Manoa	Waiahi	
42	61	Manoa	Unnamed off Waiahi	
43	80	Manoa	Luaalaea	
44	81	Manoa	Luaalaea	
45	82	Manoa	Luaalaea	Waiakeakua Detention Basin
46	83	Manoa	Luaalaea	
47	90	Manoa	Waiakeakua	
48	100	Manoa	Luaalaea	
49	110	Manoa	Luaalaea	
50	120	Manoa	Naniuapo	

31	29	Manoa	Manoa		Barrier: Falls 7
32	30	Manoa	Manoa		Barrier: Falls 8
33	31	Manoa	Manoa		
34	32	Manoa	Manoa		
35	50	Manoa	Waiahi		
36	51	Manoa	Waiahi		Barrier: Falls 11
37	52	Manoa	Waiahi		
38	5301	Manoa	Waiahi	Waiahi Detention Basin Scour	yes
39	5302	Manoa	Waiahi	Waiahi Detention Basin	box
40	5303	Manoa	Waiahi	Waiahi Detention Basin Excavation	no
41	54	Manoa	Waiahi		
42	55	Manoa	Waiahi		
43	56	Manoa	Waiahi		
44	61	Manoa	Unnamed off Waiahi		
45	80	Manoa	Luaalaea		
46	81	Manoa	Luaalaea		Barrier: Falls 12
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavati	no
50	83	Manoa	Luaalaea		
51	90	Manoa	Waiakeakua		

Overal / Summary&Impacts / SegmentInfo / HSI / Current(

Figure 1. Screen capture of Segment Info pages in old (left) and updated (right) HSHEP model result spreadsheets showing the creation of the new segment identification numbers.

Associating Habitat Availability and Habitat Suitability to the New Segments from Prior Model Information:

A similar process was used to associate the information from the HSHEP model with the newly defined stream segments. Given the short turnaround time allowed for this update, a complete redo of all stream segments within the model was not done. The new stream segments were reviewed against the model data for each segment and the appropriate data was included in the spreadsheet defining the results. As a result of this approach, there are small differences in some of the nearby segments that result in small changes to the overall habitat units within the model (54,572 HU in original model vs 54,458 HU in the new model). These changes are minuscule (0.209 % difference between models) and are unlikely to affect the overall conclusions for appropriate mitigation actions.

When reviewing the data for the new stream segment information, the original detention basin and upstream area were associated with the new detention basin footprint and upstream excavation area and the downstream riprap scour protection area was associated with the immediate downstream segment. In some cases, the new project site footprints included more than one downstream or upstream segment and in these cases the appropriate information was applied from all affected stream segments. The exact linear measurements for each area were determined from the associated spreadsheet information provided by USACE and included within the model spreadsheet (Figure 2). This allowed for some discrepancies between GIS data sources while capturing the specifics of the new project designs.

	A	B	C	D	E	S	T	U	V	W
43	56	Manoa	Waiahi			567	15	90%	4	2333
44	61	Manoa	Unnamed off Waiahi			531	15	90%	4	2184
45	80	Manoa	Luaalaea			191	34	90%	9	1768
46	81	Manoa	Luaalaea		Barrier: Falls 12	12	24	90%	7	80
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes	46	24	90%	7	306
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch	61	27	90%	8	458
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavati	no	0	25	90%	7	0
50	83	Manoa	Luaalaea			38	25	90%	7	261
51	90	Manoa	Waiakeakua			864	15	90%	4	3557
52	100	Manoa	Luaalaea			257	20	90%	5	1413
53	110	Manoa	Luaalaea			960	15	90%	4	3949
54	120	Manoa	Naniuapo			815	15	90%	4	3354
55	200	Palolo	Palolo			44	30	85%	8	344
56	201	Palolo	Palolo	Channelized	Chan Barrier	528	40	33%	4	2086
57	202	Palolo	Palolo			570	30	86%	8	4522
58	203	Palolo	Palolo	Channelized	Chan Barrier	2003	38	45%	5	10451
59	210	Palolo	Waiomao	Channelized	Chan Barrier	154	35	45%	5	739
60	211	Palolo	Waiomao			789	35	45%	5	3788
61	212	Palolo	Waiomao			269	22	83%	6	1489
62	213	Palolo	Waiomao			0	25	90%	7	0
63	2141	Palolo	Waiomao	Waiomao Detention Basin Scour	yes	46	25	90%	7	318
64	2142	Palolo	Waiomao	Waiomao Detention Basin	box	52	20	90%	5	285
65	2143	Palolo	Waiomao	Waiomao Detention Basin Excavation	Barrier: P_Falls 5 (yes)	122	35	89%	9	1150
66	216	Palolo	Waiomao			1768	15	90%	4	7275
67	220	Palolo	Pukele	Channelized	Chan Barrier	566	40	50%	6	3447
68	221	Palolo	Pukele			459	30	90%	8	3777
69	222	Palolo	Pukele			262	30	90%	8	2156
70	2231	Palolo	Pukele	Pukele Detention Basin Scour	yes	46	30	90%	8	379
71	2232	Palolo	Pukele	Pukele Detention Basin	box	49	30	90%	8	403

Figure 2. Screen capture of the updated HSHEP model spreadsheet showing the newly determined stream lengths (column S) for the site changes. For row 49, the Waiakeakua Upstream excavation area the stream length is 0 reflecting no upstream excavation area although the stream segment coding is in place for future site modifications. Row 65 shows the Waiomao Excavation area and its appropriate length of 122m (400 ft).

Determining Impacts of New Design Changes:

Determining the impacts of the new design changes was done in consultation with Glenn Higashi at the Hawaii Division of Aquatic Resources. We attempted to follow similar impact criteria as had been developed for the first model. For the upstream excavation areas, we applied the expected and maximum impact criteria values as had been previously determined for the first model. For the downstream riprap scour protection areas, we applied similar criteria values (Figure 3). In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, we applied the same values as the channelized barriers determined for the first model. In this case, we had assumed some decrease in passage for each 100 m of channelized stream (Figure 4). Although the box culverts were not 100 m in length, we considered them to have passage barrier values as if they were 100 m in length. This estimate avoided underestimating the impact of the fish passing under these dams through the box culverts.

	A	B	C	D
1	Habitat Impact Variables			
2		Habitat Remaining		
3	Type	Current Impact (live Values)	Expected Impact	Max Impact
4	Off-channel Detention Intakes	0.8	0.8	0
5	In-channel Sites	0	0	0
6	Upstream Detention Excavation	0.5	0.5	0
7	Channel Maintenance	0.5	0.5	0.5
8	Downstream Scour Area	0.5	0.5	0

Figure 3. Screen capture of the habitat impact weighting criteria used for the updated HSHEP model.

G	H	I	J	K
Barrier Impact Variables				
	Habitat Remaining			
Type	Current Impact (live Values)	Expected	Max Barrier	
Channelized Barriers (per 100m)	0.9	0.9	0.85	
Undercut Barriers	0.5	0.5	0.35	
Box Culverts	0.9	0.9	0.85	

Figure 4. Screen capture of the barrier impact weighting criteria used for the updated HSHEP model.

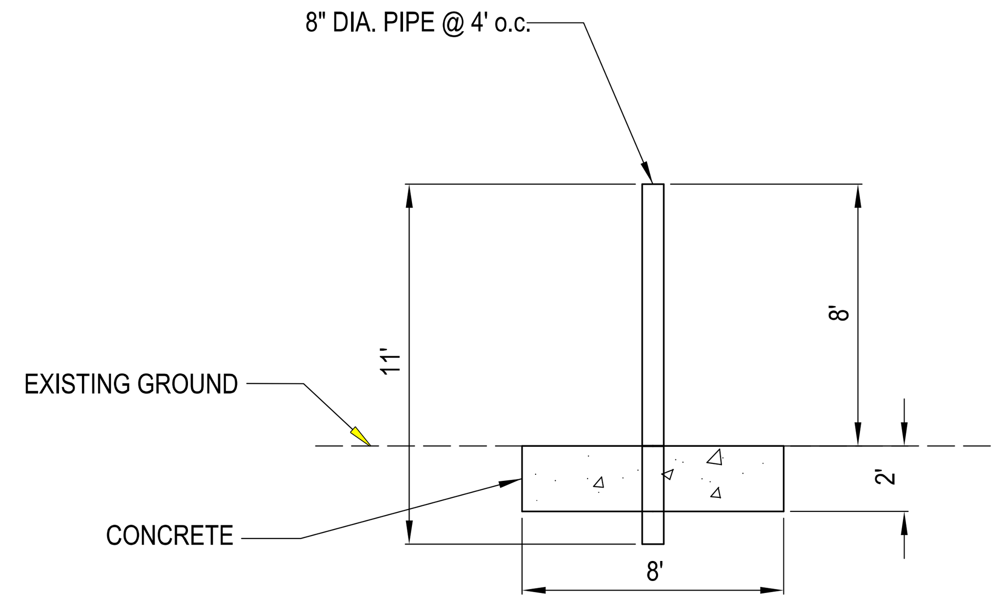
Updating the HSHEP Model Result Spreadsheet:

Results from the new model were added to the HSHEP model result spreadsheet. All formulas and dependencies were updated and double checked. The mitigation values for each of the eight different scenarios were recalculated and added to the overall results page.

Results and Conclusion:

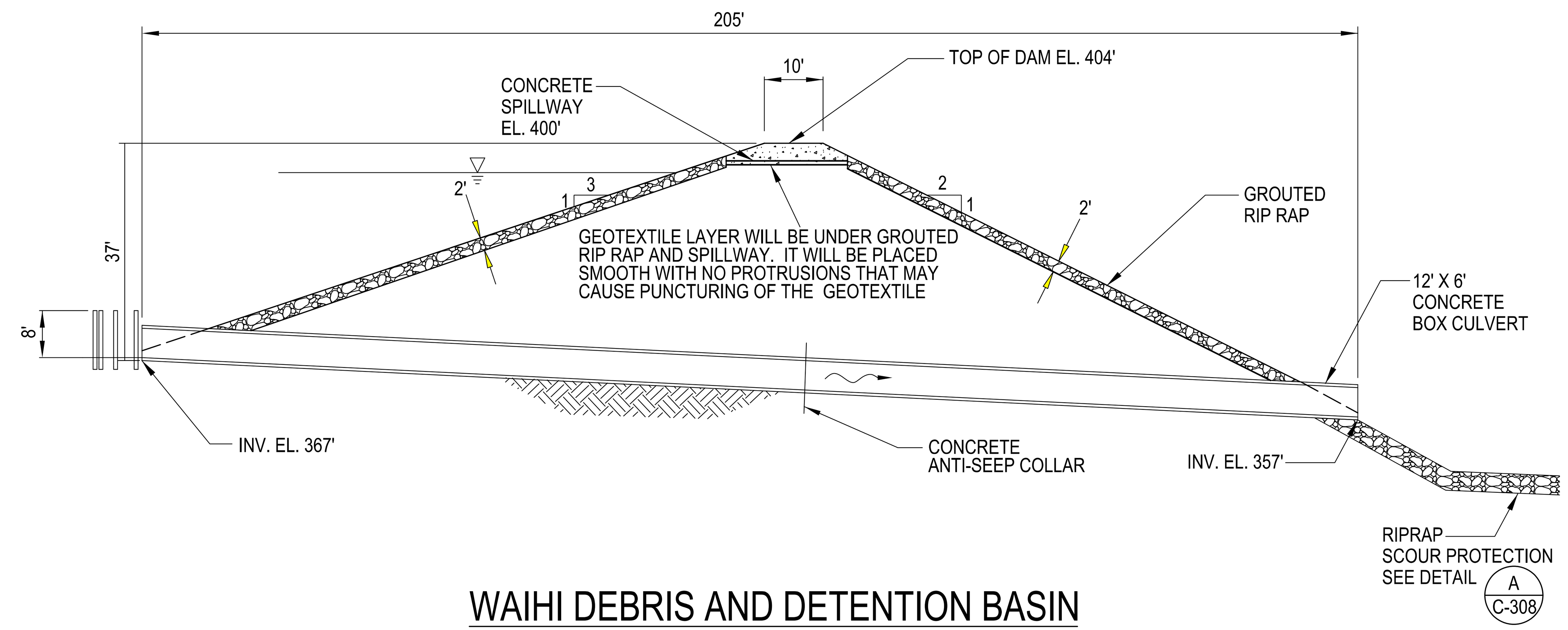
An updated spreadsheet and associated GIS file were provided to the USACE with this report. The intent of this report is not to discuss the findings but to document the process in which the spreadsheet was updated with the new site information.

In a general sense, the conclusions of this updated model are unchanged from the first model run. The biggest difference is the loss of habitat associated with the increased footprint of the projects and a decrease in upstream passage where box culverts are used. The removal of the falls 7 and 8 as a mitigation scenario remains the most promising scenario in terms of habitat units gained for effort expended.



WAIHI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=5'



WAIHI DEBRIS AND DETENTION BASIN SECTION A-A

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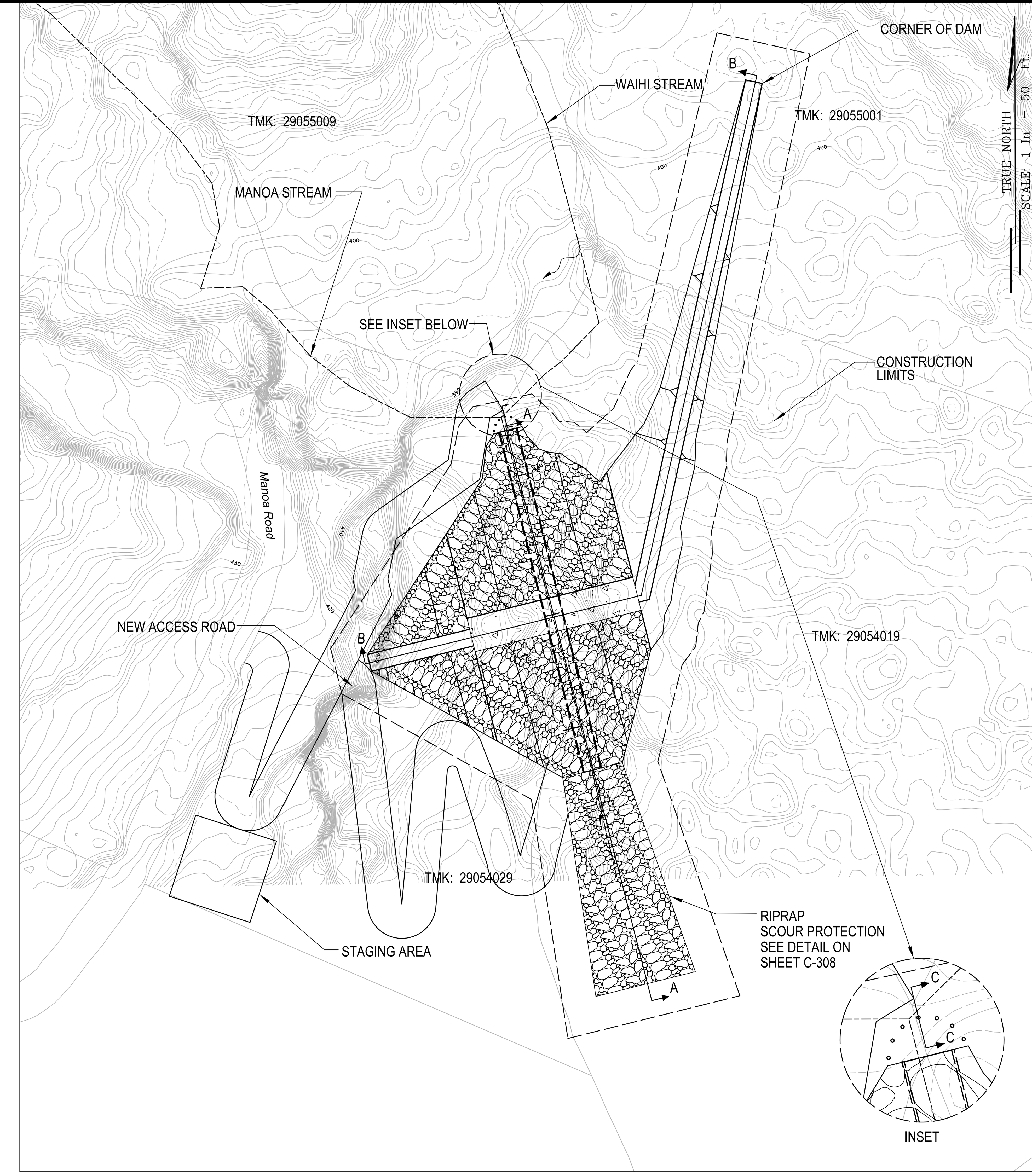


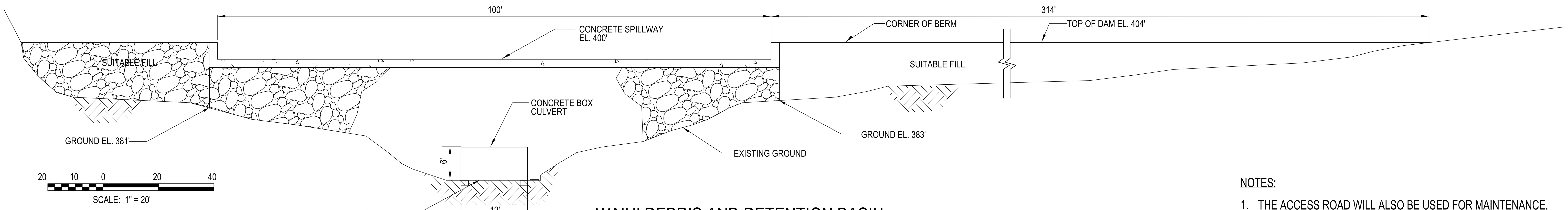
50 25 0 50 100

SCALE: 1" = 50'

PLAN

SCALE: 1"=50'

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



20 10 0 20 40

SCALE: 1" = 20'

10 5 0 10 20

SCALE: 1" = 10'

Note: All elevations are feet MSL

WAIHI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'

NOTES:

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

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ALA WAI CANAL PROJECT

WAIHI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

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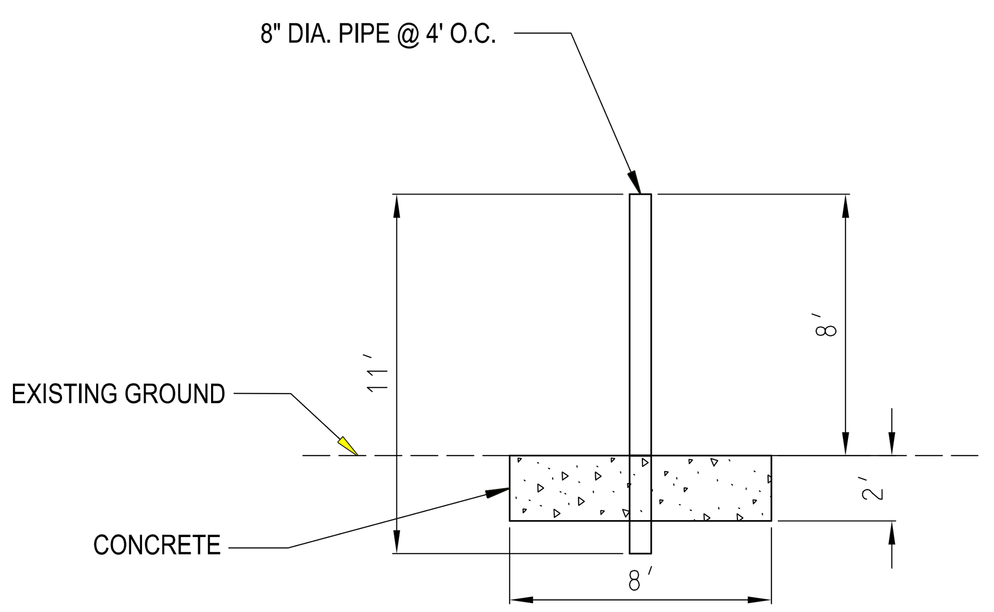
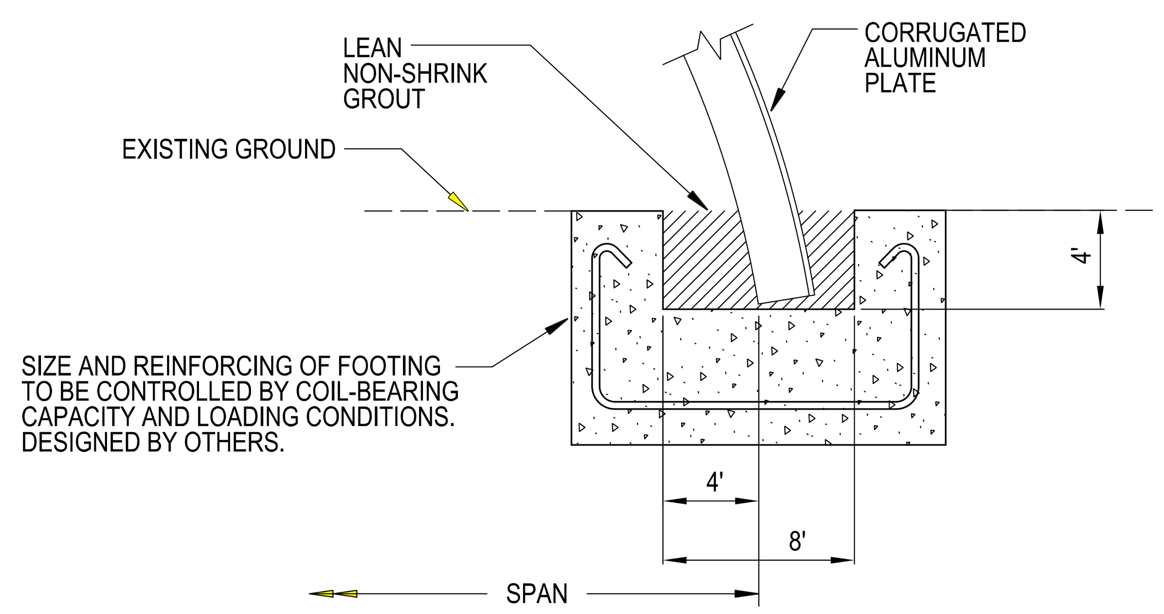
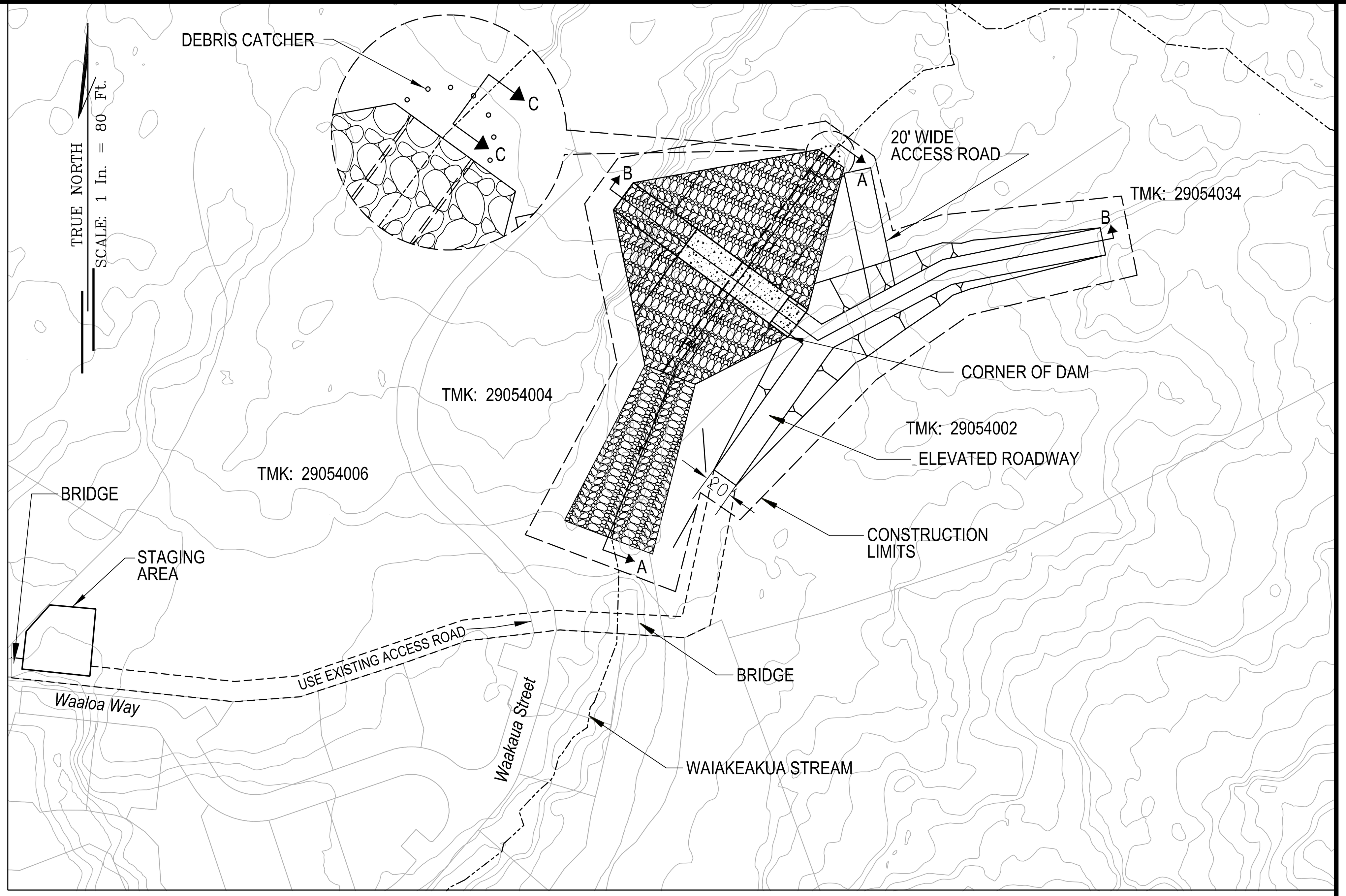
C-301
SHEET 0 OF 31



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



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

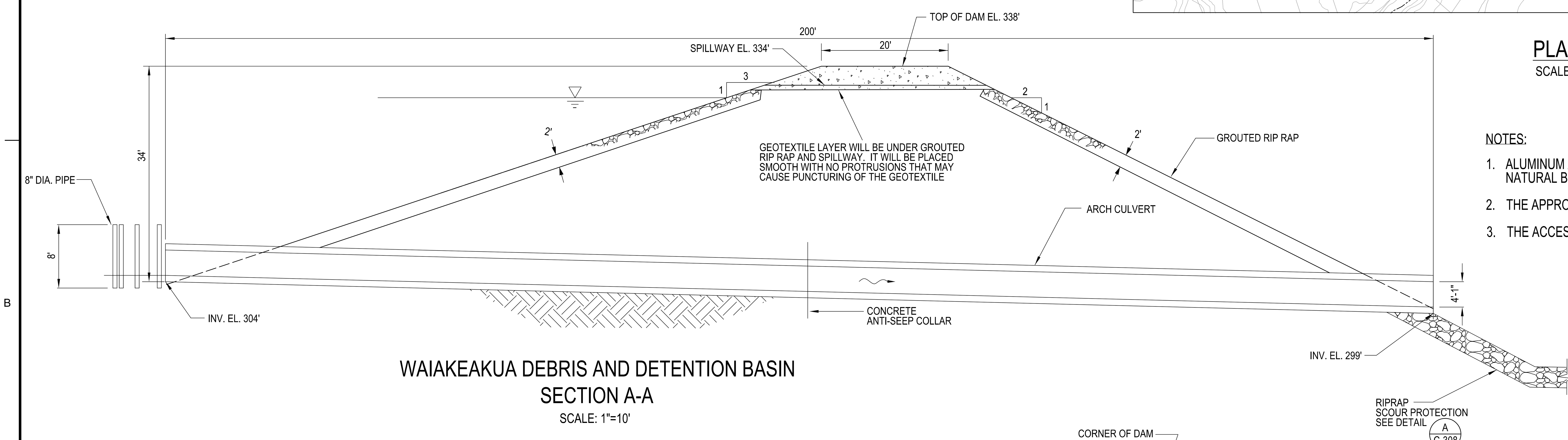


PLAN
SCALE: 1"=80'

SOLID LINE = 5' CONTOURS

80 40 0 80 160

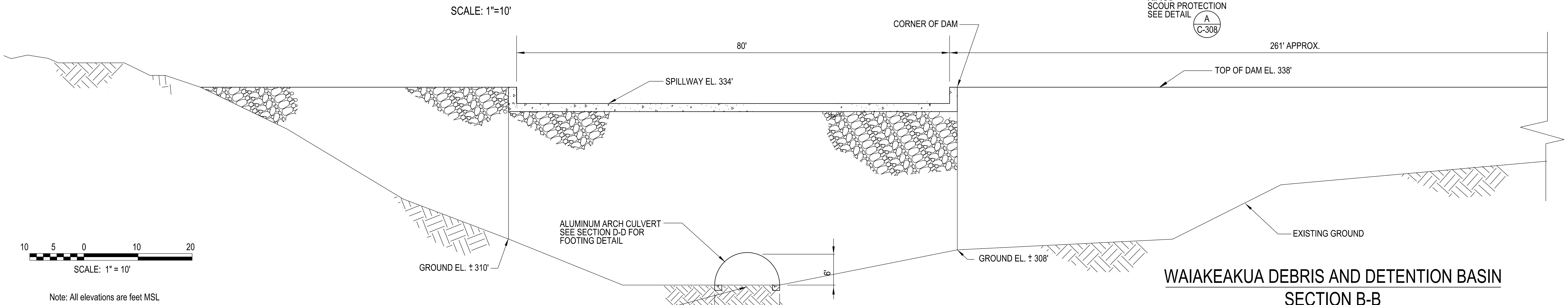
SCALE: 1" = 80'



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

NOTES:

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



Note: All elevations are feet MSL

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

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ALA WAI CANAL PROJECT

WAIAKEAKUA DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

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C-302
SHEET 0 OF 31

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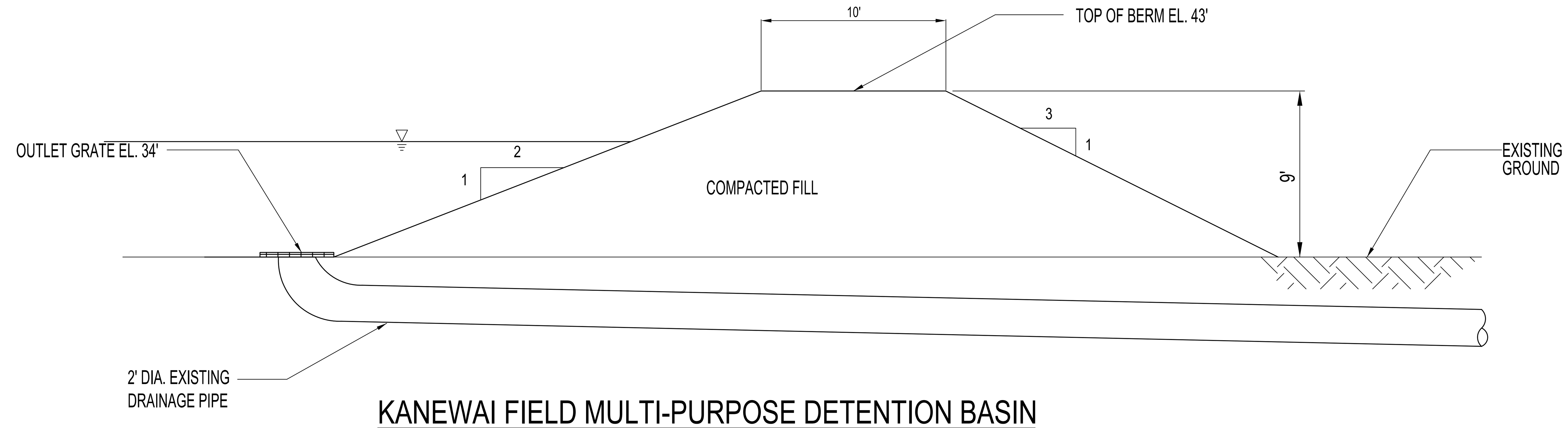
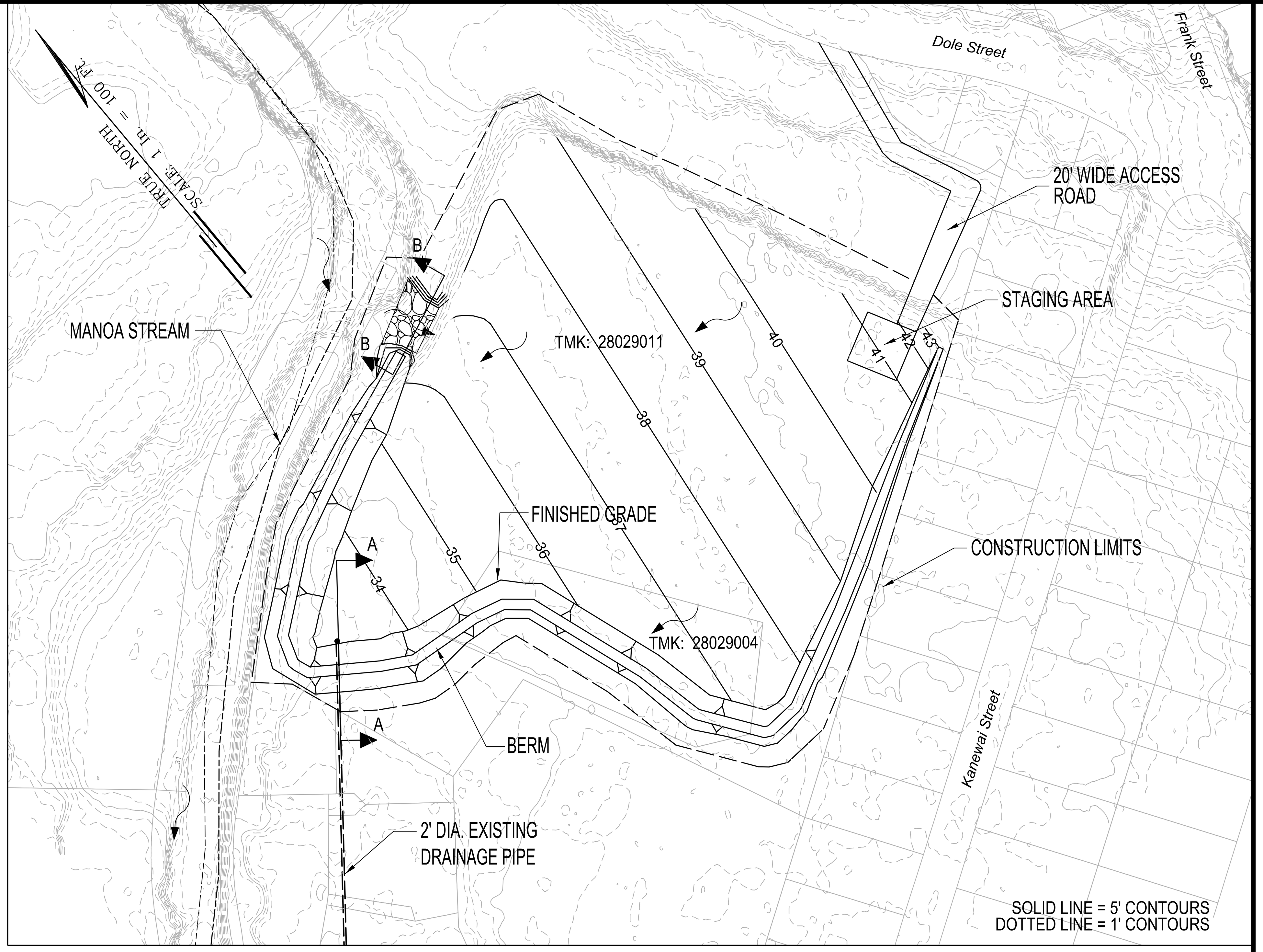
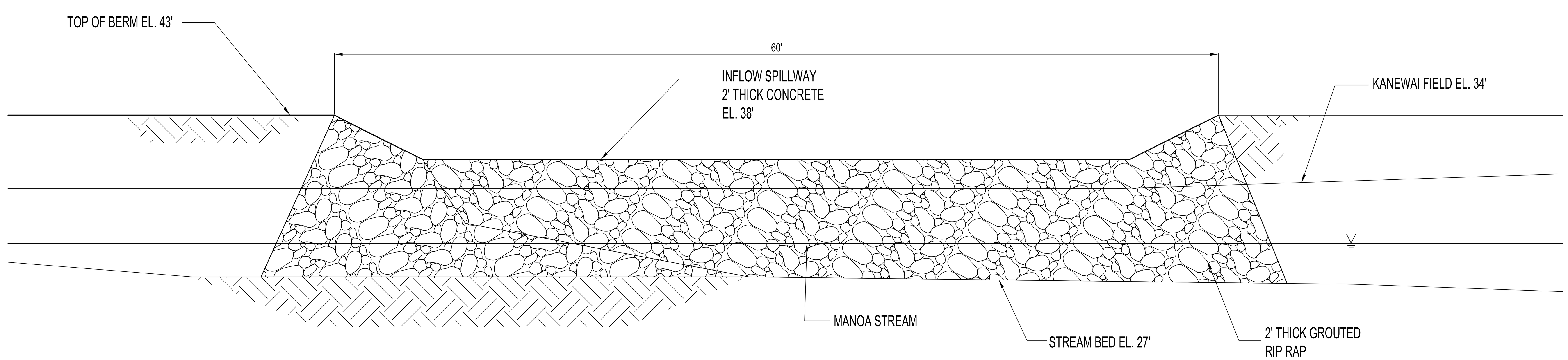


KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
SECTION A-A
SCALE: 1" = 5'



PLAN
SCALE: 1" = 100'



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

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

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ALA WAI CANAL PROJECT

KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN
PLAN AND SECTIONS

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SHEET 0 OF 31

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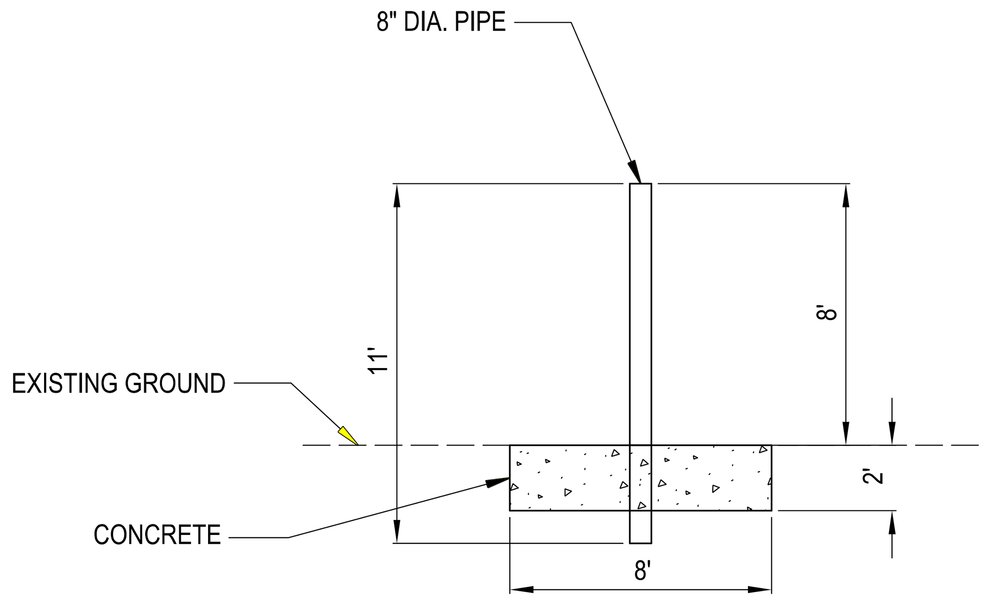
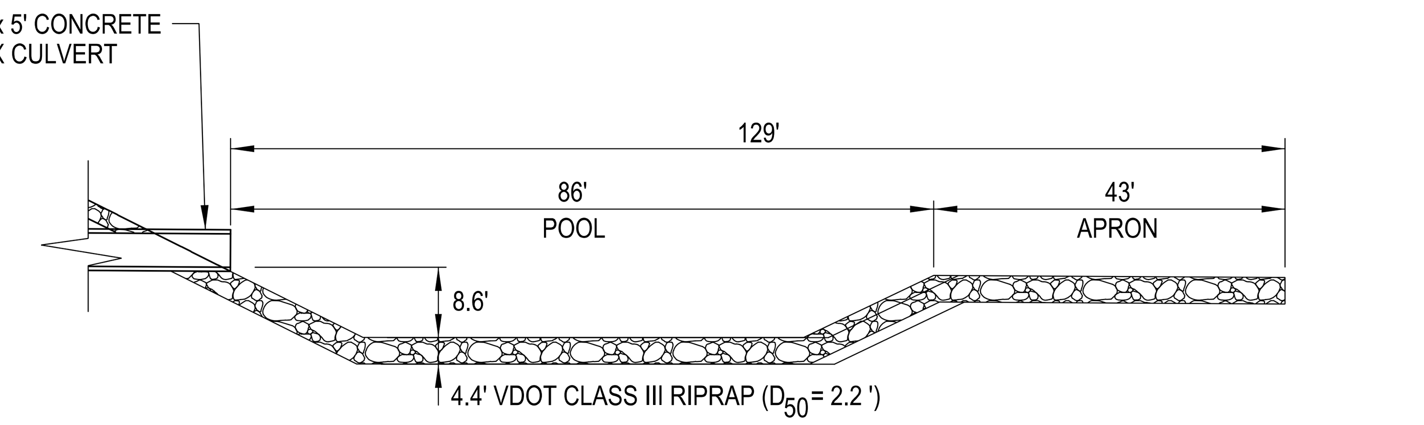


WAIOMAO DEBRIS AND DETENTION BASIN
SECTION C-C

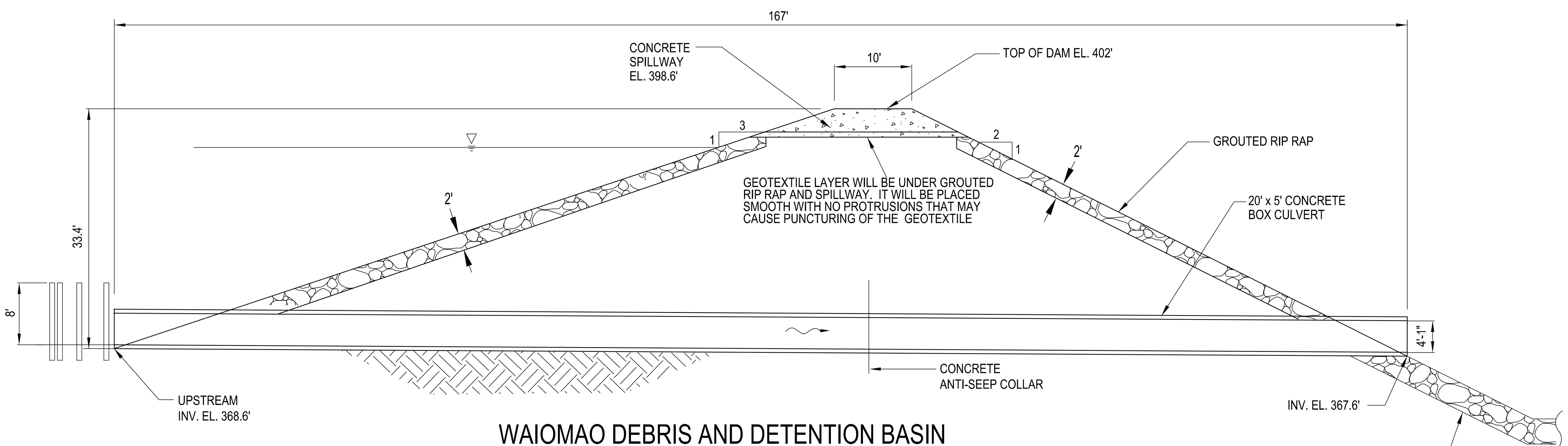
SCALE: 1"=5'



A
C-308

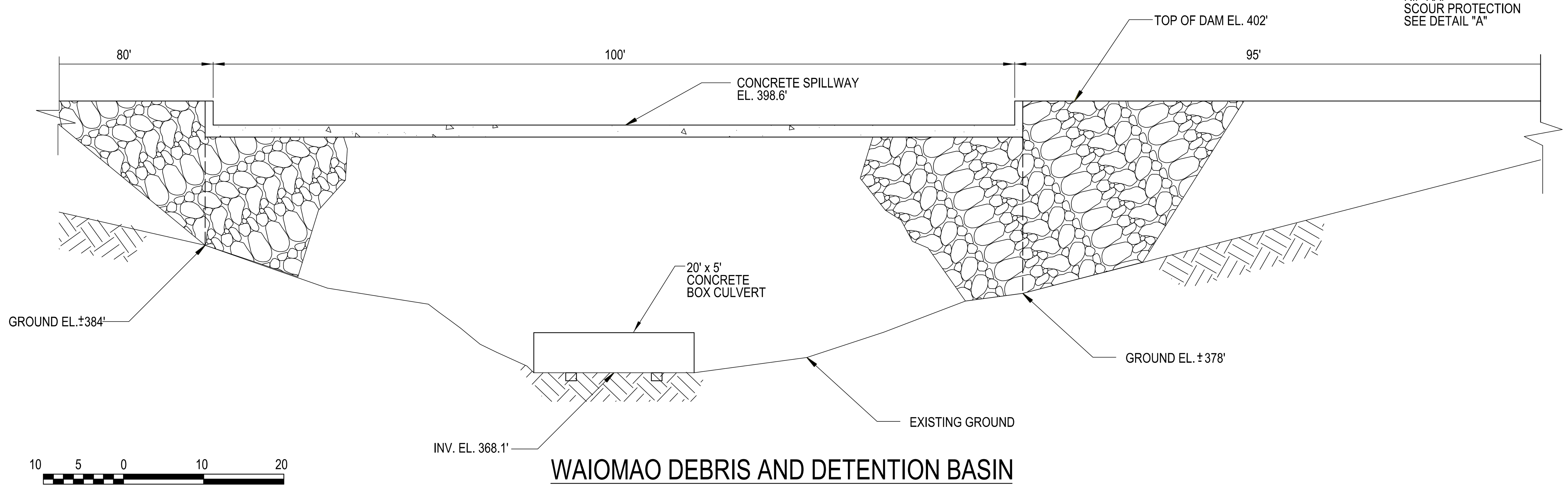
RIPRAP DISSIPATION & SCOUR PROTECTION DETAIL

SCALE: 1"=20'



WAIOMAO DEBRIS AND DETENTION BASIN
SECTION A-A

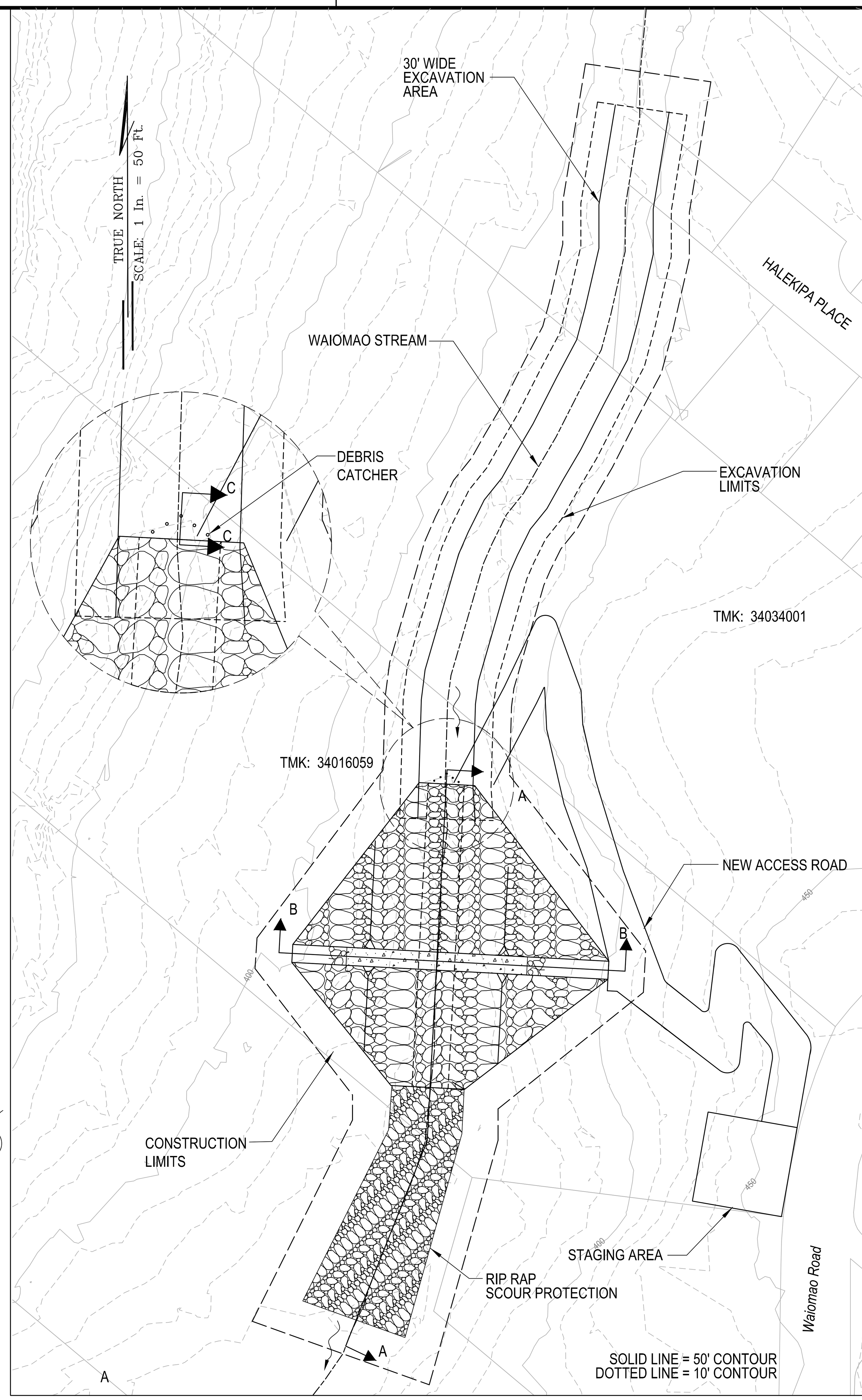
SCALE: 1"=10'



WAIOMAO DEBRIS AND DETENTION BASIN
SECTION B-B

SCALE: 1"=10'

Note: All elevations are feet MSL



PLAN

SCALE: 1"=50'

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

NOTES:

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

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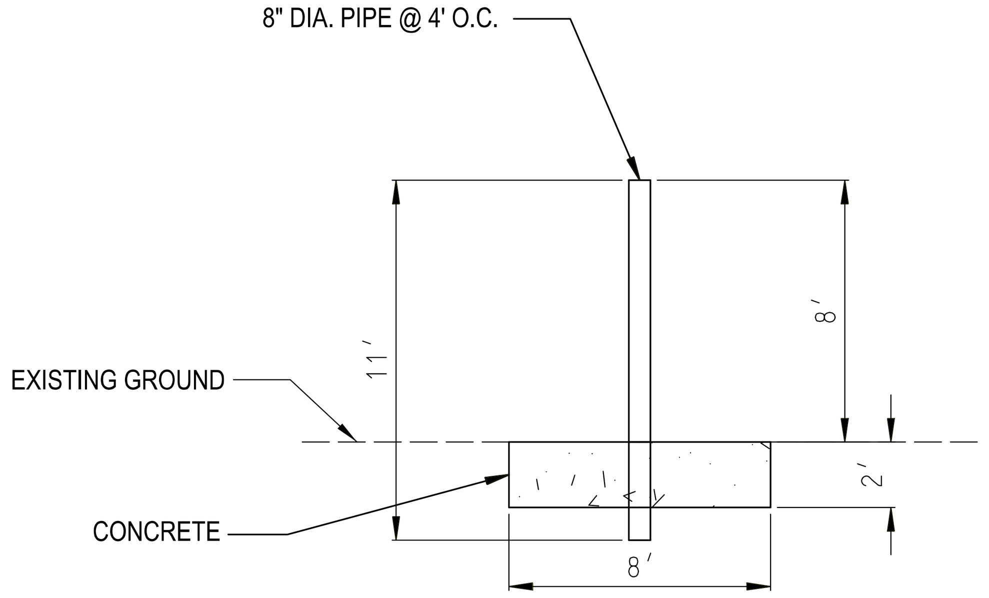
ALA WAI CANAL PROJECT

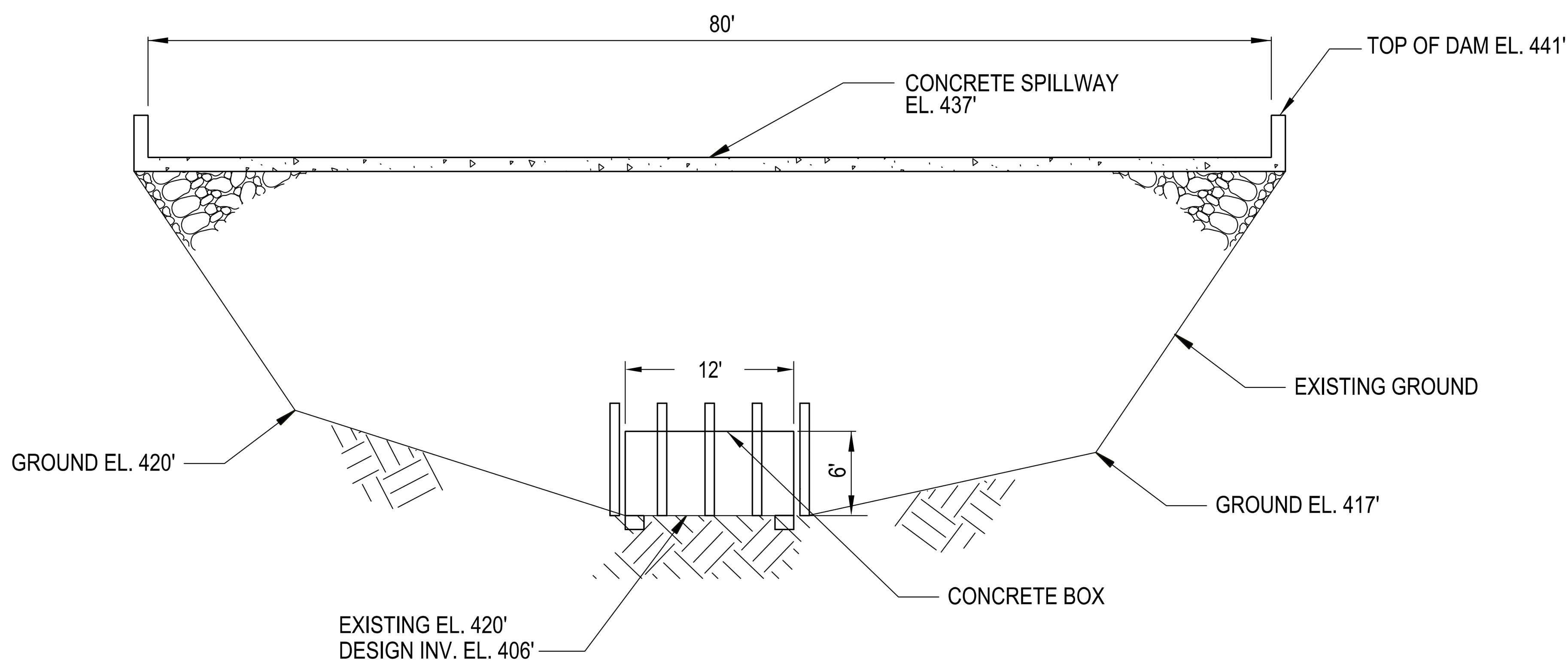
WAIOMAO DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-308
SHEET 0 OF 31



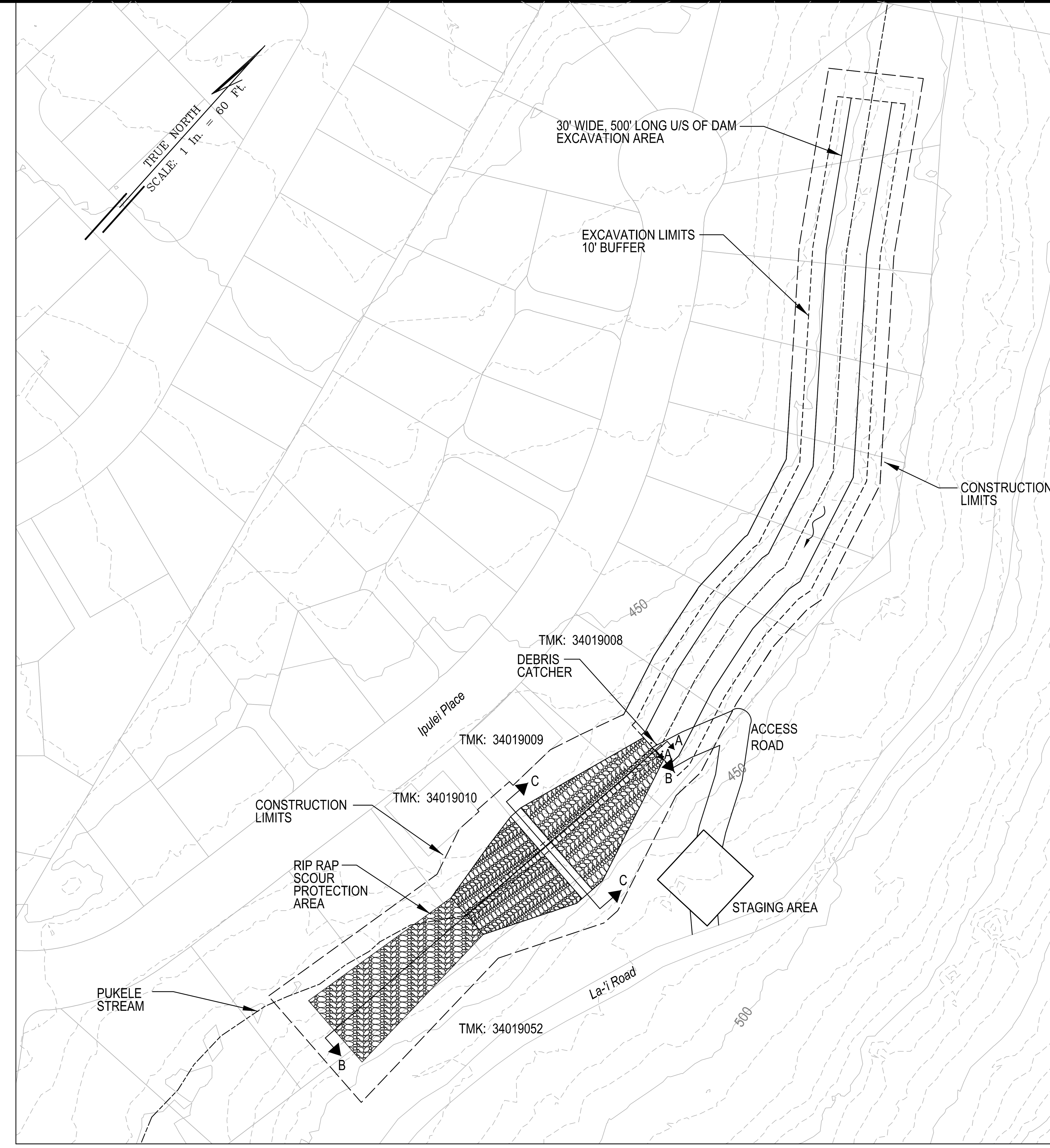
PUKELE DEBRIS AND DETENTION BASIN SECTION A-A

SCALE: 1"=5'



PUKELE DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=5'



PLAN

SCALE: 1"=60'

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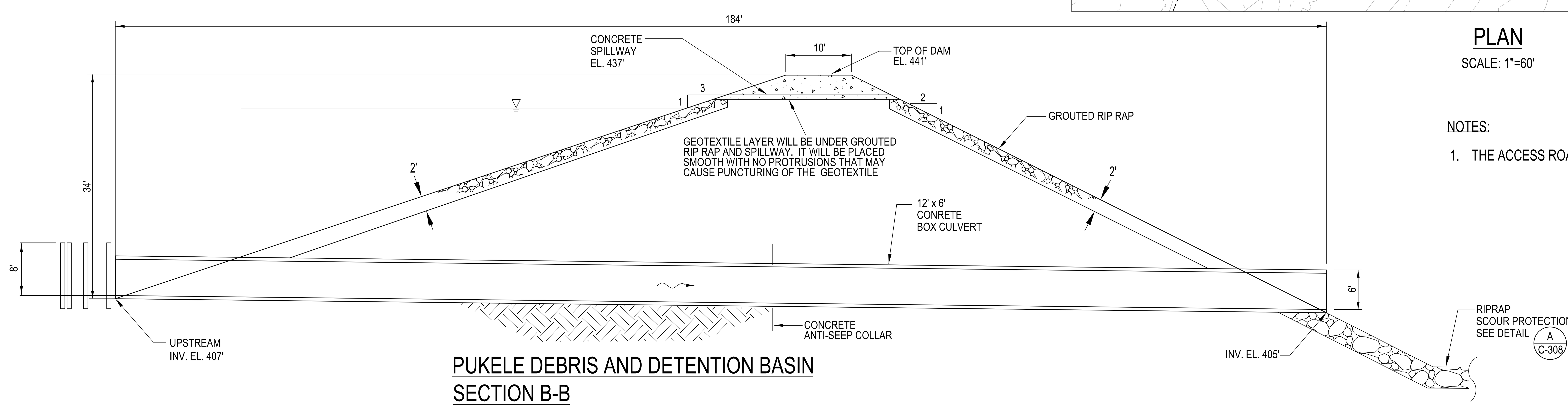
DOTTED LINE = 10' CONTOURS



PUKELE DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=5'

NOTES:

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

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

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SUBMITTED BY:		LOCATION CODE	
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ALA WAI CANAL PROJECT

PUKELE DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-313
SHEET 0 OF 31

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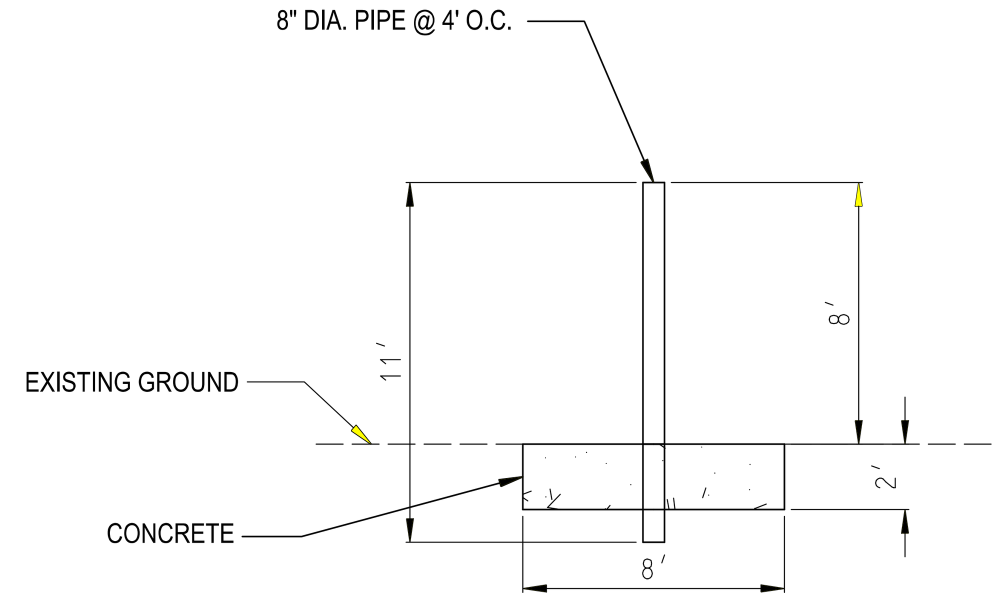
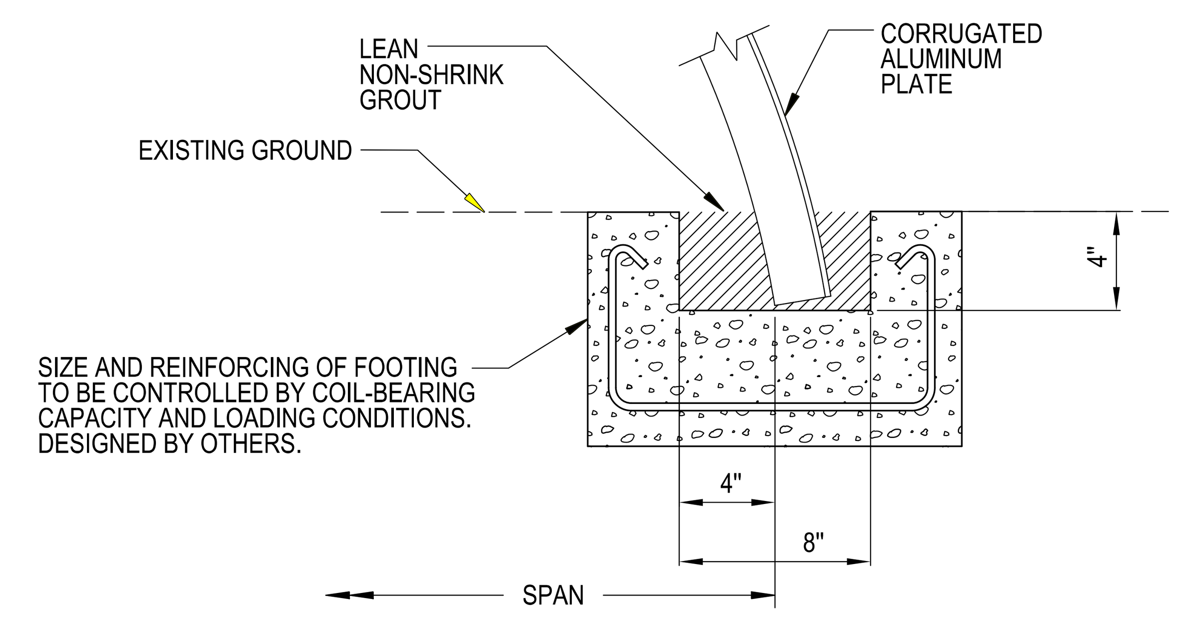


MAKIKI DEBRIS AND DETENTION BASIN SECTION A-A

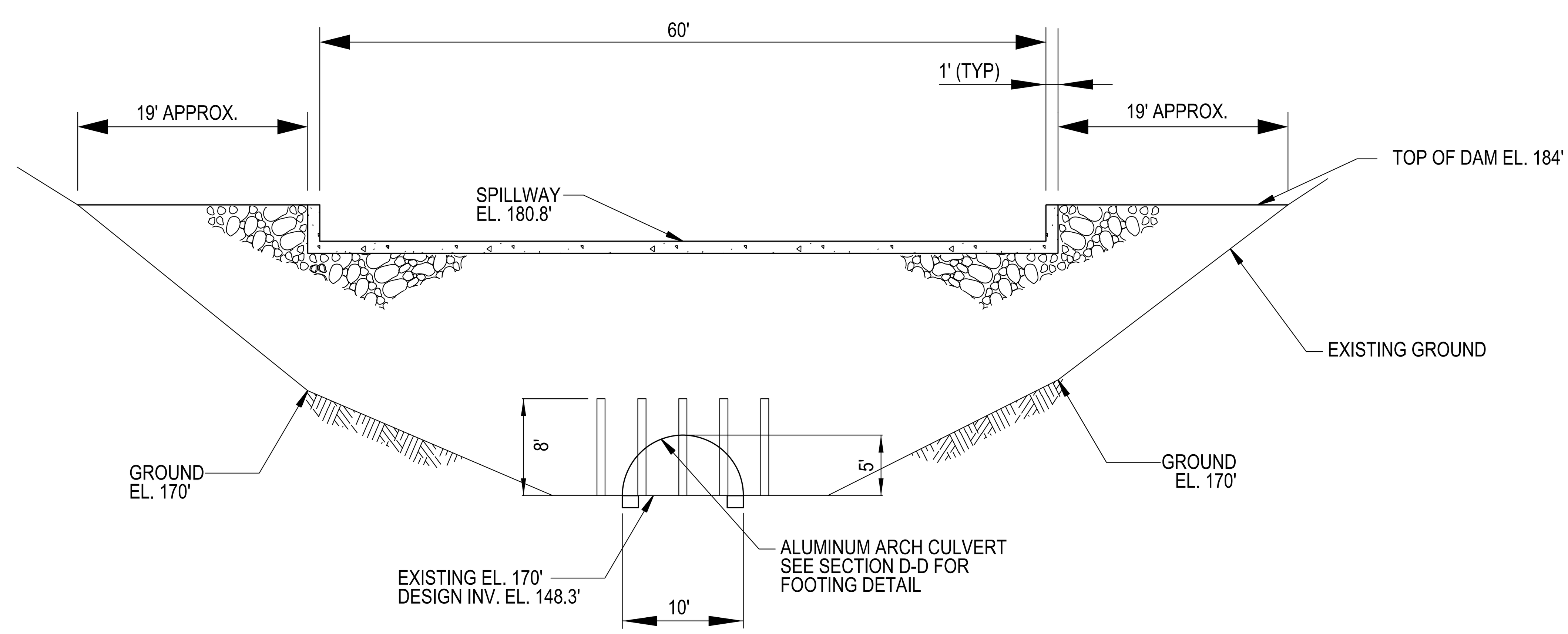
SCALE: 1"=5'



SLOTTED CONCRETE FOOTING

MAKIKI DEBRIS AND DETENTION SECTION D-D

SCALE: NTS

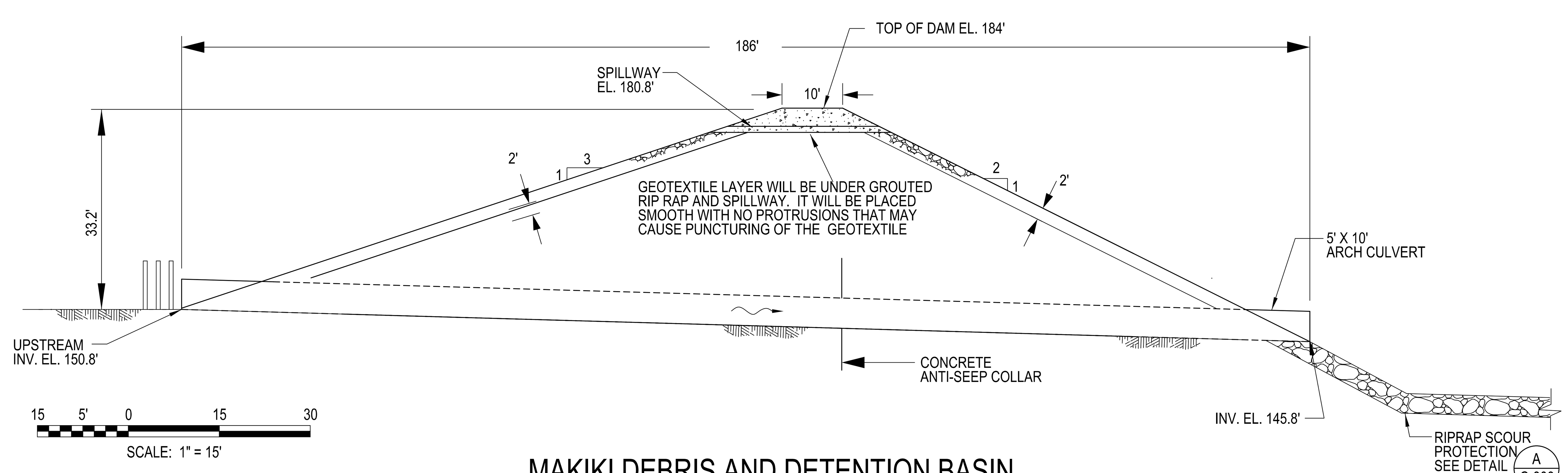


MAKIKI DEBRIS AND DETENTION BASIN SECTION B-B

SCALE: 1"=10'

NOTES:

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



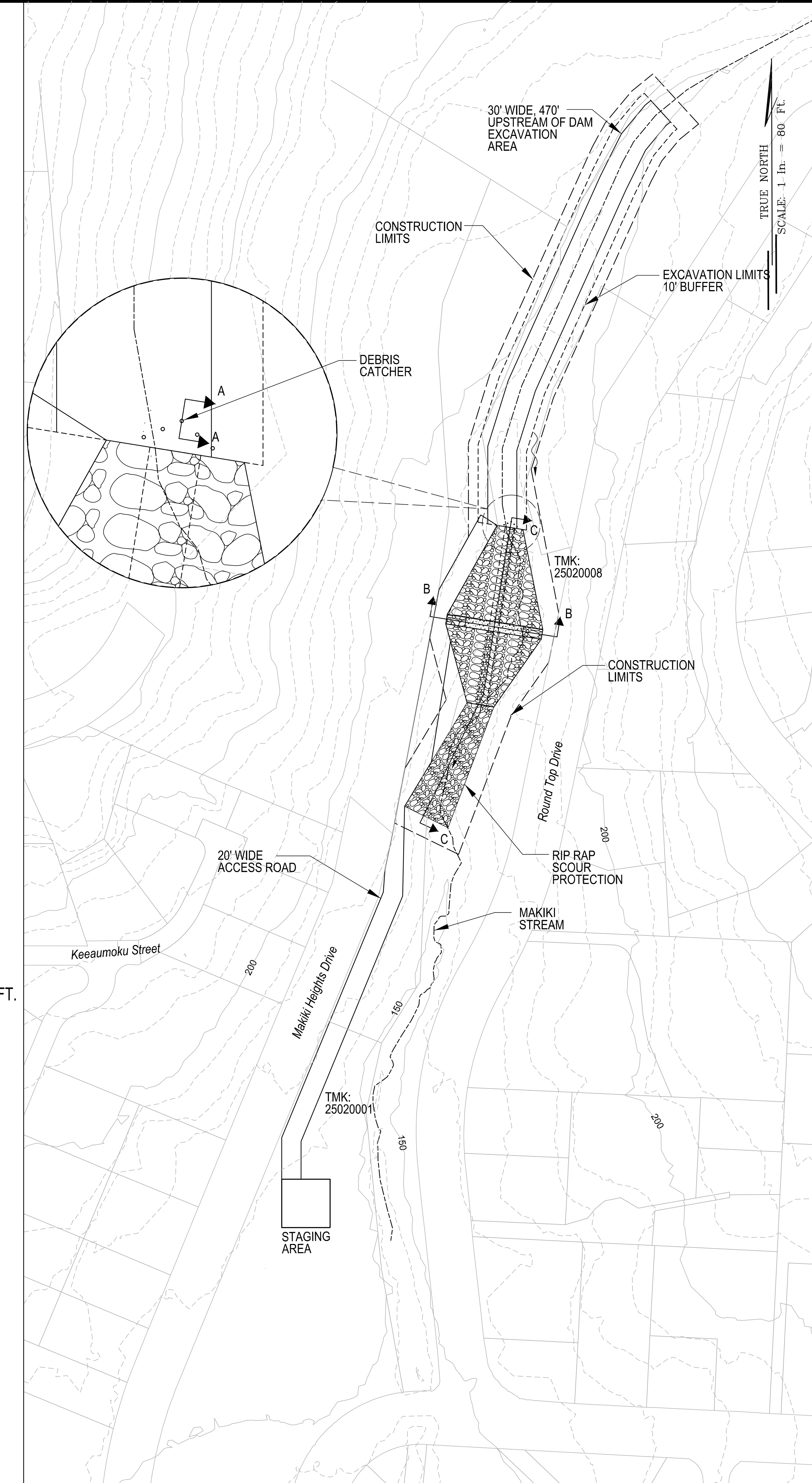
15 5' 0 15 30
SCALE: 1" = 15'

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

Note: All elevations are feet MSL

MAKIKI DEBRIS AND DETENTION BASIN SECTION C-C

SCALE: 1"=15'



PLAN

SCALE: 1"=80'

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

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ALA WAI CANAL PROJECT

MAKIKI DEBRIS AND DETENTION BASIN PLAN AND SECTIONS

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SHEET 0 OF 31

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LAST SAVED BY: j3ec9cp9 PRINTED BY: j3ec9cp9

Appendix E3
Clean Water Act Section 404(b)(1) Evaluation

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Clean Water Act, Section 404(b)(1) Evaluation
Ala Wai Canal Project
Honolulu, Hawaii

I. PROJECT DESCRIPTION

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project[1] (hereafter referred to as "the project").

The Ala Wai watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (mi^2) (12,064 acres) and extends from the ridge of the Koolau Mountains to the nearshore waters of Mamala Bay. It includes Maikiki, Manoa, and Palolo streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki district. A map of the Ala Wai watershed is provided in the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS).

A. Authority

The project is authorized under Section 209 of the Flood Control Act of 1962. Section 209 is a general authority that authorizes surveys in harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

B. Project Purpose and Need

The purpose of the project is to reduce the risk of flood hazards within the Ala Wai watershed. A high risk of flooding exists within the watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[2] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85 million in damages (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within this area, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in

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[1] The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

[2] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318 million in structural damages alone (2013 price levels).

C. Background and History

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act of 1974) to determine the potential flood risk to the Waikiki area, in response to a request by the Land Division of DLNR. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several mitigative measures and conceptual alternatives that could potentially minimize flood damages to Waikiki and surrounding area. The results of this technical study were used to establish that the USACE could be involved in the investigation of flood damage reduction in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The FCSA was executed between USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and a scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Manoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study, such that the project could be expanded to include the upstream portions of the Ala Wai watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received federal funds to identify specific actions to address flooding in Manoa Valley. The Manoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems.[3] However, because of insufficient federal funding to complete the project, the Manoa Watershed Project was terminated before implementation.

Information developed through the Manoa Watershed Project was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Manoa under the Manoa Watershed Project.

In October 2012, a charette was held to re-scope the project as part of the USACE Civil Works Planning Modernization process.[4] The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division and Headquarters staff, with the non-federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the array of alternatives, and a framework for identification of the tentatively selected plan (TSP). Based on the project review at the charette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify

[3] This work was conducted by the USACE on behalf of NRCS via a Support Agreement in compliance with a Memorandum of Agreement between USACE and USDA, pursuant to the Economy in Government Act (31 USC S. 1535.).

[4] The charrette was held on October 16-19, 2012 with the purpose of reaching consensus on the actions needed to complete the project on budget and schedule, including a clear path for identification of the TSP (USACE, 2012). Participants included the project delivery team, non-federal sponsors, USACE Division and Headquarters staff, and cooperating agency representatives.

ecosystem restoration as an objective. However, the ecosystem-related information previously identified as part of the study is being incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

D. Planning Process

General investigations, such as those carried out under Section 209 of the Flood Control Act of 1962, are funded by specific appropriations and are conducted through a feasibility planning process. The USACE feasibility planning process is comprised of six steps, as specified by USACE planning regulations and guidance, including Engineer Regulation (ER) 1105-2-100 “Planning Guidance Notebook” (USACE, 2000). These steps include: (1) specification of water and related land resources problems and opportunities; (2) inventory, forecast, and analysis of water and related land resources conditions within the study area; (3) formulation of alternative plans; (4) evaluation of the effects of the alternative plans; (5) comparison of the alternative plans; and (6) identification of a TSP based upon the comparison of the alternative plans.

Recognizing the need to modernize their planning process with an emphasis on delivering high-quality feasibility studies within shorter timeframes and at lower costs, the USACE has recently applied a SMART [Specific, Measurable, Attainable, Risk Informed, Timely] planning approach to the six-step process (USACE, 2012). The SMART planning approach emphasizes risk-based decision making and focuses on three primary requirements for feasibility studies (referred to as the “3x3x3 Rule”): completion within 3 years, at a cost of no more than $3 million, and with 3 levels of vertical team alignment (including USACE District, Major Subordinate Command (MSC), and Headquarters staff). Other key components include (1) focusing the detailed analysis and design on the tentatively selected plan, and (2) identification of the appropriate level of detail, data collection, and modeling based only on what is necessary to complete the feasibility study.

E. Project Description

Over the course of the planning process, a variety of structural and non-structural flood risk management measures were identified, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The measures are generally based on the concepts originally developed in support of the Ala Wai Flood Study (USACE, 2006) and the Manoa Watershed Project (Oceanit, 2008). The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, flood risk reduction, and life safety risks. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the Tentatively Selected Plan [TSP]); this alternative plan constitutes the proposed action. The measures included in the TSP are based on the following concepts:

- **Detention basin**: Detention basins involve construction of an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert or concrete box culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Rip-rap energy dissipation and scour protection features downstream of the culverts would protect the stream channels from erosion during high flows. Debris

catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.

   - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin via a spillway along the stream bank, then would flow back into the stream as flood conditions subside.

- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, debris catchment structures were also considered as stand-alone measures; these structures would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. They would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.
- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height (with an average height of 4 feet), and would be constructed with a minimal set back distance from the existing stream or canal walls. Local drainage patterns would be maintained to the extent possible, with flap gates and/or slide gates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). The only non-structural measure that was found to be feasible for this project is improvement of the existing flood warning system.

Consistent with USACE regulations (Engineering Regulation [ER] 1105-2-100), compensatory mitigation measures were incorporated into the TSP to compensate for unavoidable impacts to aquatic habitat. As further described in the Mitigation and Monitoring Plan for this project, the Hawaii Stream Habitat Evaluation Procedure (HSHEP) was used to quantify the potential impacts to aquatic habitat, thus establishing the basis for mitigation. Based on the known problems relating to the existing aquatic habitat quality, a suite of potential mitigation measures were developed and evaluated. This process resulted in the selection of a mitigation alternative comprised of two measures, each of which involves removal of a passage barrier to improve access to high quality upstream habitat for native aquatic species.

Each of the flood risk management measures and associated compensatory mitigation measures included in the TSP is summarized in Table 1. Locational maps and engineering drawings of each measure are included as part of the Draft Feasibility Report/EIS.

TABLE 1
Flood Risk Management Measures and Associated Compensatory Mitigation Measures in the TSP

Measure	Description of Measure
Waihi debris and detention basin	Earthen dam, approximately 37 feet high and 225 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert . New access road to be constructed for construction and O&M.
Waiakeakua debris and detention basin	Earthen dam, approximately 34 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert .
Woodlawn Ditch detention basin	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side.

TABLE 1
Flood Risk Management Measures and Associated Compensatory Mitigation Measures in the TSP

Measure	Description of Measure
Manoa in-stream debris catchment	Concrete pad, approximately 8 feet wide and 60 feet across; steel posts (up to approximately 7 feet high) evenly spaced 4 feet apart along concrete pad.
Kanewai Field multi-purpose detention basin	Earthen berm, approximately 9 feet high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.
Waiomao debris and detention basin	Earthen dam, approximately 33.5 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert. Excavation of approx. 3,060 yd3 to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.
Pukele debris and detention basin	Earthen dam, approximately 30 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert. Excavation of 14,330 yd3 to provide required detention volume upstream of berm New access road to be constructed for construction and O&M.
Makiki debris and detention basin	Earthen berm, approximately 30 feet high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side; approx. 150 feet of riprap scour protection downstream of culvert. Excavation of 3,035 yd3 to provide required detention volume upstream of berm. 20-foot-wide perimeter to be maintained as cleared around perimeter of berm
Ala Wai Canal floodwalls	Concrete floodwalls ranging up to 4 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.
Hausten Ditch detention basin	Concrete floodwalls and an earthen berm (approximately 4.3 feet high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, up to approximately 7 feet high, around the north and east perimeter of the golf course; grouted rip-rap inflow spillway along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal.
Flood warning system	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed.
Compensatory mitigation measures (Falls 7 and 8)	Removal of passage barrier at two separate in-stream structures. Each of the structures currently has an overhanging lip, such that the stream flow over these structures is free-falling and does not maintain contact with the surface of the structure, creating a barrier to upstream passage for native species. The proposed mitigation involves installation of grouted stones as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat.

Following construction, each of the measures will be operated and maintained by the non-federal sponsor. The operations and maintenance (O&M) requirements for each measure type are summarized in Table 2.

TABLE 2
Proposed Operations and Maintenance (O&M) Activities

Measure Type	Summary of O&M Activities
Debris and Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Clear accumulated debris following flood event or annually (whichever is greater)
Multi-Purpose Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year; Assumes minimal sediment or debris removal would be required
Debris Catchment	Clear accumulated debris twice per year
Floodwalls	Inspect and maintain gates (e.g., greased) annually; Inspect, test, and maintain pump system annually; Inspect floodwalls and repair as needed (e.g., patching)
Flood Warning System	Inspect and test annually (includes annual operating cost)
Mitigation Measures	Inspect for erosion annually

NOTES:
[1] Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

E. General Description of Dredged or Fill Material

1. General Characteristics of Material

The materials to be used would vary by measure; these are generally described in Table 3. The exact specifications of the materials have not yet been determined. In general, the materials would be obtained from existing sources. Stone for the rip-rap would be durable material free from cracks, seams and other defects that would tend to increase deterioration from natural causes. Rip-rap stone used for scour protection would have a mean diameter of 2.2 feet. Fill material would consist of soil and stones less than 3-inches in diameter; concrete would be a 4000 psi standard mix. Base course material would consist of clean gravel. The arch culverts would consist of corrugated aluminum, the box culverts would be 12-foot by 6-foot concrete, and the debris catchment posts would be 8-inch-diameter steel poles. Slide gates would be comprised of cast iron, and flap gates would be comprised of cast iron and steel.

2. Quantity of Material

For the purpose of this analysis, quantities were calculated based on the conservative assumption that the ordinary high water mark (OHWM) is approximately at the level of the 50-percent ACE event.[5] Based on this assumption, the quantity of material to be placed below the OHWM includes approximately 202 cubic yards of concrete, approximately 853 cubic yards of compacted fill, approximately 109 cubic yards of grouted rip-rap or stone, and approximately 70 cubic yards of base course material (gravel). Table 3 lists the type and quantity of fill material specific to each measure location. These quantities are based on the 35% level of design, and will be revisited and modified as needed during the detailed design phase.

Specific to O&M, no placement of fill material is anticipated. O&M activities would require work within the OHWM; however, these activities would generally be limited to trimming/clearing vegetation around the perimeter of the in-stream detention berms. Accumulated sediment and debris would also be removed from the debris catchment features and in-stream detention basins, as listed in Table 4.

3. Source of Material

The exact source of the material has yet to be determined. However, all fill material would be obtained from a certified pit/quarry or other approved source, and will be free of contaminants. All stone and rock would be clean and reasonably free from soil, quarry fines, and would contain no refuse.

[5] The exact location of OHWM will be verified as part of a formal jurisdictional delineation to be conducted during the detailed design phase; this analysis will be updated based on the delineation, as well as any refinements to the project design.

TABLE 3
General Description of Construction-Related Excavation and Placement of Fill Within Waters of the U.S.

Measure	Component of Measure	Excavated Material			Fill Material		
		Description	Quantity	Unit	Description	Quantity	Unit
Waihi debris and detention basin	Culvert				Concrete box, 12'x6'	160	Lin. ft
	Detention berm				Compacted fill Grouted rip-rap	140 3	yds^3 yds^3
	Scour Protection				Stone rip-rap	500	yds^3
	Debris catchment feature				Concrete footing	19	yds^3
					Steel posts (8" dia.)	7	posts
	Access road				Base course (gravel)	2	yds^3
Waiakeakua debris and detention basin	Culvert				Concrete footing	7	yds^3
	Detention berm				Compacted fill Grouted rip-rap	290 12	yds^3 yds^3
	Debris catchment feature				Concrete footing	19	yds^3
					Steel posts (8" dia.)	7	posts
	Scour Protection				Stone rip-rap	500	yds^3
Woodlawn Ditch detention basin	Culvert				Concrete footing	6	yds^3
	Detention berm				Compacted fill Grouted rip-rap	3 1	yds^3 yds^3
Manoa in-stream debris catchment	Debris catchment feature				Concrete footing	36	yds^3
					Steel posts (8" dia.)	14	posts
Kanewai Field multi-purpose detention basin	Spillway				Grouted rip-rap	41	yds^3
Waiomao debris and detention basin	Culvert				Concrete box, 12'x6'	170	Lin. ft
	Detention berm				Compacted fill Grouted rip-rap	140 3	yds^3 yds^3
	Scour Protection				Stone rip-rap	500	yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8" dia.)	5	posts
	Access road				Base course (gravel)	60	yds^3
	Detention Basin	Excavation	3,060	yds^3	none	-	-

Measure	Component of Measure	Excavated Material			Fill Material		
		Description	Quantity	Unit	Description	Quantity	Unit
Pukele debris and detention basin	Culvert				Concrete box, 12'x6'	160	Lin. ft
	Detention berm				Compacted fill Grouted rip-rap	140 6	yds^3 yds^3
	Scour Protection				Stone rip-rap	500	yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8" dia.)	5	posts
	Access road				Base course (gravel)	4	yds^3
	Detention Basin	Excavation	14,330	yds^3	none	-	-
Makiki debris and detention basin	Culvert				Concrete footing	9	yds^3
	Detention berm				Compacted fill Grouted rip-rap	140 6	yds^3- yds^3
	Scour Protection				Stone rip-rap	500	yds^3
	Debris catchment feature				Concrete footing	15	yds^3
					Steel posts (8" dia.)	5	posts
	Access road				Base course (gravel)	4	yds^3
	Detention Basin	Excavation	3,035	yds^3	none	-	-
Ala Wai Canal floodwalls	Floodwalls				None	-	-
	Access stairs				None	-	-
	Slide/flap gates				Metal slide/flap gates	47	gates
Hausten Ditch detention basin	Concrete wall				Concrete	26	yds^3
	Slide gates				Metal slide gates	4	gates
Ala Wai Golf Course multi-purpose detention basin	Spillway				Grouted rip-rap	30	yds^3
Flood warning system	Sensors				Prefabricated hoses	1	hoses
Mitigation– Falls 7	Species passage				Grouted stone	4	yds^3
Mitigation– Falls 8	Species passage				Grouted stone	3	yds^3
TOTAL		**Excavation**	**20,425**	**yds^3**	**Concrete**	**202**	**yds^3**
					Compacted fill	**853**	**yds^3**
					Grouted rip-rap / stone	**109**	**yds^3**

Measure	Component of Measure	Excavated Material			Fill Material		
		Description	Quantity	Unit	Description	Quantity	Unit
					Base course (gravel)	**70**	**yds^3**
					Stone rip-rap	**2,500**	**yds^3**

NOTES:

1. The quantities reflect excavation and placement of fill material as part of construction (assumes no discharge associated with general clearing and grubbing). Quantities were calculated based on the conservative assumption that the ordinary high water mark (OHWM) is approximately at the level of the 50-percent ACE event. The exact location of OHWM will be verified as part of a formal jurisdictional determination to be conducted during the next phase of the project; this analysis will be updated based on the delineation, as well as any refinements to the project design.

TABLE 4
General Description of Excavation and Placement of Fill Within Waters of the U.S. for Operations and Maintenance

Measure	Description	Excavated Material		Fill Material	
		Quantity[1]	Unit	Quantity	Unit
Waihi debris and detention basin	Sediment/debris removal	300	yds^3	-	-
Waiakeakua debris and detention basin	Sediment/debris removal	400	yds^3	-	-
Woodlawn Ditch detention basin	None	-	-	-	-
Manoa in-stream debris catchment	Sediment/debris removal	25	yds^3	-	-
Kanewai Field multi-purpose detention basin	None	-	-	-	-
Waiomao debris and detention basin	Sediment removal	300	yds^3	-	-
Pukele debris and detention basin	Sediment removal	100	yds^3	-	-
Makiki debris and detention basin	Sediment removal	250	yds^3	-	-
Ala Wai Canal floodwalls	None	-	-	-	-
Hausten Ditch detention	None	-	-	-	-
Ala Wai Golf Course multi-purpose detention basin	Sediment removal	200	yds^3	-	-
Flood warning system	None	-	-	-	-
Mitigation measures (Falls 7 and 8)	None	-	-	-	-

NOTES:
[1] Quantities are an estimate of the amount of sediment and debris to be removed annually; assumes no discharge of dredged or fill material associated with other O&M activities (e.g., trimming/clearing vegetation around the perimeter of the in-stream detention berms and clearing debris within the debris catchment features and in-stream detention basins).

F. Description of Proposed Discharge Sites

1. Location

The proposed measures would be located within and along the various waterways within the Ala Wai watershed; these include Makiki, Manoa and Palolo Streams and the Ala Wai Canal. Each measure is briefly described in Table 1; maps showing their location are contained in the Draft Feasibility Report/EIS.

2. Size

The amount of area within which fill material would be discharged varies by measure. The length of channel that would be within the footprint of each permanent structure (i.e. the areas that would be subject to placement of fill), as well as the length of channel within the overall construction limits for each measure is summarized in Table 5.

3. Type of Habitat

Streams in the Ala Wai watershed arise on the southern slopes of the Koʻolau range. Manoa and Palolo valleys contain the two major streams draining to the Ala Wai Canal, with Manoa Stream consisting of a complex radial set of six tributaries in its upper reaches. Makiki Stream also flows to the Ala Wai Canal, but drains a much smaller area, with at least one of its four tributaries (Kanaha Stream) flowing only intermittently (Englund and Arakaki, 2004). A formal jurisdictional determination of Waters of the U.S. has not yet been completed for the project area; however, all of the streams and Canals in the watershed are assumed to be Waters of the U.S. (AECOS, 2014).[6] Jurisdictional wetlands are not expected to be present outside the defined channel limits. This information will be verified during the next phase of the project

[6] The Ala Wai Canal is a navigable Waters of the U.S., and therefore also subject to Section 10 of the Rivers and Harbors Act.

through a formal jurisdictional determination in accordance with the new Clean Water Rule: Definition of "Waters of the United States" (33 CFR Part 328).

Each stream generally consists of an upper, middle, and lower reach that flow to an estuarine reach and then to the Ala Wai Canal, before discharging to the ocean. In this context, upper reaches are the tributary streams with youthful profiles (steep, relatively straight courses in down-cutting channels). Middle reaches have more mature profiles, slightly meandering and eroding mostly laterally. Lower reaches flow across the coastal plain and are typified by sediment accumulation. The estuarine reaches are those in which sea water and freshwater mix, typically along a gradient of increasing salinity seaward.

Riparian vegetation is present along all of the upper stream reaches, and is generally dominated by non-native species (many of which are considered invasive), including large trees such as Chinese banyan, *kukui* (*Aleurites moluccana*), mango, octopus tree, *hau* (*Hibiscus tiliaceus*), fiddlewood (*Citharexylum spinosum*), mountain apple (*Syzygium malaccense*), gunpowder tree (*Trema orientalis*), and gum (*Eucalyptus* sp.), as well as smaller herbaceous species such as exotic ginger (*Hedychium* sp.) and Job's tears (*Coix lachryma-jobi*) (Kido, 2006; Kido, 2007; Kido, 2008; Oceanit, 2004).

Within the urbanized portion of the watershed, riparian vegetation is generally limited to unchannelized stream reaches, such as along portions of Manoa Stream (for example, near the Dole Street Bridge). A majority of Palolo and Makiki streams are channelized and lack a riparian zone (Oceanit, 2004; Englund and Arakaki, 2004; Kido, 2008). Mangrove trees (*Rhizophora mangle*) are present in some areas in the lower estuarine reaches of the Manoa–Palolo Drainage Canal and the Ala Wai Canal, although concrete and concrete masonry (CRM) walls constructed as banks have eliminated much of the riparian vegetation.

A description of the habitat at each measure location is provided in Table 5.

4. Timing and Duration of Discharge

Subject to approvals and appropriation of funds, construction would begin in the year 2021. In total, construction is expected to last approximately 3 years; it is expected that construction of individual measures will require on the order of 6 to 12 months each.

G. Description of Disposal Method

In general, all material would be moved and placed mechanically.[7] Cranes, backhoes, scrapers, dump trucks and other appropriate heavy machinery would be used to deliver and place fill materials during construction. Materials would be placed in a manner that minimizes disturbance of the aquatic environment. Rip-rap would generally be placed in a systematic manner to ensure a continuous uniform layer of well-graded stone. Concrete for footings would be placed using pumps into wooden formwork. Concrete for rip-rap may be placed using pumps or by hand.

[7] Due to access limitations, it is anticipated that the mitigation measures would be constructed by hand.

TABLE 5
Description of Proposed Discharge Sites

Measure[1]	Location	Description of Habitat	Length of Stream Within Construction Limits (linear feet)	Length of Stream Subject to Placement of Fill (linear feet)	Length of Stream Within O&M Area (linear feet)
Waihi debris and detention basin	Waihi Stream, ~1,200 feet above the upper extent of development in Manoa Valley (~380' in elevation).	Site is characterized by forested habitat, with dominant species including monkeypod (*Albizia saman*), Chinese banyan, gunpowder, *kukui*, swamp mahogany (*Eucalyptus robusta*), mango, Java plum, and Christmas berry; pothos vine (*Epipremnum pinnatum*) is prominent climbing the trees. Site is located on the lower edge of a prominent belt of albizia trees.	160	130	40
Waiakeakua debris and detention basin	Waiakeakua Stream, ~200 feet above the upper extent of development in Manoa Valley (~300' in elevation).	Site (including the staging area) is characterized by forested habitat, with species including guarumo (*Cecropia obtusifolia*), macaranga (*Macaranga tanarius*), hau (*Hibiscus tiliaceus*), bamboo, and the shrub *Odontonema strictum*. Other species include red ginger (*Alpinia purpurata*), shoebutton ardesia (*Ardisia elliptica*), and white shrimp plant (*Justicia betonica*); pothos vine is prominent climbing the trees; site is located on the lower edge of a prominent belt of albizia trees.	190	110	40
Woodlawn Ditch detention basin	Woodlawn Ditch (manmade tributary to Manoa Stream), adjacent to E. Manoa Road (~200' in elevation)	Site is characterized by mixed secondary forest and tended farm/garden areas; forest is nearly monotypic stand of macaranga (*Macaranga tanarius*), with a limited number of tropical almond (*Terminalia catappa*), shoebutton ardisia, Chinese hibiscus (*Hibiscus rosa-sinensis*), coconut (*Cocos nucifera*), African tulip (*Spathodea campanulata*), and small albizia.	120	60	40
Manoa in-stream debris catchment	Middle reach of Manoa Stream, directly adjacent to lower edge of Manoa District Park (~160' in elevation)	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties); the staging areas within Manoa District Park is dominated by lawn, with some planted trees including Formosan *koa* (*Acacia confusa*), *kukui*, coconut, and royal palms (*Roystonia regia*).	48	8	40
Kanewai Field multi-purpose detention basin	Lower reach of Manoa Stream, just below Dole Street	Site is comprised of maintained field for park; predominantly a mowed lawn with two large mango trees near the west corner site; adjacent stream includes a riparian corridor with various mature trees of Java plum, *hau*, mango, macaranga, and monkeypod.	70	70	0
Waiomao debris and detention basin	Pukele Stream, adjacent to residences on Waiomao Rd. (~380' in elevation)	Site is comprised of a heavily forested riparian zone adjacent to residential properties; dominated by non-native species including octopus tree, gunpowder, monkeypod, macaranga (Macaranga tanarius), mango, and fiddlewood; pothos vine is prominent climbing the trees.	455	130	40

TABLE 5
Description of Proposed Discharge Sites

Measure[1]	Location	Description of Habitat	Length of Stream Within Construction Limits (linear feet)	Length of Stream Subject to Placement of Fill (linear feet)	Length of Stream Within O&M Area (linear feet)
Pukele debris and detention basin	Pukele Stream, adjacent to residences on Ipulei Place (~400' in elevation)	Site includes the maintained lawns of two residential homes; right bank of the stream is dominated by weedy species including Guinea grass (*Panicum maximum*) and castor bean (*Ricinus communis*); left bank is forested with non-native species including Chinese banyan, swamp mahogany, and Java plum	170	130	40
Makiki debris and detention basin	Makiki Stream, directly adjacent to Makiki Heights Drive (~160' in elevation).	Site is characterized by dense riparian forest; dominant species include Chinese banyan, African tulip (*Spathodea campanulata*), gunpowder tree, she oak (*Grevillea robusta*), and mango. The understory is as well dominated by a variety of nonnative shrubs and vines, notably pothos (*Epipremnum pinnatum*), shrimp plant (Justicia betonica), and Madeira vine (*Anredera cordifolia*). Staging area includes open *kukui* copse, with open floor.	175	130	40
Ala Wai Canal floodwalls	Perimeter of Ala Wai Canal	Vegetation along the Canal is generally limited to landscaping, with a single row of trees lining most of both sides of Canal, including *niu* (*Cocos nucifera*), with some milo (*Thespesia populnea*) and monkeypod.	0	0	0
Hausten Ditch detention basin	Hausten Ditch (drainage input to Ala Wai Canal)	Hausten Ditch is dominated by non-native species, including mangroves; native species that occur along ditch (including *'akulikuli* [*Sesuvium portulacastrum*]; *kou* [*Cordia subcordata*], and *kīpūkai* [*Heliotropium Curassavicum*]) are common species. The remainder of the site is a maintained lawn, with scattered *niu*, milo and monkeypod trees.	70	35	35
Ala Wai Golf Course multi-purpose detention basin	Ala Wai Canal	Landscaped vegetation for golf course greens and fairways; site also includes two shallow basins and a ditch that are identified as seasonally flooded wetland features on the National Wetlands Inventory (USFWS, 2006a)	70	70	0
Flood warning system	Specific locations to be determined	Assumed to be located in upper reaches of the watershed	0	0	0
Mitigation - Falls 7	Manoa Stream, approximately 400 feet downstream of Pawaina St. Bridge	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties)	50	5	0
Mitigation - Falls 8	Manoa Stream, immediately downstream of Pawaina St. Bridge	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties)	60	5	0

II. FACTUAL DETERMINATIONS

A. Physical Substrate Determinations

1. Substrate Elevation and Slope

In general, the proposed measures are designed to conform to the existing elevation and slope of the stream channel, as further described below.

- **In-stream detention basins:** Overall, the elevation and slope of the existing channel bottom would be maintained throughout the various in-stream detention basins. Specifically, the designs incorporate a natural-bottom arch culvert that would maintain the natural channel for the length of the detention berm. Energy dissipation structures and other features have been incorporated as needed to maintain channel stability.

  Although the detention berms would not substantially affect the channel form, these features would function to temporarily detain stream flows that exceed the approximately 20-percent ACE level. Three of the basins (Waiomao, Pukele, and Makiki debris and detention basins) would require excavation in the area behind the detention berm (including the stream) to provide adequate storage capacity. This work would result in localized changes in the elevation and slope of the area adjacent the stream, but the general channel form would be maintained and the excavation would be designed to blend with the existing topography to the extent possible. Inundation associated with each of the in-stream detention basins is expected to be infrequent and of short duration (e.g., less than 12 hours for the 1% ACE event), such that significant loss of environmental characteristics and values is not anticipated.

- **Multi-purpose detention basins:** These measures would primarily be located in upland areas adjacent to a stream channel, and would not involve modification of the stream bottom. To create an inflow spillway for each basin, a minimal amount of grading may be required along approximately 70 feet of the stream bank, prior to placement of rip-rap. No significant changes in the elevation or slope is expected.

- **Debris catchment features:** The debris catchment features involve installation of a small concrete pad with inset steel poles across the stream bottom. The concrete pad would be installed at existing grade, such that no changes in elevation or slope of the stream channel are anticipated. The steel poles would function to capture debris, which will be removed as part of routine O&M activities.

- **Flood warning systems:** This measure would not affect the elevation or slope of channel.

- **Mitigation measures:** The mitigation measures involve the installation of grouted stone to eliminate an overhanging lip associated with erosion at two existing in-stream structures. The measures would not affect the elevation of the stream bed.

Based on the minimal degree of change in channel substrate elevation and slope, there are not expected to be significant changes in water circulation, depth or temperature during periods of normal flow.

2. Sediment Type

The existing substrate in stream channel within the Ala Wai watershed includes a gradation of materials, with a mixed size of rock and varying levels of sediment. The substrate in the upper reaches of the watershed is typically comprised of large boulders and cobbles, and the middle reaches incorporate a mixed substrate, with a larger percentage of medium-sized substrate. The lower reaches of the watershed, including the Ala Wai Canal and Hausten Ditch include a large component of sediment and other fine particulates.

Construction of the flood management measures would modify the existing substrate within portions of the measure footprint, as described below.

- **In-stream detention basins:** These measures would involve placement of compacted fill and grouted rip-rap for construction of the detention berm. To minimize the loss of natural substrate, an arch culvert would be incorporated into the detention berm to allow for maintenance of a natural-bottom channel at Waiakeakua, Woodlawn, and Makiki, while concrete box culverts would be used at Waihi, Waiomao, and Pukele. Approximately 150 feet of stream channel downstream of the Waihi, Waiakeakua, Waiomao, Pukele, and Makiki basins would be lined with rip-rap (mean stone diameter of 2.2 feet) to dissipate energy and prevent scour during high flows. The substrate within the channel would likely be affected during construction, with an increased amount of sediment and fine particulates. Following construction, the natural substrate is expected to return to pre-construction conditions, except within the box culverts and rip-rapped scour protection. However, some amount of sediment and debris is expected to accumulate in the area behind the detention berm, and would be routinely removed as part of O&M.
- **Multi-purpose detention basins:** The multi-purpose detention basins would involve placement of rip-rap along a short section of channel bank, which would function as the inflow spillway for the detention basin. The rip-rap would replace the existing earthen stream bank.
- **Debris catchment features:** The debris catchment features would involve installation of a concrete pad, which would displace the existing substrate. However, these features would be at existing grade, and given their relatively small size, are not expected to result in a substantial loss of environmental characteristics and values.
- **Flood warning system:** The flood warning system would not displace or otherwise affect the natural substrate.
- **Mitigation measures:** The mitigation measures would involve placement of grouted stone to address erosion and undercutting associated with existing in-stream structures. The grouted stone would be sized and installed in a manner that mimics the natural channel substrate.

3. Dredged/Fill Material Movement

Fill material would be placed directly into the stream channels, which would be diverted/dewatered to accommodate construction activities. In addition, best management practices (BMPs) would also be implemented to reduce the potential for erosion and sedimentation during construction. The proposed fill material would be sufficiently sized and/or protected (e.g., with rip-rap, vegetative covering or other stabilization measures) so as to preclude downstream movement of the fill materials following construction. The stabilization methods that would be applied to specific areas will be determined during final design. With proper diversion/dewatering and implementation of BMPs, the proposed discharge is expected to be stable, such that the substrate surrounding the discharge site is not expected to be affected by erosion, slumping or lateral displacement of materials.

4. Physical Effects on Benthos

Placement of fill material would smother and/or displace benthic organisms located within the footprint of the flood risk management structures. Excavation activities (i.e. for Waiomao, Pukele, and Makiki debris and detention basins) could also result in mortality of benthic organisms within these areas. However, it is expected that the newly placed substrate would be rapidly colonized, with little to no long-term effects on benthic communities.

5. Actions Taken to Minimize Impacts

Efforts to minimize stream-related impacts on the physical substrate include the use of approved construction procedures, in compliance with Federal and State requirements, as well as implementation of BMPs. These include:

- Work within the stream channels would be limited to periods of low flow, with proper diversion/ dewatering techniques, as appropriate.
- Construction activities would be sequenced to limit the extent of exposed soil at any given time.
- Erosion prevention and sedimentation control measures would be implemented and maintained for the duration of construction.
- Dirt stockpile areas containing more than 100 cubic yards of material would be covered or kept wet.
- All fill materials would be acquired from approved sources and will be free of contaminants.
- Appropriate vehicles and equipment would be utilized for all stages of construction, and construction crews would be adequately trained to avoid and minimize impacts to the aquatic environment.

B. Water Circulation, Fluctuation, and Salinity Determinations

1. Water Chemistry

The use of clean fill material would preclude any significant impacts on water chemistry as a result of the proposed fill activities. Minor, short-term decreases in water clarity would likely occur during construction, but are not expected to occur long-term. No significant impacts on water color, odor, taste, dissolved oxygen levels, temperature or nutrient levels are anticipated.

2. Current Patterns and Circulation

None of the measures involve placement of fill materials that would substantially modify the existing flow patterns under normal flow conditions. Some aspects of the proposed measures could affect water circulation and/or temporarily alter flow patterns during high flow events, as further described below.

- **In-stream detention basins:** The in-stream detention basins include a natural-bottom arch culvert, which is sized to maintain passage of stream flows up to the 20-percent ACE level. During periods when flows exceed this level, water would be temporarily detained in the detention basins. This would result in areas with reduced flow velocity and circulation behind the detention berm (which could increase deposition of suspended particulates), and a concentration of flows with increased velocity within the culvert (which could result in increased erosion). However energy dissipation and scour protection consisting of rip-rap and stilling pools would be incorporated to regulate flow velocities and reduce the potential for erosion. In addition, these flow conditions are only expected to occur on an infrequent basis and for a short duration (less than 12 hours for the 1-percent ACE event), such that significant impacts are not anticipated.

- **Multi-purpose detention basins:** As previously described, the multi-purpose detention basins would be located in an upland area adjacent to a stream, and would include an inflow spillway on the stream bank, as needed to divert stream flows during flood conditions. The spillway would not affect flow patterns or circulation during normal stream flows. During flood flows, the detention basin would temporarily fill with stream flows, which would then be returned to the stream. As these features are located off-channel, and would serve to reduce peak flow volumes on an infrequent basis, they are not expected to affect flow patterns or circulations in a manner that would substantially affect stream characteristics or values.
- **Debris catchment features:** The debris catchment features would function to capture debris that would otherwise flow downstream and increase the potential for stream blockages. If excessive amounts of debris accumulate in the debris catchment features, stream flow circulation could be affected. However, the debris that is caught by these features would be removed as part of routine O&M, such that substantial changes in flow and circulation are not anticipated.
- **Flood warning system:** The flood warning system would not affect flow patterns or water circulation.
- **Mitigation measures:** The mitigation measures are intended to eliminate an overhanging lip associated with undercutting and erosion of in-stream structures. Grouted stone would be installed in a manner that restores water contact with the surface of the structure. This work is not expected to result in a substantial change to flow or circulation.

3. Normal Water Level Fluctuations

In general, the proposed measures are designed to maintain the normal flow regime, such that typical water level fluctuations would not be affected. However, during flood flows, both the in-stream and multi-purpose detention basins are intended to detain water, resulting in areas of inundation behind (or within) the detention berms. However, these conditions would only occur on an infrequent basis and for a short duration (e.g., less than 12 hours for a 1-percent ACE event), such that no substantial changes are anticipated relative to the stream characteristics and values.

4. Salinity Gradients

The vast majority of the proposed measures would be located in areas that are not tidally influenced. The only measures that would be located in areas subject to salinity gradients are the Hausten Ditch Detention Basin and the Ala Wai Golf Course Detention Basin. However, implementation of these measures would not divert or restrict flows in a manner that would substantially affect the salinity gradients. The Ala Wai Golf Course Detention Basin would only divert flood flows that exceed the 20-percent ACE level, and flows would return to the Ala Wai Canal as the flood waters subside (estimated to occur within less than 10 hours). Similarly, the Hausten Ditch Detention Basin would also be used only during flood flows, in which case slide gates would be activated until the flood waters subside. In both cases, modification of the flows would occur infrequently and for a short duration, such that the salinity gradient in the Ala Wai Canal is not expected to be significantly affected.

5. Actions Taken to Minimize Impact

As previously described, design features (such as energy dissipators) would be incorporated into the in-stream debris and detention basins to regulate flow velocities and reduce the potential for erosion. In addition, standard BMPs would be implemented, including those listed above (Section II(A)(5)).

C. Suspended Particulate/Turbidity Determination

1. Suspended Particulates and Turbidity Levels

As previously described, the fill materials to be placed include a combination of earthen fill, rip-rap, concrete and base course, all of which would be adequately stabilized during construction. In general, the size and characteristics of these materials would not substantially contribute to increased turbidity or suspended particulate levels over the long term. However, some degree of increased turbidity and increased concentration of suspended solids is likely to occur during construction of project features. Proper diversion/dewatering techniques and other BMPs would be implemented to avoid and minimize the potential for erosion and sedimentation to the extent possible. As such, these are expected to be temporary impacts, and would be relatively minor and restricted to a localized area. No long-term adverse effects on water quality are expected.

2. Effects on Chemical and Physical Properties of the Water Column

Temporary increases in suspended particulates and turbidity could result in minor impacts on the physical properties of the water column, including reduced light penetration and habitat quality for aquatic species. However, these changes would be short-term and localized, and it is expected that the potential effects would rapidly dissipate upon completion of construction. All discharge material would be clean and free of contaminants, such that no effects relative to toxic metal concentrations, pathogens, or viruses are anticipated.

3. Actions Taken to Minimize Impact

As previously described in Section II(A)(5), BMPs would be implemented during construction, and would help to avoid and minimize impacts associated with suspended particulates and turbidity to the extent possible.

D. Contaminant Determinations

As previously specified, all materials used for construction would be from approved sources, and would be clean and free of contaminants. Previous studies have investigated the extent of pollution in the water column and sediments within the Ala Wai Canal, with a few studies also sampling the main streams in the watershed. In general, these studies have identified the presence of contaminants including bacteria, trace metals, nutrients, pesticides, and toxic organics (Edward K. Noda and Associates, 1992a, 1992b, and 1992d; Laws et al., 1993; DOH, 1997a; DOH, 2002; Anthony et al., 2004; De Carlo et al., 2004). As previously described, the detention basins would function to temporarily hold stream flows, slowly releasing them within the streams and Canal. To the extent that contaminants are present in the detention areas (particularly within the multi-purpose detention areas, which may be subject to herbicide applications), detained water could flush contaminants into the streams, thus contributing to degraded water quality conditions. However, the multi-purpose detention features are located within areas that are already subject to flooding, such that the project is not expected to substantially increase delivery of contaminants to the streams beyond that which already occurs. Similarly, in-stream detention in the upper reaches of the watershed is not expected to substantially increase mobilization of any contaminants beyond the existing condition. As such, the proposed work is not expected to introduce or increase the presence of contaminants into the streams.

E. Aquatic Ecosystem and Organism Determinations

1. Effects on Plankton

During construction, an increase in turbidity and suspended solids in the areas associated with the proposed fill activities might have a short-term localized effect on phytoplankton productivity. It is expected that any potential impacts would be temporary, such that the plankton populations would recover quickly following construction.

2. Effects on Benthos

Placement of fill material would cover and smother benthic communities located within the footprint of each measure. In-stream excavation activities (e.g., at Waiomao, Pukele, and Makiki debris and detention basins) also could result in mortality of macroinvertebrates. However, it is expected that the affected areas would be rapidly colonized, with little to no long-term effects on benthic organisms. Where the stream channel is lined with rip-rap for scour protection, the large diameter stone may alter the character of the stream sediments, especially where fine sediments prevailed prior to construction, and lead to colonization by a different community of invertebrates. The interior of the concrete box culverts would provide little new habitat for colonization by benthic organisms.

3. Effects on Nekton

Construction activities are expected to temporarily increase turbidity and suspended solids, as well as noise and overall level of habitat disturbance, which could affect the various species present in the streams, including the assemblage of native aquatic species. However, the work area for each measure would be dewatered prior to construction, such that fish and other free-moving organisms would be precluded from the temporarily impacted areas. Once stream flows are returned to the work areas, construction-related impacts are expected to rapidly dissipate such that significant effects on nekton are not anticipated.

All of the measures have been designed to minimize the potential impacts to aquatic habitat. In particular, they have all been design to maintain passage for native species. For example, where practical, the in-stream detention basins incorporate a natural-bottom arch culvert that is expected to accommodate continued passage for native migratory species under all flow conditions. The concrete box culverts necessary at some of the detention basins are expected to have an effect on aquatic organisms similar to that of a short stretch of channelized stream. Passage through the culvert may be limited during peak storm flows when the detention basins are inundated, but these conditions would only occur on an infrequent basis and for short duration, such that impacts are expected to be minor. In addition, the mitigation measures focus on removal of existing passage barriers and improved access to high-quality upstream habitat, and would serve to mitigate for potential impacts associated with the flood management measures.

4. Effects on Aquatic Food Web

The proposed fill activities would temporarily disrupt aquatic biota during project construction, but are not expected to affect overall productivity of the stream ecosystem within the watershed.

5. Effects on Special Aquatic Sites

As previously described, the streams in the Ala Wai watershed occur along a natural gradient, with steep upper reaches, more meandering middle reaches, and lower reaches entering the estuarine environment. Sections of these streams include a range of riffle-pool complexes, to the extent that they exhibit habitat complexity with a combination of higher-gradient riffles of fast-moving water and lower-gradient pools of slow-moving water. The riffle-pool complexes range along a spectrum, generally based on the underlying gradient, where the habitat in the upper reaches tends toward steeper plunge pool features, while the middle reaches tend toward a lower-gradient combination of riffles and pools. However, to the extent that these areas display high complexity with a combination of substrates and velocities that are typical of the underlying gradient (thus providing high quality habitat for the native aquatic species), they have been identified as riffle and pool complexes for the purposes of this evaluation. This includes the habitat within the proposed in-stream debris and detention basis on Waihi, Waiakeakua, Makiki, Pukele and Waiomao Streams.[8] Discharge of fill in these reaches would displace and/or otherwise reduce habitat quality for native aquatic species.

6. Threatened and Endangered Species

As assessment of the federally listed threatened and endangered species that could potentially be affected by the project was conducted, in consultation with the U.S. Fish and Wildlife Service (USFWS). The results of

[8] The reach of Manoa Stream adjacent to the Kanewai Field multi-purpose detention basin also exhibits riffle-pool complex characteristics; however, this measure would only affect a short stretch of stream bank, and is not expected to alter any characteristics of the stream bed that may contribute to riffle-pool complex habitat.

this analysis indicate there are several listed species that the project may affect, but is not likely to adversely affect; these are summarized below. Additional detail, including a discussion of the species that are not expected to be affected by the project is provided in the Biological Assessment, which is included as an appendix to the Draft Feasibility Report/EIS.

- **Hawaiian hoary bat (*Lasiurus cinereus semotus*):** This species roosts in a wide variety of both native and non-native trees, typically at heights more than 20 feet off the ground. Little is known about the species' occurrence across the island of Oahu, including the Ala Wai watershed. However, based on the habitat preferences, it is possible that it could occur within the action area. In particular, all of the detention basins in the mid to upper portions of the watershed include forested habitat with tall trees that may be used for roosting. Although species occurrence within the measure locations is relatively unlikely, should they occur, Hawaiian hoary bats could be impacted by the project. To avoid and minimize the potential for impacts, vegetation clearing would be performed during times of the year when Hawaiian hoary bats are not expected to be breeding to avoid potential for harm or disruption to non-volant juvenile bats; specifically, trees greater than 15 feet in height would not be cleared between July 1 and August 1. In addition, all construction activities would be scheduled to occur during daytime hours, thus avoiding potential bat foraging activities, which typically occur in the evening hours.
- **Oahu elepaio (*Chasiempis sandwichensis ibidis*):** Oahu elepaio nest and forage in a variety of native and non-native forest types across a range of elevations, but are most common in riparian vegetation along streambeds and in mesic forest habitats with continuous tree canopy and dense understory. Based on recent surveys, approximately 12 birds (5 pairs and 2 single males) are known from upper portions of Palolo valley (well above the proposed Waiomao and Pukele debris and detention basin); the species is no longer believed to occur in other portions of the watershed (VanderWerf et al., 2013). Although species occurrence within the measure locations is unlikely, should they occur, Oahu elepaio could be impacted by the project. To minimize the potential for these impacts, trimming or clearing of vegetation in areas of suitable habitat would be restricted during the elepaio nesting season (January through June).
- **Hawaiian waterbirds species (including Hawaiian coot [*Fulica alai*], Hawaiian stilt [*Himantopus mexicanus knudseni*], and Hawaiian moorhen [*Gallinula chloropus sandvicensis*]):** Hawaiian waterbird species typically use a range of low-elevation ponds and wetlands. In general, the only suitable habitat that is expected to support these species within the project site are limited to areas within the Ala Wai golf course and possibly along Hausten Ditch and/or the upper edges of the Ala Wai Canal. These areas provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. In the unlikely event that Hawaiian waterbird species are present within the project site, it is expected that they would readily disperse to nearby areas with higher quality habitat in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise).

The Biological Assessment was transmitted to the USFWS with a request for concurrence with the USACE's determination that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, O'ahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen); the USACE has determined there would be no effect on all other federally listed/candidate species and/or designated critical habitat. The proposed project has been discussed with the resource agencies, and the Biological Assessment incorporates their input provided to date. Written concurrence with USACE's effects determination is pending, and will be included as part of the Final Feasibility Report/EIS.

7. Other Wildlife

Overall, the project is not expected to substantially affect the diversity or productivity of the project area, but the proposed fill activities would result in loss of habitat for terrestrial and aquatic species, as outlined in

Section 5.7 of the Draft Feasibility Report/EIS. Consistent with USACE requirements, the loss of aquatic habitat was quantified using the Hawaii Stream Habitat Evaluation Procedure (HSHEP) and mitigation measures to offset those impacts have been incorporated into the Tentatively Selected Plan. The mitigation measures are briefly described in Table 1 of this evaluation, with additional detail provided in the Mitigation and Monitoring Plan (Appendix E) of the Draft Feasibility Report/EIS.

8. Actions Taken to Minimize Impacts

The flood risk management measures have been designed to minimize impacts to the aquatic environment, to the extent practicable, both by reducing the overall measure footprint and by incorporating specific features to maintain native species passage (i.e. natural-bottom arch culvert). As previously described, habitat improvements will be implemented as part of the proposed action to compensate for unavoidable impacts to aquatic habitat, as described in Table 1 (and further described in the Mitigation and Monitoring Plan (Appendix E) of the Draft Feasibility Report/EIS).

F. Proposed Disposal Site Determinations

1. Mixing Zone Determination

Discharge of the proposed fill materials at each measure location would be conducted within an area subject to dewatering, and would involve minimal mixing zones. In general, the fill material used for the project would either consist of large components, or would be adequately stabilized, such that very little exposed material could be suspended in the water column.

2. Determination of Compliance with Applicable Water Quality Standards

Specific water quality criteria have been promulgated in the Hawaii Administrative Rules [HAR] §11-54, which, if met, are designed to allow water bodies to achieve designated beneficial uses. Water bodies that do not achieve the criteria are designated as “impaired” and are placed on the CWA §303(d) List of Impaired Waters. Based on the data presented in the 2014 State of Hawai’i Water Quality Monitoring and Assessment Report (DOH, 2014), several locations within the Ala Wai watershed are not in attainment of the designated water quality standards.

Locations with impairment listings in the watershed include the three major streams and the Ala Wai Canal. Manoa Stream is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, dieldrin, and chlordane. Palolo Stream is listed for trash, and Makiki Stream is listed for total nitrogen and total phosphorus. The Ala Wai Canal is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, enterococci, pathogens, metals, suspended solids, and organochlorine pesticides.

For each water body on the §303(d) list, a pollution budget or Total Maximum Daily Load (TMDL) must be developed to bring that water body into compliance with water quality standards. To date, the only TMDLs that have been developed are for nitrogen and phosphorus in the Ala Wai Canal. Development of the remaining TMDLs has been designated by DOH as a low priority (DOH, 2014).

As described throughout this evaluation, the project would involve discharge of a combination of compacted fill, rip-rap, concrete and base course (gravel), all of which will be adequately stabilized during construction. In general, the size and characteristics of these materials will not substantially contribute to increased turbidity or suspended particulate levels, or other constituents which impair water quality. Some degree of increased turbidity and increased concentration of suspended solids would likely occur during construction of project features. Proper dewatering techniques and other BMPs would be implemented to avoid and minimize the potential for erosion and sedimentation to the degree possible. As such, these are expected to be temporary impacts, and would be relatively minor and restricted to a localized area. No long-term adverse effects on water quality are expected, such that the project is expected to be in compliance with applicable water quality standards. Water quality certification will be obtained from the State of Hawaii Department of Health prior to project construction.

3. Potential Effects on Human Use Characteristics

The proposed project would provide flood protection throughout most of the Ala Wai watershed without significantly affecting human use characteristics such as municipal and private water supplies, and recreational or commercial fisheries.

The project would result in some impacts to recreation, as several of the measures are sited in designated recreational areas. Facilities that would be affected (at least in part) include Manoa District Park, Kanewai Park, Ala Wai Promenade, Ala Wai Community Park, Ala Wai Golf Course, and Ala Wai Canal. In addition, areas within the Honolulu Forest Reserve and Makiki Tantalus Recreation Area would be affected during construction. In general, the measures would displace some areas that are currently used for recreation. However, to the maximum extent possible, they have been designed with the smallest footprint possible, and to minimize impacts to recreational activities during non-flood conditions. For example, the Kanewai and Hausten Ditch detention basins are designed to be multi-purpose facilities, such that the baseball/ softball fields may still be used during non-flood conditions. During a flood event, the measures would function to temporarily detain water and debris, thereby precluding recreational use; however, these sites are expected to have minimal recreational value under flood conditions. Additional detail on potential impacts to recreation is provided in Section 5.10 of the Draft Feasibility Report/EIS.

Other potential impacts on human use characteristics include those associated with aesthetics. In general, the measures would introduce a large-scale built element to the natural environment, which would impact views from and toward the site. In general, the detention features in the upper portions of the watershed will either be screened by dense vegetation or otherwise fit into the natural topography, such that they are not expected to be prominently visible from any readily accessible public locations. The proposed measures along the Ala Wai Canal, including the flood walls, would diminish views along and toward the Ala Wai Canal. In addition to these views being an important resource for the Waikiki District in general, they are also significant in terms of the Ala Wai Canal's listing on the National and State Register of Historic Places (as well as a component of the Kauhale O Hookipa Scenic Byway). In spite of the visual impact of the flood walls, the analysis conducted for this project determined that they are a necessary feature to provide adequate flood protection for Waikiki, such that the impacts are unavoidable. Efforts were made throughout the planning process, to minimize the impacts to the extent possible, particularly through reduction of the overall flood wall heights. Refinements to the measure design will be made during as part of the detailed design phase, and will consider opportunities to further reduce the height of the flood walls, as well as incorporate design details that may otherwise minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment. Additional detail on potential impacts to visual resources is provided in Section 5.11 of the Draft Feasibility Report/EIS.

G. Determination of Cumulative Effects on the Aquatic Ecosystem

Although there are multiple measures throughout the watershed, they are generally located in geographically distinct areas. BMPs would be implemented for each of the measures to minimize the potential for impacts to the aquatic environment, such that they are not expected to significantly contribute to cumulative impacts. A detailed discussion of cumulative impacts is provided in Section 5.19 of the Draft Feasibility Report/EIS.

H. Determination of Secondary Effects on the Aquatic Ecosystem

No secondary impacts to the aquatic environment are anticipated to occur. Additional detail in provided in the Draft Feasibility Report/EIS.

III. FINDING OF COMPLIANCE WITH RESTRICTIONS ON DISCHARGE

The proposed fill activities would comply with Section 404(b)(1) guidelines of the Clean Water Act, as amended. No significant adaptations of the guidelines were made for this evaluation. As discussed in the Draft Feasibility Report/EIS, other alternatives considered to reduce the flood risk within the Ala Wai

Watershed include no action; a large-scale dam; debris and detention basins throughout the urbanized watershed; floodwalls alone; and non-structural solutions. However, it was determined that these alternatives were prohibitively more costly, were significantly less effective in reducing flood risk, had extensive impacts that would have been difficult to mitigate, and/or did not meet the overall project purpose of reducing flood risk throughout the watershed. Although the tentatively selected plan would involve work in areas that support riffle and pool complexes, this type of habitat occurs throughout the mid to upper reaches of the streams where peak flows are greatest. Detention of water along stream reaches without these special aquatic sites (such as in lower reaches of the watershed, as considered for Alternative 2A) is less effective at achieving the overall purpose of reducing flood risk. No other practicable alternative with less environmental impact has been identified, such that the tentatively selected plan has been identified as the least environmentally damaging practicable alternative. A detailed discussion of the potential effects of the project is presented in the Draft Feasibility Report/EIS.

The proposed fill activities would comply with all State water quality standards, Section 307 of the Clean Water Act, and the Endangered Species Act of 1973, as amended. The proposed fill activities would not have significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife and special aquatic sites. The life stages of aquatic life and other wildlife would not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity, and stability, and on recreational, and economic values would not occur. To avoid and minimize the potential for adverse impacts, the project areas would be properly dewatered and standard BMPs would be implemented. Habitat improvements would be implemented to mitigate for loss of aquatic habitat.

A public meeting will be held for the project as part of the public review process for the Draft Feasibility Report/EIS. This draft evaluation will be included as an attachment to the Draft Feasibility Report/EIS and relevant comments will be received as part of the public review process. Comments received at the public meeting and during the following comment period will be considered and this evaluation will be updated as needed.

On the basis of this evaluation, I have determined that the proposed action complies with the requirements of the 404(b)(1) guidelines for the discharge of fill material.

Date

Christopher W. Crary
Lieutenant Colonel, U.S. Army
District Engineer

References

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Appendix E4
Coastal Zone Management Federal Consistency Review

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OFFICE OF PLANNING
STATE OF HAWAII

DAVID Y. IGE
GOVERNOR

LEO R. ASUNCION
DIRECTOR
OFFICE OF PLANNING

235 South Beretania Street, 6th Floor, Honolulu, Hawaii 96813
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Ref. No. P-15106

April 11, 2016

Mr. Anthony J. Paresa, P.E.
Deputy District Engineer for
Programs and Project Management
U.S. Army Corps of Engineers, Honolulu District
Building 230
Fort Shafter, Hawaii 96858-5440

Attention: Mr. Derek Chow, Chief, Civil and Public Works Branch

Dear Mr. Paresa:

Subject: Coastal Zone Management Act (CZMA) Federal Consistency Review for the Ala Wai Canal Project, Honolulu, Oahu

The Hawaii CZM Program has completed the federal consistency review of the Ala Wai Canal flood reduction project. This CZM federal consistency review covers the "Tentatively Selected Plan," as identified in the Draft Feasibility Study with Integrated Environmental Impact Statement (August 2015), which was submitted in support of the consistency determination. The following flood risk management measures of the Tentatively Selected Plan were included in this federal consistency review: Waihi Debris and Detention Basin; Waiakeakua Debris and Detention Basin; Woodlawn Ditch Detention Basin; Manoa In-stream Debris Catchment; Kanewai Field Multi-Purpose Detention Basin; Waiomao Debris and Detention Basin; Pukele Debris and Detention Basin; Makiki Debris and Detention Basin; Ala Wai Canal Floodwalls; Hausten Ditch Detention Basin; Ala Wai Golf Course Multi-Purpose Detention Basin; and Flood Warning System. We concur with the U.S. Army Corps of Engineers determination that the proposed activity is consistent to the maximum extent practicable with the enforceable policies of the Hawaii CZM Program based on the following conditions.

1. The proposed action, identified as the "Tentatively Selected Plan" in the Draft Feasibility Study with Integrated Environmental Impact Statement (August 2015), shall be implemented as represented in the CZM consistency determination. Any changes to the subject proposal represented in the CZM consistency determination, shall be submitted to the Hawaii CZM Program for review and approval. Changes to the proposal may require a full CZM federal consistency review, including publication of a public notice and provision for public review and comment. This condition is necessary to ensure that the proposed action is implemented as reviewed for consistency with the enforceable policies of the Hawaii CZM Program. Hawaii

Revised Statutes (HRS) Chapter 205A Coastal Zone Management, is the federally approved enforceable policy of the Hawaii CZM Program that applies to this condition.

2. The mitigation measures and best management practices proposed in the "Mitigation, Monitoring and Adaptive Management Plan" (August 2015) presented in Appendix E2 of the Draft Feasibility Study with Integrated Environmental Impact Statement (August 2015), which was submitted as a supporting document for the consistency determination, shall be fully implemented. This condition ensures consistency with the Hawaii CZM Program coastal ecosystem policies in Hawaii Revised Statutes (HRS) Chapter 205A, which is a federally approved enforceable policy of the Hawaii CZM Program.

3. The proposed action shall be conducted in compliance with State of Hawaii water quality standards and requirements, including the Section 401 Water Quality Certification, as specified in Hawaii Administrative Rules (HAR) Chapter 11-54. This condition is necessary to ensure consistency with State of Hawaii water quality standards and requirements. HRS Chapter 342D Water Pollution, and HAR Chapter 11-54 Water Quality Standards, are the federally approved enforceable policies of the Hawaii CZM Program that apply to this condition.

4. As stated in the U.S. Army Corps of Engineers federal consistency supplemental information letter dated March 8, 2016: "The proposed project is subject to Section 401 of the Clean Water Act, and the Corps will be applying for a Section 401 Water Quality Certification from the State of Hawaii." This condition is necessary to ensure consistency with State of Hawaii water quality standards and requirements. HRS Chapter 342D Water Pollution, and HAR Chapter 11-54 Water Quality Standards, are the federally approved enforceable policies of the Hawaii CZM Program that apply to this condition.

5. The proposed activity shall be in compliance with the State Historic Preservation Division requirements pursuant to Hawaii Revised Statutes Chapter 6E - Historic Preservation, which is a federally approved enforceable policy of the Hawaii CZM Program.

If the requirements for conditional concurrences specified in 15 CFR § 930.4(a), (1) through (3), are not met, then all parties shall treat this conditional concurrence letter as an objection pursuant to 15 CFR Part 930, subpart C.

CZM consistency concurrence does not represent an endorsement of the project nor does it convey approval with any other regulations administered by any State or County agency. Thank you for your cooperation in complying with the Hawaii CZM Program. If you have any questions, please call John Nakagawa of our CZM Program at 587-2878.

Sincerely,

Leo R. Asuncion
Director

c: DLNR, Division of Engineering
City & County of Honolulu, Department of Planning & Permitting

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

August 5, 2015

Civil and Public Works Branch
Programs and Project Management Division

SUBJECT: Ala Wai Canal Project Consistency with Coastal Zone Management Act

Mr. John Nakagawa
Federal Consistency Program
Hawaii State Office of Planning
Department of Business,
Economic Development & Tourism
P.O. Box 2359
Honolulu, Hawaii 96804

Dear Mr. Nakagawa:

We are requesting your concurrence that the Ala Wai Canal Project described below is consistent with the Coastal Zone Management Act (CZMA).

At the request of the State of Hawaii Department of Land and Natural Resources, the Honolulu District, U.S. Army Corps of Engineers (Corps), is conducting a feasibility planning study for the proposed Ala Wai Canal Project in Honolulu, Hawaii. The Ala Wai Watershed is located on the southeastern side of the island of Oahu and includes Makiki, Manoa, and Palolo streams, all of which drain into the Ala Wai Canal. Flooding associated with a 1-percent annual chance exceedance rainfall event would affect approximately 1,358 acres within the Ala Wai Watershed, including over 3,000 properties with an estimated $318M in structural damages alone (at 2013 price levels). As such, the purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding.

In response to identified flood-related problems and opportunities, potential flood risk management measures were identified and formulated into alternatives, which were evaluated through an iterative screening and evaluation process, resulting in tentative selection of a plan for implementation. The tentatively selected plan would reduce flood risks by improving the flood warning system, and constructing six in-stream debris and detention basins in the upper reaches of Makiki, Manoa and Palolo Streams, one standalone debris catchment feature, three multi-purpose detention areas in open spaces through the developed watershed, and concrete floodwalls ranging up to 4 feet high, along one or both sides of approximately 1.9 miles of the Ala Wai Canal (including three pump stations). Additional detail, including a more detailed description of the tentatively selected plan and associated maps are enclosed for your consideration. We will also provide a copy of the Draft Integrated Feasibility Report and Environmental Impact Statement when it is published for public review, which is anticipated to occur in late August 2015.

Section 307(c)(1)(A) of the CZMA requires Federal actions that affect any land or water use or natural resources of the coastal zone will be conducted in a manner that is consistent to the maximum extent practicable with the enforceable policies of an approved state management program. As the proposed project is being undertaken by the Corps, it represents a Federal action that is understood to require compliance under the "Federal consistency" provision of the CZMA. Based on a review relative to the policies and objectives of Hawaii's Coastal Zone Management Program, we have determined that the proposed project is consistent to the maximum extent practicable. We are submitting the attached application (Enclosure 1) and assessment forms (Enclosure 2), with this request for your concurrence with our determination. Additional information on the project can be found in the enclosed Project Summary (Enclosure 3).

If you have any questions, please contact Mr. Derek Chow, Chief of our Civil and Public Works Branch, at (808) 835-4026 or e-mail derek.j.chow@usace.army.mil.

Sincerely,

for Anthony J. Paresa, P.E.
Deputy District Engineer for
Programs and Project Management

Enclosures

Hawaii CZM Program
Coastal Zone Management

HAWAII CZM PROGRAM

APPLICATION FOR CZM FEDERAL CONSISTENCY REVIEW

Project/Activity Title or Description: Ala Wai Canal Project

Location: Ala Wai Watershed

Island: Oahu

Tax Map Keys: 2-9-054:019, 029, 034, 004, 002; 2-9-055:009, 001; 2-5-020:005, 008, 001; 2-9-036:003; 2-9-029:053; 2-7-036:001; 2-9-043:002; 3-4-016:059; 3-4-034:001, 008, 009; 3-4-019:003 through 010, 052; 2-8-029:011, 004; 2-7-036:002; 2-9-067:008 through 012, 015 through 017

Applicant and Agent Information

1. U.S. Army Corps of Engineers
Name of Applicant
Building 230
Address
Fort Shafter,HI 96858
City & State / Zip Code
835-4026
Daytime Phone / Fax Number
derek.j.chow@usace.army.mil
E-mail Address

2.
Name of Agent
Address
City & State / Zip Code
Daytime Phone / Fax Number
E-mail Address

CZM Consistency Determination or Certification

x Check the type of application below and sign.

☒ I. Federal Agency Activity

CZM Consistency Determination: "The proposed activity will be undertaken in a manner consistent to the maximum extent practicable with the enforceable policies of the Hawaii Coastal Zone Management Program."

Signature [signature] Date 8/5/15
(Applicant or responsible party)

☐ II. Federal Permit or License (Please sign below)

CZM Consistency Certification: "The proposed activity complies with the enforceable policies of Hawaii's approved management program and will be conducted in a manner consistent with such program."

Signature Date
(Applicant or responsible party)

☐ III. Federal Grants and Assistance (Please sign below)

CZM Consistency Certification: "The proposed activity complies with the enforceable policies of Hawaii's approved management program and will be conducted in a manner consistent with such program."

Signature Date
(Applicant or responsible party)

Send To: Office of Planning, P.O. Box 2359, Honolulu, Hawaii 96804

Print Form

HAWAII CZM PROGRAM
FEDERAL CONSISTENCY ASSESSMENT FORM

RECREATIONAL RESOURCES

Objective: Provide coastal recreational opportunities accessible to the public.

Policies:

1) Improve coordination and funding of coastal recreation planning and management.

2) Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:

   a) Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;

   b) Requiring replacement of coastal resources having significant recreational value, including but not limited to surfing sites and sandy beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the State for recreation when replacement is not feasible or desirable;

   c) Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;

   d) Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;

   e) Encouraging expanded public recreational use of county, State, and Federally owned or controlled shoreline lands and waters having recreational value;

   f) Adopting water quality standards and regulating point and non-point sources of pollution to protect and where feasible, restore the recreational value of coastal waters;

   g) Developing new shoreline recreational opportunities, where appropriate, such as artificial reefs for surfing and fishing; and

   h) Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, County planning commissions; and crediting such dedication against the requirements of section 46-6.

RECREATIONAL RESOURCES (continued)

Check either "Yes" or "No" for each of the following questions:		**Yes**	**No**
1.	Will the proposed action involve or be near a dedicated public right-of-way?	☐	☒
2.	Does the project site abut the shoreline?	☐	☒
3.	Is the project site near a State or County park?	☒	☐
4.	Is the project site near a perennial stream?	☒	☐
5.	Will the proposed action occur in or affect a surf site?	☐	☒
6.	Will the proposed action occur in or affect a popular fishing area?	☐	☒
7.	Will the proposed action occur in or affect a recreational or boating area?	☒	☐
8.	Is the project site near a sandy beach?	☐	☒
9.	Are there swimming or other recreational uses in the area?	☒	☐

Discussion:

See next page.

RECREATIONAL RESOURCES

Given the project objective of reducing the risk of riverine flooding in the Ala Wai Watershed, the flood risk management features would generally be located within or adjacent to a stream (or the Ala Wai Canal). Several of the features would also be located within or near areas used for recreational purposes. Recreational areas that could be affected (at least in part) include Honolulu Forest Reserve, Kanewai Community Park, Makiki Tantalus Recreation Area, Ala Wai Golf Course, Ala Wai Community Park, and Ala Wai Promenade. In addition, portions of Manoa District Park and Archie Baker Park would be used for staging and access. During construction, recreational activities would be restricted within the construction limits for each feature, thus limiting the range and/or accessibility of recreational opportunities temporarily. Construction activities at Honolulu Forest Reserve and Makiki Tantalus Recreation Area, as well staging at Manoa District Park and Archie Baker Park would involve a very small portion of each facility, and would not significantly impact recreational activities. Construction of the floodwalls would not preclude recreational use of the Ala Wai Canal, but certain access points may be temporarily unavailable during the construction phase.

Over the long-term, berms for the multi-purpose debris and detention basins would occupy a portion of Kanewai Community Park, Ala Wai Community Park and Ala Wai Golf Course. To the extent practicable, the flood risk management feature designs have the smallest footprint possible, and minimize impacts to recreational activities during non-flood conditions. For example, the berm for the Ala Wai Golf Course detention basin design would accommodate the existing golf cart path, such that the layout and use of the golf course would not be significantly affected over the long-term. The berms at Kanewai Community Park and Ala Wai Community Park would be located around the outer perimeter of the parks. The Waiakeakua and Makiki debris and detention basins, which are planned in the Honolulu Forest Reserve and Makiki Tantalus Recreation Area (respectively), would also displace potential recreational area (less than one acre each). These feature designs are not multi-purpose; however, no established recreational activities are known to occur there, and sufficient area surrounding the feature would still be available for use.

In the event of a flood, when the various debris and detention structures would detain floodwaters and capture debris/sediment, the area would be temporarily unavailable for recreation. In the case of a 1 percent ACE flood event, the projected inundation period would be less than 10 hours. Following the flood event, post-flood maintenance would remove accumulated debris/sediment; this could require several days. Potential recreational impacts associated with post-flood maintenance could occur at those sites with multi-purpose detention basins, where established recreational activities regularly occur (e.g., Kanewai Community Park, Ala Wai Community Park, and Ala Wai Golf Course). However, project analyses indicate that these sites already flood (thereby impacting recreational uses) under without-project conditions. Furthermore, project operation and maintenance (O&M) activities would be programmed as part of the standard flood responses activities to minimize post-flood maintenance response time.

Overall, these impacts are not expected to significantly decrease the long-term availability and accessibility to recreational opportunities in the coastal zone management area. Although some limited areas would be affected, the project would also provide flood risk management benefits throughout much of the watershed, including recreational areas such as Kapiolani Park. Additional detail is provided in Section 5.10 of the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as “Draft Feasibility Report/EIS.”

HISTORIC RESOURCES

Objective: Protect, preserve, and where desirable, restore those natural and man-made historic and pre-historic resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

Policies:

1) Identify and analyze significant archaeological resources;

2) Maximize information retention through preservation of remains and artifacts or salvage operations; and

3) Support State goals for protection, restoration, interpretation, and display of historic resources.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Is the project site within a historic/cultural district?	☐	☒
2. Is the project site listed on or nominated to the Hawaii or National register of historic places?	☒	☐
3. Does the project site include undeveloped land which has not been surveyed by an archaeologist?	☒	☐
4. Has a site survey revealed any information on historic or archaeological resources?	☒	☐
5. Is the project site within or near a Hawaiian fishpond or historic settlement area?	☒	☐

Discussion:

See next page.

HISTORIC RESOURCES

As detailed in the Draft Feasibility Report/EIS, the project development effort to date has included an assessment of archaeological resources and a historic structure inventory for portions of the project area. The results of these studies indicate that multiple historic properties are located within the project area and could be affected by the project, including the Ala Wai Canal which is listed on the Hawaii Register of Historic Places; a detailed listing of historic properties is provided in Section 5.8 of the Draft Feasibility Report/EIS.

Potential impacts to historic properties include modifications that may affect the integrity and/or characteristics of historic properties as a result of construction and operation of the project. As detailed in Section 5.8 of the Draft Feasibility Report/EIS, treatment recommendations have been identified for properties that are expected to be adversely affected, with the intention of identifying conditions that can be placed on the design and construction to mitigate impacts to the resource. Historic buildings, bridges, and walls affected by construction would undergo appropriate historic documentation, and design input will be solicited from the State Historic Preservation Officer (SHPO); input would be incorporated into the final design where feasible. Where possible, impacts to archaeological resources would be avoided. Where avoidance is not possible, data recovery would be performed. Where practicable, community assistance would be solicited for re-use of materials, and possible reconstruction of features of Native Hawaiian cultural significance that would be disturbed by project actions. During this feasibility phase, a number of variables remain unknown that may result in adverse effects through the future planning, design, and construction phases. A Programmatic Agreement is being developed to establish a process for resolving adverse effects, and expand upon the treatment recommendations. Coordination of this Programmatic Agreement is ongoing with the Advisory Council on Historic Preservation (ACHP), SHPO, and others as appropriate.

SCENIC AND OPEN SPACE RESOURCES

Objective: Protect, preserve and where desirable, restore or improve the quality of coastal scenic and open space resources.

Policies:

1) Identify valued scenic resources in the coastal zone management area;

2) Insure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;

3) Preserve, maintain and where desirable, improve and restore shoreline open space and scenic resources; and

4) Encourage those developments that are not coastal dependent to locate in inland areas.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Does the project site abut a scenic landmark?	☒	☐
2. Does the proposed action involve the construction of a multi-story structure or structures?	☒	☐
3. Is the project site adjacent to undeveloped parcels?	☒	☐
4. Does the proposed action involve the construction of structures visible between the nearest coastal roadway and the shoreline?	☐	☒
5. Will the proposed action involve construction in or on waters seaward of the shoreline? On or near a beach?	☐	☒

Discussion:

See next page.

SCENIC AND OPEN SPACE RESOURCES

The visual landscape of the proposed project area is generally comprised of natural stream corridor and forested habitat in the upper watershed, and open spaces within the heavily developed middle to lower watershed. The General Plan for the City and County of Honolulu has identified specific views that should be preserved within the watershed, including panoramic views from the Ala Wai Canal promenade and Ala Moana Beach Park toward the Koʻolau Mountains, as well as *mauka-makai* view corridors along major roadways. In addition to these viewplanes, other important scenic resources that have been identified include those in the Waikiki District, including the Ala Wai Canal itself, which is listed as a historic property on the Hawai`i Register of Historic Places. Two scenic byways have also been established in this area under the Hawai'i Scenic Byways Program: the Diamond Head Scenic Byway and the Waikīkī - Kauhale O Hookipa Scenic Byway. The Diamond Head Scenic Byway spans from Kapiʻolani Park to Diamond Head Crater. The Waikiki - Kauhale O Hookipa Scenic Byway includes the major thoroughfares through Waikiki, including Ala Wai Boulevard.

Construction of the debris and detention basins would introduce built elements to the natural environment; however, these features have been sited and designed to blend with the natural characteristics of each site to the extent possible. None of the features are expected to substantially diminish important environmental or landscape views from readily accessible viewing locations, nor are they expected to affect significant view corridors, including those identified in the General Plan.

As planned, the floodwalls along the Ala Wai Canal would be approximately 4 feet high (on average), extending from Kapahulu Avenue to Ala Moana Blvd on the *makai* side, and from the confluence with the Mānoa Pālolo Drainage Canal to Ala Moana Blvd on the *mauka* side. The floodwalls would also include a several pump stations (which could be several stories tall): (1) at the Kapahulu Avenue end of the Canal, (2) on the Ala Wai Golf Course near the Kapahulu storm drain, and (3) at Ala Wai Community Park, near the *makai* end of University Avenue. Neither the floodwalls nor the associated pump stations are expected to substantially obstruct broad landscape views (including those of the Koʻolau Mountains), but could diminish localized views, including those along the Ala Wai Canal. Specifically, the floodwalls are expected to partially obstruct views of the Canal from cars along Ala Wai Boulevard and from pedestrians along both sides of Canal, and will also partially obstruct views from within the Canal (e.g., paddlers and others using the Canal for recreation). In addition to these views being an important resource for the Waikiki District in general, they are also significant in terms of the Ala Wai Canal as a historic property on the Hawai`i Register of Historic Places as well as the Kauhale O Hookipa Scenic Byway (which includes Ala Wai Boulevard). However, the feasibility analysis determined that the floodwalls (and associated pump stations) would be a necessary feature to provide adequate flood protection for this area. Efforts throughout the planning process would minimize the impacts to the extent possible, particularly as related to the overall structure heights. Further refinements would be made during the design phases, and would further evaluate opportunities to reduce the dimensions of the floodwalls and pump stations, as well as incorporate design details to further minimize potential visual impacts, such as use of construction materials and/or landscaping to blend the structures into the surrounding environment.

COASTAL ECOSYSTEMS

Objective: Protect valuable coastal ecosystems from disruption and minimize adverse impacts on all coastal ecosystems.

Policies:

1) Improve the technical basis for natural resources management;
2) Preserve valuable coastal ecosystems of significant biological or economic importance;
3) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land water uses, recognizing competing water needs; and
4) Promote water quantity and quality planning and management practices, which reflect the tolerance of fresh water and marine ecosystems and prohibit land and water uses, which violate State, water quality standards.

Check either "Yes" or "No" for each of the following questions:		Yes	No
1.	Does the proposed action involve dredge or fill activities?	☒	☐
2.	Is the project site within the Shoreline Setback Area (20 to 40 feet inland of the shoreline)?	☐	☒
3.	Will the proposed action require some form of effluent discharge into a body of water?	☐	☒
4.	Will the proposed action require earthwork beyond clearing and grubbing?	☒	☐
5.	Will the proposed action include the construction of special waste treatment facilities, such as injection wells, discharge pipes, or cesspools?	☐	☒
6.	Is an intermittent or perennial stream located on or near the project site?	☒	☐
7.	Does the project site provide habitat for endangered species of plants, birds, or mammals?	☒	☐
8.	Is any such habitat located nearby?	☒	☐
9.	Is there a wetland on the project site?	☒	☐
10.	Is the project site situated in or abutting a Natural Area Reserve?	☐	☒
11.	Is the project site situated in or abutting a Marine Life Conservation District?	☐	☒
12.	Is the project site situated in or abutting an estuary?	☒	☐

Discussion:

See next page.

COASTAL ECOSYSTEMS

Given the project objective to reduce riverine flooding, all of the proposed flood risk management features would involve work within or adjacent to a stream or the Ala Wai Canal. The only feature that does not involve work directly within a waterway is the Ala Wai Canal floodwalls (and associated pump stations), as the walls would be set back from the existing edge of the Canal. None of the remaining features will permanently obstruct or change the course of a waterway; however, they would involve placement of fill material within the stream channels. Specifically, construction of the features would require placement of materials including compacted fill, concrete, grouted rip-rap, as well as steel poles for the debris catchment feature. Construction of the Waiomao debris and detention basin would also involve excavation to provide adequate detention capacity. In addition, most of the features would require periodic removal of sediment/debris from the debris catchment features. These activities would impact aquatic habitat, which could indirectly affect native aquatic species. Small pockets of wetland habitat occur along the streams and Canals in a few locations (e.g., along Hausten Ditch), but these are generally within the limits of the defined channel.

Impacts to aquatic habitat would primarily be expected to occur as a result of the in-stream detention basins, as these would involve the greatest extent of in-stream work. The debris catchment structures and multi-purpose detention basins would also displace a small amount of stream habitat. The design process incorporated efforts to avoid and minimize potential impacts to the extent practicable. Project designs reduce the project footprint to the extent practicable, and include design features to minimize habitat impacts and maintain passage for native species (e.g., use of natural-bottom arch culverts). However, even with avoidance and minimization efforts, the proposed project would still result in some impacts to aquatic habitat. As such, the project incorporates compensatory mitigation to offset the anticipated loss of aquatic habitat function. Specifically, the compensatory mitigation measures would improve passage for native aquatic species at two adjacent in-stream barriers in Manoa Stream, as described in Section 5.7.2.2 of the Draft Feasibility Report/EIS.

In general, the terrestrial habitat within the project area is comprised of non-native species, many of which are considered invasive. Federally listed threatened or endangered species that have the potential to occur within the measure locations are Hawaiian hoary bat, Oʻahu elepaio, Hawaiian stilt, Hawaiian coot, Hawaiian moorhen, and the blackline Hawaiian damselfly. Pursuant to Section 7 of the ESA, the USACE has been informally consulting with the USFWS and NMFS regarding potential impacts to threatened and endangered species. Based on this ongoing consultation, the USACE evaluated the potential impacts of the proposed project and has determined that the project may affect but is not likely to adversely affect the Hawaiian hoary bat, Oʻahu elepaio, and Hawaiian waterbirds (Hawaiian coot, Hawaiian stilt, and Hawaiian moorhen). Although previously thought to be restricted to higher elevations of the watershed (and therefore not having the potential to occur within the project area), on July 28, 2015, the USFWS identified blackline Hawaiian damselflies within the proposed footprint of the Waihi debris and detention basin. Although the detailed species occurrence information has not yet been provided by USFWS, based on the verbal description provided to date, the proposed action is likely to adversely affect the blackline Hawaiian damselfly and USACE intends to initiate formal Section 7 consultation upon receipt of the species information.

Additional detail regarding potential impacts to these resources is provided in Section 5.7 of the Draft Feasibility Report/EIS.

ECONOMIC USES

Objective: Provide public or private facilities and improvements important to the State's economy in suitable locations.

Policies:

1) Concentrate in appropriate areas the location of coastal dependent development necessary to the State's economy;

2) Insure that coastal dependent development such as harbors and ports, visitor industry facilities, and energy generating facilities are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and

3) Direct the location and expansion of coastal dependent developments to areas presently designated and used for such development and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:

   a) Utilization of presently designated locations is not feasible;

   b) Adverse environmental effects are minimized; and

   c) Important to the State's economy.

Check either "Yes" or "No" for each of the following questions:	Yes	No
1. Does the project involve a harbor or port?	☐	☒
2. Is the project site within a designated tourist destination area?	☒	☐
3. Does the project site include agricultural lands or lands designated for such use?	☐	☒
4. Does the proposed activity relate to commercial fishing or seafood production?	☐	☒
5. Does the proposed activity related to energy production?	☐	☒
6. Does the proposed activity relate to seabed mining?	☐	☒

Discussion:

Several of the flood risk management features would be located within the Waikiki District, a prime tourist destination that attracts more than 79,000 visitors per day. In combination with the other flood risk management features included in the proposed project, these would function to reduce flood risk within the watershed (including the Waikiki District), thus providing significant economic benefits. A detailed discussion of the economic benefits is provided in Section 8.2 of the Draft Feasibility Report/EIS.

COASTAL HAZARDS

Objective: Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, and subsidence.

Policies:

1) Develop and communicate adequate information on storm wave, tsunami, flood erosion, and subsidence hazard;

2) Control development in areas subject to storm wave, tsunami, flood, erosion, and subsidence hazard;

3) Ensure that developments comply with requirements of the Federal Flood Insurance Program; and

4) Prevent coastal flooding from inland projects.

Check either "Yes" or "No" for each of the following questions:	**Yes**	**No**
1. Is the project site on or abutting a sandy beach?	☐	☒
2. Is the project site within a potential tsunami inundation area as depicted on the National Flood Insurance Program flood hazard map?	☐	☒
3. Is the project site within a potential flood inundation area according to a flood hazard map?	☒	☐
4. Is the project site within a potential subsidence hazard areas according to a subsidence hazard map?	☐	☒
5. Has the project site or nearby shoreline areas experienced shoreline erosion?	☐	☒

Discussion:

The objective of the proposed project is to reduce existing riverine flood risk; as such, the proposed flood risk features are generally located within potential flood inundation areas, as shown on the current Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) flood hazard maps for Hawaii. These features would function to detain floodwaters and/or improve conveyance, so as to reduce the overall risk of flooding within the watershed. In addition, the project would include improvements to the existing flood warning system, which would help to increase life safety during flood events. Additional detail on the potential flood risk reduction is provided in Section 8.3 of the Draft Feasibility Report/EIS.

MANAGING DEVELOPMENT

Objective: Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

Policies:

1) Effectively utilize and implement existing law to the maximum extent possible in managing present and future coastal zone development;

2) Facilitate timely processing of application for development permits and resolve overlapping or conflicting permit requirements; and

3) Communicate the potential short- and long-term impacts of proposed significant coastal developments early in their life cycle and in terms understandable to the general public to facilitate public participation in the planning and review process.

Check either "Yes" or "No" for each of the following questions:		**Yes**	**No**
1.	Will the proposed activity require more than two (2) permits or approval? (Provide the status of each.)	☒	☐
2.	Does the proposed activity conform with the State and County land use designations for the site?	☒	☐
3.	Has or will the public be notified of the proposed activity?	☒	☐
4.	Has a draft or final environmental impact statement or an environmental assessment been prepared?	☒	☐

Discussion:

The potential impacts of the proposed project are detailed in the Draft Feasibility Report/EIS (Section 5), which is being published for public review. A discussion of the stakeholder involved efforts to date and a detailed list of the permits and approvals that will be required for the proposed project are contained in Sections 6 and 7 of the Draft Feasibility Report/EIS, respectively.

PUBLIC PARTICIPATION

Objective: Stimulate public awareness, education, and participation in coastal management.

Policies:

1) Maintain a public advisory body to identify coastal management problems and to provide policy advice and assistance to the coastal zone management program;

2) Disseminate information on coastal management issues by means of educational materials, published reports, staff contact, and public workshops for persons and organizations concerned with coastal-related issues, developments, and government activities; and

3) Organize workshops, policy dialogues, and site-specific mediations to respond to coastal issues and conflicts.

Discussion. Please provide information about the proposal relevant to the Objective and Policies No. 2 and No. 3 above:

The planning process for the proposed project has included an extensive public involvement effort, as needed to disseminate information and obtain stakeholder input relative to the potential impacts and other aspects of the proposed project. A discussion of the public involvement efforts that have been conducted to date is contained in Section 6 of the Draft Feasibility Report/EIS.

BEACH PROTECTION

Objective: Protect beaches for public use and recreation.

Policies:

1) Locate new structures inland from the shoreline setback to conserve open space and to minimize loss of improvements due to erosion;

2) Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and

3) Minimize the construction of public erosion-protection structures seaward of the shoreline.

Discussion. Please provide information about the proposal relevant to the Objective and Policies above:

The proposed project would not affect any shoreline or beach areas.

MARINE RESOURCES

Objective: Implement the State's ocean resources management plan.

Policies:

1) Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;

2) Assure that the use and development of marine and coastal resources are ecologically and environmentally sound and economically beneficial;

3) Coordinate the management of marine and coastal resources and activities management to improve effectiveness and efficiency;

4) Assert and articulate the interests of the State as a partner with federal agencies in the sound management of ocean resources within the United States exclusive economic zone;

5) Promote research, study, and understanding of ocean processes, marine life, and other ocean resources in order to acquire and inventory information necessary to understand how ocean development activities relate to and impact upon ocean and coastal resources; and

6) Encourage research and development of new, innovative technologies for exploring, using, or protecting marine and coastal resources.

Discussion. Please provide information about the proposal relevant to the Objective and Policies above:

The proposed project would not affect any marine resources. As listed in Section 6 of the Draft Feasibility Report/EIS, coordination with NOAA and other resource agencies has been conducted as part of the planning process.

Print Form

PROJECT SUMMARY

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR), the Honolulu District, U.S. Army Corps of Engineers (USACE) is conducting a feasibility planning study for the proposed Ala Wai Canal Project in Honolulu, Hawaii. The study is authorized under Section 209 of the Flood Control Act of 1962 (Public Law 87-874), which is a general authority that authorizes surveys in harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

The Ala Wai Watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19 square miles (12,064 acres) and extends from the ridge of the Ko`olau Mountains to the nearshore waters of Mamala Bay. It includes Makiki, Manoa, and Palolo streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands (see Figure 1). This construction and subsequent draining allowed the development of the Waikiki district.

Purpose and Need

The purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding. A high risk of flooding exists within the Ala Wai watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[1] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85M in damages (at 2004 price levels) (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within the floodplain, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the

[1] The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318M in structural damages alone (2013 price levels), not accounting for loss in business income or other similar economic losses.

Project Description

In response to the flood-related problems and opportunities identified for the Ala Wai watershed, a variety of structural and non-structural flood risk management measures were considered, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, and flood risk reduction. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the tentatively selected plan. The measures included in this plan are based on the following concepts:

- **Detention basin**: The detention basins are comprised of an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.
    - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin (via a spillway along the stream bank), then would drain back into the stream.
- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, the TSP also includes a stand-alone debris catchment structure, which would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. This

structure would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.

- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height (with an average height of 4 feet), and would be constructed with a minimal set back distance from the existing canal walls. Local drainage patterns would be maintained to the extent possible, with flapgates/slidegates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). The only non-structural measure that has been identified as feasible for this project is improvement to the existing flood warning system.

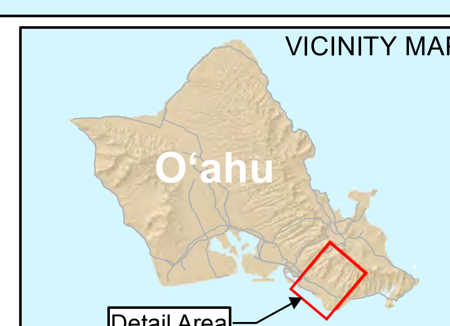
Consistent with the requirements of the Clean Water Act and USACE planning regulations, and after consideration of avoidance and minimization measures, it was determined that compensatory mitigation would be required for unavoidable impacts to aquatic habitat resulting from implementation of the flood risk management measures. Based on a detailed mitigation development process (which included the use of a habitat-based ecosystem output model to quantify habitat loss), the mitigation measures incorporated into the tentatively selected plan include removal of two existing passage barriers for native aquatic species in Manoa Stream. The flood risk management features and compensatory mitigation measures included in the tentatively selected plan are summarized in Table 1. The location of each measure is shown in Figures 2 and 3; detailed design drawings of the measures will be included in the Draft Feasibility Report with integrated Environmental Impact Statement, which will be available for public review after August 23, 2015.

TABLE 1
Description of the Tentatively Selected Plan

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements
Waihi Debris and Detention Basin	Earthen dam, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Waiakeakua Debris and Detention Basin	Earthen dam, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; energy dissipation structure to be located on downstream end of culvert.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Woodlawn Ditch Detention Basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area.
Manoa In-stream Debris Catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of concrete pad) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Kanewai Field Multi-Purpose Detention Basin	Earthen berm, approximately 7' high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Manoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for park use (with no woody vegetation) during non-flood conditions.
Waiomao Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip rap on upstream and downstream side debris catchment feature located on upstream end of culvert. Excavation of approx. 2,015 cubic yards to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam and excavation area) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Pukele Debris and Detention Basin	Earthen dam, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.

Measure	Description of Measure	Operations and Maintenance (O&M) Requirements
Makiki Debris and Detention Basin	Earthen dam, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip rap on upstream and downstream side; debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of dam) twice per year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.
Ala Wai Canal Floodwalls	Concrete floodwalls ranging up to approximately 5 feet high, offset from existing Canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to Canal; floodgate to be installed near McCully Street. Three pump stations to accommodate storm flows and gates installed at existing drainage pipes to prevent backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of floodwalls) twice per year, allowing no woody vegetation to grow in this area. Periodically inspect drainage pipes and gates, and remove any impediments to movement. Paint and/or grease metal parts, as needed.
Hausten Ditch Detention Basin	Concrete floodwalls and an earthen berm (4.3' high) to provide detention for local drainage; install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to prevent a backflow from the Ala Wai Canal during a flood event.	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm and floodwalls) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a field for recreational use during non-flood conditions. Periodically inspect slide gates and actuators and remove any impediments to movement. Paint and/or grease metal parts, as needed.
Ala Wai Golf Course Multi-Purpose Detention Basin	Earthen berm, up to approximately 7' high, around the north and east perimeter of the golf course; grouted rip rap inflow spillway along bank of Manoa Palolo Drainage Canal to allow high flows to enter the basin; sediment basin within western portion of golf course; floodgate across the main entrance road; passive drainage back into Ala Wai Canal	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year, allowing no woody vegetation to grow in this area. Area within berm to be maintained as a golf course (with no woody vegetation in sediment basin) for recreational use during non-flood conditions. Periodically inspect floodgate and remove any impediments to movement. Paint and/or grease metal parts, as needed. Inspect, test, and maintain pump system annually. Paint and/or grease metal parts, as needed.
Floodwarning System	Installation of 3 real-time rain gages (Manoa, Makiki and Palolo Streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai watershed	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection.
Falls 7 and 8 (Mitigation Measures)	Installation of grouted stones to eliminate passage barrier by providing a suitable surface for migration of native species at 2 in-stream structures on Manoa Stream	Periodically inspect in-stream structure for potential erosion or undercutting; reinforce as needed.

LEGEND
- Stream
- Major Road
- Watershed Boundary



0 0.5 1 Mile

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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

FIGURE 1
Overview of the Ala Wai Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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LEGEND

- Stream
- Watershed Boundary
- 1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)
- Flood Risk Management Measure

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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

VICINITY MAP

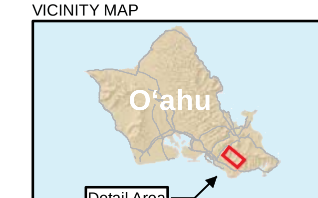

FIGURE 2a
Tentatively Selected Plan (Alternative 3A-2.2) - Upper Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

CH2MHILL

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LEGEND

Stream

Watershed Boundary

1- Percent Annual Chance Exceedance Floodplain (with Implementation of Tentatively Selected Plan)

Flood Risk Management Measure

0 0.5 1 Miles

Projection: State Plane Hawai'i Zone 3 feet NAD83 HARN

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

VICINITY MAP

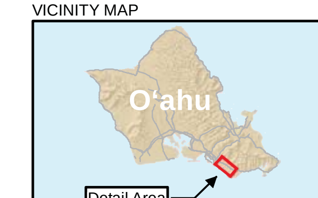

FIGURE 2b
Tentatively Selected Plan (Alternative 3A-2.2) - Lower Watershed
Ala Wai Canal Project
O'ahu, Hawai'i

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LEGEND

Stream

Compensatory Mitigation Measure

N

0 100 200
Feet

VICINITY MAP

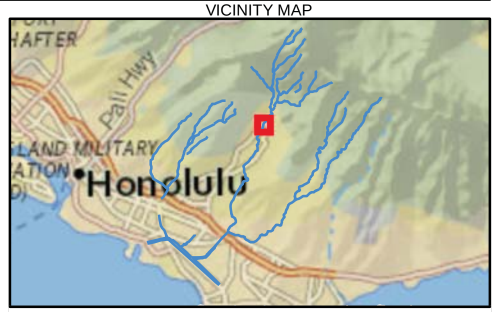

FIGURE 3
Compensatory Mitigation Measures
Ala Wai Canal Project
O'ahu, Hawai'i

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

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Appendix E5
Endangered Species Act Section 7 Consultation Documentation

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United States Department of the Interior

FISH AND WILDLIFE SERVICE

Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

In Reply Refer To:
12200-2008-SL-0187

MAY 16 2008

RECEIVED 5/19/08

Mr. Anthony Paresa, P.E.
Deputy District Engineer
Programs and Project Management
Department of the Army
U.S. Army Engineer District, Honolulu
Fort Shafter, Hawaii 96858-5440

Subject: Species List and Critical Habitat for Ala Wai Canal Project Watershed Plan, Island of Oahu

Dear Mr. Paresa:

Thank you for your letter dated April 9, 2008, received on April 18, 2008, requesting information regarding threatened and endangered species and designated critical habitat that may occur within the proposed project location. The proposed project is the development of the Ala Wai Canal Project (AWCP) Watershed Plan with the U.S. Army Corps of Engineers, Honolulu District, in partnership with the State of Hawaii, Department of Land and Natural Resources. The AWCP encompasses the watersheds of Makiki, Manoa, and Palolo streams on the Island of Oahu.

We have reviewed the information you provided and pertinent information in our files, including data compiled by the Hawaii Biodiversity and Mapping Program and the Hawaii GAP. Enclosure 1 lists the federally listed species and Enclosure 2 identifies federally designated critical habitat known to occur within the proposed project area.

We hope this information assists you in your planning effort and aides in conservation of listed species. If you have questions, please contact Aaron Nadig, Fish and Wildlife Biologist (phone: 808-792-9466; fax: 808-792-9581).

Sincerely,

for Patrick Leonard
Field Supervisor

Enclosures

Enclosure 1. Species List for Ala Wai Canal Project.

Common Name	**Scientific Name**	**Status**
Mammals		
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Endangered
Hawaiian monk seal	*Monachus schauinslandi*	Endangered
Birds		
Oahu elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Hawaiian coot	*Fulica alai*	Endangered
Hawaiian stilt	*Himantopus mexicanus knudseni*	Endangered
Hawaiian duck	*Anas wyvilliana*	Endangered
Hawaiian moorhen	*Gallinula chloropus sandvicensis*	Endangered
Invertebrates		
Oahu tree snail	*Achatinella* sp.	Endangered
Plants		
Haha	*Cyanea acuminate*	Endangered
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea koolauensis*	Endangered
No Common Name	*Diellia erecta*	Endangered
Nanu	*Gardenia mannii*	Endangered
No Common Name	*Gouania meyenii*	Endangered
Wawae iole	*Huperzia nutans*	Endangered
No Common Name	*Lobelia oahuensis*	Endangered
Ihi ihi	*Marsilea villosa*	Endangered
No Common Name	*Pteris lidgatei*	Endangered
No Common Name	*Schiedea nuttallii*	Endangered
No Common Name	*Spermolepis hawaiiensis*	Endangered

Enclosure 2. Critical Habitat for Ala Wai Canal Project.

Common Name	Scientific Name	Status
Birds		
Oahu elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Plants		
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea humboldtiana*	Endangered
No Common Name	*Delissea subcordata*	Endangered
No Common Name	*Gouania meyenii*	Endangered
No Common Name	*Lobelia monostachya*	Endangered

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Pacific Islands Regional Office
1601 Kapiolani Blvd., Suite 1110
Honolulu, Hawaii 96814-4700
(808) 944-2200 • Fax (808) 973-2941

April 25, 2008

Mr. Anthony Paresa, P.E.
Deputy District Engineer
Department of the Army
U.S. Army Engineer District, Honolulu
Ft. Shafter, Hawaii 96858-5440

Dear Mr. Paresa:

This letter responds to your April 9, 2008, letter received by our office on April 21, 2008, concerning the Ala Wai Canal Project (AWCP) Watershed Plan, located Honolulu County on the Island of Oahu. Your letter requested information on listed species and their critical habitats that may occur within the project area. Under our statutory authorities under the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. §1531 *et seq.*), the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) Pacific Islands Regional Office Protected Resources Division provides the following ESA-listed marine protected species information.

As described in your letter, the purpose of the project is to identify and implement measures to address overall watershed health including flood risk management and ecosystem restoration. Based on the map that you provided, the proposed action occurs inland, but is closely linked to the nearshore waters of Malama Bay through down stream transport of potential effects from the proposed project area. Therefore, the ESA-listed marine species that are reasonably likely to occur within the action area are green and hawksbill sea turtles, as well as the Hawaiian monk seals. A complete list of ESA-listed species under NMFS's jurisdiction in the Hawaiian Archipelago is enclosed for your review. No additional marine species are proposed or are candidates for listing under the ESA at this time, and no critical habitat has been designated or proposed for any marine protected species around the Island of Oahu, Hawaii.

Thank you for working with NMFS to protect our nation's living marine resources. Should you have any other questions regarding this project or the consultation process, please contact Donald Hubner on my staff at (808) 944-2233, or at the e-mail address Donald.Hubner@noaa.gov. Please refer to consultation #: I-PI-08-677-CY.

Sincerely,

Chris E. Yates
Assistant Regional Administrator
For Protected Resources

MARINE PROTECTED SPECIES of the HAWAIIAN ISLANDS

National Marine Fisheries Service, Pacific Islands Regional Office

MARINE MAMMALS

All marine mammals are protected under the Marine Mammal Protection Act. Those identified under the ESA Listing are also protected under the Endangered Species Act.

Common Name	Scientific Name	ESA Listing
Blue Whale	*Balaenoptera musculus*	Endangered
Blainville's Beaked Whale	*Mesoplodon densirostris*	
Bryde's Whale	*Balaenoptera edeni*	
Cuvier's Beaked Whale	*Ziphius cavirostris*	
Dwarf Sperm Whale	*Kogia simus*	
False Killer Whale	*Pseudorca crassidens*	
Fin Whale	*Balaenoptera physalus*	Endangered
Humpback Whale	*Megaptera novaeangliae*	Endangered
Killer Whale	*Orcinus orca*	
Longman's Beaked Whale	*Indopacetus pacificus*	
Melon-headed Whale	*Peponocephala electra*	
Minke Whale	*Balaenoptera acutorostrata*	
North Pacific Right Whale	*Eubalaena japonica*	Endangered
Pygmy Killer Whale	*Feresa attenuata*	
Pygmy Sperm Whale	*Kogia breviceps*	
Sei Whale	*Balaenoptera borealis*	Endangered
Short-finned Pilot Whale	*Globicephala macrorhynchus*	
Sperm Whale	*Physeter macrocephalus*	Endangered
Bottlenose Dolphin	*Tursiops truncatus*	
Common Dolphin	*Delphinus delphis*	
Fraser's Dolphin	*Lagenodelphis hosei*	
Pantropical Spotted Dolphin	*Stenella attenuata*	
Risso's Dolphin	*Grampus griseus*	
Rough-toothed Dolphin	*Steno bredanensis*	
Spinner Dolphin	*Stenella longirostris*	
Striped Dolphin	*Stenella coeruleoalba*	
Hawaiian Monk Seal	*Monachus schauinslandi*	Endangered
Northern Elephant Seal	*Mirounga angustirostris*	

SEA TURTLES

All sea turtles are protected under the Endangered Species Act.

Common Name	Scientific Name	ESA Listing
Green Turtle	*Chelonia mydas*	Threatened
Hawksbill Turtle	*Eretmochelys imbricata*	Endangered
Loggerhead Turtle	*Caretta caretta*	Threatened
Leatherback Turtle	*Dermochelys coriacea*	Endangered
Olive Ridley Turtle	*Lepidochelys olivacea*	Threatened

Last updated April 2008

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

August 5, 2015

Civil and Public Works Branch
Programs and Project Management

Ms. Kristi Young
Deputy Field Supervisor
Programmatic Division
U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Blvd, Room 3-122
Honolulu, Hawaii 96850-0001

Dear Ms. Young:

For purposes of continuing informal consultation under Section 7 of the Endangered Species Act, the Honolulu District, U.S. Army Corps of Engineers (Corps), transmits the enclosed draft Biological Assessment (BA) for the Ala Wai Canal Project, Oahu, Hawaii. The State of Hawaii Department of Land and Natural Resources (DLNR) is the non-Federal sponsor of this single purpose flood risk management project.

Based on current available documentation, the attached draft BA indicates that the project may affect, but would not likely adversely affect any Federally listed species. However, during a July 29, 2015, Fish and Wildlife Coordination Act meeting, a representative of the U.S. Fish and Wildlife Service (USFWS) verbally informed my staff that USFWS field investigations discovered a population of endangered blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) in the vicinity of a proposed project feature site.

The endangered blackline Hawaiian damselfly is endemic to the island of Oahu, found historically in stream sites at higher altitudes. We anticipate that upon receipt of the detailed species occurrence information from the USFWS, we may determine that the proposed action is likely to adversely affect the blackline Hawaiian damselfly. If that occurs, we would revise the enclosed draft BA accordingly and request initiation of formal consultation between our agencies on this project. Through consultation with the USFWS, we expect to identify appropriate actions to avoid and minimize any potential impacts to this species.

We greatly appreciate your review of our preliminary impact assessment documents, helpful comments, discussion of potential impacts, and policy review provided by your staff, especially Mr. Kevin Foster, Ms. Jiny Kim, and Mr. Dan Polhemus. Their efforts aided our task preparing this Biological Assessment. We want to continue our cooperation through completion of this work.

If you have questions, please contact Mr. Derek Chow, Chief of my Civil and Public Works Branch, at (808) 835-4026 or e-mail derek.j.chow@usace.army.mil.

Sincerely,

for Anthony J. Paresa, P.E.
Deputy District Engineer for
Programs and Project Management

Enclosure

CC:
Ms. Jiny Kim, USFWS
Mr. Aaron Nadig, USFWS
Mr. Patrick Opay, NOAA Fisheries
Mr. David Nichols, NOAA Fisheries

Biological Assessment of Threatened and Endangered Species for the Ala Wai Canal Project

Under the Endangered Species Act of 1973, As Amended

Submitted by:

U.S. Army Corps of Engineers Honolulu District
Bldg. 230, CEPOH-PP-C
Fort Shafter, HI 96858

Submitted to:

U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, HI 96850

December 2015

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1.0 INTRODUCTION

At the request of the State of Hawai`i Department of Land and Natural Resources (DLNR), the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project[1] (hereafter referred to as "the project"). The purpose of the project is to reduce flood hazards within the watershed, which is comprised of approximately 19 square miles (12,064 acres) on the southeastern side of the island of Oahu in the State of Hawai`i (Figure 1).

In accordance with Section 7 of the Endangered Species Act (ESA) (Title 16, United States Code [USC], Section 1536[c]) and in consultation with the United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Services (NMFS), this Biological Assessment (BA) defines and evaluates the potential effects of the proposed project on ESA-listed species and their designated critical habitats.

1.1 Project Authority

The project is authorized under Section 209 of the Flood Control Act of 1962. Section 209 is a general authority that authorizes surveys in harbors and rivers in Hawai`i "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

1.2 Project Purpose and Need

The purpose of the project is to reduce flood hazards within the watershed. A high risk of flooding exists within the Ala Wai watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for this study, it is estimated that the Ala Wai Canal has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood[2] before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems.

Overtopping of the Canal has previously flooded Waikiki multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Manoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85 million in damages (USACE, 2006a). Multiple other past flood events have been documented within the watershed over the course of the past century. In addition to recorded property damages, these events have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE, 2006).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within this area, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikiki on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikiki crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $723 million in structural damages alone (2013 price levels).

1.3 Project History

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and

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1 The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

2 The 1-percent ACE floodplain is the area that is inundated by a flood with a 1-percent chance (1 in 100) of occurring in any single year. These are also commonly referred to as the 100-year floodplain and 100-year flood (but do not mean that this degree of flooding occurs every 100 years). This definition also applies to floods of other magnitudes (for example, a 20-year flood is a flood that has a 5-percent chance of occurring and a 10-year flood has a 10-percent chance of occurring in any single year, respectively).

restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act of 1974) to determine the potential flood risk to the Waikiki area, in response to a request by the Land Division of DLNR. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several mitigative measures and conceptual alternatives that could potentially minimize flood damages to Waikiki and surrounding area. The results of this technical study were used to establish that the USACE could be involved in the investigation of flood damage reduction in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The FCSA was executed between USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and an EIS scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Manoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study, such that the project could be expanded to include the upstream portions of the Ala Wai watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received federal funds to identify specific actions to address flooding in Manoa Valley. The Manoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems.[3] However, because of insufficient federal funding to complete the project, the Manoa Watershed Project was terminated before implementation.

Information developed through the Manoa Watershed Project was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second EIS scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Manoa under the Manoa Watershed Project.

In October 2012, a charette was held to re-scope the project as part of the USACE Civil Works Planning Modernization process.[4] The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division and Headquarters staff, with the non-federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the array of alternatives, and a framework for identification of the tentatively selected plan. Based on the project review at the charette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify ecosystem restoration as an objective. However, the ecosystem-related information previously identified as part of the study is being incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

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[3] This work was conducted by the USACE on behalf of NRCS via a Support Agreement in compliance with a Memorandum of Agreement between USACE and USDA, pursuant to the Economy in Government Act (31 USC S. 1535.).

[4] The charrette was held on October 16-19, 2012 with the purpose of reaching consensus on the actions needed to complete the project on budget and schedule, including a clear path for identification of the TSP (USACE, 2012). Participants included the project delivery team, non-federal sponsors, USACE Division and Headquarters staff, and cooperating agency representatives.

1.4 Consultation History

The ESA is administered by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), and establishes protection and conservation of threatened and endangered species and the ecosystems upon which they depend. Section 7 of the ESA requires that all federal agencies consult with the USFWS before initiating any action that could affect a listed species. Section 7 states that any project authorized, funded, or conducted by any federal agency should not "…jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined to be critical."

In compliance with ESA consultation requirements, USACE requested information from USFWS regarding threated and endangered species and designated critical habitat within the overall Ala Wai watershed in April 2008. The USFWS responded in May 2008, and provided a list of federal listed species and designed critical habitat that could occur within the watershed (see Attachment 1). Follow-up meetings were held with agency staff on October 14, 2014; January 23, 2015; April 14, 2015; May 26, 2015; June 5, 2015; and June 29, 2015. The purpose of these meetings was to update agency staff on the current project status, discuss the project features, and to obtain any additional input on ESA-related issues. As part of the initial meeting on October 14, 2014, USFWS staff indicated that the original species list is still considered valid (such that a new list does not need to be generated), but stated that several species of Hawaiian damselfly (*Megalagrion* spp.) were federally listed in 2012 and should also be considered; in particular, a population of blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) is known from the upper reaches of Manoa Stream.

Consultation was also initiated with NMFS in 2008; in response to USACE's request, NMFS provided a complete list of ESA-listed species under their jurisdiction in the Hawaiian Archipelago on April 25, 2008 (see Attachment 1). At the time of the original consultation, the project scope and objectives were more broadly defined, with the project area extending to include the nearshore marine waters. As the objectives and scope of the project were subsequently narrowed to focus on riverine-based flood risk management, the project is not expected to directly or indirectly affect the nearshore marine waters. Therefore, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

1.5 USACE Planning Process

General investigations, such as those carried out under Section 209 of the Flood Control Act of 1962, are funded by specific appropriations and are conducted through a feasibility planning process. The USACE feasibility planning process is comprised of six steps, as specified by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Principles and Guidelines [P&G]) (U.S. Water Resources Council, 1983) and USACE planning regulations and guidance, including Engineer Regulation (ER) 1105-2-100 "Planning Guidance Notebook" (USACE, 2000). These steps include: (1) specification of water and related land resources problems and opportunities; (2) inventory, forecast, and analysis of water and related land resources conditions within the study area; (3) formulation of alternative plans; (4) evaluation of the effects of the alternative plans; (5) comparison of the alternative plans; and (6) identification of a tentatively selected plan based upon the comparison of the alternative plans.

Recognizing the need to modernize their planning process with an emphasis on delivering high-quality feasibility studies within shorter timeframes and at lower costs, the USACE has recently applied a SMART planning approach to the six-step process (USACE, 2012a). The SMART planning approach emphasizes risk-based decision making and includes three primary requirements for feasibility studies (referred to as the "3x3x3 Rule"): completion within 3 years, at a cost of no more than $3 million, and of a "reasonable" report size (approximately 100-page report, with appendices not exceeding 3 inches). Other key components include: (1) engagement of a coordinated vertical team (comprised of USACE District, Division, and

Headquarters staff) throughout the project development process as needed to identify and resolve policy, technical, and legal issues early in the process, (2) focusing the detailed analysis and design on the tentatively selected plan, and (3) identification of the appropriate level of detail, data collection, and modeling based only on what is necessary to complete the feasibility study.

1.6 Purpose and Scope of Biological Assessment

This BA has been prepared as part of the Section 7 consultation process to provide the necessary information to support the USACE's determination as to whether the proposed project is likely to adversely affect or jeopardize the continued existence of the listed species that may occur in the project area or result in the destruction or adverse modification of critical habitat. All ESA-listed species whose known or potential distribution intersects with the action area are listed in Table 1; these are the species that are addressed by this BA. As previously described, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

TABLE 1
Federally-Listed Species Addressed by the Biological Assessment

Common Name	Scientific Name	ESA Status
MAMMALS		
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Endangered
Hawaiian monk seal	*Monachus schauinslandi*	Endangered
BIRDS		
Oahu `elepaio	*Chasiempis sandwichensis ibidis*	Endangered
Hawaiian coot	*Fulica alai*	Endangered
Hawaiian stilt	*Himantopus mexicanus knudseni*	Endangered
Hawaiian duck	*Anas wyvilliana*	Endangered
Hawaiian common moorhen	*Gallinula chloropus sandvicensis*	Endangered
INVERTEBRATES		
Oahu tree snail	*Achatinella* sp.	Endangered
INSECTS		
Blackline Hawaiian damselfly	*Megalagrion nigrohamatum nigrolineatum*	Endangered
Crimson Hawaiian damselfly	*Megalagrion leptodemas*	Endangered
Oceanic Hawaiian damselfly	*Megalagrion oceanicum*	Endangered
Orangeblack Hawaiian damselfly	*Megalagrion xanthomelas*	Candidate
PLANTS		
Haha	*Cyanea acuminate*	Endangered
Haha	*Cyanea crispa*	Endangered
Haha	*Cyanea koolauensis*	Endangered
No Common Name	*Diellia erecta*	Endangered
Nanu	*Gardenia mannii*	Endangered
No Common Name	*Gouania meyenii*	Endangered
Wawae iole	*Huperzia nutans*	Endangered
No Common Name	*Lobelia oahuensis*	Endangered
Ihi ihi	*Marsilea villosa*	Endangered
No Common Name	*Pteris lidgatei*	Endangered
No Common Name	*Schiedea nuttallii*	Endangered
No Common Name	*Spermolepis hawaiiensis*	Endangered

Critical habitat has been designated within the Ala Wai watershed for the Oahu `elepaio and for a variety of federally listed plant species, including several species listed in Table 1. The location of designated critical habitat in the Ala Wai watershed is shown in Figure 2.

2.0 DESCRIPTION OF PROPOSED ACTION AND ACTION AREA

In response to the flood-related problems and opportunities identified for the Ala Wai watershed, a variety of structural and non-structural flood risk management measures were identified, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damages. The measures are generally based on the concepts originally developed in support of the Ala Wai Flood Study (USACE, 2006) and the Manoa Watershed Project (Oceanit, 2008). The conceptual measures were sited and screened using a set of project-specific criteria, including technical feasibility, availability of land, implementation costs, O&M requirements, legal and public acceptability, and flood risk reduction. Through the screening process, some measures were eliminated while others were further refined and combined into an array of alternatives; this process incorporated the range of agency and public input obtained through scoping efforts and other stakeholder engagement activities conducted to date. This effort resulted in the tentative selection of an alternative plan for implementation (also referred to as the Tentatively Selected Plan); this alternative plan constitutes the proposed action. The measures included in the Tentatively Selected Plan are based on the following concepts:

- **Detention basin**: This measure is an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.
    - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.
    - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin (via a spillway along the stream bank), then would drain back into the stream.
- **Debris catchment**: As described above, the in-stream detention basins would include a debris catchment feature. In addition, the Tentatively Selected Plan also includes a stand-alone debris catchment structure, which would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. This structure would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation.
- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height, and would be either constructed with a minimal set back distance from the existing stream or canal walls. Local drainage patterns would be maintained to the extent possible, with flapgates/slidegates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). Non-structural measures

that have been identified as feasible options for this project include improvements to the flood warning system.

The specific measures included in the Tentatively Selected Plan (and the approximate area of disturbance associated with each) is summarized in Table 2. The location of each measure is shown in Figure 3; detailed design drawings of each measure are included in Attachment 2.

Based on the requirements of the Clean Water Act and USACE planning regulations, and after consideration of avoidance and minimization measures, it was determined that compensatory mitigation would be required for unavoidable impacts to aquatic habitat resulting from implementation of the flood risk management measures. The USACE planning process requires that the mitigation requirement be based on functional habitat loss and quantified using a habitat-based methodology (i.e., ecosystem output model). As such, the Hawai`i Stream Habitat Equivalency Procedure (HSHEP) was used to quantify the loss of habitat function.[5] Detailed stream surveys were conducted, with the resulting data processed according to the variables in the HSHEP model, as needed to quantify the habitat value of the existing and future without-project condition (in terms of habitat units [HUs]). Anticipated changes in the model variables were then defined for the with-project condition, and the modeling results were then compared to quantify the anticipated habitat loss (i.e., the mitigation requirement). Potential mitigation concepts that could be implemented to offset the anticipated loss of habitat quality were then identified, and were refined through an iterative process, in coordination with the resource agencies. The increase in habitat quality associated with each of the mitigation measures was quantified using the HSHEP model, and these results were used to combine the measures into different mitigation alternatives that could be implemented to compensate for the loss of habitat quality associated with the tentatively selected plan. The habitat modeling results and cost estimates for each mitigation alternatives were then used to complete a Cost Effectiveness and Incremental Cost Analysis (CE/ICA), which provided the basis for selection of the mitigation alternative to be included as part of the tentatively selected plan.

Based on this process, the selected mitigation alternative is comprised of two measures, both of which involve removal of a passage barrier for native aquatic species in Manoa Stream (Falls 7 and Falls 8). The location of these measures is shown in Figure 4. In each location, there is currently an in-stream structure where undercutting has resulted in an overhanging lip, which creates a passage barrier for native aquatic species. Specifically, the stream flow over these structures is free-falling and does not maintain contact with the surface of the structure, such that the native species do not have any means to migrate upstream. The proposed mitigation involves installation of grouted riprap as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat. The location of the mitigation measures are shown in Figure 4; conceptual design drawings for all of the measures that were considered (including Falls 7 and 8) are included in Attachment 2.

[5] The HSHEP model was developed to support management of Hawaii's streams and associated habitat for freshwater flora and fauna through a collaborative effort by biologists at the State of Hawai`i Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. To confirm its applicability to the Ala Wai Canal Project, the model was reviewed by the USACE Ecosystem Planning Center of Expertise (EOC-PCX), and was certified for project use on May 19, 2015.

TABLE 2
Flood Risk Management Measures in the Tentatively Selected Plan

Measure[1]	Description of Measure	Total Area of Disturbance (acres)	Permanent Footprint (acres)	Vegetation Management (acres)	Inundation Area[2] (acres)
Waihi debris and detention basin	Earthen berm, approximately 24' high and 225' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	1.0	0.5	0.3	0.6
Waiakeakua debris and detention basin	Earthen berm, approximately 20' high and 185' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	1.2	0.7	0.5	0.9
Woodlawn Ditch detention basin	Three-sided berm, approximately 15' high and 840' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm and potential flooded area	1.9	1.1	1.0	1.7
Manoa in-stream debris catchment	Concrete pad, approximately 8' wide and 60' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad	0.1	0.01	0.1	0
Kanewai Field multi-purpose detention basin	Earthen berm, approximately 7' high around 3 sides of field; inflow spillway on northwest end that allows high flows to enter basin; existing drainage pipe at south end to allow water to re-enter stream; 20-foot-wide perimeter to be maintained as cleared around the perimeter of the berm and the potential flooded area	6.5	0.9	5.5	5.1
Waiomao debris and detention basin	Earthen berm, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm; excavate behind berm to provide required detention volume	1.6	0.3	1.1	0.7
Pukele debris and detention basin	Earthen berm, approximately 24' high and 120' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	0.5	0.2	0.1	0.4
Makiki debris and detention basin	Earthen berm, approximately 24' high and 100' across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with riprap on upstream and downstream side; 20-foot-wide perimeter to be maintained as cleared around perimeter of berm	0.6	0.3	0.1	0.5
Ala Wai Canal floodwalls	Concrete floodwalls along Ala Wai Canal; ranging up to approximately 5 feet high; three pump stations and gates for existing drainage pipes	11.8	0.3	0	0
Hausten Ditch detention basin	Concrete floodwalls and earthen berm (4.3' high) to provide detention for local drainage; install slide gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal	1.4	0.2	1.1	3.5
Ala Wai Golf Course multi-purpose detention basin	Earthen berm, approximately up to 7' high around outside perimeter of golf course property with floodgate across main entrance road; passive drainage back into Ala Wai Canal	25.6	4.0	8.4	134.3

NOTES:
[1] In addition to these structural measures, the Tentatively Selected Plan would also include improvements to the existing flood warning system.
[2] Inundation area is the area behind the detention basin that is expected to be inundated during a 1-percent annual chance exceedance flood event.

Following construction, each of the flood risk management measures will be operated and maintained by the non-federal sponsor. The operations and maintenance requirements for each measure type are summarized in Table 3.

TABLE 3
Proposed Operations and Maintenance Activities

Measure Type	Summary of O&M Activities
Debris and Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year Clear accumulated debris following flood event or annually (whichever is greater)
Multi-Purpose Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of berm) twice per year Assumes minimal sediment or debris removal would be required
Debris Catchment	Clear accumulated debris twice per year
Floodwalls	Inspect and maintain gates (e.g., greased) annually Inspect, test, and maintain pump system annually Inspect floodwalls and repair as needed (e.g., patching)
Flood Warning System	Inspect and test annually (includes annual operating cost)

NOTES:
[1] Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

Separate from the Ala Wai Canal Project, the State of Hawai`i DLNR is pursuing the Woodlawn Chute Structure. Although it was originally contemplated as part of the Ala Wai Canal Project, it is now being implemented as a stand-alone project (with independent utility). No interdependent or interrelated actions have been identified to date.

2.1 Action Area

The regulations governing consultations under the ESA define action area as “all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the area.” The action area should be determined based on all direct and indirect effects of the proposed action (Federal Register, 1986).

The areas that are expected to be directly affected by project implementation include those areas within which ground-disturbing activities are proposed (including clearing, grading, vegetation trimming, staging, access, construction activities, and operations and maintenance). The areas within which these activities would occur have been delineated as the construction limits, as indicated in Figure 3 (the acreage for which is summarized in Table 2) and Figure 4 (for the compensatory mitigation measures).

Indirect effects (for example, noise-related impacts) could occur both within the construction limits, as well in those areas immediately adjacent the construction limits; for the purposes of this assessment, it is assumed that indirect effects could extend 100 feet beyond the edge of the construction limits (based on the types of potential indirect impacts). As the proposed action would modify the hydraulics within the watershed, indirect effects could also occur along the length of the stream corridors, as well as in those areas that may be inundated as a result of the flood risk reduction measures (which are also shown in Figure 3, with acreages indicated in Table 2).

Based on this rationale, the action area for the proposed project has been defined to consist of the construction limits plus a 100-foot buffer for each measure (including the compensatory mitigation measures), plus the stream corridors (Makiki, Manoa and Palolo Streams) extending downstream from the proposed measures to the mouth of the Ala Wai Canal.

3.0 EXISTING ENVIRONMENTAL CONDITIONS

In general, the natural environments within the watershed generally vary along a gradient from the ridge of the Koʻolau Mountains down to the coastal plain, with similar distribution of natural and urbanized environments in Makiki, Manoa, and Palolo valleys. Dense urban development covers the coastal plain, extending to the back of each valley floor. Several of the ridges between these major valleys are also developed, in some cases to the same degree as the valley floor (for example, Makiki Heights and St. Louis Heights), at least up to where the ridgelines narrow appreciably. Given this pattern of development, most of the natural environments are concentrated within the undeveloped portions of the upper watershed, and along the stream corridors through the urban district.

A general overview of the existing environmental conditions in the watershed is provided below, followed by a more detailed summary for each measure location in Table 4. This information is based on a series of surveys conducted within the watershed, as summarized in a natural resources assessment for the project (AECOS, 2010 and 2014). A copy of these assessments are provided in Attachment 3.

3.1 Vegetation

Vegetation communities in the upper watershed include shrubland, wet forest, and mesic forest habitats, which generally occur along a decreasing precipitation gradient, ranging from the highest elevations in the watershed down to the interface with the urban areas. The steeper slopes at and below the Koʻolau ridgeline to roughly about the 1500-foot contour are relatively undisturbed and mostly dominated by native vegetation; these windswept ridge areas support what has been classified as "Montane Wet Shrubland" (Gagne and Cuddihy, 1990), or specifically on Oʻahu as "Mixed Fern Shrubland." Below the shrubland is a wet forest, which grades into a mesic forest at lower elevations just above the urban zone. Introduced species dominate these habitats, particularly trees and shrubs such as albizia (*Falcateria moluccana*), eucalyptus (*Eucalyptus globulus* and *E. robusta*), Chinese banyan (*Ficus microcarpa*), octopus tree (*Schefflera actinophylla*), guava, java plum (*Syzygium cumini*), Christmas berry (*Schinus terebinthefolius*), mango (*Mangifera indica*), and shoebutton ardisia (*Ardisia elliptica*). Many of these species are considered to be invasive. All of the flood risk measures that are located in the undeveloped upper watershed (e.g., Waihi, Waiakeakua, Pukele, Waiomao and Makiki debris basins) are generally dominated by these vegetation types.

Riparian vegetation is present along all of the upper stream reaches, and is generally dominated by non-native species (many of which are considered invasive), including large trees such as Chinese banyan, *kukui* (*Aleurites moluccana*), mango, octopus tree, *hau* (*Hibiscus tiliaceus*), fiddlewood (*Citharexylum spinosum*), mountain apple (*Syzygium malaccense*), gunpowder tree (*Trema orientalis*), and gum (*Eucalyptus* sp.), as well as smaller herbaceous species such as exotic ginger (*Hedychium* sp.) and Job's tears (*Coix lachryma-jobi*) (Kido, 2006; Kido, 2007; Kido, 2008a; Oceanit, 2004). Within the urbanized portion of the watershed, riparian vegetation is generally limited to unchannelized stream reaches, such as along portions of Manoa Stream (for example, near the Dole Street Bridge). A majority of Palolo and Makiki streams are channelized and lack a riparian zone (Oceanit, 2004; Englund and Arakaki, 2004; Kido, 2008a). Mangrove trees (*Rhizophora mangle*) are present in some areas in the lower estuarine reaches of the Manoa–Palolo Drainage Canal and the Ala Wai Canal, although most of these reaches are comprised of concrete and

As further described in Section 4, the occurrence of federally-listed plant species is generally restricted to the higher elevations of the upper watershed. These areas, as well as the slopes of Diamond Head, have been designated as critical habitat for the conservation of these species (Figure 2). However, not all of the listed species are presently known to occupy the designated critical habitat; some have not been recorded from the watershed since early in the last century and some are possibly extinct (Federal Register, 2012). No federally-listed plant species (or designated critical habitat) are known to occur in the action area.

A summary of the existing vegetation at each measure location is provided in Table 4.

3.2 Terrestrial Wildlife

A variety of terrestrial wildlife species occur throughout the watershed, including mammals, birds, invertebrates and insects (Mitchell et al., 2005). The vast majority of these species are non-native, many of which are considered invasive and pose a significant management concern (e.g., feral pig [*Sus scrofa*], mongoose [*Herpestes aruopunctatus*], and various bird species). However, there are several federally listed species that could potentially occur within the watershed.

The forested areas of the watershed provide habitat for native bird populations, including the federally listed Oahu *`elepaio* (*Chasiempis sandwichensis ibidis*); the upper-most portion of the watershed is designated as critical habitat for this species, although it is not believed to be currently occupied. Other federally listed species that are known from the upper watershed include endemic tree snails (*Achatinella* sp.) and the blackline Hawaiian damselfly species (*Megalagrion nigrohamatum nigrolineatum*). In addition, the Hawaiian hoary bat *ʻōpeʻapeʻa* [*Lasiurus cinereus semotus*], the only land mammal native to Hawaii, could potentially occur in the watershed.

In the lower portions of the watershed, federally listed waterbird species could potentially occur; these include the Hawaiian coot (*ʻalae ke'oke'o*), Hawaiian stilt (*ae'o*), Hawaiian duck (*Anas wyvilliana*), and Hawaiian moorhen (*ʻalae ʻula*). Although unlikely given their known distribution, these species could possibly use estuarine areas within the watershed as resting habitat.

Federally listed species, including those described above, are further discussed in Section 4.

3.3 Aquatic Species

Native freshwater fish in Hawai'i are limited to five gobiid species (*o'opu*), including one indigenous (*o'opu nakea* [*Awaous guamensis*]) and three endemic (*o'opu alamoʻo* [*Lentipes concolor*], *o'opu nopili* [*Sicyopterus stimpsoni*], and *o'opu naniha* [*Stenogobius hawaiiensis*]) gobies, and one endemic eleotrid (*o'opu akupa*, *Eleotris sandwicensis*) (Kinzie, 1990). The native stream macrofauna assemblage also includes several shrimp species (*'opae kala'ole* [*Atyoida bisulcata*] and *ʻopae 'oeha'a* [*Macrobrachium grandimanus*]), and mollusk species (*hapawai* [*Neritina vespertina*] and *hihiwai* [*Neritina granosa*]). As part of their lifecycle, the adults of each of these species live and breed in freshwater streams; newly hatched larvae drift to the ocean, remaining there for several months before migrating back to freshwater habitat, cued by freshets (Yamamoto and Tagawa, 2000). None of the native stream species are federally listed under the ESA.

All of these native species have been recently documented in the Ala Wai watershed, with the exception of *o'opu alamoʻo* and *hihiwai* (Parnham et al., 2008; Kido, 2008a). The presence of native species of stream macrofauna can often be used as an indicator of stream ecosystem health (Kido, 2008b). In this context, portions of the watershed display signs of good stream habitat. However, the overall watershed lacks healthy populations of native fishes and aquatic invertebrates, likely because of degradation and fragmentation of usable habitat in the urban zone (Oceanit, 2004). Recent observations of native species are typically limited to only a few individuals in the higher reaches of the upper watershed and in the estuarine environment. With these notable exceptions, the extant aquatic macrofauna is dominated by non-native species (Englund and Arakaki, 2004; Kido, 2008a).

TABLE 4
Existing Conditions at Flood Risk Management Measure Locations (summarized from AECOS, 2014)

Measure	General Location	Existing Environmental Conditions
Waihi debris and detention basin	Waihi Stream, ~1,200 feet above the upper extent of development in Manoa Valley (~380' in elevation).	Site is characterized by forested habitat, with dominant species including monkeypod (*Albizia saman*), Chinese banyan, gunpowder, *kukui*, swamp mahogany (*Eucalyptus robusta*), mango, Java plum, and Christmas berry; pothos vine (*Epipremnum pinnatum*) is prominent climbing the trees. Site is located on the lower edge of a prominent belt of albizia trees.
Waiakeakua debris and detention basin	Waiakeakua Stream, ~200 feet above the upper extent of	Site (including the staging area) is characterized by forested habitat, with species including guarumo (*Cecropia obtusifolia*), macaranga (*Macaranga tanarius*), hau (*Hibiscus tiliaceus*), bamboo, and the shrub *Odontonema strictum*. Other species

TABLE 4
Existing Conditions at Flood Risk Management Measure Locations (summarized from AECOS, 2014)

Measure	General Location	Existing Environmental Conditions
	development in Manoa Valley (~300' in elevation).	include red ginger (*Alpinia purpurata*), shoebutton ardesia (*Ardisia elliptica*), and white shrimp plant (*Justicia betonica*); pothos vine is prominent climbing the trees; site is located on the lower edge of a prominent belt of albizia trees.
Woodlawn Ditch detention basin	Woodlawn Ditch (manmade tributary to Manoa Stream), adjacent to E. Manoa Road (~200' in elevation)	Site is characterized by mixed secondary forest and tended farm/garden areas; forest is nearly monotypic stand of macaranga (*Macaranga tanarius*), with a limited number of tropical almond (*Terminalia catappa*), shoebutton ardisia, Chinese hibiscus (*Hibiscus rosa-sinensis*), coconut (*Cocos nucifera*), African tulip (*Spathodea campanulata*), and small albizia.
Manoa in-stream debris catchment	Middle reach of Manoa Stream, directly adjacent to lower edge of Manoa District Park (~160' in elevation)	Site is characterized as open stream channel, with minimal riparian vegetation (some shade is provided by trees in the adjacent residential properties); the staging areas within Manoa District Park is dominated by lawn, with some planted trees including Formosan *koa* (*Acacia confusa*), *kukui*, coconut, and royal palms (*Roystonia regia*).
Kanewai Field multi-purpose detention basin	Lower reach of Manoa Stream, just below Dole Street	Site is comprised of maintained field for park; predominantly a mowed lawn with two large mango trees near the west corner site; adjacent stream includes a riparian corridor with various mature trees of Java plum, *hau*, mango, macaranga, and monkeypod.
Waiomao debris and detention basin	Pukele Stream, adjacent to residences on Waiomao Rd. (~380' in elevation)	Site is comprised of a heavily forested riparian zone adjacent to residential properties; dominated by non-native species including octopus tree, gunpowder, monkeypod, macaranga (Macaranga tanarius), mango, and fiddlewood; pothos vine is prominent climbing the trees.
Pukele debris and detention basin	Pukele Stream, adjacent to residences on Ipulei Place (~400' in elevation)	Site includes the maintained lawns of two residential homes; right bank of the stream is dominated by weedy species including Guinea grass (*Panicum maximum*) and castor bean (*Ricinus communis*); left bank is forested with non-native species including Chinese banyan, swamp mahogany, and Java plum
Makiki debris and detention basin	Makiki Stream, directly adjacent to Makiki Heights Drive (~160' in elevation).	Site is characterized by dense riparian forest; dominant species include Chinese banyan, African tulip (*Spathodea campanulata*), gunpowder tree, she oak (*Grevillea robusta*), and mango. The understory is as well dominated by a variety of nonnative shrubs and vines, notably pothos (*Epipremnum pinnatum*), shrimp plant (Justicia betonica), and Madeira vine (*Anredera cordifolia*). Staging area includes open *kukui* copse, with open floor.
Ala Wai Canal floodwalls	Ala Wai Canal	Vegetation along the Canal is generally limited to landscaping, with a single row of trees lining most of both sides of Canal, including *niu* (*Cocos nucifera*), with some milo (*Thespesia populnea*) and monkeypod.
Hausten Ditch detention basin	Hausten Ditch (drainage input to Ala Wai Canal)	Hausten Ditch is dominated by non-native species, including mangroves; native species that occur along ditch (including *'akulikuli* [*Sesuvium portulacastrum*]; *kou* [*Cordia subcordata*], and *kīpūkai* [*Heliotropium Curassavicum*]) are common species. The remainder of the site is a maintained lawn, with scattered *niu*, milo and monkeypod trees.
Ala Wai Golf Course multi-purpose detention basin	Ala Wai Canal	Landscaped vegetation for golf course greens and fairways; site also includes two shallow basins and a ditch that are identified as seasonally flooded wetland features on the National Wetlands Inventory (USFWS, 2006a)

4.0 POTENTIALLY AFFECTED LISTED SPECIES AND CRITICAL HABITAT

In order to identify whether any of the listed species potentially occurring in the watershed could be affected by the project, the species habitat requirements and known distribution was assessed relative to the action area. In addition, the location of designated critical habitat was mapped to identify any potential overlap with the action area. Following is a summary of the potentially affected species within the watershed, and the effects analysis for each.

4.1 Hawaiian hoary bat (*Lasiurus cinereus semotus*)

The Hawaiian hoary bat (*ope'ape'a*) was listed as an endangered species in October 1970 (Federal Register, 1970). The original recovery plan was approved in May 11, 1998; a five-year review was conducted in September 2011 (USFWS, 2011a). Critical habitat has not been designated for this species.

The species is endemic to Hawaii; it is the only native terrestrial mammal that occurs in the State. It is still believed to be present on all of the main islands, with the largest populations known from Hawai`i and Kauai. Information about the species abundance is currently based on localized survey information, such that there are no reliable current population estimates. There is also limited information relative to species distribution, but the species has been observed year-round across a variety of habitats and elevations, generally ranging from the coast up to elevations of 7,500 feet (but possibly as high as 13,000 feet) (USFWS, 2011b).

The Hawaiian hoary bat is a solitary species that typically leaves its roost shortly before or after sunset and returns before sunrise. Roosting has been documented in a wide variety of both native and non-native trees, including native species (e.g., *ohia lehua* [*Metrosideros polymorpha*], *hala* [*Pandanus tectorius*], *pukiawe* [*Styphelia tameiameiae*], Polynesian-introduced species (e.g., *kukui* [*Aleurites moluccana*], and non-native species (e.g., Java plum [*Syzygium cumini*]) (USFWS, 1998a). Recent data from Hawai`i Island suggest that roosting occurs in trees at heights more than 20 feet off the ground (Bonaccorso, as reported in USFWS, 2011a). Hawaiian hoary bats forage across a range of open areas (e.g., fields, shoreline, and streams/ponds), as well as forest edges and clearings.

Threats to this species include habitat loss, predation, roost disturbance, and disease. The species' decline may have primarily been due to the historic loss of tree cover associated with deforestation in the early 19th century. Current threats may also include barbed wire fences, wind turbines, and pesticides (including contamination of prey) (USFWS, 1998a).

<u>Potential to Occur in the Action Area</u>

Little is known about the species' occurrence across the island of Oahu, including the Ala Wai watershed. However, based on the habitat preferences, it is possible that it could occur within the action area. Specifically, all of the detention basins in the mid to upper portions of the watershed (including those on Waihi, Waiakeakua, Woodlawn Ditch, Pukele, Waiomao, and Makiki Streams) include forested habitat with tall trees that may be used for roosting. Several of the measure locations in the lower watershed, such as the Kanewai Field, Hausten Ditch and Ala Wai golf course detention basins, may also provide suitable foraging habitat; however, the habitat value of these sites is likely diminished by the extensive urbanization in the surrounding areas.

<u>Potential Effects of the Proposed Action</u>

Should they occur, Hawaiian hoary bats could be directly or indirectly impacted by the project. Direct effects could include mortality or other forms of take (e.g., harm or harrassment) to individual bats as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt bats that are present within the action area. To avoid and minimize the potential for these impacts, vegetation clearing for the project would be performed during times of the year when Hawaiian hoary bats are not expected to be breeding to avoid potential for harm or disruption to non-volant juvenile bats; specifically, trees greater than 15 feet in height would not be cleared between July 1 and August 1. In addition, all construction activities would be scheduled to occur during daytime hours, thus avoiding potential bat foraging activities, which typically occur in the evening hours.

Other effects could include permanent loss or temporary impacts to habitat. However, given the amount of habitat available throughout the upper watershed, tree clearing within the action area is not expected to measurably decrease the amount of forest available to the local population of bats for roosting. In addition, as the total population of bats on Oahu is believed to be small (USFWS, 1998a) and trees are plentiful, roost trees are not expected to be a limiting factor for the species on Oahu. The forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or structure between adjacent patches. For these reasons, it is expected that any bats displaced by the clearing would readily find alternate roost sites in surrounding undisturbed forest.

Effects Determination

As described above, seasonal restrictions for tree trimming/clearing and enforcement of construction hours will be incorporated to avoid and/or minimize the potential for impacts to the Hawaiian hoary bat, should the species be present in the action area. With implementation of these measures, impacts to the Hawaiian hoary bat are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.2 Hawaiian monk seal (*Monachus schauinslandi*)

The Hawaiian monk seal (*‘ilio-holo-i-ka-uaua*) was listed as endangered under the ESA in November 1976 (Federal Register, 1876). The original recovery plan was approved in March 1983; the most recent revision was made in August 2007 (NMFS, 2007). Critical habitat was designated in the northwest Hawaiian Islands for this species in 1986 (NMFS, 2007); no critical habitat occurs within the action area.

The species is endemic to the Hawaiian archipelago; it is one of only two remaining monk seal species, and is considered to be one of the rarest marine mammals in the world. Its range is generally limited to the Hawaiian archipelago, with most of the population occurring in the northwestern Hawaiian Islands, but the population in the main Hawaiian Islands appears to be expanding. Overall, the species has been steadily declining over time, with an estimated total of 1,200 seals remaining throughout the species’ entire range. This population size is considered to be very small, raising concerns about the long-term maintenance of genetic diversity (NMFS, 2007).

Hawaiian monk seals spend approximately two-thirds of their time in marine waters, primarily in areas surrounding atolls, islands, and areas farther offshore on reefs and submerged banks. They forage for food across a range of benthic substrates (generally in waters 60-300 feet deep), feeding on a variety of fish, cephalopods and crustaceans; they may also use deepwater coral beds as foraging habitat. Terrestrial habitats are primarily sandy beaches (and occasionally other shoreline areas), which are used as haul-outs for pupping, nursing, molting and resting.

Threats to Hawaiian monk seals include both natural and human-induced factors, including reduction of habitat and prey (at least in part due to environmental change), predations by sharks, disease, entanglement in marine debris, and human disturbance (NMFS, 2007).

Potential to Occur in the Action Area

The proposed action is focused on stream-related flood risk reduction and the action area does not include any marine or coastal habitat. As such, there is no potential for the Hawaiian monk seal to occur in the action area.

Potential Effects of the Proposed Action

The proposed action will not directly or indirectly affect the Hawaiian monk seal, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on the Hawaiian monk seal.

4.3 Oahu `*Elepaio* (*Chasiempis sandwichensis ibidis*)

The Oahu `elepaio was listed as endangered under the ESA on April 18, 2000; the recovery plan for the species was approved in 2006 (USFWS, 2006b). Critical habitat for the Oahu `elepaio was designated in December 2001. The critical habitat consists of five units, which encompass a total area of approximately 65,879 acres in the Ko`olau and Wai`anae Mountains (Federal Register, 2001). Unit 5 encompasses over 10,000 acres of the southern Ko`olau Mountains and, in the Ala Wai watershed, includes most of the undeveloped upland areas from Tantalus to Mau'umae Ridge and beyond (Figure 2); the action area does not overlap with any portion of the designated critical habitat.

Historically, the species is believed to have been abundant across the more than 300,000 acres of forest habitat on Oahu. The geographic range of Oahu `elepaio has declined significantly, with the species currently occupying only about 12,811 acres, or approximately 4 percent of its former range (USFWS, 2006; Vander Werf et al., 2013). As of 2001, the population was estimated to include approximately 1,980 birds distributed across fragmented habitat in the Wai`anae Mountains and the Ko`olau Mountains, with three relatively large populations and several smaller remnant populations in each mountain range. Recent surveys indicate continued decline of the species, with a total estimated population size of 1,261 birds that have been fragmented into four large subpopulations and 12 smaller subpopulations (VanderWerf et al., 2013).

Oahu `*elepaio* nest and forage in a variety of native and non-native forest types across a range of elevations, but are most common in riparian vegetation along streambeds and in mesic forest habitats with continuous tree canopy and dense understory. Habitat structure appears to be more important than species composition, and the species has adapted to use introduced species in disturbed forest habitat (VanderWerf et al., 1997). Common native plants in areas where `*elepaio* occur include *alahe`e* (*Psydrax odorata*), *pāpala kēpau* (*Pisonia umbellifera*), *lama* (*Diospyros sandwicensis*), *hame* (*Antidesma platyphyllum*), *māmaki* (*Pipturus albidus*), *kaulu* (*Sapindus oahuensis*), and `*āla`a* (*Pouteria sandwicensis*); common introduced plants include strawberry guava (*Psidium cattleianum*), common guava (*Psidium guajava*), *kukui* (*Aleurites moluccana*), mango (*Mangifera indica*), and Christmas berry (*Schinus terebinthifolius*). The nesting season usually extends from February to May, but active nests have been documented from January to July (VanderWerf, 1998).

Much of the species' historic decline is believed to be attributed to habitat loss, particularly as a result of extensive development and urbanization at lower elevations. In recent years, the greatest threat to the species is associated with predation by alien black rats (*Rattus rattus*) and mosquito-borne diseases (VanderWerf et al., 2013). Other current threats include avian malaria and pox, although there is some evidence that the species is building an immunity to the poxvirus. In addition to these threats, natural processes (e.g., loss of genetic variability, natural disasters, etc.) further threaten the small, remnant populations.

Potential to Occur in the Action Area

A recent survey for Oahu `elepaio indicated that the population in the Ko`olau Mountains is comprised of 545 males and 317 females. The geographic range is approximately 9,749 acres, and is fragmented into 2 larger subpopulations in the central and southeastern Ko`olau Mountain (each with more than 400 birds), a smaller subpopulation in Waikane and Kahana Valleys (25 birds), and three small remnant populations in Nuuanu, Waihee and Waiahole Valleys (less than 4 birds each) (VanderWerf et al., 2013). Previous data indicated populations in both Manoa and Palolo Valleys (with 2 birds and 46 birds, respectively); as of 2012, approximately 12 birds (5 pairs and 2 single males) are known from Palolo valley, and the species is no longer believed to occur in Manoa valley (VanderWerf et al., 2013).

The portions of the action area within Manoa Valley (i.e., Waihi and Waiakeakua detention basins) contain suitable habitat; however, as described above, the species is no longer believed to occupy any portion of Manoa Valley. The portions of the action area within Palolo Valley (i.e., Pukele and Waiomao detention basins) also contain suitable habitat, but these areas are considerably downslope from the lower edge of the species' current geographic range. Given the proximity to the known range, it is possible (although unlikely) that the species could reoccupy portions of the action area.

Critical habitat for this species is located in the upper portions of the watershed, but none is present within the action area.

Potential Effects of the Proposed Action

Although species occurrence within the measure locations is unlikely, should they occur, Oahu `elepaio could be directly or indirectly impacted by the project. Direct effects could include mortality or other forms of take (e.g., harm or harassment) to individual birds or destruction of their nests as a result of heavy equipment used to clear the site and construct the flood risk management structures. The use of heavy equipment would also generate noise, which could disrupt birds that are present within the action area. To avoid and minimize the potential for these impacts, trimming or clearing of vegetation in areas of suitable habitat would be restricted during the `elepaio nesting season (January through June).

Other effects could include permanent loss or temporary impacts to habitat. However, vegetation clearing within the action area is not expected to measurably decrease the amount of forest available for `elepaio habitat. The total population of `elepaio in this region is small, and forested areas are readily available, such that habitat is not expected to be a limiting factor for the species. In addition, the forest habitat in the upper portions of the watershed is fairly homogenous, and does not vary significantly in composition or structure between adjacent patches. Therefore, in the unlikely event that `elepaio were to reoccupy this area, it is expected that they would readily find alternate habitat in the surrounding undisturbed forest.

Effects Determination

As described above, species occurrence within the action area is unlikely, but seasonal restrictions for trimming/clearing of vegetation would be incorporated to avoid and/or minimize the potential for impacts to the Oahu `elepaio, should it occur in the action area. With implementation of these measures, impacts to the Oahu `elepaio are expected to be discountable, such that the proposed action may affect, but is not likely to adversely affect the species.

As no designated critical habitat occurs within the action area, there will be no effect on critical habitat for Oahu `elepaio.

4.4 Hawaiian coot (*Fulica alai*)

The Hawaiian coot (*Fulica alai*) was listed as endangered in 1970. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

The Hawaiian coot is an endemic, non-migratory waterbird species that was historically known to occur on all of the main Hawaiian islands, except Lana`i and Kaho`olawe. No population estimates are available for the early 1900s, but the species' decline and potential threat of extinction was documented in the mid-1900s (Schwartz and Schwartz, 1949); the population was documented at fewer than 1,000 in the 1950 and 1960s (USFWS, 1978). Currently, Hawaiian coots inhabit all of the main Hawaiian islands except Kaho`olawe. Biannual waterbird surveys from 1997 through 2006 indicate the Hawaiian coot population generally averages between approximately 1,500 and 2,800 birds; on Oahu, the population generally fluctuates between 500 and 1000 birds (DOFAW, 1976-2008). Most of these occur in coastal wetlands, including the James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Kuilima wastewater treatment plant, Ka`elepulu Pond in Kailua, Pearl Harbor National Wildlife Refuge, and the Hawai`i Prince Golf Course (USFWS, 2011c).

Coots typically use naturally occurring ponds and wetlands on the coastal plain, in areas with emergent plant growth interspersed with open water (Brisbin et al., 2002). They also use aquatic features actively managed for taro cultivation and fish production, and are known to readily disperse between areas of suitable habitat (USFWS, 2011c; Engilis and Pratt, 1993). Primary food sources include invertebrates and aquatic vegetation, with foraging in mud/sand substrate and diving near the water surface. They nest in open freshwater and brackish ponds, constructing floating or semi-floating nests using aquatic vegetation; false nests are also constructed for use as loafing or brooding platforms (USFWS, 2011c). Habitat suitability is limited in large, deep ponds (USFWS, 2011c). Although coots may prefer freshwater for nesting, they are commonly found in brackish water (Berger, 1981), loafing on rafts of vegetation, mud bars, and false nests, as well as on open water.

Potential to Occur in the Action Area

The only suitable habitat that could support this species within the action area are very small pockets of wetland habitat; these are limited to isolated features within the Ala Wai golf course and possibly along Hausten Ditch and/or the upper edges of the Ala Wai Canal. However, these areas are very small and provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though unlikely), that Hawaiian coots could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that coots are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of coots (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, the detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect coots.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability of species occurrence in the action area. Given this fact, coupled with the nature of activities proposed in these areas, impacts to the Hawaiian coot are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.5 Hawaiian stilt (*Himantopus mexicanus knudseni*)

The Hawaiian stilt (*Himantopus mexicanus knudseni*) was listed as endangered in 1970. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

The Hawaiian stilt is endemic to Hawai`i and was historically known to occur all of the major islands except Lāna`i and Kaho`olawe (but were subsequently documented on Lāna`i starting in 1989) (Engilis and Pratt, 1993). Although there is no estimate of historical numbers, stilts were identified as common in the late 1800s. Population declines were documented as early as 1900, with loss of wetland habitat identified as the primary cause of decline; other contributing factors include predation by introduced species, habitat overgrowth by invasive plant species, and hunting (USFWS, 2011c).

Biannual surveys conducted from 1998 through 2007 suggest that, on average, the population is comprised of approximately 1,500 stilts and is relatively stable (DOFAW, 1976-2008; Reed and Oring, 1993; USFWS, 2011c). Oahu supports the largest number of Hawaiian stilts, with approximately 450 to 700 birds in any given year (Engilis, 1988; DOFAW, 1976-2008). Most of these occur at the James Campbell National Wildlife Refuge, the Kahuku aquaculture ponds, the Pearl Harbor National Wildlife Refuge, and on Nu`upia Ponds in Kaneohe; populations also exist at the Chevron Refinery, the fishponds at Kualoa Beach Park, at Salt Lake District Park, and at scattered locations along the northern and eastern coasts.

The Hawaiian stilt is primarily found in low-elevation wetlands with sparse, low-growing vegetation and water depths less than approximately 9 inches. Stilts forage for a variety of invertebrates in fresh, brackish, or saline waters. Stilts use open or sparsely vegetated flats and pasture lands for loafing, as well as other open areas with good visibility. Nesting predominantly occurs in areas with little to no cover, which most likely allows predators to be easily spotted.

Potential to Occur in the Action Area

A small amount of potentially suitable habitat occurs within the action area; these areas include the aquatic features within the Ala Wai golf course, Hausten Ditch and possibly the upper reaches of the Ala Wai Canal. However, these areas are limited in size and provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); they are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though relatively unlikely), that Hawaiian stilts could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that stilts are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of stilts (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, areas within the Hausten Ditch and Ala Wai golf course detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract a larger number of waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect stilts.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability that Hawaiian stilts would occur in the action area. Given this fact, coupled with the nature of the proposed activities, impacts to the Hawaiian stilt are expected to be insignificant, such that the proposed action may affect, but is not likely to adversely affect the species.

4.6 Hawaiian duck (*Anas wyvilliana*)

The Hawaiian duck (*Anas wyvilliana*) was listed as endangered in 1967. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

Hawaiian ducks were known historically from all of the main Hawaiian Islands except Lāna`i and Kaho`olawe. Although there is no estimate of historical numbers, Hawaiian ducks were identified as common in the 1800s. By the 1960s, Hawaiian ducks were nearly extirpated on all islands, except Kauai and possibly Niihau; Hawaiian ducks were subsequently reintroduces to Oahu, Maui and Hawai`i (USFWS, 2011c).

Although populations of Hawaiian ducks are believed to still exist on each of these islands, the remaining populations are affected by hybridization with feral mallards. Engilis et al. (2002) estimated the statewide population of pure Hawaiian ducks to be 2,200 birds, with 2,000 on Kaua`i and 200 on Hawai`i. Allozyme data indicate there has been extensive hybridization between Hawaiian ducks and feral mallards on O`ahu, with the near disappearance of Hawaiian duck alleles from the population (Browne et al. 1993). Hawaiian ducks are still reported from wetlands on O`ahu's windward coast (Kawainui, Hāmākua, and He`eia Marshes, Ka`elepulu and Nu`upia Ponds, and Ho`omaluhia Botanical Garden), north shore (James Campbell National Wildlife Refuge, Kahuku aquaculture ponds, Punaho`olapa, Hale`iwa), Pearl Harbor area (Pearl Harbor National Wildlife Refuge, Pouhala Marsh), and Lualualei; however, it is not known whether these individuals are actually Hawaiian ducks or hybrids (USFWS, 2011c).

The Hawaiian duck historically used a wide variety of natural habitats for nesting and feeding, including freshwater marshes, flooded grasslands, coastal ponds, and streams at elevations ranging from sea level to 3,000 meters (9,900 feet); other areas that may be utilized as habitat include agricultural and artificial wetlands, sewage treatment ponds, irrigation ditches, and reservoirs. Wetlands that are relatively small, isolated, or close to houses are less likely to be occupied (Uyehara et al., 2008). Nests are established on the ground, which makes them highly vulnerable to predators (e.g., mongoose, cats).

<u>Potential to Occur in the Action Area</u>

The aquatic environments within the action area provide suitable habitat for the Hawaiian duck. However, given the extensive urban development, it is unlikely that these areas would be utilized by the species. Coupled with the very low number of Hawaiian ducks that remain on Oahu (none of which have been reported from this region on Oahu), the species is not expected to occur in the action area.

<u>Potential Effects of the Proposed Action</u>

As the Hawaiian duck is not expected to occur in the action area, the proposed action is not expected to affect this species.

<u>Effects Determination</u>

The proposed action is expected to have no effect on the Hawaiian duck.

4.7 Hawaiian moorhen (*Gallinula chloropus sandvicensis*)

The Hawaiian moorhen (*Gallinula chloropus sandvicensis*) was listed as endangered in 1967. The original recovery plan was approved in 1978, and most recently revised in 2011 (USFWS, 2011c). Critical habitat has not been designated for this species.

Historically, the Hawaiian moorhen was found on all of the main Hawaiian Islands except Lāna`i and possibly Ni`ihau. The population (especially on Oahu, Maui and Molokai) was drastically reduced by the late 1940s; the species was subsequently extirpated on Maui and Molakai and reintroduction efforts failed (presumably due to nest predation). Hawaiian moorhens are currently found only on the islands of Kaua`i and O`ahu. The population is small, but relatively stable, with an average of 287 birds from 1998 to 2007 (DOFAW 1976-2008). Approximately half of the birds are found on Oahu; they are widely distributed on the island, but are most prevalent on the northern and eastern coasts between Hale`iwa and Waimanalo. Small numbers occur in Pearl Harbor, where they foraging in semi-brackish water. The population on the leeward coast is limited to Lualualei Valley (USFWS, 2011c).

Hawaiian moorhen habitat consists of freshwater marshes, taro patches, reedy margins of water courses (e.g., streams, irrigation ditches), reservoirs, wet pastures, and occasionally saline and brackish water areas. They appear to prefer lowland freshwater habitats. Key habitat features include dense stands of robust emergent vegetation near open water, floating mats of vegetation, water depths less than 1 meter (3.3 feet), and fresh water (as opposed to saline or brackish water). Interspersion of emergent vegetation and open water is also believed to be important.

Potential to Occur in the Action Area

The only suitable habitat that could support this species within the action area are very small pockets of wetland habitat; these are limited to isolated features within the Ala Wai golf course, and possibly Hausten Ditch and the upper reaches of the Ala Wai Canal. However, these areas lack some of the key habitat features, and therefore are expected to provide very minimal habitat value in comparison to other nearby areas (e.g., Pearl Harbor National Wildlife Refuge); these areas are not expected to provide suitable nesting habitat, but could be used for resting habitat. As such, it is possible (though unlikely), that Hawaiian moorhens could occur in the action area.

Potential Effects of the Proposed Action

As described above, the extent and quality of potentially suitable habitat within the action area is very limited, and is likely to only be used as resting habitat (if at all). In the unlikely event that moorhens are present within the action area, it is expected that they would readily disperse to nearby areas with higher quality habitat (e.g., Pearl Harbor National Wildlife Refuge) in response to disturbance; as such, the potential effects of the proposed action are expected to be limited to temporary construction-related disturbance (e.g., noise). Injury or mortality of moorhens (or their nests) is not expected.

Areas of potentially suitable wetland habitat may be temporarily unavailable during construction (due to increased levels of disturbance), but sufficient habitat is expected to be available in nearby areas (e.g., Pearl Harbor National Wildlife Refuge). Following construction, the extent and quality of habitat is expected to be the same as the existing condition. During large-scale flood events, the detention basins would be inundated for short periods (i.e., less than 24 hours) which could temporarily increase the extent of potential habitat. Although increased habitat may be viewed as a benefit, in heavily urbanized areas (such as the Ala Wai watershed), it can also create an attractive nuisance for waterbird species. Specifically, areas of increased habitat may attract waterbirds, which are then vulnerable to predator species that are prevalent in an urban environment (e.g., feral cats, mongoose). However, given the low probability of species occurrence and the infrequent recurrence and short-term duration of flooding, these conditions are not expected to significantly affect moorhen.

Effects Determination

Based on the minimal extent and quality of suitable habitat, there is a low probability of species occurrence in the action area. Given this fact, coupled with the nature of activities proposed in these areas, impacts to the Hawaiian moorhen are expected to be insignificant, such that the proposed action is not likely to adversely affect the species.

4.8 Blackline Hawaiian Damselfly (*Megalagrion nigrohamatum nigrolineatum*)

The blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was also designated in 2012; Unit 11 is located within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The blackline Hawaiian damselfly was known historically from the Ko`olau and Wai`anae Mountains, at elevations ranging from sea level to over 2,400 feet (730 m) (Williams, 1936; Polhemus, 1994). There are currently 17 known populations from lowland wet ecosystem in the headwaters and upper reaches of streams of the Ko`olau Mountains.

This species occurs in the slow sections or pools along mid-reach and headwater sections of perennial upland streams and in seep-fed pools along overflow channels bordering such streams. Colonies are constrained to portions of streams not occupied by non-native predatory fish (for example, stream reaches above geologic or manmade barriers) (Federal Register, 2012).

The blackline Hawaiian damselfly is threatened by habitat loss, as well as competition and predation by non-native fish species. Habitat loss may occur as a result of invasive California grass (*Brachiaria mutica*), which forms dense stands that can eliminate standing water.

Potential to Occur in the Action Area

The blackline Hawaiian damselfly has been observed in and in the immediate vicinity of the proposed Waihi Stream debris and detention basin's footprint (Figures 5 and 6). Observations of individual sightings and potential breeding areas by FWS biologists were documented in the Draft Fish and Wildlife Coordination Act Report dated November 2015 that was developed for this project under consultation with the Service under the Fish and Wildlife Coordination Act of 1934 (16 U.S.C. 661 *et seq.*; 48 Stat. 401), as amended.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

At Waihi Stream, both riffle and pool habitat and riparian habitat contribute to supporting the extant population of federally listed damselflies. Some indirect and direct permanent loss of habitat due to the construction of the basin, staging area and access road would be anticipated. Additional permanent loss of habitat due to maintenance removal of debris in the detention catchment area is also likely.

Effects Determination

Due to the documented observation of the species and potential breeding habitat within and in the vicinity of the proposed basin footprint, indirect and direct impacts during construction and maintenance operations is likely to result in a "take" of the species as defined under the ESA. Therefore, the proposed action may affect and is likely to adversely affect the blackline Hawaiian damselfly.

4.9 Crimson Hawaiian Damselfly (*Megalagrion leptodemas*)

The crimson Hawaiian damselfly (*Megalagrion leptodemas*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was designated in 2012; Unit 11 is within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The crimson Hawaiian damselfly was known historically from the windward side of the Wai`anae Mountains and scattered locations in the Ko`olau Mountains, but is currently only known from 3 locations in the Ko`olau Mountains: Moanalua, north Halawa, and Maakua (Federal Register, 2012). This species is found in lowland wet and wet cliff ecosystems, and breeds in the slow reaches of streams and seep-fed pools (Williams, 1936; Polhemus, 1994). All colonies are constrained to portions of streams not occupied by non-native predatory fish (for example, stream reaches above geologic or manmade barriers) (Federal Register, 2012).

The crimson Hawaiian damselfly is threatened by habitat loss and alteration, as well as competition and predation by non-native fish species. Given the small remaining populations sizes, the species is also threatened by natural events (e.g., drought) that could extirpate the remaining populations.

Potential to Occur in the Action Area

Pockets of suitable habitat for this species occurs in the upper reaches of the action area; however, it is now restricted to three locations in the Ko`olau Range (Federal Register, 2012). Given its current range, this species is not expected to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

<u>Potential Effects of the Proposed Action</u>

The proposed action is not expected to directly or indirectly affect the crimson Hawaiian damselfly, or its critical habitat.

<u>Effects Determination</u>

The proposed action is expected to have **No Effect** on the crimson Hawaiian damselfly.

4.10 Oceanic Hawaiian Damselfly (*Megalagrion oceanicum*)

The oceanic Hawaiian damselfly (*Megalagrion oceanicum*) was listed as endangered in September 2012; a recovery plan has not yet been approved. Critical habitat was designated in 2012; Unit 12 is within the upper portions of the Ala Wai watershed (Federal Register, 2012).

The oceanic Hawaiian damselfly is endemic to the island of Oahu, and was known historically from both the Ko`olau and Wai`anae Mountains. It is now believed to be extirpated from the Wai`anae Mountains, and is only known to occupy the upper reaches (above 100 meters [300 feet]) of perennial streams on the windward side of the Ko`olau Range (Polhemus, 1994; Federal Register, 2012).

Immature stages of this species are found in swiftly flowing sections of streams, usually amid rocks and gravel in stream riffles and small cascades (Williams, 1936; USFWS, 2007). The naiads usually crawl among gravel or submerged vegetation; older naiads often forage out of the actual stream channel and have been observed among wet moss on rocks, and wet rock walls and seeps (Williams, 1936). Adults are strong flyers, and when disturbed frequently fly upward into the forest canopy overhanging the stream (Williams, 1936; Polhemus, 1994).

The oceanic Hawaiian damselfly is threatened by habitat loss and alteration (e.g., water diversions), as well as competition and predation by non-native fish and insect species. Habitat loss may occur as a result of invasive California grass, which forms dense stands that can eliminate standing water. Given the small remaining populations sizes, the species is also threatened by natural events (e.g., drought) that could extirpate the remaining populations.

<u>Potential to Occur in the Action Area</u>

Pockets of suitable habitat for this species occurs in the upper reaches of the action area; however, it is now restricted to a handful of locations on the windward side of the Ko`olau Range (Polhemus, 1994; USFWS, 2012b). Given its current range, this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

<u>Potential Effects of the Proposed Action</u>

The proposed action is not expected to directly or indirectly affect the oceanic Hawaiian damselfly, or its critical habitat.

<u>Effects Determination</u>

The proposed action is expected to have **No Effect** on the oceanic Hawaiian damselfly.

4.11 Orangeblack Damselfly (*Megalagrion xanthomelas*)

The orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) is currently a candidate for listing under the ESA (Federal Register, 2014; USFWS, 2014a).

This species was historically the most abundant damselfly species in Hawaii, and occurred on all the major islands except Kahoolawe. It is now restricted to a total of 16 populations distributed across the islands of Oahu, Maui, Molokai, Lanai, and Hawai`i (Perkins, 1913; Polhemus, 1996; USFWS, 2014a). Currently, the only known population on Oahu is located near Tripler Army Medical Facility (Englund, 2001).

Orangeblack Hawaiian damselflies generally occur in lowland aquatic habitats, and prefer standing or very slow moving bodies of water. The most common habitat in which this species was found during surveys across its current distribution include coastal wetlands fed by basal springs, and terminal or lower mid-reaches of perennial streams (Polhemus, 1996).

Threats to this species include predation from nonnative aquatic species (including fish and insects), and habitat loss due to dewatering of streams and invasion by nonnative plants. Invasive plants (e.g., California grass (*Brachiaria mutica*)) also contribute to loss of habitat by forming dense, monotypic stands that completely eliminate open water (Federal Register, 2014).

<u>Potential to Occur in the Action Area</u>

Pockets of suitable habitat for this species occurs within the action area; however, the last report of this species on Oahu was in 1935 (Williams, 1936), with the exception of one remnant population recently discovered near Tripler Army Medical Facility. Given its current range, this species is not expected to not have the potential to occur within the action area.

<u>Potential Effects of the Proposed Action</u>

The proposed action is not expected to directly or indirectly affect the orangeblack Hawaiian damselfly.

<u>Effects Determination</u>

The proposed action is expected to have **No Effect** on the orangeblack Hawaiian damselfly.

4.12 Oahu tree snail (*Achatinella* sp.)

All 41 species of the genus *Achatinella* (Oahu tree snails) were listed as endangered in February 1981. The original recovery plan was approved 1992; a five-year review was most recently conducted in 2011 (USFWS, 2012). Critical habitat has not been designated for this species.

The genus is endemic to Oahu, where it was once common in the native forests of the Ko`olau and Wai`anae Ranges. At the time the recovery plan was written in 1993, approximately half of the species were either extinct or had not been seen for a significant length of time; nearly all of the remaining species have extremely small populations in areas restricted to the high ridges of the mountain ranges. Surveys conducted from 2005 to 2009 indicate *Achatinella mustelina*, a species restricted to the Wai`anae Range, is the most abundant of the Hawaiian tree snails. *Achatinella sowerbyana*, from the northern Ko'olau Mountains, is the next most abundant species (USFWS, 2012).

Members of the genus Achatinella are currently found in mountainous areas of dry to wet forests and shrublands at elevations of 1300 feet (400 meters). They are arboreal, nocturnal, and feed by grazing fungus from the surface of native plant leaves and trunks. Species that *Achatinella* sp. have been observed inhabiting including *koa* (*Acacia koa*), *kukui* (*Aleurites moluccana*), *hame* (*Antidesma* sp.), *banana* (*musa paradisiaca*), *kookoolau* (*Bidens* spp.), *ahakea* (*Bobea elatior*), *ohia lehua* (*Metrosideros polymorpha*), *kopiko* (*Psychotria* spp.), and *papala kepau* (*Pisonia umbellifera*) (USFWS, 1992).

Historically, the primary causes of reduction in the species' range and abundance were likely destruction of native forest habitat and the introduction of predators, such as rats. More recently, the genus is threatened by predation by introduced snails and rats, and the spread of non-native vegetation into higher elevation forests (USFWS, 1992).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Achatinella* sp. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect Oahu tree snails, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on Achatinella sp.

4.13 *Haha* (*Cyanea acuminata*)

Cyanea acuminata was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2013 (USFWS, 2013a). Critical habitat was designated for this species in 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Cyanea acuminata is a short-lived perennial shrub that is endemic to the island of Oahu. When listed, there were 15 populations with a total of less than 100 individuals (USFWS, 1998b). The total population has increased over time, with a total of 458 plants documented in 2012; this includes three populations with 50 or more mature individuals (USFWS, 2013a).

This species typically grows on slopes, ridges, or stream banks from 305 to 915 meters (1,000 to 3,000 feet) elevation. The plants are found in mesic to wet *ohia-uluhe*, *koa-ohia,* or *Diospyros sandwicensis* (*lama*)-*ohia* forest (HHP 1997, Lammers 1990 as reported in USFWS, 1998b). The major threats to *Cyanea acuminata* are habitat degradation and/or destruction by feral pigs; predation by rats and slugs; competition with non-native plant species; and climate change (USFWS, 2013a).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea acuminata*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Cyanea acuminata*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Cyanea acuminata*.

4.14 *Haha* (*Cyanea crispa*)

Cyanea crispa was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently completed in 2009 (USFWS, 2009a). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Cyanea crispa is a short-lived perennial shrub that is endemic to the Ko`olau Mountains of Oahu. It was historically known from the upper elevations of the Ko`olau Mountains, from Kaipapau Valley to Waialae Iki Ridge. At the time critical habitat was designated in 2003, there were 11 occurrences with a total of 56 individuals in locations including Hidden Valley, Palolo Valley, Kapakahi Gulch, Moanalua Valley, Wailupe, Ko`olau Summit Trail, Kawaipapa Gulch, Maakua Gulch, Kaipapa Gulch, Maunawili, and Pia Valley. As of 2012, there were 7 occurrences with a total of 56 individuals.

Cyanea crispa occurs in habitats ranging from steep, open mesic forests to gentle slopes or moist gullies of closed wet forests, at elevations between 185 and 730 meters (600 and 2,400 feet). Species that commonly occur in association with *Cyanea crispa* include *Cyrtandra* species (*haiwale*), *papala kepau*, and *Touchardia latifolia* (*olona*). The major threats to *Cyanea cripsa* are habitat alteration; predation by rats, slugs and feral pigs; competition with non-native plant species; and extinction due to naturally occurring events and/or reduced reproductive vigor due to the small number of remaining individuals, their limited gene pool, and restricted distribution (USFWS, 2009a).

<u>Potential to Occur in the Action Area</u>

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea crispa*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

<u>Potential Effects of the Proposed Action</u>

The proposed action is not expected to directly or indirectly affect *Cyanea crispa*, or critical habitat designated for this species.

<u>Effects Determination</u>

The proposed action is expected to have **No Effect** on *Cyanea crispa*.

4.15 *Haha* (*Cyanea koolauensis*)

Cyanea koolauensis was listed as endangered in October 1996 (Federal Register, 1996). The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013b). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (USFWS, 2012b).

Cyanea koolauensis is a short-lived perennial shrub that is endemic to the Ko`olau Mountains of Oahu. At the time critical habitat was designated in 2003, there were 42 occurrences with a total of less than 80 individuals, known from Waimea-Malaekahana Ridge to Hawai`i Loa Ridge in the Ko`olau Mountains. As of 2012, there were 15 occurrences with approximately 100 individuals (USFWS, 2012b).

Cyanea koolauensis is usually found on slopes, stream banks, and ridge crests in wet *Metrosideros polymorpha-Dicranopteris linearis* forest or shrubland at elevations between 163 and 959 m (535 and 3,146 ft). Associated native plant species include *Acacia koa*, *Antidesma platyphyllum*, *Bidens* sp., *Bobea elatior*, *Broussaisia arguta*, *Cibotium* sp., *Diplopterygium pinnatum*, *Dubautia* sp., *Hedyotis* sp., *Machaerina* sp., *Melicope* sp., *Pittosporum* sp., *Pritchardia martii* (*loulu hiwa*), *Psychotria mariniana*, *Sadleria* sp., *Scaevola* sp. (*naupaka*), *Syzygium sandwicensis*, or *Wikstroemia* sp. (HINHP Database 2001; Lammers 1999; in Federal Register, 2003). The major threats to this species are habitat destruction by feral pigs; pherbivory by rats and slugs, trampling by hikers and military activities; competition with aggressive nonnative plant species; and climate change (USFWS, 2013b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Cyanea koolauensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Cyanea koolauensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Cyanea koolauensis*.

4.16 No Common Name (*Diellia erecta*)

Diellia erecta was listed as endangered in October 1994. The original recovery plan was approved in 1999; a five-year review was most recently conducted in 2009 (USFWS, 2009b). Critical habitat was designated for this species in 2003 and 2012. None of the critical habitat is within the Ala Wai watershed (Federal Register, 2012).

Diellia erecta is a short-lived perennial fern that was historically known from the Kokee area of Kauai, the Ko`olau Mountains on Oahu, Molokai, Lanai, Maui, and the island of Hawaii. As the time that critical habitat was designated in 2003, this species was known from Kauai, Molokai, Maui, and Hawaii; there was 1 known occurrence of 20 individuals on Hawai`i Loa Ridge on Oahu (Federal Register, 2012). In 2008, fewer than 100 wild individuals were known, with the remaining Oahu population consisting of four mature and 10 immature individuals (USFWS, 2009b).

Diellia erecta is typically found on moderate to steep gulch slopes or sparsely vegetated rock faces, in lowland mesic forests at elevations between 210 and 1,590 meters (700 and 5,200 feet); most populations occur in remote and highly fragmented native communities. Associated plant species include *pilo* (*Coprosma* sp.), *Dodonaea viscosa* (*aalii*), *Dryopteris unidentata*, *kolea* (*Myrsine* sp.), *kopiko* (*Psychotria* sp.), *halapepe* (*Pleomele auwahiensis*), *ohia ha* (*Syzygium sandwicensis*), and *akia* (*Wikstroemia* sp.) (USFWS, 2009b). The major threats to *Diellia erecta* are habitat degradation by pigs, goats, and cattle; competition with alien plant species; and random naturally occurring events causing extinction due to the small number of existing individuals (USFWS, 2009b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Diellia erecta*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Diellia erecta*.

Effects Determination

The proposed action is expected to have **No Effect** on *Diellia erecta*.

4.17 *Nanu* (*Gardenia mannii*)

Gardenia mannii was listed as endangered in October 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013c). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed (Federal Register, 2012).

Gardenia mannii is a tree species that is endemic to Oahu, and was historically known from 7 widely scattered occurrences in the Wai`anae Mountains and 39 occurrences distributed along the length of the Ko`olau Mountains of Oahu (Federal Register, 2003). At the time of listing, there were 27 known populations with a total of 70-100 individuals, with only 3 populations having at least 25 mature individuals (USFWS, 1998b). By 2003, there were 49 occurrences in both the Wai`anae and Ko`olau Mountains, totaling between 69 and 80 individuals (USFWS, 2012b). As of the last 5-review in 2013, a total of 96 individuals are known, a decline from the approximately 110 individuals reported in the previous 5-year review (USFWS, 2013c).

This species is usually found on moderate to moderately steep gulch slopes between 300 and 750 meters (980 and 2,460 feet) in elevation. It typically occurs with other native mesic or wet forest species, with species including ohia, alaa, koa, and uluhe. Other associated plants include *kalia*, *hoio* (*Diplazium sandwichianum*), *alani*, *hoawa*, *ohe mauka* (*Tetraplasandra oahuensis*), *hame*, *kanawao*, *pilo*, *kawau*, *maile* (*Alyxia oliviformia*), and *kopiko* (USFWS, 1998b).

The major threats to *Gardenia mannii* are habitat degradation and/or destruction by feral pigs; potential impacts from military activities; competition with nonnative plant species; fire; and risk of extinction from random environmental events and/or reduced reproductive vigor due to the widely dispersed, small number of remaining individuals.

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Gardenia mannii*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Gardenia mannii*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Gardenia mannii*.

4.18 No Common Name (*Gouania meyenii*)

Gouania meyenii was listed as endangered in October 1991. The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2010 (USFWS, 2010a). Critical habitat was designated for this species in 2003 and 2012; Lowland Dry Unit 16 is located on the slopes of Diamond Head within the Ala Wai watershed (Federal Register, 2012).

Gouania meyenii is a short-lived perennial shrub that was historically known from the Wai`anae Mountains; it was also recorded from Diamond Head in 1831. Currently, on Oahu, this species is found on Kamaileunu Ridge and Makaha-Wai`anae Kai Ridge; as of 2009, there are believed to be a total of 20-40 individuals (USFWS, 2010a).

This species typically grows on rocky ledges, cliff faces, and ridge tops in dry shrubland or *ohia* lowland mesic forest at an elevation of 580 to 820 meters (1,900 to 2,700 feet). Associated plants include *aalii*, *akoko*, *kopiko*, *manono*, *alani*, *olopua*, *kookoolau*, *Carex meyenii*, *lama*, *kolokolo kuahiwi*, and *Senna gaudichaudii* (*kolomona*) (USFWS, 1998b).

The major threats to *Gouania meyenii* are competition from alien plants, fire, habitat degradation by feral pigs and goats, and the small number of remaining populations (USFWS, 2010a).

<u>Potential to Occur in the Action Area</u>

The only portion of the watershed that has suitable habitat that could support this species occurs on the slopes of Diamond Head; the species was documented in this area in 1831 and critical habitat has since been designated. The proposed project does not involve any work on or near the slopes of Diamond Head, and no portion of the project otherwise supports suitable habitat for *Gouania meyenii*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

<u>Potential Effects of the Proposed Action</u>

The proposed action is not expected to directly or indirectly affect *Gouania meyenii*, or critical habitat designated for this species.

<u>Effects Determination</u>

The proposed action is expected to have **No Effect** on *Gouania meyenii*.

4.19 ***Wawae iole* (*Huperzia nutans*)**

Huperzia nutans (formerly *Phlegmariurus nutans*) (*wawae iole*) was listed as endangered in March 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2013 (USFWS, 2013d). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Huperzia nutans is a short-lived fern ally, historically known from Kauai and Oahu. At the time critical habitat was designated in 2003, there were 3 occurrences containing 7 individuals in the Ko`olau Mountains of Oahu (Kaukonahua Ridge, Kaukonahua Gulch, and along Waikane-Schofield Trail). The most recent survey data found 5 small fragmented populations with a total of 11 individuals (USFWS, 2013d).

This species grows on tree trunks, usually on open ridges and slopes in *ohia*-dominated wet forests and occasionally mesic forests between 600 and 1,070 meters (2,000 and 3,500 feet) in elevation. Commonly occurring native species in these areas typically include *kanawao*, *kopiko*, *uluhe*, *uki*, *kokio*, *keokeo*, and *hame* (USFWS, 1998b).

The primary threat to *Huperzia nutans* is extinction due to naturally-occurring events and/or reduced reproductive vigor due to the limited distribution and small number of remaining individuals. Additional threats to the species are feral pigs and the noxious alien plants.

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Huperzia nutans*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Huperzia nutans*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Huperzia nutans*.

4.20 No Common Name (*Lobelia oahuensis*)

Lobelia oahuensis was listed as endangered in March 1994. The original recovery plan was approved in 1998; a five-year review was most recently conducted in 2011 (USFWS, 2011d). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Lobelia oahuensis is a short-lived shrub that was historically known from Kahana Ridge, Kipapa Gulch, and the southeastern Ko`olau Mountains of Oahu (from Waikane and Halawa to Mount Olympus and the summit ridges above Kuliouou and Waimanalo) (Federal Register, 2012). At the time of listing, there were approximately 100-200 individuals; as of 2011, there were approximately 48 to 68 individuals of *Lobelia oahuensis* known from seven or eight locations.

The species occurs on summit cliffs in cloud-swept wet forests or in areas of low-shrub cover that are frequently exposed to heavy wind and rain. Associated plants include *akia*, *kanawao*, *manono*, *hapuu*, *ohia*, *uluhe*, *pilo*, *uki*, *olapa* (*Cheirodendron trigynum*), *naenae pua melemele* (*Dubautia laxa*), and *Labordia hosakana* (*kamakahala*).

The primary threats to *Lobelia oahuensis* are competition with nonnative plant species, and habitat degradation by feral pigs, predation by rats and slugs, and a risk of extinction from naturally-occurring events and/or reduced reproductive vigor due to the small remaining population size (Federal Register, 2012).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the habitat conditions or native species that are typically associated with *Lobelia oahuensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Lobelia oahuensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Lobelia oahuensis*.

4.21 *Ihi ihi* (*Marsilea villosa*)

Marsilea villosa (*ihihi*) was listed as endangered in June 1992. The original recovery plan was approved in 1996; a five-year review was most recently completed in 2011 (USFWS, 2011e). Critical habitat was designated for this species in 2003 and 2012; Lowland Dry Unit 7 is within the Ala Wai watershed, but is unoccupied (Federal Register, 2012).

Lobelia oahuensis is an endemic fern that was historically known from Oahu, Molokai and Niihau; populations on Oahu were reported from Kokohead, Lualualei, Ewa Plains, Nuuanu Valley, Palolo Valley and Makapuu. There were previously 11 populations documented across the islands, but as of 2010, only 6 populations are believed to be remaining. On Oahu, these include naturally occurring populations at Kokohead and Lualualei, and planted populations at Makapuu and Hanauma Bay (USFWS, 1996).

Marsilea villosa typically grows in cinder craters, vernal pools, mud flats, or lowland grasslands. It is found in areas that periodically flood, such as small depressions with clay soils; it requires standing water and drying to complete its life cycle. It can withstand shade, but is most vigorous in open areas.

The main reason for the decline of *Marsilea villosa* on Oahu is habitat degradation and destruction of natural hydrology. The greatest immediate threats to the survival of this species are encroachment and competition from naturalized, nonnative plants; continued development and habitat degradation; fire; small population size; and fragmentation, trampling, and other impacts from humans and introduced mammals (USFWS, 2011e).

Potential to Occur in the Action Area

The action area is generally comprised of either densely vegetated non-native riparian/forest habitat (such as that associated with the upper watershed detention basins), or developed areas (such as that associated with the multi-purpose detention basins and floodwalls). No portion of the action area supports regularly flooded depressional features. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Marsilea villosa*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Marsilea villosa*.

4.22 No Common Name (*Pteris lidgatei*)

Pteris lidgatei was listed as endangered in September 1994. The original recovery plan was approved in 1998; a five-year review was most recently completed in 2014 (USFWS, 2014b). Critical habitat was designated for this species in 2003 and 2012; Lowland Wet Unit 16 is located in the upper-most slopes of the Ala Wai watershed, but is unoccupied (USFWS, 2012b).

Lobelia oahuensis is a short-lived terrestrial fern that was historically known from Oahu, Molokai, and Maui. At the time of listing, there were 7 populations with 33 individuals on Oahu and Maui, with Oahu populations located at Kawaliki Stream, North Waimano Gulch (two populations), Kawainui Drainage, and S. Kaukonahua Gulch (USFWS, 1998c). As of 2014, only a total of 18 individuals remain (USFWS, 2014b).

This species is found in lowland wet forest habitats, at elevations ranging from 530 to 910 meters (1,750 to 3,000 feet). It typically occurs on streambanks and near waterfalls with mosses and other species of ferns. Ohia is the dominant native overstory tree species (USFWS, 2014b).

The primary threats to *Pteris lidgatei* are competition with non-native plant species; habitat destruction by feral pigs; slug herbivory; landslides and flooding; and a risk of extinction from naturally occurring events and/ or reduced reproductive vigor due to the small number of remaining individuals (USFWS 1998b; USFWS, 2014b).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Pteris lidgatei*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the upper portions of the watershed, but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Pteris lidgatei*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Pteris lidgatei*.

4.23 No Common Name (*Schiedea nuttallii*)

Schiedea nuttallii was listed as endangered in October 1996. The original recovery plan was approved in 1999; a five-year review was most recently completed in 2013 (USFWS, 2013e). Critical habitat was designated for this species in 2003 and 2012; no designated critical habitat occurs within the Ala Wai watershed (Federal Register, 2012).

Schiedea nuttallii is a short-lived shrub that was historically known from Kauai, Oahu, Molokai, and Maui. At the time of listing, there were approximately 75 wild individuals. As of 1996, there were a total of 40-100 individuals; locations on Oahu include Kahanahaiki Valley on the Army's Makua Military Reservation, Pahole Natural Area Reserve, and Ekahanui Gulch in the Honouliuli Preserve. Since that time, the total number of wild individuals has decreased to a total of 11, but approximately 225 individuals exist in outplanted populations.

Schiedea nuttallii on Oahu typically grows on steep rock walls and forested slopes in *Acacia koa-Metrosideros polymorpha* lowland mesic forest and *Metrosideros polymorpha-Dodonaea viscosa* forest at elevations between 436 and 1,185 m (1,430 and 3,887 feet). Associated plants include *hame*, *kopiko*, *olomea*, *papala kepau*, and *Hedyotis acuminata* (USFWS, 1999).

Schiedea nuttalii on Oahu is threatened by competition with nonnative plant species; predation by the black twig borer, slugs, and snails; habitat degradation by feral pigs; and a risk of extinction from naturally occurring events (e.g., landslides) and/or reduced reproductive vigor due to the small number of individuals (USFWS, 1999).

Potential to Occur in the Action Area

The upper-most extent of the action area is comprised of the detention basin measure locations along Waihi, Waiakeakua, Pukele and Waiomao Streams. These sites are located near the urban-conservation interface at elevations generally ranging between 300-400 feet, and are dominated by non-native vegetation; none of the sites support the native species that are typically associated with *Schiedea nuttallii*.

As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

No critical habitat has been designated for this species within the Ala Wai watershed.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Schiedea nuttallii*.

Effects Determination

The proposed action is expected to have **No Effect** on *Schiedea nuttallii*.

4.24 No Common Name (*Spermolepis hawaiiensis*)

Spermolepis hawaiiensis was listed as endangered in November 1994. The original recovery plan was approved in 1999; a five-year review was most recently completed in 2010 (USFWS, 2010b). Critical habitat was designated for this species in 2003 and 2012; Lowland Dry Unit 6 and 7 is within the Ala Wai watershed (Federal Register, 2012).

Spermolepis hawaiiensis is an endemic herb that was historically known from Waimea on Kauai, Kokohead on Oahu, Paomai and Kahinahina on Lanai and Apua on Hawai`i (USFWS, 1999). At the time critical habitat was designated in 2003, there were 6 occurrences totaling between 110 and 910 individuals in the Wai`anae and Ko`olau Mountains (Diamond Head). As of 2012, the number of individuals ranged between several hundred to thousands of individuals, depending on annual weather conditions (Federal Register, 2012).

Spermolepis hawaiiensis on Oahu typically grows on steep to vertical cliffs or at the base of cliffs and ridges in coastal dry cliff vegetation at elevations of 25 to 839 m (82 to 2,752 ft). Associated native plant species include *Artemisia australis*, *Bidens* sp., *Dodonaea viscosa*, *Doryopteris* sp., *Heteropogon contortus*, *Santalum ellipticum*, or *Waltheria indica*.

The primary threats to *Spermolepis hawaiiensis* on Oahu are habitat degradation by feral goats; competition with nonnative plant species; and habitat destruction and death of plants due to erosion, landslides, and rock slides resulting from natural weathering (USFWS, 1999).

Potential to Occur in the Action Area

The only portion of the watershed that has suitable habitat that could support this species occurs on the slopes of Diamond Head. The proposed project does not involve any work on or near the slopes of Diamond Head, and no portion of the project otherwise supports suitable habitat for *Spermolepis hawaiiensis*. As such, suitable habitat is not present and this species is not expected to not have the potential to occur within the action area.

Critical habitat for this species is located in the watershed (surrounding Diamond Head), but does not overlap with the action area.

Potential Effects of the Proposed Action

The proposed action is not expected to directly or indirectly affect *Spermolepis hawaiiensis*, or critical habitat designated for this species.

Effects Determination

The proposed action is expected to have **No Effect** on *Spermolepis hawaiiensis*.

5.0 EFFECTS DETERMINATION

Based on the information presented in Section 4.0, the effects determinations for the species addressed in this BA are summarized in Table 5. As no critical habitat occurs within the action area, there will be no effect on any critical habitat. As previously noted, species that are restricted to the marine environment do not occur within the action area, such that the proposed project would have no effect on these species.

TABLE 5
Summary of Effects Determination

Common Name	Scientific Name	Potential to Occur in Action Area	Potential Effects	Effects Determination
Hawaiian hoary bat	*Lasiurus cinereus semotus*	Possibly (though unlikely); bats could roost in the forested portions of the action area	Harm/harassment as a result of clearing and construction, but potential impacts to be minimized with seasonal restrictions on tree clearing	May affect, but not likely to adversely affect
Hawaiian monk seal	*Monachus schauinslandi*	No; no marine or coastal habitat present within action area	None	No Effect
Oahu `elepaio	*Chasiempis sandwichensis ibidis*	Unlikely given the current distribution (although birds could possibly reoccupy habitat)	Harm/harassment as a result of clearing and construction, but potential impacts to be minimized with seasonal restrictions on vegetation clearing	May affect, but not likely to adversely affect
Hawaiian coot	*Fulica alai*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Hawaiian stilt	*Himantopus mexicanus knudseni*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Hawaiian duck	*Anas wyvilliana*	No; not expected given the extent of habitat disturbance and current species distribution	None	No Effect
Hawaiian common moorhen	*Gallinula chloropus sandvicensis*	Unlikely given the minimal extent/quality of habitat and current species distribution	Temporary disturbance during construction; short-term habitat increase (and attractive nuisance) during flood events	May affect, but not likely to adversely affect
Blackline Hawaiian damselfly	*Megalagrion nigrohamatum nigrolineatum*	Individuals and potential breeding habitat has been observed within and near the proposed Waihi Stream basin.	A "take" of the species is likely due to construction and maintenance activities.	May affect, and is likely to adversely affect
Crimson Hawaiian damselfly	*Megalagrion leptodemas*	No; outside known range	None	No Effect
Oceanic Hawaiian damselfly	*Megalagrion oceanicum*	No; outside known range	None	No Effect
Orangeblack Hawaiian damselfly	*Megalagrion xanthomelas*	No; outside known range	None	No Effect
Oahu tree snail	*Achatinella* sp.	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea acuminata*	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea crispa*	No; no suitable habitat, and outside known range	None	No Effect
Haha	*Cyanea koolauensis*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Diellia erecta*	No; no suitable habitat, and outside known range	None	No Effect

Common Name	Scientific Name	Potential to Occur in Action Area	Potential Effects	Effects Determination
Nanu	*Gardenia mannii*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Gouania meyenii*	No; no suitable habitat, and outside known range	None	No Effect
Wawae iole	*Huperzia nutans*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Lobelia oahuensis*	No; no suitable habitat, and outside known range	None	No Effect
Ihi ihi	*Marsilea villosa*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Pteris lidgatei*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Schiedea nuttallii*	No; no suitable habitat, and outside known range	None	No Effect
No Common Name	*Spermolepis hawaiiensis*	No; no suitable habitat, and outside known range	None	No Effect

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Biological Opinion and Informal Consultation of the U.S. Fish and Wildlife Service for the Proposed Construction, Operation, and Maintenance of the Ala Wai Canal Project, Island of Oʻahu

Photo Credit: Dan Polhemus

August 12, 2016
(01EPIF00-2016-F-0157)

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawai'i 96850

In Reply Refer To:
01EPIF00-2016-F-0157

Mr. Anthony J. Paresa, P.E.
Deputy District Engineer
Programs and Project Management Division
Department of the Army
Honolulu District
U.S. Army Corps of Engineers
Fort Shafter, Hawai'i 96858-5440

Subject: Biological Opinion and Informal Consultation for the Proposed Construction, Operation, and Maintenance of the Ala Wai Canal Project, Island of O'ahu

Dear Mr. Anthony J. Paresa, P.E:

This document transmits the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the proposed Ala Wai Canal Project, located within the Ala Wai watershed, on the island of O'ahu, and its effects on the federally endangered blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*) in accordance with section 7 of the Endangered Species Act of 1973 as amended (ESA) (16 U.S.C. 1531 *et seq*.). Your January 11, 2016, request for formal consultation was received on January 13, 3016.

A separate informal consultation is found in Appendix A for project impacts that may affect but are not likely to adversely affect the federally endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), O'ahu 'elepaio (*Chasiempis ibidis*), Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian common gallinule (*Gallinula chloropus sandvicensis*), and the Hawaiian duck (*Anas wyvilliana*). The U.S. Army Corps of Engineers, Honolulu District (USACE) made a no-effect determination for project impacts to the federally endangered crimson Hawaiian damselfly (*Megalagrion leptodemas*), oceanic Hawaiian damselfly (*Megalagrion oceanicum*), orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*), O'ahu tree snails (*Achatinella* sp.), hāhā (*Cyanea acuminata*), hāhā (*Cyanea crispa*), hāhā (*Cyanea koolauensis*), *Diellia erecta*, nānū (*Gardenia mannii*), *Gouania meyenii*, wāwae 'iole (*Huperzia nutans*), *Lobelia oahuensis*, 'lhi'ihi (*Marsilea villosa*), *Pteris lidgatei*, *Schiedea nuttallii*, and *Spermolepis hawaiiensis*.

This biological opinion is based on information provided in the March 2016 Revised Biological Assessment (BA) of Threatened and Endangered Species for the Ala Wai Canal Project, the December 2015 BA of Threatened and Endangered Species for the Ala Wai Canal Project, the

August 24, 2015 Draft Feasibility Study with Integrated Environmental Impact Statement for the Ala Wai Canal Project, and other information available to us. A complete administrative record of this consultation is on file in our office.

CONSULTATION HISTORY

May 16, 2008 – The Service provided a species list (2008-SL-0187) to the USACE for the proposed Ala Wai Canal Project Watershed Plan.

October 14, 2014 – The USACE (Athlene M. Clark) coordinated an Ala Wai Resource Agency Meeting with the State of Hawaiʻi, U.S. Environmental Protection Agency, the Service and USACE's consultants to discuss the tentatively selected plan for the Ala Wai Canal study; provide the background on the approach to assessing any compensatory mitigation requirements through the Hawaiʻi Stream HEP Model approach; get concurrence on any required ESA consultation; and discuss the next steps for a Fish and Wildlife Coordination Act (FWCA) 2b report. The Service advised the USACE that the 2008 species list was still considered valid, that a new species list does not need to be generated, that several species of Hawaiian damselfly (*Megalagrion* spp.) were federally listed in 2012 and should also be considered; in particular, a population of blackline Hawaiian damselfly was known from the upper reaches of Mānoa Stream.

February 23, 2015 – The USACE emailed the draft BA for the Ala Wai Canal Study and requested review and input regarding ESA species information, and advised the Service that they were still waiting on information on the presence or absence of damselfly species to be input into the draft BA.

May 26, 2015 – The USACE coordinated a meeting to discuss schedules and work needed before the Public Release of the Draft Feasibility Study/Environmental Impact Statement (EIS) for the Ala Wai Canal Project. The primary objective was to coordinate the Feasibility Study/EIS Report process with the Service. The USACE (Steve Johnson, new acting Project Manager) explained that a BA had been drafted, but damselfly information was still needed before the documentation could be finalized. The USACE's consultant noted a preliminary draft had previously been sent to the Service for input. The Service stated the review of the preliminary draft would focus on recommendations for avoidance and minimization measures to listed species (damselflies, Hawaiian hoary bats, and Hawaiian waterbirds). The USACE noted that the Service was funded in April 2015 to complete the FWCA Draft Coordination Report, including damselfly surveys in the upper portions of the watershed.

June 16, 2015 – The Service provided technical assistance for the draft BA and recommended the USACE to include measures to reduce the spread of invasive species as a result of their project.

June 29, 2015 – Follow-up meeting with resource agencies to discuss contaminated sediments and project planning documents.

September 30, 2015 – The Service received the Draft Feasibility Study with Integrated EIS for the Ala Wai Canal Project and returned comments on November 9, 2015.

December 18, 2015 – A meeting was held with resource agencies to discuss the draft FWCA report, concerns regarding contaminants, proposed January surveys for blackline Hawaiian damselflies within the Waiakeakua stream action area, and timing of ESA section 7 consultation. The Service stated they would wait for the USACE request letter to start the process for section 7 consultation.

January 13, 2016 – The Service received the January 11, 2016 USACE letter request for informal and formal consultation and associated BA, which included a likely to adversely affect determination at Waihī Stream for the blackline Hawaiian damselfly.

February 11, 2016 – The Service, USACE, and the State of Hawaiʻi Department of Land and Natural Resources (DLNR) – Division of Aquatic Resources (DAR) conducted a site visit and survey and to document the presence or absence of the blackline Hawaiian damselfly within the Waiakeakua Stream.

February 18, 2016 – The Service requested the BA be updated to include the revised project description based on the presence of the blackline Hawaiian Damselfly at the proposed Waiakeakua Stream Debris and Detention Basin location and a discussion of proposed project mitigation measures to avoid and minimize adverse effects to the species. Additionally based on additional information within the project action areas, the Service recommended the Hawaiian duck be incorporated into the USACE analysis that the proposed project may affect, but was not likely to adversely affect, the Hawaiian duck.

February 26, 2016 – The Service had a meeting with the USACE to present appropriate FWCA mitigation to address the loss of riffle and pool habitat and indirect impacts to coral reef resources due to sedimentation. The Service reminded the USACE there were additional damselflies found within the Waiakeakua project area. FWCA mitigation was proposed to conduct mitigation work at Falls 7 and 8 to assist native species to migrate upstream. The proposal was accepted on the condition that the City and County of Honolulu plan to repair Fall 6.

March 30, 2016 – The USACE submitted a revised BA and Formal consultation was initiated.

June 22, 2016 – The USACE notified the Service that they would be submitting revised drawings of the Waihī and Waiakeakua Debris and Detention Basin footprints. The design changes would change the original project footprints. The revised structures would be increased slightly in size and change in shape to increase the amount of water to be temporarily impounded and include rip rap for scour protection on the downstream end.

June 30, 2016 – The USACE submitted the revised footprints for the Waihī and Waiakeakua basins and the revised drawings for the structures based on the refinements for the entire project and the drawings that depict the structure for each. The drawing set included changes to other features that would also change previous information for the FWCA.

July 18, 2016 – The USACE and the Service met via teleconference to discuss the new proposed changes to the construction footprint. The Service notified the USACE that any major changes in the project description could change the analysis portion of the opinion and may delay the timeline. The USACE submitted changes to the basin designs. Changes included the magnitude of impacts from the project, but not changes in location.

DESCRIPTION OF THE PROPOSED ACTION

History and Background

The State of Hawaiʻi DLNR and the USACE conducted a feasibility study for the Ala Wai Canal Project (Project) to restore and manage for flood control within the Ala Wai watershed, in Honolulu, on the island of Oʻahu. The watershed is comprised of approximately 19 square miles (12,064 acres) on the southeastern side of the island of Oʻahu in the State of Hawaiʻi (Figure 1).

A high risk of flooding exists within the Ala Wai watershed due to aging and undersized flood conveyance infrastructure. Based on the peak flows computed for the feasibility study, it was estimated that the Ala Wai Canal (Canal) has the capacity to contain about a 20- to 10-percent annual chance exceedance (ACE) flood before overtopping the banks. The risk of flooding is exacerbated by the flashy nature of the streams in the watershed, with heavy rains flowing downstream extremely quickly due to steep topography and relatively short stream systems (USACE 2016, p. 1).

Overtopping of the Canal has previously flooded Waikīkī multiple times, including during the November 1965 and December 1967 storms and during the passage of Hurricane Iniki in 1992. Upstream areas are also at risk of flooding, as demonstrated by several recent events, including the October 2004 storm that flooded Mānoa Valley and the March 2006 storm that flooded Makiki. The October 2004 event was estimated to have a 4-percent chance of occurring in any single year, and caused more than $85 million in damages (USACE 2006, p. 1). Multiple other past flood events have been documented within the watershed over the course of the past century (USACE 2016, p. 1). In addition to recorded property damages, flooding events in the Ala Wai have contributed to health and safety risks, including two known deaths (associated with flooding in December 1918 and December 1950) (USACE 2006 as cited in USACE 2016, p. 1).

Analyses conducted in support of this project show that the 1-percent ACE floodplain extends over approximately 1,358 acres of the watershed. Within this area, the affected population is comprised of approximately 54,000 residents plus an additional estimated 79,000 visitors in Waikīkī on any given day. In addition to threatening the safety of both residents and visitors, a major flood event could result in catastrophic damages to structures and property throughout the watershed, with impacts to Waikīkī crippling the local economy. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $723 million in structural damages alone (2013 price levels) (USACE 2016, p. 1).

In response to a request from DLNR, the reconnaissance phase of the Ala Wai Canal Project was initiated in April 1999. At that time, Federal, State, and local agencies sought a comprehensive management and restoration plan to restore aquatic habitat and biological diversity in the Canal and upstream tributaries. The reconnaissance report was submitted in August 1999 and recommended that the USACE assist the State with restoration of the Canal. Approval by the USACE for continuation into the feasibility phase was granted in September 1999.

Independently, the Ala Wai Flood Study was initiated in September 1998 under the Planning Assistance to States (PAS) Program (Section 22 of the Water Resources Development Act of 1974) to determine the potential flood risk to the Waikīkī area, in response to a request by the Land Division of DLNR. The study was completed in October 2001 and documented a high flood hazard associated with potential overtopping of the Ala Wai Canal. This study identified several measures and conceptual alternatives that could potentially minimize flood damage to Waikīkī and surrounding areas. The results of the technical study were used to establish that the USACE could be involved in the investigation of flood damage reduction in the Canal. As a result, a flood risk management objective was added to the Ala Wai Canal Project, thus expanding the project focus to both ecosystem restoration and flood risk management in the Canal area.

The Feasibility Cost Sharing Agreement was executed between the USACE and the non-Federal sponsor, DLNR Engineering Division, in 2001. The feasibility phase of the project was initiated in July 2002, and an EIS scoping meeting was held in June 2004. Subsequently, in October 2004, heavy rains caused Mānoa Stream to overtop its banks, resulting in significant damages. In response, the USACE temporarily ceased work on the feasibility study so that the project could be expanded to include the upstream portions of the Ala Wai watershed. While the cost-share agreement was being amended to address a more comprehensive scope, the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) received federal funds to identify specific actions to address flooding in Mānoa Valley. The Mānoa Watershed Project was initiated in 2006 and resulted in detailed topographic mapping, hydrologic and hydraulic modeling, and identification of potential measures to address specific flood problems. However, because of insufficient federal funding to complete the project, the Mānoa Watershed Project was terminated before implementation.

Information developed through the Mānoa Watershed Project was subsequently incorporated into the Ala Wai Canal Project, which was re-started in 2007. A second EIS scoping meeting was held in October 2008. Project-related efforts were primarily focused on bringing the technical information for the entire watershed up to the same level of detail as produced for Mānoa under the Mānoa Watershed Project.

Figure 1. Ala Wai Watershed, O‘ahu

In October 2012, a charrette was held to re-scope the project as part of the USACE Civil Works Planning Modernization process. The purpose of the charrette was to bring together the USACE project delivery team (PDT), Pacific Ocean Division and Headquarters staff, with the non-federal sponsor and other cooperating agencies, in order to determine the path forward for completing the feasibility study in compliance with current USACE planning requirements. Key outcomes of the charrette included consensus on the problems and opportunities, objectives and constraints, screening and decision criteria, the array of alternatives, and a framework for identification of the tentatively selected plan. Based on the project review at the charrette, ecosystem restoration was eliminated as a study objective, as it was determined that the biological resources within the watershed do not have enough national significance to adequately justify ecosystem restoration as an objective. However, the ecosystem-related information previously identified as part of the study is being incorporated as part of environmentally sustainable design considerations, particularly as related to maintaining in-stream habitat and migratory pathways for native aquatic species.

Mānoa Stream is a large stream in a bowl-like catchment, originating near 855 m (2800 ft) on the southwestern flank of Kōnāhuanui peak and adjacent ridgelines in the Koʻolau Mountains, and flows southwestwards for approximately 9.25 km (5.75 mi) to its terminus in the Ala Wai canal. The stream has two major branches, these being the Waihī on the west side of the basin, and the Waiakeakua on the east. The upper half of the Mānoa catchment lies in steep, forested terrain on the slopes of the Koʻolau Mountains, in a very wet area that receives up to 3850 mm (~151 in, or 12.6 ft) of rain annually at the headwaters of the Waihī branch, and 3550 mm (~140 in, or 12 ft) annually at the headwaters of the Waiakeakua branch (Giambelluca *et al*. 2013 as cited in Polhemus 2015, in litt.). The stream in its upper reaches flows in natural, unmodified channels for approximately 3.6 km (2.25 mi), being heavily shaded by a forest of introduced tree species intermixed with some native vegetation on the upper slopes. Below Paradise Park, the stream passes through suburban neighborhoods in a partially modified channel for about 1.6 km (1.0 mi). At the Mānoa District Park, near 50 m (160 ft) elevation the stream becomes confined within an artificial concrete channel, which continues downstream to the East Mānoa Road bridge. Downstream from this bridge the stream flows in a re-aligned but partially natural channel, mostly following the base of the steep eastern wall of Mānoa Valley. Downstream from Kānewai Park, at approximately 9 m (30 ft) elevation, the stream channel has been straightened, but not concrete-lined, and continues in this fashion for 2.25 km (1.4) miles, passing below the H-1 freeway and then continuing to its confluence with the Ala Wai Canal.

Project Description
The proposed Ala Wai Canal Project consists of a variety of structural and non-structural flood risk management measures, with a focus on the following approaches to flood risk management: (1) peak flow reduction, (2) increased channel capacity, (3) debris management, and (4) minimization of flood damage.

These measures included the following:

- <u>Detention basin</u>: This measure is an earthen structure that would allow high-frequency stream flows to pass, but would capture and delay larger volume stream flows, helping to reduce flood peaks. Detention basins may be located either within a stream channel or in an open space area directly adjacent to a stream/canal.

  - The in-stream detention basins would be comprised of an earthen berm that extends perpendicularly across a stream channel that would, in combination with the natural topography, provide temporary containment of storm flows. The basins would not be designed to permanently contain water; they would include a natural-bottom arch culvert that would maintain passage of low flows and also allow the basin to completely drain into the stream as flood conditions subside. An emergency spillway would allow water to overflow the berm in the event the capacity of the detention basin is exceeded. Debris catchment structures would be incorporated as part of each measure, and would function to capture large in-stream debris. To facilitate safe operation and maintenance of each basin, the area surrounding the berm would be kept clear of woody vegetation.
  - The off-stream detention basins would function similarly to the in-stream detention basins, but would be formed by construction of a berm around the perimeter of a nearby open space; stream flows would be directed into the detention basin (via a spillway along the stream bank), then would drain back into the stream.

- <u>Debris catchment</u>: As described above, the in-stream detention basins would include a debris catchment feature. In addition, the Tentatively Selected Plan also includes a stand-alone debris catchment structure, which would generally consist of a narrow concrete pad that would span the stream, with evenly-spaced steel posts. This structure would allow stream flows to pass, while functioning to block large debris as it flows downstream. Similar to the in-stream detention basins, the area surrounding the catchment structure would be kept clear of woody vegetation. The extent and duration of in-stream work would be minimized to the extent practicable.

The location of each proposed measure is shown in Figure 2; detailed design drawings of each measure are included in Appendix B. These specific measures and the approximate area of disturbance associated with each proposed location within the watershed is summarized in Table 1. Following construction, the proposed operation and maintenance required for each of the flood risk management measures will be operated and maintained by the non-federal sponsor and are summarized in Table 2. Each of the measures described below is assumed to have a life expectancy of 50 years, with maintenance performed on a routine basis.

Additionally, a Flood Warning System would be incorporated into the proposed project. Three real-time rain gauges (Mānoa, Makiki and Pālolo Streams) and one real-time streamflow or stage gauge (in Ala Wai Canal) would be installed as part of the flood warning system for the watershed. Locations of gauging stations are to be determined, but will be sited based on flood warning need, peak flow locations, and accessibility to site.

Based on the requirements of the Clean Water Act and the USACE planning regulations, and after consideration of avoidance and minimization measures, it was determined that FWCA compensatory mitigation would be required for unavoidable impacts to aquatic habitat resulting from implementation of the flood risk management measures. The USACE planning process requires that the FWCA mitigation requirement be based on functional habitat loss and quantified using a habitat-based methodology (i.e., ecosystem output model). As such, the

Hawaiʻi Stream Habitat Equivalency Procedure (HSHEP) was used to quantify the loss of habitat function. Detailed stream surveys were conducted, with the resulting data processed according to the variables in the HSHEP model, as needed to quantify the habitat value of the existing and future without-project condition (in terms of habitat units [HUs]). Anticipated changes in the model variables were then defined for the with-project condition, and the modeling results were then compared to quantify the anticipated habitat loss (i.e., the mitigation requirement). Potential mitigation concepts that could be implemented to offset the anticipated loss of habitat quality were then identified, and were refined through an iterative process, in coordination with the resource agencies. The increase in habitat quality associated with each of the mitigation measures was quantified using the HSHEP model, and these results were used to combine the measures into different mitigation alternatives that could be implemented to compensate for the loss of habitat quality associated with the proposed project.

The selected mitigation alternative is comprised of two measures, both of which involve removal of a passage barrier for native aquatic species in Mānoa Stream (Falls 7 and Falls 8). The location of these measures is shown in Appendix C and described below. In each location, there is currently an in-stream structure where undercutting has resulted in an overhanging lip, which creates a passage barrier for native aquatic species. Specifically, the stream flow over these structures is free-falling and does not maintain contact with the surface of the structure, such that the native species do not have any means to migrate upstream. The proposed mitigation involves installation of grouted riprap as part of the existing in-stream structure to provide a suitable surface for migration of the native species to upstream habitat.

Proposed FWCA mitigation:

- Remove existing passage barriers: A combination of demolition/removal of existing concrete, and reconstruction with a boulder and/or riprap step-pool structure to create continuous water surface contact for fish passage.
    - Falls 7 (0.6 mile above Mānoa District Park)
    - Falls 8 (0.7 mile above Mānoa District Park)

Figure 2. Locations of proposed flood control measures for the Ala Wai Canal Project.

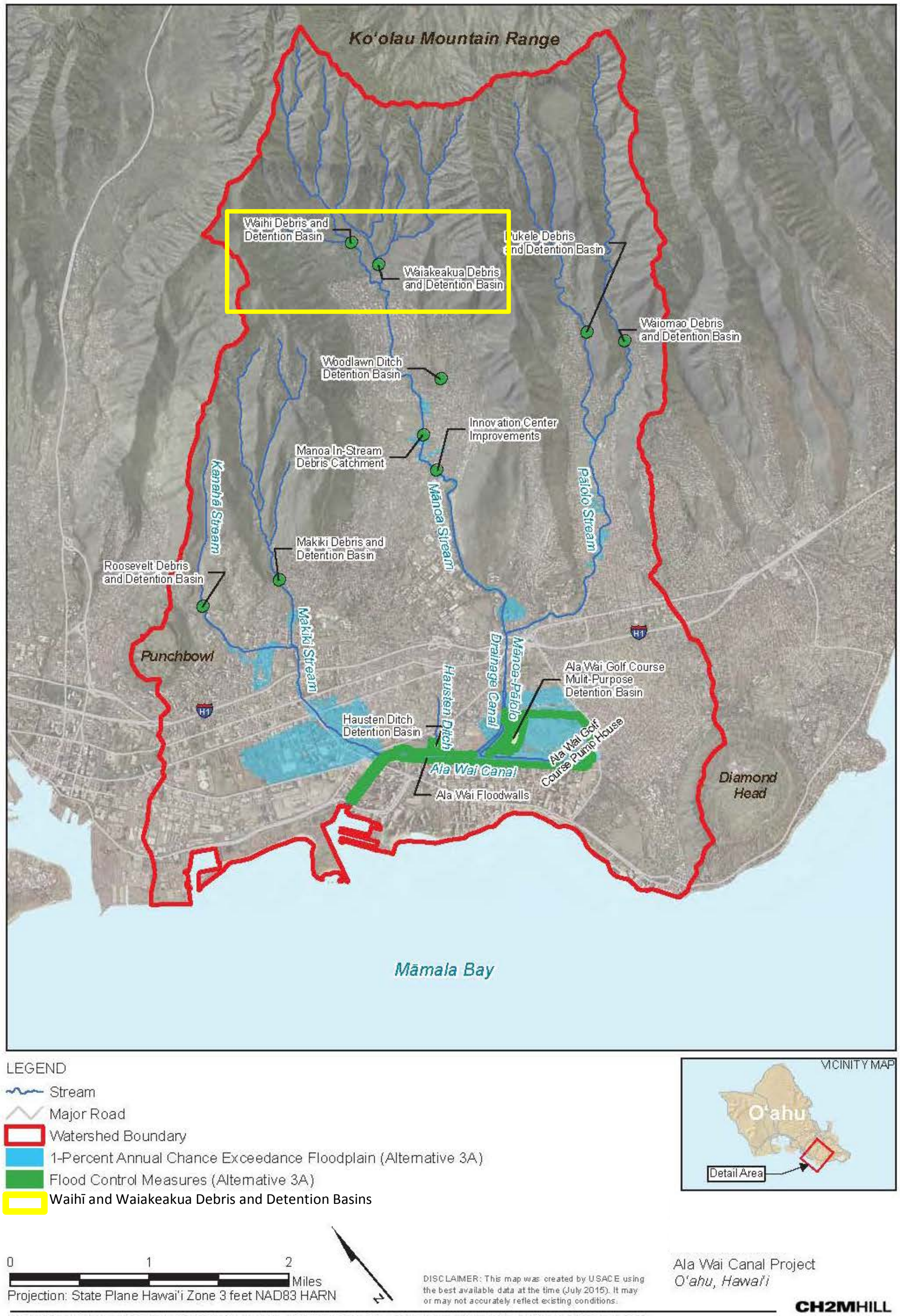


Table 1. Proposed Flood Risk Management Measures for the Ala Wai Canal Project.

Measure[1]	Description of Measure	Total Area of Disturbance		Permanent Structure Footprint		Temporary Disturbance (e.g., Staging) (ac)	Vegetation Management		Extent of Inundation (duration for 1% ACE)
		Total Area (ac)	Length of Steam (ft)	Total Area (ac)	Length of Steam (ft)		Total Area (ac)	Length of Steam (ft)	
Waihī Debris and Detention Basin	Earthen dam, approximately 37' high and 225' across; with a 12' x 6' box culvert to allow small storm flows to pass. Culvert length will be 205 ft. Construct a 124' wide concrete spillway above culvert with grouted riprap on the upstream and downstream side. Downstream side riprap scour protection will be approximately 150' linear length. Debris catchment feature located on upstream end of culvert. Create new access road for construction and operation and maintenance. A fence will be built along the access roads, and is meant to be a deterrent to prevent people from readily accessing the basin areas from nearby roadways but will not encompass the entire area. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Construction footprint will be 35,000 ft^2.	1.5	335	0.8	335	0.1	0.3	40	1.35 acres inundated for up to 4.5 hours
Waihī Debris Catchment	Concrete pad, approximately 8' wide and 140' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along a concrete pad.	0.3	48	0.07	8	0.1	0.2	40	None
Waiakeakua Debris and Detention Basin	Earthen dam, approximately 34' high and 185' across; with a 200' length arch culvert to allow small storm flows to pass. Construct a 105' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Downstream side of riprap will be approximately 150' linear length. Debris catchment feature to be located on upstream end of culvert, and energy dissipation structure (concrete blocks) to be located on downstream end of culvert. A fence will be built along the access roads, and is meant to be a deterrent to prevent people from	1.7	350	1.0	350	0.1	0.5	40	3.2 acres inundated for up to 9 hours

	readily accessing the basin areas from nearby roadways but will not encompass the entire area. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Construction footprint will be approximately 41,620 ft^2.								
Waiakeakua Debris Catchment	Concrete pad, approximately 8' wide and 140' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along a concrete pad.	0.2	48	0.03	8	0.1	0.2	40	None

NOTES:
[1] In addition to these structural measures, the proposed project would also include improvements to the existing flood warning system.
[2] Inundation area is the area behind the detention basin that is expected to be inundated during a 1-percent annual chance exceedance flood event.

Table 2. Proposed Operation and Maintenance Activities.

Measure Type	Summary of Operation and Maintenance Activities
Debris and Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structures) twice a year, allowing no woody vegetation to grow in this area. Clear accumulated debris following flood event and annually.

NOTES:
[1]Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

Conservation Measures to Avoid and Minimize Effects to Listed Species

- Construction activities within the stream channels would be limited to low-flow conditions. In addition to minimizing the extent of dewatering required, this would also serve to minimize the potential to disrupt migration of native aquatic species.
- Proper dewatering techniques would be implemented, as needed. For example, sand bags or a cofferdam could be used to isolate the work area and to concentrate upstream flows into a large diameter pipe. The pipe would extend downstream thus allowing the stream flow to bypass the construction area and maintain downstream flows.
- If needed, a pump would be used to dewater the construction area, once the pipe is effectively bypassing stream flows. The pump would be properly screened to preclude entrapment of fish, and the area would be adequately inspected to ensure no fish are stranded.
- Turbidity and siltation from project-related work will be minimized and contained to within the vicinity of the site through the appropriate use of silt containment devices.
- Phasing of project features will be implemented to the extent practicable to aid in the capture of silt that may be released when constructing other project features (e.g. a downstream basin could be constructed prior to an upstream basin to help capture sediments that could be released into the waterway during construction of the upstream basin).
- Exposed soil near water will be protected from erosion after exposure and stabilized as soon as practicable (e.g. hydroseeded with certified weed-free seed mixes)
- All project-related materials and equipment to be placed in the water shall be cleaned of pollutants prior to use.
- No project-related materials will be stockpiled in the water.
- All debris will be disposed of off-site at an approved disposal and/or composting site.
- Fueling of project-related vehicles and equipment will take place away from the water.
- A Spill Control Plan will be developed and implemented that will describe the procedures and equipment that will be used to stop, contain and clean up any accidental releases of petroleum and/or hazardous materials to the environment.
- All construction equipment, materials and vehicles arriving from outside the island of Oʻahu will be washed and/or visually inspected (as appropriate) for excessive debris, plant materials, and invasive or harmful non-invasive species before transportation to the project site; import of materials that are known or likely to contain seeds or propagules of invasive species will be prohibited.
- Offsite sources of revegetation materials (such as seed mixes) will be certified as weed-free or inspected before transport to the project area.

- All areas that are hydroseeded will be monitored for six months after hydroseeding to identify invasive plants that establish from seeds inadvertently introduced as part of the seed mix; all invasive plants identified within the hydroseeded area will be removed.
- At the end of the construction period, areas impacted by construction of the project will be surveyed to confirm that no problematic and/or invasive species had been introduced and become established. Appropriate remedial actions will be undertaken to facilitate containment or eradication of the target species as soon as reasonably possible.
- All project personnel will be briefed on ESA-listed species that could be present on the project site and on the protections afforded to these species under the ESA. This information will also be included in the USACE Operations and Maintenance Manual for the project for the use and reference by maintenance personnel.
- No attempt will be made by project personnel to feed, touch or otherwise intentionally interact with any ESA protected species. If a protected species is present in the vicinity of any active work area, they must be allowed to leave the area on their own accord before work in that area can resume.

ACTION AREA

The action area of a project is defined by regulation as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR §402.02). The action area for this formal consultation is 49,870 feet^2 and 58,075 feet^2 of Waihī and Waiakeakua Streams, respectively, plus all areas of downstream habitat including side seeps and canopy from vegetation along stream corridors which support habitat for the blackline Hawaiian damselfly. This action area includes the proposed construction footprint (including all ground-disturbing activities, clearing, grading, vegetation trimming, staging, access roads, construction activities, operations and maintenance) as well as the installation of 150 feet of riprap that will preclude habitat and change the ecosystem downstream.

Figure 2. Waihī Debris and Detention Basin.

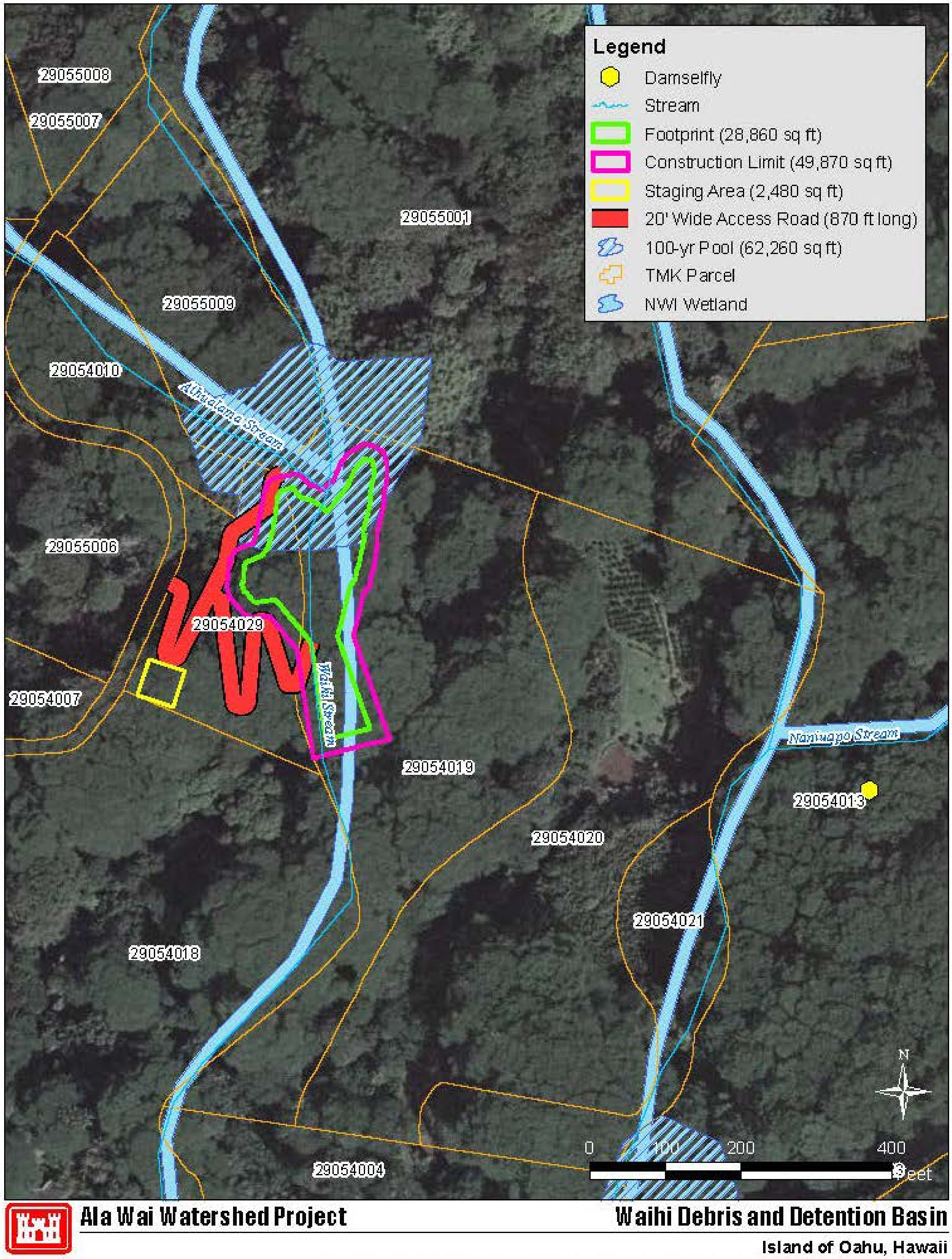
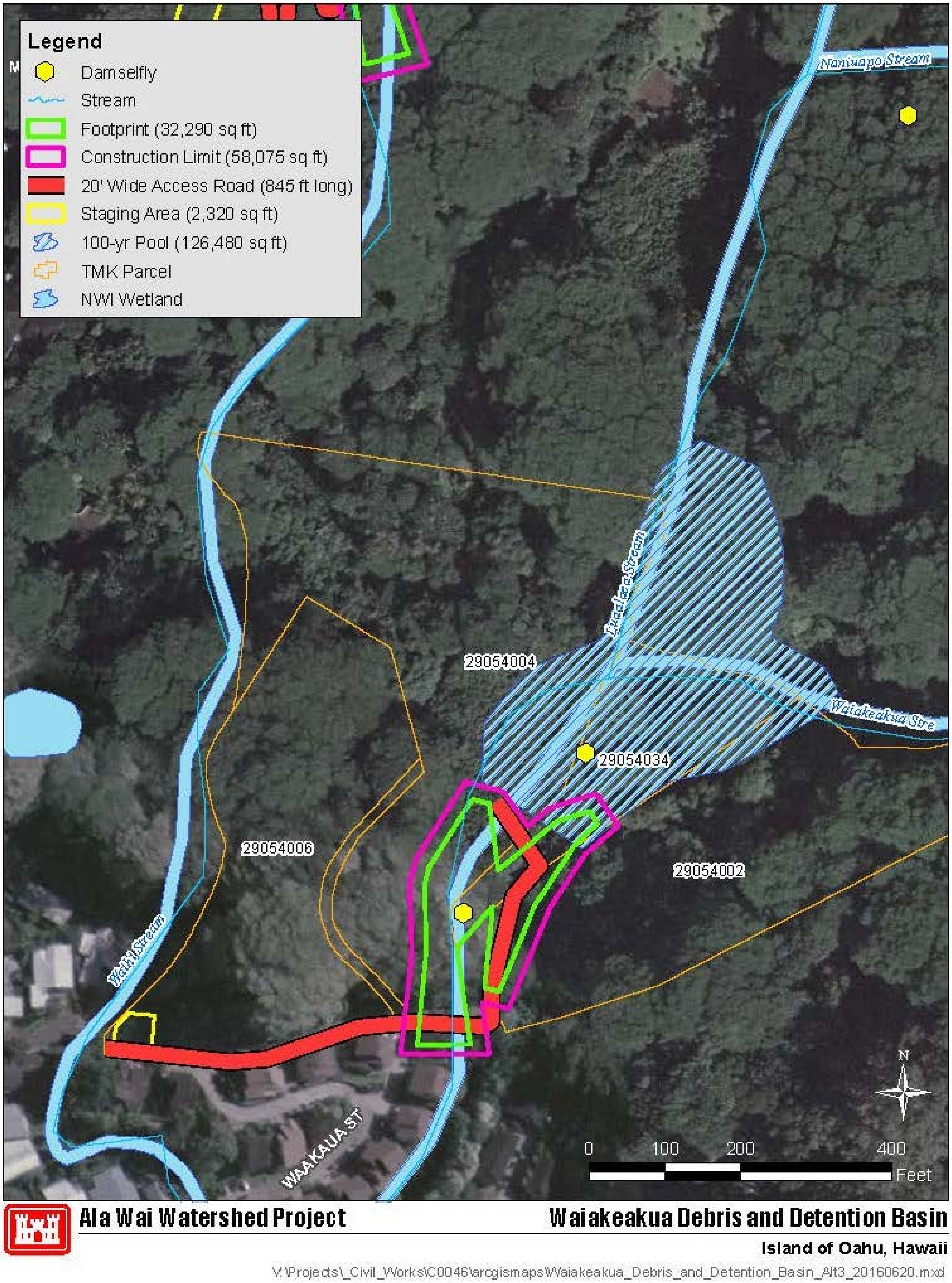


Figure 3. Waiakeakua Debris and Detention Basin.



ANALYTICAL FRAMEWORK FOR THE JEOPARDY/ADVERSE MODIFICATION ANALYSES

In accordance with policy and regulation, the jeopardy analysis of this Biological Opinion relies on four components: (1) Status of the Species, which evaluates the range-wide condition of the blackline Hawaiian damselfly, the factors responsible for that condition, and the survival and recovery needs of this species; (2) the Environmental Baseline, which evaluates the current condition of the blackline Hawaiian damselfly in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species; (3) the Effects of the Action, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the blackline Hawaiian damselfly; and (4) Cumulative Effects; which evaluates the effects of future, non-Federal activities in the action area on the blackline Hawaiian damselfly.

In accordance with the policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed Federal action in the context of the blackline Hawaiian damselfly current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of the blackline Hawaiian damselfly in the wild.

The jeopardy analysis in this Biological Opinion places an emphasis on consideration of the range-wide survival and recovery needs of the blackline Hawaiian damselfly and the role of the action area in the survival and recovery of these species as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

STATUS AND ENVIRONMENTAL BASELINE OF THE SPECIES

Status of Species

Blackline Hawaiian Damselfly

The blackline Hawaiian damselfly was listed as an endangered subspecies on October 18, 2012. Previously, the damselfly had been on the candidate species list since 1984. Critical habitat was designated on October 18, 2012. Unique primary constituent elements for the 11 lowland wet critical habitat units for the blackline Hawaiian damselfly include perennial and slow reaches of streams or pools.

Historic and Current Distribution

The blackline Hawaiian damselfly is endemic to the island of Oʻahu, where it was known historically from the Koʻolau and Waiʻanae Mountains (Polhemus 1994a, pp. 6-11) and relatively widespread from sea level to over 2,400 ft (730 m) (Williams 1936, p. 318). Although native damselflies were formerly one of the most conspicuous elements of Hawaiian stream and wetland communities, many species became increasingly rare or have disappeared altogether where they were historically found (Englund 1999, pp. 225, 228).

Currently, the species is found in the lowland wet ecosystem on the windward and leeward sides of the Koʻolau Mountains, in the headwaters and upper reaches of 17 streams: Koloa, Kaipapaʻu, Maʻakua, upper Kaluanui, Helemano headwaters, Poamoho, Kahana, Waiāhole, Waiawa, Kaʻalaea, Waiheʻe, Kahaluʻu, Punaluʻu, north Hālawa, Heʻeia, Kalihi, and Maunawili (TNC 2007; Polhemus 2008b, in litt.; Wolff 2008, in litt.; HBMP 2008; Preston 2011, in litt.; Polhemus 2016a, in litt.; Polhemus 2016b, in litt.). The 17 stream colonies are estimated to total 800 to 1,000 individuals, with approximately 50 individuals per stream (Polhemus 2008a, in litt.). Recent surveys have documented damselflies in an additional 3 new locations: Kalihi (Stream 2) and Mānoa Stream (Waihī and Waiakeakua Streams) (Polhemus 2016a, in litt). Population estimates were not known for Kalihi Stream. However, population estimates for Waihī and Waiakeakua Streams totaled 66 and 36, respectively, increasing our estimate to total 902-1,102 blackline Hawaiian damselflies. Due to rugged terrain, the upper elevation sections of many streams are difficult to access, and have not yet been surveyed. Therefore, the total population number for the species is unknown.

Life History

The blackline Hawaiian Damselfly is a moderately-sized and delicate subspecies (Polhemus and Asquith 1996, p. 73), that breeds in the slow sections or pools along the mid-reach and headwater sections of perennial upland streams, and in seepage fed pools along overflow channels bordering such streams (Polhemus 1994b, p. 44).

Males and females are frequently observed in tandem, the female having then been noticed inserting her eggs, or attempting to, in plant tissue in running water, and may also place them above water (Williams 1936, p. 318). Like most damselflies, the blackline Hawaiian damselfly, are aquatic as immatures (Polhemus and Asquith 1996, p. 4). The naiads can swim but prefer to remain concealed, typically occurring under stones or in mats of algae (Williams 1936, p. 318). Adults are relatively weak fliers, and often perch on streamside rocks and vegetation. The males of most native aquatic *Megalagrion* species are territorial, guarding areas around water where females lay eggs (Moore 1983, p. 89).

The following description of adults is similar for all *Megalagrion* species, and not specific to the blackline Hawaiian damselfly. When mature, damselfly naiads crawl out of the water onto rocks or vegetation and molts into a winged adult (Polhemus and Asquith 1996, p. 4). The emerged adults are poor fliers and thus susceptible to predators; they immediately fly into nearby vegetation where they rest until completely dried and hardened (Polhemus and Asquith 1996, p. 4). Adult damselflies are predacious and capture small insects out of the air with their legs; adults will range widely when hunting for insect prey (Polhemus and Asquith 1996, p. 4).

In Hawaiʻi, damselflies do not appear to be seasonal, except at elevations above 1,500 meters, and adults can be found in most areas throughout the year. Even so, adults of many species are sensitive to weather and time of day, tending to be inactive during periods of rain and cloud cover, and most active in full sunlight (Polhemus and Asquith 1996, p. 7).

Threats

Habitat Destruction and Modification by Agriculture and Urban Development

Although we are unaware of any comprehensive, site-by-site assessment of wetland loss in

Hawaii, Erikson and Puttock (2006, p. 40) and Dahl (1990, p. 7) estimated that at least 12 percent of lowland to upper-elevation wetlands in Hawaiʻi had been converted to non-wetland habitat by the 1980s. If only coastal plain (below 1,000 ft (300 m)) marshlands and wetlands are considered, it is estimated that 30 percent have been converted to agricultural and urban development (Kosaka 1990, in litt.). Historical records show these marshlands and wetlands provided habitat for many damselfly species, including the blackline Hawaiian damselfly (Polhemus 2007, pp. 233, 237–239; HBMP 2008).

Although filling of wetlands is regulated by permitting today, the loss of riparian or wetland habitats used by the blackline Hawaiian damselfly may still occur due to Oʻahu's population growth and development, with concurrent demands on limited developable land and water resources (Lester 2007, in litt.). In addition, marshes have been slowly filled and converted to meadow habitat, as a result of sedimentation from increased storm water runoff from upslope development, the accumulation of uncontrolled growth of invasive vegetation, and blockage of downslope drainage (Wilson Okamoto & Associates, Inc. 1993, pp. 3-4, 3-5).

The threats posed by conversion of wetland and other aquatic habitat for agriculture and urban development are ongoing and are expected to continue into the future. Hawaiʻi's population has increased almost 9 percent in the past 14 years, along with the associated increased demands on limited land and water resources (Hawaiʻi Department of Business, Economic Development and Tourism (HDBEDT) 2013). These modified areas lack the aquatic habitat features that the blackline Hawaiian damselfly requires for essential life-history needs, such as slow sections of and sidepools along perennial streams, and they no longer support populations of the species. Agriculture and urban development have thus contributed to the present curtailment of the habitat of the blackline Hawaiian damselfly, and we have no indication that this threat is likely to be significantly ameliorated in the near future.

Habitat Destruction and Modification by Stream Diversion

By the 1930s, water diversions had been developed on all of the main Hawaiian Islands, and by 1978, the stream flow in more than half the 366 perennial streams in Hawaiʻi had been altered in some manner (Brasher 2003, p. 1,055). Some stream diversion systems are extensive, such as the Waiāhole Ditch on Oʻahu, built in the early 1900s, which diverts water from 37 streams within the ranges of the blackline damselfly, on the windward side of Oʻahu to the dry plains on the leeward side of the island via a tunnel cut through the Koʻolau range (Stearns and Vaksvik 1935, pp. 399–403; Tvedt and Oestigaard 2006, pp. 43–44). Historically, damselflies in the genus *Megalagrion* were a common component of Hawaiian streams and wetlands at elevations ranging from sea level to the summit of the Koʻolau range on Oʻahu. This loss of stream habitat may have contributed to the extirpation of populations of the three damselflies from lower elevations (Polhemus 2007, pp. 233–234, 238–239).

Habitat Destruction and Modification by Dewatering of Aquifers

In addition to the diversion of stream water and the resultant downstream dewatering, many streams on Oʻahu have experienced reduced or zero surface flow as a result of the dewatering of their source aquifers. Often these aquifers, which previously fed the streams, were tapped by tunneling or through the placement of wells (Stearns and Vaksvik 1935, pp. 386–343; Stearns 1985, pp. 291–305). These groundwater sources were diverted for both domestic and agricultural use, and in some areas have completely depleted nearby stream and spring flows. For example, both the bore tunnels and the contour tunnel of the Waiāhole Ditch system intersect perched aquifers (aquifers above the primary ground water table), which subsequently are drained to the elevation of the tunnels (Stearns and Vaksvik 1935, pp. 399–406). This has reduced stream habitat available to the blackline Hawaiian damselfly. Likewise, the boring of the Haʻikū tunnel on Oʻahu in 1940 caused a 25 percent reduction in the base flow of Kahaluʻu Stream, which is more than 2.5 mi (4 km) away (Takasaki *et al*. 1969, pp. 31–32), and has reduced available habitat for the blackline Hawaiian damselfly (HBMP 2008). Many of these aquifers were also the sources of springs that contributed flow to Oahu's windward streams; draining of these aquifers caused many of the springs to dry up, including some more than 0.3 mi (0.5 km) away from the bore tunnels (Stearns and Vaksvik 1935, pp. 379–380).

Habitat Destruction and Modification due to Vertical Wells
Surface flow of streams has also been affected by vertical wells drilled in premodern times, because the basal aquifer (lowest groundwater layer) and alluvial caprock (sediment-deposited harder rock layer) through which the lower sections of streams flow can be penetrated and hydraulically connected by wells (Gingerich and Oki 2000, p. 6; Stearns 1940, p. 88). This allows water in aquifers normally feeding the stream to be diverted elsewhere underground. Dewatering of the streams by tunneling and well placement near or in streams was a significant cause of habitat loss, and these effects continue today. Historically, for example, there was sufficient surface flow in Mākaha and Nānākuli Streams on Oʻahu to support loʻi kalo (artificial ponds for kalo (taro) cultivation) in their lower reaches, but this flow disappeared subsequent to construction of vertical wells upstream (Devick 1995, pers. comm.). The inadvertent dewatering of streams through the penetration of their aquifers (which are normally separated from adjacent waterbearing layers by an impermeable layer), by tunneling or through placement of vertical wells, caused the loss of habitat of blackline Hawaiian damselfly habitat, as this species was historically known from these areas.

Habitat Destruction and Modification by Stream Channelization
Stream degradation has been particularly severe on the island of Oʻahu where, by 1978, 58 percent of the perennial streams and banks had been channelized (e.g., concrete lined, partially lined, or altered) to control flooding (Polhemus and Asquith 1996, p. 24; Brasher 2003, p. 1,055). These alterations have resulted in an overall 89 percent loss of the total stream length island-wide (Polhemus and Asquith 1996, p. 24; Parrish *et al*. 1984, p. 83). The channelization of streams creates artificial, wide-bottomed stream beds, and often results in removal of riparian vegetation, which reduces shading, increases substrate homogeneity, increases temporal water velocity (increased water flow speed during times of higher precipitation including minor and major flooding), and causes higher water temperatures (Parrish *et al*. 1984, p. 83; Brasher 2003, p. 1,052). Tests conducted on native aquatic species showed that the higher water temperatures in channelized streams caused stress, and sometimes death (Parrish *et al*. 1984, p. 83). Natural streams meander and are lined with rocks, trees, and natural debris, and during times of flooding, jump their banks. Channelized streams are straightened and often lack natural obstructions, and during times of higher precipitation or flooding, facilitate a higher water flow velocity. Hawaiian damselflies are largely absent from channelized portions of streams (Polhemus and Asquith 1996, p. 24), which has likely contributed to a reduction in the historical range of Hawaiian damselfly species, including the blackline Hawaiian damselfly. In contrast,

undisturbed Hawaiian stream systems exhibit a greater amount of riffle and pool habitat canopy closure, higher consistent flow velocity, and lower water temperatures that are characteristic of streams to which the Hawaiian damselflies, in general, are adapted (Brasher 2003, pp. 1,054–1,057).

Channelization of streams has not been restricted to lower stream reaches. For example, there is extensive channelization of O‘ahu’s Kalihi Stream above 1,000 ft (300 m) elevation. Extensive stream channelization on O‘ahu has also contributed to the loss of habitat for the blackline Hawaiian damselfly (Englund 1999, p. 236; Polhemus 2008c, p. 45, in litt.).

Stream diversion, channelization, dewatering, and vertical wells represent serious and ongoing threats to the blackline Hawaiian damselfly for the following reasons: (1) They reduce the amount and distribution of stream habitat available to the species; (2) they reduce stream flow, leaving lower elevation stream segments completely dry except during storms, or leaving many streams completely dry year round, thus reducing or eliminating stream habitat; and (3) they indirectly lead to an increase in water temperature that results in physiological stress and to the loss of blackline Hawaiian damselfly naiads. The blackline Hawaiian damselfly is particularly vulnerable to extinction due to such changes (i.e., stream diversion, channelization, and dewatering), a vulnerability which is exacerbated by their range and habitat constrictions and declines in their population numbers.

Habitat Destruction and Modification by Climate Change
The blackline Hawaiian damselfly may also be affected by temporary habitat loss associated with droughts which are not uncommon in the Hawaiian Islands. Between 1860 and 1986 the island of O‘ahu has been affected by 48 periods of drought, 28 of which have affected the water supply on the island (Giambelluca *et al.* 1991, pp. 3–4).

Climate change will be a particular challenge for biodiversity because the introduction and interaction of additional stressors may push species beyond their ability to survive (Lovejoy 2005, pp. 325-326). The synergistic implications of climate change and habitat fragmentation are the most threatening facet of climate change for biodiversity (Hannah *et al*. 2005, p. 4). The magnitude and intensity of the impacts of global climate change and increasing temperatures on native Hawaiian ecosystems are unknown. We are not aware of climate change studies specifically related to the blackline Hawaiian damselfly. Based on the best available information, climate change impacts could lead to the decline or loss of native species that comprise the communities in which the blackline Hawaiian damselfly occur (Pounds *et al*. 1999, pp. 611–612; Still *et al*. 1999, p. 610; Benning *et al*. 2002, pp. 14,246 and 14,248). In addition, weather regime changes (e.g., droughts, floods) will likely result from increased annual average temperatures related to more frequent El Niño episodes in Hawai‘i. These changes may decrease water availability and increase the consumptive demand on O‘ahu’s natural streams and reservoirs by O‘ahu’s residents (Giambelluca *et al*. 1991, p. v). The effects of increasing temperatures on the aquatic habitat of the blackline Hawaiian damselfly species are not specifically known, but likely include the loss of aquatic habitat from reduced stream flow, evaporation of standing water, and increased water temperature (Pounds *et al*. 1999, pp. 611–612; Still *et al*. 1999, p. 610; Benning *et al*. 2002, pp. 14,246 and 14,248). Research, however, have been done for the orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*); laboratory studies indicate the eggs and naiads of the damselfly are sensitive to increased salinity and temperature, and no naiads survived at 20 ppt (about 57 percent seawater) (Tango 2010, p. 23). Egg hatch increased with increased temperature and decreased salinity, whereas naiad survival increased with decreased temperature and was greatest at intermediate salinity (5 and 10 ppt) (Tango 2010, p. 27). We can assume the blackline Hawaiian damselfly likely are also sensitive to changes in water temperature and salinity.

Oki (2004, p. 4) has noted long-term evidence of decreased precipitation and stream flow on the Hawaiian Islands, based upon evidence collected by stream gauging stations. This long-term drying trend, coupled with existing ditch diversions and periodic El Niño caused drying events, has created a pattern of severe and persistent stream dewatering events (Polhemus 2008c, in litt.). Future changes in precipitation and the forecast of those changes are highly uncertain because they depend, in part, on how the El Niño – La Niña weather cycle (a disruption of the ocean atmospheric system in the tropical Pacific having important global consequences for weather and climate) might change (Hawaiʻi Climate Change Action Plan 1998, pp. 2–10).

The blackline Hawaiian damselfly may be especially vulnerable to extinction due to anticipated environmental changes that may result from global climate change. Environmental changes that may affect these species are expected to include habitat loss or alteration and changes in disturbance regimes (e.g., storms and hurricanes), in addition to direct physiological stress caused by increased stream water temperatures to which the native Hawaiian damselfly fauna are not adapted. The probability of a species going extinct as a result of these factors increases when its range is restricted, habitat decreases, and population numbers decline (Intergovernmental Panel on Climate Change 2007, p. 8). The blackline Hawaiian damselfly has limited environmental tolerances, limited range, specific habitat requirements, small population size, and low numbers of individuals. Therefore, we would expect these species to be particularly vulnerable to projected environmental impacts that may result from changes in climate, and subsequent impacts to their habitats (e.g., Pounds *et al*. 1999, pp. 611–612; Still *et al*. 1999, p. 610; Benning *et al*. 2002, pp. 14,246 and 14,248). We believe changes in environmental conditions that may result from climate change may negatively impact the blackline Hawaiian damselfly and their habitat, and we do not anticipate a reduction in this potential threat in the near future.

Habitat Destruction and Modification by Invasive Species

The threat posed by introduced ungulates to the blackline Hawaiian damselfly and their habitats is serious, because they cause: (1) Trampling and grazing that directly disturb plant communities in riparian areas used by the blackline Hawaiian damselfly for perching, reproduction, and hunting for prey; (2) increased soil disturbance, leading to mechanical damage to plants in riparian areas used by the damselflies for perching, reproduction, and hunting for prey; and (3) increased watershed erosion and sedimentation, which negatively affects aquatic habitats used by the blackline Hawaiian damselfly. Although plants used for perching by damselflies are not necessarily native plants, ungulate activity damages or removes all plants near the stream. Damselflies depend on plants near the stream for their daily activities, territory establishment, reproduction, and hunting activities. These threats are expected to continue or increase without ungulate control or eradication (USFWS 2012, p. 57676).

Predation by Nonnative Fish

Predation by nonnative fish is a serious and ongoing threat to the blackline Hawaiian damselfly. blackline Hawaiian damselfly naiads occur in standing or seep-fed pools, slow-flowing sections of streams, under stones or mats of moss, and algae in streams, where they are vulnerable to predation by nonnative fish. Information suggests that Hawaiian damselflies experience limited natural predation pressure from the five species of freshwater fish native to Hawaiʻi—gobies (Gobiidae) and sleepers (Eleotridae) (Ego 1956, p. 24; Kido *et al*. 1993, pp. 43–44; Englund 1999, pp. 236–237). Hawaiʻi's native fishes are benthic (bottom) feeders, and stream dwelling Hawaiian damselfly species, including the blackline Hawaiian damselfly, avoid these areas in preference for shallow side channels, sidepools, and higher velocity riffles and seeps (Englund 1999, pp. 236–237). While fish predation has been an important factor in the evolution of behavior in damselfly naiads in continental systems (Johnson 1991, p. 8), it can only be speculated that Hawaiʻi's stream-dwelling damselflies adapted behaviors to avoid the benthic feeding habits of native fish species.

Over 70 species of nonnative fish have been introduced into Hawaiian freshwater habitats (Devick 1991, p. 190; Englund 1999, p. 226; Englund and Eldredge 2001, p. 32; Brasher 2003, p. 1,054; Englund 2004, p. 27; Englund *et al*. 2007, p. 232), with at least 51 species now established (Freshwater Fishes of Hawaiʻi 2008). The initial introduction of nonnative fish to Hawaiʻi began with the release of food stock species by Asian immigrants at the beginning of the 20th century; however, the impact of these first introductions on Hawaiian damselflies cannot be assessed because they predated the initial collection of damselflies in Hawaiʻi (Perkins 1899, pp. 64–76). Between 1905 and 1922, poeciliid fish were introduced for biological control of mosquitoes, including the mosquito fish (*Gambusia affinis*), sailfin molly (*Poecilia latipinna*), green swordtail (*Xiphophorus helleri*), moonfish (*Xiphophorus maculatus*), and guppy (*Poecilia reticulata*) (Van Dine 1907, p. 9; Englund 1999, p. 225; Brasher 2003, p. 1,054). By 1935, some Oʻahu damselflies were becoming less common, and these introduced fish were the suspected cause of their decline (Williams 1936, p. 313; Zimmerman 1948, p. 341). From 1946 through 1961, several additional nonnative fish were introduced for the purpose of controlling nonnative aquatic plants and for recreational fishing (Brasher 2003, p. 1,054). During the 1980s, additional nonnative fish species were established in Oʻahu waters, including aggressive predators and habitat-altering species such as the channel catfish (*Ictalurus punctatus*), cichlids (e.g., *Tilapia* spp.), sailfin catfish (*Liposarcus multiradiatus*), top minnows (*Limia vittata*), and piranha (*Serrasalmus* sp.) (Devick 1991, pp. 189, 191–192; Brasher 2003, p. 1,054; Freshwater Fishes of Hawaiʻi 2008). Englund (1999, p. 233) found several of these species to be abundant in nearly all lowland Oʻahu streams and water systems, although not all were as capable of colonizing higher elevation stream reaches as the introduced poeciliid species.

Geologic or manmade barriers (e.g., waterfalls, steep gradients, dry stream midreaches, or constructed diversions) appear to prevent access by nonnative fish species to stream areas above these barriers; however, there is still a chance of facilitated fish movement. For example, in 2000, a maintenance worker introduced *Tilapia* spp. into ponds located on the grounds of Tripler Medical Army Hospital that were upslope from the remaining Oʻahu population of the orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) (Englund 2000, in litt.). The ponds were drained and the *Tilapia* spp. removed. The importance of their removal was underscored by the fact that a large storm caused the ponds to fill and overflow downslope into the stream supporting the damselflies soon after the *Tilapia* spp. were removed (Preston *et al*. 2007, p. 263). Current literature indicates that the extirpation of Hawaiian damselflies from nearly all of their historical lowland habitat sites on Oʻahu is the result of predation by introduced nonnative fish (Moore and Gagne 1982, p. 4; Liebherr and Polhemus 1997, p. 502; Englund 1999, pp. 235–237; Brasher 2003, p. 1,055; Englund *et al*. 2007, p. 215; Polhemus 2007, pp. 238– 239). The threats posed by continued introduction and establishment of nonnative fish in Hawaiian waters, and the possible movement of those nonnative species to new streams and other aquatic habitat, are ongoing and expected to continue into the future. This represents a serious threat to the survival of the blackline Hawaiian damselfly.

Additional impacts from other invasive species
Bullfrogs and toads have a negatively correlated pattern of occurrence with the blackline Hawaiian damselfly (USFWS 2012, p. 57679). The damselfly also faces the threat of predation by ants (Borror *et al*. 1989, pp. 737–741).

Small number of populations and individuals
Species that are endemic to single islands, like the blackline Hawaiian damselfly, are inherently more vulnerable to extinction than widespread species because of the increased risk of genetic bottlenecks; random demographic fluctuations; climate change; and localized catastrophes such as hurricanes, landslides, rockfalls, drought, and disease outbreaks (Mangel and Tier 1994, p. 607; Pimm *et al.* 1988, p. 757). These problems are further magnified when populations are few and restricted to a very small geographic area, and when the number of individuals is very small. Populations with these characteristics face an increased likelihood of stochastic extinction due to changes in demography, the environment, genetics, or other factors (Gilpin and Soulé 1986, pp. 24–34).

Small, isolated populations often exhibit reduced levels of genetic variability, which diminishes the species' capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence (e.g., Barrett and Kohn 1991, p. 4; Newman and Pilson 1997, p. 361). The problems associated with small population size and vulnerability to random demographic fluctuations or natural catastrophes are further magnified by synergistic interactions with other threats, such as those discussed above.

The threat to the blackline Hawaiian damselfly from limited numbers of populations (i.e., known from only 18 streams) and individuals, and impacts to water quality and quantity is immediate and significant for the following reasons: this species may experience reduced reproductive vigor due to inbreeding depression; this species may experience reduced levels of genetic variability leading to diminished capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence; and a single catastrophic event (e.g., hurricane, landslide, introduction of nonnative predators into the habitat) may result in extirpation of an entire stream population.

<u>Environmental Baseline for Blackline Hawaiian Damselfly</u>

The blackline Hawaiian damselfly occurs in Waihī Stream within habitat consisting of rocky riffles and shallow pools, with small tributaries entering from along the banks and forming small, shallow, standing pools lateral to the main stream channel (Foster *et al*. 2015, in litt.). The stream channel at the upper end of the stream reach is open and unshaded, making an abrupt transition downstream to a heavily shaded area from large figs and other introduced trees. The damselfly is found throughout shaded sections of the channel, particularly in lateral pools formed by small tributaries, with both mating pairs and ovipositing females observed (Foster *et al*. 2015, in litt.). At certain sites up to 7 individuals were observed simultaneously. The total population estimate for the blackline Hawaiian damselfly in Waihī is 66 individuals (Vorsino *et al*. 2016, in litt.).

The damselfly also occurs in concentrated numbers in riffles at slower sections of stream, shaded by nonnative vegetation and at stream forks to the upper limit of where the Waiakeakua Stream begins to become confined between bedrock walls (Polhemus 2016c, in litt.). A survey for damselflies documented 11 adults sporadically along the stream reaches within the action area for the Waiakeakua Stream. The total population estimate for the blackline Hawaiian damselfly in Waiakeakua is 36 individuals (Vorsino 2015, in litt.).

The populations of blackline damselflies occur directly within the boundaries of the action area, including several pools within and immediately adjacent to the delineated Project (Figures 4 and 5). Blackline Hawaiian damselflies were more numerous in shallow side channels that likely precluded fish. Damselflies were observed in mainstream channel areas as well, however, were less numerous and more dispersed (Smith 2016, in litt.). The damselfly's distribution within the project action area is likely limited by a higher abundance of nonnative fish species in the lower reaches of the Mānoa stream.

High Definition Stream Surveys (HDSS) were conducted in the upper Mānoa Stream to document the presence of certain fish species (Table 3). State biologists and technicians found bristlenose catfish and mosquitofish as the most common species. Some native gobies likely exist in this section of the stream, but were not observed. Instream habitat appeared to be good for native fish species. Bristlenose catfish were observed all the way to the falls (Parham and Higashi 2015, p. 27, in litt.). Although nonnative fish occur within the stream, a limited number of damselflies are able to persist. However, these damselflies would not likely persist in the absence of side pools and riffle habitat.

Table 3. Species observed during the HDSS effort in upper Mānoa Stream. Species listed in order of most to least common (Parham and Higashi 2015, p. 27, in litt.).

Scientific Name	Common Name	Observations
Procambarus clarkii	Crayfish	9
Ancistrus cf. temminckii	Bristlemouth catfish, bristlenose/bearded catfish (Yamamoto and Tagawa, 2000)	7
Gambusia affinis	Western mosquitofish	4
Poecilia sphenops	Liberty molly	2
Pterygoplichthys multiradiatus	Sailfin catfish (AFS), long-fin armored catfish (Yamamoto and Tagawa, 2000)	1

These two locations of the blackline Hawaiian damselfly are partially contained within the action area. These two populations represent 2 of the 20 known populations and approximately 102 of the total 902-1,102 total individuals within the species' total range (roughly 10 percent).

The presence of this species in both Waihī and Waiakeakua Streams indicate that additional populations of *M. nigrohamatum nigrolineatum* are likely to occur along all of the upper portions of Mānoa Stream. Additional survey work in the upper Mānoa catchment would be useful to verify the complete status of the species within the action area as well as the status of the population as a whole.

Figure 4. Proposed Waihī Debris and Detention Basin with Observed Damselfly Points.

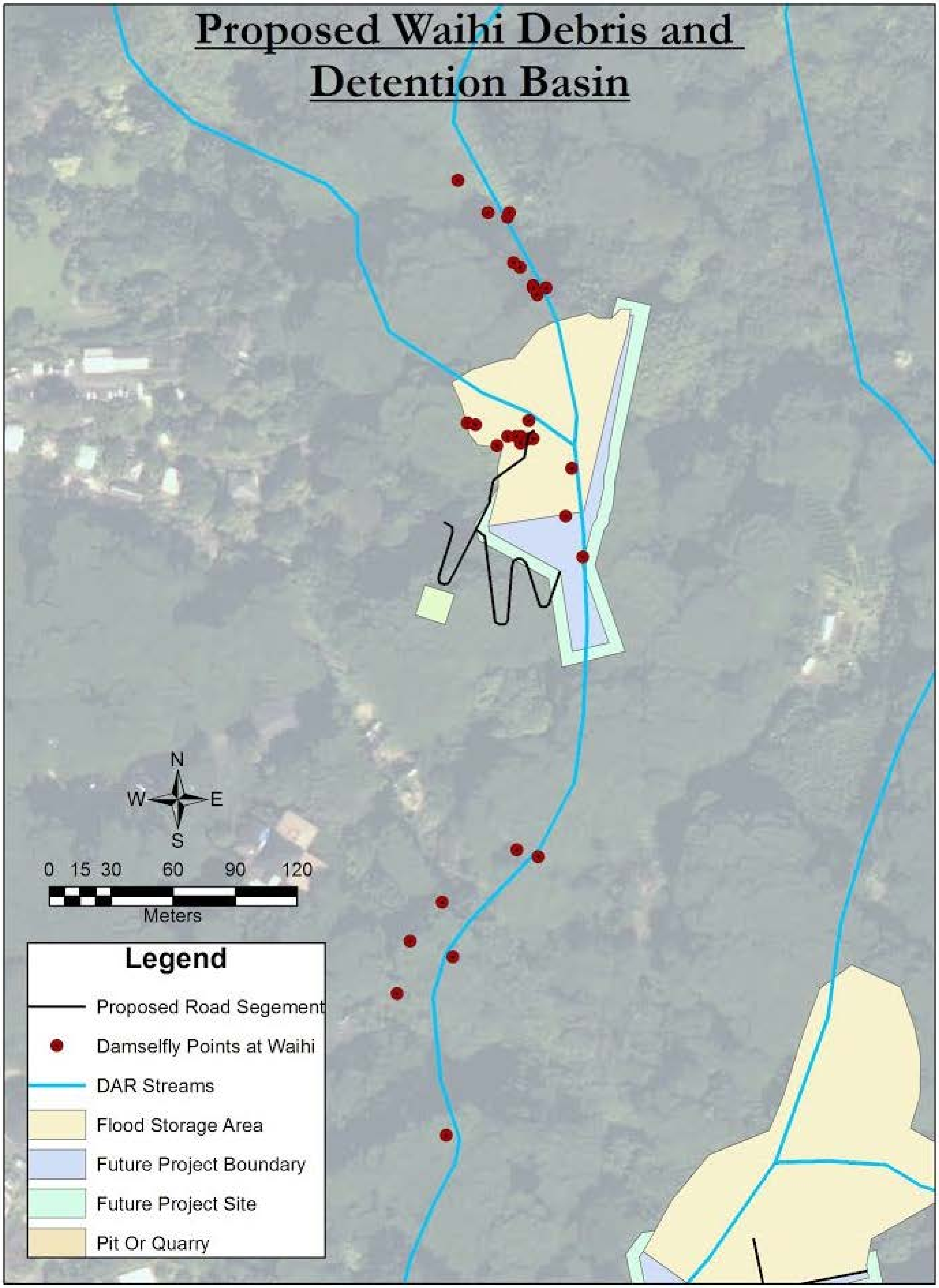
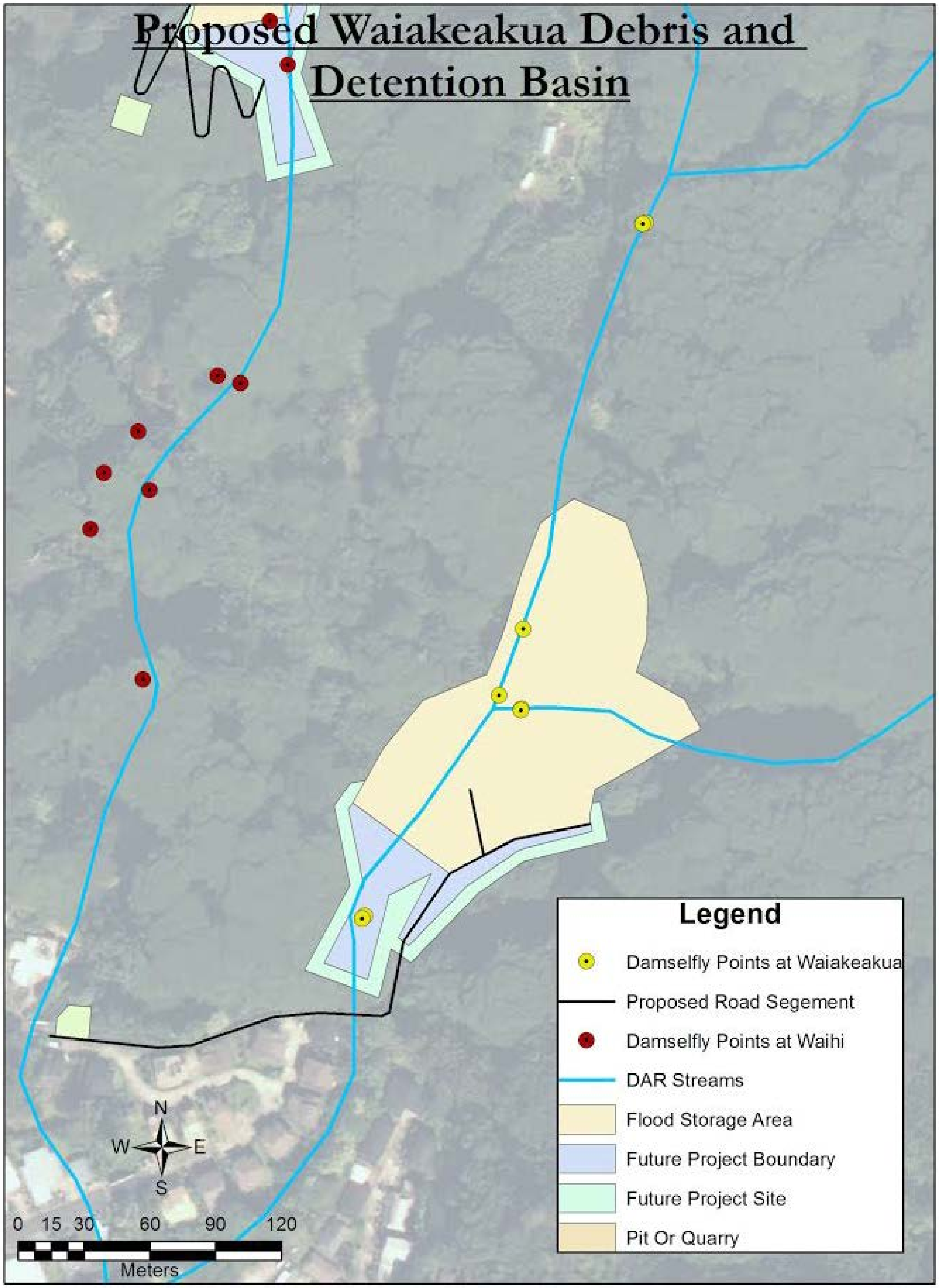


Figure 5. Proposed Waiakeakua Debris and Detention Basin with Observed Damselfly Points.



EFFECTS OF THE ACTION

Exposure Analysis Approach

The Service has developed an analysis framework for section 7 consultations that incorporates the general structure, primary concepts, and nomenclature of the U.S. Environmental Protection Agency's ecological risk assessment framework (USFWS 2005b). Factors causing adverse effects are called "stressors" and beneficial effects are called benefits. In this approach, the Service determines the resources that will be exposed to the proposed action's stressors and benefits by evaluating the location, timing, duration, frequency, and intensity of potential exposure to each stressor and benefit, and identifying the physical, chemical, and biotic features that will be directly and indirectly exposed. Then the causal relationships between sources of stressors and benefits and the response of listed resources are analyzed. The exposure analysis also estimates future changes in the abundance or distribution of listed species expected to result from exposure to stressors and benefits.

The proposed action's stressors and benefits may include the following actions at Waihī and Waiakeakua Streams:

- Construction of detention basins
- Construction of debris catchments
- Placement of culverts
- Placement of riprap
- Construction of access roads

Effects to Blackline Hawaiian Damselfly

Construction of detention basins

The proposed action is expected to have direct effects on the blackline Hawaiian damselfly population within the action area. The proposed construction of the Waihī and Waiakeakua detention basins will eliminate the habitat where the blackline Hawaiian damselflies occur at the proposed detention basins and below each construction site. Additionally, damselflies will be taken if run over, walked on, buried, etc. Although, the proposed construction of the detention basis is expected to take out habitat used by the damselfly, we do not anticipate any changes to the habitat upstream of the action area because the detention basins are not designed to hold water permanently and will not remove any habitat upstream. We anticipate adverse effects to adult blackline Hawaiian damselflies and associated life stages due to complete habitat loss and mortality at both locations as a result of the construction of detention basins.

Construction of debris catchments

The proposed action is expected to have direct effects on the blackline Hawaiian damselfly population within the action area. The proposed construction of the Waihī and Waiakeakua debris catchment areas will eliminate the habitat where the blackline Hawaiian damselflies occur at the construction sites. Additionally, damselflies will be taken if run over, walked on, buried, etc. We anticipate adverse effects to adult blackline Hawaiian damselflies and associated life stages due to complete habitat loss and mortality at both locations as a result of the construction of debris catchment areas.

Placement of culverts

The proposed action is expected to have direct effects on the blackline Hawaiian damselfly population within the action area. The proposed placement of culverts within the Waihī and Waiakeakua Streams will eliminate the habitat where the blackline Hawaiian damselflies occur at the culverts and below the culvert sites. Additionally, damselflies will be taken if run over, walked on, buried, etc. We anticipate adverse effects to adult blackline Hawaiian damselflies and associated life stages due to complete habitat loss and mortality at both locations as a result of the placement of culverts.

Placement of riprap

The proposed action is expected to have direct effects on the blackline Hawaiian damselfly population within the action area. The proposed placement of riprap upstream and downstream of the debris and detention basins in the Waihī and Waiakeakua Streams will eliminate the habitat where the blackline Hawaiian damselflies occur at each location where riprap is placed. Changes of stream flow will alter the water regime and vegetation which provide canopy cover that provide habitat for damselflies. Additionally, damselflies will be taken if run over, walked on, buried, etc. We anticipate adverse effects to adult blackline Hawaiian damselflies and associated life stages due to complete habitat loss and mortality at both locations as a result of the placement of riprap at upstream and downstream.

Construction of access roads

The proposed action is expected to have direct effects on the blackline Hawaiian damselfly population within the action area. The proposed construction of the Waihī access roads will eliminate the habitat where the blackline Hawaiian damselfly occurs at all locations where there is construction of an access road. Additionally, damselflies will be taken if run over, walked on, buried, etc. We anticipate adverse effects to adult blackline Hawaiian damselflies and associated life stages due to complete habitat loss and mortality as a result of the construction of access roads at Waihī Stream.

In summary, we anticipate adverse effects to 46 and 20 adult blackline Hawaiian damselflies and associated life stages in Waihī and Waiakeakua Streams, respectively, due to complete loss of riffle and pool habitat within the action area as a result of the proposed project.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future non-Federal actions that are reasonably certain to occur within the action area subject to consultation. Future federal actions will be subject to the consultation requirements established in section 7 of the Act and, therefore, are not considered cumulative for the proposed action. The Service is unaware of any foreseeable actions within the action area.

CONCLUSION

After reviewing the current status, the environmental baseline, the effects of the proposed action, and the cumulative effects, it is the Service’s biological opinion that the proposed construction, operation and maintenance of the Ala Wai Canal Project discussed herein is not likely to jeopardize the continued existence of the blackline Hawaiian damselfly. As stated in the Effects section above, a loss of features, such as side channels and scour pools free from nonnative fish, will be lost as a result of the proposed project, preventing these areas from becoming and persisting as habitat for damselflies. While 66 damselflies will be lost, this will result in a 6-7.3 percent decrease to the estimated total population number of the blackline Hawaiian damselflies as a whole. These impacts are not expected to affect the damselfly population at other stream locations and are expected to have a small effect to the total population of the species.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations promulgated pursuant to section 4(d) of the Act prohibit the take of endangered or threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. Harm is further defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Harass is defined by the Service as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, hut arc not limited to, breeding, feeding or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, carrying out an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2) of the Act, taking that is incidental to and not intended as part of the agency action is not considered a prohibited taking under the Act provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary, and must be undertaken by the USACE so that they become binding conditions for the exemption in section 7(o)(2) to apply. If the USACE (1) fails to assume and implement the terms and conditions or (2) fails to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, the USACE must report the progress of the action and its impact on the species to the Service as specified in this incidental take statement and reporting requirements below [50 CFR §402.14(i)(3)].

AMOUNT OR EXTENT OF TAKE

Based on our analysis presented in this Biological Opinion, the Service anticipates the following take may occur for as long as the Ala Wai Canal Project construction, operation, and maintenance are active and in place:

1) Up to 66 blackline Hawaiian damselfly adults and associated life cycle stages over the life of the project due to elimination of breeding habitat and mortality as a result of the proposed action.

Effect of the Take

In this Biological Opinion, the Service determined that this level of anticipated take is not likely to jeopardize the continued existence of the blackline Hawaiian damselfly based on the information provided in this document.

Reasonable and Prudent Measures

The reasonable and prudent measures given below, with their implementing term and conditions, are designed to minimize the impacts of incidental take that might otherwise result from the proposed actions. If, during the course of the action, the level of incidental take is exceeded, such incidental take represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. In addition, the action that caused the taking must cease; the action agency must immediately provide an explanation of the causes of the taking; and must review with the Service the need for possible modification of the reasonable and prudent measures. The following reasonable and prudent measures are necessary and appropriate to minimize the effect of take on the blackline Hawaiian damselfly.

1. The USACE shall minimize the loss of blackline Hawaiian damselfly.
2. The USACE shall minimize the loss of habitat.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, the USACE must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting and monitoring requirements. These terms and conditions are non-discretionary.

In order to implement the reasonable and prudent measure #1 above, the following terms and conditions apply:

1. The USACE shall hire a qualified biologist (approved by the Service) to collect damselflies to be relocated to another protected location or to be held in captivity in a qualified facility until site is identified.
2. The USACE shall monitor and report on the levels of take that occur on an annual basis. To determine the level of incidental take the USACE shall:
    a. Monitor and report any observed blackline Hawaiian damselflies prior to construction of the access roads and debris and detention basins at the Waihī and Waiakeakua construction footprints. The USACE will monitor blackline Hawaiian damselfly information for one year after the completion of construction at these sites. The monitoring methodology will be approved by the Service prior to construction implementation, and will, at a minimum, include counts of adult blackline Hawaiian damselflies.
    b. Submit reports summarizing the methods and results of the above monitoring efforts to the Service's Pacific Islands Fish and Wildlife Office (300 Ala Moana Blvd., Room 3-122, Honolulu, Hawai'i 96850) annually until the monitoring is complete.
3. The USACE shall submit annual reports detailing the implementation of the above Reasonable and Prudent Measures and Terms and Conditions. The first report shall be

due at the end of January of the first year after the project is initiated. Annual reports shall be submitted throughout the duration of the proposed action.

In order to implement the reasonable and prudent measure #2 above, the following terms and conditions apply:

1. The USACE shall consider purchasing private land to relocate the access roads downstream of the proposed Waihī debris and detention basin to minimize loss of riffle and pool habitat.
2. The USACE shall limit the removal of tree canopy cover over areas of damselfly habitat.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs all Federal agencies to use their authority to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. The term "conservation recommendations" has been defined as suggestions from the Service regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information. The recommendations provided here relate only to the proposed action and do not necessarily represent complete fulfillment of the agency's 7(a)(1) responsibility for the species.

1. The USACE should control or eliminate nonnative fish, e.g. poeciliids, within upstream areas of the Mānoa stream with appropriate use of chemical or rotenone treatments to allow establishment of additional populations of endemic damselflies such as *Megalagrion leptodemas*, *M. oceanicum* and *M. xanthomelas*.
2. Once poeciliids are removed from a reach of stream, the USACE should create fish barriers that could prevent poeciliid fish from recolonizing upstream areas.
3. The USACE should construct or fund stream restoration to allow for persistence and/or re-establishment of native fish and invertebrates (while providing a barrier to exclude nonnative fish passage) into essential headwater stream reaches at Falls 7 and 8.
4. The USACE should construct or fund stream restoration to allow for persistence and/or re-establishment of native fish and invertebrates (while providing a barrier to exclude nonnative fish passage) into essential headwater stream reaches within the Ala Wai watershed.
5. The USACE should initiate restoration of habitat for native fish and the blackline Hawaiian damselfly at the lower elevations of the Mānoa stream.
6. The USACE should implement an effective program to educate the public to the harmful effects of releasing aquarium fish into Hawaiian waters.

REINITIATION-CLOSING STATEMENT

This concludes formal consultation on this action. As required in 50 CFR §402.16, reinitiation of consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operation causing such take must cease pending reinitiation.

We appreciate your efforts to conserve protected species. If you have any questions concerning this biological opinion, please contact Jiny Kim of the USFWS Pacific Islands Fish and Wildlife Office at (808) 792-9400.

Sincerely,

Mary M. Abrams

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Appendix A.
Not Likely to Adversely Affect Determination for the Hawaiian hoary bat, Oʻahu ʻelepaio, Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and the Hawaiian duck

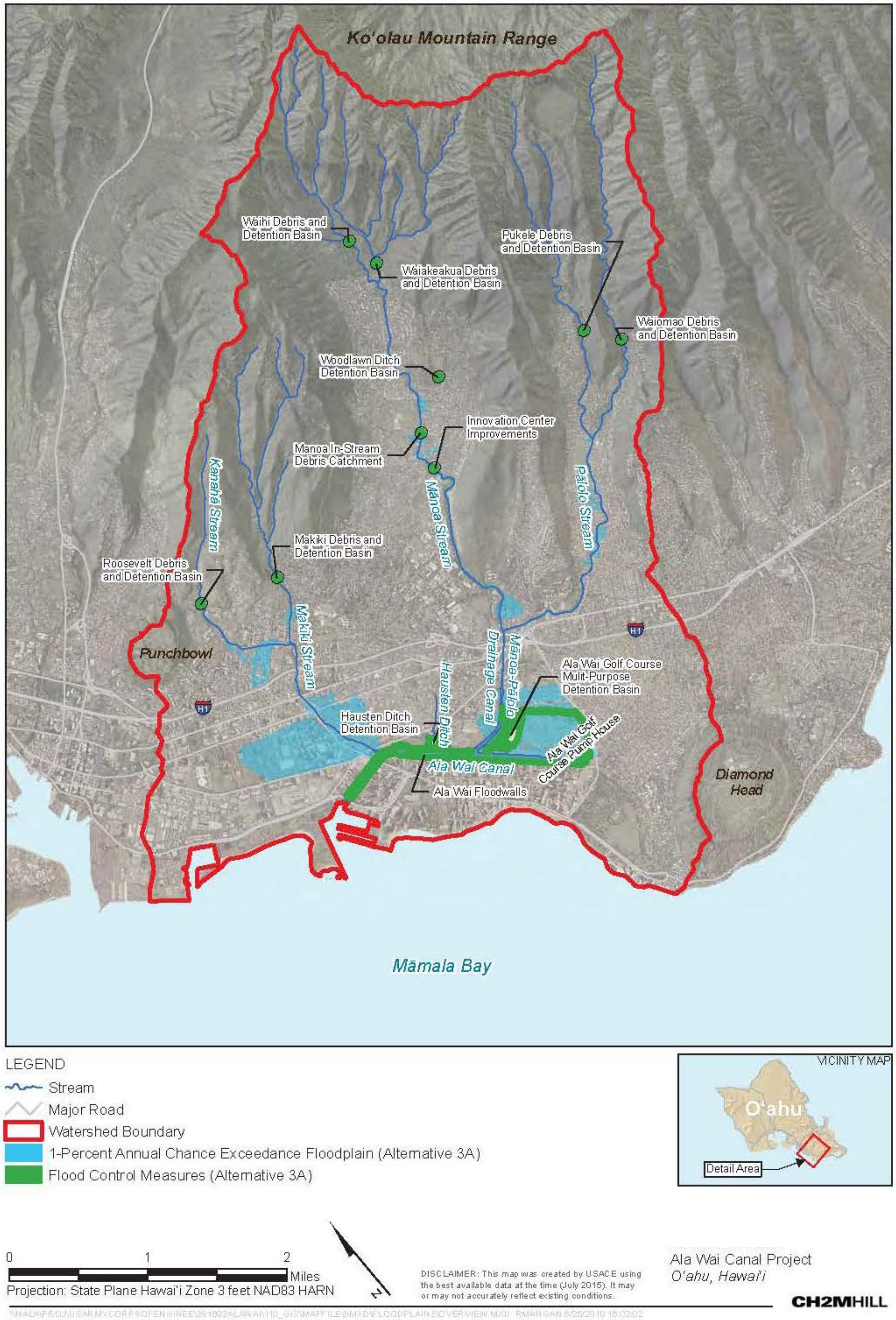
This Appendix is in response to your request for our concurrence with your determination that the proposed Ala Wai Canal Project, as described above, will not adversely affect the endangered Hawaiian hoary bat (*Lasiurus cinereus semotus*), Oʻahu ʻelepaio (*Chasiempis ibidis*), Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica alai*), Hawaiian gallinule (*Gallinula chloropus sandvicensis*), and the Hawaiian duck (*Anas wyvilliana*). We acknowledge that you have made the determination that the proposed Ala Wai Canal Project will have no effect to other species, including the endangered crimson Hawaiian damselfly (*Megalagrion leptodemas*), oceanic Hawaiian damselfly (*Megalagrion oceanicum*), orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*), Oʻahu tree snails (*Achatinella* sp.), hāhā (*Cyanea acuminata*), hāhā (*Cyanea crispa*), hāhā (*Cyanea koolauensis*), *Diellia erecta*, nānū (*Gardenia mannii*), *Gouania meyenii*, wāwae ʻiole (*Huperzia nutans*), *Lobelia oahuensis*, ʻlhiʻihi (*Marsilea villosa*), *Pteris lidgatei*, *Schiedea nuttallii*, *Spermolepis hawaiiensis*, and designated critical habitat for Oʻahu ʻelepaio. The findings and recommendations in this consultation are based on: (1) your Revised Biological Assessment dated March 2016, and (2) other information available to us. A complete administrative record is on file in our office. This response is in accordance with section 7 of the Endangered Species Act of 1973 (Act), as amended (16 U.S.C. 1531 *et seq*.).

<u>Project Description</u>
The project description and action areas are the same as described above for the formal consultation with the addition of the following described below.

Additional project locations:

- **Woodlawn Ditch detention basin**: Woodlawn Ditch (a manmade tributary to Mānoa Stream), adjacent to East Mānoa Road.
- **Mānoa in-stream debris catchment**: Middle reach of Mānoa Stream, directly adjacent to lower edge of Mānoa District Park.
- **Kānewai Field multi-purpose detention basin**: Lower reach of Mānoa Stream, just below Dole Street.
- **Waiʻōmaʻo debris and detention basin**: Pūkele Stream, adjacent to various residences on Waiʻōmaʻo Road.
- **Pūkele debris and detention basin**: Pūkele Stream, adjacent to residences on Ipulei Place.
- **Makiki debris and detention basin**: Makiki Stream, directly adjacent to Makiki Heights Drive.
- **Ala Wai Canal floodwalls**: Ala Wai Canal
- **Hausten Ditch detention basin**: Hausten Ditch (drainage input to Ala Wai Canal)
- **Ala Wai Golf Course multi-purpose detention basin**: Ala Wai Canal

Figure 1. Locations of proposed flood control measures for the Ala Wai Canal Project.



Additional project measures:

- **Floodwalls**: The floodwalls would be comprised of concrete walls that would function to increase existing channel capacity. The floodwalls would range in height, and would be either constructed with a minimal set back distance from the existing stream or canal walls. Local drainage patterns would be maintained to the extent possible, with flapgates/slidegates and pumps incorporated where necessary.
- **Non-structural measures**: Non-structural measures generally involve the use of knowledge, practices or agreements to change a condition, such as through policies and laws. These may also include efforts such as improved flood warning, greater communication of flood risks, and tools or incentives to property owners to help protect their property (such as flood insurance). Non-structural measures that have been identified as feasible options for this project include improvements to the flood warning system.

These specific measures and the approximate area of disturbance associated with each proposed location within the watershed is summarized in Table 1. Following construction, the proposed operation and maintenance required for each of the flood risk management measures will be operated and maintained by the non-federal sponsor and are summarized in Table 2. Each of the measures described is assumed to have a life expectancy of 50 years, with maintenance performed on a routine basis.

Table 1. Proposed Flood Risk Management Measures for the Ala Wai Canal Project.

Measure[1]	Description of Measure	Total Area of Disturbance		Permanent Structure Footprint		Temporary Disturbance (e.g., Staging) (ac)	Vegetation Management		Extent of Inundation (duration for 1% ACE)
		Total Area (ac)	Length of Steam (ft)	Total Area (ac)	Length of Steam (ft)		Total Area (ac)	Length of Steam (ft)	
Woodlawn Ditch Detention Basin	Construct a three-sided berm, approximately 15’ high and 840’ across to create the detention basin. Construct arch culvert with 80’ wide concrete spillway above culvert with riprap on upstream and downstream side. Arch culvert and spillway will tie into Woodlawn ditch for drainage. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.	1.9	120	1.1	60	0.1	1	40	1.7 acres inundated for up to 10 hours
Mānoa In-Stream Debris Catchment	Construct concrete pad over stream bed, approximately 8’ wide and 60’ across; with steel posts (up to approximately 7’ high) evenly spaced 4’ apart along concrete pad.	0.1	48	0.01	8	0.1	0.1	40	None
Kānewai Field Multi-Purpose Detention Basin	Construct earthen berms, approximately 9’ high around 3 sides of field to create a detention basin. Construct 60’ wide grouted riprap inflow spillway of concrete along bank of Mānoa Stream (on northwest end) to allow high stream flows to enter the new detention basin. Existing drainage pipe at south end of basin will allow water to re-enter stream. A 20-foot-wide area around the perimeter of the berm and potentially flooded area will be cleared and maintained.	6.1	70	0.9	70	0.1	5.5	0	5.1 acres inundated for up to 10 hours
Waiʻōmaʻo Debris and Detention Basin	Earthen dam, approximately 33.5’ high and 120’ across; with an arch culvert to allow small storm flows to pass. Culvert length will be 170’ in length. Construct a 110’ wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Downstream riprap scour protection will be approximately 150 linear feet. Construct an energy dissipation structure on downstream end of culvert. Debris catchment feature located on upstream end of culvert. Excavate approximately 3,060	1.6	720	0.5	320	0.1	1.1	40	1.0 acre inundated for up to 10 hours

	cubic yards of soil to provide required detention volume upstream of berm. Low-flow channel with existing substrate to be restored following excavation. Create new access road for construction and operation and maintenance. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Existing Waiʻōmaʻo USGS Gauging Station will be demolished during construction. Project footprint will be 19,890 square feet.								
Waiʻōmaʻo Debris Catchment	Construct a concrete pad, approximately 8' wide and 50' across with steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	0.4	48	0.1	8	0.1	0.1	40	None
Pūkele Debris and Detention Basin	Earthen berm, approximately 30' high and 120' across; with an arch culvert to allow small storm flows to pass. Culvert length will be 160 feet. Construct a 110' wide concrete spillway above culvert with grouted riprap on upstream and downstream side. Downstream riprap will be approximately 150 linear feet for scour protection. Debris catchment feature located on upstream end of culvert. Energy dissipation structure to be located on downstream end of culver. Excavate 14,330 square yards upstream of dam to provide required detention volume upstream of berm. Create new access road for construction and operation and maintenance. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Project footprint will be 16,660 square feet.	1.6	810	0.4	310	0.1	0.1	40	0.8 acre inundated for up to 9 hours
Pūkele Debris Catchment	Concrete pad, approximately 8' wide and 25' across; steel posts (up to approximately 7' high) evenly spaced 4' apart along concrete pad.	0.2	48	0.1	8	0.1	0.1	40	None
Makiki Debris and Detention Basin	Earthen dam, approximately 24' high and 100' across; with an arch culvert to allow small storm flows to pass. Arch culvert length will be 160 ft. Construct a 90' wide	1.5	780	0.4	310	0.1	0.1	40	0.5 acre inundated for up to 9 hours

	concrete spillway above culvert with grouted riprap on the upstream and downstream side. Downstream side riprap will be approximately 150 linear feet for scour protection. Debris catchment feature located on upstream end of culvert. Energy dissipation structure to be located on downstream end of culvert. Excavate 14,040 square feet upstream of dam for required detention capacity. Create new access road for construction and operation and maintenance. A 20-foot-wide area around the perimeter of the berm will be cleared and maintained. Project footprint will be 17,165 square feet.								
Ala Wai Canal Floodwalls and Pump Station	Add concrete floodwalls along Ala Wai Canal ranging in height up to approximately 5 feet high. Floodwalls will be offset from existing canal walls. Existing stairs to be extended and new ramps to be installed to maintain access to canal. Add three pump stations and gates to existing drainage pipes to prevent drainage flooding that may be caused on the exterior of the new Ala Wai floodwalls. Pump stations to be located at diamond head end of Ala Wai canal, within Ala Wai Golf Course at head of Kapahulu Ditch, and in Ala Wai Park, near Hausten Ditch detention basin. Slide and flap gates will be installed at existing drainage pipes along the entire canal to prevent backflow out of the canal. New floodgate to be installed at Ala Wai Clubhouse near McCully Street.								
Hausten Ditch Detention Basin	Construct concrete floodwalls and earthen berm (approximately 7' high) around a portion of the Ala Wai Park to provide detention for local drainage. Install concrete wall with four slide gates adjacent to the upstream edge of the existing bridge to control flow and prevent a backflow of floodwaters between Hausten Ditch and Ala Wai Canal during a flood event. The area within the berm to be maintained as a field	1.4	70	0.2	35	0.1	1.1	35	3.5 acres inundated for up to 4 hours

	for recreational use during non-flood conditions.								
Ala Wai Golf Course Multi-Purpose Detention Basin	Construct earthen berm approximately 7' high around northern and eastern outside perimeter of golf course property. Add floodgate across main entrance road. Construct 60' long concrete inflow spillway with grouted riprap along bank of Mānoa-Pālolo Drainage Canal to allow high flows to enter the basin. Excavate sediment basin within "rough" (out of bounds; western portion) areas of the golf course to act as sediment catchment during storm events with passive drainage back into Ala Wai Canal.	25.6	70	4	70	0.6	8.4	0	134 acres inundated for up to 10 hours
Flood Warning System	Installation of 3 real-time rain gages (Mānoa, Makiki, and Pālolo Streams) and 1 real-time streamflow or stage gage (Ala Wai Canal) as part of flood warning system for Ala Wai Watershed.	minimal	minimal	minimal	minimal	minimal	0	0	None
Falls 7 and 8	Installation of grouted stones to eliminate passage barrier by providing a suitable surface for migration of native species at 2 in-stream structures.	0.05	110	0.004	10	0.05	0	0	None

NOTES:
[1] In addition to these structural measures, the proposed project would also include improvements to the existing flood warning system.
[2] Inundation area is the area behind the detention basin that is expected to be inundated during a 1-percent annual chance exceedance flood event.

Table 2. Proposed Operation and Maintenance Activities.

Measure Type	Summary of Operation and Maintenance Activities
Multi-Purpose Detention Basin	Cut/clear vegetation within cleared zoned (20 feet around perimeter of structures) twice a year, allowing no woody vegetation to grow in this area.
Debris Catchment	Clear accumulated debris twice per year.
Floodwalls	Periodically inspect drainage pipes and gates, and remove any impediments to movement. Inspect, test, and maintain pump systems annually. Paint and/or grease metal parts, as needed (e.g. patching).
Flood Warning System	Periodically inspect gages for proper operating conditions. Keep area around sensors free from sediment deposits and plant growth, or other impediments to data collection. Inspect and test annually (includes annual operating cost).
Falls 7 and 8	Periodically inspect in-stream structure for potential erosion or undercutting; reinforce as needed.

NOTES:
[1]Debris and sediment cleared from the flood risk management measure locations would be disposed at an existing authorized location.

Conservation Measures to Avoid and Minimize Effects to Listed Species
The following conservation measures identified in your Revised Biological Assessment will be implemented at the project sites to avoid and minimize effects to the Hawaiian hoary bat, O‘ahu ‘elepaio, Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck. These conservation measures are considered part of the project description. Any changes to, modifications of, or failure to implement these conservation measures may result in the need to reinitiate this consultation.

- No woody plants greater than 15 ft (5 m) in height will be removed or trimmed during the Hawaiian hoary bat-breeding season (June 1 to September 15). Removal of any woody vegetation that exceeds 15 feet in height would be conducted outside of the Hawaiian hoary bat’s pupping season (June 1 through September 15) during construction and operation of the project’s features. In addition, construction and maintenance operations would be restricted to daylight hours to avoid potential bat foraging activities.
- The trimming and clearing of vegetation in areas of suitable ‘elepaio habitat would be restricted during their nesting season (January through June). Seasonal restrictions for trimming/clearing of vegetation would be incorporated to avoid and/or minimize the potential for impacts to the O‘ahu ‘elepaio, should it occur in the action area.
- All project personnel will be briefed on ESA-listed species that could be present on the project site and on the protections afforded to these species under the ESA. This information will also be included in the USACE Operations and Maintenance Manual for the project for the use and reference by maintenance personnel.
- No attempt will be made by project personnel to feed, touch or otherwise intentionally interact with any ESA protected species. If a protected species is present in the vicinity of any active work area, they must be allowed to leave the area on their own accord before work in that area can resume.

Hawaiian hoary bat
The Hawaiian hoary bat is a medium-sized [0.5-0.8 ounces (14-22 grams)], nocturnal, insectivorous bat. The Hawaiian hoary bat is known from the islands of Hawai‘i, Maui, O‘ahu,

Kaua‘i, and Moloka‘i. There is a general lack of historic and current data on this subspecies, and its present status and habitat requirements are not well understood. Bats are most often observed foraging in open areas, near the edges of native forests, or over open water, although this may be due to the ease of detection in these habitats. Hawaiian hoary bats roost solitarily in the foliage of trees.

Threats to the Hawaiian hoary bat include habitat destruction (elimination of roosting sites), direct and indirect effects of pesticides, disease and entanglement on barbed wire fences. In addition, Hawaiian hoary bats roost in both exotic and native woody vegetation and, while foraging, will leave young unattended in “nursery” trees and shrubs. If trees or shrubs suitable for bat roosting are cleared during the breeding season, there is a risk that young bats could inadvertently be harmed or killed. By implementing the above conservation measure, the proposed project will avoid potential adverse effects to Hawaiian hoary bats.

<u>O‘ahu ‘elepaio</u>

The O‘ahu ‘elepaio is a small [12.5 grams (0.44 ounces) average weight; 15 centimeters (cm) (5.9 inches (in)) total body length] territorial, non-migratory monarch flycatcher endemic to the island of O‘ahu. O‘ahu ‘elepaio are found in a variety of forest types ranging from wet to dry, including wet, mesic, and dry forest consisting of native and/or introduced plant species, but higher population density can be expected in closed canopy riparian forest with a continuous canopy and dense understory.

The breeding season occurs from January to June, where they weave nests from a variety of vegetation, spending time both in trees and leaf litter while searching for food. The primary threat to the O‘ahu ‘elepaio is loss of habitat, as well as predation from introduced predators. If potentially disruptive activities, such as tree removal (including trimming), are implemented during the breeding season, there is a risk that nests (eggs and chicks) could be inadvertently harmed or killed. By implementing the above conservation measure, the proposed project will avoid potential adverse effects to O‘ahu ‘elepaio.

<u>Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck</u>

Hawaiian stilts use a variety of aquatic habitats but are limited by water depth and vegetation cover. Hawaiian stilts are known to use ephemeral lakes, anchialine ponds, prawn farm ponds, marshlands and tidal flats. Foraging habitat for Hawaiian stilt is early successional marshland or other aquatic habitat with a water depth less than nine inches and perennial vegetation that is limited and low-growing. Hawaiian stilts prefer to nest on freshly exposed mudflats interspersed with low growing vegetation (Service 2011, p. 57). Nesting also occurs on islands (natural and manmade) in freshwater or brackish ponds (Shallenberger 1977, p. 23, Coleman 1981, p. 42, Morin 1994, p. 68-69). The nesting season normally extends from mid-February through August, with peak nesting varying among years (Robinson *et al*. 1999, pg. 14).

The Hawaiian coot generally occurs within wetland habitats with suitable emergent plant growth interspersed with open water, especially freshwater wetlands, but also freshwater reservoirs, cane field reservoirs, sewage treatment ponds, taro lo‘i, brackish wetlands, and limited use of saltwater habitats (Service 2011, p. 33). The species typically forages in water less than 12 in (30 cm) deep, but will dive in water up to 48 in (120 cm) deep (Service 2011, p. 33). Hawaiian coots prefer to forage in more open water. Logs, rafts of vegetation, narrow dikes, mud bars, and artificial islands are utilized for resting. Ephemeral wetlands support large numbers of coots during the non-breeding season.

Nesting habitat includes freshwater and brackish ponds, irrigation ditches, reservoirs, small openings in marsh vegetation, commercial prawn farm ponds and taro fields (Shallenberger 1977, p. 27; Udvardy 1960, pp. 20-21). Nesting occurs primarily from March through September, although some nesting occurs in all months of the year (Shallenberger 1977, p. 27; Morin 1998, p. 10). The timing of nesting appears to correspond with seasonal weather conditions (Byrd *et al*. 1985, p. 59; Engilis and Pratt 1993, pp. 154-155). Nest initiation is tied to rainfall as appropriate water levels are critical to nest success.

Hawaiian coots are generalists and feed on land, grazing on grass adjacent to wetlands, or in the water. They have been observed grazing from the surface of the water, or foraging by diving to obtain food resources (Shallenberger 1977, p. 27). Coots will travel long distances, including between islands, when local food sources are depleted (Engilis and Pratt 1993, pp. 154-155).

The Hawaiian gallinule is a secretive waterbird, preferring to forage, nest and rest in dense, late-succession wetland vegetation. Most birds feeding along the water's edge or in open water will quickly seek cover when disturbed. Preferred habitat for the Hawaiian gallinule includes: interspersed dense stands of robust late succession vegetation near open water (approximately 50 percent water to 50 percent vegetation), floating or barely emergent mats of vegetation, and water depth less than 3 feet (Service 2005).

Birds nest year-round but appear to have two active seasons, from November through February and May through August (Service 2005). The timing of nesting is believed to be related to water levels and late succession wetland vegetation. Nesting phenology is apparently tied to water levels and the presence of appropriately dense vegetation. The particular species of emergent plant used for nest construction is not as important as stem density and vegetation height (Service 2005).

The Hawaiian duck is one of two extant native duck species (Family: Anatidae) found in Hawai'i and is closely related to the well-known, but non-native, mallard. Hawaiian ducks occur in a wide variety of natural and artificial wetland habitats including freshwater marshes, flooded grasslands, coastal ponds, streams, montane pools, forest swamplands, taro, lotus, shrimp, and fish ponds, irrigation ditches, reservoirs, and mouths of larger streams (Service 2005). Some important habitats are located on National Wildlife Refuges or on State lands and receive management attention. However, other important habitats are not protected.

Hawaiian duck nesting biology is poorly understood. Nesting occurs year-round, but most activity occurs between January and May (Engilis *et al*. 2002). Nests are usually on the ground near water, but few nests are found in areas frequented by humans or areas supporting populations of mammalian predators.

The primary causes of the decline of the Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck (collectively referred to as Hawaiian waterbirds) are the loss of wetland habitat, predation by introduced animals, over-hunting in the late 1800s and early 1900s, disease, and environmental contaminants (Service 2011, p. iv-v). A significant amount of Hawai‘i's wetlands have been lost due to human activities, including filling and drilling for agriculture, houses, hotels, and golf courses. The majority of the remaining wetlands are degraded by altered hydrology, invasive species, human encroachment, and contaminants. Hydrologic alterations of wetlands, including flood control and channelization, often make wetland habitat less suitable by altering water depth and timing of water level fluctuations (Service 2011, p. 79-80).

Introduced alien predators, such as small Indian mongoose (*Herpestes auropunctatus*), cats (*Felis catus*), dogs (*Canis lupus familiaris*), rats (*Rattus sp*.), cattle egret, non-native fish, and bull frog (*Rana catesbeiana*) are all presently found within wetlands and pose a serious threat to Hawaiian waterbird reproductive success by taking eggs, young birds, and even adults (Service 2011, p. 82-83).

Disease such as avian botulism type C pose a threat to Hawaiian waterbirds. Botulism can occur in any area with standing fresh or brackish water frequented by waterbirds. Botulism is a continuing threat that kills or sickens waterbirds every year in Hawai‘i.

Waterbirds have been negatively affected through direct mortality, decreased reproductive success, or degradation of feeding habitat from contaminants (Parnell *et al*. 1988, p. 135). Because waterbirds are predators, they are susceptible to contaminants accumulated in the food chain.

A potential new threat to Hawaiian waterbirds is climate change. Sea level rise may result in the loss of some wetland habitat and affect the suitability of other wetlands for waterbirds (Service 2010, p. 7). The projected landcape- or island-scale changes in temperature and precipitation, as well as the potentially catastrophic effects of projected increases in storm frequency and severity, point to likely adverse effects of climate change to Hawaiian waterbirds.

Because the proposed project will not decrease habitat currently used by Hawaiian waterbirds, increase predation or disease and contaminant exposure to waterbirds, or increase the effects of climate change to Hawaiian waterbirds we do not anticipate potential impacts as a result of the project. And by implementing the above conservation measures, the proposed project will avoid potential adverse effects to the Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck.

Summary

We concur that the proposed project may affect, but is not likely to adversely affect, the Hawaiian hoary bat, O‘ahu ‘elepaio, Hawaiian stilt, Hawaiian coot, Hawaiian gallinule, and Hawaiian duck. Unless the project description changes, or new information reveals that the proposed project may affect listed species in a manner or to an extent not considered, or a new species or critical habitat is designated that may be affected by the proposed action, no further action pursuant to section 7 of the Act is necessary.

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Appendix B. Figures

All figures provided by the U.S. Army Corps of Engineers. 2016.

Figure 1. Ala Wai Canal Floodwalls Design Plan.

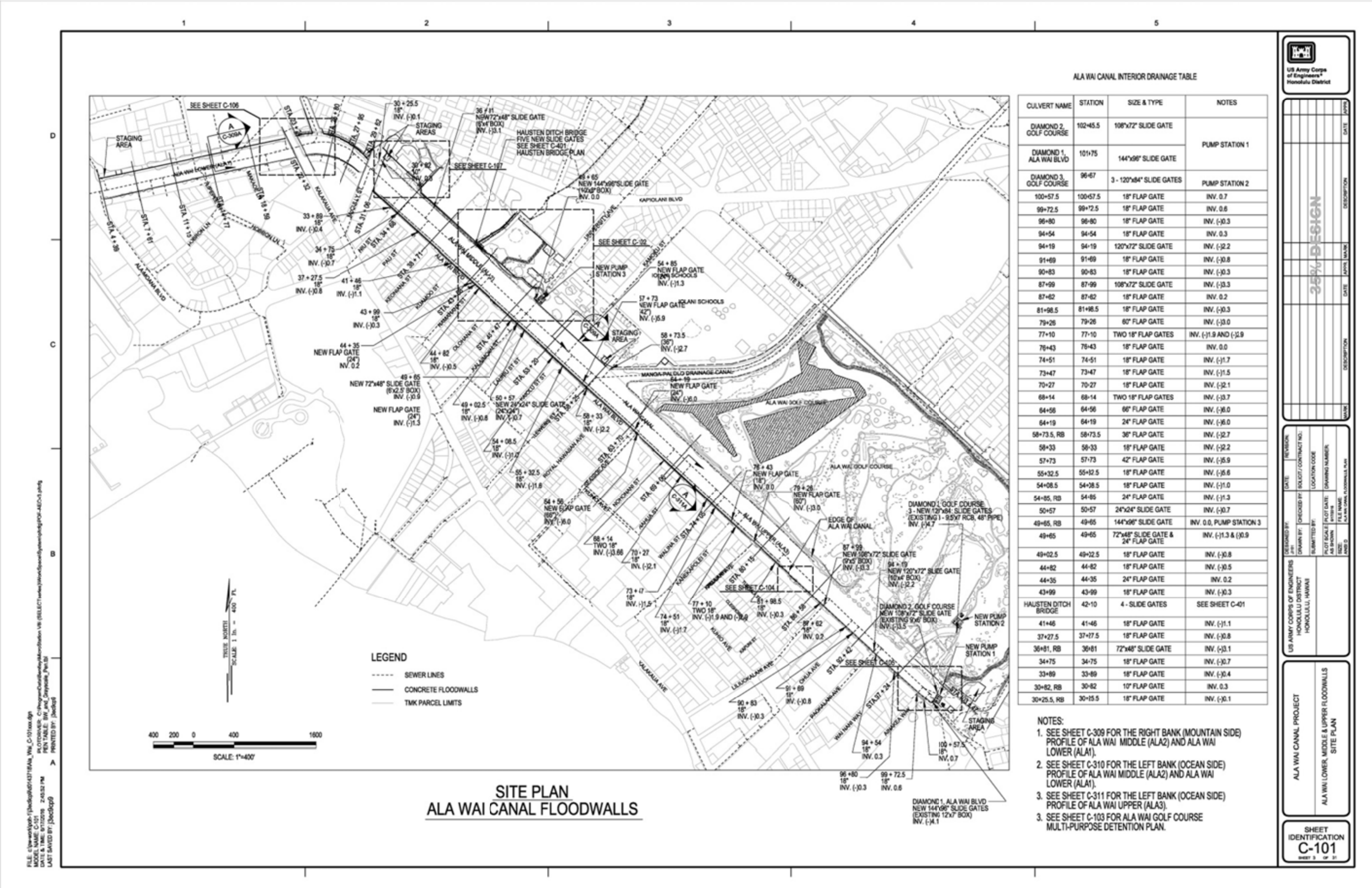
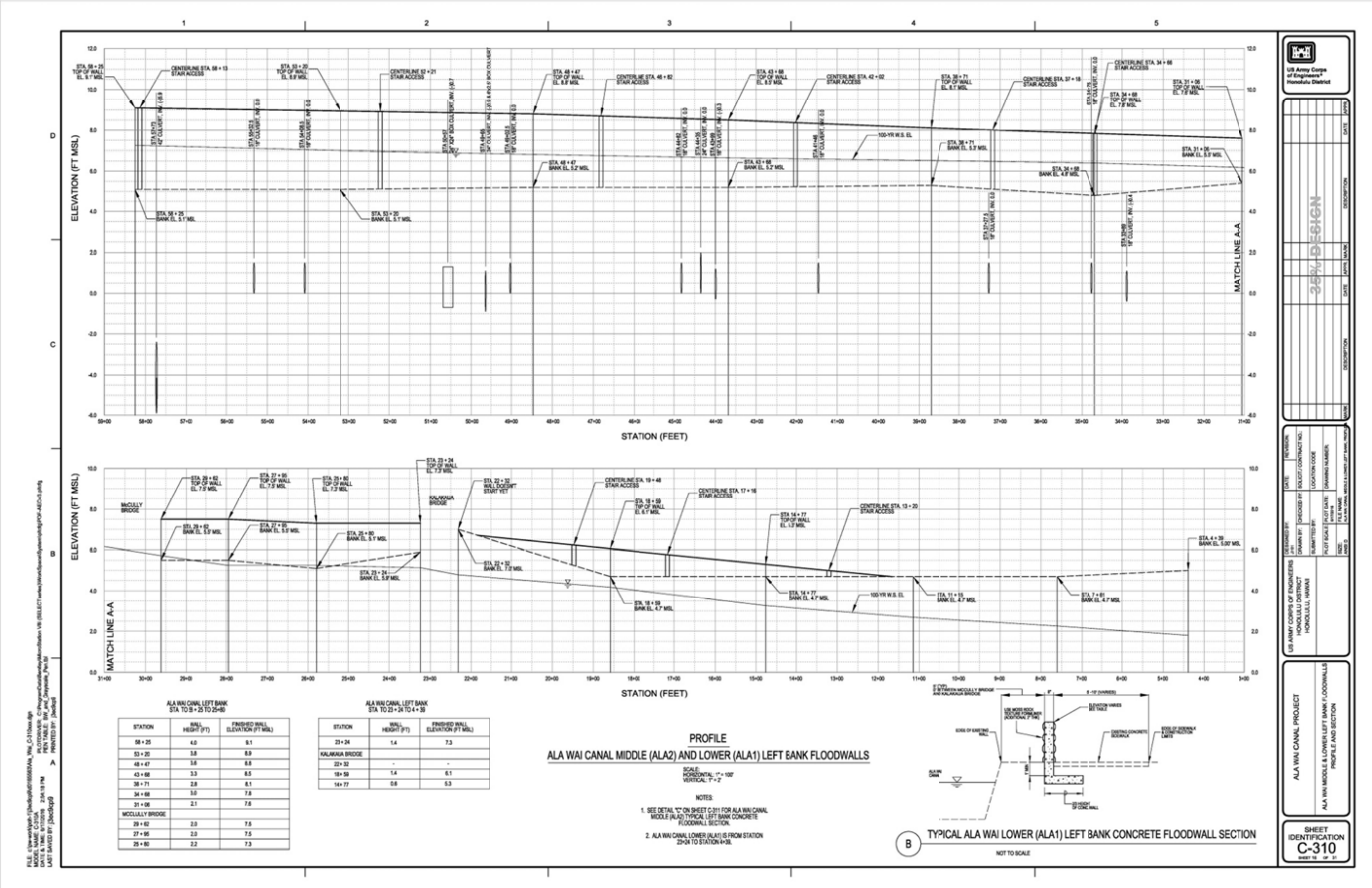


Figure 2. Ala Wai Canal Middle and Lower Left Bank Floodwalls Design Plan.



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

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

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

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

Figure 3. Schedule of Slide Gates along the Ala Wai Canal Design Plan.

SCHEDULE OF SLIDE GATES
ALONG THE ALA WAI CANAL

CULVERT NAME	STATION	SIZE (WIDTHxHEIGHT) AND TYPE	H	G
DIAMOND 2, GOLF COURSE	102+45.5	108"x72" RECTANGULAR OPENING SLIDE GATE	15'-0"	11'-6"
DIAMOND 1, ALA WAI BLVD	101+75	144"x96" RECTANGULAR OPENING SLIDE GATE	19'-0"	15'-0"
DIAMOND 3, GOLF COURSE	96+67	3 - 120"x84" RECTANGULAR OPENING SLIDE GATE	17'-6"	26'-0"
94+19	94+19	84"x48" RECTANGULAR OPENING SLIDE GATE	15'-6"	12'-6"
87+99	87+99	108"x60" RECTANGULAR OPENING SLIDE GATE	15'-0"	11'-6"
50+57	50+57	24"x24" SQUARE OPENING SLIDE GATE	6'-6"	4'-0"
49+65, RB	49+65	144"x96" RECTANGULAR OPENING SLIDE GATE	19'-0"	15'-0"
49+65	49+65	72"x48" RECTANGULAR OPENING SLIDE GATE	11'-0"	7'-6"
36+81, RB	36+81	72"x48" RECTANGULAR OPENING SLIDE GATE	11'-0"	7'-6"
HAUSEN	42+10	4-120"x84" SLIDE GATE	10'-0"	7'-0"

GENERAL NOTES:

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

US Army Corps of Engineers Honolulu District

35% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI WATERSHED PROJECT

SCHEDULE OF SLIDE GATES

SHEET IDENTIFICATION
C-601

Figure 4. Ala Wai Canal and McCully Street Design Plan.

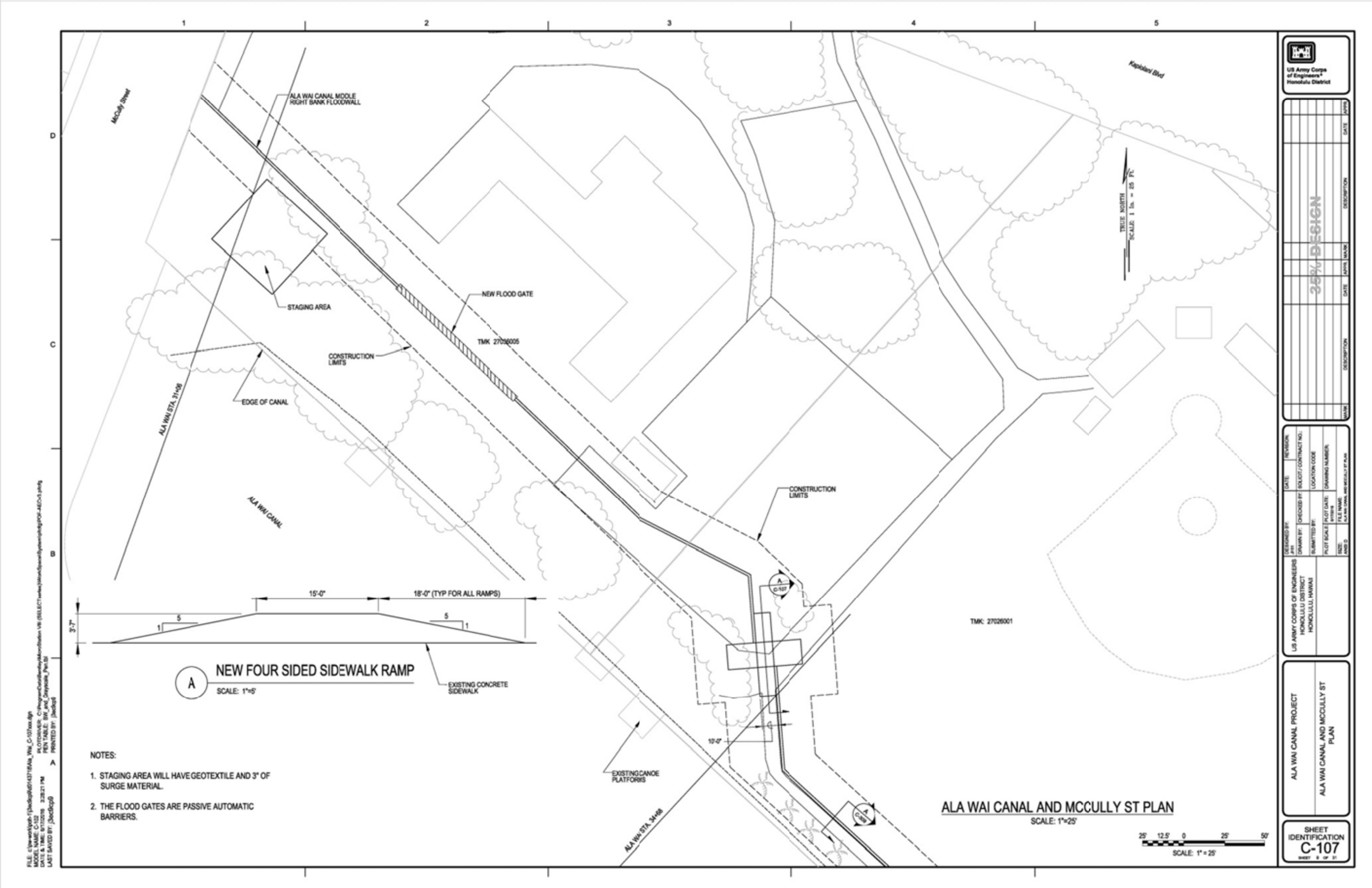


Figure 5. Waihī Debris and Detention Basin Design Plan.

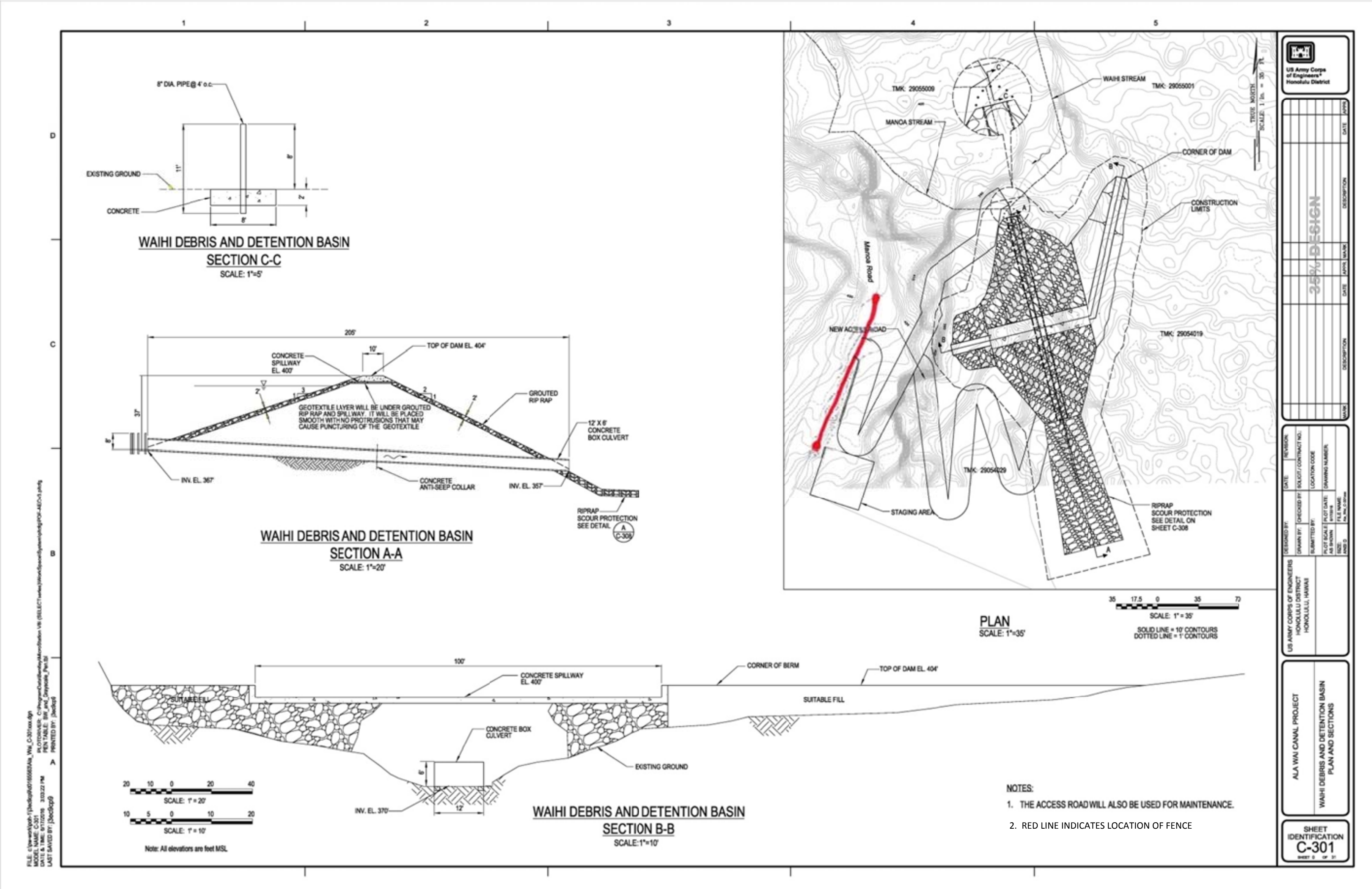


Figure 6. Waiakeakua Debris and Detention Basin Design Plan.

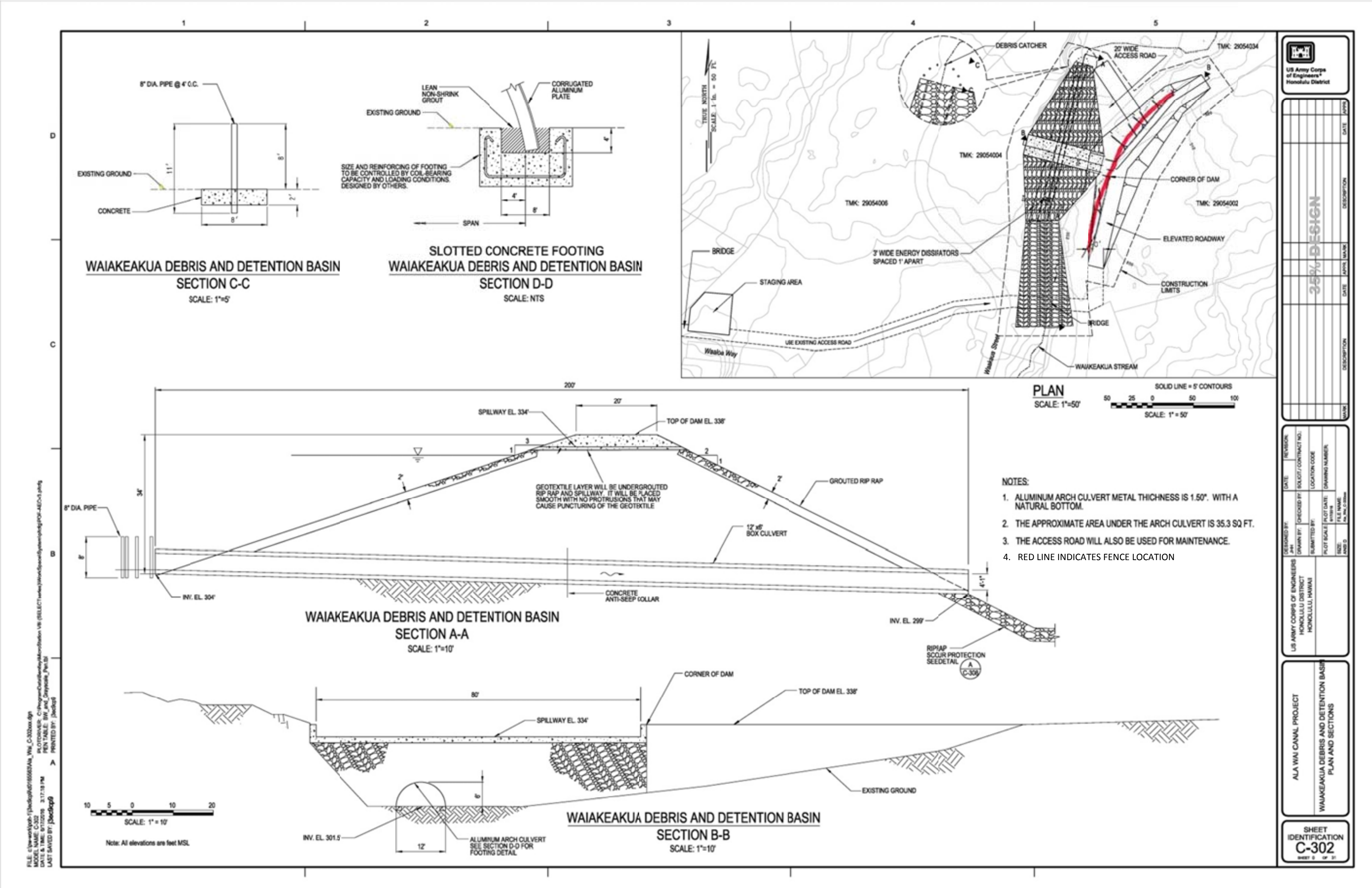


Figure 7. Kānewai Field Multi-Purpose Detention Basin Design Plan.

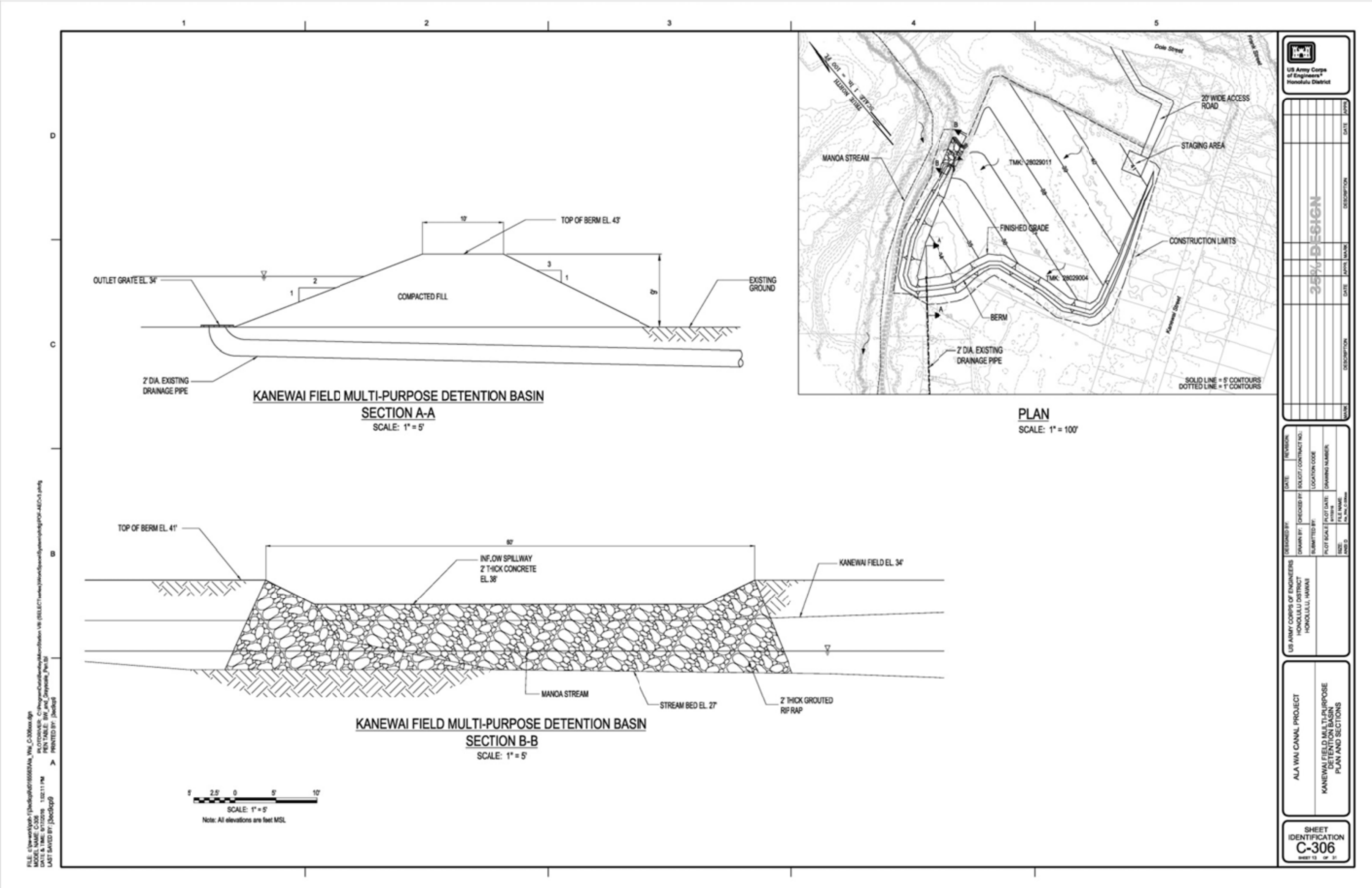


Figure 8. Wai‘ōma‘o Debris and Detention Basin Design Plan.

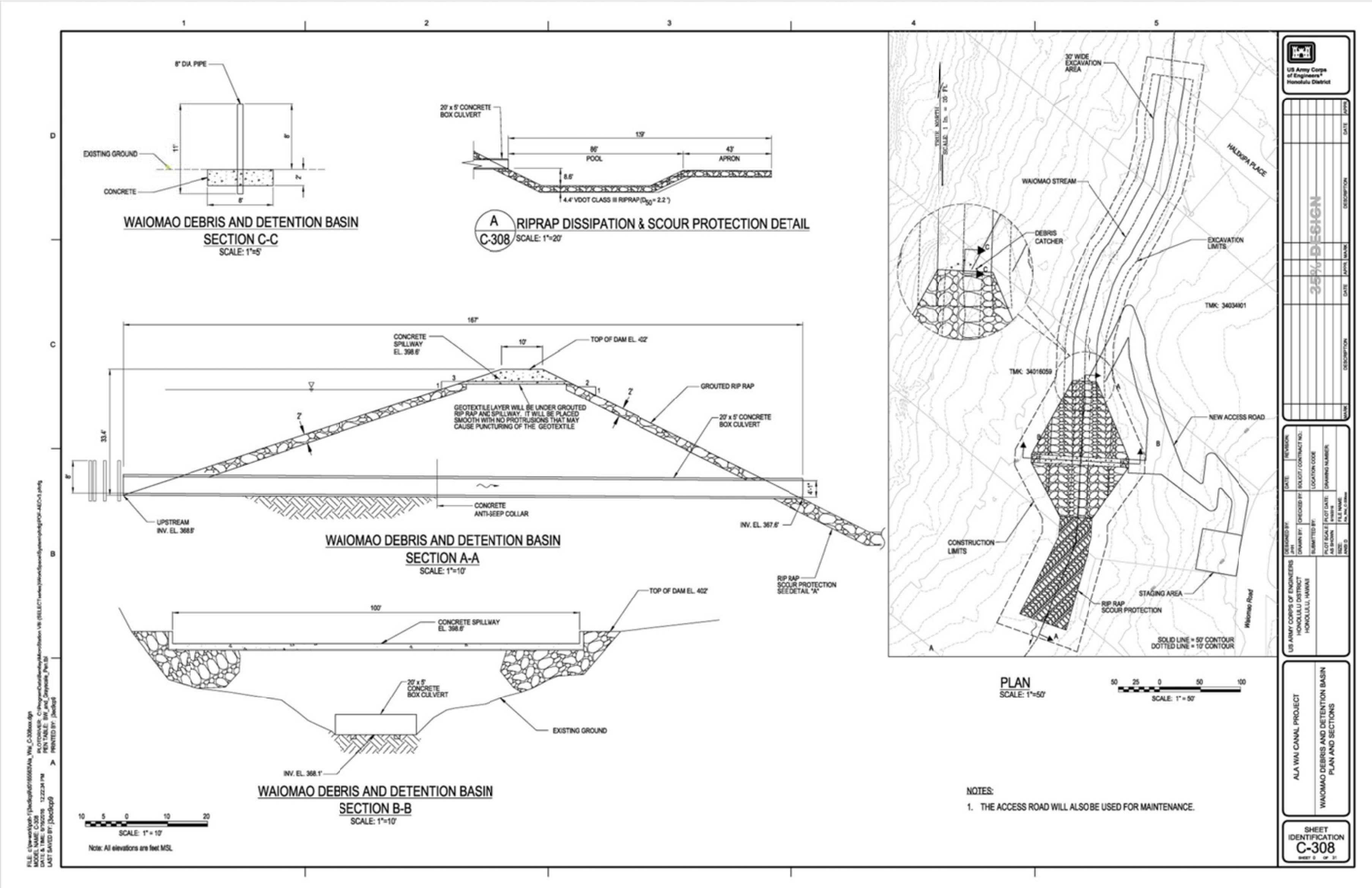


Figure 9. Pūkele Debris and Detention Basin Design Plan.

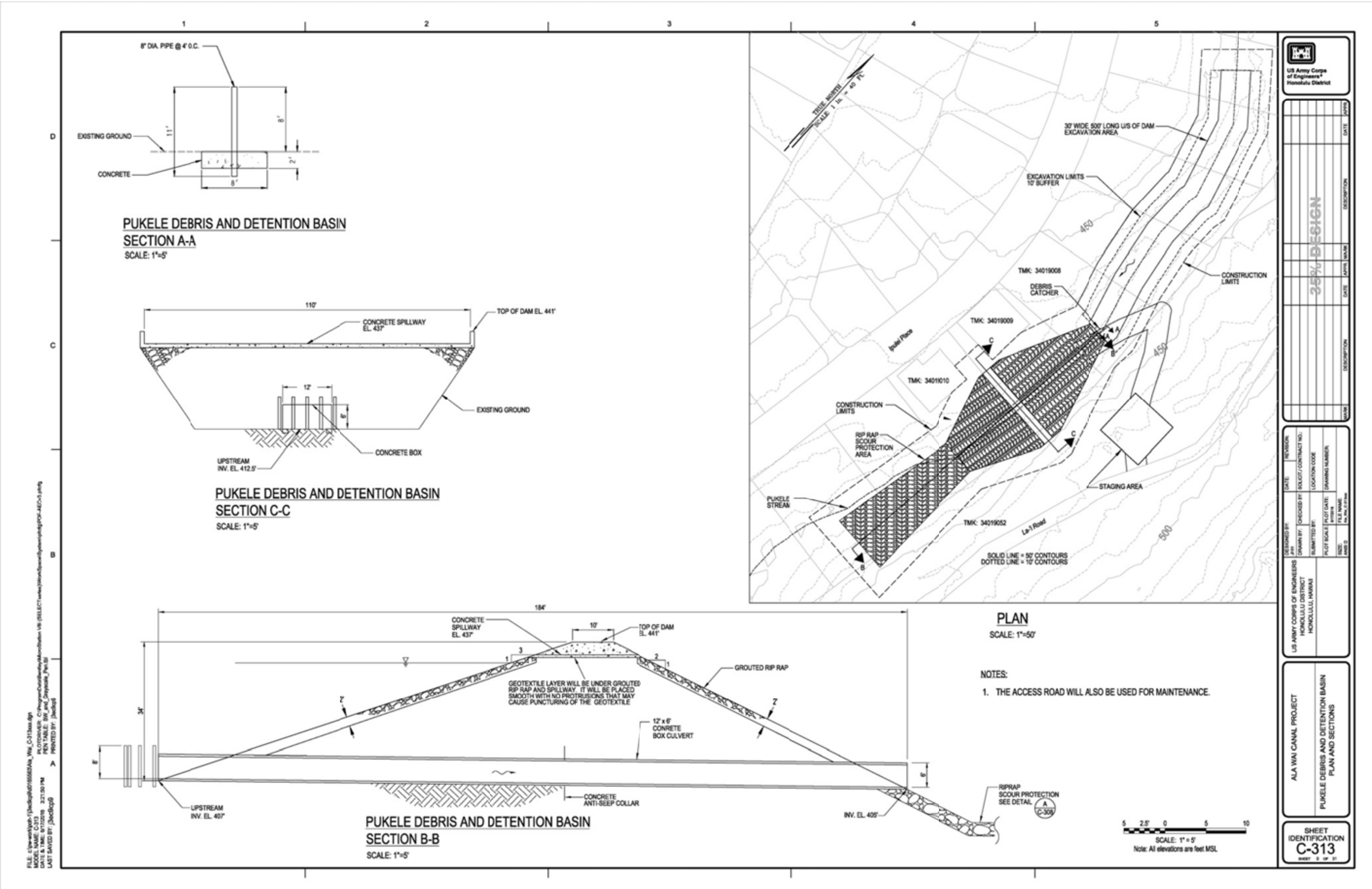


Figure 10. Makiki Debris and Detention Basin Design Plan.

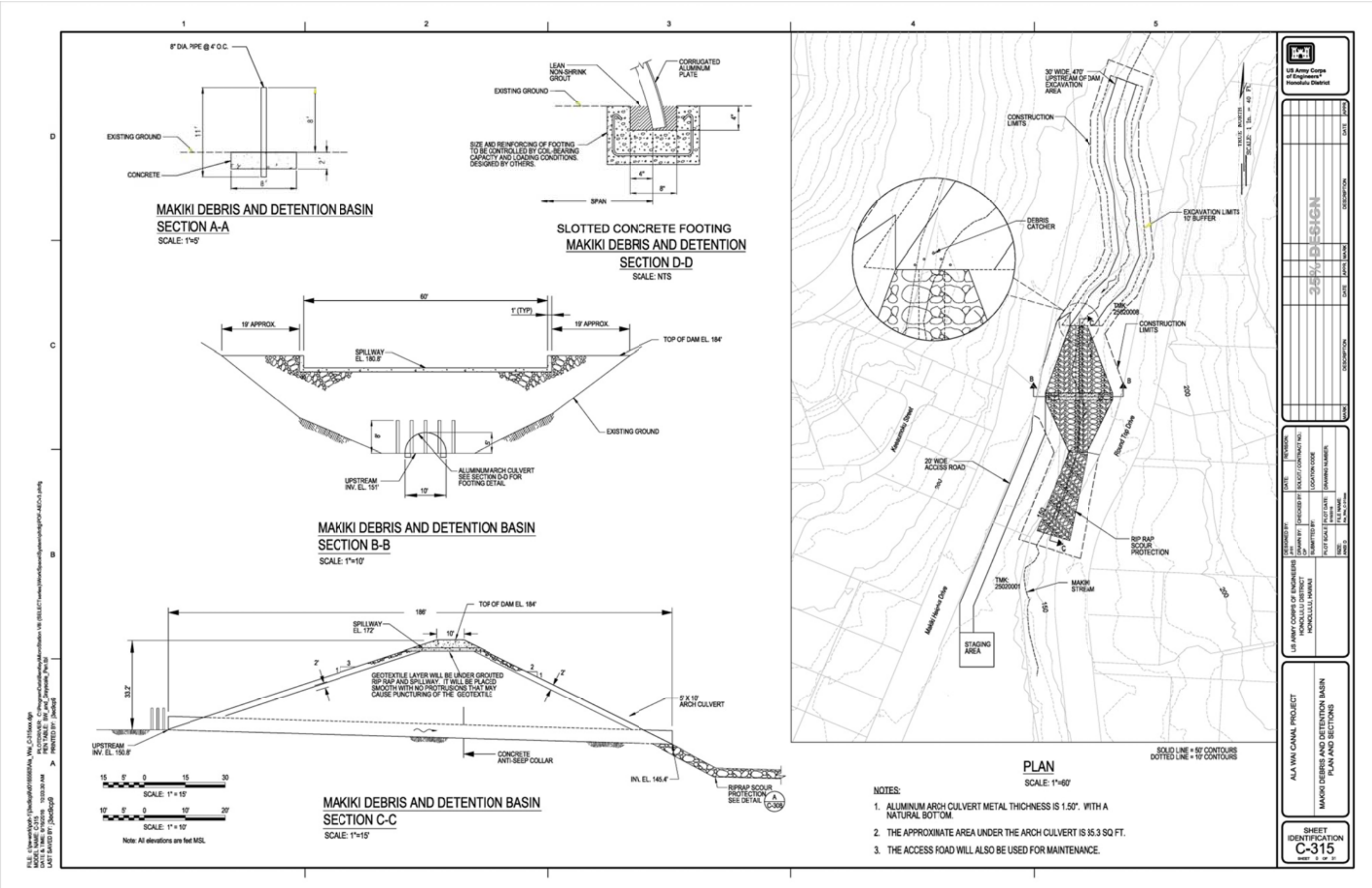
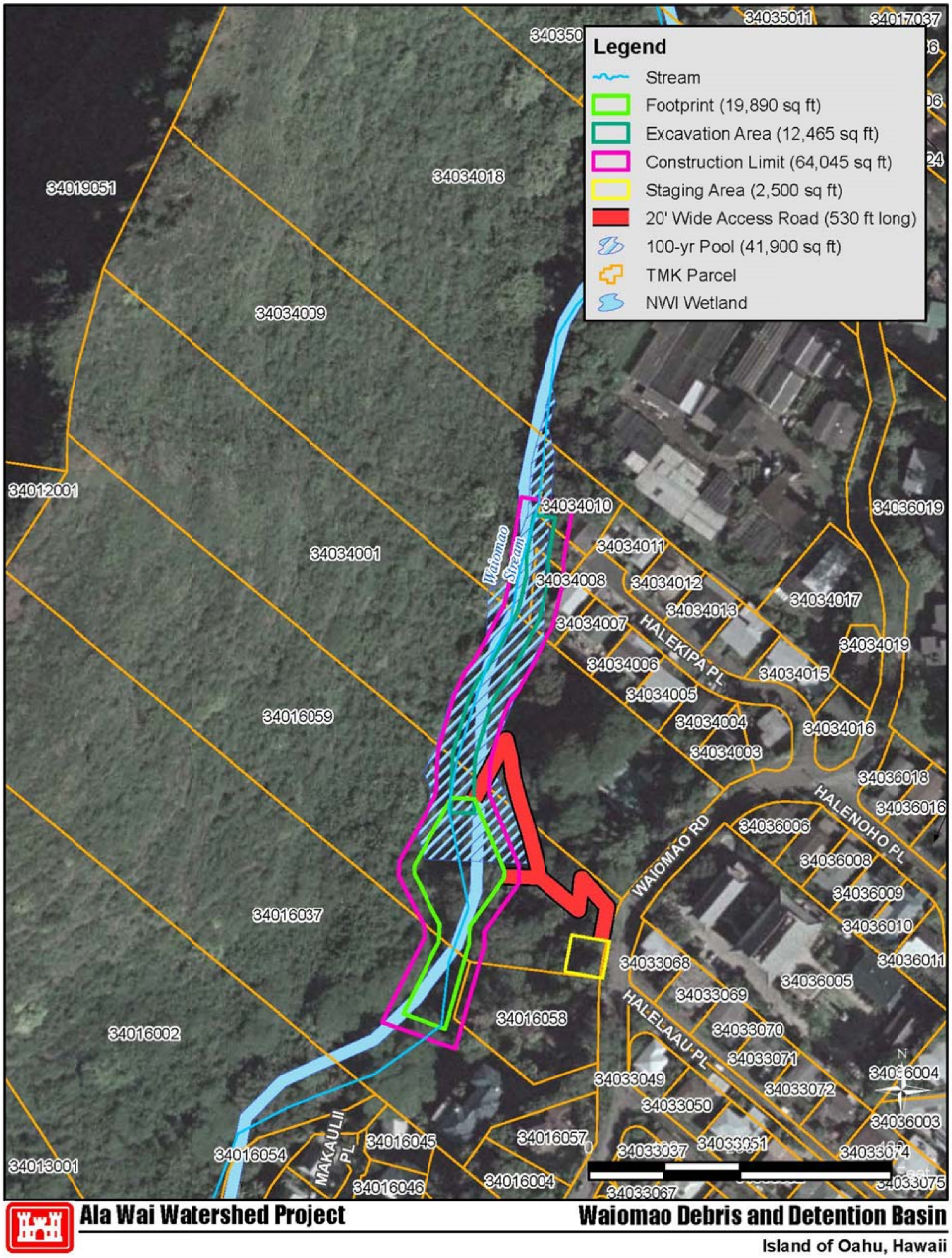


Figure 11. Wai‘ōma‘o Debris and Detention Basin.



V:\Projects_Civil_Works\C0046\arcgismaps\Waiomao_Debris_and_Detention_Basin_Alt3_20160620.mxd

Figure 12. Pūkele Debris and Detention Basin.

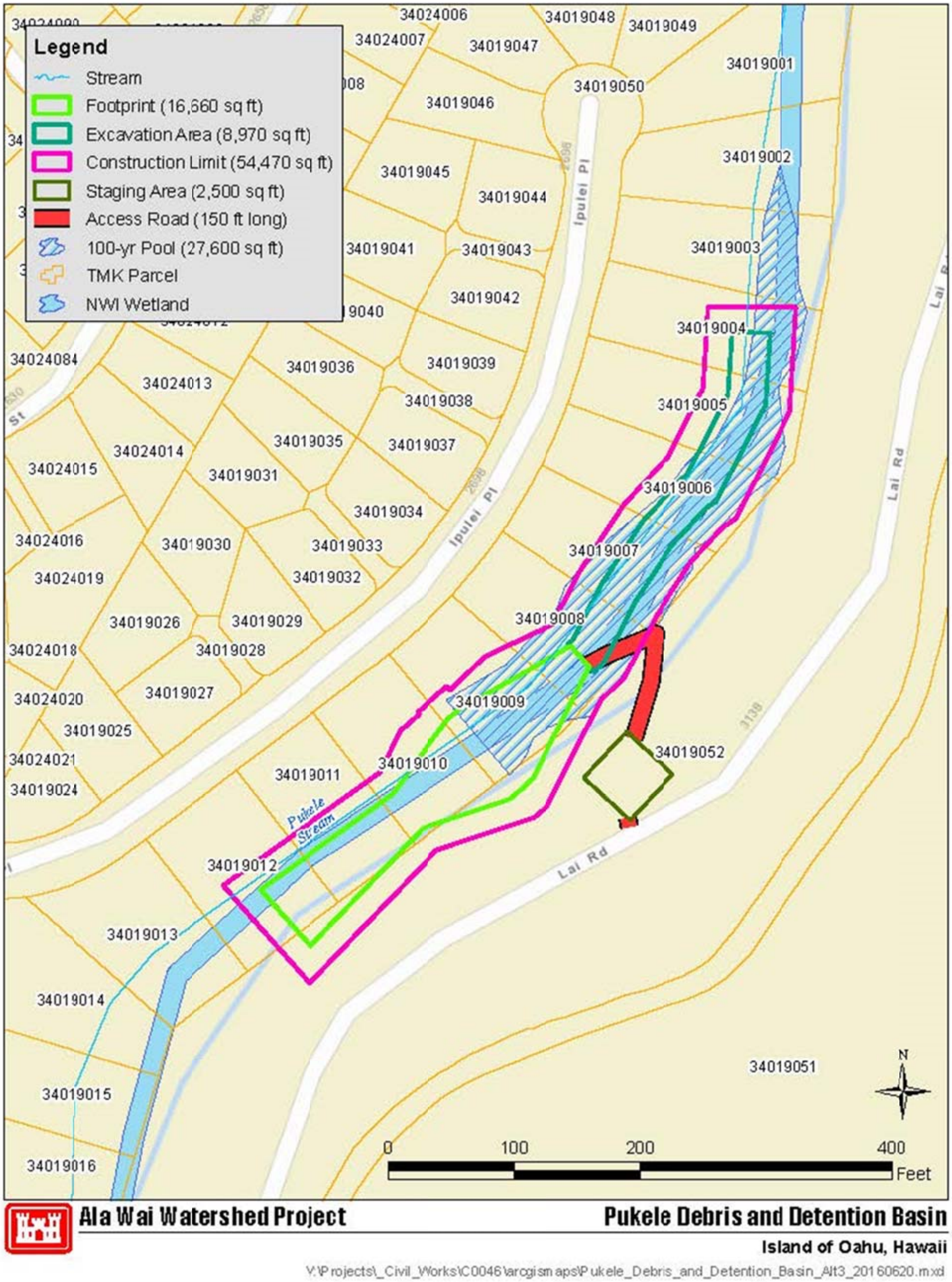
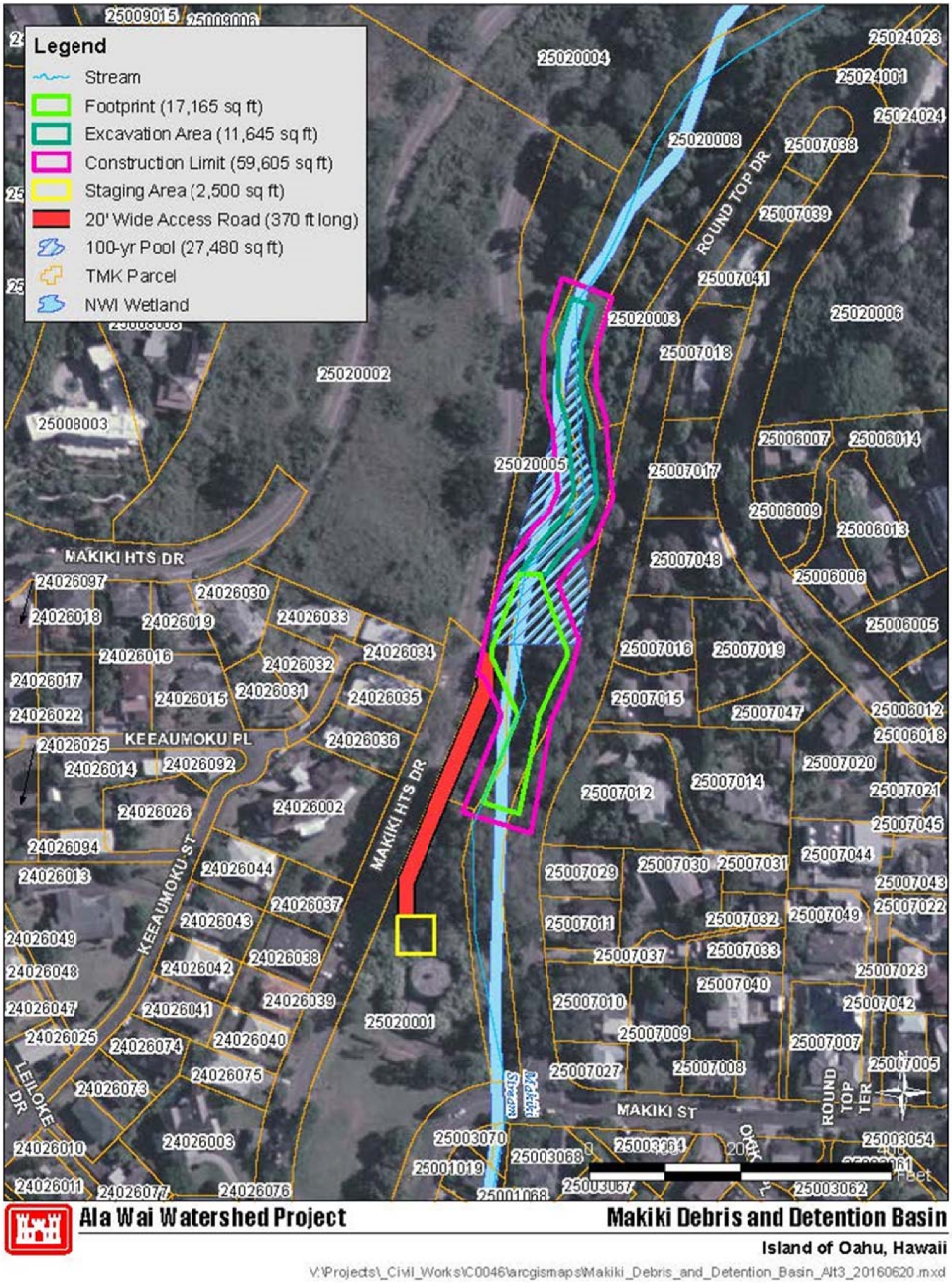


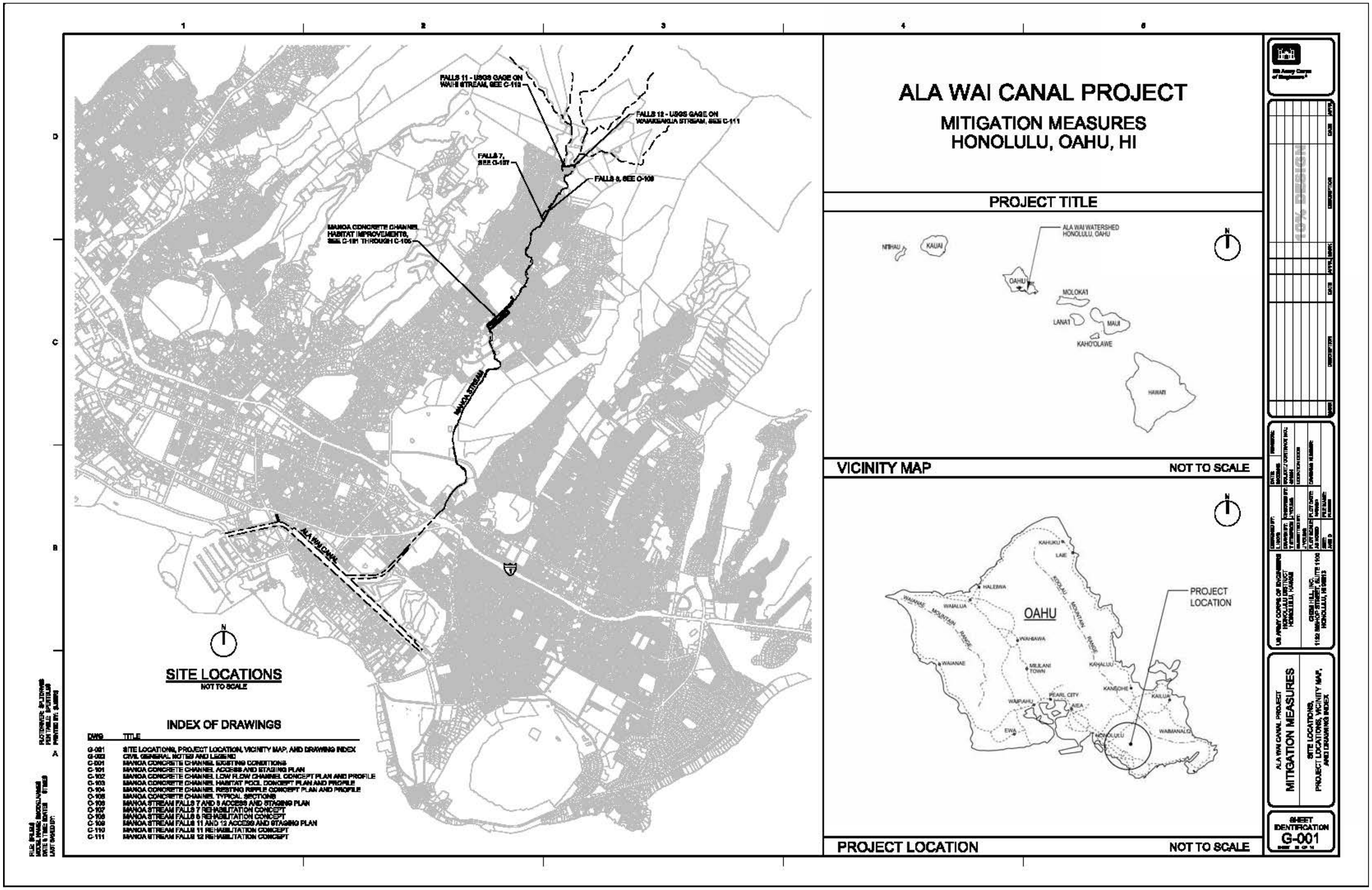
Figure 12. Makiki Debris and Detention Basin.

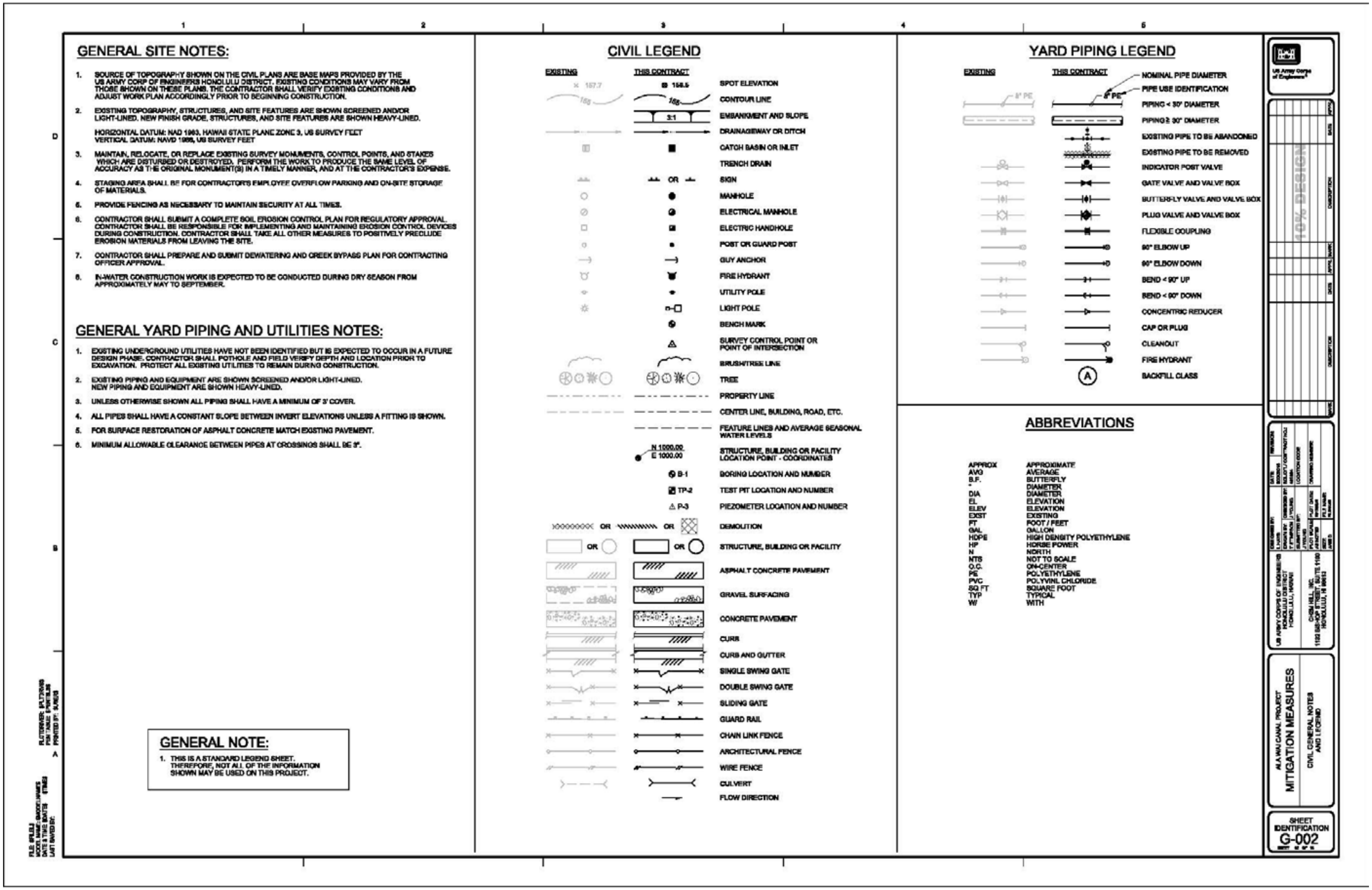


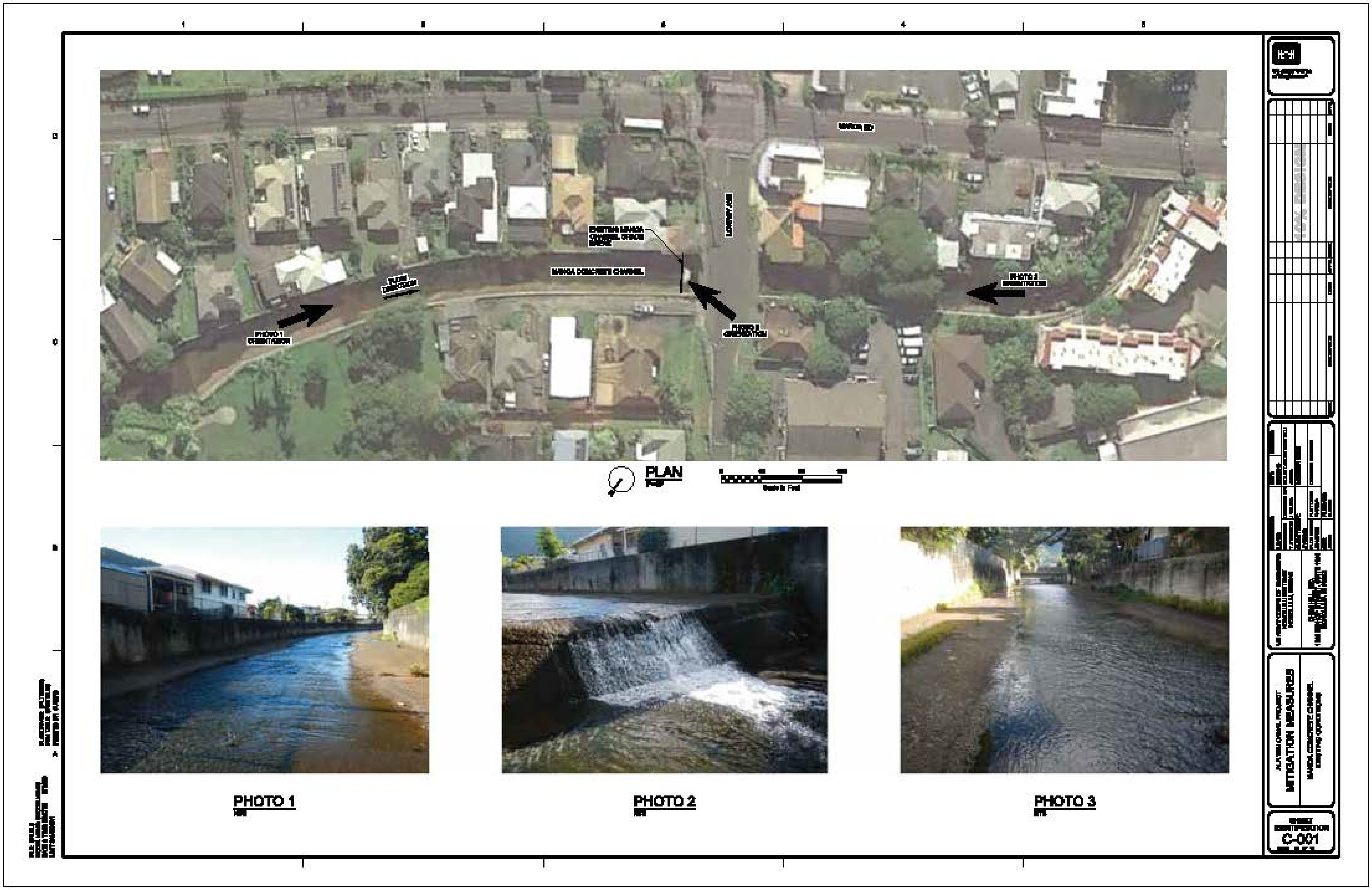
Appendix C.

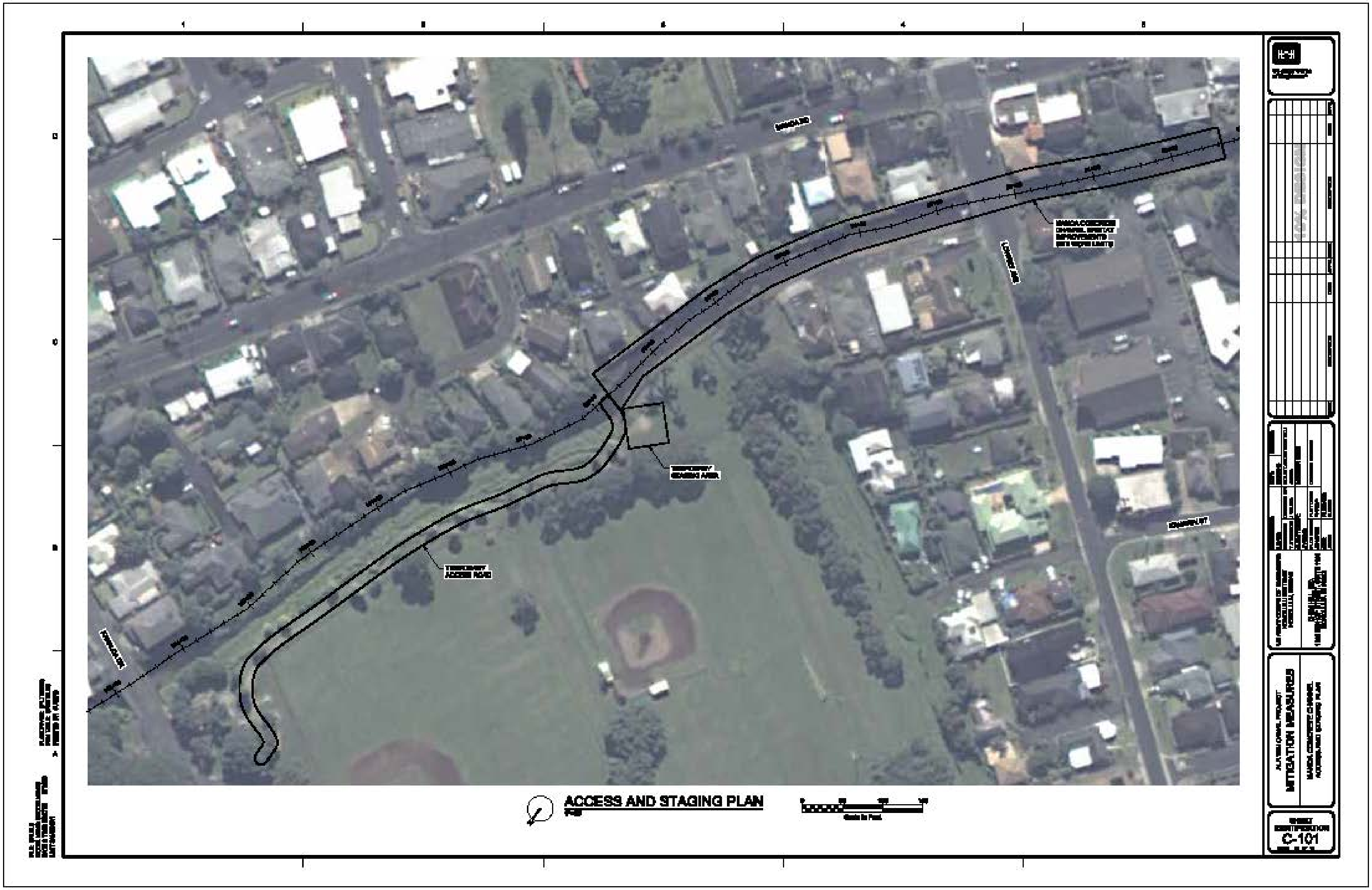
Figures and Project Details for Falls 7 and 8 (FWCA Compensatory Mitigation).

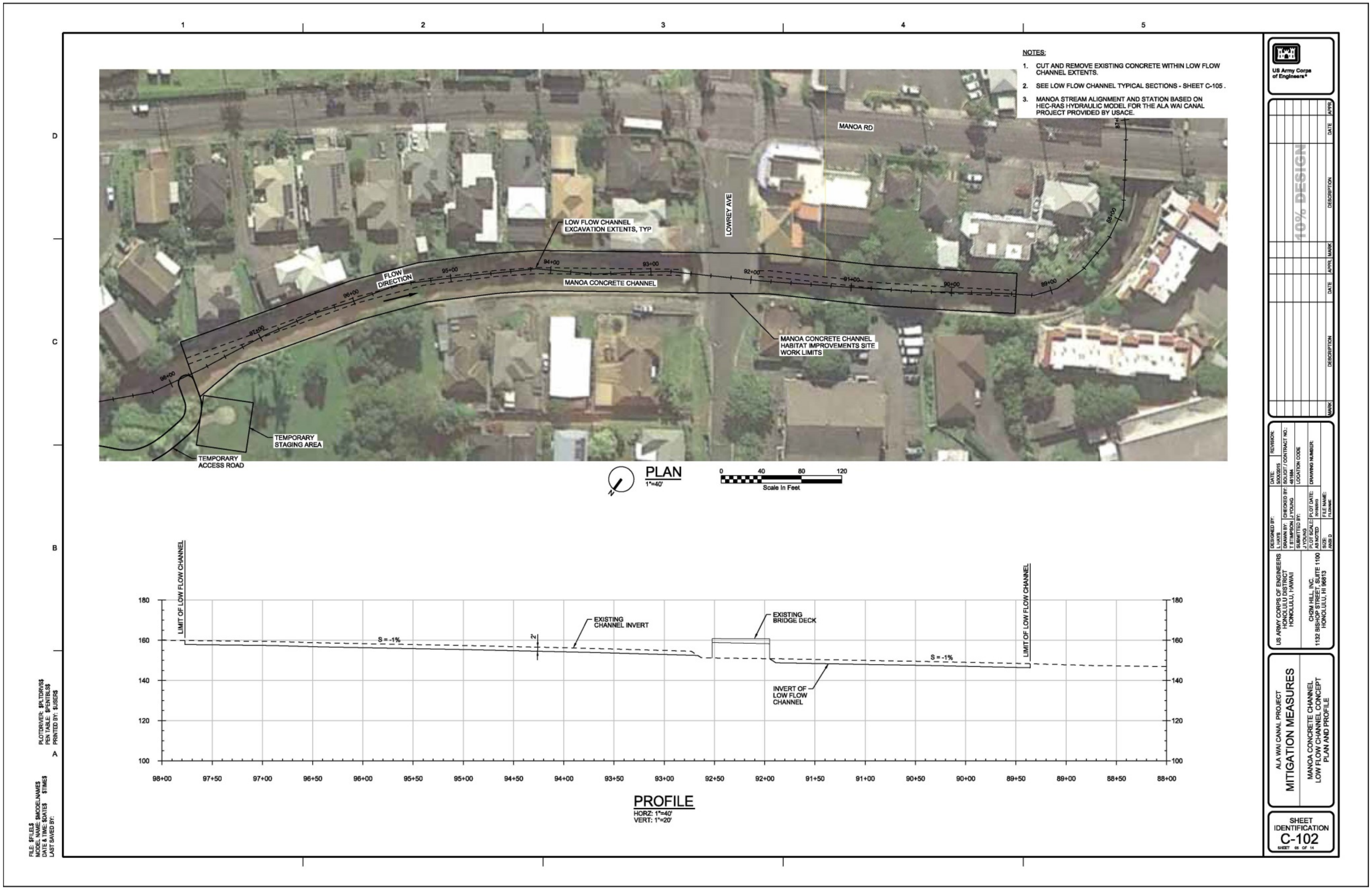
All figures provided by the U.S. Army Corps of Engineers. 2016.


ALA WAI CANAL PROJECT
MITIGATION MEASURES
HONOLULU, OAHU, HI
PROJECT TITLE
FALLS 11 - USGS GAGE ON WAIHI STREAM, SEE C-110
FALLS 12 - USGS GAGE ON WAIAKEAKUA STREAM, SEE C-111
FALLS 7, SEE C-107
FALLS 8, SEE C-108
MANOA CONCRETE CHANNEL HABITAT IMPROVEMENTS, SEE C-101 THROUGH C-105
MANOA STREAM
ALA WAI CANAL
SITE LOCATIONS
NOT TO SCALE
INDEX OF DRAWINGS
DWG TITLE
G-001 SITE LOCATIONS, PROJECT LOCATION, VICINITY MAP, AND DRAWING INDEX
G-002 CIVIL GENERAL NOTES AND LEGEND
C-001 MANOA CONCRETE CHANNEL EXISTING CONDITIONS
C-101 MANOA CONCRETE CHANNEL ACCESS AND STAGING PLAN
C-102 MANOA CONCRETE CHANNEL LOW FLOW CHANNEL CONCEPT PLAN AND PROFILE
C-103 MANOA CONCRETE CHANNEL HABITAT POOL CONCEPT PLAN AND PROFILE
C-104 MANOA CONCRETE CHANNEL RESTING RIFFLE CONCEPT PLAN AND PROFILE
C-105 MANOA CONCRETE CHANNEL TYPICAL SECTIONS
C-106 MANOA STREAM FALLS 7 AND 8 ACCESS AND STAGING PLAN
C-107 MANOA STREAM FALLS 7 REHABILITATION CONCEPT
C-108 MANOA STREAM FALLS 8 REHABILITATION CONCEPT
C-109 MANOA STREAM FALLS 11 AND 12 ACCESS AND STAGING PLAN
C-110 MANOA STREAM FALLS 11 REHABILITATION CONCEPT
C-111 MANOA STREAM FALLS 12 REHABILITATION CONCEPT
ALA WAI WATERSHED HONOLULU, OAHU
NIIHAU
KAUAI
OAHU
MOLOKAI
LANAI
MAUI
KAHO'OLAWE
HAWAII
VICINITY MAP
NOT TO SCALE
OAHU
PROJECT LOCATION
PROJECT LOCATION
NOT TO SCALE
MITIGATION MEASURES
SHEET IDENTIFICATION
G-001

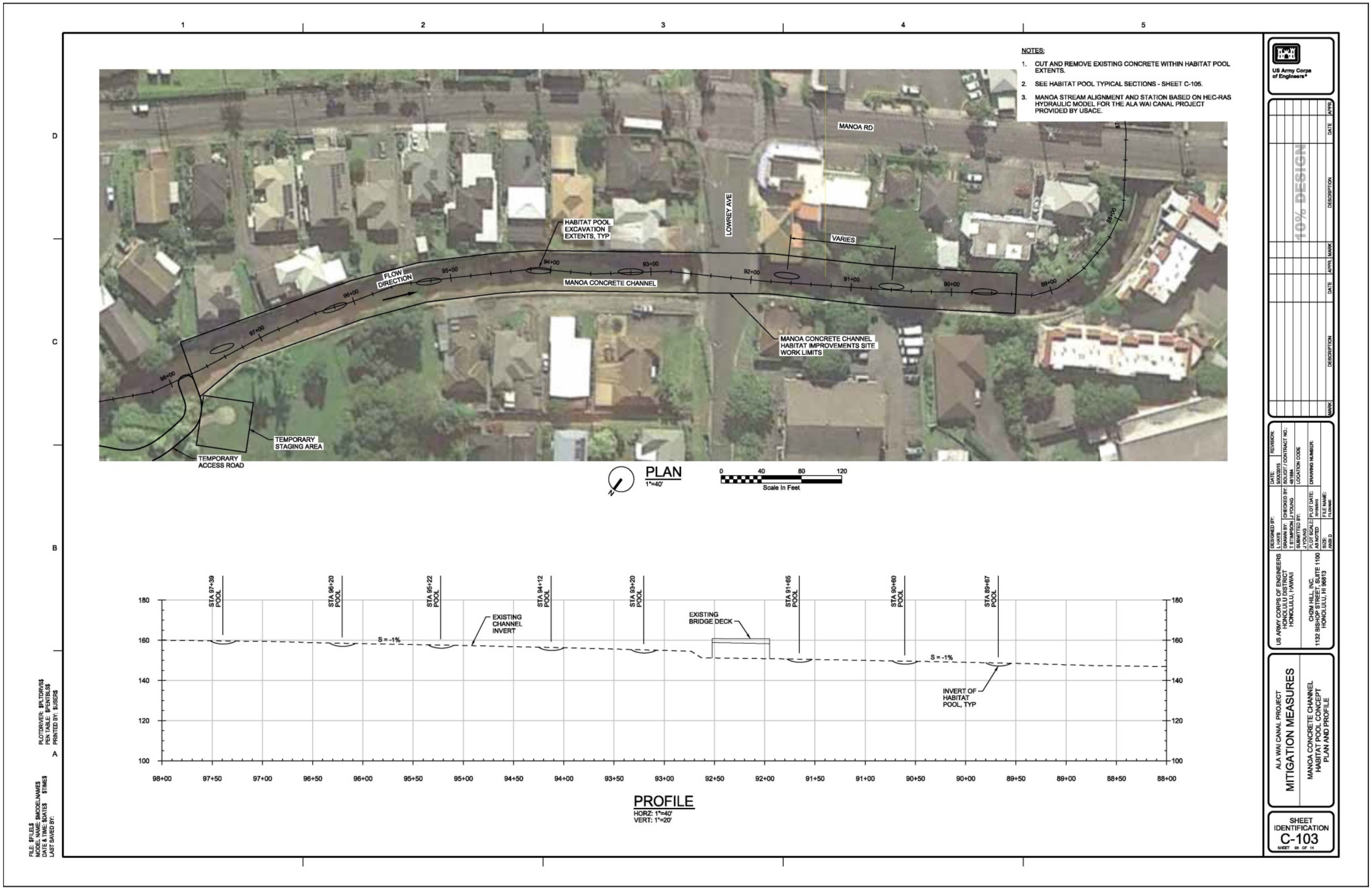

GENERAL SITE NOTES:
1. SOURCE OF TOPOGRAPHY SHOWN ON THE CIVIL PLANS ARE BASE MAPS PROVIDED BY THE US ARMY CORP OF ENGINEERS HONOLULU DISTRICT. EXISTING CONDITIONS MAY VARY FROM THOSE SHOWN ON THESE PLANS. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS AND ADJUST WORK PLAN ACCORDINGLY PRIOR TO BEGINNING CONSTRUCTION.
2. EXISTING TOPOGRAPHY, STRUCTURES, AND SITE FEATURES ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW FINISH GRADE, STRUCTURES, AND SITE FEATURES ARE SHOWN HEAVY-LINED.
HORIZONTAL DATUM: NAD 1983, HAWAII STATE PLANE ZONE 3, US SURVEY FEET
VERTICAL DATUM: NAVD 1988, US SURVEY FEET
3. MAINTAIN, RELOCATE, OR REPLACE EXISTING SURVEY MONUMENTS, CONTROL POINTS, AND STAKES WHICH ARE DISTURBED OR DESTROYED. PERFORM THE WORK TO PRODUCE THE SAME LEVEL OF ACCURACY AS THE ORIGINAL MONUMENT(S) IN A TIMELY MANNER, AND AT THE CONTRACTOR'S EXPENSE.
4. STAGING AREA SHALL BE FOR CONTRACTOR'S EMPLOYEE OVERFLOW PARKING AND ON-SITE STORAGE OF MATERIALS.
5. PROVIDE FENCING AS NECESSARY TO MAINTAIN SECURITY AT ALL TIMES.
6. CONTRACTOR SHALL SUBMIT A COMPLETE SOIL EROSION CONTROL PLAN FOR REGULATORY APPROVAL. CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING AND MAINTAINING EROSION CONTROL DEVICES DURING CONSTRUCTION. CONTRACTOR SHALL TAKE ALL OTHER MEASURES TO POSITIVELY PRECLUDE EROSION MATERIALS FROM LEAVING THE SITE.
7. CONTRACTOR SHALL PREPARE AND SUBMIT DEWATERING AND CREEK BYPASS PLAN FOR CONTRACTING OFFICER APPROVAL.
8. IN-WATER CONSTRUCTION WORK IS EXPECTED TO BE CONDUCTED DURING DRY SEASON FROM APPROXIMATELY MAY TO SEPTEMBER.
GENERAL YARD PIPING AND UTILITIES NOTES:
1. EXISTING UNDERGROUND UTILITIES HAVE NOT BEEN IDENTIFIED BUT IS EXPECTED TO OCCUR IN A FUTURE DESIGN PHASE. CONTRACTOR SHALL POTHOLE AND FIELD VERIFY DEPTH AND LOCATION PRIOR TO EXCAVATION. PROTECT ALL EXISTING UTILITIES TO REMAIN DURING CONSTRUCTION.
2. EXISTING PIPING AND EQUIPMENT ARE SHOWN SCREENED AND/OR LIGHT-LINED. NEW PIPING AND EQUIPMENT ARE SHOWN HEAVY-LINED.
3. UNLESS OTHERWISE SHOWN ALL PIPING SHALL HAVE A MINIMUM OF 3' COVER.
4. ALL PIPES SHALL HAVE A CONSTANT SLOPE BETWEEN INVERT ELEVATIONS UNLESS A FITTING IS SHOWN.
5. FOR SURFACE RESTORATION OF ASPHALT CONCRETE MATCH EXISTING PAVEMENT.
6. MINIMUM ALLOWABLE CLEARANCE BETWEEN PIPES AT CROSSINGS SHALL BE 3".
GENERAL NOTE:
1. THIS IS A STANDARD LEGEND SHEET. THEREFORE, NOT ALL OF THE INFORMATION SHOWN MAY BE USED ON THIS PROJECT.
CIVIL LEGEND
EXISTING
THIS CONTRACT
SPOT ELEVATION
CONTOUR LINE
EMBANKMENT AND SLOPE
DRAINAGEWAY OR DITCH
CATCH BASIN OR INLET
TRENCH DRAIN
SIGN
MANHOLE
ELECTRICAL MANHOLE
ELECTRIC HANDHOLE
POST OR GUARD POST
GUY ANCHOR
FIRE HYDRANT
UTILITY POLE
LIGHT POLE
BENCH MARK
SURVEY CONTROL POINT OR POINT OF INTERSECTION
BRUSH/TREE LINE
TREE
PROPERTY LINE
CENTER LINE, BUILDING, ROAD, ETC.
FEATURE LINES AND AVERAGE SEASONAL WATER LEVELS
STRUCTURE, BUILDING OR FACILITY LOCATION POINT - COORDINATES
BORING LOCATION AND NUMBER
TEST PIT LOCATION AND NUMBER
PIEZOMETER LOCATION AND NUMBER
DEMOLITION
STRUCTURE, BUILDING OR FACILITY
ASPHALT CONCRETE PAVEMENT
GRAVEL SURFACING
CONCRETE PAVEMENT
CURB
CURB AND GUTTER
SINGLE SWING GATE
DOUBLE SWING GATE
SLIDING GATE
GUARD RAIL
CHAIN LINK FENCE
ARCHITECTURAL FENCE
WIRE FENCE
CULVERT
FLOW DIRECTION
YARD PIPING LEGEND
EXISTING
THIS CONTRACT
NOMINAL PIPE DIAMETER
PIPE USE IDENTIFICATION
PIPING < 30" DIAMETER
PIPING ≥ 30" DIAMETER
EXISTING PIPE TO BE ABANDONED
EXISTING PIPE TO BE REMOVED
INDICATOR POST VALVE
GATE VALVE AND VALVE BOX
BUTTERFLY VALVE AND VALVE BOX
PLUG VALVE AND VALVE BOX
FLEXIBLE COUPLING
90° ELBOW UP
90° ELBOW DOWN
BEND < 90° UP
BEND < 90° DOWN
CONCENTRIC REDUCER
CAP OR PLUG
CLEANOUT
FIRE HYDRANT
BACKFILL CLASS
ABBREVIATIONS
APPROX APPROXIMATE
AVG AVERAGE
B.F. BUTTERFLY
" DIAMETER
DIA DIAMETER
EL ELEVATION
ELEV ELEVATION
EXIST EXISTING
FT FOOT / FEET
GAL GALLON
HDPE HIGH DENSITY POLYETHYLENE
HP HORSE POWER
N NORTH
NTS NOT TO SCALE
O.C. ON-CENTER
PE POLYETHYLENE
PVC POLYVINL CHLORIDE
SQ FT SQUARE FOOT
TYP TYPICAL
W/ WITH
10% DESIGN
MITIGATION MEASURES
CIVIL GENERAL NOTES AND LEGEND
SHEET IDENTIFICATION
G-002


PLAN
PHOTO 1
PHOTO 2
PHOTO 3
MITIGATION MEASURES
C-001

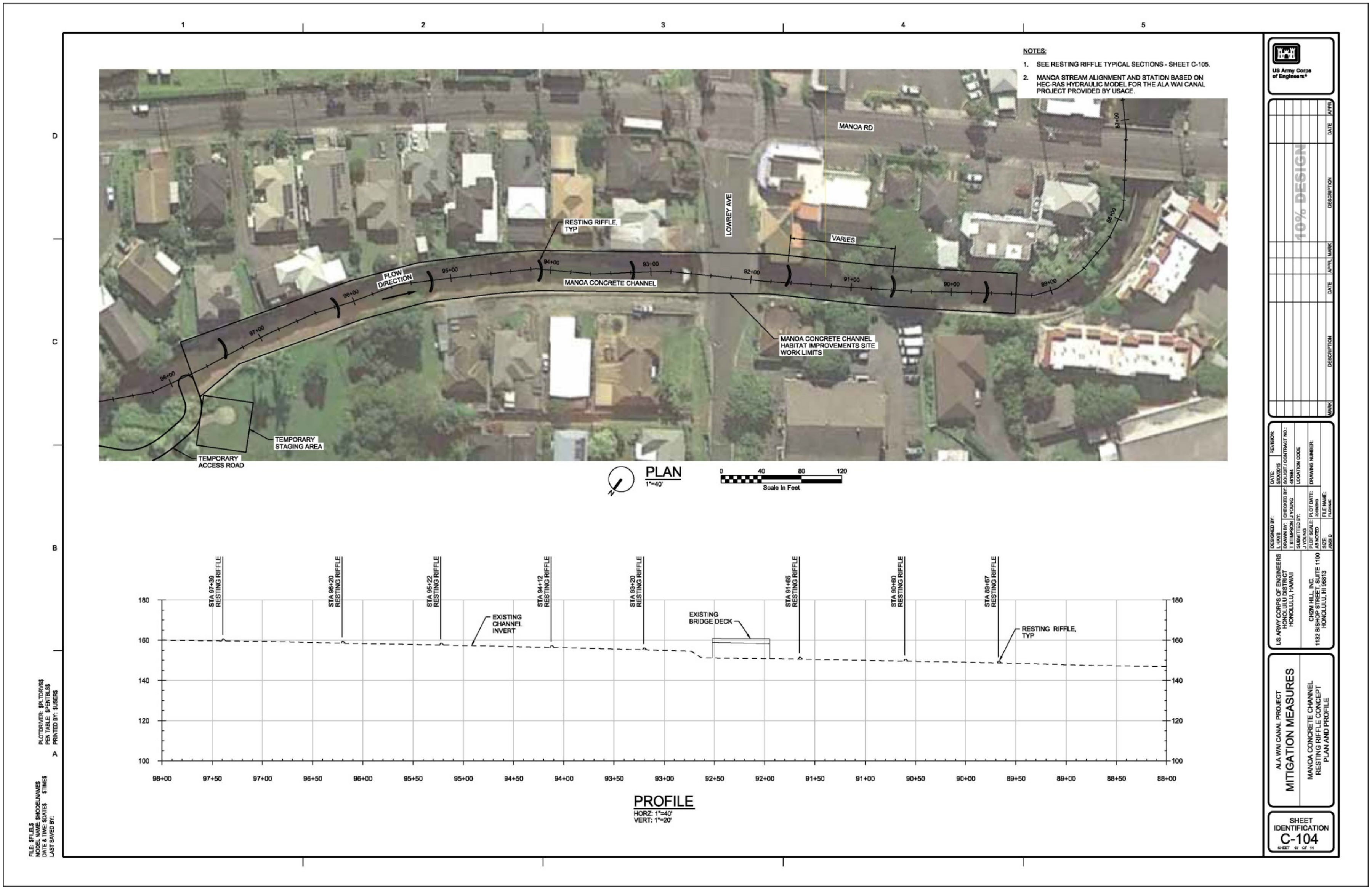

ACCESS AND STAGING PLAN
MITIGATION MEASURES
C-101

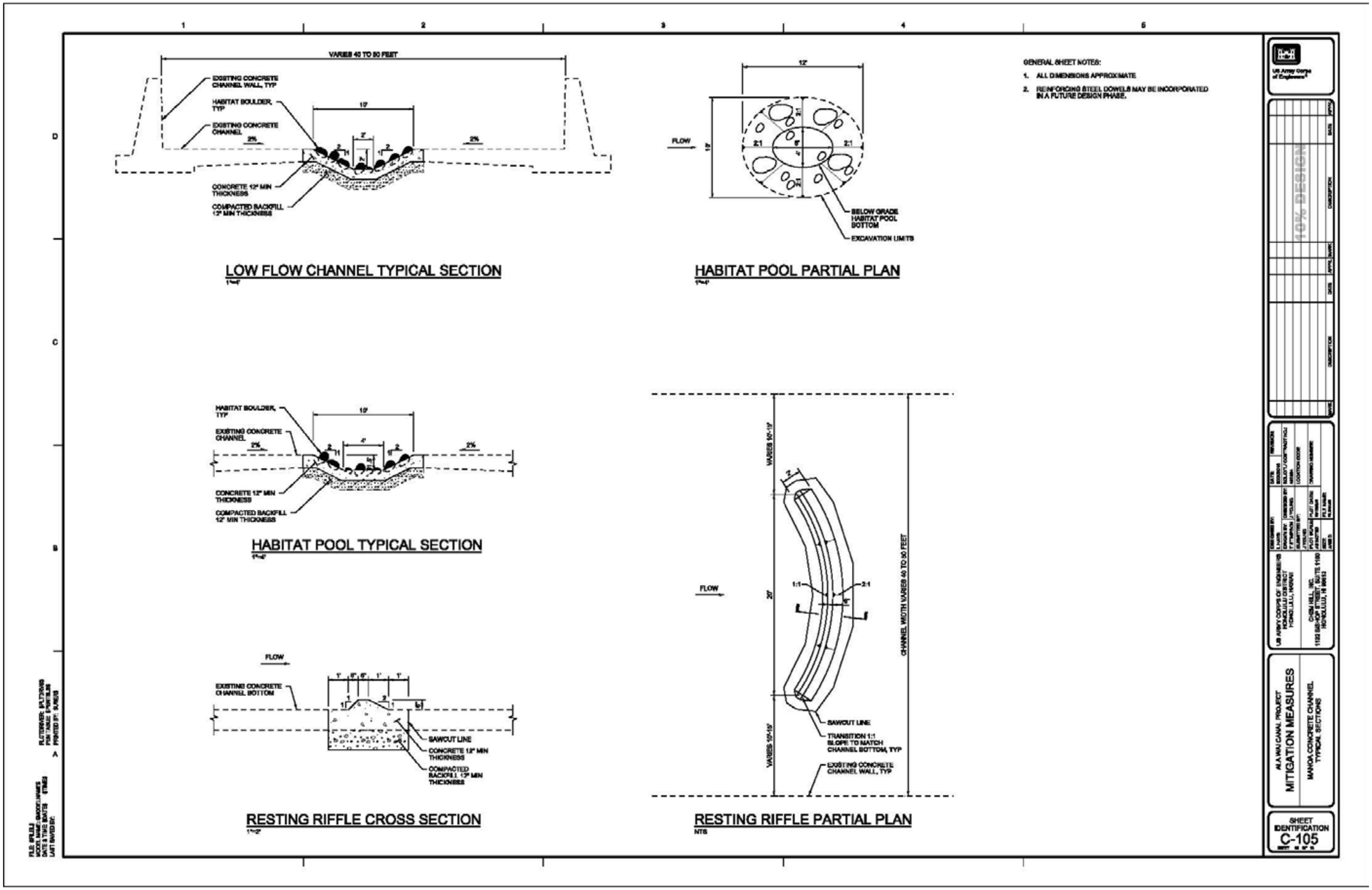


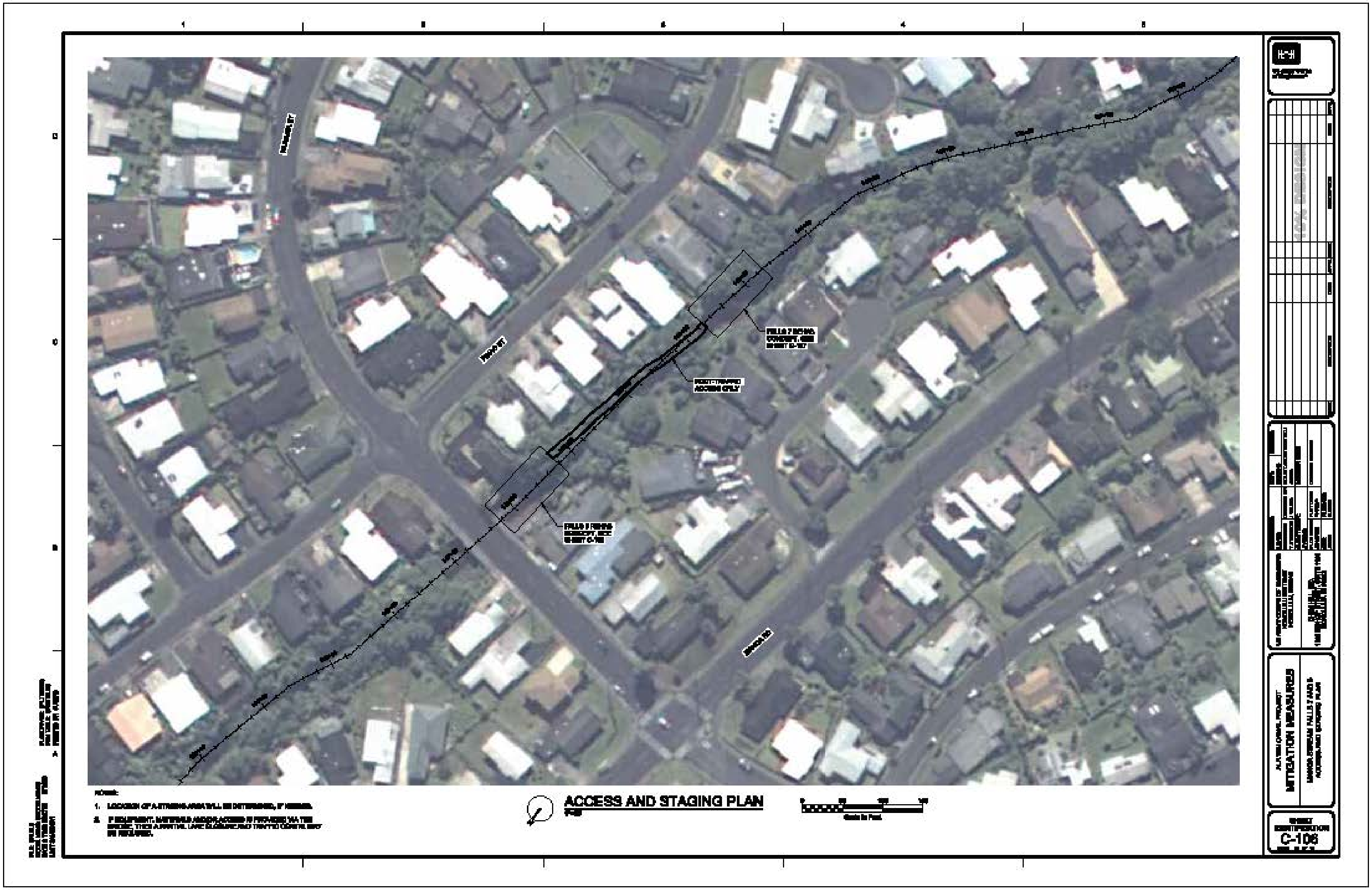
NOTES:
1. CUT AND REMOVE EXISTING CONCRETE WITHIN LOW FLOW CHANNEL EXTENTS.
2. SEE LOW FLOW CHANNEL TYPICAL SECTIONS - SHEET C-105 .
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.
MANOA RD
LOWREY AVE
LOW FLOW CHANNEL EXCAVATION EXTENTS, TYP
FLOW DIRECTION
MANOA CONCRETE CHANNEL
MANOA CONCRETE CHANNEL HABITAT IMPROVEMENTS SITE WORK LIMITS
TEMPORARY STAGING AREA
TEMPORARY ACCESS ROAD
PLAN
1"=40'
Scale In Feet
LIMIT OF LOW FLOW CHANNEL
EXISTING CHANNEL INVERT
EXISTING BRIDGE DECK
S = -1%
INVERT OF LOW FLOW CHANNEL
PROFILE
HORZ: 1"=40'
VERT: 1"=20'
US Army Corps of Engineers
10% DESIGN
US ARMY CORPS OF ENGINEERS HONOLULU DISTRICT HONOLULU, HAWAII
CH2M HILL, INC. 1132 BISHOP STREET, SUITE 1100 HONOLULU, HI 96813
ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL LOW FLOW CHANNEL CONCEPT PLAN AND PROFILE
SHEET IDENTIFICATION
C-102



NOTES:
1. CUT AND REMOVE EXISTING CONCRETE WITHIN HABITAT POOL EXTENTS.
2. SEE HABITAT POOL TYPICAL SECTIONS - SHEET C-105.
3. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.
US Army Corps of Engineers
10% DESIGN
MANOA RD
LOWREY AVE
HABITAT POOL EXCAVATION EXTENTS, TYP
VARIES
FLOW DIRECTION
MANOA CONCRETE CHANNEL
MANOA CONCRETE CHANNEL HABITAT IMPROVEMENTS SITE WORK LIMITS
TEMPORARY STAGING AREA
TEMPORARY ACCESS ROAD
PLAN
1"=40'
Scale In Feet
STA 97+39 POOL
STA 96+20 POOL
STA 95+22 POOL
STA 94+12 POOL
STA 93+20 POOL
STA 91+65 POOL
STA 90+60 POOL
STA 89+67 POOL
EXISTING CHANNEL INVERT
EXISTING BRIDGE DECK
S = -1%
INVERT OF HABITAT POOL, TYP
PROFILE
HORZ: 1"=40'
VERT: 1"=20'
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII
CH2M HILL, INC.
1132 BISHOP STREET, SUITE 1100
HONOLULU, HI 96813
ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL
HABITAT POOL CONCEPT
PLAN AND PROFILE
SHEET IDENTIFICATION
C-103


NOTES:
1. SEE RESTING RIFFLE TYPICAL SECTIONS - SHEET C-105.
2. MANOA STREAM ALIGNMENT AND STATION BASED ON HEC-RAS HYDRAULIC MODEL FOR THE ALA WAI CANAL PROJECT PROVIDED BY USACE.
MANOA RD
LOWREY AVE
RESTING RIFFLE, TYP
VARIES
FLOW DIRECTION
MANOA CONCRETE CHANNEL
MANOA CONCRETE CHANNEL HABITAT IMPROVEMENTS SITE WORK LIMITS
TEMPORARY STAGING AREA
TEMPORARY ACCESS ROAD
PLAN
1"=40'
Scale In Feet
STA 97+39 RESTING RIFFLE
STA 96+20 RESTING RIFFLE
STA 95+22 RESTING RIFFLE
STA 94+12 RESTING RIFFLE
STA 93+20 RESTING RIFFLE
STA 91+65 RESTING RIFFLE
STA 90+60 RESTING RIFFLE
STA 89+67 RESTING RIFFLE
EXISTING CHANNEL INVERT
EXISTING BRIDGE DECK
RESTING RIFFLE, TYP
PROFILE
HORZ: 1"=40'
VERT: 1"=20'
10% DESIGN
US Army Corps of Engineers
US ARMY CORPS OF ENGINEERS HONOLULU DISTRICT HONOLULU, HAWAII
CH2M HILL, INC. 1132 BISHOP STREET, SUITE 1100 HONOLULU, HI 96813
DESIGNED BY: L HAYS
DRAWN BY: T STIMPSON
CHECKED BY: J YOUNG
SUBMITTED BY: J YOUNG
PLOT SCALE: AS NOTED
SIZE: ANSI D
DATE: 5/XX/2015
SOLICIT / CONTRACT NO.: 481884
ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL RESTING RIFFLE CONCEPT PLAN AND PROFILE
SHEET IDENTIFICATION
C-104


VARIES 40 TO 50 FEET
EXISTING CONCRETE CHANNEL WALL, TYP
HABITAT BOULDER, TYP
EXISTING CONCRETE CHANNEL
10'
2'
2%
CONCRETE 12" MIN THICKNESS
COMPACTED BACKFILL 12" MIN THICKNESS
LOW FLOW CHANNEL TYPICAL SECTION
12'
FLOW
2:1
BELOW GRADE HABITAT POOL BOTTOM
EXCAVATION LIMITS
HABITAT POOL PARTIAL PLAN
GENERAL SHEET NOTES:
1. ALL DIMENSIONS APPROXIMATE
2. REINFORCING STEEL DOWELS MAY BE INCORPORATED IN A FUTURE DESIGN PHASE.
HABITAT POOL TYPICAL SECTION
10% DESIGN
RESTING RIFFLE CROSS SECTION
EXISTING CONCRETE CHANNEL BOTTOM
SAWCUT LINE
CHANNEL WIDTH VARIES 40 TO 50 FEET
TRANSITION 1:1 SLOPE TO MATCH CHANNEL BOTTOM, TYP
EXISTING CONCRETE CHANNEL WALL, TYP
RESTING RIFFLE PARTIAL PLAN
NTS
ALA WAI CANAL PROJECT
MITIGATION MEASURES
MANOA CONCRETE CHANNEL TYPICAL SECTIONS
SHEET IDENTIFICATION
C-105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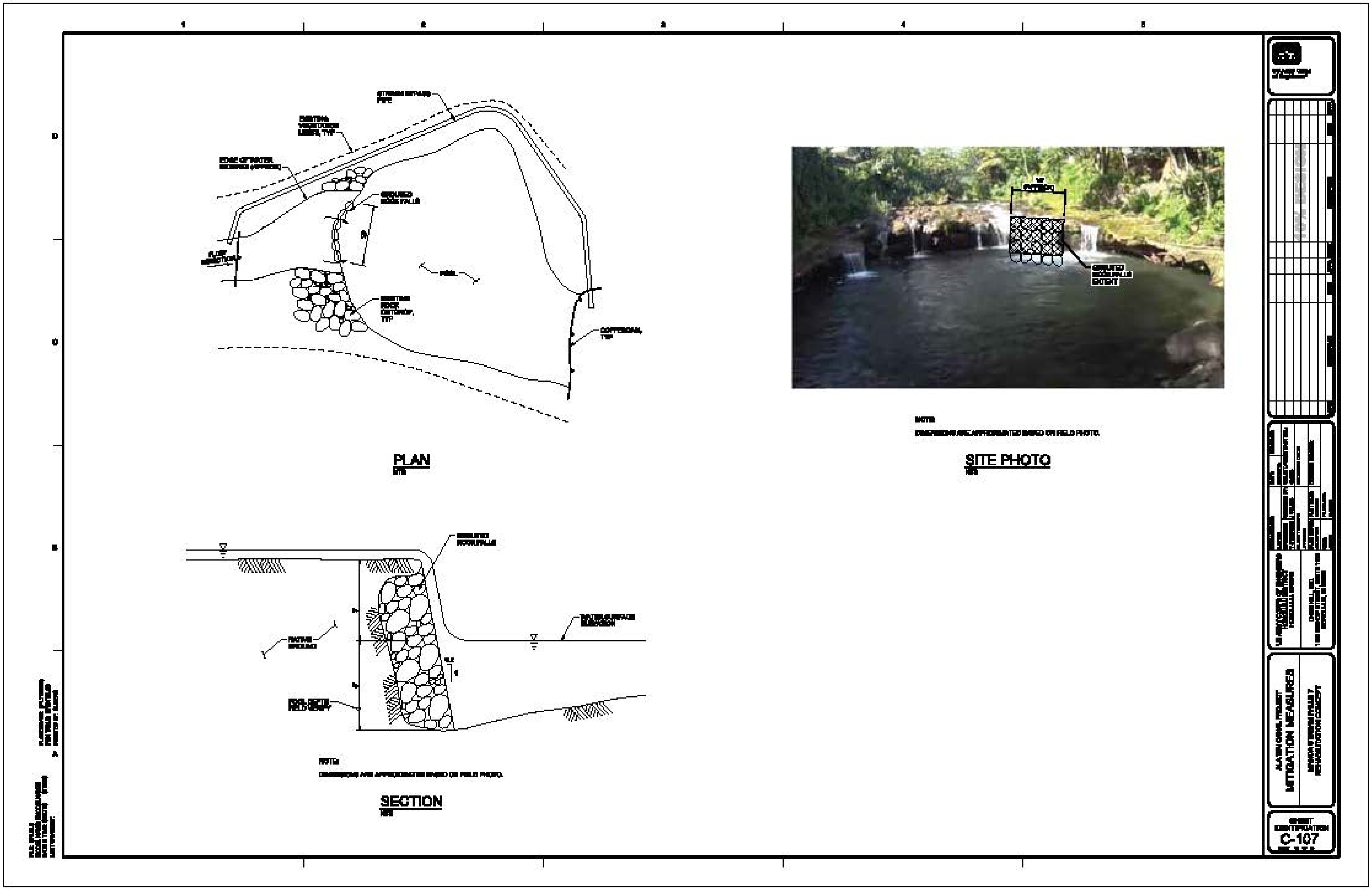
MITIGATION MEASURES
C-106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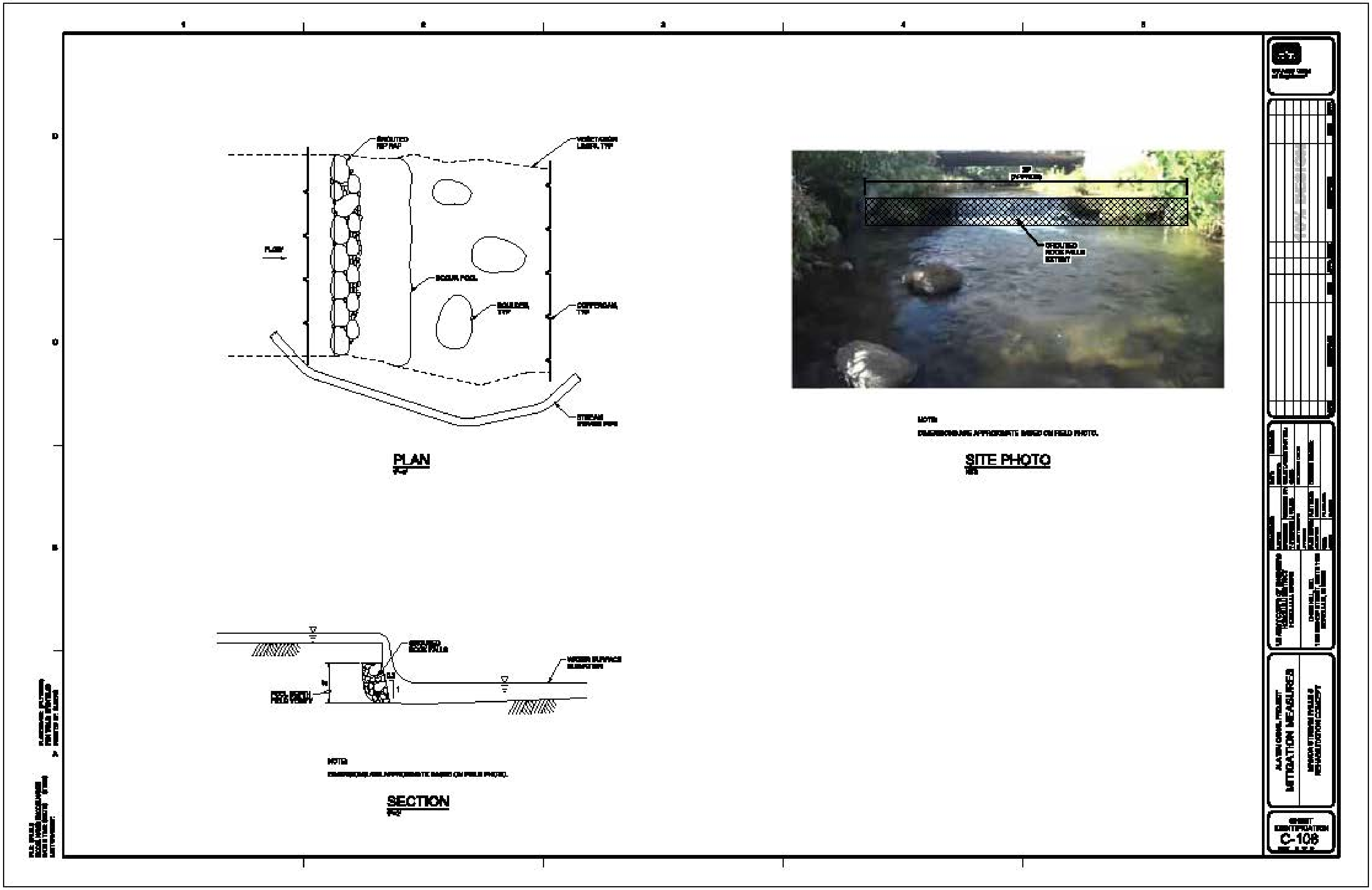
SITE PHOTO
SECTION
MITIGATION MEASURES
C-107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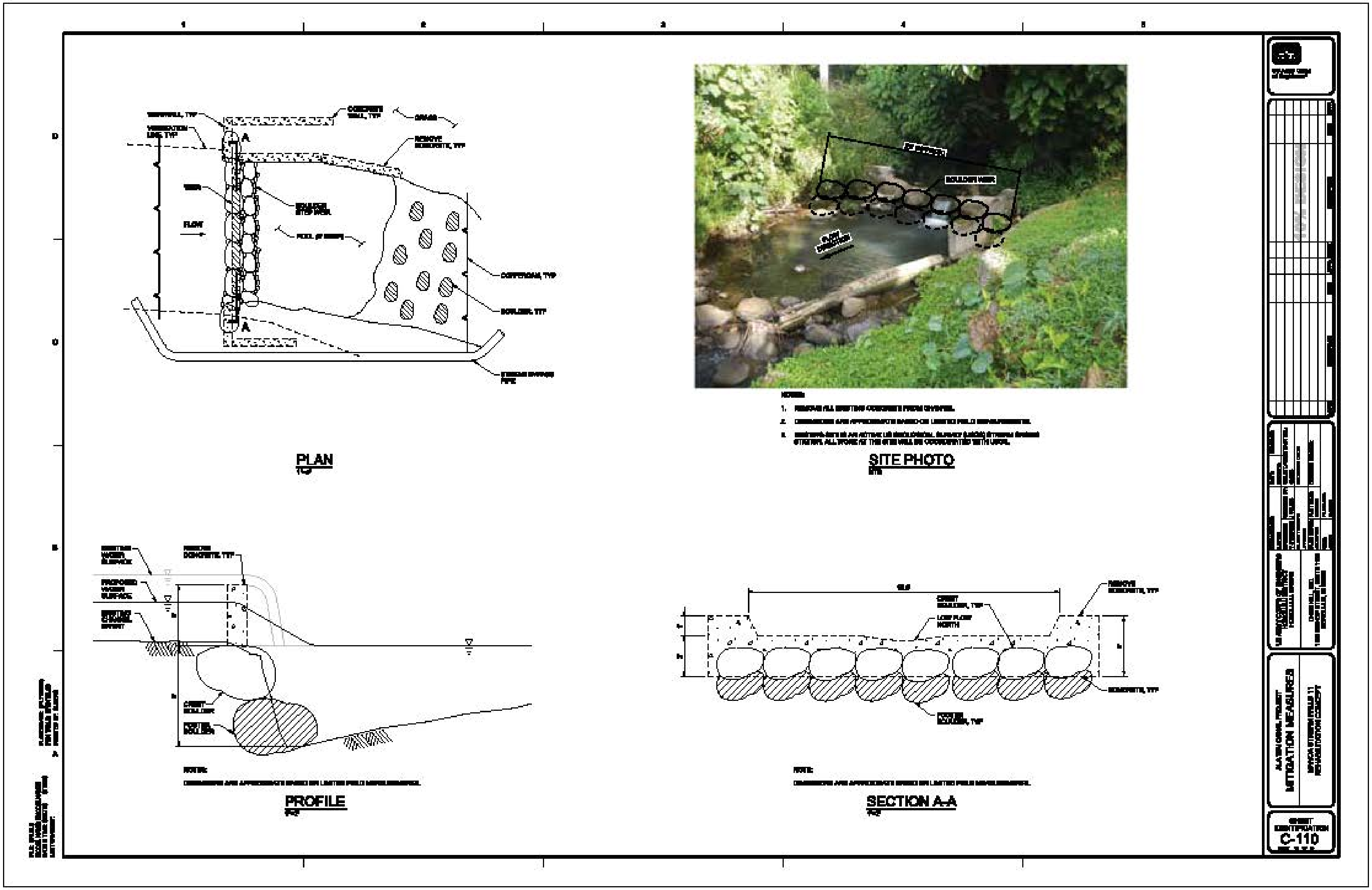
SITE PHOTO
SECTION
MITIGATION MEASURES
C-108


TEMPORARY ACCESS
TEMPORARY STAGING AREA
ACCESS AND STAGING PLAN
MITIGATION MEASURES
C-109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SECTION A-A
MITIGATION MEASURES
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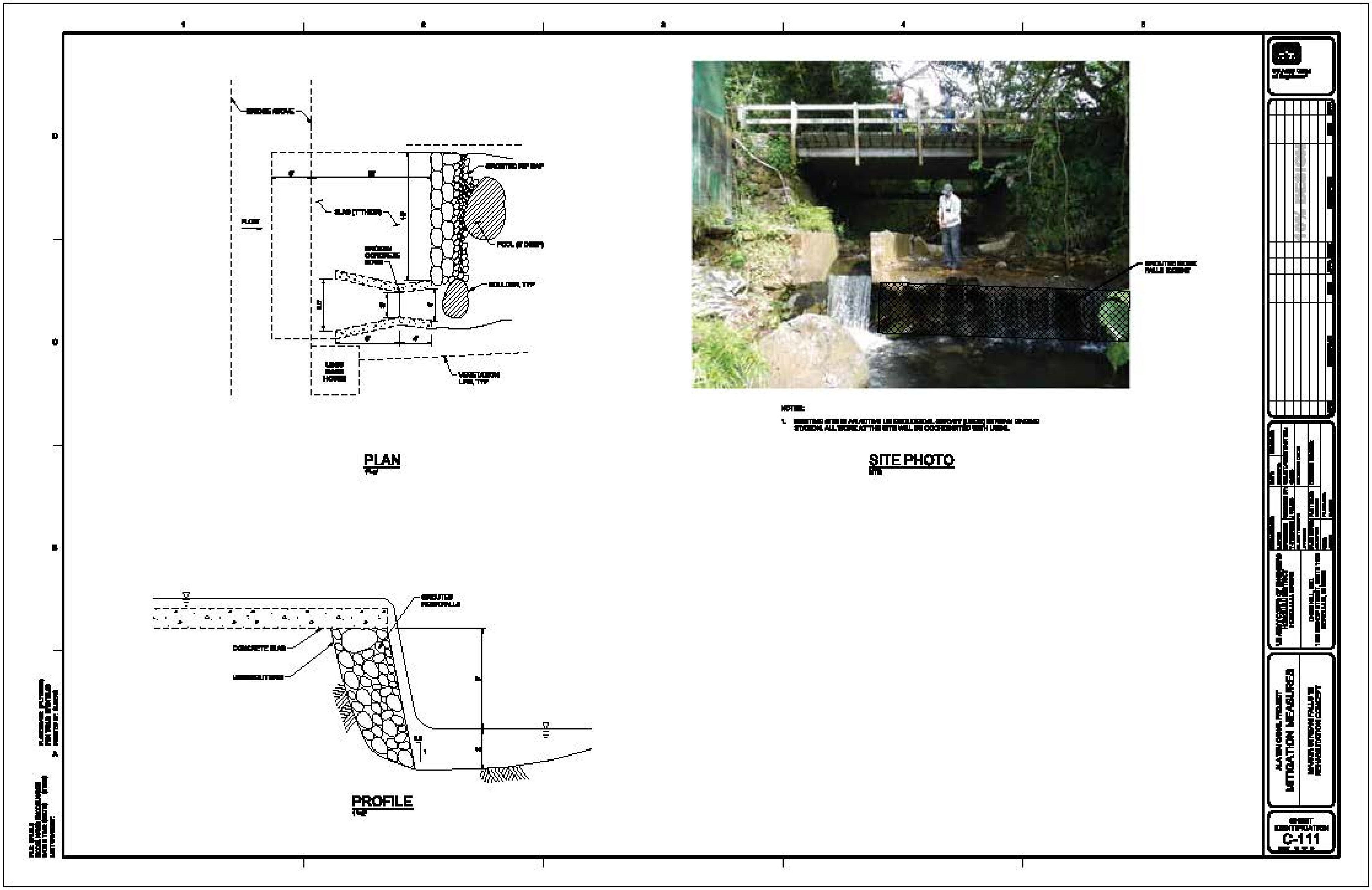
PLAN
SITE PHOTO
PROFILE
MITIGATION MEASURES
C-111

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

2 1 OCT 2016

Civil and Public Works Branch
Programs and Project Management Division

Dr. Mary M. Abrams
Field Supervisor
Pacific Islands Fish and Wildlife Office
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3-122
Box 50088
Honolulu, Hawaii 96850

Dear Dr. Abrams:

The Honolulu District, U.S. Army Corps of Engineers (USACE) seeks your concurrence with clarifications we propose to the U.S. Fish and Wildlife Service's (USFWS) Biological Opinion (BO) for the Ala Wai Canal Flood Risk Management Study. It is our understanding that this opinion is final which concludes the consultation process under Section 7 of the Endangered Species Act (ESA). However, based on discussions with your staff at a meeting held on October 11, 2016, we have jointly come to the conclusion that it will be beneficial to further clarify the terminology used in the biological opinion and reiterate our understanding of the USFWS's intent for executing the terms and conditions in the incidental take statement. The sections below discuss the items for clarification that include; the amount or extent of take and the terms and conditions.

I. Amount or Extent of Take.

The section of the BO that addressed the amount or extent of take is transcribed below:

"Based on our analysis presented in this Biological Opinion, the Service anticipates the following take may occur for as long as the Ala Wai Canal Project construction, operations, and maintenance are active and in place:

1) *Up to 66 blackline Hawaiian damselfly adults and associated life cycle stages over the life of the project due to elimination of breeding habitat and mortality as a result of the proposed action."*

Clarification: The number of blackline Hawaiian damselfly adults and associated life cycles were based upon the observed sightings during the field surveys through application of a model that provided a reasonable estimation of the numbers of damselflies that would be affected. Per discussion with your staff, the 66 blackline Hawaiian damselflies includes all life cycles and assumes total loss at both the Waihi and Waiakeakua project areas for the entire life of the project (construction, operations and maintenance).

II. Terms and Conditions

The terms and conditions describe how USACE must comply with the reasonable and prudent measures described in the incidental take statement to minimize the amount of incidental take of the damselfly. Applicable paragraphs are transcribed below in italics. Based upon discussion and agreement with your staff, proposed clarifications follow that describe how USACE will execute the terms and conditions.

A. Reasonable and prudent measure: *"1. The USACE shall minimize the loss of blackline Hawaiian damselfly."*

"In order to implement the reasonable and prudent measure #1 above, the following terms and conditions apply:

1. The USACE shall hire a qualified biologist (approved by the Service) to collect damselflies to be relocated to another protected location or to be held in captivity in a qualified facility until site is identified."

Clarification: USFWS has provided options for compliance which USACE and the sponsor can exercise at their discretion.

If the option to relocate damselflies is executed, USACE will coordinate with USFWS on the selection of the qualified biologist and relocation site and the procedures to be followed for the relocation effort. Relocation would be conducted by a qualified biologist hired by USACE and USFWS will not unreasonably withhold concurrence of the use of an individual or contractor with suitable qualifications. The relocation site will occur directly upstream of the project areas, outside of the footprint of construction. Relocation will only include the damselfly larva life stage. USFWS has advised that the larval stage has the greatest potential to survive the relocation effort. Relocation or collection for storage will occur one time at each project site, immediately prior to construction. USACE is not required to demonstrate success with the relocation effort. The relocation effort is to reduce the amount of take of damselflies.

The option to hold damselflies in captivity until they can be relocated to another site cannot be executed at this time. The Division of Forestry and Wildlife (DOFAW), Department of Land and Natural Resources (DLNR), State of Hawaii has a facility that can hold damselflies and is currently seeking a permit from the USFWS to work with the species. With this permit, DOFAW would be able to collect blackline Hawaiian damselfly adults, larvae and eggs for holding and rearing at their facility from the Waihi and Waiakeakua project areas before the start of construction. Relocation of the damselflies would be coordinated and executed under terms of their permit with the USFWS. Biologists from DOFAW will collect blackline Hawaiian damselfly adults, larvae and eggs (all life stages) and store acquired specimens at a DOFAW-owned and operated facility. Release of adult individuals or relocation of lavae and eggs outside of the facility to the natural environment will be at the discretion of the DLNR. Collection and holding of damselflies by the DOFAW is the preferred method by USFWS to reduce the amount of take.

"2. The USACE shall monitor and report on the levels of take that occur on an annual basis.

To determine the level of incidental take the USACE shall:

a. Monitor and report any observed blackline Hawaiian damselflies prior to construction of the access roads and debris and detention basins at the Waihī and Waiakeakua construction footprints. The USACE will monitor blackline Hawaiian damselfly information for one year after the completion of construction at these sites. The monitoring methodology will be approved by the Service prior to construction implementation, and will, at a minimum, include counts of adult blackline Hawaiian damselflies.

b. Submit reports summarizing the methods and results of the above monitoring efforts to the Service's Pacific Islands Fish and Wildlife Office (300 Ala Moana Blvd., Room 3-122, Honolulu, Hawai'i 96850) annually until the monitoring is complete.

3. The USACE shall submit annual reports detailing the implementation of the above Reasonable and Prudent Measures and Terms and Conditions. The first report shall be due at the end of January of the first year after the project is initiated. Annual reports shall be submitted throughout the duration of the proposed action."

Clarification: For Terms and Conditions #2 and #3, USFWS has requested three monitoring events which will result in the submittal of reports by USACE. These include a preconstruction survey, a post-construction survey, and a survey of the completed project area within one year of construction completion. Reports will be provided to the designated receiving office by the end of January of the year following the completion of the report. If DOFAW performs the collection of damselflies prior to construction, it will provide the numbers of adults, larvae and eggs collected to USACE for reporting to USFWS.

B. Reasonable and prudent measure: *"2. The USACE shall minimize the loss of habitat."*

"In order to implement the reasonable and prudent measure #2 above, the following terms and conditions apply:

1. The USACE shall consider purchasing private land to relocate the access roads downstream of the proposed Waihi debris and detention basin to minimize loss of riffle and pool habitat."

Clarification: Based on email correspondence received from USFWS staff on October 11, 2016, it is USACE's understanding that the concern regarding habitat loss due to the location of the road is focused on the loss of hillside seep habitat, not riffle and pool habitat as noted above. While the concern is noted, operations and maintenance requires access to the upstream side of the structure in order to perform debris removal activities. Relocating this road on the downstream side of the structure would significantly increase the distance and subsequent environmental impacts of the roadway and also require a stream crossing in order to access the upstream side of the structure. USACE has considered relocating the Waihi access road and determined that due to the greater environmental damage and costs, relocating the road is not feasible.

"2. The USACE shall limit the removal of tree canopy cover over areas of damselfly habitat."

Clarification: USACE will limit tree removal to the greatest extent practicable. However, USACE activities will only occur on-site during the construction period. Following completion of construction, USACE cannot control the actions of others within the project area.

In the future, we request receipt of a draft BO prior to finalization in order ensure that the federal action is properly defined and that the parties' mutual understanding of the terms and conditions are clearly set forth in the BO.

We request a letter of concurrence from you regarding the information above at your earliest opportunity. Our understanding is that your staff will utilize the information of this letter to append the existing BO. If you have any questions or require additional information, please contact Mr. Michael Wyatt, Project Manager of my Civil and Public Works Branch, at (808) 835-4031 or email michael.d.wyatt@usace.army.mil.

Sincerely,

James D. Hoyman, P.E.
Lieutenant Colonel, U.S. Army
District Engineer

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122
Honolulu, Hawai'i 96850

In Reply Refer To:
01EPIF00-2016-F-0157

NOV 17 2016

Colonel James D. Hoyman, P.E.
Lieutenant Colonel, U.S. Army
District Engineer
Honolulu District
U.S. Army Corps of Engineers
Fort Shafter, Hawai'i 96858-5440

Subject: Request for Clarification of the Terms and Conditions of the Ala Wai Canal Project Biological Opinion, Island of O'ahu

Dear Colonel Hoyman:

This U.S. Fish and Wildlife Service's (Service) received your letter on October 21, 2016, requesting our agreement with your proposed clarifications to our Biological Opinion and Informal Consultation for the Proposed Construction, Operation, and Maintenance of the Ala Wai Canal Project (BO). Based on meeting discussions with the staff of the U.S. Army Corps of Engineers, Honolulu District (USACE) and the Service (October 11, 2016) we have jointly agreed that the Service could agree on a written letter from the USACE for ways to implement the terms and conditions as issued in our BO. This agreed upon document would fulfill some of the requirements for the USACE clarification questions on implementation of our terms and conditions for the blackline Hawaiian damselfly (*Megalagrion nigrohamatum nigrolineatum*). The sections below discuss the items for your clarification and our comments.

Our BO states: The amount or extent of take is "*…up to 66 blackline Hawaiian damselfly adults and associated life cycle stages over the life of the project due to elimination of breeding habitat and mortality as a result of the proposed action*".

Your clarification: "*The number of blackline Hawaiian damselfly adults and associated life cycles were based upon the observed sightings during the field surveys through application of a model that provided a reasonable estimation of the numbers of damselflies that would be affected. Per discussion with your staff, the 66 blackline Hawaiian damselflies includes all life cycles and assumes total loss at both the Waihī and Waiakeakua project areas for the entire life of the project (construction, operations and maintenance).*"

We agree with your clarification above.

Our BO states: "*In order to implement the reasonable and prudent measure #1 above, the following terms and conditions apply:*

1. *The USACE shall hire a qualified biologist (approved by the Service) to collect damselflies to be relocated to another protected location or to be held in captivity in a qualified facility until site is identified.*"

Your clarification: "*USFWS has provided options for compliance which USACE and the sponsor can exercise at their discretion.*

If the option to relocate damselflies is executed, USACE will coordinate with USFWS on the selection of the qualified biologist and relocation site and the procedures to be followed for the relocation effort. Relocation would be conducted by a qualified biologist hired by USACE and USFWS will not unreasonably withhold concurrence of the use of an individual or contractor with suitable qualifications. The relocation site will occur directly upstream of the project areas, outside of the footprint of construction. Relocation will only include the damselfly larva life stage. USFWS has advised that the larval stage has the greatest potential to survive the relocation effort. Relocation or collection for storage will occur one time at each project site, immediately prior to construction. USACE is not required to demonstrate success with the relocation effort. The relocation effort is to reduce the amount of take of damselflies."

We agree with your clarification above.

Your clarification: "*The option to hold damselflies in captivity until they can be relocated to another site cannot be executed at this time. The Division of Forestry and Wildlife (DOFAW), Department of Land and Natural Resources (DLNR), State of Hawaii has a facility that can hold damselflies and is currently seeking a permit from the USFWS to work with the species. With this permit, DOFAW would be able to collect blackline Hawaiian damselfly adults, larvae and eggs for holding and rearing at their facility from the Waihi and Waiakeakua project areas before the start of construction. Relocation of the damselflies would be coordinated and executed under terms of their permit with the USFWS. Biologists from DOFAW will collect blackline Hawaiian damselfly adults, larvae and eggs (all life stages) and store acquired specimens at a DOFAW-owned and operated facility. Release of adult individuals or relocation of lavae and eggs outside of the facility to the natural environment will be at the discretion of the DLNR. Collection and holding of damselflies by the DOFAW is the preferred method by USFWS to reduce the amount of take.*"

We appreciate your efforts to describe the proposed implementation of the terms and conditions #1, however, the Hawai'i Department of Land and Natural Resources – Division of Forestry and Wildlife (DOFAW) does not currently have a facility that can hold blackline damselflies. As we discussed in our meeting on October 11, the Service is not able to agree to this commitment on behalf of DOFAW. We recommend you work with our office to create further dialogue and details with DOFAW for the proposed work. Furthermore, the collection and holding damselflies is the preferred method by the Service to minimize the extent of take of adult damselflies and all associated life stages as the result of your proposed project.

Our BO states: "*to implement the reasonable and prudent measure #1 above, the following terms and conditions apply…*

2. *The USACE shall monitor and report on the levels of take that occur on an annual basis. To determine the level of incidental take the USACE shall:*

    a. *Monitor and report any observed blackline Hawaiian damselflies prior to construction of the access roads and debris and detention basins at the Waihī and Waiakeakua construction footprints. The USACE will monitor blackline Hawaiian damselfly information for one year after the completion of construction at these sites. The monitoring methodology will be approved by the Service prior to construction implementation, and will, at a minimum, include counts of adult blackline Hawaiian* damselflies."
    b. *Submit reports summarizing the methods and results of the above monitoring efforts to the Service's Pacific Islands Fish and Wildlife Office (300 Ala Moana Blvd., Room 3-122, Honolulu, Hawai'i 96850) annually until the monitoring is complete.*

3. *The USACE shall submit annual reports detailing the implementation of the above Reasonable and Prudent Measures and Terms and Conditions. The first report shall be due at the end of January of the first year after the project is initiated. Annual reports shall be submitted throughout the duration of the proposed action.*"

Your clarification: "*For Terms and Conditions #2 and #3, USFWS has requested three monitoring events which will result in the submittal of reports by USACE. These include a preconstruction survey, a post-construction survey, and a survey of the completed project area within one year of construction completion. Reports will be provided to the designated receiving office by the end of January of the year following the completion of the report. If DOFAW performs the collection of damselflies prior to construction, it will provide the numbers of adults, larvae and eggs collected to USACE for reporting to USFWS.*"

We agree with your clarification, however, disagree with obligating DOFAW to provide "*…numbers of adults, larvae and eggs collected to USACE for reporting…*" We agree this information should be provided by the party who will perform the collection of damselflies, but the Service is not able to commit DOFAW to these requirements. We recommend you work with our office and DOFAW to create the dialogue to request and initiate a proposed work plan.

Our BO states: "*In order to implement the reasonable and prudent measure #2 above, the following terms and conditions apply:*

1. *The USACE shall consider purchasing private land to relocate the access roads downstream of the proposed Waihī debris and detention basin to minimize loss of riffle and pool habitat.*"

Your clarification: "*Based on email correspondence received from USFWS staff on October 11, 2016, it is USACE's understanding that the concern regarding habitat loss due to the location of the road is focused on the loss of hillside seep habitat, not riffle and pool habitat as noted above. While the concern is noted, operations and maintenance requires access to the upstream side of the structure in order to perform debris removal activities. Relocating this road on the* *downstream side of the structure would significantly increase the distance and subsequent environmental impacts of the roadway and also require a stream crossing in order to access the upstream side of the structure. USACE has considered relocating the Waihi access road and determined that due to the greater environmental damage and costs, relocating the road is not feasible.*"

As stated in our email, we clarified the construction of the access roads at Waihī stream will result in the loss of seep habitat, not riffle and pool habitat; therefore, we agree with your clarification above. However, the blackline Hawaiian damselfly occurs in both slow sections or pools along mid-reach and headwater sections of perennial upland streams, as well as in seep-fed pools along overflow channels bordering such streams. Therefore, we recommended you consider the purchase of private land or other options to relocate the access roads downstream of the current proposed areas in Waihī to minimize loss of seep habitat. If after further development of your project plans this becomes an option, we recommend you relocate the proposed road to minimize habitat loss for the blackline Hawaiian damselfly.

Our BO states: "*…to implement the reasonable and prudent measure #2…*

2. *The USACE shall limit the removal of tree canopy cover over areas of damselfly habitat."*

Your clarification: "*USACE will limit tree removal to the greatest extent practicable. However, USACE activities will only occur on-site during the construction period. Following completion of construction, USACE cannot control the actions of others within the project area.*"

We agree with your clarification.

Your comments: "*In the future, we request receipt of a draft BO prior to finalization in order ensure that the federal action is properly defined and that the parties' mutual understanding of the terms and conditions are clearly set forth in the BO.*"

We acknowledge your request for a draft opinion for future projects, however, we advise you to request for a draft BO when initiating consultation to allot for scheduling of document reviews. Additionally, each project will likely be assigned to different biologists or Team leaders; therefore, we recommend you communicate early with Service biologists to ensure advanced notice and timely submission of draft documents.

We will add your clarification letter and this response letter to our project files. To reiterate, our existing BO is a standalone document and should be considered as such. Additional documentation is beneficial to clarifying any underlying questions and conversations as documentations for the project.

We appreciate your willingness to work with our office and encourage you to continue conversations to further protect Hawai‘i’s endangered species. Please contact Jiny Kim, Fish and Wildlife Biologist (phone: 808-792-9400, email: Jiny_Kim@fws.gov) should you have any questions or concerns about this letter.

Sincerely,

Aaron Nadig
Island Team Manager
O‘ahu, Kaua‘i, Northwestern Hawaiian Islands, and American Samoa

Appendix E6
Renderings of Flood Risk Management Measures

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Figure E1. Conceptual Rendering of the Waiakeakua Debris and Detention Basin

Figure E2. Conceptual Rendering of the Woodlawn Ditch Detention Basin

Figure E3. Conceptual Rendering of the Pukele Debris and Detention Basin

Figure E4. Conceptual Rendering of the Makiki Debris and Detention Basin

Figure E5. Conceptual Rendering of the Ala Wai Canal Floodwalls (near Ala Wai Boulevard)

Figure E6. Conceptual Rendering of the Ala Wai Canal Floodwalls (near Kalakaua Avenue)

Figure E7. Conceptual Rendering of the Hausten Ditch Detention Basin (with aesthetic improvements)

Figure E8. Conceptual Rendering of the Ala Wai Golf Course Detention Basin

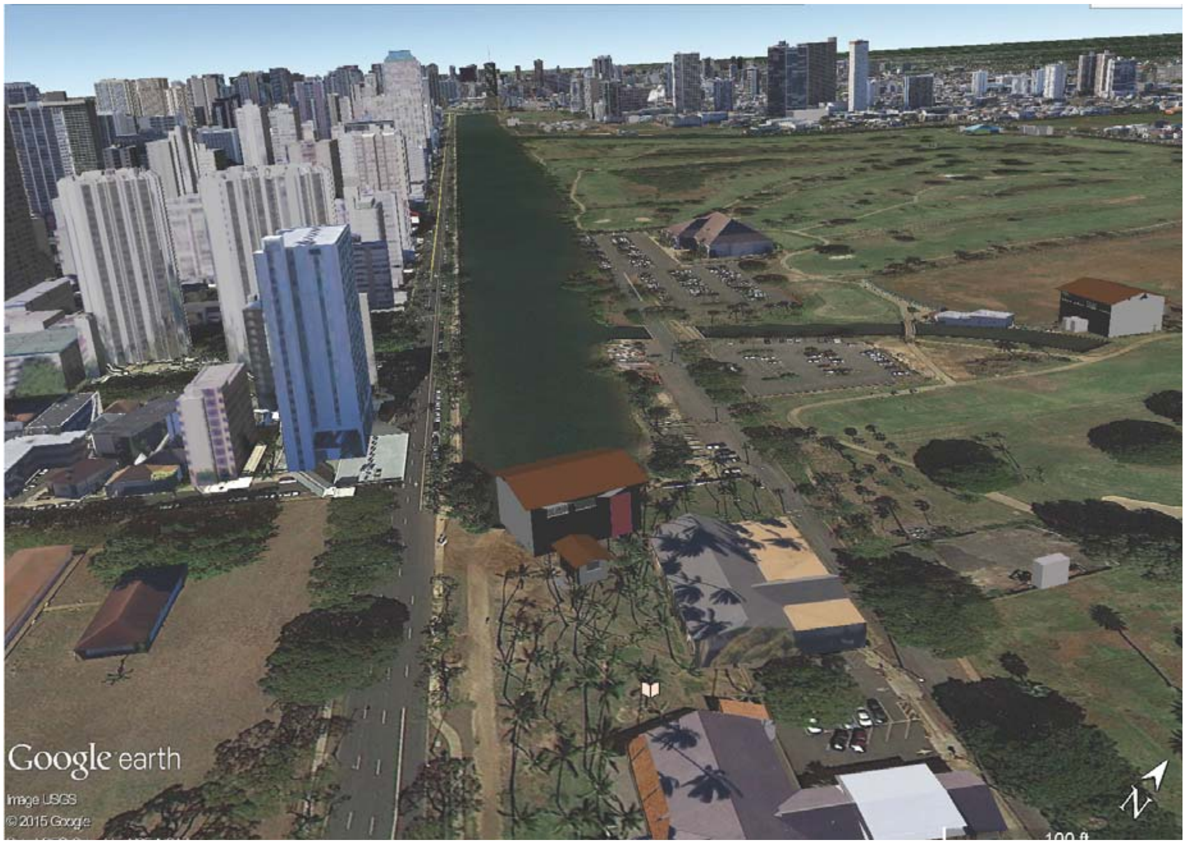

Figure E9. Conceptual Rendering of the Pump Stations at the East End of the Ala Wai Canal

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Appendix E7
Fish and Wildlife Coordination Act Report

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United States Department of the Interior

FISH AND WILDLIFE SERVICE

Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122,
Honolulu, Hawaii 96850

In Reply Refer To:
2014-CPA-0062

OCT 3 1 2016

Anthony J. Paresa, P.E.
Deputy District Engineer
Programs and Project Management/Civil Works
U.S. Army Corps of Engineers
Building 230
Fort Shafter, Hawaii, 96858-5440

Dear Mr. Paresa:

In coordination with your staff, the U.S. Fish and Wildlife Service (Service) is providing this Final Coordination Act Report for the proposed Ala Wai Flood Risk Management Study. The Fish and Wildlife Coordination Act of 1934 [16 U.S.C. 661 et seq.; 48 Stat. 401], as amended (FWCA), was established to provide a basic procedural framework for the orderly consideration of fish and wildlife conservation measures to be incorporated into Federal water resources development projects. This report has been prepared under the authority of and in accordance with provisions of the FWCA, the Federal Clean Water Act of 1977 [33 U.S.C. 1251 et seq.; 62 stat. 1155], as amended (CWA), and the Endangered Species Act [16 U.S.C 1531 et seq.], as amended (ESA). These comments are also consistent with the National Environmental Policy Act of 1969 [42 U.S.C. 4321 et seq.; 83 Stat. 852], as amended, and other authorities mandating the Service's review of projects and provision of technical assistance to conserve trust resources.

This report was prepared by the Service in coordination with the State of Hawaii's Department of Land and Natural Resources. We have also solicited comments from the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), and U.S. Environmental Protection Agency (EPA).

We appreciate the opportunity to provide input on the proposed project. If you have questions regarding the report, please contact Fish and Wildlife Biologist Kevin Foster (kevin_b_foster@fws.gov or 808-792-9420) or Aquatic Ecosystem Conservation Program Coordinator Dan Polhemus (Dan_Polhemus@fws.gov or 808-792-9400).

Sincerely,

Mary M. Abrams

Mary M. Abrams, Ph.D
Field Supervisor

Enclosures:
Final Coordination Act Report – Ala Wai
Flood Risk Management Study

cc:
NMFS-PIRO, Honolulu
HDAR-DLNR, Honolulu
USEPA-Region IX, Honolulu

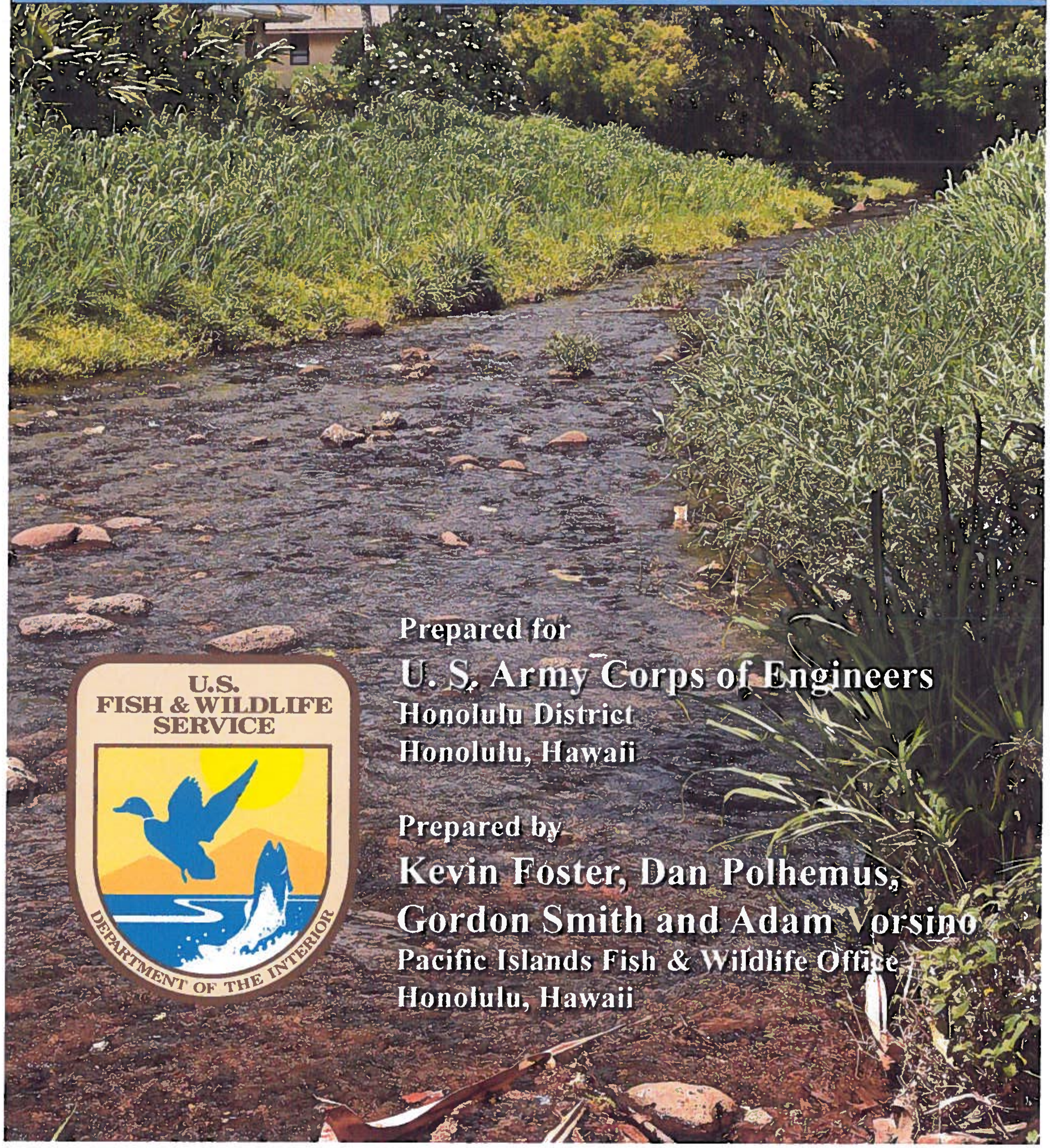
Phase 2 Freshwater Habitat Characterization

Ala Wai Watershed Flood Risk Management Study

Oahu, Hawaii

Planning Aid Report - Fish & Wildlife Coordination Act

FINAL REPORT October 2016



U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

Prepared for
U. S. Army Corps of Engineers
Honolulu District
Honolulu, Hawaii

Prepared by
Kevin Foster, Dan Polhemus, Gordon Smith and Adam Vorsino
Pacific Islands Fish & Wildlife Office
Honolulu, Hawaii

FINAL
FISH AND WILDLIFE COORDINATION ACT REPORT
ALA WAI WATERSHED FLOOD RISK MANAGEMENT STUDY
OAHU ISLAND, HAWAII

Prepared by:

Kevin B. Foster, Dan A. Polhemus, Gordon Smith, and Adam Vorsino
U.S. Department of the Interior
U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
Honolulu, Hawaii

Prepared for:

U.S. Army Corps of Engineers – Honolulu District
Honolulu, HI

October 2016

TABLE OF CONTENTS

INTRODUCTION

Authority, Purpose and Scope

The current document constitutes the U.S. Fish and Wildlife Service's (Service) final report on plans developed by the U.S. Army Corps of Engineers – Honolulu District (USACE) for flood risk management in the Ala Wai watershed, island of Oahu, State of Hawaii (Figures 1, 2 and 3). This report has been prepared under the authority of the Fish and Wildlife Coordination Act of 1934 (FWCA) [16 U.S.C. 661 *et seq.*; 48 Stat. 401], as amended, and other authorities mandating Department of the Interior (DOI) concern for environmental values. This report is also consistent with the National Environmental Policy Act of 1969 (NEPA) [42 U.S.C. 4321 *et seq.*; 83 Stat. 852], as amended and the Endangered Species Act of 1973 [16 U.S.C. 1531 *et. seq.*; 87 Stat. 884], as amended (ESA). The purpose of this report is to document existing fish and wildlife resources at the proposed project sites and to ensure that fish and wildlife conservation receives equal consideration with other proposed project objectives as required under the FWCA. The report includes an assessment of conspicuous diurnal fish and wildlife resources at the proposed project sites, an evaluation of potential impacts associated with the proposed alternative actions, and recommendations for fish and wildlife mitigation measures.

The proposed Ala Wai Watershed Flood Risk Management Study is authorized under the Rivers and Harbors Act of 1967 (Public Law 87-874). Section 209 is a general study authority that authorizes surveys in harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply and other beneficial water uses, and related land resources." This civil works project is being undertaken by the USACE as the Federal sponsor, in partnership with the State of Hawaii Department of Land and Natural Resources (DLNR), the non-Federal sponsor.

The overall purpose of the project is to reduce the risk of riverine flooding in the Ala Wai Watershed. Flooding has occurred within the watershed on multiple occasions, resulting in recorded property damages and health and safety risks. Analyses conducted in support of this project show that the 1-percent annual chance exceedance (ACE) floodplain extends over approximately 1,358 acres of the watershed. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318 million in structural damages alone (2013 price levels), not accounting for loss in business income or other similar economic losses.

The USACE is conducting an integrated Feasibility Study/Environmental Assessment to assess the technical, environmental and economic feasibility of the implementation of flood control improvements within the Ala Wai Watershed. The study will include structural measures, including the following: (1) Waihi Debris and Detention Basin; (2) Waiakeakua Debris and Detention Basin; (3) Woodlawn Ditch Detention Basin; (4) Manoa In-Stream Debris Catchment;

(5) Kanewai Field Multi-purpose Detention Basin; (6) Waiomao Debris and Detention Basin; (7) Pukele Debris and Detention Basin; (8) Makiki Debris and Detention Basin; (9) Ala Wai Canal Floodwalls; (10) Hausten Ditch Detention Basin; and (11) Ala Wai Golf Course Multi-Purpose Detention Basin (for feature locations, see Fig. 3). Also, a non-structural measure includes a flood warning system. Finally, the USACE is proposing Aquatic Habitat Mitigation to offset project construction-related unavoidable impacts to fish and wildlife resources.

The preferred action will evaluate the construction of site specific in-stream debris and detention basins, access roads to support initial construction, vegetation removal, fill, and multi-purpose detention basin and floodwall construction activities for Manoa, Palolo, Makiki streams and the Ala Wai Canal. The preferred action will also evaluate a flood warning system for the entire Ala Wai watershed. Finally, operational and maintenance activities will be evaluated for debris and detention basins, multi-purpose detention basins, floodwalls and a flood warning system.

Construction of other structures, such as a single large dam or floodwater management pumping stations, has also been evaluated, but these are not anticipated to be feasible or effective. A large dam approximately 50-ft high and 350-ft long across Waihi and Waiakeakua Streams was considered. However, based on hydraulic modeling, it was determined that the most effective location of a dam of this size would be in the mid-watershed. Since this is a densely urban area, the large dam alternative was determined not to be feasible. Also, pumping during peak flows from the Ala Wai Canal or widening and deepening the canal or construction of another canal outlet have been considered, but determined not feasible or effective. Finally, other non-structural options were considered but determined insufficient to reduce overall flood risk. Therefore, these measures have been removed from further USACE consideration.

Service biologists have discussed the proposed project with staff of the National Marine Fisheries Service (NMFS) and the Hawaii Department of Land and Natural Resources, Division of Aquatic Resources (DAR). Concerns relative to the protection and conservation of important fish and wildlife resources in the Ala Wai Watershed expressed by DAR were incorporated into this FWCA report. Copies of this report are being provided to the NMFS, DAR, the Hawaii Office of State Planning, Coastal Zone Management Program (CZMP), the U.S. Environmental Protection Agency (EPA), and the Hawaii Department of Health Clean Water Branch (CWB).

Prior Fish and Wildlife Service Studies and Reports

In September 2015, the Service provided the USACE with a preliminary field data report concerning observations of federally listed damselflies within the footprint of the Ala Wai Watershed Flood Control Study. Service biologists were able to survey all proposed project footprints along Makiki Stream, Manoa Stream, and Palolo Stream. During these surveys, observations of stream habitat features, diadromous macrofauna and the insect order Odonata, which includes the federally listed species from the genus *Megalagrion*, were recorded. At

Waihi Stream, observations of the listed *Megalagrion nigrohamatum nigrolineatum* (Figs. 4 and 5) were documented throughout the survey area. This prior report presented data for the Service's qualitative survey of these federally listed damselflies within the project area.

In December 2015, the Service provided the USACE with a draft Coordination Act Report for the proposed Ala Wai Flood Risk Management Study. In this report, the Service evaluates the preferred action of specific in-stream debris and detention basins, access roads to support initial construction, vegetation removal, fill and multi-purpose detention basin and floodwall construction activities for Manoa, Palolo, Makiki streams and the Ala Wai Canal.

DESCRIPTION OF THE PROJECT AREA

The Ala Wai watershed is located on the leeward side of Oahu Island, Hawaii, on the southern slope of the extinct Koolau volcano between Punchbowl Crater and Diamond Head Crater (Figs. 1-3). The watershed is about 19 square miles (mi^2) (about, 12,064 acres), bounded to the north by the Koolau Mountains (with ridge crest elevations about 740 m or 2,400 feet), and by Mamala Bay, to the south. The Ala Wai watershed is comprised of three major drainages that include the Makiki drainage (1,687 acres), Manoa and Palolo drainage (6,247 acres) and storm water drainage from Kapahulu, Moiliili, Ala Moana and Waikiki areas (4,099 acres), all of which drain into the Ala Wai Canal. Makiki Stream, Manoa Stream and Palolo Stream are considered perennial streams, supporting surface flows in all or part of each stream throughout the year.

Makiki Stream

Makiki Stream is a relatively small stream originating near 655 meters (m) (1850 feet (ft)) on the southwestern flank of Mt. Tantalus in the Koolau Mountains, and flows southwestwards for approximately 5.6 kilometers (km) (3.5 miles (mi)) to its terminus in the Ala Wai canal (Fig. 3). The stream has three major branches, these being from west to east the Kanaha, Kanealole, and Moleka streams, the latter two of which join prior to their confluence with the Kanaha. The upper half of the Makiki catchment lies in steep, forested terrain on the slopes of Mt. Tantalus and Round Top, an area that receives up to 3,420 millimeters (~134 inches) of rain annually (Giambelluca, *et al.* 2013). The stream in this section flows in natural, unmodified channels, heavily shaded by a forest of introduced tree species, and is fed by two major springs, the Makiki Spring on the Kanealole branch, and the Herring Spring on the Moleka branch. At approximately 45 m (150 ft) elevation, just downstream from Makiki Street, the stream channel is artificially confined within a concrete box culvert, which runs under the streets and neighborhoods of Honolulu before re-emerging at sea level near the intersection of Philip Street and Kalakaua Avenue. From this point the stream runs in an open concrete channel for another 0.6 km (0.4 mi) to the Ala Wai Canal. There are no historic or active ditch diversions in the Makiki Stream catchment.

Makiki Stream has an active USGS gauge located at 21°17'48" N, 157°50'12" W, at an elevation of 3 m (10 ft), and has 69 years of record. Based on this time series, the stream at the gauge has a median discharge of 0.56 cubic feet per second (cfs).

Manoa Stream

Manoa Stream is a large stream in a bowl-like catchment, originating near 855 m (2,800 ft) on the southwestern flank of Konahuanui peak and adjacent ridgelines in the Koolau Mountains, and flows southwestwards for approximately 9.25 km (5.75 mi) to its terminus in the Ala Wai canal (Figure 3). The stream has two major branches, these being the Waihi on the west side of the basin, and the Waiakeakua on the east. The upper half of the Manoa catchment lies in steep, forested terrain on the slopes of the Koolau Mountains, in a very wet area that receives up to 3850 millimeters (~151 inches, or 12.6 ft) of rain annually at the headwaters of the Waihi branch, and 3550 millimeters (~140 inches, or 12 ft) annually at the headwaters of the Waiakeakua branch (Giambelluca, *et al.* 2013). The stream in its upper reaches flows in natural, unmodified channels for approximately 3.6 km (2.25 mi), being heavily shaded by a forest of introduced tree species, with some native vegetation on the upper slopes. Below Paradise Park, the stream passes through suburban neighborhoods in a partially modified channel for about 1.6 km (1.0 mi). At the Manoa District Park, near 50 m (160 ft) elevation the stream becomes confined within an artificial concrete channel, which continues downstream to the East Manoa Road bridge. Downstream from this bridge the stream flows in a re-aligned but partially natural channel, mostly following the base of the steep eastern wall of Manoa Valley. Downstream from Kanewai Park, at approximately 9 m (30 ft) elevation, the stream channel has been straightened, but not concrete-lined, and continues in this fashion for 2.25 km (1.4) miles, passing below the H-1 freeway and then continuing to its confluence with the Ala Wai Canal.

Both the Waihi and Waiakeakua branches of Manoa Stream also have active USGS stream gauges. The Waihi gauge is located at 21°19'42" N, 157°48'03" W, at an elevation of 88 m (290 ft), and has 69 years of record. Based on this time series, the stream at the gauge has a median discharge of 2.0 cfs. The Waiakeakua gauge is located at 21°19'41 N, 157°47'59" W, at an elevation of 89 m (294 ft), and has 97 years of record. Based on this time series, the stream at the gauge has a mean discharge of 3.6 cfs. The median of the combined flows of the two branches is therefore on the order of 5.6 cfs (approximately 10 times the discharge volume of Makiki Stream), which is reflective of the conditions prevailing during the current survey.

Palolo Stream

Palolo Stream is another large stream in a somewhat more tightly confined catchment than adjacent Manoa Stream, and originates near 810 m (2,665 ft.) on the southwestern flank of Mt. Olympus and adjacent ridgelines in the Koolau Mountains, and flows southwestwards for approximately 7.1 km (4.4 mi) before joining with Manoa Stream just upslope of the H-1 freeway (Figure 3). The stream has two major branches, these being the Pukele on the west side of the basin, and the Waiomao on the east. The upper third of the Palolo catchment lies in steep, forested terrain on the slopes of the Koolau Mountains, in a wet area that receives up to 3,050 millimeters (~120 inches, or 10 ft) of rain annually at the headwaters of the Pukele branch, and 2650 millimeters (~104 inches) annually at the headwaters of the Waiomao branch (Giambelluca *et al.* 2013). The stream headwaters in these upper reaches traverse unmodified channels for approximately 3.2 km. (2.0 mi.), being shaded by a forest of introduced tree species, with some native vegetation on the upper slopes. At approximately 160 m (530 ft) elevation both stream branches begin to traverse the suburban neighborhoods of Palolo Valley, with their channels becoming progressively more straightened and modified. Pukele Stream appears to be intermittent in its upper reaches, but receives significant spring inflow just upstream of the 10th Avenue bridge. Not far downstream of this bridge, at 75 m (250 ft) elevation, the stream becomes confined within a concrete channel, and retains this artificial character for the remaining 0.48 km (0.30 mi) of its length, until its confluence with Waiomao Stream at 68 m (225 ft) elevation. The Waiomao Stream exhibits higher volume in its headwaters, receiving perennial inflow from the outlet of a perched wetland in Kaau Crater. This branch also retains a more natural character to its channel until just before its confluence with the Pukele Stream, at which point it is confined within an artificial concrete channel, which then continues for the remaining 3.2 km (2.0 mi) length of the stream until its confluence with Manoa Stream just downslope of Kanewai Park.

The Pukele branch of Palolo Stream has an active USGS gauge located 21°18'24" N, 157°47'18" W, at an elevation of 105 m (345 ft), and has 65 years of record. Based on this time series, the stream at the gauge has a median discharge of 0.60 cfs. The Waiomao branch of Palolo Stream has an existing gauge structure located at 21°18'24" N, 157°46'50" W, at an elevation 120 m (400 ft), which formerly operated from 1911 to 2014; this gauge is no longer actively maintained. Based on historical records, it appears that the median discharge from the Waiomao branch is approximately 0.80 cfs, giving Palolo Stream below the confluence a combined median discharge volume of 1.40 cfs.

During the course of the current investigation continuous flow was present at all sites surveyed. Even so, a previous site visit to Pukele Stream in April 2015 had revealed the channel at this site to be dry, indicating that base flow in this reach becomes hyporheic at certain times of the year (generally the drier summer months), with water restricted to remnant pools forming at bedrock or saprolitic sills. The artificial channel at Woodlawn Ditch was consistently dry in both April 2014 and during the current sampling period. Following the definitions in Polhemus *et al.* (1992), Woodlawn Ditch is considered to be an intermittent, artificial ditch; the Pukele Stream sampling site is considered to represent a naturally interrupted stream midreach; and all other sampling sites surveyed are considered to represent continuously perennial stream midreach ecosystems possessing riffle and pool habitat.

Ala Wai Canal

The Ala Wai Canal is a man-made waterway, approximately 2 miles in length that was created for land reclamation purposes between 1920 and 1924. The depth of the canal ranges from about 3-8 m (10 to 25 ft) deep. The Ala Wai Harbor was originally constructed during the early 1900s by the United States military. The entire watershed drains through the Ala Wai Canal into Mamala Bay. Mamala Bay encompasses the ocean area offshore of southern Oahu from Diamond Head Crater to Barbers Point (Kalaeloa) Deep Draft Harbor. Complex coral reef communities have been described throughout Mamala Bay.

The State of Hawaii, Division of Aquatic Resources (DAR), in their Oahu volume of the *Atlas of Hawaiian Watersheds* series (Parham, *et al.* 2008) assigned the Ala Wai catchment an overall ranking of 8 on a scale of 1 to 10, with larger numbers equating to higher watershed quality based on land cover classes, size, wetness, reach diversity, and biological resources. This is a relatively high statewide ranking for a drainage system on Oahu, and is reflective of the relatively natural conditions prevailing in the upper catchment, despite the urbanization in the lower catchment. The DAR analysis did not break out metrics for the three individual streams within the Ala Wai catchment, because all flow into a single coterminous estuary.

FISH AND WILDLIFE RESOURCE CONCERNS AND PLANNING OBJECTIVES

The Service's primary concerns with the proposed project include potential impacts to endangered species and other fish and wildlife resources and their habitats from planned fill and debris removal activities in the stream and riparian habitat. Specific Service planning objectives are to maintain and enhance the existing significant habitat values at the proposed project site by (1) obtaining basic biological data for the proposed project site, (2) evaluating and analyzing the impacts of proposed-project alternatives on fish and wildlife resources and their habitats, (3) identifying the proposed-project alternative least damaging to fish and wildlife resources, and (4) recommending mitigation for unavoidable project-related habitat losses consistent with the FWCA and the Service's Mitigation Policy.

Under the authority of the ESA, the Department of the Interior and the Department of Commerce share responsibility for the conservation, protection, and recovery of federally listed endangered and threatened species. Authority to conduct consultations has been delegated by the Secretary of the Interior to the Director of the Service and by the Secretary of Commerce to the Assistant Administrator for Fisheries of the National Oceanic Atmospheric Administration (NOAA). Section 7(a)(2) of the ESA requires federal agencies, in consultation with and with the assistance of the Service or NMFS, to insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitats. The Biological Opinion is the document that states the opinion of the Service or NMFS as to whether the federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.

The Service's Mitigation Policy (Service, 1981) outlines internal guidance for evaluating project impacts affecting fish and wildlife resources. The Mitigation Policy complements the Service's participation under NEPA and the FWCA. The Service's Mitigation Policy was formulated with the intent of protecting and conserving the most important fish and wildlife resources while facilitating balanced development of this nation's natural resources. The policy focuses primarily on habitat values and identifies four resource categories and mitigation guidelines. The resource categories are the following:

a. Resource Category 1: Habitat to be impacted is of high value for the evaluation species and is unique and irreplaceable on a national basis or in the ecoregion section.

b. Resource Category 2: Habitat to be impacted is of high value for the evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion section.

c. Resource Category 3: Habitat to be impacted is of high to medium value for the evaluation species and is relatively abundant on a national basis.

d. Resource Category 4: Habitat to be impacted is of medium to low value for the evaluation species.

The riffle and pool habitat is extensive at the planned Waihi Stream Detention Basin and Waiakeakua Stream Detention Basin project sites, and represents the major habitat of concern. The institutional significance of U.S. riffle and pool habitat has been established through its designation as a Special Aquatic Site under the Clean Water Act (40 CFR Part 230 §230.44/FR v.45n.249) (CWA). Such areas possess special ecological characteristics in regard to biological diversity, productivity, habitat, wildlife protection, and easily disrupted biological integrity, and contribute to the general overall environmental health or vitality of an entire ecosystem within a region. Furthermore, the riffle and pool habitat at this site supports a population of the federally listed blackline damselfly (*Megalagrion nigrohamatum nigrolineatum*).

For the purpose of this report and analysis, the federally listed blackline damselfly (*Megalagrion nigrohamatum nigrolineatum*) at the proposed project site was selected as the primary evaluation species for this section of the FWCA analysis. This species is endemic to the island of Oahu, and formerly occurred in both the windward and leeward drainages of the Koolau and Waianae mountain ranges (Polhemus & Asquith 1996). The species was extirpated in the Waianae Mountains sometime after 1980 (Polhemus 2007), but continues to persist as a series of discontinuous populations in the Koolau Mountains. The map and associated data in Polhemus (2007) indicated 22 known populations of this species still extant, although the population at

Waihi Stream was not reflected on this map, because it was unknown at that time. Although *M. nigrohamatum nigrolineatum* is the most widespread endemic damselfly remaining on Oahu, the loss of all remaining populations in the western half of the island in the past 35 years clearly indicates that its global population status is still declining.

EVALUATION METHODOLOGY

Damselfly Assessment

An initial qualitative survey conducted by Service biologists on July 27 and 28, 2015 revealed the presence of *M. nigrohamatum nigrolineatum* along Waihi Stream. Based on these results, a subsequent quantitative damselfly assessment was conducted on October 9 and 15, 2015, at the Waihi Stream location where the USACE has indicated it is planning to construct a Debris and Detention Basin. This assessment was designed to describe the damselfly population along this stream reach, and to gauge potential project impacts from the primary project alternative and the no action alternative. The distribution and relative abundance of damselflies were recorded along a transect that began upstream of the project footprint, passed through the footprint, and continued downstream (Figs. 4-6). Global Positioning System (GPS) data were also collected to identify the location of each survey transect.

The initial survey work at Waihi Stream was conducted by Service biologists Dr. Dan Polhemus, Mr. Gordon Smith and Ms. Jiny Kim, accompanied by Service volunteer Mr. Hunter Polhemus. All damselfly survey work was conducted between 9:00am and 5:00pm, and curtailed during periods of heavy rain.

Based on the presence of *M. nigrohamatum nigrolineatum* in the area downstream of the proposed project footprint at sites adjacent to water features on the grounds of the now-defunct Paradise Park, a second quantitative survey was undertaken on October 15, 2015 to determine to what extent native damselflies were utilizing habitats in this area. This supplemental Waihi corridor survey work was conducted by Service biologists Dr. Dan Polhemus, Mr. Gordon Smith and Ms. Jiny Kim, accompanied by Service volunteer Mr. Hunter Polhemus between 9:00 AM and 12:00 noon. Because this survey was cut short by the onset of rainy weather, another supplemental survey was conducted at the same sites by service biologist Dr. Dan Polhemus and Service volunteer Mr. Hunter Polhemus on October 23, 2015, during sunny weather from 9:00 AM to 12:00 noon. For these three Waihi Stream surveys as a whole, Dr. Polhemus and Ms. Kim provided all photographs and collected the GPS waypoints that appear in this report.

The Waiakeakua branch of Manoa Stream was initially surveyed qualitatively by Service biologists Dr. Dan A. Polhemus and Mr. Gordon Smith on 27 July 2015. At the time, no definitive native damselfly sightings were recorded, but one fleeting observation indicated that such species might be potentially be present. Following the positive detections at nearby Waihi Stream, the Waiakeakua site was revisited on February 11, 2016 by a survey team consisting of

Dr. Dan Polhemus and Service volunteer Mr. Hunter Polhemus, accompanied by Ms. Becca Frager and Mr. Kevin Nishimura from the U. S. Army Corps of Engineers, and Mr. Glenn Higashi and an assistant from the State of Hawaii Division of Aquatic Resources. As with the Waihi survey described above, this assessment was designed to determine the presence or absence of *M. nigrohamatum nigrolineatum* at this site, describe and quantify any native damselfly population that might be present along this stream reach, and to gauge potential project impacts from the primary project alternative and the no action alternative. This second survey revealed that *M. nigrohamatum nigrolineatum* was in fact present within the proposed project area on Waiakeakua Stream. For surveys on this tributary, Dr. Polhemus and Mr. Higashi provided all photographs and GPS waypoints that appear in this report.

Methodology

During each of the surveys outlined above, a team of 2-4 experienced observers moved downstream at a slow pace, beginning at a point on the stream reach above the proposed project foot print and continuing downstream through the footprint itself, and then along the stream reach below the footprint. For the first survey, the point of entry for the initial quantitative survey along Waihi Stream was at the point where that stream crosses the Manoa Falls trail. The point of exit was at the Waaloa Way bridge (Figs. 4-6). The total distance covered was approximately 0.5 mile. Any small tributaries entering the main stream channel were also reconnoitered for the presence or absence of damselflies. For the second set of quantitative surveys the points of entry and exit were adjacent to the Treetops restaurant building, with access to water features obtained by walking along disused roads and walkways, with the total distance spanned adjacent to the stream being approximately 0.10 mile. At Waiakeakua stream, the survey proceeded from the USGS gauging station at the second bridge on Waakaua Street to the first stream fork, then up the right fork to the point where it passes under the third bridge on Waakaua Street, and up the left fork to the site of an abandoned residence. The total distance covered from the gauging station to the forks was approximately 0.10 mile, the distance traversed up the right fork above the confluence was also approximately 0.10 mile, and the distance traversed up the left fork above the confluence was approximately 0.15 mile, for a total of 0.35 mile of total stream corridors sampled at this site.

The observers continuously scanned for adult damselflies as they moved down the stream channel. When a damselfly was spotted, the team halted, and one observer kept the initially sighted damselfly in view. The other 3 observers scanned in all other directions for 2 minutes, to determine if other damselflies were also present in the area. If observations of additional individuals were made, these were called out verbally, and the newly sighted individuals also continuously tracked, in order to prevent double counting. At the end of 2 minutes the team huddled, discussed their mutual observations, and attained consensus as to the total number of individuals sighted. These data were then recorded, noting also any tandem pairs or oviposition behavior observed. The team then continued moving downstream until the next adult damselfly was spotted, at which point the above procedure was repeated. The above process was carried out down the entire length of Waihi Stream and along the reaches of Waiakeakua Stream described above. In total, sightings were made at 10 individual points along Waihi Stream, and at 5 individual points along Waiakeakua Stream; these observations were recorded by GPS and illustrated (Figs. 4-6). A preliminary estimate of population size and density was developed using transect data collected on two separate dates from the Waihi Stream area, and on one date from the Waiakeakua Stream area. All analyses were conducted in the R statistical environment (Team 2013) using the R package 'unmarked' (Fiske et al. 2015).

To derive this estimate it was assumed that observers were able to collect information on the species and status of the organism approximately 25 meters from an observation point along the Waihi stream transect. Counts were summarized for both survey days, and all points were assessed for possible direct (area modification) or indirect (downstream of modified area) impact. Of the 31 presence point localities collected on 10/9/2015, and 20 collected on 10/15/2015, between 56 and 75% of the damselfly presence localities were located in, or downstream of, the area to be modified.

To estimate population size and abundance in unmarked populations, the methodology of Chandler et al. (2011) was used. This likelihood estimate has been shown to effectively estimate population size, density, and survey detection probability, and is especially powerful at accounting for the spatial dynamics of motile organisms. For this assessment two models that assumed either a Negative Binomial distribution, or a Poisson distribution, were compiled to form an ensemble estimate using a weighted mean approach.

The Likelihood estimate from Chandler et al (2011) is briefly described below:

$$L(\lambda, \Phi, p | y_{it}) = \prod_{i=1}^{R} \left\{ \sum_{M_i = \max(y_{it})}^{\infty} \left(\prod_{T=1}^{T} \frac{M_i}{y_{i1}!\, y_{i2}!\, y_{i3}!\, y_{it0}!} \times (\Phi\pi_1)^{y_{it1}} (\Phi\pi_2)^{y_{it2}} (\Phi\pi_3)^{y_{it3}} (\Phi\pi_0)^{M_i - y_{it}} \right) f(M_i | \lambda) \right\}$$

Eq. 3 from Chandler et al (2011)

- M_i is the superpopulation size, or the assumed maximum number of individuals that could possibly be collected at plot i for occasion to t over all occasions (T) and plots (R).
- y_{it} is a vector of counts made at plot i on occasion t that are conditional on the subset of the superpopulation present N_{it} at that plot and occasion
- π_{it} represents a vector of multinomial cell probabilities computed from detection probabilities (p)
- λ is the discrete mean of the Poisson of negative binomial probability distribution as a function of M_i.
- Φ is the probability that a member of the superpopulation is present within the survey plot.

Fish Biomass Assessment

A complementary assessment of fish and wildlife resources was conducted by the Bishop Museum and State of Hawaii Division of Aquatic Resources in October, 2014 to help determine fish species composition and biomass within the affected Makiki, Palolo and Manoa Streams. Fish and other stream animal surveys were accomplished using two methods. The first method involved visual surveys completed in tandem with High Definition Fish Survey (HDFS) and High Definition Stream Surveys (HDSS) (see below). The visual surveys were further confirmed with net samples conducted by DAR biologists and technicians. While the visual surveys were widespread and covered all the habitat areas, these surveys likely missed some small or cryptic animals.

The second and more extensive fish and aquatic animal survey involved the use of the HDFS approach. The HDFS method utilized pole-mounted, high- definition, underwater video cameras to capture images of fish or other aquatic animals at a specific location. The underwater cameras were also geo-referenced so that specific time and place information was recorded for all video observations. By logging GPS data with underwater video, the HDFS results can easily be integrated with the HDSS habitat information gathered at the same location.

An estimate fish biomass for the more common and native species was prepared in September 23, 2016 by Dr. James Parham, Bishop Museum and submitted to the Service (Appendix C). The original and new survey videos were analyzed and the results presented to estimate an aggregate species' biomass within the Ala Wai Watershed Streams.

Methodology

To develop biomass estimates for fishes in Manoa, Palolo and Makiki Streams, a series of steps were completed.

1. The underwater video was watched, each sample site was given a unique Site ID and the sites date, time, GPS location, video file, and stream name were recorded.
2. From the underwater video footage, an estimate of the viewing area (m^2) was determined. This was used in the estimate of fish biomass (g/ m^2). Area was estimated by determining the forward visibility, the distance traveled if the camera moved, and the proportion of the site obscured.
3. The underwater video footage was watched and scored for the species type, their size, and number present at each sample location. With any timed observation of live animals (visual or video), it is possible that the same fish may swim in and out of the viewing area. As a result, the maximum number of fish (Max N) in the screen during the sample viewing time

is used to control for this possibility. Once the video frame with the maximum number of an individual species was determined, the individuals were then counted within predetermined size classes. The result of this step was a size class count for each species within each underwater video sample site.

- For this analysis of fish biomass, the native goby, o'opu nakea (*Awaous stamineus*), and the introduced fishes, longfin armored catfish (*Hypostomus watwata*), bristlenose catfish (*Ancistrus temmincki*), and convict cichlid (*Archocentrus nigrofasciatus*) were selected by USFWS and DAR. The native goby, o'opu nakea, is the most widespread native stream fish in the Ala Wai Watershed streams and the two catfish species occupy similar habitat to the native gobies. Convict cichlid are representative of a non-demersal species.

4. The biomass for each fish within a size class was determined from length/weight measurements collected from specimens in Oahu streams provided by DAR. The standard length/weight relationship, Weight = a $(\text{Length})^{b}$. was fit to the data using Table Curve 2D v 5.01 (Systat Software Inc., 2002) to find the species specific coefficient values for a and b. The median length of the observed species within each size class was used to estimate the weight of the species observed by applying the length/weight relationship. This step provided the total weight of a species within each sample site.

5. The results of the biomass estimate at individual sample sites was averaged within stream and stream reach areas. The streams (Manoa, Palolo, and Makiki) and reaches (lower, middle, and upper) provided a way to generalize the results into more appropriate areas associated with the flood mitigation actions.

DESCRIPTION OF FISH AND WILDLIFE RESOURCES

In contrast to diadromous macrofauna, Odonata and other Hawaiian stream insects are strictly associated with freshwaters, and do not make periodic transits to the ocean, although they can disperse along the stream corridor by flight. As such, the occurrences of individual species can be more localized, and there are a number of endemic species restricted to individual islands. Within the Odonata, the group of greatest concern to the Service is a set of native damselflies in the endemic Hawaiian genus *Megalagrion*, five of which have now been listed under the Endangered Species Act. Three of these listed species – *Megalagrion leptodemas*, *Megalagrion oceanicum*, and *Megalagrion nigrohamatum nigrolineatum* – are endemic to Oahu, and all of these taxa, as well as several other non-ESA-listed species in the genus, had been previously recorded from the Ala Wai watershed (Appendix A1-A10).

Given previous records of ESA-listed Odonata in the Ala Wai watershed, it was necessary to ascertain that these species did not occupy the stream reaches that will be impacted by the proposed project. In other cases, native damselflies have been found on Oahu at unexpectedly low elevations and in relatively developed settings, the salient example being a remnant population of *Megalagrion xanthomelas* on a tributary to Moanalua Stream at Tripler Army Medical Center (Polhemus 1996). Therefore, the Service's biological survey team made a visual census for *Megalagrion* and other Odonata species at all proposed project sites. Service biologists evaluated these project sites and found evidence of *M. nigrohamatum nigrolineatum* at the Waihi and Waiakeakua Project Construction Sites, but found no evidence of damselflies within any of the other proposed project sites.

Waihi Stream at Paradise Park – Debris and Detention Basin

Habitat throughout the reach surveyed consisted of rocky riffles and shallow pools, with small tributaries entering from along the banks and forming small, shallow, standing pools lateral to the main stream channel. The channel at the upper end of the reach surveyed was open and unshaded, abruptly transitioning downstream to heavy shading from large figs and other introduced trees. Such heavy shading continued the rest of the way to the Waaloa Way Bridge.

Megalagrion nigrohamatum nigrolineatum was found throughout the shaded section of the channel, particularly in the lateral pools formed by small tributaries, with both mating pairs and ovipositing females observed. On October 9, 2015, approximately 31 damselflies were observed in the area of the stream where planned construction activities may occur. On October 15, approximately 20 damselflies were observed outside of the planned construction site, but in areas that may be vulnerable to indirect effects related to project construction, personnel and vehicles. On October 23, 2015 approximately 10 damselflies were again observed adjacent to water features in the former Paradise Park, in areas lying outside of the planned construction site, but that may be vulnerable to indirect effects related to project construction, personnel and vehicles. These damselflies were not observed near any of the deep ponds in the area, which harbored introduced fishes, but were instead found in the vicinity of shallow, laminar flows formed by pond overflows, and lying parallel to or crossing disused asphalt roads. These small overflows also created muddy areas with small isolated pools, around which adult damselflies were also observed.

Waiakeakua Stream above USGS gauge at Waakaua Street bridge – Debris and Detention Basin

The habitat throughout this reach consists entirely of riffle and shallow pool habitat, heavily shaded downstream by a thick overstory of hau (*Hibiscus tiliaceus*) and upstream by various tall, introduced trees. The stream banks are steep in many sections, and have a heavy growth of bamboo. The USGS gauge at the lower terminus of the reach surveyed has a vertical, overhanging drop at the exit to the Parshall flume that represents a barrier to faunal passage of diadromous biota in this system. Weather at the time of the survey as partly cloudy, transitioning to fully sunny as the day progressed.

Megalagrion nigrohamatum nigrolineatum was sporadically encountered along the stream reaches surveyed. Individuals were particularly concentrated at three spots:

1) The riffle at the first right hand bend upstream of the bridge and gauging site, beyond the hau patch that overtops the stream just above the bridge.

2) At the confluence of the two stream forks, on both branches, for approximately 50 feet upstream of the confluence on the right hand fork and 100 feet above the confluence on the left hand fork.

3) At the upper limit of the survey on the left fork, where the stream begins to become confined between bedrock walls.

On February 11, 2016, a total of 2 male damselflies were observed in the area of the stream where planned construction activities for the Waiakeakua detention basin may occur, and an additional 9 damselflies were observed outside of the planned construction site, but in areas that may be vulnerable to indirect effects related to project construction, personnel and vehicles. A subsequent change in scope regarding the size of this detention basin has resulted in these latter sightings points now also falling within the project footprint.

Makiki Debris and Detention Basin

Makiki Stream – midreach above Board of Water Supply pump station, 60 m. (200 ft.), 21°19'02'N, 157°48'06"W, water temperature 26 °C, 27 July 2015. Macrofauna observed: *Macrobrachium lar.* Odonata observed: *Ischnura posita* (I).

Habitat throughout the reach surveyed consisted of riffles and small pools, with the stream entering a concrete channel below. The stream channel was heavily shaded by tall, introduced trees, and contained a significant amount of debris, particularly discarded automobile tires. The water was clear, probably originating from the Herring Spring further up Makiki Valley. Weather was sunny at the time of the survey.

Woodlawn Ditch and Detention Basin

Manoa Stream – Woodlawn Ditch below East Manoa Road, 71 m. (235 ft.), 21°18'58'N, 157°48'07"W, 27 July 2015. Macrofauna observed: None. Odonata observed: None.

The Woodlawn Ditch at this location consists of an entirely dry, heavily shaded channel with steep banks and a bed of rocks and gravel. No aquatic biota was present. Weather was sunny at the time of the survey.

Manoa Stream – midreach at Woodlawn Street bridge, 44 m. (145 ft.), 21°18'29'N, 157°48'33"W, water temperature 27 °C, 27 July 2015. Macrofauna observed: Armored catfish. Odonata observed: None.

Habitat in this reach consisted entirely of riffles, with no deep pools. The channel was ~50% shaded upstream of the bridge, and ~90% shaded below the bridge. The stream banks were covered with grasses and yellow-flowering *Wedelia trilobata*. Weather was sunny at the time of the survey.

Manoa Park Instream Debris Catchment

Manoa Stream – midreach at Kahaloa Street Bridge, Manoa District Park, 50 m. (165 ft.), 21°18'49'N, 157°48'23"W, water temperature 25 °C, 27 July 2015. Macrofauna observed: Armored catfish, Poeciliidae. Odonata observed: *Pantala flavescens* (native).

Habitat in this reach consisted entirely of riffles below the Kahaloa Street bridge, and a long, deep pool upstream of the bridge. The channel was mostly unshaded throughout the reach surveyed. The stream banks were covered with grasses, and the stream entered a concrete channel at the downstream terminus of the reach surveyed. Weather was sunny at the time of the survey.

Kanewai Field Multi-Purpose Detention Basin

This site is land-side managed vegetation. No Fish and Wildlife Resources exist at this location.

Waiomao Debris and Detention Basin

Palolo Stream – Waiomao Stream upstream of Lamaku Place to former USGS gauging station, 114 m. (375 ft.), 21°18'22'N, 157°47'02"W, water temperature 25.5 °C, 28 July 2015. Macrofauna observed: Armored catfish, Poeciliidae, *Awaous.* Odonata observed: None.

This stream was surveyed from the end of Lamaku Place upstream to the former USGS gauging station. The habitat along the reach surveyed consisted of riffles and pools, with the waters of the stream tea-colored due the the presence of tannins from its headwater wetland in the Kaau Crater. The stream bed contained numerous exposures of bedrock, which often formed small cascades. The stream channel was heavily shaded by introduced trees. Weather was sunny at the time of the survey.

Pukele Debris and Detention Basin

Palolo Stream – Pukele Stream at Ipulei Place, 128 m. (420 ft.), 21°18'34'N, 157°47'11"W, water temperature 24 °C, 28 July 2015. Macrofauna observed: None. Odonata observed: None.

Habitat throughout the reach surveyed consisted of riffles and deep pools with very clear water, moderately shaded by tall introduced trees. The stream banks were steep, and covered with grasses, bare dirt, or in some sections rock revetment. No water was observed at this site during a previous visit on 14 April 2015. Although flow was present at the time of the current surveys, no aquatic biota was observed, indicating that this reach may be intermittent. Weather was sunny at the time of the survey.

Hausten Ditch Detention Basin

This site is land-side managed vegetation. No Fish and Wildlife Resources exist at this location.

Ala Wai Golf Course Detention Basin.

This site is land-side managed vegetation. No Fish and Wildlife Resources exist at this location.

Fish Biomass Results for Manoa, Palolo and Makiki Streams

A total of 745 sites throughout Manoa, Palolo and Makiki streams were surveyed using the HDFS methodology (Table 1). The area in upper Manoa Stream containing 230 sites was the most recently survey by DAR. A total of 310 sites was surveyed in the upper end of the streams and are the most useful comparison for the upper detention basins proposed in the flood mitigation plan.

Table 1: Location of survey sites

Stream	Reach Code	Sample Sites
Palolo	Lower	45
Makiki	Lower	94
Manoa	Middle	63
Palolo	Middle	133
Manoa	Upper	230
Palolo	Upper	103
Makiki	Upper	77
Total		745

Species Observations:

All 745 survey sites were reviewed for the presence of native gobies or the three introduced species. O'opu nakea and o'opu naniha were the most common native gobies (Table 2). Only one o'opu nopili (*Sicyopterus stimpsoni*) and three o'opu akupa (*Eleotris sandwicensis*) were observed in all of the samples. Nearly 300 each of the longfin armored catfish, bristlenose catfish, and convict cichlid were observed throughout the streams. The bristlenose catfish was the most common species counted in the upper stream reaches, although liberty mollies and guppies were likely observed in greater numbers.

Table 2: Size distribution of selected fishes in Ala Wai Watershed streams.

O'opu nakea

Category	Length Range (in)	Number Observed
small	< 3	6
medium	3 to 5	10
large	> 5	5
Total		21

O'opu naniha

Category	Length Range (in)	Number Observed
small	< 3	0
medium	3 to 5	5
large	> 5	13
Total		18

Longfin Armored Catfish

Category	Length Range (in)	Number Observed
small	< 2.5	11
medium	2.5 to 4	81
large	4 to 6	138
ex. Large	> 6	57
Total		287

Bristlenose catfish

Category	Length Range (in)	Number Observed
small	< 2	41
medium	2 to 3.5	133
large	> 3.5	120
Total		294

Convict Cichlid

Category	Length Range (in)	Number Observed
small	> 2	70
medium	2 to 4	162
large	> 4	62
Total		294

Biomass estimates for the various species varied both among streams and among reaches (Table 3). This is partially due to the sampling locations, because habitat availability was not consistent among locations, and also partially due to the presence of other species. In Manoa stream, for example, smallmouth bass were common throughout the deeper areas of the middle reach and tilapia were very common in the lower reaches.

Several patterns were apparent. First, native fishes are not common in the Ala Wai Watershed streams. It is likely that habitat modification and the introduction of numerous other species has decreased their abundance.

Second, O'opu nakea can be found throughout the streams with at slightly higher abundances in the middle and upper reaches.

Third, longfin armored catfish were very common in the lower and middle reaches of the streams and sometimes found in extremely high density. This species could be found in very shallow, swift water and in deeper, slower pools. Longfin armored catfish do not appear to occur in the upper reaches of the streams.

Fourth, Bristlenose catfish however are more common in the upper reaches of the streams although they exist throughout all stream reaches. Bristlenose catfish occupy similar habitat to the native gobies in the upper reaches of the streams and were observed co-occurring with o'opu nakea in a few locations.

Table 3: Biomass estimates for the various species for lower, middle and upper reaches of Palolo Stream, Makiki Stream and Manoa Stream.

				Observed weight (g)				Biomass (g/m2)			
Area code	Stream	Reach Code	Total Area Surveyed (m2)	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea
2	Palolo	Lower	42.4	977.6	63.5	399.9	8.9	23.0	1.5	9.4	0.2
3	Makiki	Lower	94.4	255.4	101.0	326.1	34.7	2.7	1.1	3.5	0.4
4	Manoa	Middle	112.6	4,333.6	127.0	419.2	0.0	38.5	1.1	3.7	0.0
5	Palolo	Middle	77.2	981.6	127.9	2,396.0	86.3	12.7	1.7	31.0	1.1
7	Manoa	Upper	97.6	0.0	463.1	0.0	0.0	0.0	4.7	0.0	0.0
8	Palolo	Upper	68.2	0.0	1,019.2	0.0	72.0	0.0	14.9	0.0	1.1
9	Makiki	Upper	111.6	0.0	315.4	0.0	71.2	0.0	2.8	0.0	0.6

Climate Change

Future impacts from climate change are likely to affect ecosystems in the Ala Wai watershed during the remainder of this century and beyond. In particular, more episodic, but severe rainfall events may lead to flash floods of higher amplitutde and intensity. Rising sea levels will also influence the Ala Wai Canal estuarine system, and will impact coastal infrastructure, resulting in flooding, increased coastal erosion, drinking water contamination, sewage overflow and increased decreased coastal water quality (PIRC 2012). Sea level rise may also result in increased development in upland areas as residents are compelled to move inland from low-lying coastal sites, a dynamic that would place added stress on natural resources in the midreaches and headwaters of the watershed.

DESCRIPTION OF ALTERNATIVES EVALUATED

In September, 2015, the USACE provided the Service with initial project design information. In September, 2016, the USACE provided the Service with supplemental project design information that expanded the scope of the planned project construction at most detention basin sites (Table 4). The project calls for the construction of dams crossing the Waihi tributary, the Waiakeakua tributary, Manoa Stream, Makiki Stream and Palolo Stream. Culverts would be constructed to allow natural base flow to pass beneath these structures and the bottoms of the streams would not be hardened at these sites. Detention Basins would be designed where debris would accumulate upstream of each dam/culvert. Permanent access roads would need to be constructed to support planned project construction and future maintenance. Also, temporary staging areas would be necessary to prepare support equipment (Figure 4). The detention basins would be designed to catch debris, and such debris would need to be removed after every big storm, or at minimum once a year by the City and County during regular maintenance cycles. City and County maintenance debris removal typically involves tracked vehicles, such as bulldozers or backhoes, entering streams and removing accumulated sediment and other debris.

Alternative 1: Detention Basin Construction

Table 4 represents the approximate areal extent of each the preferred project Alternative construction activities (Figures 8-17).

Table 4a. Waihi Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	58,870 Permanent
Dam/Culvert	35,200 Permanent
Staging Area	2,480 Temporary
Access Road	17,000 Permanent

Table 4b. Waiakeakua Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	139,740 Permanent
Dam/Culvert	41,620 Permanent
Staging Area	2,320 Temporary
Access Road	21,600 Permanent

Table 4c. Makiki Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	21,245 Permanent
Dam/Culvert	17,165 Permanent
Staging Area	2,500 Temporary
Access Road	14,400 Permanent
Storage Excavation	14,040 Permanent

Table 4d. Woodlawn Ditch Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	75,830 Permanent
Dam/Culvert	37,520 Permanent
Staging Area	2,500 Temporary
Access Road	11,000 Permanent

Table 4e. Manoa Park In-Stream Debris Catchment Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	0
Dam/Culvert	540 Permanent
Staging Area	2,500 Temporary
Access Road	0

Table 4f. Kanewai Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	212,810 Permanent
Dam/Culvert	39,425 Permanent
Staging Area	2,480 Temporary
Access Road	6,500 Permanent

Table 4g. Waiomao Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	44,950 Permanent
Dam/Culvert	19,890 Permanent
Staging Area	2,500 Temporary
Access Road	9,600 Permanent
Storage Excavation	12,465 Permanent

Table 4h. Pukele Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	34,660 Permanent
Dam/Culvert	16,660 Permanent
Staging Area	2,500 Temporary
Access Road	3,000 Permanent
Storage Excavation	15,620 Permanent

Table 4i. Hausten Ditch Debris and Detention Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	150,600 Permanent
Dam/Culvert	10,505 Permanent
Staging Area	5,950 Temporary
Access Road	0

Table 4j. Ala Wai Multi-Purpose Basin Planned Construction Limits

Construction Activity	Area (in square feet) / Impact Duration
Detention Basin (100 year Pool)	5,851,950 Permanent
Dam/Culvert	172,795 Permanent
Staging Area	25,727 Temporary
Access Road	0

Alternative 2: No Action

No action would be taken to modify stream located within the Ala Wai Watershed, resulting in no change to current habitats.

PROJECT IMPACTS

Riffle and pool habitat and riparian habitat contribute to supporting the extant population of federally listed damselflies. We would anticipate some permanent loss of habitat due to the construction of the dam and culvert in the stream (Table 5). We would also anticipate additional permanent loss of habitat due to maintenance removal of debris in the detention catchment area, due to the use of City and County of Honolulu heavy equipment, such as bulldozers, front end loaders, and backhoes. The use of heavy equipment to remove debris from the basin catchment area will result in the removal of not only debris, but also native vegetation and topsoil, and will destroy both the riffle and pool and adjacent riparian habitat. The project access road would also have further negative impact on native damselflies, due to alteration and permanent loss of riparian habitat. Finally, the staging area would have temporary impacts on native damselflies, but we would anticipate these impacts to be constrained to the duration of the construction period.

Table 5a. Waihi Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	111,070 Permanent
Stream and Riparian	2,480 Temporary

Table 5b. Waiakeakua Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	202,960 Permanent
Stream and Riparian	2,320 Temporary

Table 5c. Makiki Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	66,850 Permanent
Stream and Riparian	2,500 Temporary

Table 5d. Woodlawn Ditch Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	124,350 Permanent
Stream and Riparian	2,500 Temporary

Table 5e. Manoa Park In-Stream Debris Catchment Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	540 Permanent
Stream and Riparian	2,500 Temporary

Table 5f. Kanewai Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Managed Vegetation	258,735 Permanent
Managed Vegetation	2,480 Temporary

Table 5g. Waiomao Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	86,905 Permanent
Stream and Riparian	2,500 Temporary

Table 5h. Pukele Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Stream and Riparian	69,940 Permanent
Stream and Riparian	2,500 Temporary

Table 5i. Hausten Ditch Debris and Detention Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Managed Vegetation	161,105 Permanent
Managed Vegetation	5,950 Temporary

Table 5j. Ala Wai Multi-Purpose Basin Planned Construction Limits

Affected Habitat	Area (in square feet) / Impact Duration
Managed Vegetation	6,024,745 Permanent
Managed Vegetation	25,727 Temporary

Table 6. Total Combined Project Permanent and Temporary Impacts By Habitat Type

Habitat Type	*Area (in square feet) / Impact Duration*
Stream and Riparian	662,615 Permanent Loss
Stream and Riparian	17,300 Temporary Loss
Managed Vegetation	6,444,585 Permanent Loss
Managed Vegetation	34,157 Temporary Loss

In summary, the Service would anticipate that the permanent loss of about 662,615 square feet (15.21 acres) of stream and riparian habitat would result from planned project construction activities. A subset of this area, approximately 314,030 square feet (7.2 acres), would result in the permanent loss of damselfly habitat. We would also anticipate approximately 17,300 square feet (0.39 acres) of stream and riparian habitat would be temporarily lost due. Likewise, a subset of this area, approximately 4,800 square feet (0.11 acres), would result in the temporary loss of damselfly habitat.

For managed vegetation habitat, we would expect that about 6,444,585 square feet (147.94 acres) would be permanently lost and 34,157 square feet (0.78 acres) would be temporarily lost.

Based on the Service's survey data and using this likelihood estimate, the size of the *M. nigrohamatum nigrolineatum* population along the survey transect was estimated at approximately 64 individuals, as derived from the ensemble model using the repeated count data described above. A density estimate of 37 individuals per hectare (±SE = 20.89) was projected. Assuming that between 50 to 55% of the damselfly population in the area would be affected by the Waihi Debris and Detention Basin; this construction project may negatively impact approximately 28 to 31 adult damselflies at this specific time point. For Waiakeakua stream, approximately 58% of the population would be affected by the construction area, as such the construction would likely affect about 20 damselflies.

Information regarding the population size of nymphs (immatures) was not obtained, but impacts to this life stage would also occur, which could potentially double the total number of individuals affected. In addition, most of the individuals observed during this survey (90%) were males. Although the primary sex ratio for *M. nigrohamatum nigrolineatum* is not known, and some damselfly species are known to have skewed sex ratios, there is no current data to indicate that the primary sex ratio in this species deviates from 1:1. As such, females may be residing in more cryptic sites along the stream corridor prior to mating. This is a further indication that negative impacts are likely to affect up to 3 times more individuals than conservatively estimated above.

Given that for this assessment no information regarding demographic characteristics of the population was used, any future incorporation of life stage based counts (*i.e.*, nymph and adult), basic demographic information, and increasing the number of data collection dates to include seasonal variance will likely increase the accuracy of the population size/density assessment. Also, the methodology used here assumes some level of sensitivity variance due to emigration between localities (Chandler, Royle, and King 2011). It may be useful in future assessments to account for this sensitivity variance using a multi-observer/double observer sampling methodology (Royle and Dorazio 2006).

FISH AND WILDLIFE SERVICE RECOMMENDATIONS

Avoidance and Minimization

Based on observations from the Service survey, the federally listed damselfly *Megalagrion nigrohamatum nigrolineatum* was commonly observed in the upper portion of the project area in the Manoa Stream catchment. Furthermore, biologists observed several breeding sites within the project footprint. The Service is therefore concerned that up to 46 individuals and three breeding sites at Waihi Stream, and up to 20 individuals at Waiakeakua Stream may be negatively impacted by planned project construction-related dredging activities, and considers this to be a conservative estimate for reasons discussed above.

Therefore, to avoid planned project construction-related impacts to federally listed damselflies, the Service recommends that both the Waihi Stream Debris and Detention Basin and

Waiakeakua Stream Debris and Detention Basin be consolidated into one debris and detention basin that will be relocated downstream and south of the following position (Fig. 7):

Latitude = 1708314.06637
Longitude = 57831.148998
(Note: Coordinate system: NAD_1983_PA11_StatePlane_Hawaii_3_FIPS_5103_Feet).

Compensatory Mitigation

The Service supports removal of migration barriers at Falls 7 and 8 to facilitate migration of native gobies, *O'opu nakea* and *O'opu naniha* through the various reaches of Manoa stream and the ocean for the purposes of offsetting planned project impacts to affected fish resources. Please refer to the USACE's Mitigation, Monitoring and Adaptive Manage Plan and performance criteria (Appendix D). Calculations for habitat replacement were drawn from Dr. Jim Parham's report, "Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) Associated with the Streams in the Ala Wai Canal Flood Risk Management Study," July 12, 2016 (Appendix E). An addendum to the Adaptive Management Plan – Ala Wai Canal Project was prepared by the USACE-Honolulu District on July 14, 2016 (Appendix F). The HSHEP model was certified by the U.S. Army Corps of Engineers in May 28, 2015 (Appendix G).

In addition, the Service considers the aquatic resources and riparian habitat at Waihi Stream and Waiakeakua stream to be unique in that these areas provide specialized ecological functions that support the evaluation species, the federally listed *Megalagrion nigrohamatum nigrolineatum*, including breeding areas. At no other location within the project area have similar riffle/pool and riparian habitat conditions, such as those that support the evaluation species, been observed; this is primarily due to the close proximity of the other sites to human development. The Service considers the riffle/pool and riparian habitat at Waihi Stream and Waiakeakua Stream to meet the definition of Resource Category 2 (Habitat to be impacted is of high value for evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion section). The Service does not believe the HSHEP sufficiently considered the importance and unique riffle/pool and riparian ecological qualities of Waihi Stream and Waiakeakua Stream. Although we support the proposed mitigation for purposes of offsetting impacts to native fish, the USACE's proposed mitigation will not offset expected project impacts to Resource Category 2 riffle/pool and riparian habitat, also support federally listed damselflies. The Service recommends that unavoidable impacts at Waihi Stream and Waiakeakua stream should be mitigated in a manner that is consistent with national mitigation goals of "no net loss of in-kind habitat value for resource category 2", which also benefits evaluation species, such as the listed *Megalagrion nigrohamatum nigrolineatum*. We are willing to work with the USACE to develop appropriate mitigation that benefits the survival of this species.

Recommended Compensatory Mitigation:

The Service recommends that the USACE restore riffle/pool and riparian habitat to adequately offset planned project construction-related impacts at Waihi Stream and Waiakeakua Stream. We recommend a 3:1 ratio be used as a scale for compensatory mitigation to ensure adequate riffle/pool and riparian habitat is restored to offset anticipated losses. Based on information recently provided by the USACE, we expect that about 314,030 square feet (7.2 acres) of riffle/pool and riparian habitat will be permanently lost at Waihi and Waiakeakua streams. Therefore, we recommend that the USACE restore 942,090 square feet (21.6 acres) of degraded riffle/pool and riparian habitat to similar quality currently at Waihi Stream and Waiakeakua stream (Table 4). Also, we recommend the USACE restore 14,400 square feet (0.3 acres) of riffle/pool and riparian habitat be restored for a period equivalent to the time that of temporary construction-related loss.

Table 4. Compensatory Mitigation Ratio 3:1 Offset

Habitat Type	*Area (in square feet) / Impact Duration*	*3:1 Ratio (square feet)*
Stream and Riparian	314,030 Permanent Loss	942,090 in perpetuity
Stream and Riparian	4,800 Temporary Loss	14,400 equivalent to the duration of impact

We are willing to work with the USACE to develop a mitigation plan to ensure that restoration of riffle/pool and riparian habitat is successfully implemented. We recommend that a mitigation plan include Scientific Monitoring and this could be undertaken jointly by the Service and the State of Hawaii Department of Land and Natural Resources (DLRN). We also recommend that Performance Standards be designed in concert with the USACE, Service and State of Hawaii DLNR to ensure the quality and effectiveness of the recommended restoration is achieved.

Contaminated Sediments

At Manoa Stream, the U. S. Geological Survey has described a variety of contaminants found within stream sediments. Elevated levels of nutrients (*e.g.*, nitrates, phosphates), organochlorine insecticides (*e.g.*, dieldrin, chlordane, and DDT) and semivolatile organic compounds, herbicides, and polyaromatic hydrocarbons (PAHs) have all been detected in the stream sediments of the Manoa watershed (USGS, 2001). Stream sediments at the proposed catchment basins will be subject to repeated exposure and re-entrainment due to continuous debris maintenance removal conducted with heavy equipment by the City and County of Honolulu. Therefore, we recommend that planned construction and maintenance-related activities be conducted in accordance with State of Hawaii Department of Health regulations concerning contaminated stream sediments.

Post-construction Monitoring

The Service recommends that post-construction monitoring field work be conducted to evaluate anticipated impacts to federally listed damselflies and stream habitat. Some of these areas have already been identified and documented through the FWCA surveys. Post-construction surveys are important because they provide information on whether actual project-related impacts are greater or less than anticipated project-related impacts. If there are any appreciable differences, the compensatory mitigation can be recalculated so that it is appropriately scaled to the actual project-related impacts.

Post-construction surveys should be conducted immediately (*e.g*, ideally 1 week to 1 month) after final construction activities have ceased. Follow up monitoring surveys should be conducted at intervals of six months and one year from final construction to determine if any secondary or indirect impacts have occurred to resources adjacent to the project construction site.

The Service also recommends that performance standards for compensatory mitigation be developed in cooperation with other state and federal resource agencies. The effectiveness of the implemented compensatory mitigation should be evaluated, and including long-term monitoring, plans for adaptive management, and financial assurances should be obtained to ensure the compensatory mitigation projects for both the removal of Falls 7 and 8 and also for the restoration of riffle/pool and riparian habitat are implemented.

Best Management Practices

The following special conditions apply to all activities pertaining to project construction and maintenance activities for this project:

(1) The permittee should make every effort to develop and implement a plan spanning the length of this general permit which schedules conducting anticipated work at streams and storm-drains during the dry season, and anticipated work at beach areas during nonswell season. Work should be ceased and re-scheduled in the event of an out-of-season heavy rainfall or swell;

(2) Use of bulldozers to remove sediments may be allowed when the permittee provides documentation that the sediment is unvegetated, or otherwise void of vegetal root systems and that equipment-specific best management practices (BMPs) shall be in place to avoid more than *de minimis* discharges to waters of the United States;

(3) Avoid conducting maintenance activities that will lead to mid- and long-term destabilization and exposure of bare sediment/sand along stream banks, stream bed and beaches;

(4) Prior to starting any authorized activity, determine via surveys or available literature whether coral reef and/or seagrass beds are present near, or downstream of, areas where the activities will be conducted. Where coral reef or seagrass could be indirectly impacted by the authorized work, the permittee must minimize any potential impacts by limiting the extent of inwater work by conducting the work from land, limiting the footprint of the work/dredge area, and implementing appropriate BMPs;

(5) No debris, petroleum projects, or deleterious materials or wastes shall be allowed to fall, flow, leach, or otherwise enter any waters of the United States;

(6) All authorized activities shall be done in a manner so as to confine and isolate the construction activity and to control and minimize turbidity. Silt curtains or other appropriate and effective silt containment devices approved by the Corps shall be used to minimize turbidity and shall be properly maintained throughout the entire period of in-water work to prevent the discharge of any material to the downstream aquatic habitat. All sediment control devices installed as BMPs (i.e., fabric sandbags, silt curtains/screens, etc.) downstream or makai of the authorized work shall remain in place until the in-water work is completed and will be removed in their entirety and disposed of at an appropriate upland location once the water quality of the affected area has returned to its pre-construction condition;

(7) Return flow or runoff from upland dewatering site(s)/disposal site(s) shall be contained on land and shall not be allowed to discharge and/or re-enter any waters of the United States;

(8) No sidecasting or stockpiling of excavated materials in the aquatic environment is authorized. All excavated materials shall be placed above the high tide line (in coastal areas), above the ordinary high water mark at all other waters of the United States, or disposed of in an upland location. The permittee shall demonstrate that there is no reasonable expectation that disposal locations adjacent to high tide lines on the ocean, or in floodplains adjacent to other rivers or streams, would result in the material being eroded into the nearby waterbody by high tides and/or flood events;

(9) Warning signs shall be properly deployed and maintained until the portion of the in-water work is completed and the affected area water quality has returned to its preconstruction condition and turbidity control devices have been removed from the waterway;

(10) Fueling, repair, and other activities with any potential to release pollutants will occur in a location where there is no potential for spills to have an effect on waters of the United States;

(11) If a visible plume and/or floating petroleum products are observed outside of the containment area, the following measures shall be taken:

(a) All in-water work shall stop;

(b) The permittee or contractor shall inform the Corps immediately and the Corps will consult with appropriate agencies;

(c) The site shall be inspected by the permittee to ascertain the source of the plume;

(d) Control measures shall be refurbished, modified, and/or improved,
e.g., additional silt containment devices will be installed, as necessary to ensure the integrity of the containment area;

(e) Work shall not continue until after the plume or oil sheen is no longer visible.

(12) An individual, designated responsible for environmental monitoring, will be on-site during clearing operations. This individual will conduct visual inspections, perform water quality sampling and other environmental monitoring, as appropriate, and report all results to the Corps on a regular basis during clearing operations;

(13) When the Corps is notified that an authorized activity is detrimental to fish and wildlife resources, the Corps will issue a suspension order until all pertinent issues have been satisfactorily resolved. The permittee shall comply with any Corps-directed remedial measures deemed necessary to mitigate or eliminate the adverse effect;

(14) Unless terminated earlier, the expiration date of this general permit will be five years from the date of issuance. At that time, there will be a re-evaluation and review of the environmental effects of the activities authorized under the general permit. The re-evaluation will incorporate the views of federal, state, and local agencies and the public following issuance of a new public notice. This general permit may be reissued, revised, or revoked, as appropriate. Individual projects authorized under this permit, but not completed prior to the expiration date of the general permit, may proceed in accordance with the terms and conditions of this permit, regardless of the outcome of the re-evaluation and review.

The USACE shall designate an individual to oversee compliance of each BMP during clearing operations. This individual will complete a daily on-site inspection and report all results to the USACE on a regular basis during clearing operations.

SUMMARY AND FISH AND WILDLIFE SERVICE POSITION

Federally listed damselflies, and riffle and pool habitat, have been identified as the species of major concern and habitat of major concern respectively in regard to the proposed project. The blackline damselfly, *Megalagrion nigrohamatum nigrolineatum*, which is restricted to the island of Oahu, occurs at the Waihi Stream and Waiakeakua Stream Debris and Detention Basins, and was selected as the evaluation species for this study. The institutional significance of riffle and pool habitat, and federally listed species, have been established through their designation under the Clean Water Act [40 CFR Part 230 §230.44/FR v. 45n.249] and the Endangered Species Act [16 U.S.C. 1531 *et seq.;* 87 Stat. 884] respectively. To various degrees, the riffle and pool habitat within and adjacent to the planned construction sites at Waihi Stream and Waiakeakua Stream promotes specialized ecological functions important to *M. nigrohamatum nigrolineatum*, including species recruitment, foraging, and sheltering from predators. Based on recent field surveys at Waihi Stream and Waiakeakua Stream, the Service estimates that at least 66 blacklined damselflies would be negatively impacted as a consequence of project implementation. We recommend that the Debris and Detention Basins at Waihi Stream and Waiakeakua Stream be moved to a site lower in the Manoa Stream catchment to avoid project construction-related impacts to *M. nigrhamatum nigrolineatum* and habitat at Waihi Stream and Waiakeakua streams (Fig. 7). If moving the debris and detention basins at Waihi and Waiakeakua Streams is not feasible, then we recommend the Service, USACE and State of Hawaii Department of Land and Natural Resources work together to develop appropriate mitigation to offset unavoidable project impacts to Resource Category 2 riffle/pool habitat and riparian habitat.

To offset unavoidable project impacts to fish resources, we recommend the removal of migration barriers at Falls 7 and 8 to facilitate migration of native gobies, *O'opu nakea* and *O' opu nopili* through the various reaches of Manoa stream and the ocean.

To offset unavoidable impacts to Resource Category 2 riffle/pool and riparian habitat, we recommend that a mitigation plan be developed to restore degraded riffle/pool and riparian habitat in the amount of 942,090 square feet in perpetuity and 14,400 square feet equivalent to the temporary duration project construction impacts.

The Service further recommends that a risk assessment be conducted to evaluate the potential hazards that may arise from mobilization of contaminated stream sediments. We also recommend that post-construction monitoring be conducted to confirm anticipated project-related impacts did not exceed expectations. Finally, the USACE shall designate an individual to oversee compliance of each BMP during clearing operations on a daily basis and report all results to the USACE on a regular basis during clearing operations.

Any changes to the proposed project plan or to the recommendations in this report will also require additional coordination with the Pacific Islands Fish and Wildlife Office in Honolulu, Hawaii.

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FIGURES

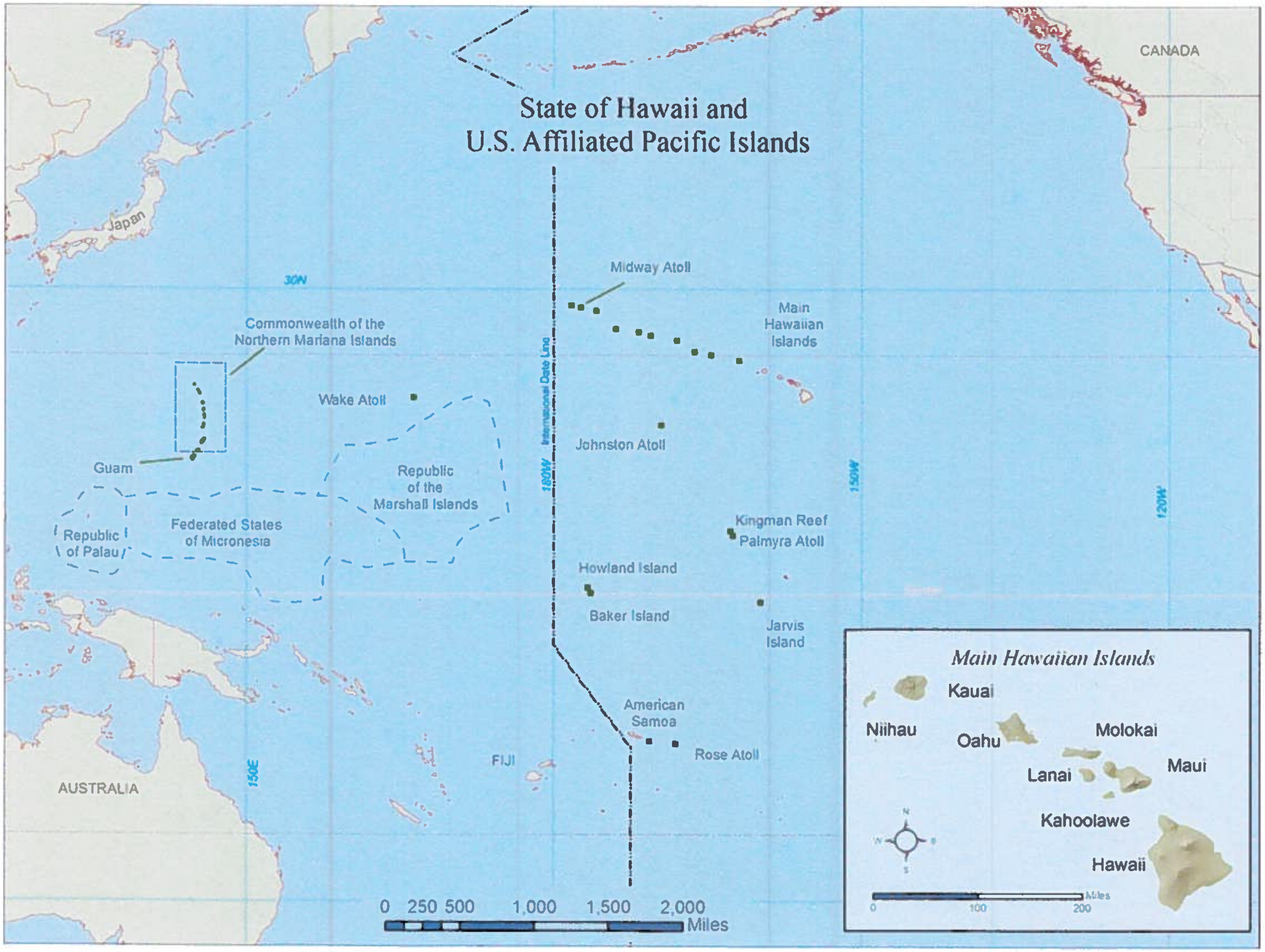


Figure 1. Map of the Pacific Ocean showing location of the Hawaiian Islands

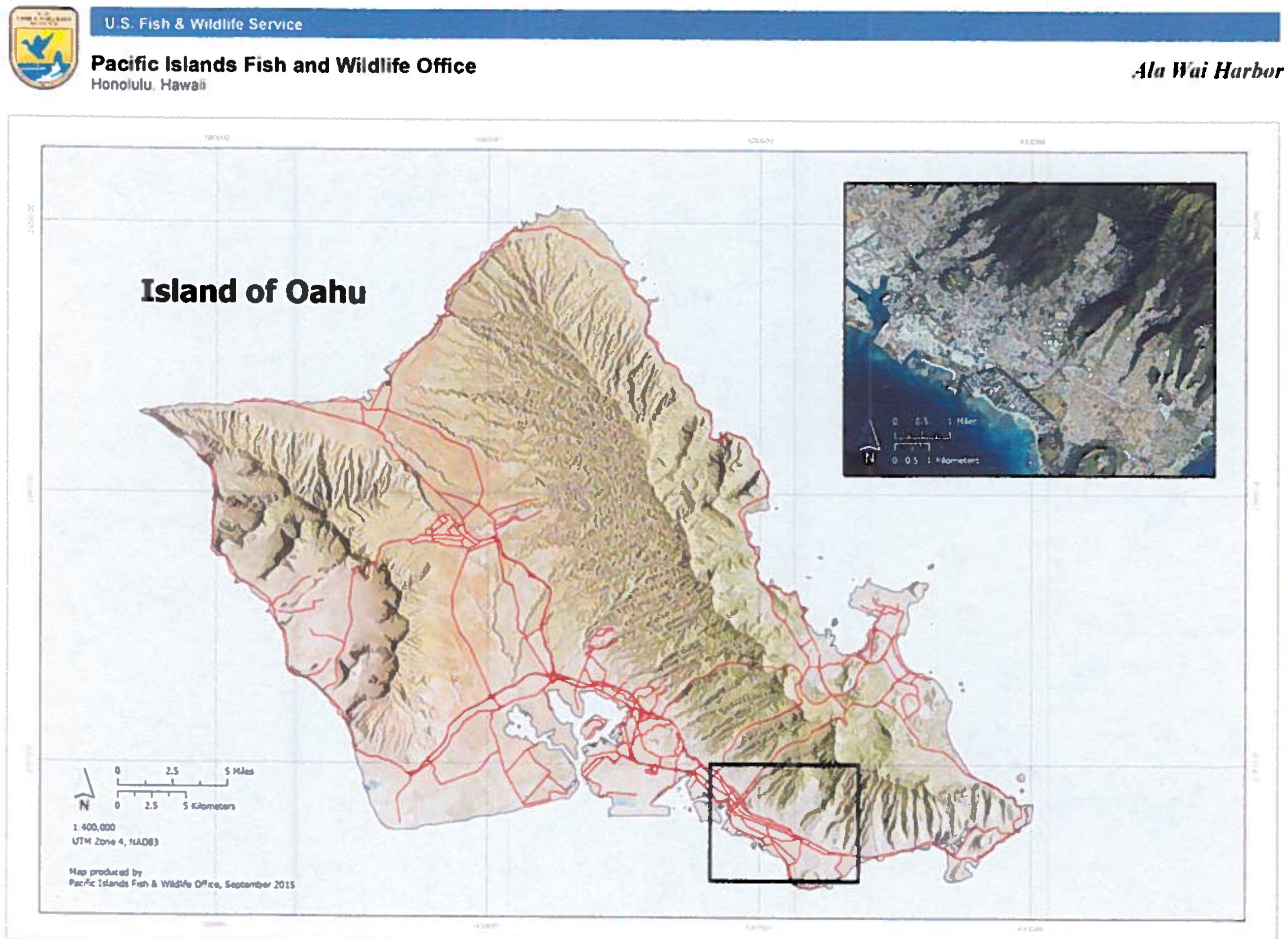


Figure 2. Map of Hawaii Island with Ala Wai Watershed inset.

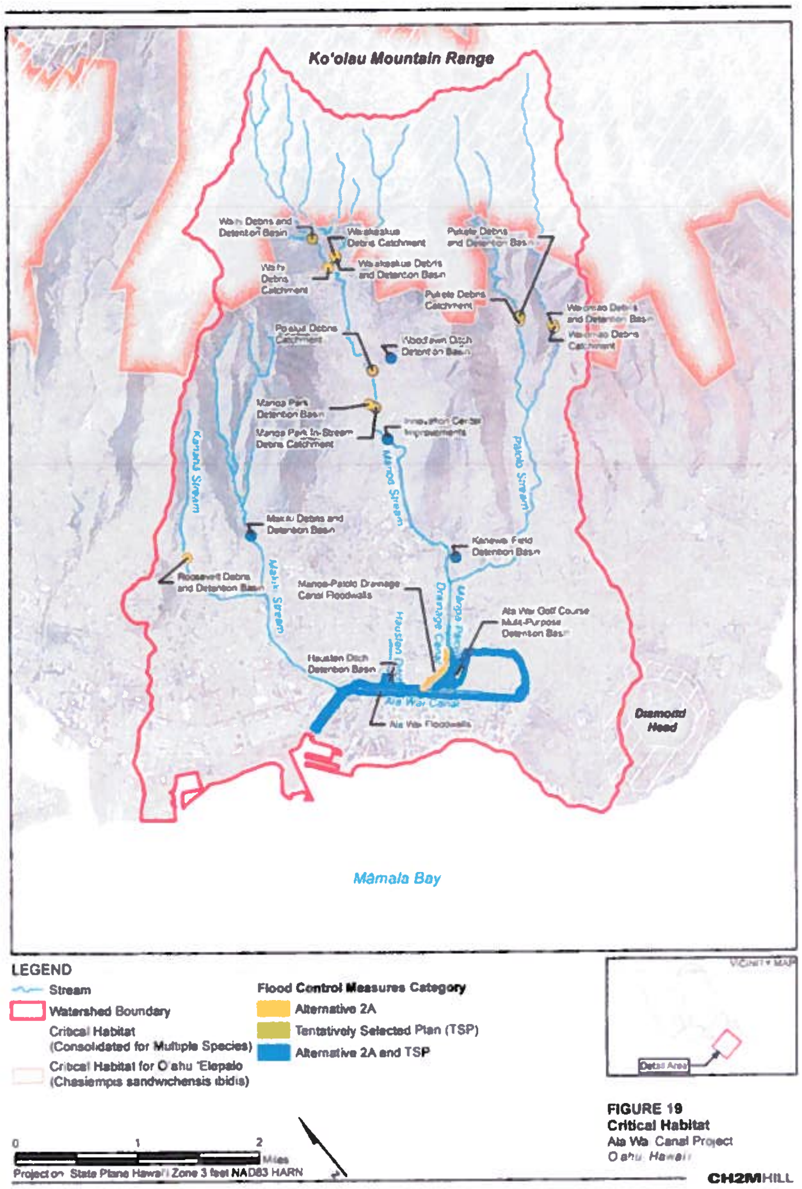


Figure 3. Map of Ala Wai Watershed Flood Control Project Area.

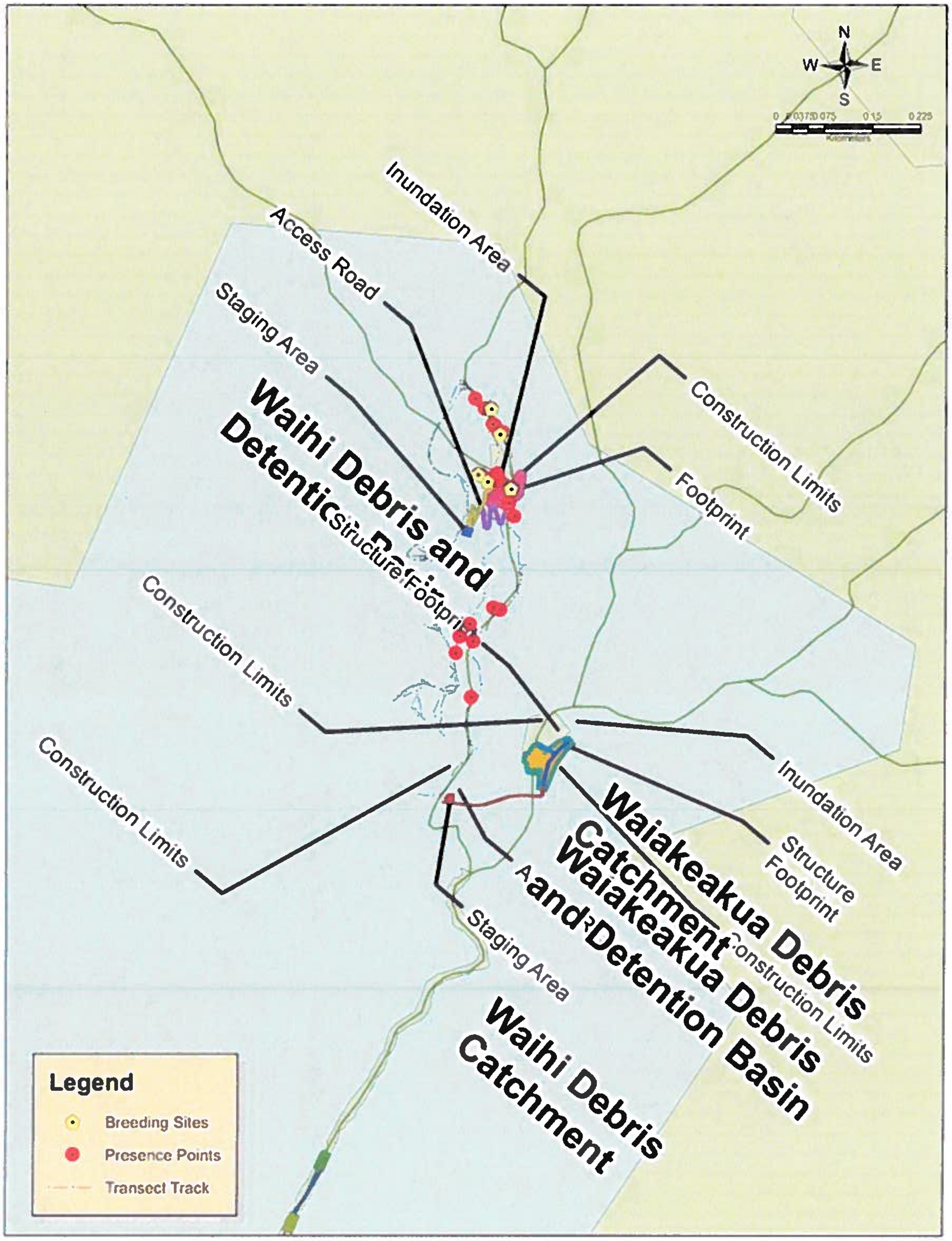


Figure 4. Map of Damselfly observations at Waihi Stream Debris and Detention Basin (DDB).

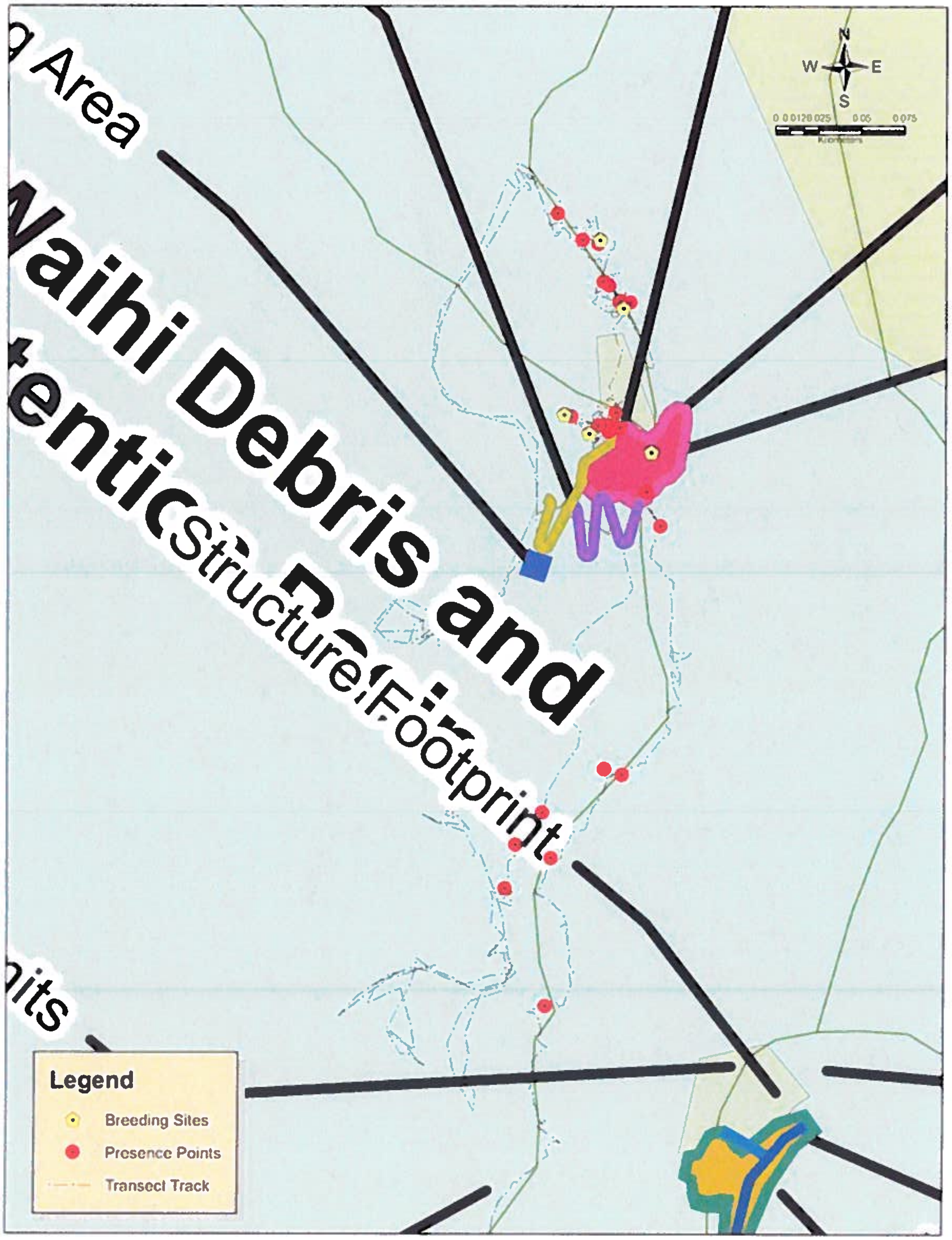


Figure 5. Closeup Map of Damselfly observations at Waihi Stream DDB.

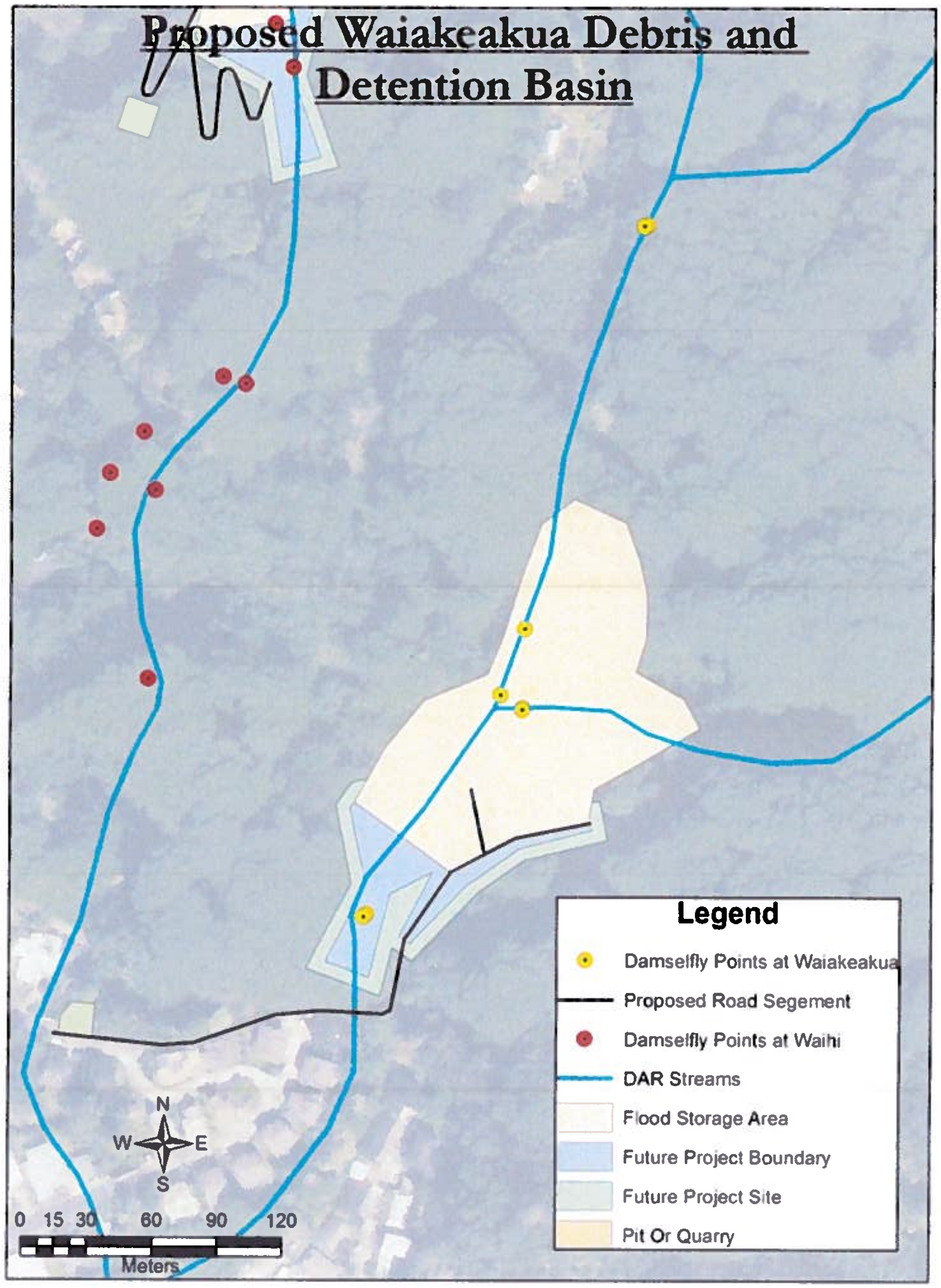


Figure 6. Map of Damselfly observations at Waiakeakua Stream DDB.

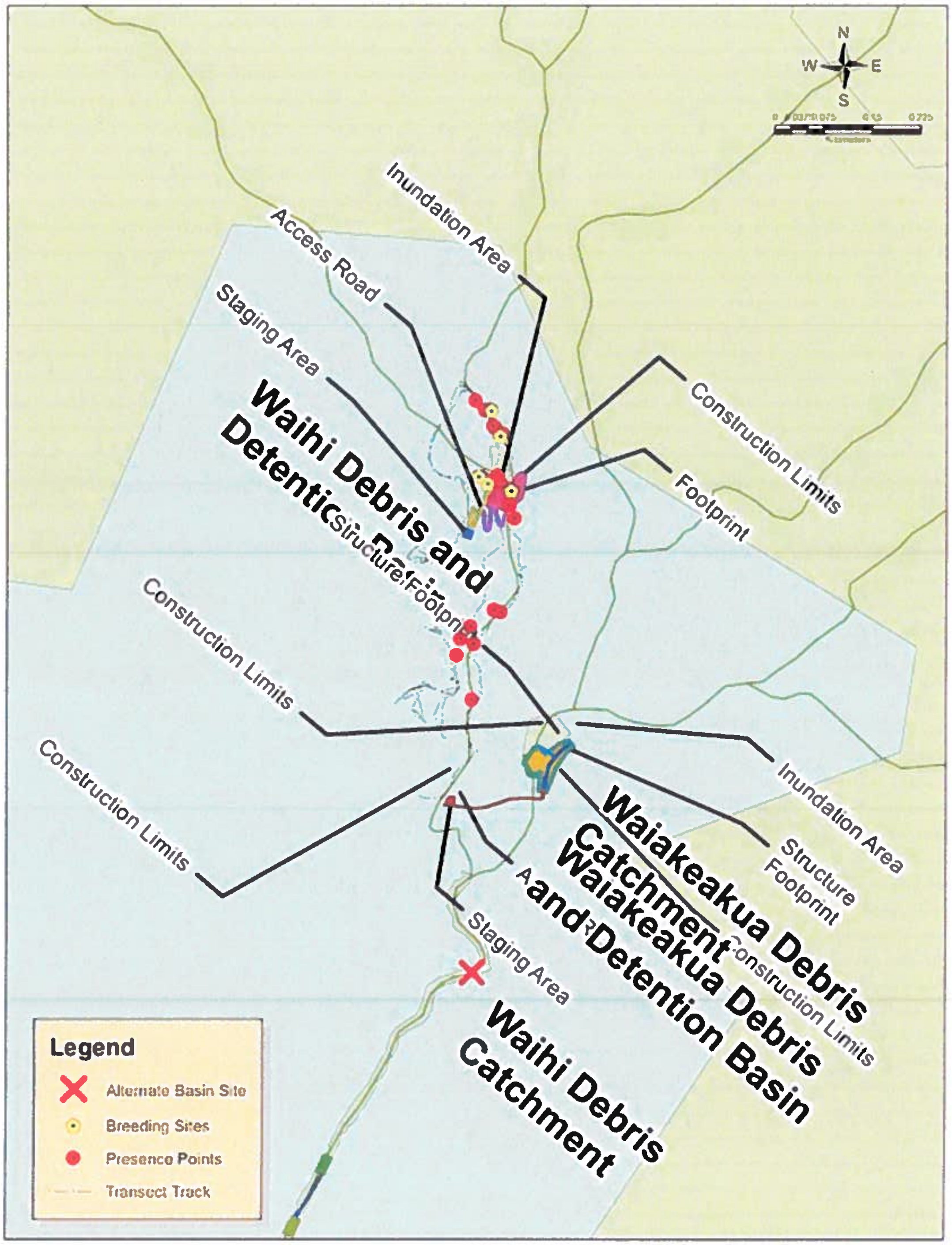


Figure 7. Alternative Basin Site (Debris and Detention): Red X = Latitude = 1708314.06637 and Longitude = 57831.148998
(Note: Coordinate system: NAD_1983_PA11_StatePlane_Hawaii_3_FIPS_5103_Feet)

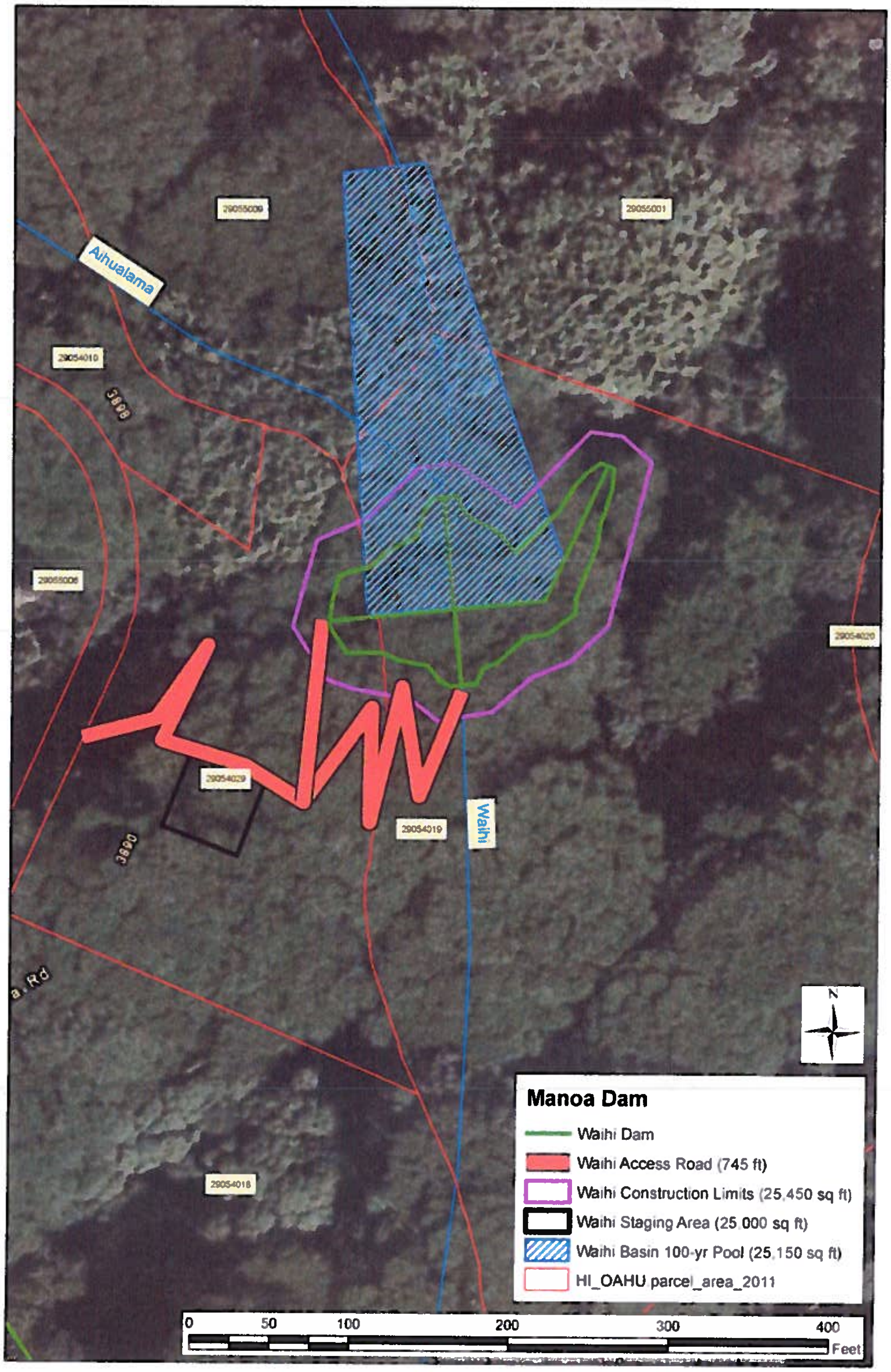


Figure 8. Map of Waihi Stream Debris and Detention Basin, Manoa Stream.

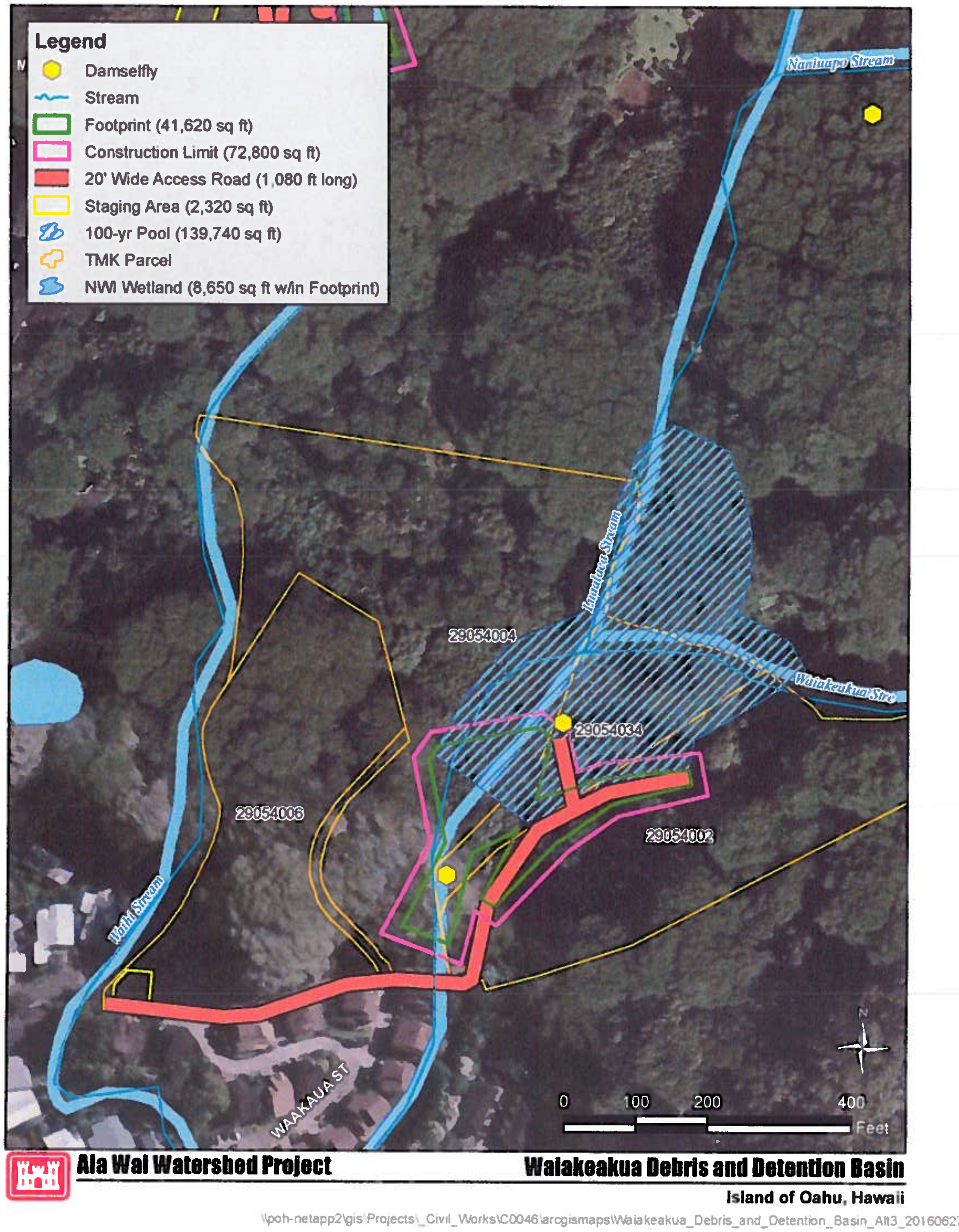


Figure 9. Map of Waiakeakua Stream Debris and Detention Basin, Manoa Stream.

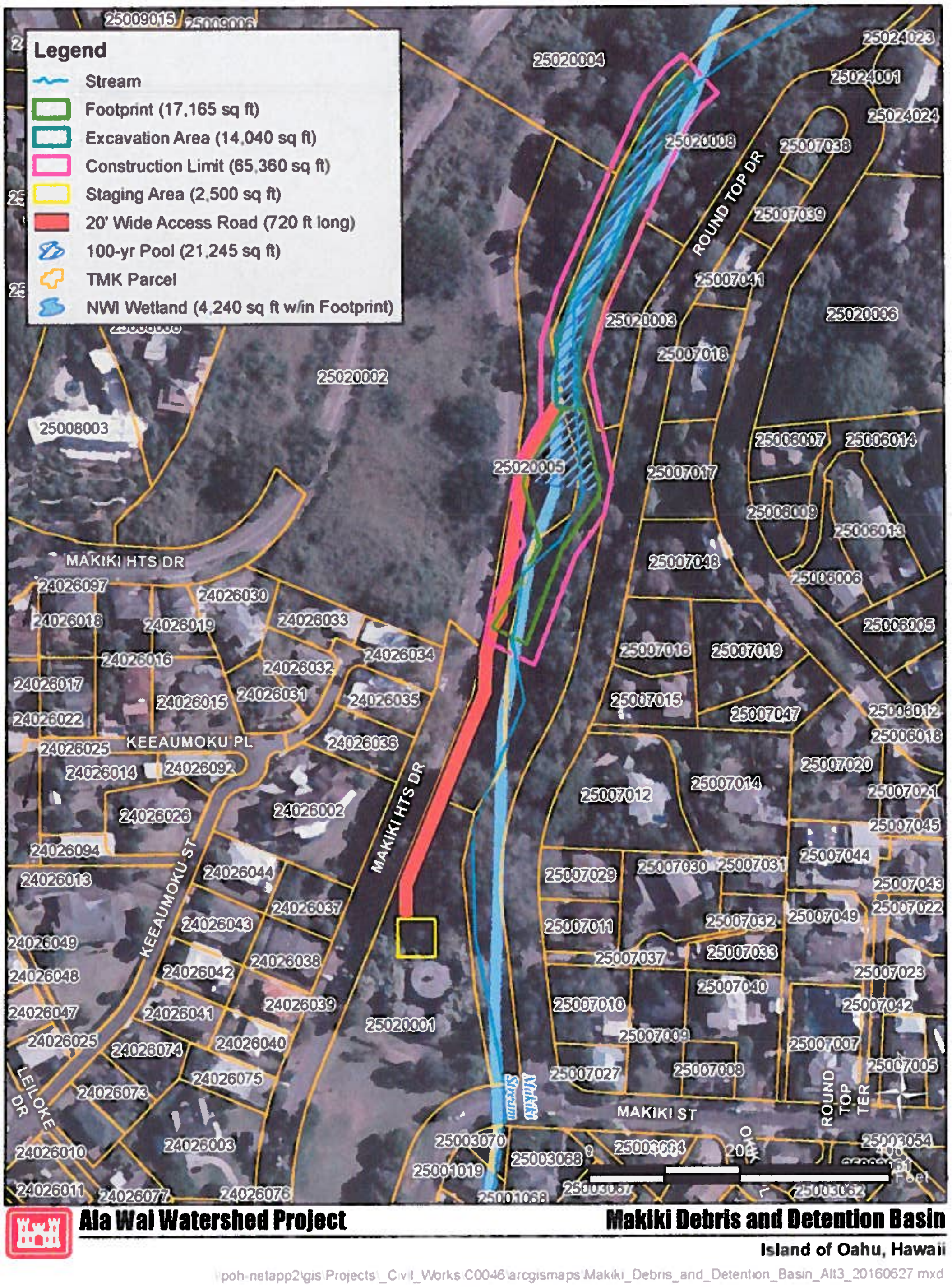


Figure 10. Map of Makiki Stream Debris and Detention Basin, Makiki Stream.

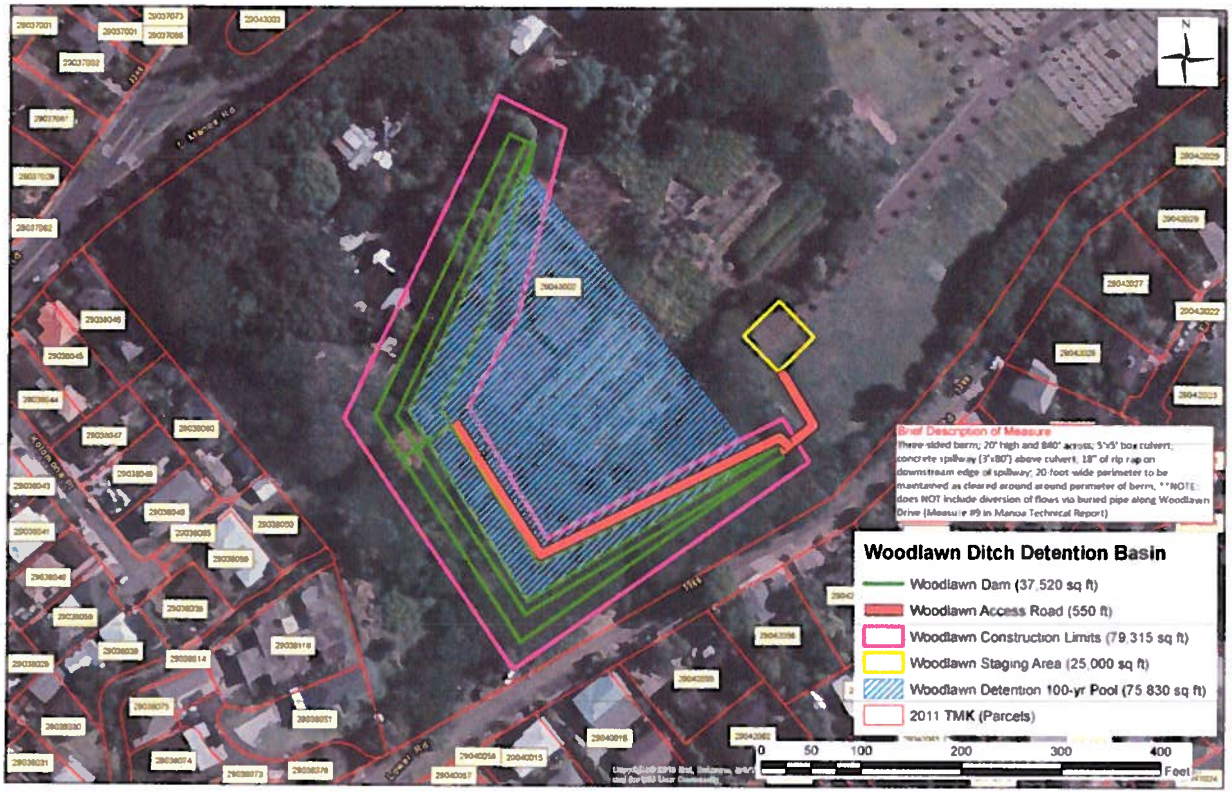


Figure 11. Map of Woodlawn Ditch Detention Basin, Manoa Stream.

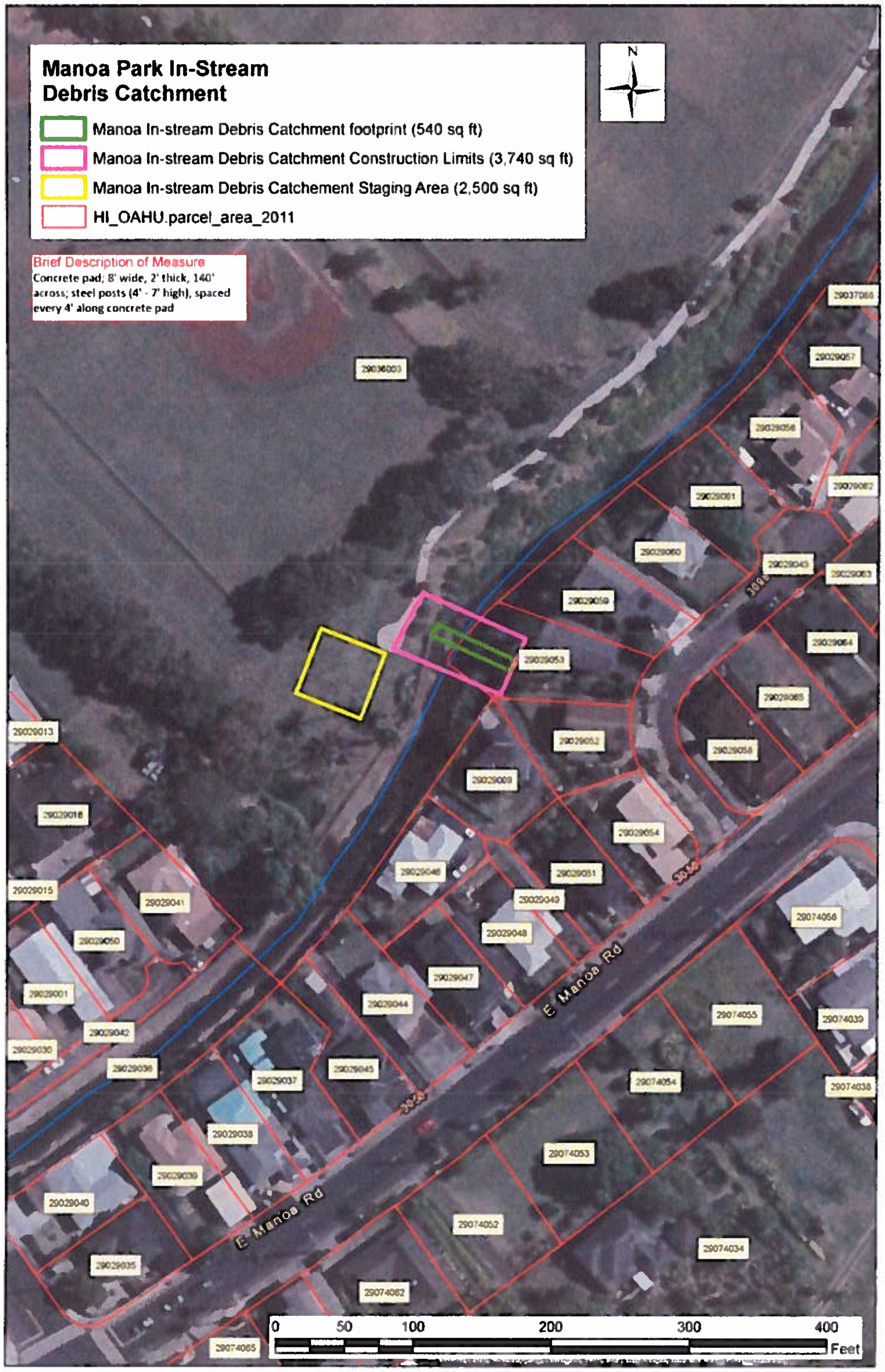
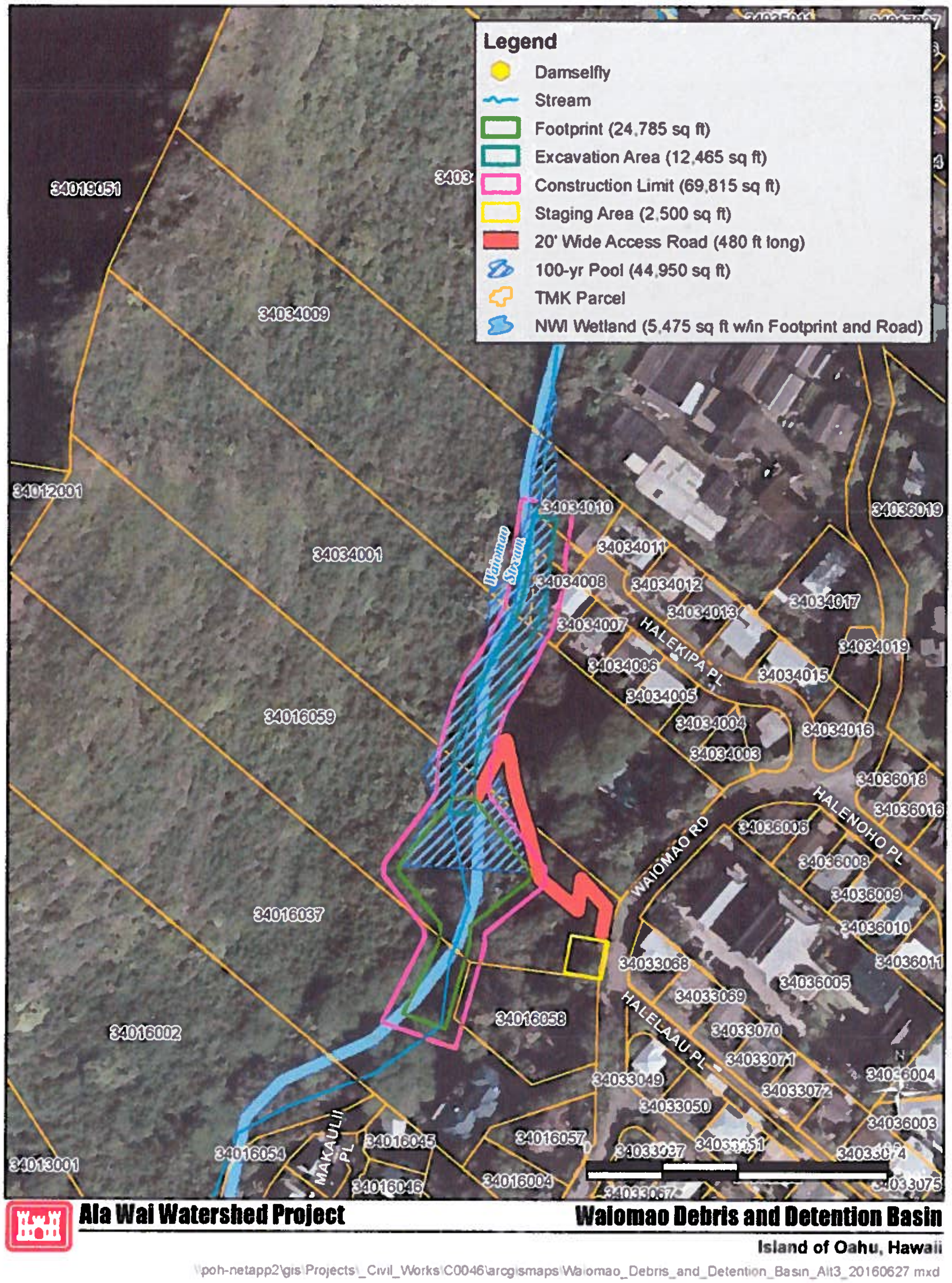


Figure 12. Map of Manoa In-stream Debris Catchment, Manoa Stream.

Figure 13. Map of Kanewai Field Multi-Purpose Detention Basin, Manoa Stream.



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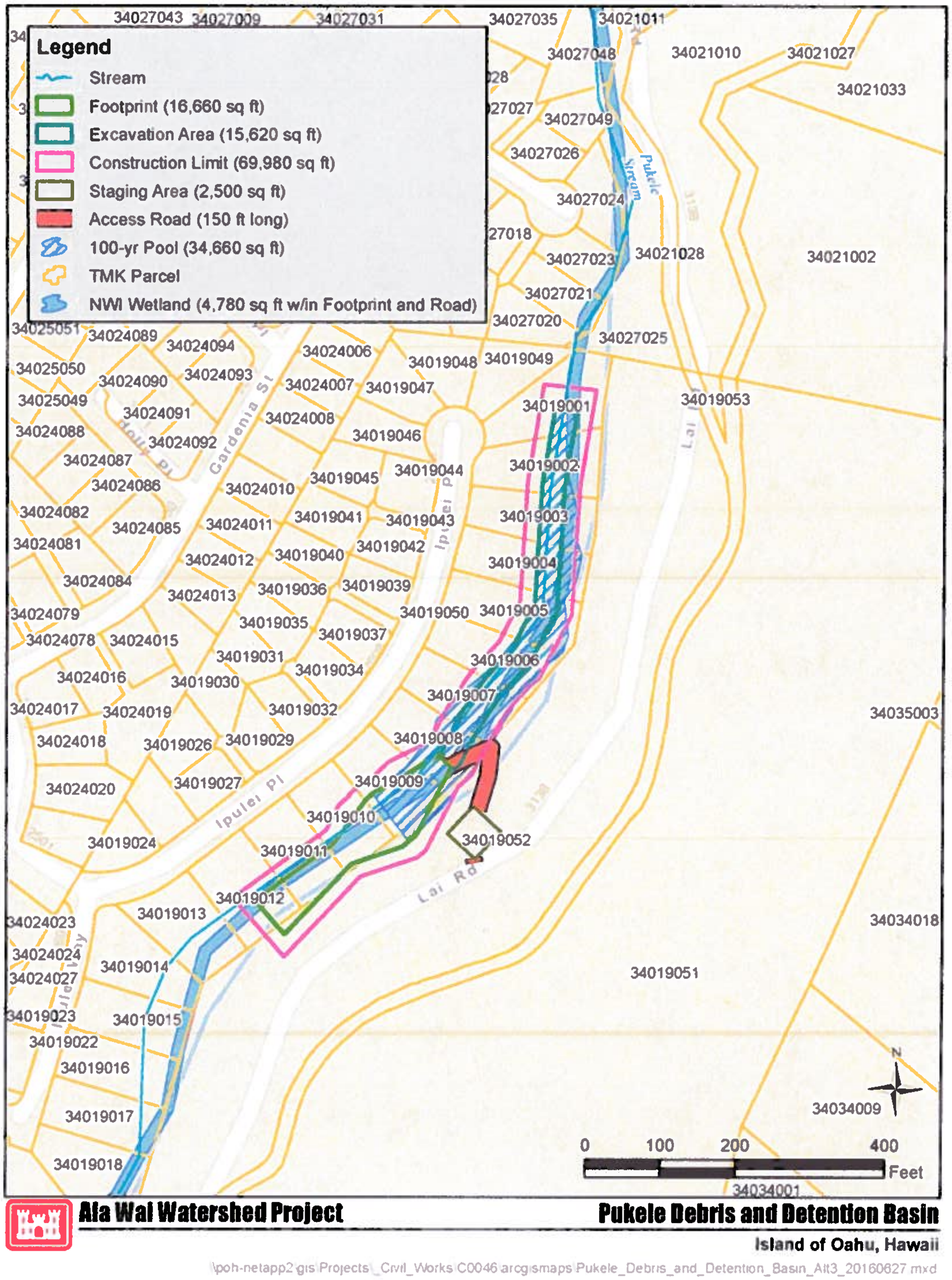


Figure15. Map of Pukele Debris and Detention Basin, Manoa Stream.

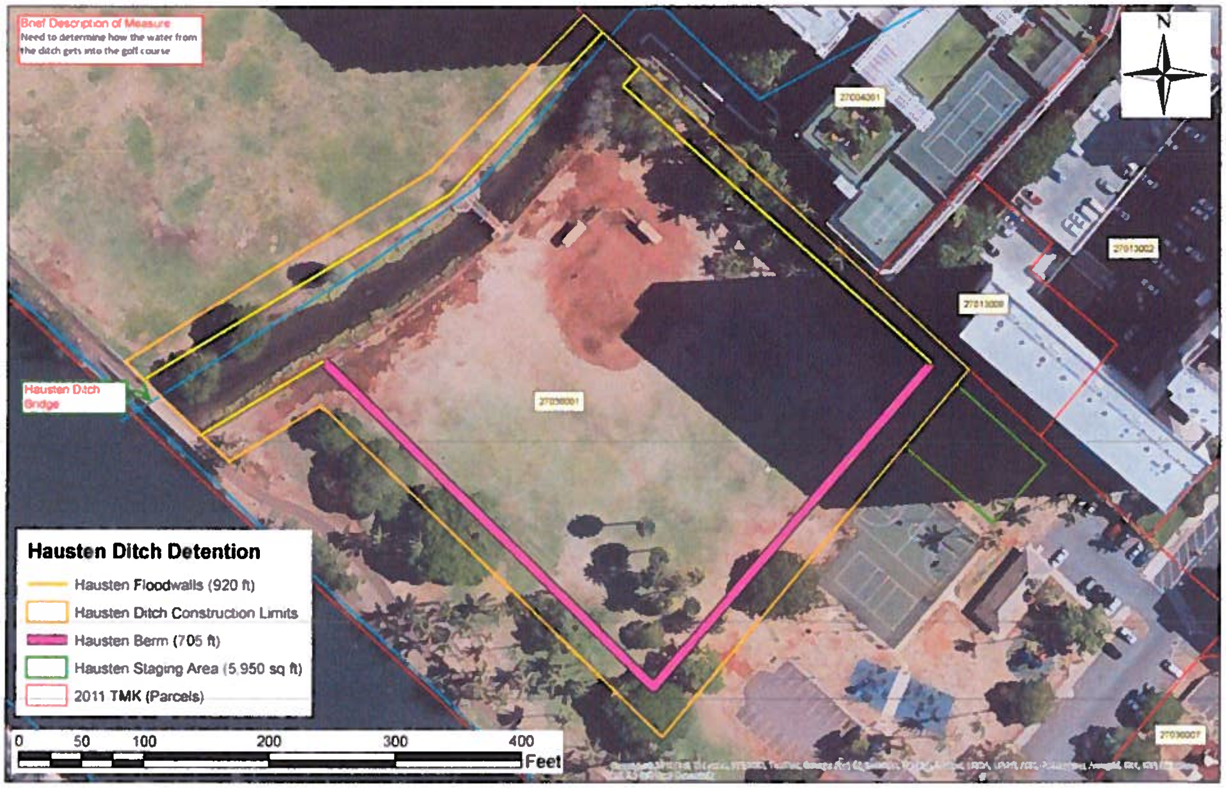


Figure 16. Map of Hausten Ditch Detention Basin, Manoa Stream.

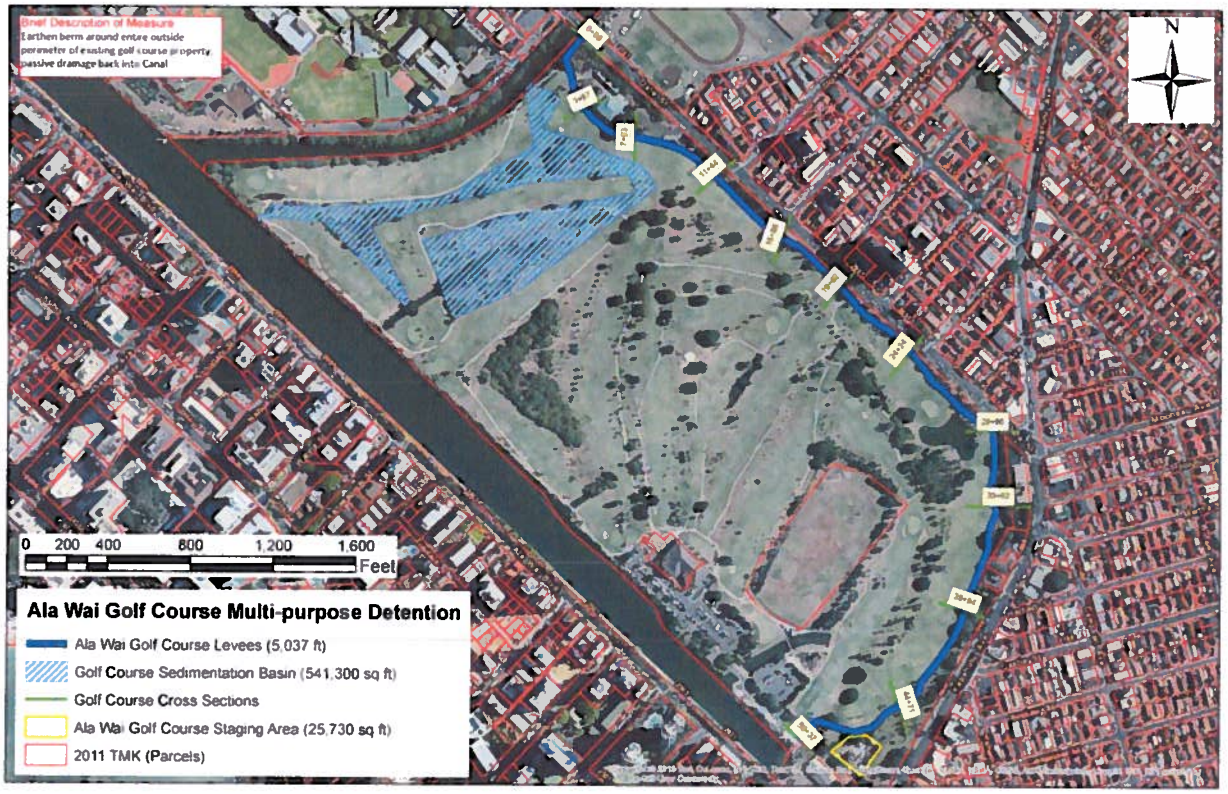


Figure 17. Map of Ala Wai Golf Course Multi-Purpose Detention Basin.

APPENDIX A – PHOTOGRAPHS OF FISH AND WILDLIFE RESOURCES

Figure A-1. Blackline damselfly, *Megalagrion nigrohamatum nigrolineatum*, male.

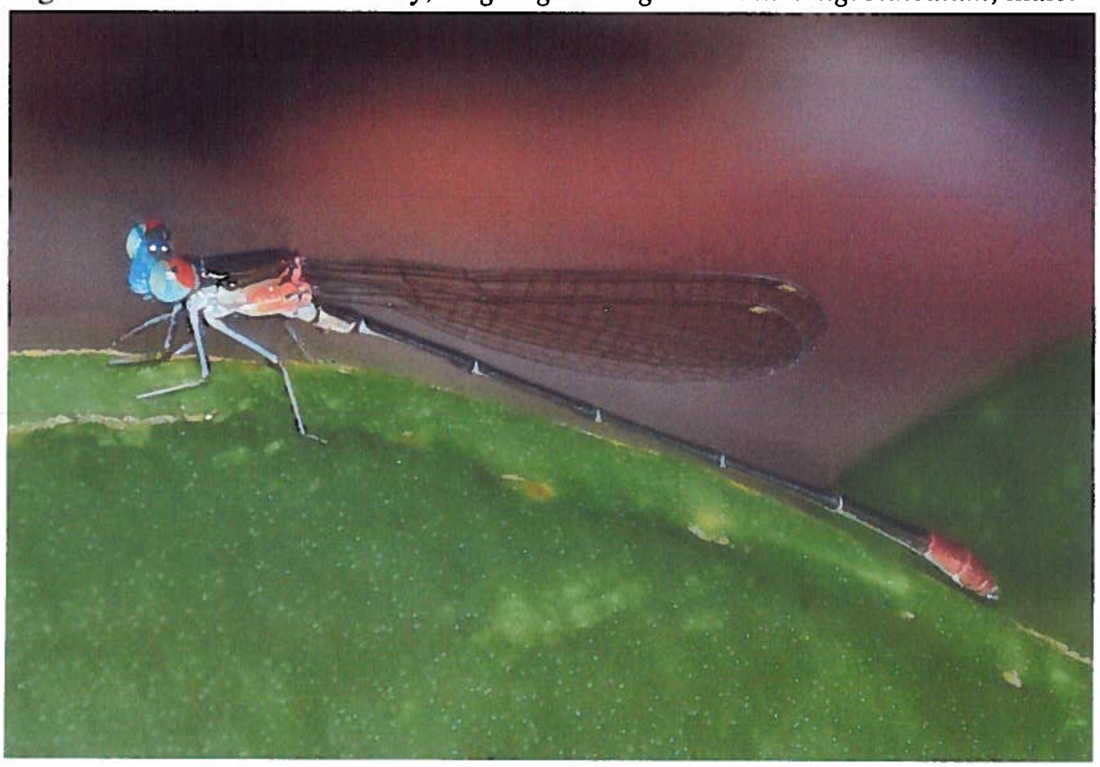


Figure A-2. Blackline damselfly, *Megalagrion nigrohamatum nigrolineatum*, male

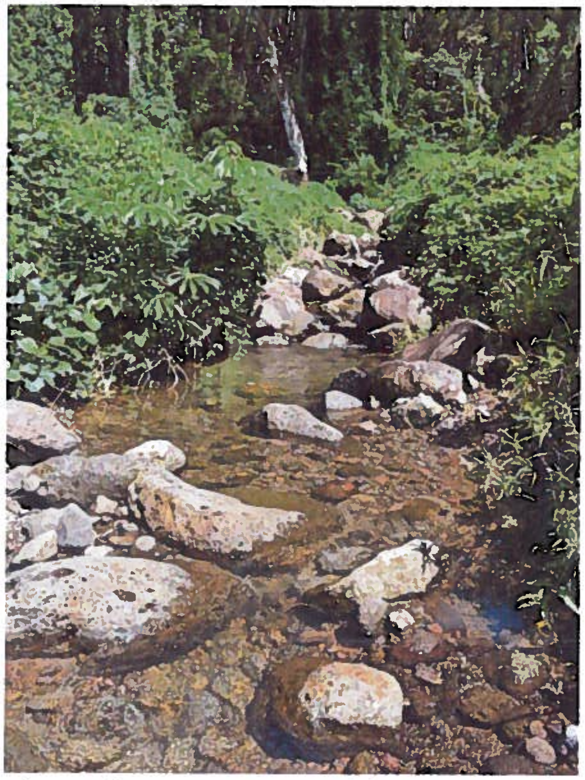


Figure A-3a.Manoa Stream, Waihi DDB Site (Basin).

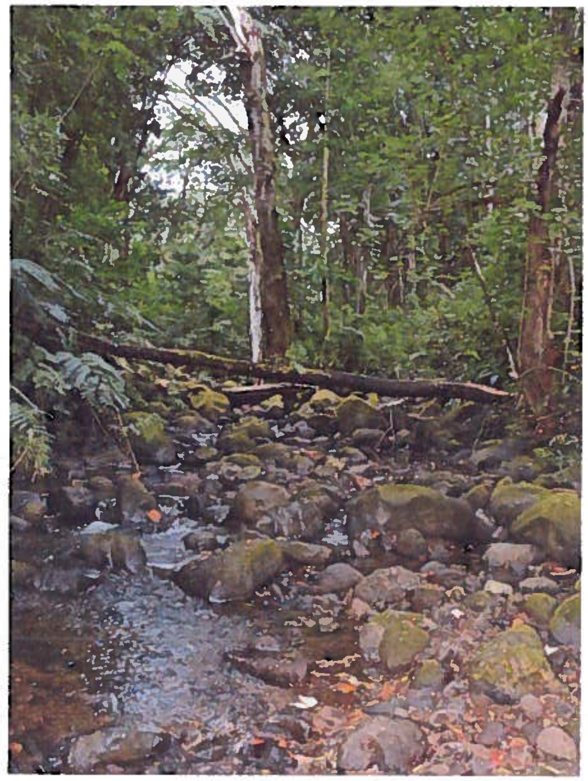


Figure A-3b.Manoa Stream, within project footprint.

Figure A-4a. Manoa Stream Waihi DDB
Breeding Habitat: *M. nigrohamatum nigrolineatum*

Figure A-4b. Manoa Stream,Waihi DDB,
Riparian seepage.

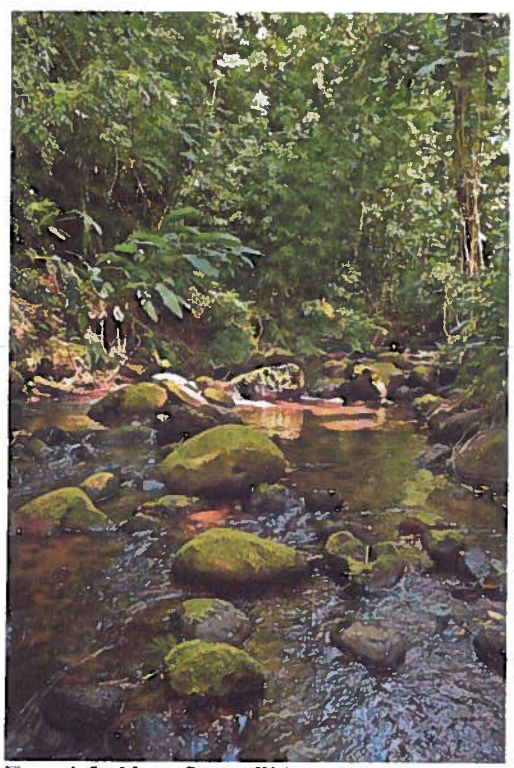


Figure A-5a. Manoa Stream, Waiakeakua stream, DDB Site.
Fork going upstream above confluence, near the upper
Bound of the project footprint.

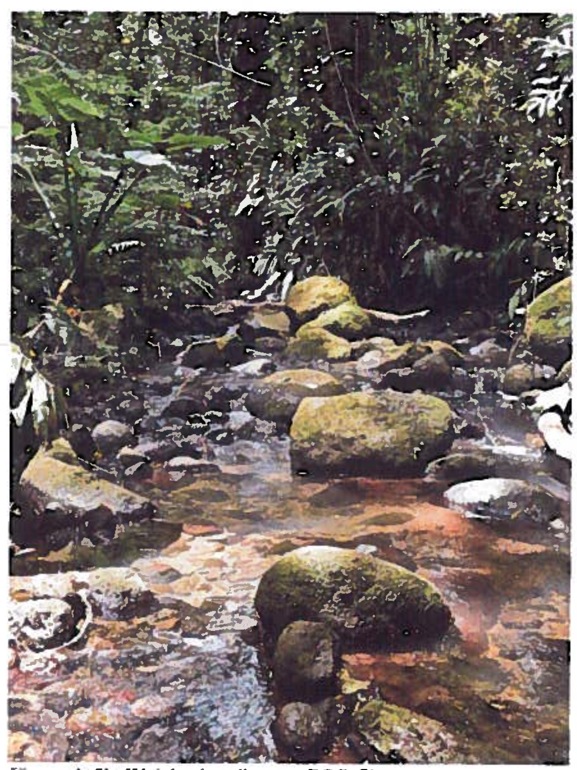


Figure A-5b. Waiakeakua Stream, DDB Site.
Main stream between gauge forks. Both areas represent M.
nigrohamatum nigrolineatum habitat.

Figure A-6. Makiki Stream, DDB Site.

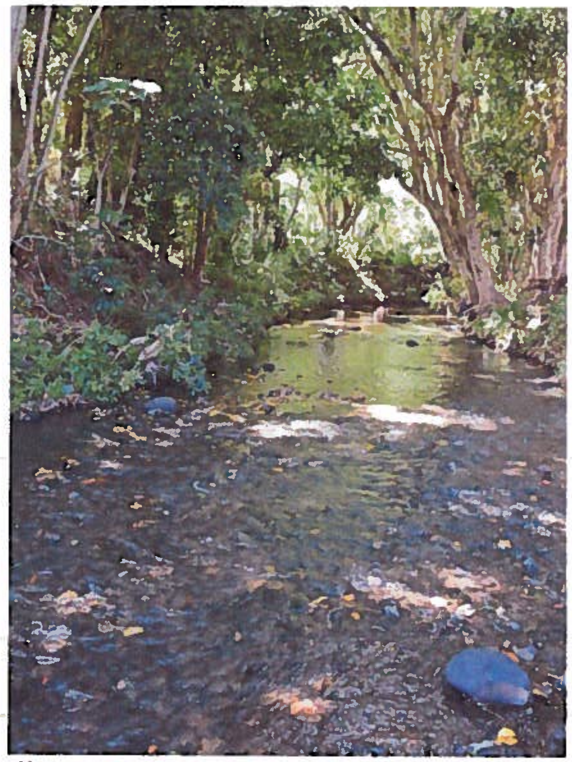


Figure A-7. Manoa Stream, Woodlawn DDB Site.

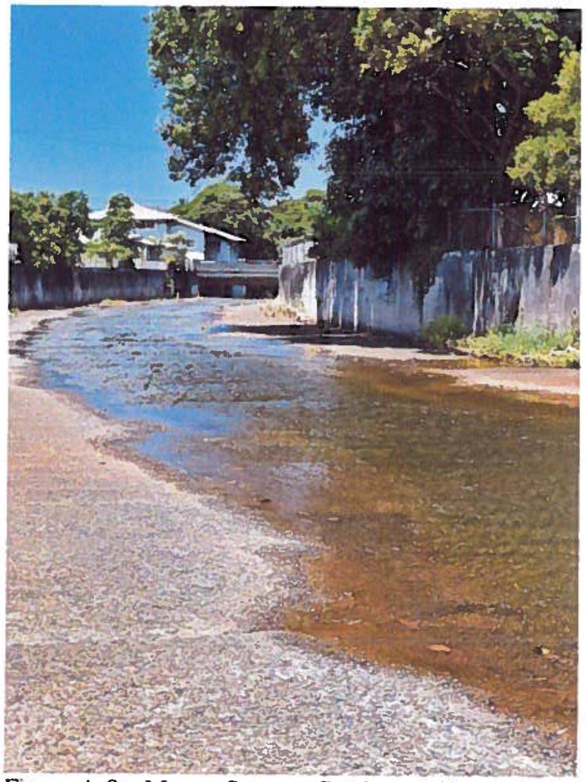


Figure A-8a. Manoa Stream, Catchment Site.

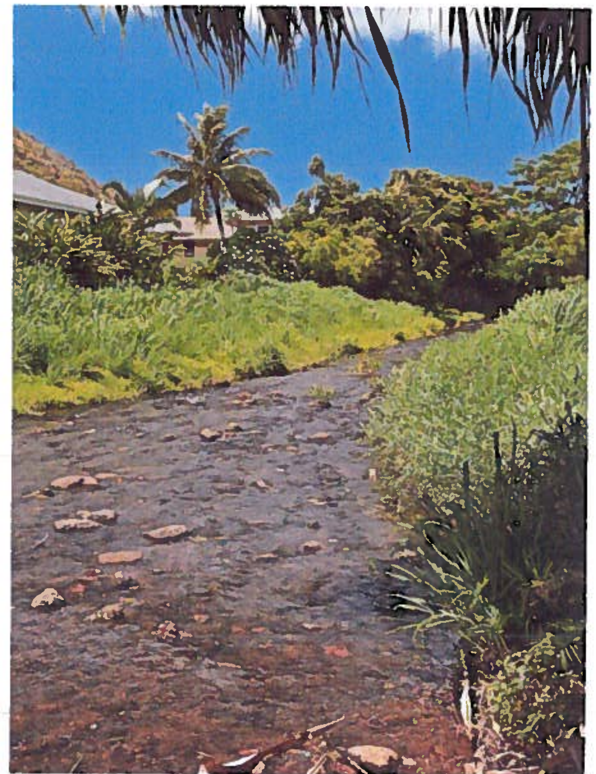
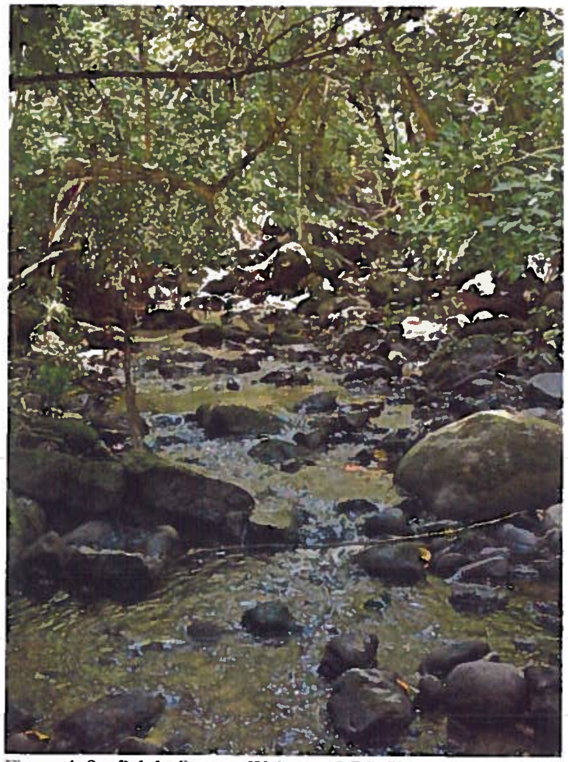


Figure A-8b. Manoa Stream, Catchment Site.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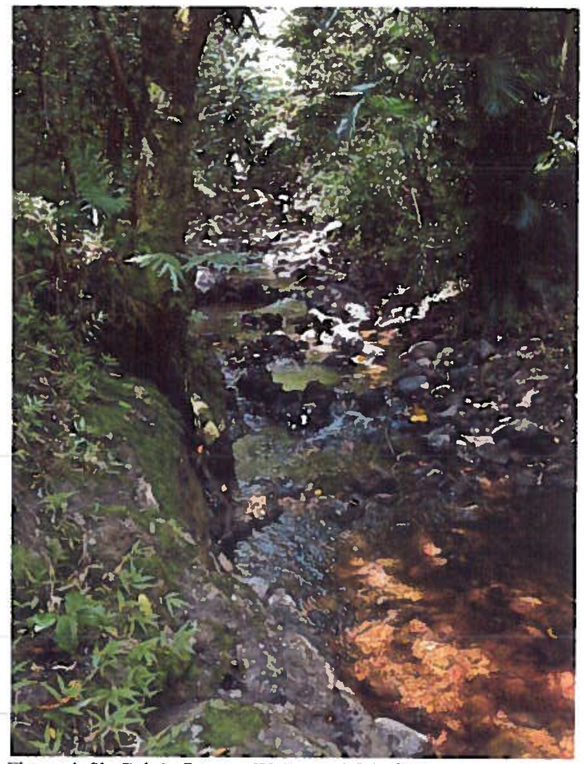


Figure A-9b. Palolo Stream, Waiomao DDB Site.

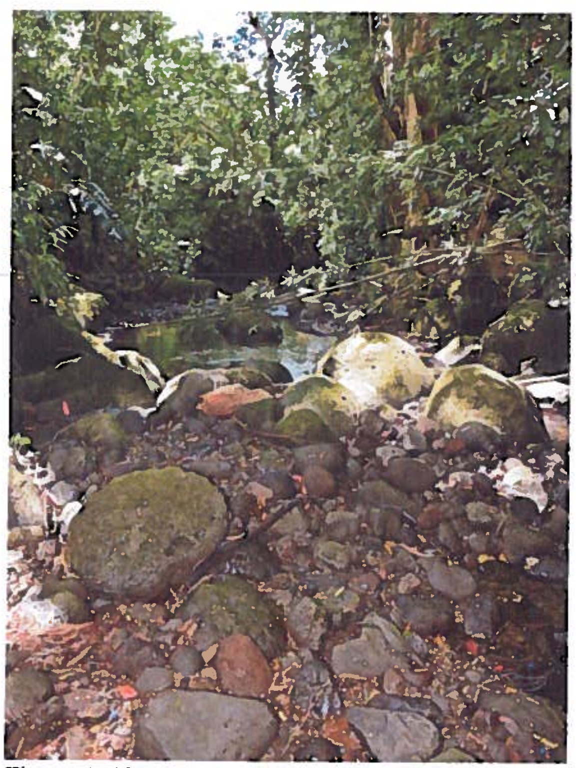
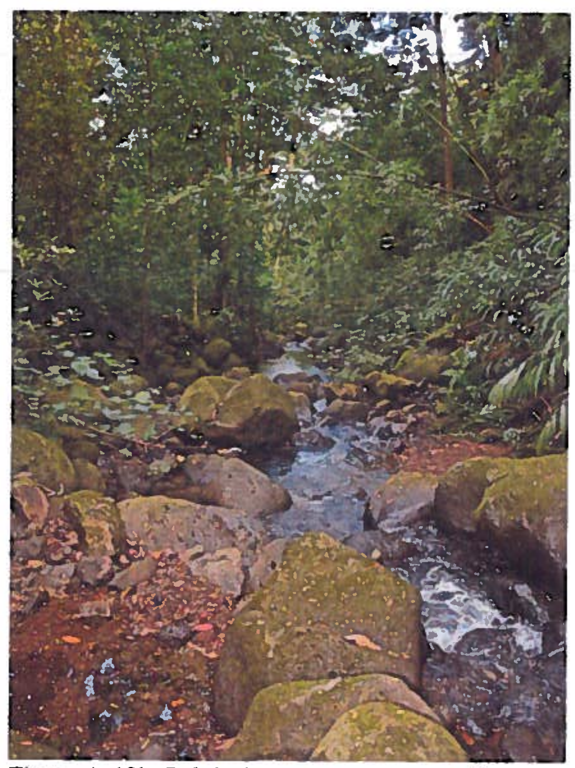


Figure A-10a. Palolo Stream, Pukele DDB Site.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APPENDIX B – PHOTOGRAPHS OF POST-DEBRIS REMOVAL MAINTENANCE AT WAILUPE DEBRIS AND DETENTION BASIN

Figure B-1. Examples of Maintenance Dredging in Detention Basin Pool Area – Vegetation and debris removed and soil exposed by bulldozer.

Figure B-2. Examples of Maintenance Dredging in Detention Basin Pool Area – Exposed soil and altered stream.

Figure B-3. Examples of Maintenance Dredging in Detention Basin Pool Area - Large boulders and debris accumulate in the stream.

Figure B-4. Examples of Maintenance Dredging in Detention Basin Pool Area – Backhoe removing debris from stream.

Figure B-5. Examples of Maintenance Dredging in Detention Basin Pool Area – Culvert.

APPENDIX C – Fish Biomass Estimates from High Definition Fish Survey Video in Ala Wai Watershed Streams, Oahu September 23, 2016 Dr. James Parham, Certified Fisheries Professional

Fish Biomass Estimates from High Definition Fish Survey Video in Ala Wai Watershed Streams, Oahu

September 23, 2016

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Introduction:

The USACE along with its state partners has proposed the Ala Wai Canal Flood Mitigation Project to reduce the risk of flooding and associated property damage within the Ala Wai watershed. In general, the flood risk management project is focused on holding back or diverting peak flood flows to lessen the impact of a flooding event. The infrastructure needed to do this is expected to have an impact on aquatic habitat and native Hawaiian stream animals.

As part of the assessment of habitat and instream conditions, the Hawaii Division of Aquatic Resources (DAR) collected geo-referenced underwater video footage using the High Definition Fish Survey (HDFS) methodology from the Ala Wai Watershed streams (Manoa, Palolo, and Makiki). The results of the surveys were summarized by Parham and Higashi 2015 in a report documenting the species observed and their distribution throughout the streams. Subsequent to that report, DAR has collected additional underwater video footage from Manoa Stream.

To support a review of the USACE Flood Mitigation Project, the USFWS needs an estimate fish biomass for the more common species. To estimate a species' biomass within the Ala Wai Watershed Streams, the original and new survey videos were analyzed with this specific output as a goal. This report describes the methods used and results for fish biomass estimate from the HDFS surveys in the Ala Wai Streams.

Methods:

To develop biomass estimates for fishes in Manoa, Palolo and Makiki Streams, a series of steps were completed.

1. The underwater video was watched, each sample site was given a unique Site ID and the sites date, time, GPS location, video file, and stream name were recorded.

2. From the underwater video footage, an estimate of the viewing area (m^2) was determined. This was used in the estimate of fish biomass (g/m^2). Area was estimated by determining the forward visibility, the distance traveled if the camera moved, and the proportion of the site obscured.

3. The underwater video footage was watched and scored for the species type, their size, and number present at each sample location. With any timed observation of live animals (visual or video), it is possible that the same fish may swim in and out of the viewing area. As a result, the maximum number of fish (Max N) in the screen during the sample viewing time is used to control for this possibility. Once video frame with the maximum number of an individual species was determined, the individuals were then counted within predetermined size classes. The result of this step was a size class count for each species within each underwater video sample site.

- For this analysis of fish biomass, the native goby, o'opu nakea (*Awaous stamineus*), and the introduced fishes, longfin armored catfish (*Hypostomus watwata*), bristlenose catfish (*Ancistrus temmincki*), and convict cichlid (*Archocentrus nigrofasciatus*) were selected by USFWS and

DAR. The native goby, o'opu nakea, is the most widespread native stream fish in the Ala Wai Watershed streams and the two catfish species occupy similar habitat to the native gobies. Convict cichlid are representative of a non-demersal species.

4. The biomass for each fish within a size class was determined from length/weight measurements collected from specimens in Oahu streams provided by DAR. The standard length/weight relationship, Weight = a(Length)^{b}, was fit to the data using Table Curve 2D v 5.01 (Systat Software Inc., 2002) to find the species specific coefficient values for a and b. The median length of the observed species within each size class was used to estimate the weight of the species observed by applying the length/weight relationship. This step provided the total weight of a species within each sample site.

5. The results of the biomass estimate at individual sample sites was averaged within stream and stream reach areas. The streams (Manoa, Palolo, and Makiki) and reaches (lower, middle, and upper) provided a way to generalize the results into more appropriate areas associated with the flood mitigation actions.

Results

All the data used in this report are provided in an associated spreadsheet.

Sampling effort:

A total of 745 sites throughout Manoa, Palolo and Makiki streams were surveyed using the HDFS methodology (Table 1). The area in upper Manoa Stream containing 230 sites was the most recent survey by DAR. A total of 310 sites was surveyed in the upper end of the streams and are the most useful comparison for the upper detention basins proposed in the flood mitigation plan.

Table 1: Location of survey sites

Stream	Reach Code	Sample Sites
Palolo	Lower	45
Makiki	Lower	94
Manoa	Middle	63
Palolo	Middle	133
Manoa	Upper	230
Palolo	Upper	103
Makiki	Upper	77
Total		745

Species Observations:

All 745 survey sites were reviewed for the presence of native gobies or the three introduced species. O'opu nakea and o'opu naniha were the most common native gobies (Table 2). Only one o'opu nopili (*Sicyopterus stimpsoni*) and three o'opu akupa (*Eleotris sandwicensis*) were observed in all of the samples. Nearly 300 each of the longfin armored catfish, bristlenose catfish, and convict cichlid were observed throughout the streams. The bristlenose catfish was the most common species counted in the upper stream reaches, although liberty mollies and guppies were likely observed in greater numbers.

Table 2: Size distribution of selected fishes in Ala Wai Watershed streams.

O'opu nakea

Category	Length Range (in)	Number Observed
small	< 3	6
medium	3 to 5	10
large	> 5	5
Total		21

O'opu naniha

Category	Length Range (in)	Number Observed
small	< 3	0
medium	3 to 5	5
large	> 5	13
Total		18

Longfin Armored Catfish

Category	Length Range (in)	Number Observed
small	< 2.5	11
medium	2.5 to 4	81
large	4 to 6	138
ex. Large	> 6	57
Total		287

Bristlenose catfish

Category	Length Range (in)	Number Observed
small	< 2	41
medium	2 to 3.5	133
large	> 3.5	120
Total		294

Convict Cichlid

Category	Length Range (in)	Number Observed
small	> 2	70
medium	2 to 4	162
large	> 4	62
Total		294

Length / Weight relationships:

DAR provided length and weight information from recent field surveys in Oahu streams. Michael Blum from Tulane University collected the information on longfin armored catfish, bristlenose catfish, and convict cichlids. Kauaoa Fraiola collected the information on o'opu nakea. The length and weight data for each species was plotted on a graph and the standard length weight relationship was fitted to the data. The following graphs and tables show the results for the length/weight relationships for these four species.

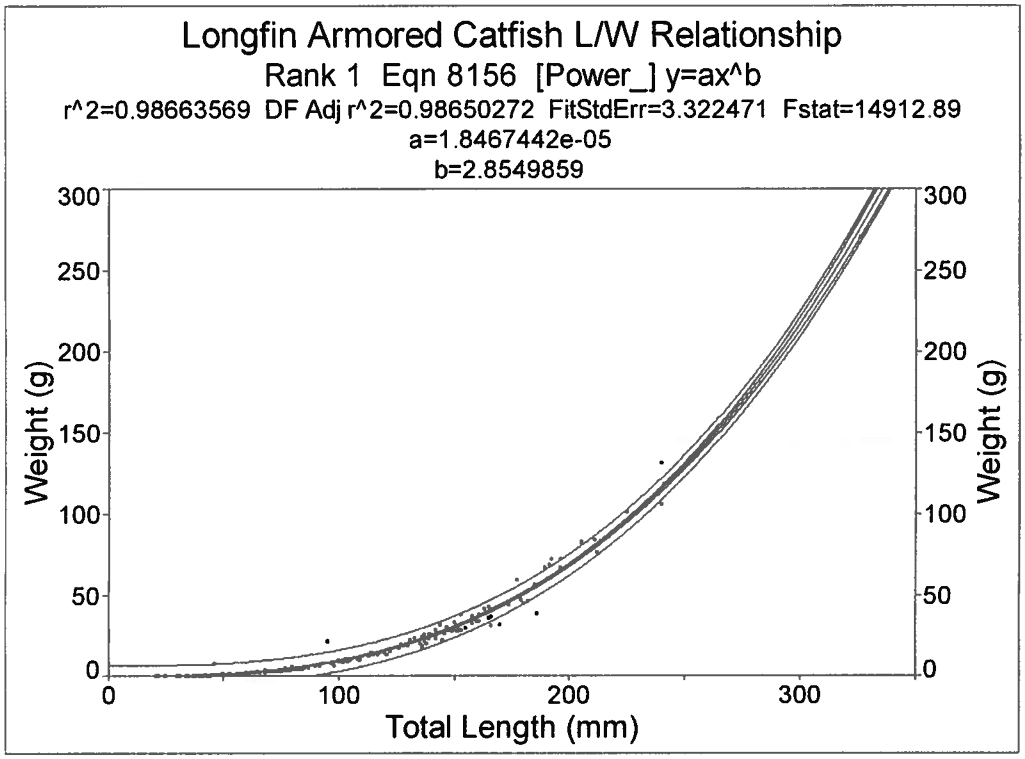

Figure 1: Length to Weight relationship for longfin armored catfish (*Hypostomus watwata*) based on 204 individuals collected from Oahu streams.

Table 3: Size categories, estimated median length within the size category, and related weights for longfin armored catfish (*Hypostomus watwata*).

Category	Length Range (in)	Length Median (in)	Length Median (mm)	Weight (g)
small	< 2.5	2	51	1.37
medium	2.5 to 4	3.5	89	6.77
large	4 to 6	5	127	18.74
ex. Large	> 6	7.5	191	59.63

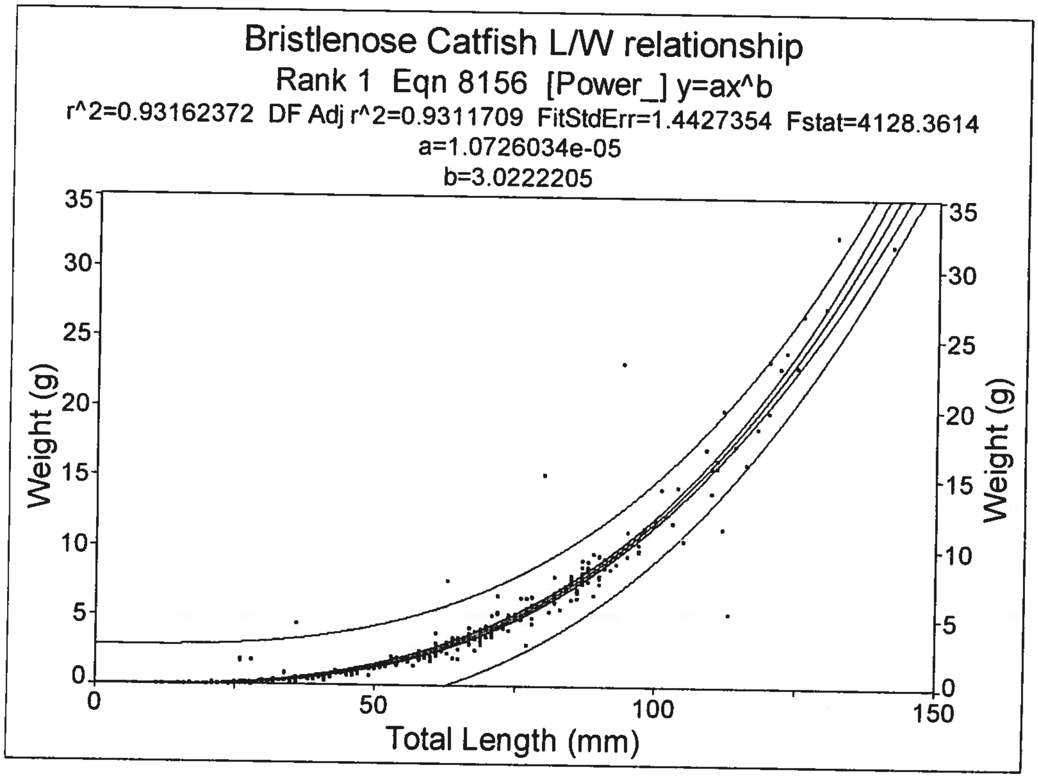

Figure 2: Length to Weight relationship for bristlenose catfish (*Ancistrus temmincki*) based on 305 individuals collected from Oahu streams.

Table 4: Size categories, estimated median length within the size category, and related weights for bristlenose catfish (*Ancistrus temmincki*).

Category	Length Range (in)	Length Median (in)	Length Median (mm)	Weight (g)
small	< 2	1.5	38	0.64
medium	2 to 3.5	3	76	5.23
large	> 3.5	4	102	12.47

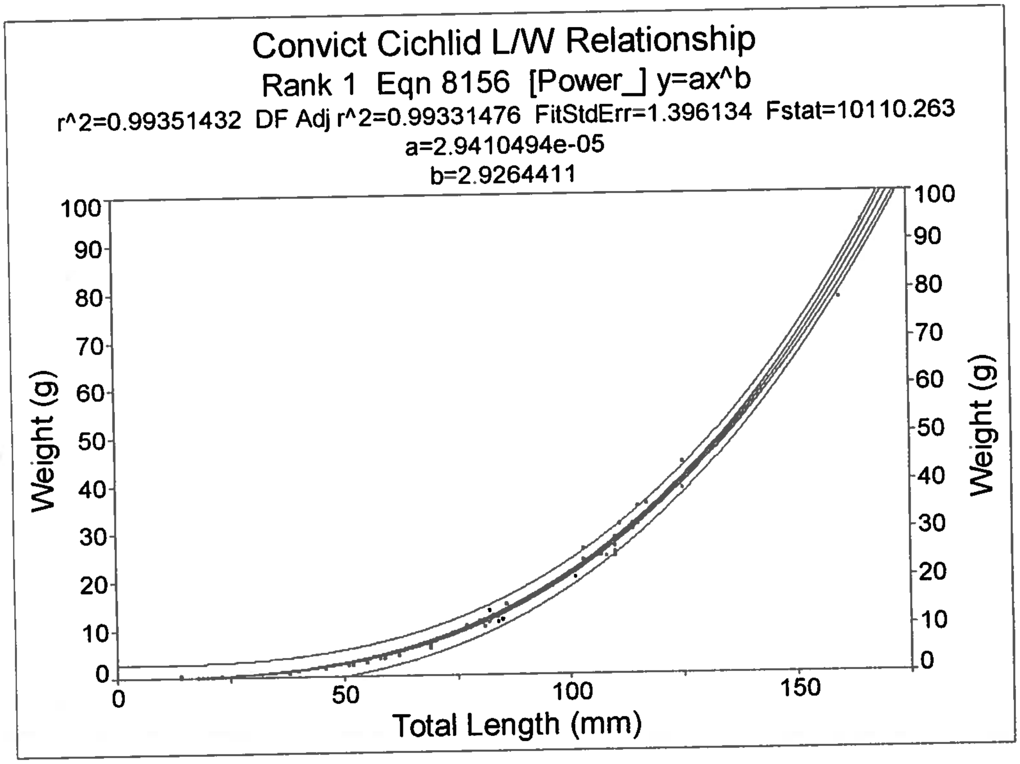

Figure 3:Length to Weight relationship for convict cichlid (*Archocentrus nigrofasciatus*) based on 68 individuals collected from Oahu streams.

Table 5: Size categories, estimated median length within the size category, and related weights for convict cichlid (*Archocentrus nigrofasciatus*).

Category	Length Range (in)	Length Median (in)	Length Median (mm)	Weight (g)
small	< 2	1.5	38	1.24
medium	2 to 4	3	76	9.46
large	> 4	4.5	114	30.99

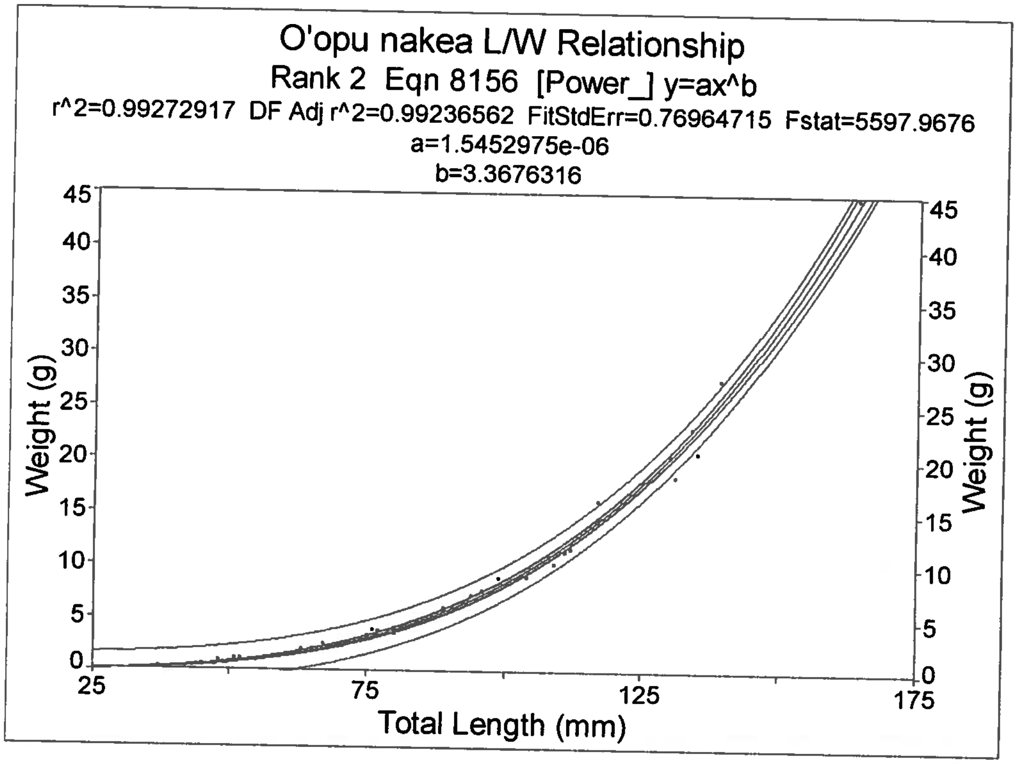

Figure 4: Length to Weight relationship for o'opu nakea (*Awaous stamineus*) based on 44 individuals collected from Oahu streams.

Table 6: Size categories, estimated median length within the size category, and related weights for o'opu nakea (*Awaous stamineus*).

Category	Length Range (in)	Length Median (in)	Length Median (mm)	Weight (g)
small	< 3	2.5	64	1.82
medium	3 to 5	4	102	8.86
large	> 5	6	152	34.71

Biomass Estimates:

Biomass estimates for the various species varied both among streams and among reaches (Table 7 and Table 8). This is partially due to sampling locations as habitat availability was not consistent among locations and partially due to the presence of other species. In Manoa stream, for example, smallmouth bass were common throughout deeper areas of the middle reach and tiliapia were very common in the lower reaches. For a better understanding of the variability of habitat, please see the report "Ala Wai Flood Risk Management Project Impact to Native Stream Animal Habitat and Possible Habitat Mitigation Options" by Parham, 2015.

Several patterns were apparent. Native fishes are not common in the Ala Wai Watershed streams. It is likely that habitat modification and the introduction of numerous other species has decreased their abundance. O'opu nakea can be found throughout the streams with at slightly higher abundances in the middle and upper reaches. Longfin armored catfish were very common in the lower and middle reaches of the streams and sometimes found in extremely high density. This species could be found in very shallow, swift water and in deeper, slower pools. Longfin armored catfish do not appear to occur in the upper reaches of the streams. Bristlenose catfish however are more common in the upper reaches of the streams although they exist throughout all of the stream reaches. Bristlenose catfish occupy similar habitat to the native gobies in the upper reaches of the streams and were observed co-occurring with o'opu nakea in a few locations.

Table 7: Biomass estimates grouped by stream and reach.

				Observed weight (g)				Biomass (g/m^2)			
Area code	Stream	Reach Code	Total Area Surveyed (m^2)	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea
2	Palolo	Lower	42.4	977.6	63.5	399.9	8.9	23.0	1.5	9.4	0.2
3	Makiki	Lower	94.4	255.4	101.0	326.1	34.7	2.7	1.1	3.5	0.4
4	Manoa	Middle	112.6	4,333.6	127.0	419.2	0.0	38.5	1.1	3.7	0.0
5	Palolo	Middle	77.2	981.6	127.9	2,396.0	86.3	12.7	1.7	31.0	1.1
7	Manoa	Upper	97.6	0.0	463.1	0.0	0.0	0.0	4.7	0.0	0.0
8	Palolo	Upper	68.2	0.0	1,019.2	0.0	72.0	0.0	14.9	0.0	1.1
9	Makiki	Upper	111.6	0.0	315.4	0.0	71.2	0.0	2.8	0.0	0.6

Table 8: Biomass estimates grouped by reach.

		Observed weight (g)				Biomass (g/m^2)			
Reach Code	Total Area Surveyed (m^2)	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea	Longfin Armored Catfish	Bristlenose Catfish	Convict Cichlid	O'opu Nakea
Lower	136.8	1,233.0	164.5	726.1	43.6	9.0	1.2	5.3	0.3
Middle	189.8	5,315.2	254.9	2,815.2	86.3	28.0	1.3	14.8	0.5
Upper	277.4	0.0	1,797.8	0.0	143.2	0.0	6.5	0.0	0.5

Conclusions:

The use of HDFS in the Ala Wai watershed streams was the first time it had been applied in Hawaii. The HDFS approach had both strengths and weaknesses for estimating fish biomass in Hawaiian streams.

Strengths:

- the use of geo-referenced underwater video is much faster and applicable to a wider range of instream conditions than visual assessments using snorkeling gear. We were able to sample in shallow water and in poor quality water where snorkelers may not want to swim. Preliminary estimates on the improvement in speed comparing HDFS to snorkel surveys has shown approximately a 10-fold improvement in speed. If this holds true for this survey, we would have collected approximately 75 observations of fish using the snorkeling approach as compared to nearly 750 observations using HDFS.
- The video is reviewable and can be used for multiple different uses. The original purpose was to document the occurrence and distribution of species within the streams. The video collected for that purpose was combined with additional video and used to estimate fish biomass. This eliminated the need to go out and collect additional surveys for this new purpose.
- The geo-referenced video can be analyzed in conjunction with High Definition Stream Survey video allowing a much better understanding of the distribution and occurrence of species with respect to instream habitat.

Weaknesses:

- Standardization of the sampling approach should be improved to increase reliability of the results. Using a fixed time in each location would make it easier to have comparable samples. This recommendation has already been instituted in the HDFS approach and made the newer upper Manoa surveys easier to review.
- In other standardization that should be implemented is the inclusion of standard measurement devices (i.e. rulers) that would be placed in some portion of the samples. This would provide a very helpful reference when estimating the area or the size of individual fish. DAR is in the process of testing various measuring devices for use in this method.

The Ala Wai watershed streams are highly modified in both habitat and contain of numerous introduced species. Native species are still present at low densities throughout the streams. The bristlenose catfish may be a good analog to understanding native goby biomass in these highly modified systems. This catfish species lives on the bottom and scrapes algae for food. From personal observations of native gobies throughout Hawaiian streams, they appear to be of similar size and use similar habitats to the bristlenose catfish. It may be that bristlenose catfish outcompete native gobies or it may be that native gobies can no longer easily access habitat in the Ala Wai watershed streams and that the bristlenose catfish are filling the void left by the native gobies. Either way the biomass of the native species is far lower than I have observed in other island streams.

It should also be noted that these biomass estimates are not inclusive of all species observed during the surveys and therefore should not be used to estimate total biomass in any stream section. Other fish species like tilapia, smallmouth bass or liberty mollies as well as crustaceans like grass shrimp, crayfish and Tahitian prawns were observed during the surveys and may be locally abundant.

APPENDIX D – MITIGATION, MONITORING AND ADAPTIVE MANAGE PLANALA WAI CANAL PROJECT, OAHU, HAWAII, U.S. ARMY CORPS OF ENGINEERS,HONOLULU DISTRICT, AUGUST 2015

Draft

Mitigation, Monitoring and Adaptive Management Plan

Ala Wai Canal Project; Oahu, Hawaii

U.S. Army Corps of Engineers, Honolulu District

August 2015

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1.1 Introduction

At the request of the State of Hawaii Department of Land and Natural Resources (DLNR) and as authorized under Section 209 of the Flood Control Act of 1962, the U.S. Army Corps of Engineers, Honolulu District (USACE) is conducting a feasibility study for the Ala Wai Canal Project, Oahu, Hawaii (hereafter referred to as "the project"). The purpose of the project is to reduce the threat to life and reduce property damage from riverine flooding within the Ala Wai Watershed.

The Ala Wai Watershed is located on the southeastern side of the island of Oahu, Hawaii. The watershed encompasses 19square miles (mi^2) (12,064 acres) and extends from the ridge of the Ko'olau Mountains to the nearshore waters of Mamala Bay. It includes Maikiki, Manca, and Palolo Streams, which drain to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki district.

The project is currently a feasibility study, considering a variety of non-structural and structural flood risk management measures. Plan formulation and evaluation resulted in tentative selection of an alternative plan for implementation (referred to as the tentatively selected plan). A detailed discussion of the plan formulation process and the components of the tentatively selected plan are provided in the Draft Feasibility Study Report with Integrated Environmental Impact Statement (EIS), hereafter referred to as "Feasibility Report/EIS ."

As detailed in the Implementation Guidance for Section 2036(a) of the Water Resources Development Act (WRDA) of 2007- Mitigation for Fish and Wildlife and Wetland Losses, it is the policy of the USACE Civil Works program to demonstrate that damages to all significant ecological resources have been avoided and minimized to the extent practicable, and that any remaining unavoidable damages have been compensated to the extent possible. The mitigation planning process should seek to compensate for non-negligible impacts to the extent incrementally justified and ensure that the recommended project will not have more than negligible adverse impacts on ecological resources. Engineering Regulation (ER) 1105-2-100 ("Planning Guidance Notebook") requires the use of a habitat-based methodology, supplemented with other appropriate information to describe and evaluate the impacts of the alternatives plans, and to identify the mitigation need of the with-project condition as measured against the future without-project condition. Once a mitigation need has been identified, mitigation objectives must be developed to address the identified losses. Mitigation objectives are used to guide formulation of appropriate mitigation management features and to establish benchmarks for evaluating the performance of the mitigation plans.

The regulations require assessment of environmental impacts and associated mitigation actions in a manner that addresses changes in ecological resource quality. Changes to habitat must be assessed as a function of improvement or degradation in habitat quality and/or quantity, as expressed quantitatively in physical units or indexes (but not monetary units). In the case of mitigation for significant environmental impacts, ecosystem restoration actions must be formulated and evaluated in terms of their net contributions to increases in ecosystem value, expressed in non-monetary units. Mitigation actions also need to go through a Cost Effectiveness and Incremental Cost Analysis (CE/ICA) to ensure benefits are optimized relative to cost.

Preparation of a mitigation plan is required, and should present the objectives, plan design, determination of success criteria and monitoring needs, all of which should be developed in coordination with Federal and State resource agencies to the extent practicable. The mitigation plan should include the following:

The project has also previously been referred to as the "Ala Wai Watershed Project"; for consistency with the Congressional documentation, the project will continue to be referred to as the "Ala Wai Canal Project."

(1) a description of the physical action to be undertaken to achieve the mitigation objectives within the watershed in which such losses occur;

(2) the type, amount, and characteristics of the habitat being restored;

(3) ecological success criteria for mitigation based on replacement of lost functions and values of the habitat, including hydrologic and vegetative characteristics;

(4) a plan for monitoring to determine the success of the mitigation, including the cost and duration of any monitoring and the entities responsible for any monitoring;

(5) a contingency plan (i.e. adaptive management) for taking corrective actions in cases where monitoring demonstrates that mitigation measures are not achieving ecological success; and

(6) should land acquisition be proposed as part of the mitigation plan, a description of the lands or interests in lands to be acquired for mitigation and the basis for a determination that such lands are available for acquisition.

This mitigation and monitoring plan has been developed in compliance with these requirements. It includes a discussion of the quantification of habitat impacts, identification of mitigation objectives and proposed mitigation actions, and development of the proposed monitoring and adaptive management approach.

2.1 Assessment of Impacts to Aquatic Habitat

As described above, USACE regulations require the use of a habitat-based methodology to describe and evaluate the impacts of alternative plans, as well as to identify the need for mitigation to offset unavoidable ecological impacts of the with-project conditions as measured against the future without-project condition. As the outputs of ecosystem restoration are not readily convertible to actual monetary units (as is required for traditional benefit-cost analyses), ecosystem outputs must be clearly identified and quantified in appropriate units, preferably ones that measure change in ecosystem value and productivity. Measurable changes in ecosystem values are typically described in terms of suitability indices or habitat units, with an ecosystem output model used to quantify the changes over a SO-year period of analysis. Following is a description of the ecosystem output model selected for use on the project, and a summary of the modeling results for the existing (without-project) condition and with implementation of the tentatively selected plan.

2.2 Description of Ecosystem Model

Analogous with Habitat Evaluation Procedure (HEP) method and Habitat Suitability Index models developed by natural resource biologists elsewhere, the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) is a habitat-based model that was developed as a tool to support management of Hawaii's streams and associated habitat for freshwater flora and fauna. Specifically, the model is intended to provide managers with the ability to quantify changes in habitat for native Hawaiian stream animals in response to actions such as channel alterations, flow modifications, land use change and watershed development, or construction of in-channel structures. It captures the major aspects of native stream animal ecology, the typical geomorphology of Hawaiian streams, and common modifications to the environment.

The HSHEP model is an outgrowth of a history of collaboration among biologists at the State of Hawaii Division of Aquatic Resources (DAR) and researchers at various universities, agencies, museums, and private companies. The collaborative effort focused on understanding the different aspects of the ecology and management of amphidromous stream animals, which have a life history involving downstream and upstream migration (Fitzsimons and Nishimoto, 2007). In recent years, efforts have focused on combining the information gained from the wide range of studies into an integrated model of Hawaiian streams that include the life history characteristics of amphidromous animals, island hydrology and geomorphology, and critical management issues.

The HSHEP model follows the overall Habitat Evaluation Procedure (HEP) model concepts developed by the U.S. Fish and Wildlife Service (USFWS) to evaluate the quantity and quality of habitat available for a species of concern (USFWS, 1980a,b, USFWS, 1981). In general, a Habitat Evaluation Procedure (HEP) model uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. This process may be used to assess changes associated with different management scenarios for a specific area, or to allow comparison across multiple sites. The HSHEP merges this traditional HEP approach with multi-spatial modeling capabilities for Hawaiian streams (Parham, 2002; Kuamo'o et al., 2006; Parham, 2008). The multi-spatial component addresses issues of scale in understanding differences in habitat availability and species distribution.

A detailed description of the HSHEP model development and design is provided in Attachment 1. The USACE Ecosystem Center of Expertise (ECO-PCX) reviewed this information, and granted approval for its use on the Ala Wai Canal Project on May 19, 2015 (Attachment 2).

2.2 Methodology

Detailed stream and fish surveys to support the HSHEP modeling effort were conducted by aquatic biologists, Dr. James Parham (Bishop Museum) and Glenn Higashi (DAR). As part of this effort, the streams in the Ala Wai Watershed were surveyed, including approximately 8.7 kilometers of Manoa Stream, 1.6 kilometers of Makiki Stream, and 3.7 kilometers of Palolo Stream. The stream surveys were recorded using high-definition video, and the survey data were subsequently processed according to the variables in the HSHEP model. Using the HSHEP model, the habitat suitability was then determined for each of the native aquatic species along approximately each meter of stream; the average suitability was then calculated for defined stream segments. A combination of the habitat suitability and the area of each segment were then used to calculate HUs for each individual species, as well as for the combination of all native species within each segment.

Despite the robust dataset available for native species in Hawaii's streams, there is still some degree of inherent uncertainty in the underlying assumptions used to model habitat quality. In particular, the extent to which in-stream structures restrict upstream migration (e.g., in response to varying flow regimes over time) has not previously been quantified, but has an important bearing on the modeling of upstream habitat quality. As such, the resource agencies requested consideration of different assumptions of species passage, in order to better understand the possible range of resulting habitat quality values. In response to this request, both the "expected scenario" and a "worst-case scenario" were modeled, as described below.

- The "expected scenario" reflects the project team's best professional judgement; it assumes that existing in-stream structures with an overhanging lip create a passage barrier for native species 50% of the time, and channelized reaches reduce passage by 10% for every 100 meters. These assumptions were used as the basis for calculation of the baseline impact and evaluation of mitigation requirements.
- The "worst-case scenario" reflects a more conservative set of assumptions that overhanging structures only allow for passage of native species approximately 35% of the time, and channelized reaches reduce passage by 15%for every 100 meters. This scenario is intended to bound the range of possible conditions, thus providing a basic sensitivity analysis of the model

results. It was used as a means to validate the outcomes of the mitigation development process (that is, to confirm that the mitigation would still adequately compensate for the habitat impacts even with a more conservative set of assumptions).

The model results for the existing and future-without project condition, as well as the conditions based on implementation of the tentatively selected plan are presented below. Application of the model for the mitigation measures is discussed in Section 3.3. Additional detail regarding model application is provided in Attachment 3.

2.3 Model Results

2.3.1 Existing and Future Without-Project Condition

Based on the methodology described above, the HSHEP model was used to determine existing quality of the streams and associated aquatic habitat within the Ala Wai Watershed. The analysis also considered the future without-project condition (i.e., the most likely condition expected to exist in the future in the absence of the proposed project), as this defines the benchmark against which alternative plans are evaluated.

Future changes in watershed and stream conditions have the potential to influence the amount and/or quality of freshwater stream habitat. For example, future watershed improvements could positively influence stream health, thus increasing habitat quality over time. Conversely, continued degradation could reduce the amount and/or quality of stream habitat. Based on the extent of existing urbanization and development within the Ala Wai Watershed, and more specifically along the streams, it is expected that further development will be minimal. Some degree of redevelopment may occur in the neighborhoods throughout the watershed, however this is not expected to substantially affect the physical or biological characteristics of the streams. While there may be some slight changes in localized conditions, the overall species composition and habitat structure is not expected to change dramatically over the period of analysis. Therefore, for the purposes of this analysis, it is assumed that habitat conditions will remain relatively constant over time, such that the HUs associated with the existing and future without-project conditions will be commensurate.

The HUs associated with the existing and future without-project conditions are summarized in Table I; a detailed discussion of the results is provided in Attachment 3.

TABLE 1
Habitat Units Associated with the Existing and Future Without-Project Condition

Location	Habitat Units (HUs)	
	Expected Scenario	Worst-Case Scenario
Manoa Stream	36,713	3S,391
Palolo Stream	1,377	834
Makiki Stream	7,800	7,495
Hausten Ditch	8,681	8,681
Total	**S4,572**	**52,401**

2.3.2 Tentatively Selected Plan

The tentatively selected plan for the Ala Wai Canal Project is comprised of a series of flood risk management measures, including debris and detention basins, debris catchment structures, flood walls, and improvements to the flood warning system. A description of each measure and the estimated area of impact is provided in Table 2. A detailed discussion of the tentatively selected plan (and the plan formulation process) is provided in the Draft Feasibility Report/EIS.

The characteristics of the proposed measures were used to define changes in habitat quality using the HSHEP model, as needed to calculate HUs based on implementation of the tentatively selected plan. Changes in habitat quality associated with implementation of the tentatively selected plan include potential loss of aquatic habitat (e.g., due to placement of structures within the stream) and decreased passage for native aquatic species. As described in Section 3.6 of the Draft Feasibility Report/EIS, design features have been incorporated to avoid and minimize these impacts to the extent practicable (e.g., use of natural bottom arch culverts to maintain species passage); however, some degree of impact is unavoidable. The anticipated changes in habitat conditions were based on professional judgment of the project team, including input from the resource agencies.

Key assumptions that were made as part of the HSHEP modeling of the with-project condition are listed below. The assumptions were discussed and agreed upon with the resource agencies (as part of a meeting with USFWS and DAR on January 23, 2015), and were subsequently refined as part of the model application process.

- The area to be impacted by each measure was defined as the length of stream within the permanent structure footprint plus the area needed for O&M (generally the entire length of stream within the construction limits).
    - The aquatic habitat to be impacted by the Kanewai Detention Basin and the Ala Wai Golf Course Detention Basin is limited to the streambank within the notched spillway footprint.
    - The Ala Wai Canal floodwalls will not result in any impacts to the aquatic environment.
    - Improvements to the flood warning system will involve negligible work in the streams; as such, it is assumed there would be no impact to the aquatic environment.
- To be conservative, it has been assumed that habitat for aquatic species would be entirely eliminated within the permanent footprint of the debris catchment and detention structures (and stand-alone debris catchment structures), but that species passage would be maintained via a natural bottom arch culvert.
    - Within the area to be excavated behind the Waiomao Debris and Detention Basin, a low-flow channel will be reformed and the existing substrate will be replaced following construction. Recognizing that there could be some degree of long-term habitat degradation associated with the excavation (and ongoing vegetation management), it is assumed that there would be an approximately 50% decrease in habitat quality within this area. The "worst-case scenario" assumes 100% loss of habitat within the area to be excavated.
    - An in-stream structure associated with an abandoned USGS gaging station is located within the area to be excavated for the Waiomao Debris and Detention Basin, and will be removed as part of project construction. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat (thereby offsetting some of the habitat losses). This benefit is reflected in the with-project condition.
    - It is assumed that there would be an approximately 20% loss of habitat quality within the reach directly affected by the notched spillways for the Kanewai and Ala Wai Golf Course detention basins. The "worst-case scenario" assumes 100% loss of habitat within these reaches.

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

- The debris and detention structures are not designed to trap sediment (except for the sediment basin at the Ala Wai golf course). Therefore, it has been assumed that there would be no substantial changes in substrate/embeddedness in downstream habitat.
- The inundation area behind each detention structures is not included as part of the impact area. Inundation of the_se areas would be infrequent and short in duration; for example, inundation resulting from the 1%annual chance exceedance (ACE) flood would last less than 12 hours. As such, there are expected to be little to no potential effects to stream habitat and aquatic species.

The results of the HSHEP modeling for the with-project condition are summarized in Table 3; a detailed discussion of the results is provided in Attachment 3 . Based on a comparison of these results to those for the future without-project condition, implementation of the project is expected to result in a loss of 192 HUs as shown in Table 3.

As it is expected that the impacts would be immediately realized following construction of the project features (i.e., there would not be a delay or "compounding" effect on habitat quality over time), it is therefore assumed that habitat conditions would remain constant.over the life of the project.

TABLE 3
Loss of Habitat Units Associated with Implementation of the Tentatively Selected Plan (As Compared to the Future Without-Project Condition)

Location	Habitat Units (HUs)				
	Existing Conditions	With-Project Conditions			Net Loss
		Lost	Gained"	Total	
EXPECTED SCENARIO					
Manoa Stream	36,713	191	0	36,522	191
Palolo Stream	1,377	11	118	1,484	-107
Makiki Stream	7,800	24	0	7,777	24
Hausten Ditch	8,681	84	0	8,597	84
Total	54,572	310	118	54,380	192
WORST-CASE SCENARIO					
Manoa Stream	35,391	808	0	34,584	808
Palolo Stream	834	3	32	863	-29
Makiki Stream	7,495	11	0	7,484	11
Hausten Ditch	8,681	420	0	8,261	420
Total	52,401	1,242	32	51,192	1,210

Note:
• The "expected scenario" reflects the project team's best professional judgement, and serves as the basis for calculation of the baseline impact and evaluation of mitigation requirements. The "worst-case scenario" reflects a more conservative set of assumptions and is intended to provide a basic sensitivity analysis of the model results (to help validate the outcomes of the mitigation development process).
• The anticipated gain of HUs for the with-project condition is associated with removal of an abandoned USGS gaging station within the area to be excavated for the Waiomao Debris and Detention Basin. This in-stream structure is a barrier to upstream passage of native species, and its removal will provide habitat benefits by increasing accessibility to upstream habitat.

3.1 Description of Proposed Mitigation

3.2 Mitigation Objectives

Based on the type of habitat to be impacted, and within the context of the habitat requirements for native Hawaiian aquatic species (as defined in the HSHEP model), the following objectives were developed to guide the mitigation development effort

- Restore and/or enhance physical conditions to improve in-stream habitat for native Hawaiian aquatic species
- Improve passage for native Hawaiian aquatic species to increase access to upstream areas of high-quality habitat

In consultation with the resource agencies, it was determined that application of these mitigation objectives should not be limited to the specific habitat parameters or areas impacted by the project, but rather should be considered within the context of the overall watershed. In other words, the mitigation development process should entail a watershed approach, wherein the conditions throughout the watershed are assessed to identify those habitat parameters and locations where mitigation might provide the greatest benefit for native aquatic species as a whole.

3.2 Mitigation Development Approach

To support the mitigation development effort, a framework was developed based on a series of iterative tasks informed by the stream surveys and HSHEP modeling results. Each task was conducted within the context of the SMART planning approach employed for the overall flood risk management project, as described in the Draft Feasibility Report/EIS. First, as shown in Figure 1 the key stressors and primary factors limiting habitat quality for native aquatic species in the Ala Wai Watershed were broadly defined based on best professional judgment and the results of the stream surveys. This information was used as the basis for identifying potential mitigation concepts, or actions that could be implemented to address the various stressors. Using the HSHEP model results for the existing conditions, these concepts were further refined and applied to site-specific locations. A site visit was conducted for each of the potential mitigation locations to validate and refine the mitigation concept. In addition, other relevant information was gathered, including land ownership and existing channel maintenance activities. This information was then considered as part of a detailed screening process, which involved a comprehensive set of criteria (based on those used for the overall flood risk management project, and tailored to the mitigation effort). Those measures carried forward from the screening process were then combined into various mitigation alternatives that could be implemented to compensate for the habitat impacts associated with the overall flood risk management project. Conceptual design drawings were prepared for the range of mitigation measures/alternatives (to an approximately 10 percent level of design), based upon which cost estimates were developed. In addition, the habitat benefits associated with each alternative were quantified using the HSHEP model. The costs and benefits were then used as inputs to a CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The resource agencies were consulted throughout this process, and their input was incorporated as appropriate. The results of this process are described in the subsequent sections.

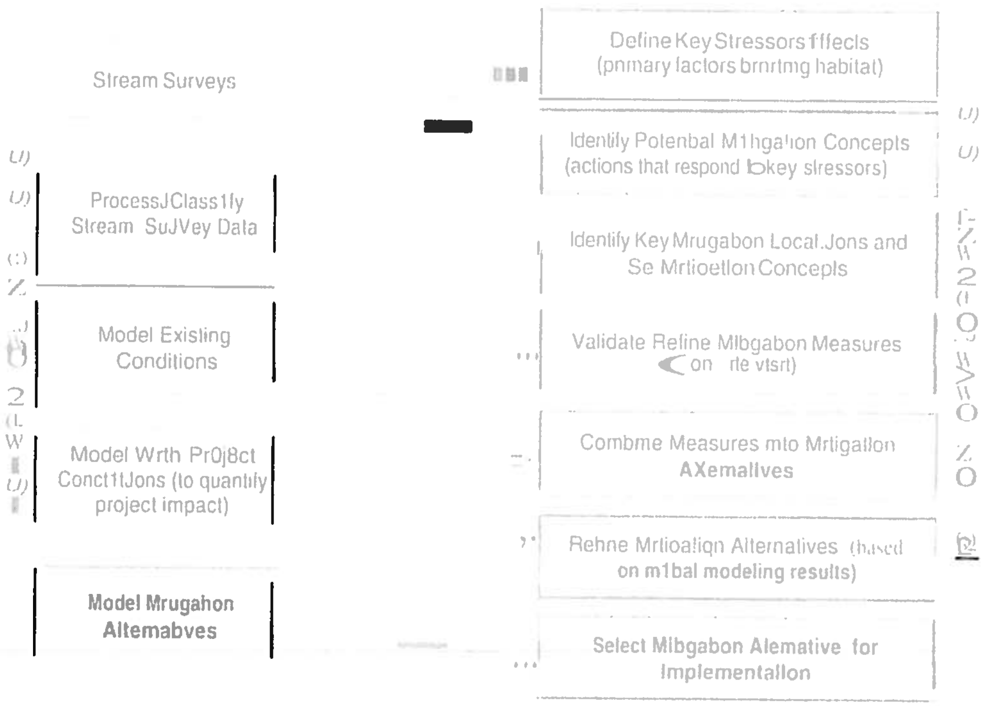


FIGURE 1
Overv ew of the HSHEP Modeling and Mitigation Development Process

3.3 Development of Mitigation Measures/Alternatives

3.3.1 Mitigation Concepts

As described above, the initial list of mitigation concepts was developed in response to the primary factors believed to be limiting habitat quality for native aqu_atic species in the Ala Wai Watershed. this effort was primarily based on best professional judgment and the results of the stream surveys. The list of initial mitigation concepts is provided in Table 4.

It is important to note that there are some stressors that are generally understood to be contributing to degradation of Hawaii s stream habitat and faunal assemblage, but were determined to either be outside the scope of mitigation efforts for this project or are not considered key limiting factors in the Ala Wai Watershed (given other overriding conditions). These include prevalence of invasive aquatic species and inputs of stormwater runoff. Although both of these stressors are common throughout the Ala Wai Watershed. it was determined that the project could result in a limited response to these conditions, and as such, mitigation efforts should focus on key stressors related to physical habitat conditions.

TABLE 4
Initial Mitigation Concepts

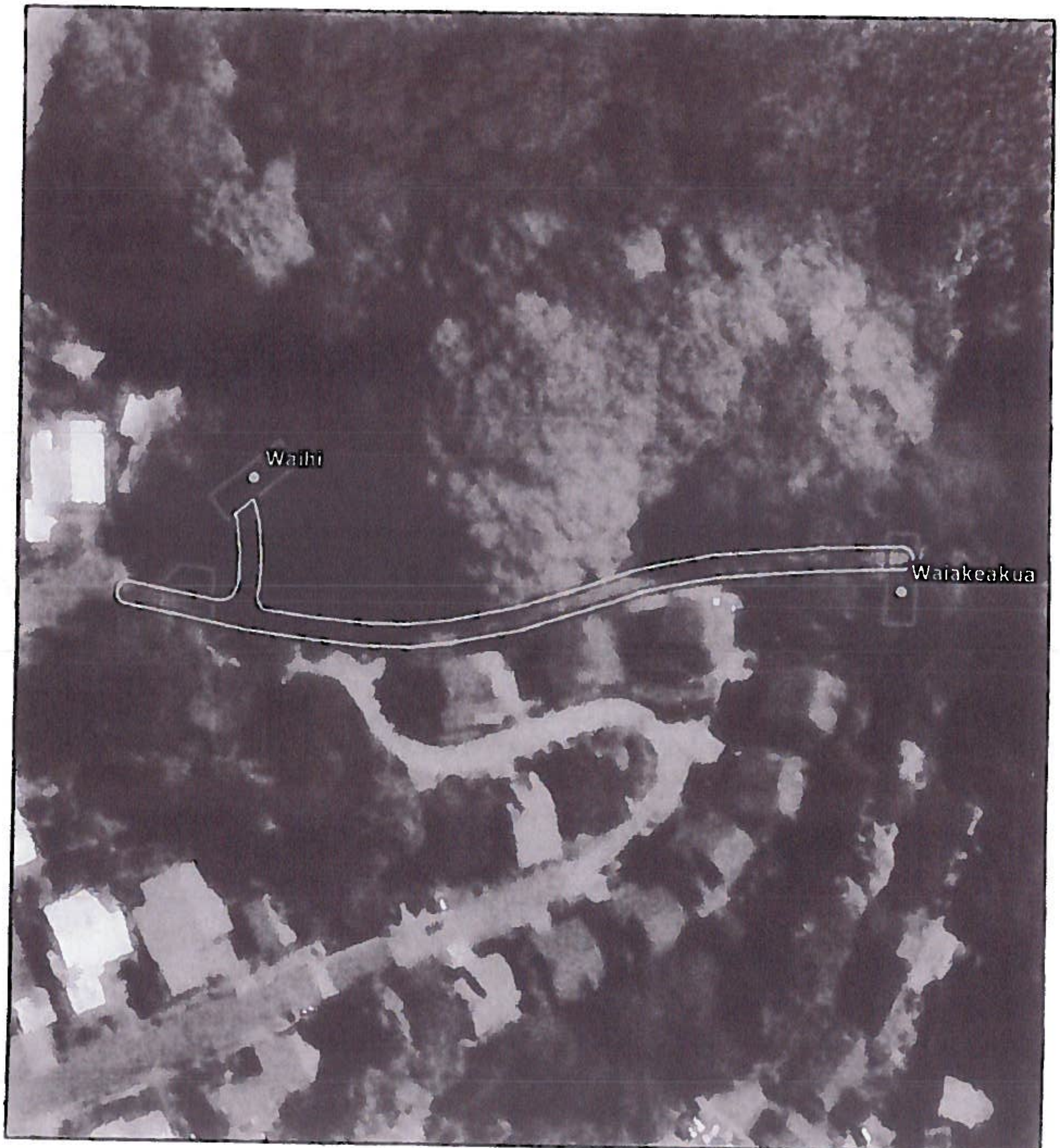
Response to Key Stressors	Mitigation Concept
Improve migratory pathway	Remove passage barrier (e.g., overhung structures)
	Install low-flow channel along channelized reach
	Install resting riffles along channelized reach
Improve in-stream habitat	Add new habitat pools in channelized reach
	Enhance existing in-stream habitat in unchannelized reach
Provide bank stabilization	Stabilize exposed/eroding banks
	Stabilize failing walls
Improve riparian habitat	Restore/enhance riparian habitat

The initial concepts were further reviewed and validated within the context of the HSHEP model source data and preliminary results for the existing habitat conditions. Through this effort, several of the concepts were eliminated from further consideration, as follows:

- **Enhance existing in-stream habitat in unchannelized reach:** Although there are reaches of unchannelized habitat with less than ideal conditions (e.g., degraded channel form, presence of trash, etc.), the results of the stream surveys indicate that these reaches still provide adequate habitat for native aquatic species, especially when compared to channelized reaches. As such, it was determined that enhancement of habitat in unchannelized reaches would not address a key stressor for native aquatic species in the Ala Wai Watershed.
- **Stabilize failing walls:** Although a wall failure could certainly affect in-stream habitat, should one occur, it was determined that stabilization of existing channel infrastructure is more of a channel maintenance issue than a habitat management issue. Therefore, this measure was eliminated from further consideration.
- **Restore/enhance riparian habitat:** Given the heavy urbanization and encroachment of development in the areas directly adjacent to the streams, there is very little opportunity for restoration of the riparian corridor in the Ala Wai Watershed without extensive land acquisition (which is beyond the scope of mitigation for this project). Although dominated by non-native species, the extant riparian habitat is not believed to be key limiting factor relative to in-stream habitat quality for native aquatic species (especially when considered in context with other factors, such as channelization). As such, this measure was also eliminated from further consideration.

3.3.2 Preliminary Mitigation Measures

The remaining mitigation concepts were carried forward for further consideration, and based on the review of the HSHEP model source data and preliminary results, key areas for habitat improvement were identified based on those concepts. This information was used as the basis for siting each of the mitigation concepts in locations where habitat benefits could be maximized. A site visit was conducted for each of the potential mitigation locations to validate and refine the various mitigation concepts. The resulting measures are summarized in Table S, and the locations are shown in Figure 2.



LEGEND
Impact Area Description
construction Limits
Access
Staging

Notes
1 Area of interest subject to change

J

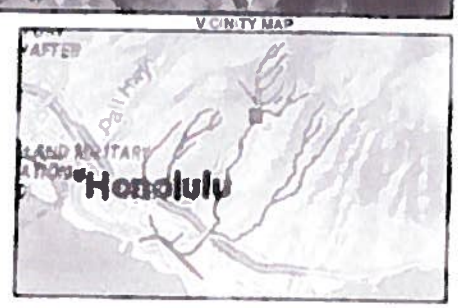
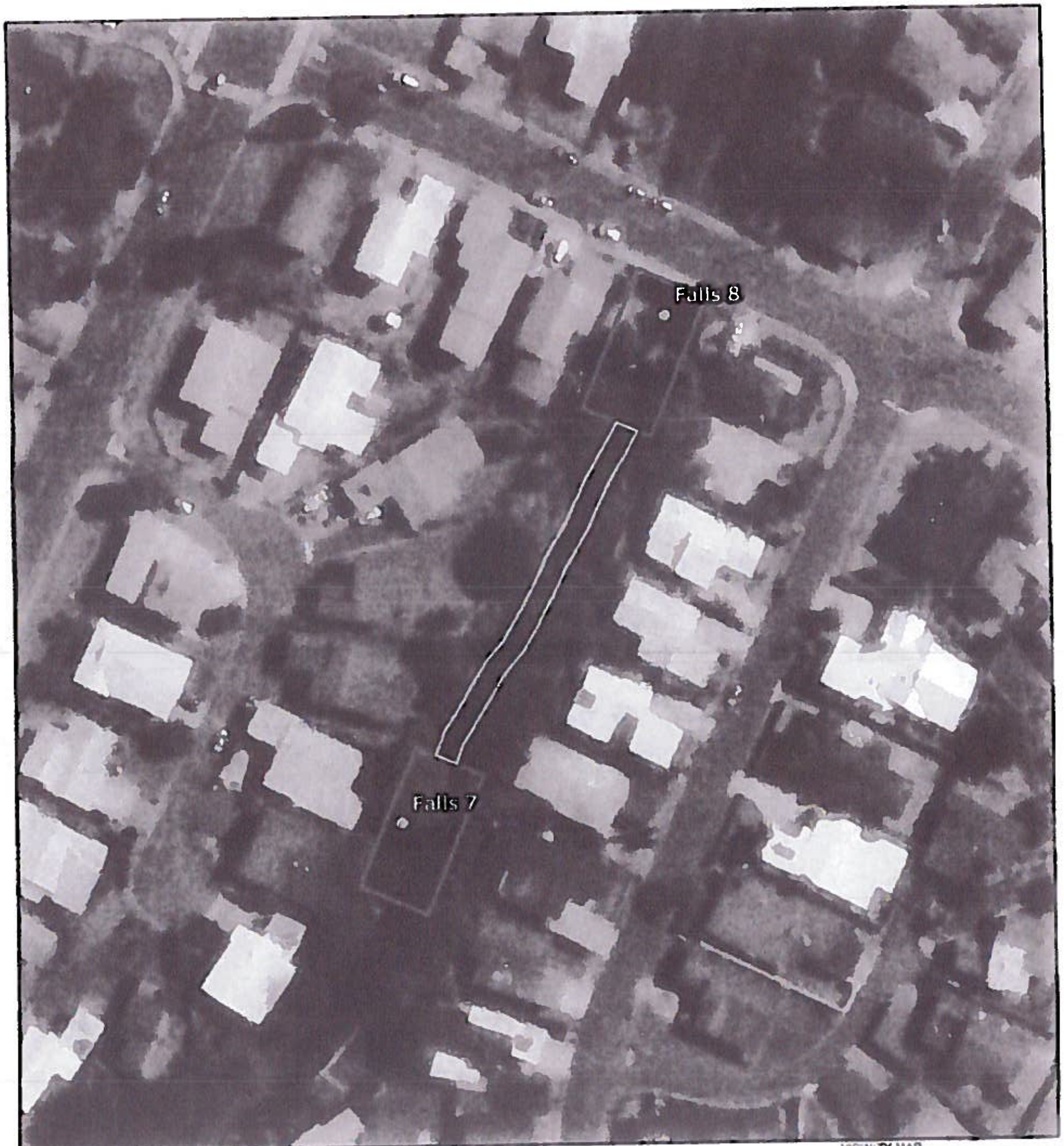


FIGURE 2a
Falls 11 and 12
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL.



LEGEND
Impact Area Description
Construction Limits
Access
Staging

Notes
1 Area of interest subject to change

FIGURE 2b
Falls 7 and 8
Mitigation Measure Impact Areas
Ala Wai Watershed

CH2MHILL.

LEGEND

Impact Area Description

[ ]construction Limits

Access

Staging

Notes

1 Area of interest subject to change

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FIGURE 2c

Manoa Concrete Channel

Mitigation Measure Impact Areas

Ala Wai Watershed

CH2MHILL

TABLE 5
Prel1' m-1narv M1' t'1gation Measures

Mitigation Measure	Location	Description
Remove Passage Barner		
Falls 6	Manca Stream, approximately 0.3 mile upstream of Manca District Park	Remove overhanging lip associated with undercutting at existing utility line crossing
Falls 7	Manca Stream, approximately 0.6 mile upstream of Manca District Park	Remove overhanging lip associated with undercutting at existing in-stream structure
Falls 8	Manoa Stream, approximately 0.7 mile upstream of Manca District Park	Remove overhanging lip associated with undercutting at existing in-stream structure
Falls 11	Waihi Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls 12	Waiakeakua Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Falls PS	Waiomao Stream, at USGS gaging station	Remove overhanging lip associated with undercutting at existing USGS gaging station
Install Low-flow Channel and/or Habitat Pools Along Channelized Reach•		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Palolo Stream	Approx. 1.5 miles of concrete channel through Palaia Valley	Notch low-flow channel and/or habitat pools into concrete and add natural substrate
Install Resting Riffles Along Channelized Reach•		
Manoa Stream	Approx. 1100 feet of concrete channel downstream of Manoa District Park	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Palolo Stream	Approx. 1.5 miles of concrete channel through Palolo Valley	Mount low-profile curbs onto surface of concrete to create pockets of resting habitat
Bank Stabilization		
Manoa Stream	Above Kahaloa Bridge near Manca District Park	Reduce slope and install geotextile fabric and vegetation to stabilize -300 feet of eroding bank

NOTE:
• Installation of a low-flow channel, habitat pools and/or resting riffles was initially considered for the channelized reach of Makiki Stream. However, it was determined that the extensive section of underground channel that is upstream of the channelized reach would severely limit the benefits gained by these measures. As such, these measures were eliminated from further consideration.

3.3.3 Screening and Refinement of Mitigation Measures

In order to ensure that the mitigation measures carried forward for further consideration meet a set of minimum standards, a detailed screening process was conducted. This process utilized a comprehensive set of criteria based on those used for the overall flood risk management project (which were defined within the context of he federal criteria specified in the Engineer Regulation [ER] 1105-2-100; "USACE Planning Guidance Notebook") and tailored to the mitigation effort. The screening criteria that were applied to the mitigation measures are summarized in Table 6.

TABLE 6
Criteria Used to Screen Mitigation Measures

Criteria	Description
Technical feasibility	Is it feasible/viable to construct measure?
Application in Hawaii	Has the measure been successfully applied in Hawaii?
Compatibility/Dependency	Is the measure dependent on another action to be functional?
Flood reduction	Does measure substantially increase potential for flooding?
Implementation cost*	What is the ROM cost to construct the measure?
Cost effectiveness*	Is the habitat gain worth the cost?
Land availability and ownership	Is there enough space to implement measure (including staging/access?)
	Is the land owned by State/C&C or a few private landowner?
	Can real estate rights be reasonably obtained?
O&M requirements	What is the estimated level of effort (need for new practice/equipment)?
	Would the measure conflict with existing O&M practices?
Acceptability	Will the measure displace people/activities? It is legally acceptable?
Biological resources	Would the measure adversely affect any known sensitive biological resources?
	Would the measure increase the potential for passage of non-native (invasive) species?
Historic/archaeological resources	Would the measure adversely affect any known historic/archaeological resources?
Sediment contamination	Would the measure be located in an area with known (or high potential for) sediment contamination?

NOTE:
* Recognizing that the purpose of the CE/ICA is to provide a quantifiable basis for evaluation of cost-effectiveness, the criteria related to implementation cost and cost- effectiveness were used to screen out measures that were considered to be excessively expensive or ineffective, so as to focus the mitigation development effort on reasonable and practicable mitigation solutions, consistent with the SMART planning approach.

The information required to complete the screening process was subsequently compiled, including consultation and coordination with State and County agencies, and other entities as needed. This effort resulted in the elimination of the measures listed below; the detailed screening results are contained in Attachment 4. In addition, based on additional information obtained through consultation, it was determined that two of the measures were no longer warranted, such that they were also eliminated from further consideration, as listed below.

- **Remove Passage Barrier at Falls 6:** Based on coordination with the City & County of Honolulu, it was determined that the Department of Facilities Maintenance (DFM) is in the process of resolving the erosion and undercutting associated with this structure . The design effort has been completed and the proposed design is expected to adequately address fish passage requirements; therefore, this measure was eliminated from further consideration (and instead is reflected in the future without-project conditions) .
- **Remove Passage Barrier at Falls PS:** The specific location of this structure was verified based on the stream survey data, and was determined to be within the footprint of the excavation area for the Waiomao Debris and Detention Basin. It was confirmed that the

structure would be removed as part of construction of the debris and detention basin such that the mitigation measure was eliminated from further consideration (and instead is reflected in the with-project condition).

- **Install Low-Flow Channel, Habitat Pools and/or Resting Riffles Along Channelized Portion of Palolo Stream:** Based on initial review of the real estate requirements, it was determined that this measure involved a multitude of property owners, and obtaining the real estate rights would require extensive coordination and would be cost-prohibitive. Therefore these measures were eliminated from further consideration.

The remaining measures were carried forward for further consideration as part of the identification of mitigation alternatives

3.3.4 Conceptual Design of Mitigation Measures

For the measures carried forward from the screening process, conceptual design drawings were developed to a 10 percent level of design. This effort incorporated the best available information and collective knowledge of the habitat requirements for native aquatic species; it also considered lessons learned from other past projects and input from the resource agencies. Key design considerations are discussed below.

The passage barrier removal design was based on previous passage barrier removal efforts completed by DAR (and others) on Waihe'e Stream (see Figure 3). Based on information gained from this successful effort, the measure would restore a near vertical surface to the face of the existing in stream structure, which is expected to allow for native aquatic species passage, while deterring upstream passage of non-native species. It would be comprised of non-systematic placement of grouted stones that would mimic natural stream features and allow multiple pathways for water flow.

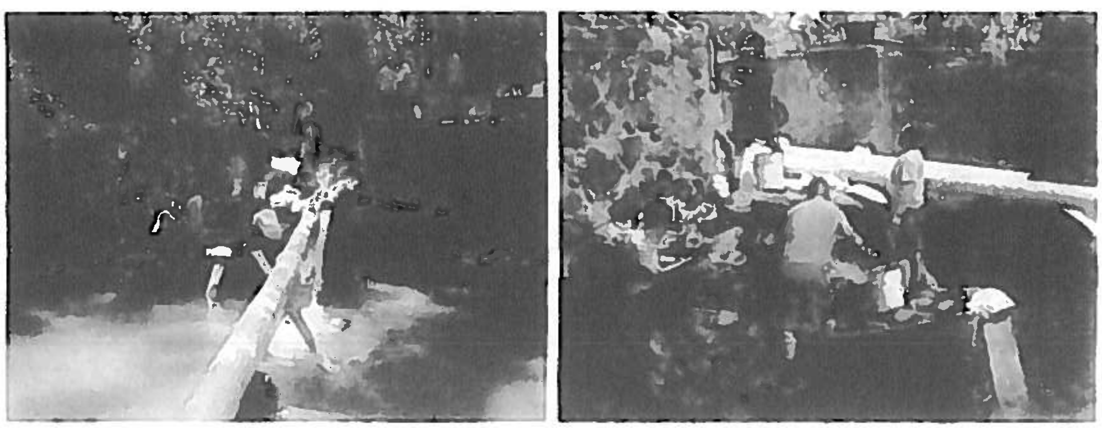

FIGURE 3
Previous Passage Barrier Removal Efforts on Waihe'e Stream (photos provided by Glenn Higashi [DAR])

The design for installation of in-stream habitat and passage within the channelized reach of Manoa Stream incorporates design features and dimensions based on best professional judgment regarding native species habitat requirements. Specifically, the conceptual designs assume that up to 6 inches of water is required to maintain passage (e.g., for the resting riffles), and at least 18inches of water is needed to provide in-stream habitat (e.g., for the habitat pools and low flow channel); the dimensions and spacing of these features reflects characteristics of natural stream habitat. Passage and/or habitat would be installed over the full 1,100feet of the channelized reach in Manoa Stream given the mitigation objectives, shorter increments were not considered

The 10-percent design drawings for each of the mitigation measures carried forward from the screening process are contained in Attachment 5.

3.3.5 Identification of Mitigation Alternatives

Based upon the 10-percent design concepts, the mitigation measures were then combined into alternatives that could be implemented to adequately compensate for the habitat impacts associated with the overall flood risk management project. Specifically, this effort sought to identify alternatives comprised of measures that either alone or in combination would provide a gain of HUs equal to or greater than the loss of HUs anticipated from implementation of the tentatively selected plan, thus compensating for the loss of habitat quality associated with project implementation. Recognizing that there are many possible measure combinations, consistent with SMART planning principles, a focused number of alternatives were defined based on estimated habitat benefits and functionality, as discussed below.[2]

Given the limited passage allowed by existing in-stream barriers, removal of a barrier is expected to provide little to no benefit to native aquatic species if downstream barriers are still in place. Therefore, the alternatives were formulated to only include combinations of barrier removal starting at the furthest downstream barrier (i.e. Falls 7) and moving upstream. Possible alternatives involving removal of upstream barriers with downstream barriers still in place were not considered (e.g., Falls 8, 11 and/or 12). As Falls 11 and 12 are located on separate tributaries to Manoa Stream, they were combined with Falls 7 and 8, both in parallel and together. As preliminary analyses indicated that the concrete channel improvements were not cost effective, they were not considered in combination with any other measures. Based on these concepts, the following alternatives were identified:

- Remove passage barrier at Falls 7
- Remove passage barriers at Falls 7 and 8
- Remove passage barriers at Falls 7, 8 and 11
- Remove passage barriers at Falls 7, 8, and 12
- Remove passage barriers at Falls 7, 8, 11 and 12
- Install low-flow channel in concrete portion of Manoa Stream
- Install habitat pools in concrete portion of Manoa Stream
- Install resting riffles in concrete portion of Manoa Stream

Cost estimates were prepared for each alternative based on the conceptual design drawings. In addition, the habitat benefits were determined for each alternative, based on the HSHEP model outputs. The results of these efforts were then used to support the CE/ICA, which provided the basis for selection of the mitigation alternative for implementation. The results of this process are described in the subsequent sections.

3.4 Evaluation of Mitigation Alternatives

3.4.1 Habitat Benefits

Using the same methodology as described in Section 2, the HSHEP model was used to quantify the HUs associated with the various mitigation alternatives; the results are summarized in Table 7. As shown in Table 7, the mitigation alternatives involving removal of passage barriers provide a

[2] Although the CE/ICA software allows for all possible measure combinations to be automatically generated based on the cost and benefit of each measure, the benefits for the passage barrier removal measures are not additive, thus requiring the HSHEP model to be run for each individual measure combination.

significant increase in HUs relative to the concrete channel improvements. Despite the relatively small footprint of the barrier removal measures, the large gain of HUs reflects the overall extent of upstream habitat that would be made available to migrating native species. In contrast, the improvements along the channelized reach of Manoa Stream would only affect a relatively small, localized area.

However, in all cases, the mitigation alternatives would provide substantially more HUs than needed to offset the impacts of the flood risk management project. Because the flood risk management measures would only affect in-stream habitat within the footprint of the proposed flood risk management structures (with no anticipated impacts to species passage), a relatively small number of HUs are expected to be lost. Although the mitigation benefit would far exceed the impact of the proposed project, the mitigation alternatives reflect a reasonable range of options to improve instream habitat for native species, based on the best professional judgment of the project team. Despite the large number of HUs provided relative to the anticipated project impact, the estimated costs and level of effort of the mitigation alternatives is within the range that is appropriate for the scale and level of detail available for the proposed flood risk management project. Although different mitigation options or smaller-scale efforts that would result in fewer HUs (i.e. an increase in HUs more commensurate with the number of HUs lost) could certainly be identified, these would not address the key habitat needs identified for native aquatic species in the Ala Wai Watershed.

TABLE 7
Gain of Habitat Units Associated with Implementation of Mitigation Alternatives (As Compared to the With-Project Condition

Location	With-Project (HUs Lost)	Mitigation Alternatives (HUs Gained)							
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EXPECTED SCENARIO									
Manoa Stream	191	1,353	3,870	5,456	6,082	7,668	1,292	1,214	1,207
Palolo Stream	-107	0	0	0	0	0	0	0	0
Makiki Stream	24	0	0	0	0	0	0	0	0
Hausten Ditch	84	0	0	0	0	0	0	0	0
Total	**192**	**1,353**	**3,870**	**5,456**	**6,082**	**7,668**	**1,292**	**1,214**	**1,207**
WORST-CASE SCENARIO									
Manoa Stream	808	803	2,817	4,457	5,105	6,745	1,299	1,225	1,219
Palaia Stream	-29	0	0	0	0	0	0	0	0
Makiki Stream	11	0	0	0	0	0	0	0	0
Hausten Ditch	420	0	0	0	0	0	0	0	0
Total	**1,210**	**803**	**2,817**	**4,457**	**5,105**	**6,745**	**1,299**	**1,225**	**1,219**

3.4.2 Cost Estimates

An estimate of the implementation costs was developed as a bottom rolled-up type estimate at the conceptual (10 percent) design level, using FY2014 unit prices. In addition to the estimated costs, the CE/ICA also considers the O&M costs, as these are considered necessary to achieve the habitat benefits over the lifetime of the project. The estimated costs for each mitigation alternative is summarized in Table 8. Annualization of these costs, as needed to support the economic analysis is included in Attachment 6.

TABLE 8

Summary of Estimated Costs for MitiQation Alternatives (FY2014 Price Level)

Cost Component [1]	Falls 7	Falls 7 and 8	Falls 7, 8 and 11	Falls 7, 8 and 12	Falls 7, 8, 11and 12	Low-Flow Channel	Habitat Pools	Resting Riffles
Construction	$67,869	$132,848	$169,801	$170,544	$207,498	$798,018	$172,393	$178,294
Real Estate	$15,900	$27,100	$32,700	$29,300	$34,900	$4,500	$4,500	$4,500
Pre construction Monitoring	$9,2.50	$9,250	$9,250	$9,2.50	$9,2.50	$9 250	$9,250	$9,2.50
Post-construction Monitoring	$76,2.50	$76,250	$76,2.50	$76,2.50	$76,2.50	$76,2.50	$76,2.50	$76,2.50
O&M	$2,9,467	$45,712	$67,450	$67,636	$76,874	$92,301	$55,599	$57,074
Interest During Construction	$1,491	$2,.918	$3,729	$3,746	$4,557	$17,52.6	$3,786	$3,916
Contingency	$40,300	$60,118	$73,889	$74,116	$85,387	$239,055	$72,180	$73,980
Total Estimated Cost	$2,40,52.6	$354,197	$433,070	$430,841	$494,715	$1,236,900	$393,958	$403,2.64

NOTES:

[1] Based on FY2014 (October 2013) price levels) and 3.5% discount rate; to be updated prior to Final Feasibility Report/EIS.

'Assume contingency equal to 25.5% of the construction cost plus 20% of the pre-construction monitoring, post-construction monitoring, andOMRR&R costs

3.4.3 Cost Effectiveness and Incremental Cost Analysis (CE/ICA)

As specified in the USACE regulations, the outputs of ecosystem restoration are not monetized, as is required for traditional benefit-cost analyses. Rather, evaluation of alternative restoration plans considers the relationship of habitat benefits to project costs to identify the most cost-effective plans for various levels of restoration output and provide a basis for determining whether increasing levels of restoration output are worth the added cost.

The evaluation process includes two distinct analyses to identify cost-effective and incrementally justified plans. First, the cost effectiveness analysis is conducted to identify which alternative plans have output levels that cannot be produced more cost effectively by another plan. "Cost effective" means that, for a given level of output, no other plan costs less, and no other plan yields more output for less money. Subsequently, through the incremental cost analysis, the range of plans is evaluated to arrive at a "best" level of output. The subset of cost effective plans are examined sequentially (by increasing scale and increment of output) to ascertain which plans are most efficient in the production of restoration benefits; these are referred to as "best buy plans." They provide the greatest increase in output for the least increase in cost. That is, they have the lowest incremental cost per unit of output. The incremental analysis will not necessarily identify an optimal plan; rather, there may be a series of best buy plans. In this case, the results must be synthesized with other decision-making criteria (for example, acceptability, completeness, effectiveness, reasonableness of costs, risk and uncertainty) to provide the basis for selection of a particular plan.

The IWR Planning Suite software (IWR Plan version 1.0.11.0) was used to conduct the CE/ICA for this project. Inputs to the CE/ICA included average annual habitat units (AAHUs) and estimated average annual cost (AAC), which are calculated based on the benefits and costs (as presented in

Tables 7 and 8, respectively) averaged over the SO-year period of analysis. As previously noted, the analysis was based on the "expected scenario."

As listed in Table 9, the results of the CE/ICA indicate that the following mitigation alternatives are cost-effective: No Action; Falls 7; Falls 7 and 8; Falls 7, 8 and 12; and Falls 7, 8, 11 and 12. Only Falls 7, 8, 11 and 12 and the No Action Alternative are considered best buy plans. A detailed discussion of the CE/ICA and the results are provided in Attachment 6.

TABLE 9
CE/ICA Results

Alternative	Estimated Cost for CE/ICA [1,2]	AAC	AAHUs	Cost-Effective	AAC/ AAHU	Best Buy?	Incremental Cost of BB Plan over Last BB Plan	Incremental Output of BB Plan over Last BB Plan	Incremental Cost/Output of Best Buy Plan
No Action	$0	$0	0	Yes	-	Yes	-	-	-
Resting Riffles	$403,264	$15,105	1,195	No	$12.64	No	N/A	N/A	N/A
Habitat Pools	$393,958	$14,753	1,202	No	$12.27	No	N/A	N/A	N/A
Low-Flow Channel	$1,236,900	$49,564	1,279	No	$38.75	No	N/A	N/A	N/A
Falls 7	$240,526	$9,014	1,340	Yes	$6.73	No	N/A	N/A	N/A
Falls 7 and 8	$354,197	$13,362	3,831	Yes	$3.49	No	N/A	N/A	N/A
Falls 7, 8 and 11	$433,070	$16,101	5,401	No	$2.98	No	N/A	N/A	N/A
Falls 7, 8 and 12	$430,841	$16,000	6,021	Yes	$2.66	No	N/A	N/A	N/A
Falls 7, 8, 11 and 12	$494,715	$18,440	7,591	Yes	$2.43	Yes	$19,102	7,783	$2.45

NOTES:
[1] The estimated costs utilized for CE/ICA are equal to the investment costs plus future costs, in present value terms. For each alternative, the investment costs include construction, real estate, PED, and construction management; future costs include post-construction monitoring and O&M.
The costs for the mitigation alternatives all fall within the estimated cost that is currently assumed for the tentatively selected plan, as described in the Cost Engineering Appendix.

3.5 Selection of Mitigation Plan

While the selected alternative need not be a best buy plan for the purposes of mitigation, it must be cost-effective; other decision-making criteria may include acceptability, completeness, effectiveness, reasonableness of costs, and risk and uncertainty. As summarized in Table 9, four of the passage barrier removal alternatives are cost-effective; only Falls 7, 8, 11 and 12 is a best buy plan (along with the No Action alternative).

Although Falls 7 alone is cost-effective, there is some degree of risk and uncertainty that this alternative would not adequately meet the required mitigation burden. Although there is assumed to be some degree of existing passage through Falls 8 (such that the habitat model indicates an adequate gain of HUs for removal of Falls 7 under the "expected scenario"), there is inherent risk in this assumption, such that it is possible that there is little to no existing passage through Falls 8. Based on this assumption, removal of Falls 7 alone would only measurably increase access to the approximately 100 meters of in-stream habitat between Falls 7 and Falls 8, and would not adequately meet the mitigation burden (as indicated by the "worst-case scenario").

Furthermore, the incremental cost per habitat unit (AAC/AAHU) drops significantly with the addition of Falls 8, such that substantially more benefits would be realized for a relatively small increase in cost. As shown in Table 9, the incremental cost of implementing Falls 7 is $6.73 per unit output, but is only $3.49 for Falls 7 and 8. Given the proximity of these features and the nature of the required work, the added cost of addressing Falls 8 is minimal, but the added benefit would be substantial (as a much greater extent of upstream habitat would be made available) . Although the incremental cost of adding Falls 12and/or Falls 11and 12is even lower ($2.66 and $2.43, respectively), these alternatives provide an excessive amount of habitat benefit relative to the project impacts, that the project team determined these were not worth the added cost.

These considerations, which are consistent with the USACE's Environmental Operating Principles [3] (USACE, 2012), were used the project team as the basis for selection of Falls 7 and 8 as the selected mitigation alternative for the project.

4.1 Monitoring and Adaptive Management

As specified in the guidance, monitoring includes the systematic collection and analysis of data that provides information needed to assess project performance, determine whether ecological success has been achieved, or whether adaptive management may be needed to attain project benefits The monitoring plan should include a descript on of the monitoring activities, the criter ia for success and the estimated cost and duration of the monitoring (recognizing that monitoring should continue until such time as the Secretary determines that the success criteria have been met).

A preliminary description of these items is provided below. It is expected that this information would continue to be refined as the detailed designs are further refined, and the monitoring plan would be finalized during the next phase of the project.

4.2 Monitoring Approach and Activities

In order to capitalize on the detailed baseline data and comprehensive approach to quantifying aquatic habitat quality, monitoring of the mitigat on efforts would involve repeated stream and fish surveys, w ith analysis as part of the HSHEP model. The information gathered as part of these efforts directly relate to the mitigation objectives, which focus on the physical in-stream habitat conditions and passage for native species. Specifically, the stream surveys would record the physical in-stream conditions, with the HSHEP model outputs translating those conditions into habitat quality for native aquatic species . The fish surveys would directly measure the presence and abundance of native species along the stream gradient, particularly in reaches where passage has been restored. Consideration of these data relative to the HSHEP model results would help to correlate species presence/abundance with habitat quality and passage Direct comparison with the baseline conditions data (and each subsequent year of monitoring data) would also allow for a clear understanding of the change in conditions over time

4.3 Performance Criteria

Performance criteria represent the desired conditions to be achieved by the end of the performance monitoring period, as needed to determine project success . To the extent possible, performance criteria should be SMART (specific, measurable, achievable , relevant, and time-bound), and include target values and ranges, as appropriate, accounting for natural variability and management actions

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[3] In particular, the USACE's Environmental Operating Principles direct the USACE to "create mutually supporting economic and environmentally sustainable solutions,' as well as to consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs "

The proposed criteria are summarized in Table 10; specific quantities for these criteria would be developed as part of the final design phase.

TABLE 10
Performance Standards and Monitoring Requirements

Mitigation Objective	Performance Criteria	Monitoring Approach
Restore and/or enhance physical in-stream conditions to improve habitat for native Hawaiian aquatic species	Increased habitat units (HSHEP) ; specific quantification to be determined in final design phase	Stream surveys with HSHEP model
Improve passage for native Hawaiian aquatic species to upstream areas of high-quality habitat	Increased presence (either in total, or as a percentage) of native species in upper reaches, specific quantification to be determined in final design phase	Fish surveys with species counts

4.4 Analysis and Reporting

To provide the basis for evaluating project performance, the data collected as part of the above-described monitoring efforts would be compiled and analyzed. The analysis would use the performance criteria to evaluate whether the mitigation measures are achieving restoration success The results of the analysis would be presented in a report; a report would be produced annually for each year that monitoring is conducted (see Section 4.5 for a discussion of the monitoring schedule). After the final year of monitoring, assuming the performance criteria have been met, the project sponsors would be responsible for preparing a close-out report.

In the event that the evaluation indicates that the project has not met the performance criteria, the project sponsors would consider implementation of adaptive management actions as needed to attain the ecosystem objectives for the project. Considerations for the adaptive management approach are discussed below.

4.4 Adaptive Management

Adaptive management is a structured process of learning and using newly-acquired knowledge to adjust and improve project implementation. The adaptive management process promotes flexible decision-making as outcomes from management actions are better understood. This approach helps to reduce the risk of not achieving ecosystem restoration goals. Implementation guidance for WRDA 2007 specifies that an adaptive management plan should be developed for all ecosystem restoration projects. Specifically, the information generated by the performance monitoring, as described above should be used by the project sponsors to guide decisions relative to operational or structural changes that may be needed to ensure that the ecosystem restoration project meets the success criteria. This decision-making process may depend on a number of variables, including the timing and/or spatial scale of the performance issue, the urgency with which the issue must be addressed, and/or the type of adjustment that is needed to respond to the issue. The guidance specifies that if an adjustment is anticipated due to high uncertainty in achieving the desired outputs/results, the nature and cost of such actions should be explicitly described as part of the decision document and expressed in each of the monitoring reports as they are performed.

To evaluate the adaptive management measures that may be required for the proposed project, the potential risk and uncertainty relative to achieving the performance standards was assessed and potential adaptive management measures were identified. Specific measures that were considered included changes to project-related conditions, as well as external factors. As part of the assessment, the extent to which these adaptive management measures could address the potential deficiencies was considered.

In general, this assessment concluded that there is little risk that the structural components of the mitigation actions would require modification, such that the adaptive management does not need to account for physical changes to the in-stream structures. Similar efforts to eliminate passage barriers have been conducted on Oahu with high levels of success, and the proposed mitigation design would build upon these efforts. Structural repairs to address erosion and/or settlement that might occur over time would be covered as part of standard O&M. In terms of achieving the performance standards, the primary risk that was identified is associated with increased abundance and predation by non-native aquatic species. As previously described, prevalence of non-native species is not currently believed to be a key limiting factor for native aquatic species in the Ala Wai Watershed (given the overall habitat conditions); however, to the extent that the monitoring results indicate that this may be the case in the future, the adaptive management approach for the project incorporates non-native species removal. It is assumed that this effort would be similar to those previously conducted by the State of Hawaii DAR staff (assumed to cost approximately $30,000); any adaptive management costs incurred during the monitoring period would be cost-shared with the non-federal sponsor.

4.5 Monitoring Schedule

The implementation guidance for Section 2039 of WRDA 2007 specifies that monitoring would be initiated upon completion of construction, and should continue until ecological success has been documented; the law allows for but does not require a 10-year cost-shared monitoring plan. If monitoring is required beyond the 10-year period, it would be the responsibility of the non-federal sponsor. Based on the nature of the proposed mitigation measures, it is assumed that monitoring would be conducted annually over a 5-year period, which would start upon completion of construction.[4] The exact timing of monitoring would be determined in the final design phase.

4.6 Responsibilities and Cost

Consistent with the requirements of WRDA 2007, the cost of monitoring would be included as part of the total project costs and be cost-shared, with 65 percent of the costs paid by USACE and the other 35 percent paid by the State of Hawaii, as the non-federal sponsor. The estimated cost for the proposed monitoring activiies is summarized in Table 11. Any additional post-construction monitoring past the designated monitoring period would be entirely the responsibility of the non-federal sponsor. As the non-federal sponsor, the State of Hawaii would also be responsible for O&M activities for the mitigation measures implemented as part of the tentatively selected plan.

TABLE 11
Estimated Monitoring Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Stream and fish surveys	Assumes a total of 20 person-days per monitoring event	$5,000
Data processing	Assumes a total of 5 person-days per monitoring event	$1,250

4 In many cases, pre project monitoring is conducted as needed to establish the basis for measuring restoration success. It is assumed that a single pre monitoring event would be conducted prior to construction.

TABLE 11
Esr1mated Moni·1on.nQ Costs

Parameter	Estimated Level of Effort (Per Monitoring Event)	Approximate Cost
Analysis and reporting	Assumes a total of 10 person-days per monitoring event; assumes $500 in expenses per monitoring event	$3,000
Total (per monitoring event)		$9,250
Project Total (assuming 5 monitoring events)		$46,250

NOTE: Assumes $250 in labor charges per person-day.

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APPENDIX E – REPORT ON UPDATING THE SPREADSHEET RESULTS FOR THE HAWAIIAN STREAM HABITAT EVALUATION PROCEDURE (HSHEP) ASSOCIATED WITH THE STREAMS IN THE ALA WAI CANAL FLOOD RISK MANAGEMENT STUDY, JULY 12, 2016, JAMES E. PARHAM.

Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study.

7/12/2016

Submitted to:

Michael D. Wyatt, POH

US Army Corps of Engineers

Honolulu, Hawaii

Submitted by:

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Introduction:

The Hawaiian Stream Habitat Evaluation Procedure (HSHEP) was used to estimate current conditions and project impacts for proposed actions in Manoa, Makiki, and Palolo Streams associated with the Ala Wai Canal Flood Mitigation Project. The application of the model was based on extensive field surveys within the streams as well as stream surveys statewide. To estimate project impacts, the designs of the flood mitigation projects were used as defined at the time. As the project has advanced, changes to the design specification occurred in response to overall project review. This report documents changes to the original HSHEP model which reflect the new project design specifications.

In addition to this report, an updated spreadsheet of the results and GIS shapefiles of the newly defined segments has been provided to the US Army Corps of Engineers (USACE).

Methods:

Several steps needed to be completed to update the spreadsheet to allow the new changes to be reflected in the results:

1. New stream segments associated with the updated plans were created in ArcGIS 10.2.
2. The new segments had their instream habitat conditions associated with them from the prior model.
3. The new segments had the habitat suitability for the native instream biota associated with them from the prior model.
4. The impacts of the new design specification changes were reviewed and criteria were determined for them.
5. All of these changes were updated into the HSHEP spreadsheet and new impacts were determined for the current conditions and eight different mitigation scenarios.

The following further describes the steps:

<u>Development of New Stream Segments:</u>

The USACE provided PDF copies of the new flood mitigation projects sites (Appendix 1) and associated GIS shapefiles. In addition to the drawings, a spreadsheet of the changes was also provided (Appendix 2). Some additional guidance to understanding the changes was also provided by USACE in an email discussion.

Primarily, there were three changes associated with the new plans:

1. The addition or expansion of an upstream excavation area,
2. the replacement of the open bottom arch culverts with box culverts, and
3. the addition of downstream riprap scour protection areas.

These changes were not found at all sites and impacted different amounts of the stream channel. To create the new stream segments, the old stream segments were split and redefined based on the GIS shapefiles to reflect the new designs. At all five sites, all three types of plan changes were included within the model (Figure 1). When the project did not call for one of the changed types, a segment with zero length was included in the model. This was done for consistency of approach and for flexibility in modeling possible future changes to the plans. Stream segment code numbers were modified to clearly identify the site changes.

30	28	Manoa	Manoa	
31	29	Manoa	Manoa	
32	30	Manoa	Manoa	
33	31	Manoa	Manoa	
34	32	Manoa	Manoa	
35	50	Manoa	Waiahi	
36	51	Manoa	Waiahi	
37	52	Manoa	Waiahi	
38	53	Manoa	Waiahi	Waiahi Detention Basin
39	54	Manoa	Waiahi	
40	55	Manoa	Waiahi	
41	56	Manoa	Waiahi	
42	61	Manoa	Unnamed off Waiahi	
43	80	Manoa	Luaalaea	
44	81	Manoa	Luaalaea	
45	82	Manoa	Luaalaea	Waiakeakua Detention Basin
46	83	Manoa	Luaalaea	
47	90	Manoa	Waiakeakua	
48	100	Manoa	Luaalaea	
49	110	Manoa	Luaalaea	
50	120	Manoa	Nanipapo	

1	29	Manoa	Manoa		Barrier: Falls 7
	30	Manoa	Manoa		Barrier: Falls 8
	31	Manoa	Manoa		
	32	Manoa	Manoa		
	50	Manoa	Waiahi		
36	51	Manoa	Waiahi		Barrier: Falls 11
3	52	Manoa	Waiahi		
38	5301	Manoa	Waiahi	Waiahi Detention Basin Scour	yes
3'	5302	Manoa	Waiahi	Waiahi Detention Basin	box
40	5303	Manoa	Waiahi	Waiahi Detention Basin Excavation	no
41	54	Manoa	Waiahi		
42	55	Manoa	Waiahi		
4	56	Manoa	Waiahi		
44	61	Manoa	Unnamed off Waiahi		
4	80	Manoa	Luaalaea		
46	81	Manoa	Luaalaea		Barrier: Falls 12
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavation	no
50	83	Manoa	Luaalaea		
51	90	Manoa	Waiakeakua		

Overall Summary&Impacts SegmentInfo HSI Current(I)

Figure 1. Screen capture of Segment Info pages in old (left) and updated (right) HSHEP model result spreadsheets showing the creation of the new segment identification numbers.

<u>Associating Habitat Availability and Habitat Suitability to the New Segments from Prior Model Information</u>:

A similar process was used to associate the information from the HSHEP model with the newly defined stream segments. Given the short turnaround time allowed for this update, a complete redo of all stream segments within the model was not done. The new stream segments were reviewed against the model data for each segment and the appropriate data was included in the spreadsheet defining the results. As a result of this approach, there are small differences in some of the nearby segments that result in small changes to the overall habitat units within the model (54,572 HU in original model vs 54,458 HU in the new model). These changes are minuscule (0.209 % difference between models) and are unlikely to affect the overall conclusions for appropriate mitigation actions.

When reviewing the data for the new stream segment information, the original detention basin and upstream area were associated with the new detention basin footprint and upstream excavation area and the downstream riprap scour protection area was associated with the immediate downstream segment. In some cases, the new project site footprints included more than one downstream or upstream segment and in these cases the appropriate information was applied from all affected stream segments. The exact linear measurements for each area were determined from the associated spreadsheet information provided by USACE and included within the model spreadsheet (Figure 2). This allowed for some discrepancies between GIS data sources while capturing the specifics of the new project designs.

	A	B	C	D	E	S	T	U	V	W
43	56	Manoa	Waiahi			567	15	90%	4	2333
44	61	Manoa	Unnamed off Waiahi			531	15	90%	4	2184
45	80	Manoa	Luaalaea			191	34	90%	9	1768
46	81	Manoa	Luaalaea		Barrier: Falls 12	12	24	90%	7	80
47	8201	Manoa	Luaalaea	Waiakeakua Detention Basin Scour	yes	46	24	90%	7	306
48	8202	Manoa	Luaalaea	Waiakeakua Detention Basin	arch	61	27	90%	8	458
49	8203	Manoa	Luaalaea	Waiakeakua Detention Basin Excavati	no	0	25	90%	7	0
50	83	Manoa	Luaalaea			38	25	90%	7	261
51	90	Manoa	Waiakeakua			864	15	90%	4	3557
52	100	Manoa	Luaalaea			257	20	90%	5	1413
53	110	Manoa	Luaalaea			960	15	90%	4	3949
54	120	Manoa	Naniuapo			815	15	90%	4	3354
55	200	Palolo	Palolo			44	30	85%	8	344
56	201	Palolo	Palolo	Channelized	Chan Barrier	528	40	33%	4	2086
57	202	Palolo	Palolo			570	30	86%	8	4522
58	203	Palolo	Palolo	Channelized	Chan Barrier	2003	38	45%	5	10451
59	210	Palolo	Waiomao	Channelized	Chan Barrier	154	35	45%	5	739
60	211	Palolo	Waiomao			789	35	45%	5	3788
61	212	Palolo	Waiomao			269	22	83%	6	1489
62	213	Palolo	Waiomao			0	25	90%	7	0
63	2141	Palolo	Waiomao	Waiomao Detention Basin Scour	yes	46	25	90%	7	318
64	2142	Palolo	Waiomao	Waiomao Detention Basin	box	52	20	90%	5	285
65	2143	Palolo	Waiomao	Waiomao Detention Basin Excavation	Barrier: P_Falls 5 (yes)	122	35	89%	9	1150
66	216	Palolo	Waiomao			1768	15	90%	4	7275
67	220	Palolo	Pukele	Channelized	Chan Barrier	566	40	50%	6	3447
68	221	Palolo	Pukele			459	30	90%	8	3777
69	222	Palolo	Pukele			262	30	90%	8	2156
70	2231	Palolo	Pukele	Pukele Detention Basin Scour	yes	46	30	90%	8	379
71	2232	Palolo	Pukele	Pukele Detention Basin	box	49	30	90%	8	483

Figure 2. Screen capture of the updated HSHEP model spreadsheet showing the newly determined stream lengths (column S) for the site changes. For row 49, the Waiakeakua Upstream excavation area the stream length is 0 reflecting no upstream excavation area although the stream segment coding is in place for future site modifications. Row 65 shows the Waiomao Excavation area and its appropriate length of 122m (400 ft).

Determining Impacts of New Design Changes:

Determining the impacts of the new design changes was done in consultation with Glenn Higashi at the Hawaii Division of Aquatic Resources. We attempted to follow similar impact criteria as had been developed for the first model. For the upstream excavation areas, we applied the expected and maximum impact criteria values as had been previously determined for the first model. For the downstream riprap scour protection areas, we applied similar criteria values (Figure 3). In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, we applied the same values as the channelized barriers determined for the first model. In this case, we had assumed some decrease in passage for each 100 m of channelized stream (Figure 4). Although the box culverts were not 100 m in length, we considered them to have passage barrier values as if they were 100 m in length. This estimate avoided underestimating the impact of the fish passing under these dams through the box culverts.

	A	B	C	D
1	Habitat Impact Variables			
2		Habitat Remaining		
3	Type	Current Impact (live Values)	Expected Impact	Max Impact
4	Off-channel Detention Intakes	0.8	0.8	0
5	In-channel Sites	0	0	0
6	Upstream Detention Excavation	0.5	0.5	0
7	Channel Maintenance	0.5	0.5	0.5
8	Downstream Scour Area	0.5	0.5	0

Figure 3. Screen capture of the habitat impact weighting criteria used for the updated HSHEP model.

G	H	I	J	K
Barrier Impact Variables				
	Habitat Remaining			
Type	Current Impact (live Values)	Expected	Max Barrier	
Channelized Barriers (per 100m)	0.9	0.9	0.85	
Undercut Barriers	0.5	0.5	0.35	
Box Culverts	0.9	0.9	0.85	

Figure 4. Screen capture of the barrier impact weighting criteria used for the updated HSHEP model.

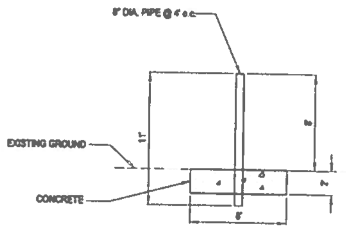
Updating the HSHEP Model Result Spreadsheet:

Results from the new model were added to the HSHEP model result spreadsheet. All formulas and dependencies were updated and double checked. The mitigation values for each of the eight different scenarios were recalculated and added to the overall results page.

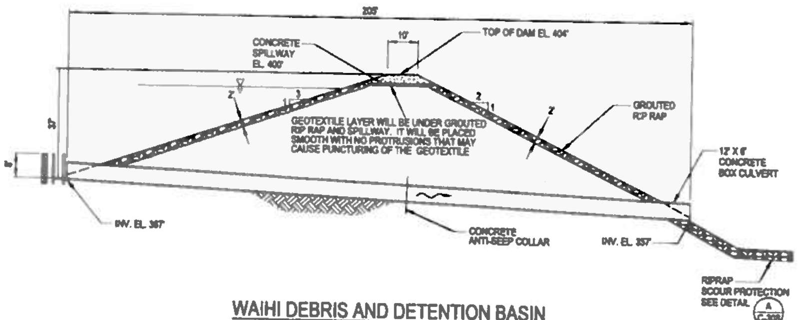
Results and Conclusion:

An updated spreadsheet and associated GIS file were provided to the USACE with this report. The intent of this report is not to discuss the findings but to document the process in which the spreadsheet was updated with the new site information.

In a general sense, the conclusions of this updated model are unchanged from the first model run. The biggest difference is the loss of habitat associated with the increased footprint of the projects and a decrease in upstream passage where box culverts are used. The removal of the falls 7 and 8 as a mitigation scenario remains the most promising scenario in terms of habitat units gained for effort expended.



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



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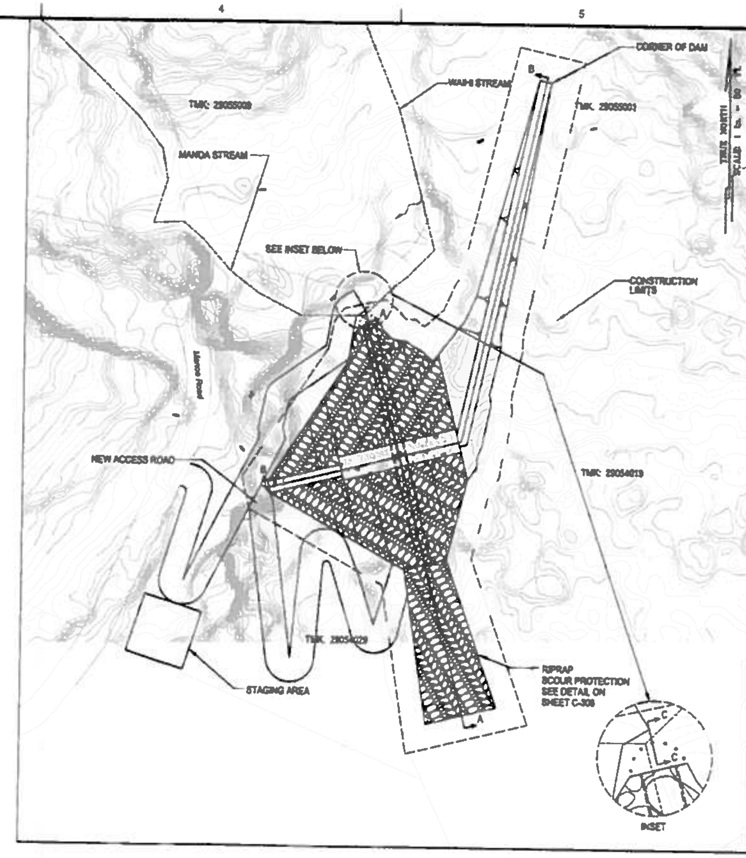
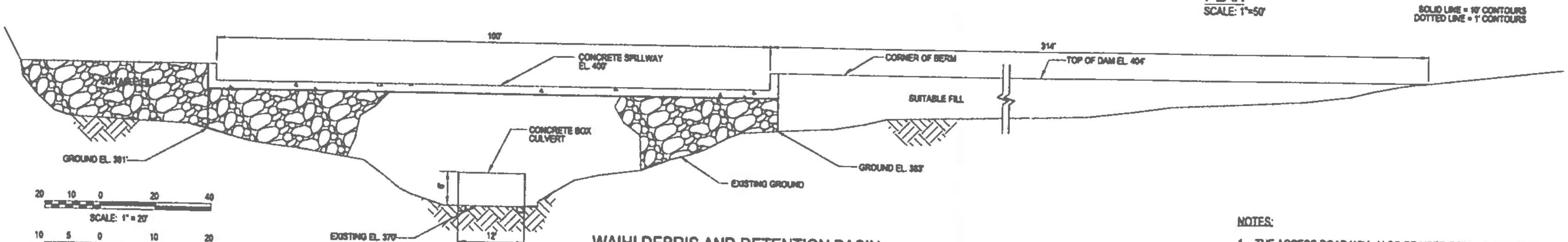
SECTION A-A
SCALE: 1"=20'



PLAN
SCALE: 1"=50'

50 25 0 50 100
SCALE: 1" = 50'
SOLID LINE = 10' CONTOURS
DOTTED LINE = 1' CONTOURS



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

20 10 0 20 40
SCALE: 1" = 20'
10 5 0 10 20
SCALE: 1" = 10'
Note: All elevations are feet MSL

NOTES:
1. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.

35% DESIGN

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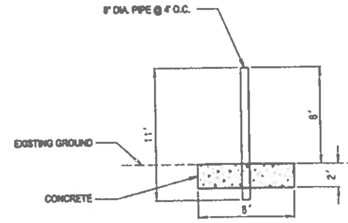
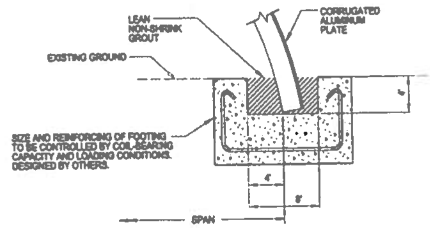
HONOLULU, HAWAII

ALA WAI CANAL PROJECT
WAIHI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

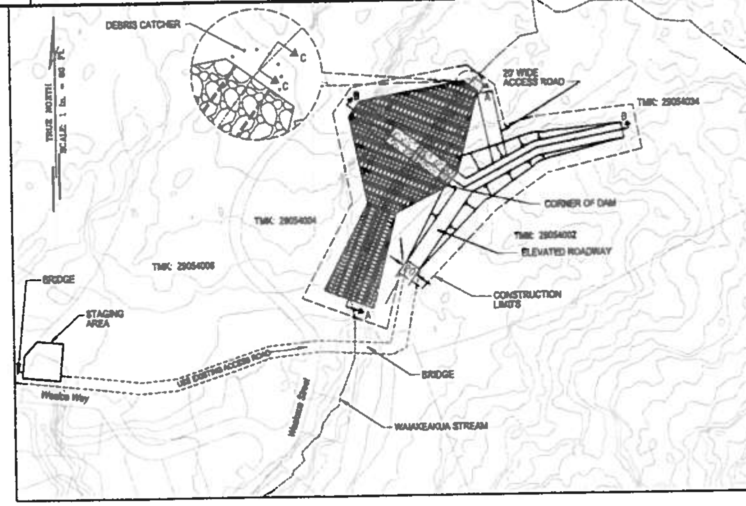
SHEET IDENTIFICATION
C-301



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



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

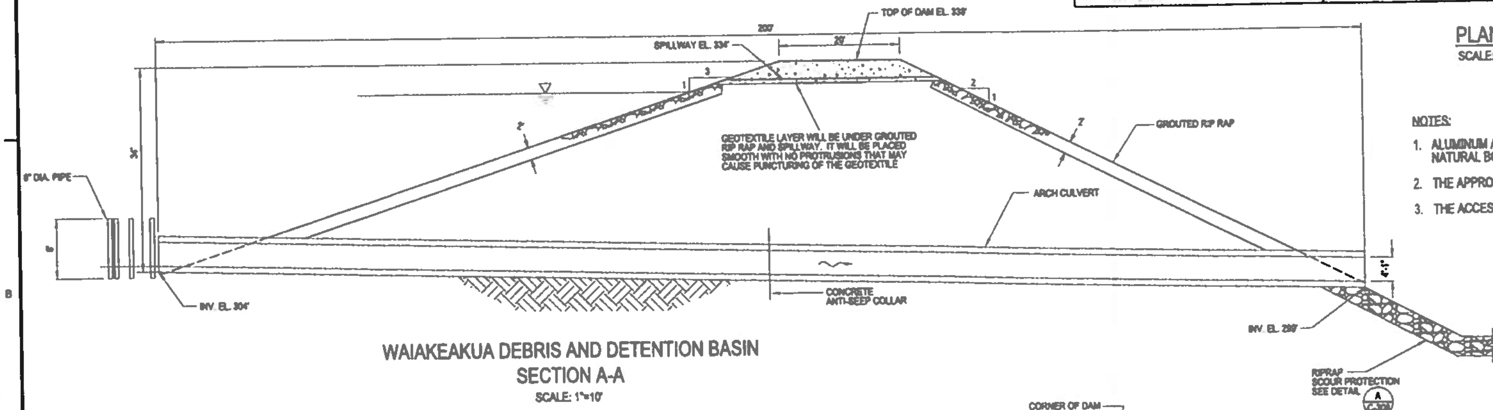


PLAN
SCALE: 1"=80'

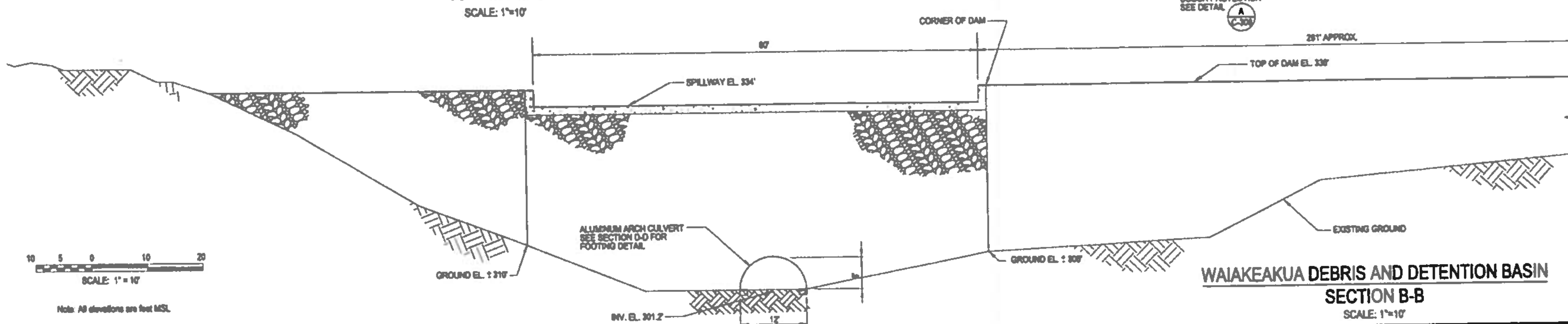
SOLID LINE = 5' CONTOURS
80 40 0 80 160
SCALE: 1" = 80'

NOTES:

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



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



Note: All elevations are feet MSL.

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

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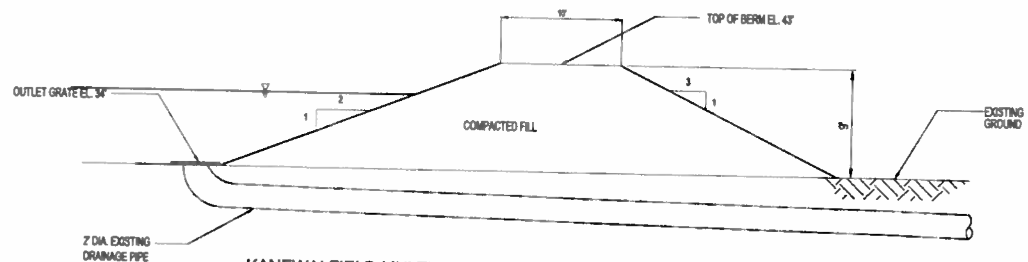
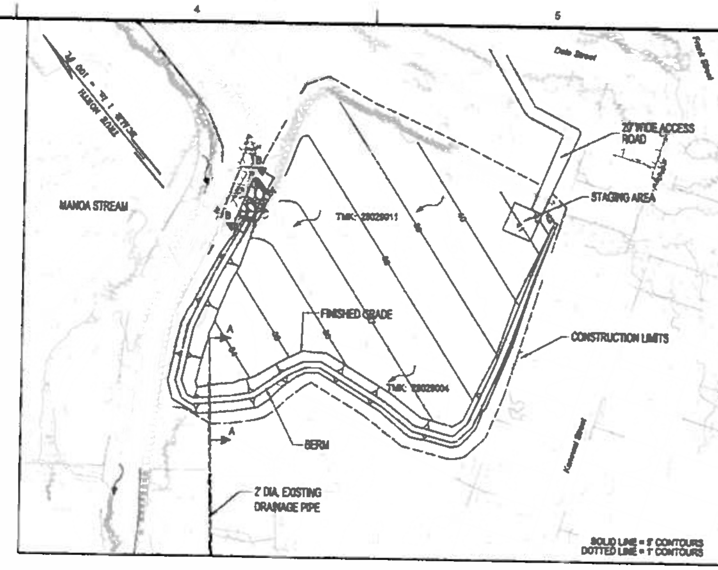
ALA WAI CANAL PROJECT
WAIAKEAKUA DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

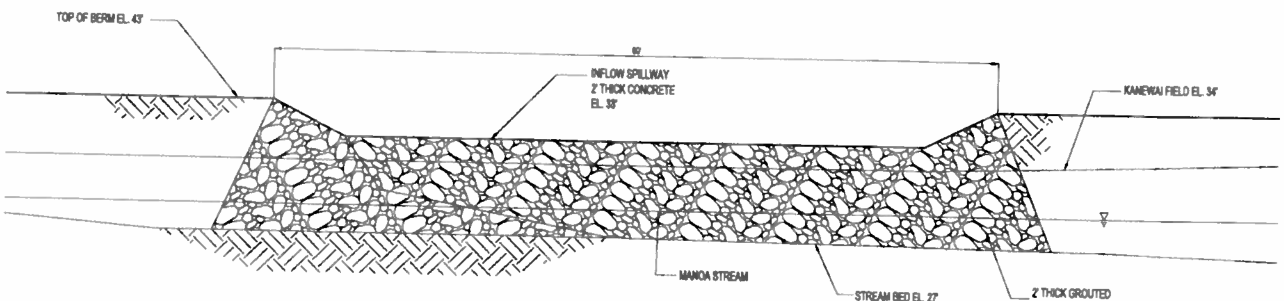
SHEET IDENTIFICATION
C-302



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



PLAN
SCALE: 1" = 100'



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

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

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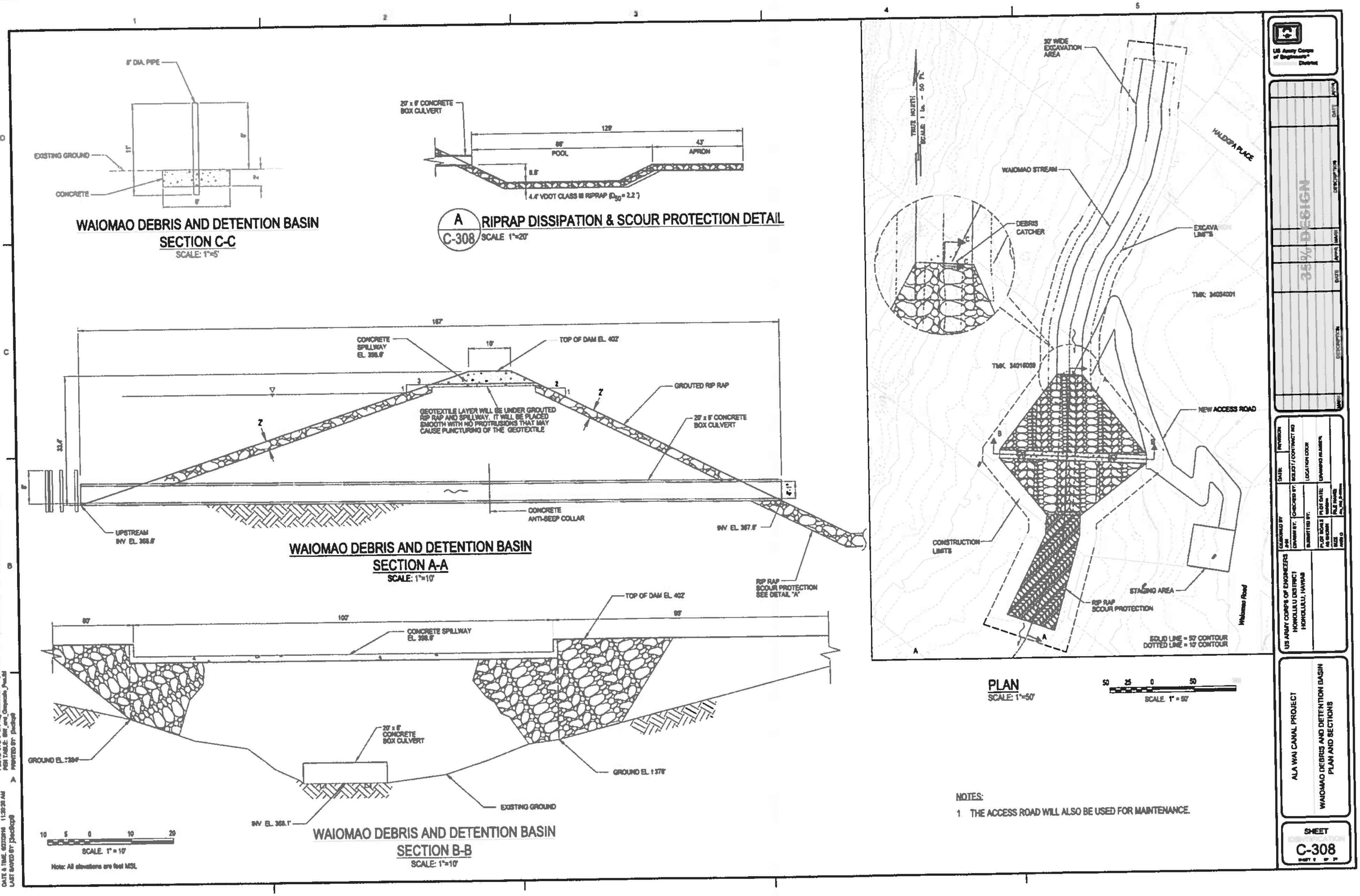
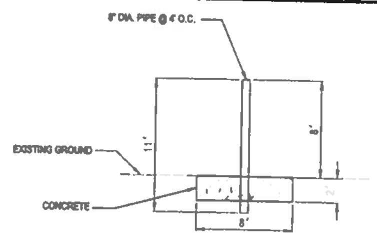
ALA WAI CANAL PROJECT
KANEWAI FIELD MULTI-PURPOSE DETENTION BASIN PLAN AND SECTIONS

SHEET IDENTIFICATION
C-306

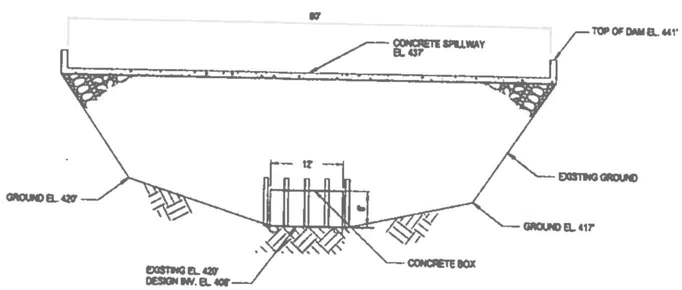


NOTES:

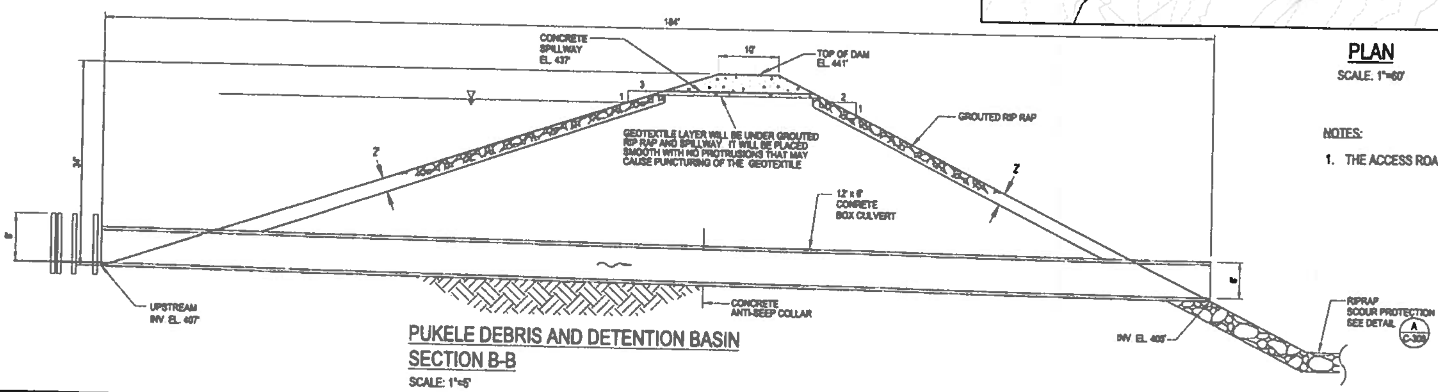
1. THE ACCESS ROAD WILL ALSO BE USED FOR MAINTENANCE.



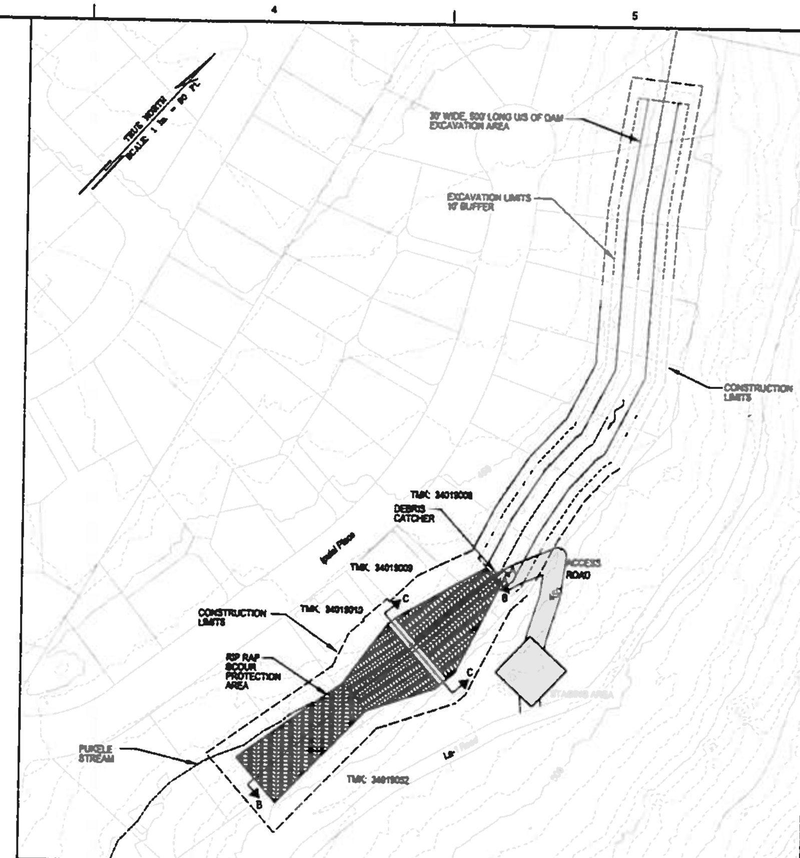
PUKELE DEBRIS AND DETENTION BASIN
SECTION A-A
SCALE 1"=5'



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



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



PLAN
SCALE: 1"=60'

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

NOTES:

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

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

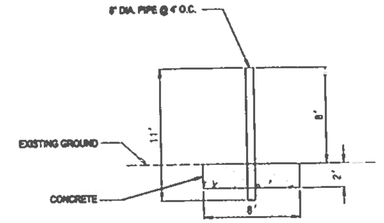
US Army Corps of Engineers Honolulu District

35% DESIGN

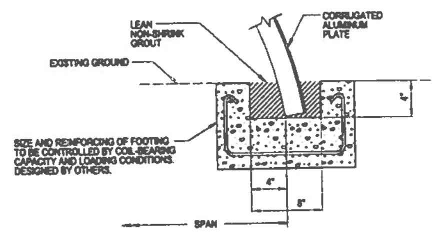
US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT
PUKELE DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

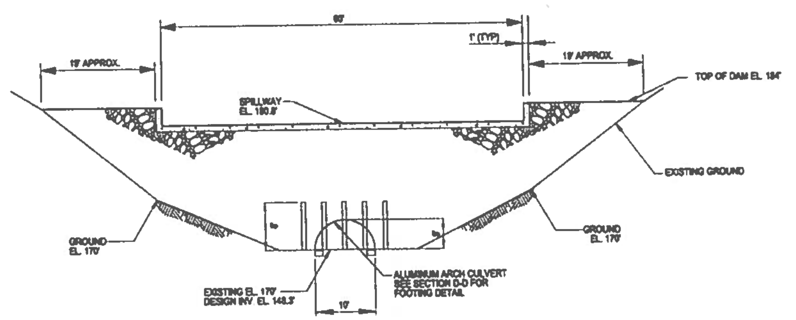
SHEET IDENTIFICATION
C-313



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



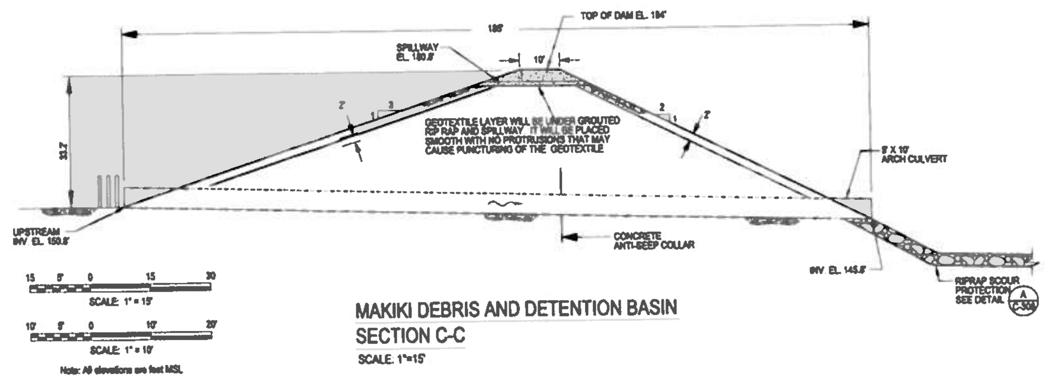
SLOTTED CONCRETE FOOTING
MAKIKI DEBRIS AND DETENTION
SECTION D-D
SCALE: NTS



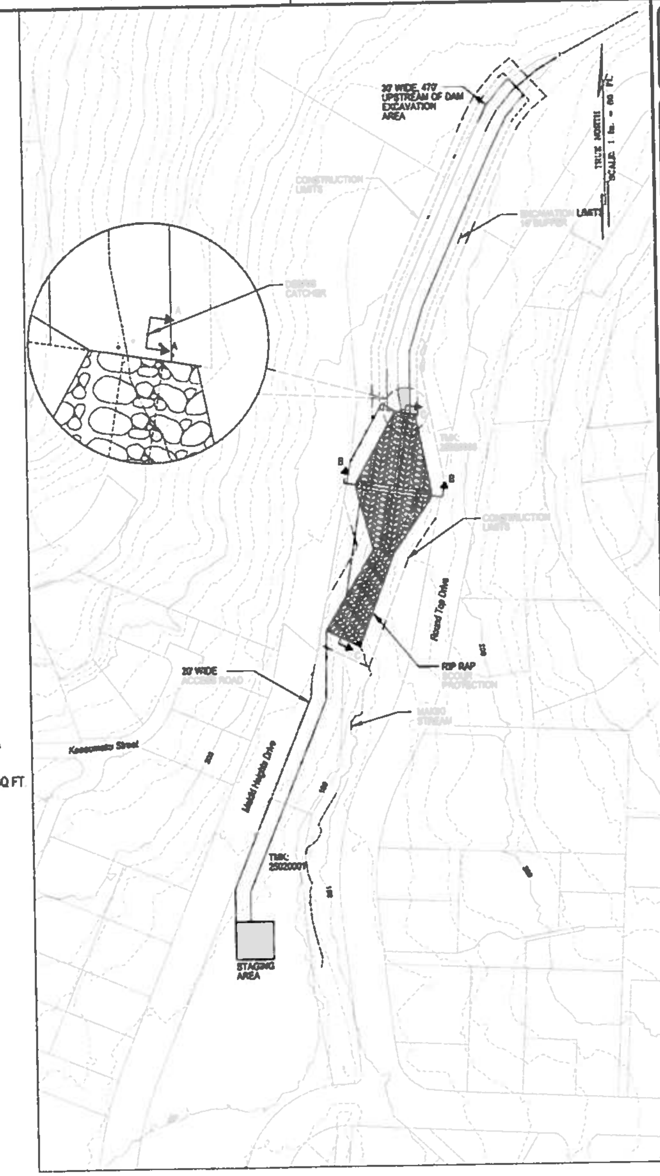
MAKIKI DEBRIS AND DETENTION BASIN
SECTION B-B
SCALE: 1"=1

NOTES:

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



MAKIKI DEBRIS AND DETENTION BASIN
SECTION C-C
SCALE: 1"=15'



PLAN
SCALE: 1"=60'

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

US Army Corps of Engineers® Honolulu District

35% DESIGN

US ARMY CORPS OF ENGINEERS
HONOLULU DISTRICT
HONOLULU, HAWAII

ALA WAI CANAL PROJECT
MAKIKI DEBRIS AND DETENTION BASIN
PLAN AND SECTIONS

SHEET IDENTIFICATION
C-315

Ala Wai Canal FRM Detention Basin Areas

	Footprint (ft²)				Storage	
Basin	2015	2016	Difference	Difference (ac)	2015	2016
Makiki	7,250	17,165	**9,915**	**0.228**	-	14,040
Waihi	12,714	35,200	**22,486**	**0.516**	-	-
Waiakeakua	29,180	41,620	**12,440**	**0.286**	-	-
Woodlawn	37,520	37,520	-	-	-	-
Manoa Debris	540	540	-	-	-	-
Kanewai	39,425	39,425	-	-	-	-
Waiomao	6,985	19,890	**12,905**	**0.296**	21,235	12,465
Pukele	2,920	16,660	**13,740**	**0.315**	-	15,620
Hausten Ditch	-	-	-	-	-	-
Ala Wai Golf	531,300	531,300	-	-	-	-
Total Acreage	15.33	16.97	1.64	1.64	0.49	0.97

No data

Questionab

Cross-checl

Design Changes	Berm Height	Top Width	Elevation	Storage excavation	Bottom Widt	Distance
Makiki	30	10	184	Yes	30	470
Waihi	37	10	404	No	0	0
Waiakeakua	34	20	338	No	0	0
Woodlawn				No		
Manoa Debris				No		
Kanewai	9	1	43	No	0	0
Waiomao	33.5	10	402	Yes	30	400
Pukele	30	10	441	Yes	30	500
Hausten Ditch	7.02			No		
Ala Wai Golf	7.49			Yes		

Excavation (ft²)		Construction Limits (ft²)				
Difference	Difference (ac)	2015	2016	Difference	Difference (ac)	2015
14,040	**0.322**	11,800	65,360	**53,560**	**1.230**	2,500
-	-	25,450	64,225	**38,775**	**0.890**	2,500
-	-	51,820	72,800	**20,980**	**0.482**	2,500
-	-	79,315	79,315	-	-	2,500
-	-	3,740	3,740	-	-	2,500
-	-	275,729	267,610	**(8,119)**	**(0.186)**	2,500
(8,770)	**(0.201)**	47,690	69,815	**22,125**	**0.508**	2,500
15,620	**0.359**	9,770	69,980	**60,210**	**1.382**	2,500
-	-	-	-	-		5,950
-	-	-	-	-		-
0.48	0.48	11.60	15.91	4.31	4.31	0.60

le result
ed

Volume (Y^3)	Outlet	Length	Scour protection?	
3035	Arch culvert	160	Yes	
0	Box culvert	205	Yes	
0	Arch culvert	200	Yes	
		60	No	No change
		8	No	No change
0	Existing pipe	0	No	Change in berm height
3060	Box culvert	170	Yes	
14330	Box culvert	160	Yes	
			No	One-foot increase in WSE for 100-year
			No	Half-foot increase in WSE for 100-year, no chan[illegible]

Staging Area (ft^2)			100-Year Pool (ft^2)			
2016	Difference	Difference (ac)	2015	2016	Difference	Difference (ac)
2,500	-	-	23,140	21,245	**(1,895)**	**(0.04)**
2,480	**(20)**	**(0)**	25,150	58,870	**33,720**	**0.77**
2,320	**(180)**	**(0)**	37,647	139,740	**102,093**	**2.34**
2,500	-	-	75,830	75,830	-	-
2,500	-	-	-	-	-	-
2,480	**(20)**	**(0)**	222,468	212,810	**(9,658)**	**(0.22)**
2,500	-	-	2,525	44,950	**42,425**	**0.97**
2,500	-	-	-	34,660	**34,660**	**0.80**
5,950	-	-	-	-	-	-
-	-		-	-	-	-
0.59	(0.01)		8.88	13.50	4.62	4.62

	2015 Culvert Length	Difference
	130	30
	130	75
	110	90
	60	0
	8	0
	0	0
	130	40
	130	30
		0
ge in excavated area		0

NWI Impact	
Ft^2	
4,240	OK
3,485	OK
8,650	OK
-	Need NWI Impact for 2016 design
-	Need NWI Impact for 2016 design
-	Need footprint calc for 2015 design
5,475	OK
4,780	Need 100-year pool calc for 2015 design
-	Need footprint calc for 2015 design
-	Need footprint calc for 2015 design

0.611

APPENDIX F – ADDENDUM TO MITIGATION, MONITORING AND ADAPTIVE MANAGEMENT PLAN, ALA WAI CANAL PROJECT, U.S. ARMY CORPS OF ENGINEERS – HONOLULU DISTRICT, JULY 14, 2016.

Addendum to
Mitigation, Monitoring and Adaptive Management Plan
Ala Wai Canal Project
U.S. Army Corps of Engineers, Honolulu District
14 July 2016

1. The draft Mitigation, Monitoring, and Adaptive Management Plan (MMAMP; USACE 2015) and its attachments describe the use of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) to evaluate the impacts of the Ala Wai Canal project on aquatic habitat, and summarize the results of the HSHEP modeling effort. As with other Habitat Evaluation Procedure (HEP) models, the HSHEP uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density. The suitability relationships are converted into standardized Habitat Suitability Indices (HSI) that encompass the range of observed habitat conditions. Habitat quality is assessed based on the HSI values and habitat quantity is defined based on area, which when multiplied, provide overall habitat units (HUs) for a given area. Adverse impacts to stream habitat can then be expressed as HUs lost, while mitigation efforts that improve stream habitat can be quantified as HUs gained.

2. When the HSHEP was applied to the Ala Wai Canal project, following the methodology and assumptions detailed in the MMAMP, the resulting total HUs lost within the Ala Wai watershed due to project impacts was calculated as 192 under the "expected scenario" (described in Section 2.2 of the MMAMP) and 1,210 under the "worst-case scenario". When these HU losses were compared against the HU gains calculated for an array of mitigation alternatives developed for the project, it was apparent that the mitigation alternative involving the removal of migration barriers at "Falls 7" and "Falls 8" would provide a sufficient gain in HUs to offset the HU losses from project impacts (Table 7 of the MMAMP).

3. In May 2016, the Corps' internal review of the project revealed that several of the project elements would need to be redesigned to provide sufficient stormwater retention and management capacity. Some of the design changes, such as additional excavation within the detention basins and riprap scour protection downstream of the detention structures, represented additional impacts to stream habitat beyond what had been modeled by the HSHEP.

4. The Corps contracted James Parham of Parham and Associates Environmental Consulting, LLC, to update and rerun the HSHEP model to reflect the changes to project design (Parham 2016a). Dr. Parham's update of the HSHEP spreadsheet included creating new model stream segments to reflect the updated plans, reviewing the impacts of the project changes and determining criteria for them. The most relevant design changes included in the updated model included:

- The addition or expansion of an upstream excavation area at three sites;
- The replacement of the open bottom arch culverts with box culverts at three sites; and
- The addition of downstream riprap scour protection areas at five sites.

Dr. Parham consulted with Glenn Higashi at the Hawaiian Division of Aquatic Resources in determining the impacts of the design changes. They followed a similar impact criteria methodology as had been developed for the first model, as much as possible. For the upstream excavation areas, they applied the expected and maximum impact criteria values as had been previously determined for the first model; similar criteria values were applied to the new downstream riprap scour protection areas. In both of these cases, it is likely that there will be some habitat in the stream in these areas although it is not considered a natural stream bottom. The maximum impact would remove 100% of habitat in these areas. No changes in criteria scoring were made for the actual detention dam footprint as that had already been determined for the first model. For the change from the natural bottom arch culvert to the box culvert, they applied the same values as the determined for channelized stream segments in the first model. Each box culvert was assigned the barrier impact value of 100 meters of channelized stream, although the box culverts will range in length from roughly 49 to 62 meters, providing some conservatism to the assessment of impact of the box culverts (Parham 2016b).

5. Table 1 below updates Table 7 from the MMAMP, comparing the calculated HUs lost with the redesigned project ("2016 Scope") with those calculated for the original scope, and with the net HU gained from an abbreviated set of mitigation alternatives. Despite the additional impacts to stream habitat inherent in the project design changes, the benefit from the "Falls 7 and 8" mitigation alternative remains sufficient to offset the total project impacts.

Table 1. Comparison of HUs Lost/Gained between Original and Expanded Project Scope

Location	*2015 Scope With-Project HUs Lost*	2016 Scope With-Project HUs Lost	Mitigation Alternatives – Net HUs Gained		
			"Falls 7"	"Falls 7, 8"	"Falls 7, 8, 11"
EXPECTED SCENARIO					
Manoa Stream	*191*	233	1,308	3,736	5,147
Palolo Stream	*-107*	-59	0	0	0
Makiki Stream	*24*	38	0	0	0
Hausten Ditch	*84*	84	0	0	0
Total	***192***	**295**	**1,308**	**3,736**	**5,147**
WORST CASE SCENARIO					
Manoa Stream	*808*	825	796	2,688	4,065
Palolo Stream	*-29*	-15	0	0	0
Makiki Stream	*11*	29	0	0	0
Hausten Ditch	*420*	420	0	0	0
Total	***1,210***	**1,259**	**796**	**2,688**	**4,065**

References:

U.S. Army Corps of Engineers, Honolulu District (USACE). 2015. Mitigation, Monitoring, and Adaptive Management Plan (draft), Ala Wai Canal Project, Oahu, Hawaii. August 2015.

Parham, James E. 2016a. Ala Wai HSHEP Impact Worksheet Final 07/07/2016 with updated plans. 7 July 2016.

Parham. 2016b. Report on updating the spreadsheet results for the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) associated with the streams in the Ala Wai Canal Flood Risk Management Study. 12 July 2016.

APPENDIX G - SINGLE-USE APPROVAL OF THE HAWAIIAN EVALUATION PROCEDURE FOR THE ALA WAI CANAL FLOOD RISK MANAGEMENT PROJECT, HAWAII, MAY 28, 2015.

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

REPLY TO
ATTENTION OF

CECW-P 28 May 2015

MEMORANDUM FOR Director, National Ecosystem Restoration Planning Center of Expertise (ECO-PCX)

SUBJECT: Single-Use Approval of the Hawaiian Stream Habitat Evaluation Procedure for the Ala Wai Canal Flood Risk Management Project, Hawaii

1. The HQUSACE Model Certification Panel has reviewed the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) in accordance with EC 1105-2-412 and has determined that the model and its accompanying documentation are sufficient to approve its use for the Ala Wai Canal flood risk managament study, Oahu, Hawaii. Adequate technical reviews have been accomplished and the Panel considered the assessments of the ECO-PCX and the Agency Technical Review in making this determination.

2. The HSHEP model was developed through collaboration between the Hawaii Division of Aquatic Resources and researchers at universities, state agencies, museums, and private entities. The model follows the Habitat Evaluation Procedure concepts and methodology to capture the major aspects of native stream animal ecology, geomorphology of Hawaiian streams, and common modifications to the environment. The intent of the model is to be useful in assessing the potential impacts of stream channel modification, flow alteration, land use change, climate change, stream restoration, and barrier modifications on native stream animal habitat quality and quantity. The HSHEP is designed to be used at site, stream segment, and stream and watershed scales depending on the scenario and level of detail required. Variables at the watershed scale include stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. Variables in the model describe instream habitat and animal distributions include factors such as elevation, distance from the ocean, and the presence of instream barriers. Finally, at the site level, more specific characteristics are included as suitability indices for six instream flow assessment (e.g., depth, velocity, and substrate) or habitat assessment (e.g., habitat type, depth, substrate, and temperature for habitat assessment) depending on the project objectives. Habitat suitability for eight species of native stream animals (i.e., five fish, two crustaceans, and one mollusk) was determined using presence/absence data as the basis for habitat utilization. Habitat utilization is the frequency of occurrence for an individual species in each habitat category. Suitability is developed by dividing the percent utilization for each habitat category with the percent available. The resulting suitability curve ranges from 0 (unsuitable) to 1.0 (highly suitable). By combining HSHEP results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable.

3. The HSHEP model has been reviewed by the Hawaii Division of Aquatic Resources, the USFWS and private consultants utilizing the model for hydroelectric licensing applications. Additionally, the ECO-PCX managed a review of the HSHEP model. The review was conducted by an ecologist with expertise in tropical island flora and fauna, associated habitat requirements, and extensive ecological modeling expertise, Dr. Kyle McKay, ERDC Environmental Laboratory. Comments received pursuant to this review recommended actions to clarify and improve model documentation and improve the overall usability of the model. The model documentation and inherent user's guide was

updated to more explicitly describe the intended use and appropriate documentation for variables, use of scales, and addition of variables. Documentation was improved to further detail application methodology, assumptions and limitations of the model, and address statistical model development issues.

4. The HSHEP has sufficient technical quality, is computationally correct, meets usability criteria and is policy compliant.

APPLICABILITY: The HSHEP is approved for single use on the Ala Wai Canal flood risk management study, Oahu, Hawaii.

BRUCE D. CARLSON
Deputy Chief, Planning and Policy Division
Directorate of Civil Works

APPENDIX H – STATE OF HAWAII, DIVISION OF AQUATIC RESOURCES, DEPARTMENT OF LAND AND NATURAL RESOURCES.

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOU
COMMISSION ON WATER RESOURCE MANA

KEKOA KALUHIWA
FIRST DEPUTY

JEFFREY T. PEARSON P.E.
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANA
CONSERVATION AND COASTAL LAN
CONSERVATION AND RESOURCES ENFORC
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMIS
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF AQUATIC RESOURCES
1151 PUNCHBOWL STREET, ROOM 330
HONOLULU, HAWAII 96813

October 27, 2016

Mary Abrams, Project Leader
U.S. Fish and Wildlife Service
Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard
Honolulu, Hawaii 96850

Dear Ms. Abrams:

The Division of Aquatic Resources (DAR), Department of Land and Natural Resources (DLNR) has been collaborating and conducting stream habitat and fish surveys along with U.S. Fish and Wildlife damselfly surveys on the Ala Wai Canal Flood Risk Management Study streams-Makiki, Manoa and Palolo. The data and results of this study were incorporated into the Fish and Wildlife Coordination Act (FWCA) report.

Project impacts include habitat loss from the footprint of the debris/detention basins and dam culverts to slow flood flows and fish migration barrier issues. In stream habitat loss can be mitigated by removal of migration barriers at Falls 7 and 8 to facilitate migration of native gobies, *'O'opu nakea,* and *'O'opu nopili,* through the various reaches of Manoa stream from the ocean which DAR fully supports. The distribution of *'O'opu naniha* is not usually found above these falls. These barriers are undercut preventing the native gobies from migrating upstream. Based on previous experience in the restoration of an undercut barriers in Waihee Stream on Oahu, DAR recommends that the modification to the barrier provide a surface of contact that has slope angle of near vertical to prevent invasive species migrating upstream.

USFWS staff conducted damselfly surveys on Ala Wai streams and discovered the federally listed blackline damselfly, *Megalagrion nigrohamatum nigrolineatum*, which is restricted to the island of Oahu, occurring at two sites: the Waihi Stream and Waiakeakua Stream Debris and Detention Basins on Manoa Stream. This was selected as the evaluation species for this study.

The Stream Habitat Evaluation Procedure (HSHEP) for the Ala Wai Canal Flood Risk Management Study was modeled for in stream native fish habitat and therefore didn't capture the importance and unique riffle/pool and riparian ecological qualities of Waihi Stream and Waiakeakua Stream for Hawaiian damselflies. The Service considers the riffle/pool and riparian habitat at Waihi Stream and Waiakeakua Stream to meet the definition of Resource Category 2 (Habitat to be impacted is of high value for evaluation species and is relatively scarce or becoming scarce on a national basis or in the ecoregion section).

DAR agrees on the Service's recommendation that the Debris and Detention Basins at Waihi Stream and Waiakeakua Stream be moved to a site lower in the Manoa Stream catchment to avoid project construction-related impacts to *M. nigrhamatum nigrolineatum* and habitat at Waihi Stream and Waiakeakua streams. If moving the debris and detention basins at Waihi and Waiakeakua Streams is not feasible, then we recommend the Service, USACE and State of Hawaii Department of Land and Natural Resources work together to develop appropriate mitigation to offset unavoidable project impacts to Resource Category 2 riffle/pool habitat and riparian habitat.

DAR agrees on the Service's construction and maintenance BMPS and further recommendations that a risk assessment be conducted to evaluate the potential hazards that may arise from mobilization of contaminated stream sediments and that post-construction monitoring be conducted to confirm anticipated project-related impacts did not exceed expectations. Finally, the USACE shall designate an individual to oversee compliance of each BMP during clearing operations on a daily basis and report all results to the USACE on a regular basis during clearing operations.

Thank you for providing DAR the opportunity to review and comment on the FWCA report.

Sincerely,

Bruce S. Anderson, Ph.D.
Administrator

DEPARTMENT OF THE ARMY
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
FORT SHAFTER, HAWAII 96858-5440

November 1, 2016

Civil and Public Works Branch
Programs and Project Management Division

Kevin Foster
Pacific Islands Fish and Wildlife Office
U.S. Fish and Wildlife Service
300 Ala Moana Boulevard, Room 3-122
Box 50088
Honolulu, Hawaii 96850

Dear Mr. Foster:

Thank you for taking the time to provide the U.S. Army Corps of Engineers (USACE) with a final Fish and Wildlife Coordination Act report (CAR) for the Ala Wai Canal Flood Risk Management study. We have fully considered the comments included in the CAR and provide the following response to you in the interests of open communication and coordination between our agencies.

USACE Engineering Regulations (ER) 1105-2-100 Appendix C provides a prescriptive process for the development of compensatory mitigation for aquatic resource impacts of civil works projects. Included below is information related to how the mitigation plan has evolved to provide you with additional context for the selection of the current mitigation plan and the USACE investment recommendation to Congress. The process utilized is outlined below for your information and future use:

1. Inventory and categorize ecological resources

A series of resource inventories conducted by USACE and others have been utilized in this study. In addition to a species list for the study area provided by USFWS in 2008, natural resource inventories were completed by AECOS under contract to USACE in 2010 and 2014 which have been shared with your agency. At a 14 OCT 2014 meeting to discuss Fish and Wildlife Coordination Act compliance, USFWS encouraged USACE to utilize the best available information from the State of Hawaii. In response to this request, specific stream surveys were conducted by the State of Hawaii, along with James Parham of the Bishop Museum, as in-kind and contract services for the study to parameterize the habitat modeling utilized to assess the current, future without-project condition, and future with-project condition.

2. Determine significant net losses

Assessment of impacts resulting from the alternative plans was conducted through use of the Hawaii Stream Habitat Evaluation Procedure (HSHEP). A 23 JAN 2015 meeting was convened to provide USFWS a presentation on the HSHEP model and discuss its use in the study. At that time, 10% conceptual designs were presented and initial impacts and potential mitigation measures were assessed and discussed. HSHEP utilizes multiple scales of analysis ranging from a watershed scale to site-specific scale assessment to evaluate impacts. The model assesses both the amount of habitat available as well as the quality of habitat through the habitat suitability index. This includes stream habitat types and geomorphic characteristics including cascades, riffles, runs, various types of pools and substrate types. Ground cover and watershed condition are also included to characterize the riparian environment. Survey data is utilized to verify the frequency of selected species within each habitat. The model then applies those physical parameters to the ecological habitat needs of fourteen different species. Loss of habitat can occur from physical displacement of habitat as a result of project feature and/or elimination of access to upstream habitat for migratory species as a result of an ecological barrier (dam, vertical impoundment, velocity barrier, etc.). It was the understanding of USACE from the 23 JAN 2015 meeting that both the State of Hawaii and USFWS were generally supportive of the use of HSHEP in evaluating impacts under the National Environmental Policy Act. Use of the HSHEP model was approved by USACE on 28 MAY 2015 and the technical sufficiency of the model was affirmed through an internal review.

3. Define mitigation planning objectives

The 23 JAN 2015 meeting further explored the mitigation planning objectives, screening criteria for mitigation plans, and plan selection constraints with USFWS. In general, USACE was encouraged by USFWS and the State of Hawaii to adopt a watershed context to mitigation as opposed to mitigating individual impacts at specific project sites. Criteria utilized in screening mitigation plans included technical feasibility, the likelihood of success in Hawaii, dependency on other features, potential for reducing flood risk, implementation cost, cost effectiveness, land availability and ownership, operations and maintenance requirements, acceptability, avoidance of adverse effects to biological resources, avoidance of adverse effects to cultural resources and avoidance of adverse effects on mobilization of contaminated sediments. USACE consequently evaluated a number of mitigation plans that focused on a holistic substitute of fish and wildlife resources as opposed to direct replacement mitigation approach (per 40 CFR 1508.20). The fundamental assumption with this approach is that at a minimum, no net loss in the cumulative habitat value within the watershed will occur as a result of the mitigation.

4. Define a common unit of measurement

Mitigation for adverse impacts proposed by USACE must be quantified in a common unit of measurement. The common unit of measurement utilized in the HSHEP model is habitat units (HUs). HUs are the expected average annual quantity of a specific quality of habitat expected to be found in a given areas. HUs are spatially explicit and are evaluated throughout the watershed in a number of temporal conditions including existing conditions as well as future without-project and future with-project conditions. USACE assumes that the HSHEP model assessment of HUs integrates all of the critical considerations of adverse and beneficial project impacts including assessment of habitat type, quality of habitat and position of specific habitat within important ecological regions of the watershed. Habitat impacts at locations such as Waihi Basin and Waiakeakua Basin, for example, include specific physical parameters such as quality of riffle and pool habitat in the with- and without-project condition.

5. Identify and assess mitigation strategies

The initial concepts for mitigation measures were presented at the 23 JAN 2015 and received tentative support from both USFWS and the State of Hawaii. These concepts were further refined and included in the draft Feasibility Report and integrated Environmental Impact Statement which was released for public review on 20 AUG 2015.

6. Define and estimate costs of mitigation plan increments

Under USACE ER 1105-2-100 Appendix C, USACE is required to perform an incremental cost analysis in order to justify the least cost mitigation plan that provides full mitigation of losses. This analysis utilizes estimated costs for mitigation features and compares the relative benefit defined under the common metric of HUs. As noted in the mitigation plan included in Appendix E of the Feasibility Report and Environmental Impact Statement, increments required to achieve replacement of HUs includes promotion of fish passage at Falls 7 and Falls 8 of Manoa Stream. Implementation of the mitigation plan at Falls 7 did not fully replace the HUs lost as a result of the flood risk management project, however, with the addition of Falls 8, the number of HUs dramatically exceeds the losses estimated. As a result, the combined flood risk management features and mitigation features are estimated to provide a net benefit in HUs to the watershed.

The FWCA report provided by USFWS includes a number of recommendations for consideration in the selection of a recommended plan. As noted above, USACE has fully considered those comments and provides its response below.

<u>Avoidance and minimization of impacts</u>. USFWS has encouraged USACE to relocate the Waihi Detention Basin further downstream to avoid impacts to Endangered Species Act (ESA) protected damselflies that have been found in the area. It is worth noting that a biological opinion (bi-op) received from separate ESA Section 7 consultation with USFWS and the bi-op proposes relocation of the basin as well as other actions to minimize a take of ESA species. USACE has agreed to perform several actions to minimize impacts to ESA species under the bi-op, however, the location of the detention basins is seen as an unavoidable impact. USACE has concluded that moving the basins further downstream would induce additional risk to surrounding homes while moving the basins upstream would potentially increase environmental impacts. For this reason, the basins were not moved to avoid the assessed impacts. In addition, many of the upstream detention basins on other tributaries include excavation to meet flood storage targets whereas in the Manoa basins (Waihi and Waiakeakua) given the environmental sensitivity, excavation for flood storage was eliminated altogether in order to avoid adverse impacts.

Compensatory mitigation. The CAR notes the use of HSHEP to evaluate impacts resulting from flood risk management features throughout the watershed. While the CAR identifies two of the fish species utilized in HSHEP, it is worth noting that the model also includes habitat evaluations of additional fish species, as well as crustaceans and mollusks. The governing assumption is that the diversity of the species selected accounts for the habitat quality over a range of ecological habitat requisites. Further, it should be acknowledged that the HSHEP model specifically accounts for various types of riffle and pool habitat. While the CAR posits that the habitat lost in the area of Waihi and Waiakeakua is of unique value, USFWS fails to demonstrate how those losses are unaccounted for in the HSHEP model other than through conjecture. In fact, the impacts assessed for the Manoa valley features constitute 78% of the overall permanent adverse impacts from the flood risk management features even though the features in Manoa compose only 46% of the total area permanently impacted by the project: 233 HUs lost in Manoa valley of the 295 HUs lost for the entire project. The root of the disparity in acreage impacted versus HUs lost is due to the quality of habitat lost, as calculated by the HSHEP model; i.e. quality of habitat is a key consideration in the impact assessment. As such, the USACE position is that the HSHEP analysis uses appropriate resource categorization to account for both the quality and quantity of habitat lost as a result of the Waihi and Waiakeakua features. It is also worth noting that the mitigation features proposed at Falls 7 and Falls 8 are both located on Manoa stream which will receive an estimated net gain of 3736 HUs as a result of the mitigation plan. The amount of mitigation provided on a HU basis will far overcompensate for the losses. This is a result of the dual estimates (estimated and worst case scenario) provided by the analysis, but also is a function of the magnitude of benefits provided by restoring fish passage above Falls 8, which will open a significant aquatic corridor within the Manoa stream.

It is noted that the CAR calls for an additional 3:1 replacement of habitat for compensatory mitigation for the Waihi and Waiakeakua stream impacts. Given the information in the preceding paragraph, USACE is unable to justify further compensatory mitigation for adverse impacts beyond what is proposed in the mitigation plan. However, it is unclear how USFWS calculated permanent losses within these areas to arrive at its compensatory mitigation recommendation. Based on information provided to USFWS, accounting for the construction limits and access roads as permanent impacts from the detention basins, the estimated impacts from the Waihi and Waiakeakua detention basins are respectively 81,225 ft^2 and 94,400 ft^2, totaling 175,625 ft^2 or approximately four acres. This is a significant difference from the 314,030 ft^2 calculated by USFWS in the CAR, however the CAR estimates unfortunately are not further supported with any maps or analysis which could be used verify how USFWS arrived at its determination.

Contaminated Sediments. At the 23 JAN 2015 meeting between USFWS and USACE, USACE identified several contaminated sites within the watershed which provided a planning constraint on the mitigation plan. This criteria was further applied as selection criteria for the recommended mitigation plan. Consequently, known contaminated sites have been avoided throughout the development of the recommended plan. USACE is aware of the concerns related to remobilization of sediment, in general, throughout the duration of the project. Sediment mobilization will primarily be addressed through best management practices identified in Section 5 of the Feasibility Study and Environmental Impact Statement. Erosion and sediment control will be revisited during the Design Phase in order to ensure that adequate measures are in place to minimize sediment mobilization during construction. An operations and maintenance plan will also be developed which will dictate erosion and sediment control criteria during post-construction activities conducted by the non-Federal sponsor. On balance, it is assumed that construction of the debris and detention basins will have a minor positive impact on sediment mobilization in the watershed due to the flow attenuating characteristics of the basins.

Post-Construction Monitoring. Through Section 7 ESA consultation, USACE has agreed to provide monitoring of damselflies for ESA compliance in the vicinity of the Waihi and Waiakeakua detention basins at three specific periods: a preconstruction site survey, a post-construction site survey and an additional survey within one-year of construction completion. This appears to be consistent with the recommendations of the CAR. Additional monitoring of the mitigation sites will occur annually for no more than five years following the completion of the construction, as specified in Appendix E of the Feasibility Report and Environmental Impact Statement.

Best Management Practices. The guidelines provided in the CAR for implementation of best management practices to reduce sediment erosion during construction appear to be reproduced from the USACE Clean Water Act (CWA) Section 404 regulatory guidelines. USACE has no objection to these guidelines in principle, however, be advised that USACE does not seek permits from its own agency for the construction of Civil Works projects. Methods to control site erosion are outlined in Section 5 of the Feasibility Report and Environmental Impact Statement and will be further refined during the Design Phase of the project.

Thank you again for your participation in the development of this study. If you have any questions or require additional information, please contact USACE at (808) 835-4031 or email michael.d.wyatt@usace.army.mil.

Sincerely,

Michael D. Wyatt
Senior Planner/Project Manager

Appendix E8
Draft Record of Decision

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DRAFT

RECORD OF DECISION
ALA WAI CANAL FLOOD RISK MANAGEMENT STUDY
O'AHU, HAWAI'I
FEASIBILITY STUDY WITH INTEGRATED ENVIRONMENTAL IMPACT STATEMENT
FLOOD RISK MANAGEMENT

The Final Ala Wai Canal Flood Risk Management Study, O'ahu, Hawai'i Feasibility Study with Integrated Environmental Impact Statement (EIS), dated [DATE], addresses flood risk management for the Ala Wai Watershed, located in Honolulu, Hawaii. Based on the report, the reviews of other Federal, State, and local agencies, input from the public, and the review by my staff, I find that the plan recommended by the Chief of Engineers is technically feasible, economically and environmentally justified, cost effective, in accordance with environmental statutes, and in the public interest.

The Final Feasibility Report/EIS evaluated various structural and non-structural alternative plans to address the flood risk management needs of the Ala Wai Watershed. The recommended plan (Alternative 3A-2.2) is the National Economic Development (NED) plan and consists of a series of in-stream and multi-purpose debris and detention basins, as well as floodwalls along the Ala Wai Canal. Specific flood risk management features include:

- Construction of six in-stream debris and detention basins in the upper reaches of the watershed;
- Construction of one stand-alone debris catchment feature;
- Construction of two multi-purpose detention basins in open space areas through the developed watershed;
- Construction of floodwalls along the Ala Wai Canal (including two associated pump stations); approximately 1.7 miles along left bank, approximately 0.9 mile along right bank (including gaps for bridges) and an earthen levee of approximately 0.9 miles in length along the perimeter of the Ala Wai Golf Course; and
- Improvements to the existing flood warning system (non-structural).

Mitigation features include:

- Improvements to two in-stream structures to eliminate a migratory passage barrier for native aquatic species; and
- Monitoring mitigation performance and corrective action for a duration of five years.

In addition to a "No Action" plan, a range of structural and non-structural alternatives for flood risk management were considered through the plan formulation and evaluation process, as described in the Final Integrated Feasibility Report and EIS. An initial screening was performed on a wide variety of management measures at a qualitative level. Management measures to reduce peak flows, increase channel capacities, improve debris management and channel maintenance, as well as non-structural measures to reduce flooding consequences were considered. Management measures carried forward past the initial screening were grouped in to combinations of management measures consisting of five alternative plans in addition to the No Action plan. Alternatives considered included a Manoa Dam, multiple debris and detention basins in the developed portion of the watershed, multiple debris and detention basins in the upper watershed, a focus on line of protection along the Ala Wai Canal, and a non-structural alternative. Alternative Plans were screened at a qualitative level and two alternatives, in addition to the No Action Alternative, were carried forward into the final array of alternative plans. The final array of plans were developed a 10% level of design and quantitative technical analysis was applied. Based on an evaluation and comparison of environmental effects and criteria established under USACE guidance, the recommended plan was selected. Alternative 3A-2.2, which is the National Economic Development (NED) plan and the environmentally preferable alternative, would reduce the risks associated with a flood event with a 1-percent annual change of exceedance with 95-percent conditional non-exceedance probability.

Consistent with reducing flood risk in an environmentally sustainable manner, the project will be designed, constructed and operated to avoid impacts to native aquatic species by incorporating natural-bottom arch culverts to maintain species passage where appropriate and by limiting work in the streams to low-flow conditions. All practicable means to avoid or minimize adverse environmental effects have been incorporated into the recommended plan.

The draft Ala Wai Canal Flood Risk Management Study, O’ahu, Hawai’i Feasibility Study with Integrated Environmental Impact Statement was circulated for public review for 45 days from August 20 to November 9, 2015. A public meeting was held September 30, 2015. A response was provided to all comments submitted within the 45-day public review period, and a copy of each response is provided in the final Ala Wai Canal Flood Risk Management Study, O’ahu, Hawai’i Feasibility Study with Integrated Environmental Impact Statement. No changes to the alternatives or recommended plan resulted from the receipt of agency comments.

The recommended plan will have adverse impacts on the blackline Hawaiian damselfly, which has been the subject of consultation between USACE and the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the Endangered Species Act (ESA). USACE has agreed to terms and conditions of the USFWS biological opinion which implement the reasonable and prudent measures to avoid and minimize impacts to the blackline Hawaiian damselfly.

All applicable laws, executive orders, regulations and local government plans were considered in the evaluation of alternatives. Based on review of these evaluations, I find that the benefits outweigh the costs and any adverse effects. This Record of Decision completes the National Environmental Policy Act process.

____
Date

____
[NAME]
Assistant Secretary of the Army (Civil Works)

Appendix E9
Essential Fish Habitat (EFH) Assessment

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ESSENTIAL FISH HABITAT ASSESSMENT

ALA WAI CANAL PROJECT
OAHU, HAWAII

Prepared by:
U.S. ARMY ENGINEER DISTRICT, ALASKA
ENVIRONMENTAL RESOURCES SECTION

For:
HONOLULU DISTRICT, U.S. ARMY CORPS OF ENGINEERS
CIVIL AND PUBLIC WORKS BRANCH
PROGRAMS AND PROJECT MANAGEMENT DIVISION
FORT SHAFTER, HAWAII

March 2016

updated July 2016

ESSENTIAL FISH HABITAT ASSESSMENT

Ala Wai Canal Project
Oahu, Hawaii

1. Introduction

1.1 Preface

The 1996 amendments to the Magnuson-Stevens Fishery Conservation and Management Act set forth the essential fish habitat (EFH) provision to identify and protect important habitats of federally managed marine and anadromous fish species. Federal agencies that fund, permit, or undertake activities that may adversely affect EFH are required to consult with the National Marine Fisheries Service (NMFS) regarding the potential effects of their actions on EFH and respond in writing to NMFS recommendations.

EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities.

1.2 Project Purpose

The purpose of the project is to reduce flood risk within the Ala Wai Watershed, which includes lands within and upgradient of central Honolulu, Hawaii. Flooding has occurred within the watershed on multiple occasions, resulting in recorded property damages and health and safety risks. Flooding can result from typical rainfall events, and is exacerbated by the flashy nature of the streams, and by debris generated by the surrounding watershed. Historic alterations to the stream channels do not adequately manage flood risk. Analyses conducted in support of this project show that the 1-percent annual chance exceedance (ACE) floodplain extends over approximately 1,358 acres of the watershed. Modeling results indicate the 1-percent ACE flood would result in damages to more than 3,000 structures, with approximately $318 million in structural damages alone (USACE 2015).

1.3 Project Authority

The Ala Wai Canal Project feasibility study is authorized under Section 209 of the Flood Control Act of 1962 (Public Law 87-874). Section 209 is a general study authority that authorizes surveys of harbors and rivers in Hawaii "with a view to determining the advisability of improvements in the interest of navigation, flood control, hydroelectric power development, water supply, and other beneficial water uses, and related land resources."

The Corps is the Federal sponsor of the project; the non-Federal sponsor is the State of Hawaii Department of Land and Natural Resources (DLNR), represented by the Engineering Division. A Feasibility Cost Sharing Agreement (FCSA) was originally executed with DLNR in March 2001; the agreement was amended in December 2006 and November 2012.

1.4 Project Area Description

The Ala Wai watershed is located on the southeastern side of the island of Oahu. The watershed encompasses 19 square miles (12,064 acres) and extends roughly 5 miles from the ridge of the Koʻolau Mountains to the near-shore waters of Mamala Bay. It includes the drainages of Makiki, Manoa, and Palolo streams, which flow to the Ala Wai Canal, a 2-mile-long, man-made waterway constructed during the 1920s to drain extensive coastal wetlands. This construction and subsequent draining allowed the development of the Waikiki District. The study area is shown in Figure 1.

The Ala Wai watershed contains approximately 200,000 residents, and is the most densely populated watershed in Hawaii. The upper portion (approximately 7.5 square miles, or 40 percent of the watershed) is zoned as Conservation District, which is intended to protect natural and cultural resources, including the island's aquifer. The remaining approximately 11 square miles of the middle and lower watershed is heavily urbanized, supporting a high density of single-family residences, condominiums, hotels, businesses, and schools.

1.5 Project Description

The Ala Wai Project "tentatively selected plan" consists of multiple structures intended to slow and temporarily detain high flows of water within the watershed and reduce the risk of flooding, particularly in the Waikiki area and the lower portions of the watershed, and to also create locations where debris swept into the streams will preferentially accumulate for more effective removal from the stream system. These structures include floodwalls along the Ala Wai Canal, 3 large multi-purpose detention basins in the lower watershed, 6 in-stream debris and detention basins in the upper watershed, and 1 standalone debris catchment structure. In addition, the plan includes improvements to the flood warning system, and compensatory mitigation in the form of in-stream improvements to eliminate migratory passage barriers for native species at two locations.

These plan components are described in detail in the draft feasibility report/environmental impact statement (FR/EIS; USACE 2015); the structural components are summarized in Table 1 below, and their locations shown on Figure 1. The existing project design drawings (35% stage for the flood risk management structures, 10% stage for the mitigation features) were provided to the NMFS previously.

Table 1 – Summary of Ala Wai Project Structural Components

1	Ala Wai Canal floodwalls	Concrete floodwalls along Ala Wai Canal, approx. 1.7 miles along the left bank and 0.9 mile along the right bank, ranging up to approximately 5 feet high; three pump stations and gates to address potential flooding on land-side of floodwalls
2	Hausten Ditch detention basin	Concrete floodwalls and earthen berm (4.3 feet high) to provide detention for local drainage; install slide gates at existing bridge to control flow of floodwaters between Hausten Ditch and Ala Wai Canal
3	Ala Wai Golf Course multi-purpose detention basin	Earthen berm, up to approximately 7 feet high around outside perimeter of golf course property, with floodgate across main entrance road; passive drainage back into Ala Wai Canal
4	Kanewai Field multi-purpose detention basin	Earthen berm, approximately 9 feet high, around 3 sides of the field; grouted rip-rap inflow spillway along bank of Mānoa Stream to allow high flows to enter the basin; existing drainage pipe at south end of basin to allow water to re-enter stream.
5	Manoa in-stream debris catchment	Concrete pad, approximately 8 feet wide and 60 feet across, within concrete-lined portion of stream channel; steel posts (up to approx.7 feet high) evenly spaced 4 feet apart along concrete pad.
6	Makiki debris and detention basin	Earthen dam surfaced with concrete spillway above culvert and rip-rap on upstream and downstream sides, approximately 24 feet high and 100 feet across; arch culvert to allow small storm flows to pass. Debris catchment feature located on upstream end of culvert. New access road to be constructed for construction and O&M.
7	Woodlawn Ditch detention basin	Three-sided berm, approximately 15 feet high and 840 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with rip-rap on upstream and downstream side
8	Pukele debris and detention basin	Earthen dam, approximately 30 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert. Excavation of 14,330 yd3 to provide required detention volume upstream of berm. New access road to be constructed for construction and O&M.
9	Wai'oma'o debris and detention basin	Earthen dam, approximately 33.5 feet high and 120 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert, with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert. Excavation of approx. 3,060 yd3 to provide required detention volume upstream of berm; low-flow channel with existing substrate to be restored following excavation. New access road to be constructed for construction and O&M.
10	Waiakeakua debris and detention basin	Earthen dam, approximately 34 feet high and 185 feet across; arch culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert .New access road to be constructed for construction and O&M.
11	Waihi debris and detention basin	Earthen dam, approximately 37 feet high and 225 feet across; box culvert to allow small storm flows to pass; concrete spillway above culvert with grouted rip-rap on upstream and downstream side; debris catchment feature located on upstream end of culvert; approx. 150 feet of riprap scour protection downstream of culvert . New access road to be constructed for construction and O&M.

12	Mitigation Measure Falls 7	Remove overhanging lip associated with undercutting at existing in–stream structure within Manoa Stream, approximately 0.6 mile upstream of Manoa District Park
13	Mitigation Measure Falls 8	Remove overhanging lip associated with undercutting at existing in–stream structure within Manoa Stream, approximately 0.7 mile upstream of Manoa District Park

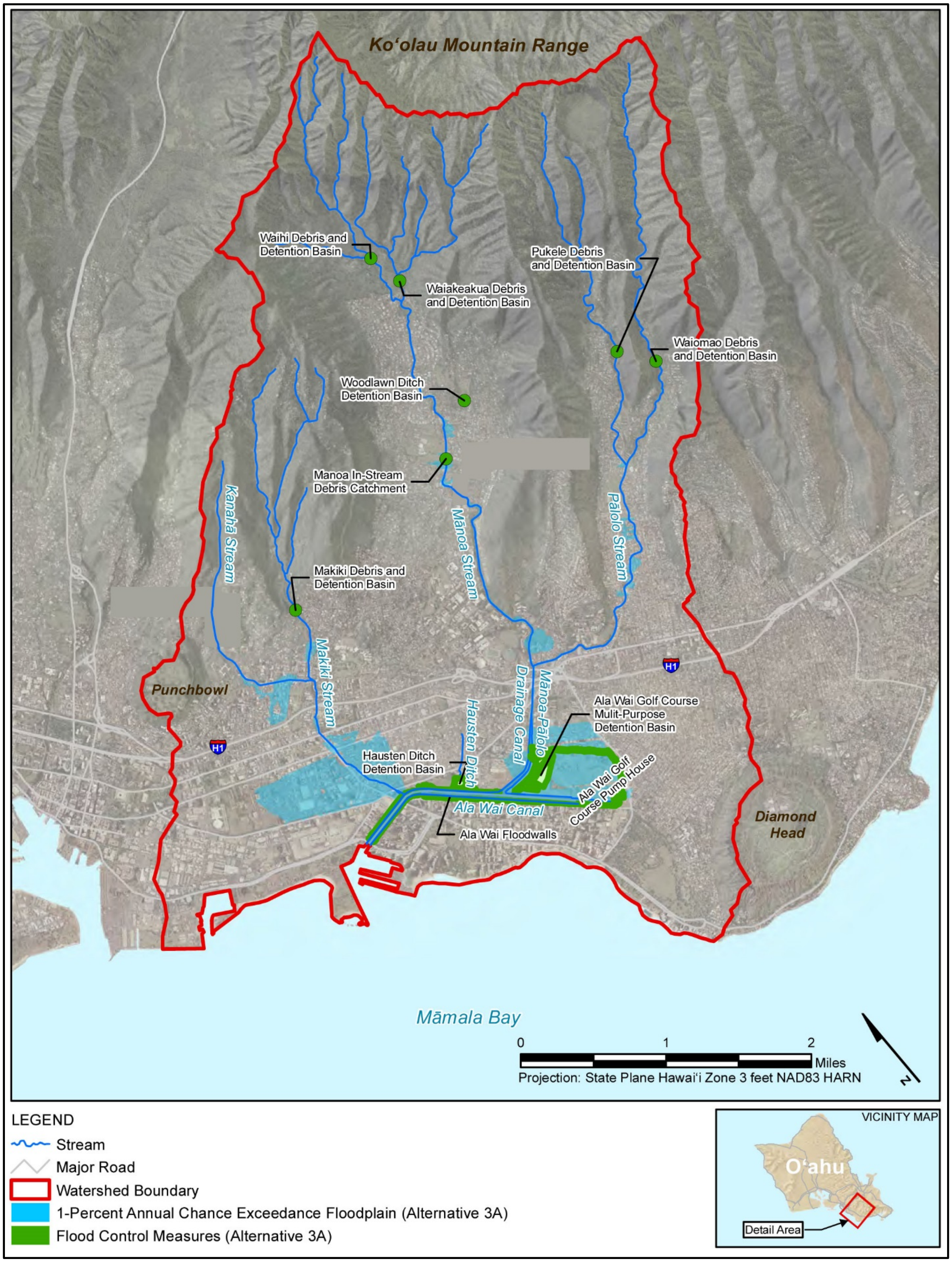

Figure 1. Location of Ala Wai Watershed and Project Features (adapted from USACE 2015).

Post-construction operations and maintenance (O&M) at each of the structures will include periodic inspections, controlling vegetation within the project limits (allowing no woody vegetation to grow, and trimming other vegetation to 6 inches or less) twice per year, and clearing accumulated debris (i.e., organic detritus and trash) annually and after flood events. In general the project limit for each feature will extend no further than 20 from the dam or berm. An exception is the Wai'oma'o debris and detention basin, the construction of which will include excavation of an expanded detention basin upstream of the dam; the roughly 250-foot-by-100-foot area cleared for the excavation will be included in the project limit and maintained as described above.

2. Essential Fish Habitat

Essential fish habitat (EFH) in the marine waters surrounding the Hawaiian Islands is described in two fishery ecosystem plans (FEPs) prepared by the Western Pacific Regional Fishery Management Council (WPRFMC). The FEP for the Hawaiian Archipelago (WPRFMC 2009a) specifically manages demersal resources and habitats associated with the extended Hawaiian Islands, while pelagic resources are managed under a separate Pacific Pelagic FEP (WPRFMC 2009b).

No EFH exists in the project areas. The Ala Wai Canal, which receives surface waters from the Ala Wai watershed, is contiguous with Mamala Bay (figure 1), which fronts much of the southeast Oahu coastline. The draft FR/EIS identified the following EFH as being present in Mamala Bay:

- Bottomfish: water column down to 400 meters from shoreline out to the 200-mile U.S. Exclusive Economic Zone (EEZ) boundary (for eggs and larvae); and water column and all bottom habitat from shoreline to a depth of meters (for juveniles and adults);
- Coral Reef Ecosystem: Water column and all bottom substrate down to 100 meters depth from shoreline out to EEZ boundary;
- Crustaceans (lobsters/crab): Water column down to 150 meters depth from shoreline out to EEZ boundary (for eggs and larvae); and bottom from shoreline down to 100 meters depth (for juveniles and adults);
- Pelagics: water column down to 200 meters (for eggs and larvae) and 1,000 meters (for juveniles and adults) from shoreline out to EEZ boundary.

3. Essential Fish Habitat Evaluation

The Ala Wai Canal draft FR/EIS (USACE 2015) made the determination that the project will have no adverse effect on the EFH described above. The NMFS has stated that it believes that the project activities may adversely affect EFH in Mamala Bay due to potential increases in sedimentation and turbidity (Goldberg 2016). These potential indirect effects to marine resources proposed by the NMFS are plausible to the extent that the project activities could introduce quantities of sediment into the Ala Wai watershed sufficiently large that effects on the marine environment beyond the watershed could reasonably be anticipated.

The risk of discharge of sediment into the watershed at a particular project site would be related to the amount of soil or sediment disturbed during construction or maintenance activities, and to the proximity of those activities to a stream channel. Referring to the Table 1 summary of project structural components, components 1 through 4 involve no or very limited work within a stream channel, and earthwork that is confined to uplands. The Ala Wai Golf Course, Hausten Ditch, and Kanewai Field multi-purpose detention basins create basins that are outside the stream channel, and require at most minor modifications to portions of the existing stream banks to create spillways that would function during high-flow conditions. Component 5 involves installation of steel poles and an additional concrete pad within an existing concrete-lined portion of Manoa Stream, and would disturb no soil or sediment. Likewise, the compensatory mitigation features (components 12 and 13) involve the construction of small rock structures that within the stream channel that should require the disturbance of little or no soil or sediment.

Elements 6 through 11 are detention basins constructed within stream channels, and have the greatest potential for introducing sediment into the watershed during construction and maintenance in the absence of appropriate sediment management measures.

The following analysis of project impacts on water quality in general within the project area is extracted directly from Section 5.6 of the draft FR/EIS; the sources cited within the passage below are likewise provided in that document:

> *5.6.1.2 Environmental Setting*
> The quality of surface water and groundwater resources can be affected by a variety of pollutants, resulting from both natural and human-derived sources. Given the heavily developed nature of the Ala Wai Watershed, groundwater and surface water resources are especially vulnerable to contamination and other changes in quality, particularly within the urbanized areas. Following is a description of the existing quality of surface and groundwater resources within the Ala Wai Watershed.
>
> *Surface Water Quality*
> Numerous studies have investigated the extent of pollution in the water column and sediments within the Ala Wai Canal, with a few studies also sampling the main streams in the watershed. In general, these studies have identified problems related to bacteria, trace metals, nutrients, pesticides, toxic organics, and sediment (Edward K. Noda, 1992a, 1992b, and 1992c; Laws et al., 1993; DOH, 1997a; DOH, 2002; Anthony et al., 2004; De Carlo et al., 2004); these are briefly described below. In addition to these constituents, significant amounts of trash and debris are commonly observed in the streams and canals.
>
> • Bacteria: High levels of fecal coliform, enterococcus bacteria and other indicators of fecal pollution (e.g., *Clostridium perfringens*) have been detected in the Ala Wai Canal and streams,

particularly after runoff events (DOH, 1997a). Leptospirosis, a bacterial infection spread primarily through animals (e.g., rats), is another problem in tropical waters; cases in Hawai'i have been reported by people swimming in stream waters. Although no studies have been conducted to determine the degree of threat to public health, a blanket advisory has been issued for all fresh waters in the State (DOH, 2014).

• Trace Metals: Studies on dissolved and particulate trace metals in the Ala Wai Watershed by De Carlo et al. (2004) show elevated levels, with ongoing inputs of lead, zinc, copper, barium, and cobalt from urban sources and less significantly, inputs of arsenic, cadmium, and uranium from agricultural sources. Although the lead concentrations have been decreasing since leaded gasoline was phased out, there are still continued inputs believed to be linked to lead-based paint used in older homes and from brake pads and other automotive uses (De Carlo et al., 2004; Sutherland, 2000). High levels of copper and zinc also result from heavy use of these substances in automobile brake pads and tires. De Carlo et al. (2004) propose that road-deposited sediments may also contribute to the elevated concentrations of barium and cobalt in the lower watershed.

• Nutrients: Nitrogen and phosphorus concentrations in the streams and Canal have consistently exceeded the State water quality standards (DOH, 1997a). The highest nutrient levels have consistently been reported at the upper end of the Ala Wai Canal (near Kapahulu Avenue), which receives urban runoff from storm drain outfalls (Edward K. Noda, 1992b); however, high levels have also been documented in forested upper watershed areas (Yim and Dugan, 1975). Sources of nitrogen and phosphorus are soil erosion, animal wastes, fertilizers, automobile exhaust, food wastes, rotting vegetation, sewage, and specifically in the lower canal areas, illicit discharges from boats in the yacht harbor.

• Pesticides: The organochlorine compounds dieldrin, chlordane, and heptachlor were used for many decades as pesticides to control termites in Hawai'i, until they were phased out in the 1980s. As these compounds typically have low solubility, they are mostly transported through soil erosion and surface runoff, then accumulate with bottom sediments in the streams and move through the food chain (Brasher and Wolff, 2004). Because of their widespread use, dieldrin and chlordane have been detected in fish and stream bed sediment samples from Mānoa Stream at concentrations that exceed aquatic life and wildlife protection guidelines (Brasher and Anthony, 2000). In comparison to other streams sampled across the nation, urban streams on O'ahu (such as Mānoa Stream) had the highest concentrations of chlordane and dieldrin detected (Brasher and Wolff, 2004).28 Anthony et al. (2004) believe that, because of the persistence of dieldrin, soil and stream bed sediments in urban Honolulu serve as a long-term reservoir of dieldrin. Similarly, the valley-fill aquifer that contributes to low flows in Mānoa Stream may also be a persistent reservoir of dieldrin.

Most of the sampling efforts and analyses in the Ala Wai Watershed have concentrated on insecticides. Although not to the same degree, herbicides have also been detected in Mānoa Stream, with the most frequent detections involving prometon (in base flows) and bentazon (in storm runoff) (Anthony et al.,2004). Both of these herbicides are used in urban areas; bentazon is used for turfgrass, so detections are believed to represent wash off from soils during rainstorms (Anthony et al., 2004). It is not clear if detections of these herbicides pose any risk to aquatic life.

• Toxic Organics: Toxic organics include such compounds as volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), phthalates, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs); these contaminants are commonly associated with products that are prevalent in urban areas, including gasoline compounds, construction materials, plastics, and vehicle exhaust. Similar to organochlorine pesticides, many of these compounds, particularly SVOCs and PCBs, have low solubility and are transported through soil erosion and surface runoff, ultimately moving up the food chain via benthic algae and invertebrates (Brasher and Wolff, 2004).

• Sediment: The Ala Wai Canal generally serves as a sink for the watershed, capturing sediment that is transported via its tributary streams, a function presumably provided by the former coastal wetlands in this area. Historical accounts reference large quantities of sediment being deposited in the nearshore waters during storm events (Weigel, 2008), as occurs in other steep tropical environments, but the natural background erosion and transport rates are not known. Nevertheless, input of fine sediment is believed to have increased over time because of feral pig wallows and shallow-rooted exotic vegetation in the upper watershed, eroding channel banks, and runoff from adjacent urban areas. Sediment loading contributes to habitat degradation in the streams and in the nearshore marine environment by smothering substrate, filling interstitial spaces, and harming coral reef communities. Calculations of the sedimentation rate in the Ala Wai Canal over time have been relatively consistent, ranging between approximately 7,000 to 8,000 cubic meters per year (m^3/yr) (Gonzalez, 1971; Laws et al., 1993; McMurty, 1995). The most recent dredging effort was conducted in 2002 and 2003, during which approximately 141,440 m3 of sediment was removed from the Ala Wai Canal and the lower portion of the Mānoa–Pālolo Drainage Canal (D. Imada, personal communication, June 14, 2010).

Other parameters that are important to water quality in streams include temperature, pH and dissolved oxygen. Temperature is an important biological parameter, and is tied closely to water flow and shading by riparian vegetation. Temperature records comparing urban and forested streams on Oʻahu indicate that urban streams have a higher mean temperatures and much greater diurnal and seasonal swings in temperature as compared with forested streams (AECOS, 2010; Brasher, 2003). Dissolved oxygen and pH levels are temperature dependent, with reduced quality in waters with stagnant flow and warm temperatures. In general, neither low dissolved oxygen nor deviant pH levels occur in the natural stream reaches in the watershed (AECOS, 2010). However, channel modifications that result in stagnation and/or high temperature fluctuations can lead to detrimental dissolved oxygen and pH levels, in some cases leading to eutrophication, particularly in the Ala Wai Canal (AECOS, 2010; Laws et al., 1993).

Water Quality Standards

Specific water quality criteria have been promulgated in HAR Section 11-54, which, if met, are designed to allow water bodies to achieve designated beneficial uses. Water bodies that do not achieve the criteria are designated as “impaired” and are placed on the Clean Water Act Section 303(d) List of Impaired Waters. Based on the data presented in the 2014 State of Hawai’i Water Quality Monitoring and Assessment Report (DOH, 2014), several locations within the Ala Wai Watershed have been designated as impaired water bodies, including the three major streams and the Ala Wai Canal. Mānoa Stream is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, dieldrin, and chlordane. Pālolo Stream is listed for trash, and Makiki Stream is listed for total nitrogen and total phosphorus. The Ala Wai Canal is listed for total nitrogen, nitrate and nitrite nitrogen, total phosphorus, turbidity, enterococci, pathogens, metals, suspended solids, and organochlorine pesticides. For each water body on the Section 303(d) list, a Total Maximum Daily Load (TMDL) must be developed to bring that water body into compliance with water quality standards. To date, the only TMDLs that have been developed are for nitrogen and phosphorus in the Ala Wai Canal. Development of the remaining TMDLs has been designated by the State of Hawai'i Department of Health (DOH) as a low priority (DOH, 2014).

Groundwater Quality

The quality of groundwater can be affected by contamination from both natural and anthropogenic sources; chemical leaching and saltwater intrusion are two common sources of contamination. Chemical leaching occurs when residual contaminants such as petrochemicals or pesticides percolate from the surface soil layers into the freshwater lens. Saltwater intrusion can occur when brackish water infiltrates the freshwater lens, often caused by overpumping (or improper pumping) of the aquifer (CWRM, 2008a). The Hawai'i Groundwater Protection Program (GWPP), administered by the DOH Safe Drinking Water Branch, is focused on assessment of water quality and development of pollution prevention and protection measures. As part of the program, a groundwater contamination map is maintained to identify drinking water wells, nonpotable wells, and fresh water springs where contaminants have been detected (DOH, 2015). The map identifies dieldrin as the only contaminant detected within the three wells sampled within the watershed. The detection levels ranged from 0.01 to 0.03 parts per billion (ppb), which are below DOH and Federal drinking water standards.

5.6.2 Impacts and Mitigation

Effects on water quality were considered to be significant if implementation of an alternative plan would result in any of the following:

- Substantially degrade surface water quality such that it would violate water quality standards, contribute to exceedance of aquatic life guidelines, or otherwise impair beneficial uses;
- Substantially increase contaminant levels in the groundwater;

The potential effects to water quality that could result from implementation of the alternatives, measures that would be conducted to mitigate those effects, and the resulting degree of impact are discussed in the following subsections.

5.6.2.1 No Action Alternative

Under the No Action Alternative, no Federally sponsored flood risk management measures would be constructed. Although potential construction-related impacts to water quality would not occur, nor would the potential long-term benefits associated with the capture and removal of flood-related debris and sediment via the debris and detention features. Input of sediment (such as that caused by erosion of the near-stream and upper watershed areas) and transport of sediment-bound contaminants is generally expected to continue at the same rate, as the factors that influence erosion (e.g., invasive species cover in the upper watershed) are already widespread. Based on the existing TMDLs, it is expected that nutrient levels in the watershed would be reduced, although the extent to which the reductions are achieved cannot be predicted. Given the persistence of dieldrin and other pesticides, inputs from long-term reservoirs are expected to continue over time. Although there are ongoing discussions about the need to reduce anthropogenic sources of contaminants (e.g., use of heavy metals in brake pads and tires), the extent to which regulatory restrictions would be established at either the Federal or State level are unknown. As such, significant reductions for the range of contaminants in the watershed are not expected for the future without-project conditions. It is assumed that the Canal would continue to be dredged at approximately the same rate, or at least once every 25 years, and as such, the sediment and associated contaminants that accumulate in the Canal would continue to accumulate and be removed at approximately the current rate.

5.6.2.2 Tentatively Selected Plan (Alternative 3A-2.2)

In addition to impacting soil resources and channel stability, construction-related erosion could increase the delivery of sediment and associated pollutants via stormwater runoff, which could temporarily affect water quality in the streams and downstream receiving waters. Although sediment-bound pollutants are known to occur throughout the watershed (particularly in the urbanized areas), none of the soils that would be exposed by construction are expected to contain excessive levels of contamination. In general, construction of the flood risk measures would involve placement of imported materials, with only minimal amounts of excavation. All materials used to construct the measures would be from approved sources, and would be clean and free of contaminants. Areas requiring excavation (e.g., for the Waiʻōmaʻo detention basin, and to create the spillway for the Kanewai detention basin and the Ala Wai Golf Course detention basin) are either located in the upper watershed and/or in undeveloped open space areas, which are not subject to significant inputs of roadway sediments or other anthropogenic contaminants, such that a significant increase in pollutant delivery to the streams is not expected as a result of construction. As further discussed in Section 5.12, none of the measure locations are known to contain hazardous or toxic waste. In addition, the proposed project would require the storage and use of some hazardous materials, which if handled inappropriately, could result in an accidental spill or inadvertent discharge to the streams or groundwater. In particular, construction activities would involve the use of heavy equipment, cranes, compactors, and other construction equipment that use petroleum products such as fuels, lubricants, hydraulic fluids, and coolants, all of which are detrimental to water quality.

As construction would disturb more than 1 acre of land, the project would be regulated under the State's NPDES [National Pollutant Discharge Elimination System] stormwater program, which requires preparation of a SWPPP [Stormwater Pollution Prevention Plan] to obtain permit coverage. The objective of a SWPPP is to describe the measures that would be implemented to prevent sedimentation, erosion, and stormwater contamination, in compliance with the requirements of the NPDES program. … Preparation and implementation of the SWPPP, as well as adherence to other requirements of the NPDES program, would reduce the potential construction-related water quality impacts to a less-than-significant level; no mitigation is required.

Once constructed, the structures themselves are not expected to contribute pollutants to the streams or otherwise measurably affect water quality. The detention structures would be comprised of compacted, earthen berms with concrete or grouted rip-rap spillways; the debris catchment structures would be comprised of a concrete pad with metal posts; the floodwalls would be comprised of concrete walls; and the mitigation measures would be comprised of grouted stone. All materials used to construct the measures would be from approved sources, and would be clean and free of contaminants. Although the debris and detention basins may slightly reduce riparian shading (e.g., vegetation management around the perimeter of the detention berms), they are not expected to contribute to any measurable changes in water temperature, nor pH or dissolved oxygen levels.

Over the long term, the project features are not expected to increase channel or bank erosion, or otherwise contribute to sediment and/or contaminant inputs to the streams, such that water quality conditions are generally expected to be commensurate with the existing condition. During flood conditions, the flood risk management measures are designed to either detain or contain stream flows within and directly adjacent to the waterways; the project includes features to maintain stormwater delivery (e.g., pumps associated with the Ala Wai Canal floodwalls), but would not significantly alter the quality, quantity, or pattern of stormwater inputs to the streams and/or Canal.

The detention basins would function to temporarily hold stream flows, slowly releasing them within the streams and Canal. To the extent that contaminants are present in the detention areas (particularly within the multipurpose detention areas, which may be subject to herbicide applications), detained water could flush contaminants into the streams, thus contributing to degraded water quality conditions. Conversely, contaminants in the water column or stream sediments could be deposited in the detention basins, thus transferring contamination into those area. However, the multi-purpose detention features are located within areas that are already subject to flooding under the existing without project condition, such that the project is not expected to substantially increase delivery of contaminants to the streams beyond that which already occurs or otherwise alter the location or degree of water quality contaminants. Similarly, in-stream detention in the upper reaches of the watershed is not expected to substantially increase mobilization of any contaminants beyond the existing condition. As such, the potential for water-quality impacts associated with detention of flood waters is expected to be less than significant.

Although the structures are not designed to capture sediment (with the exception of the Ala Wai Golf Course detention basin), some degree of sediment deposition is expected to occur within the detention basins, particularly during periods of inundation associated with flood stage flows. As previously described, sediment and debris (including trash and other man-made debris) that accumulates within the debris and detention features would be removed as part of the routine O&M activities and properly disposed of at an approved, offsite location that is qualified to accept the material. Removal of these materials from the debris and detention basins is anticipated to provide some degree of water quality benefit to downstream areas. As the structures are not explicitly designed to capture sediment, the quantity of sediment and any associated pollutants to be removed has not been quantified. Given the anticipated sediment capture in the debris and detention basins, in combination with the Canal’s function as a sediment sink, the project is not expected to increase (and could possibly decrease) sediment delivery to the nearshore waters.

The worst scenario for impacts to EFH would arguably be a catastrophic rainfall that forced high volumes of water, sediment, contaminants, and debris unimpeded out of the watershed and through the Ala Wai Canal into the marine environment. The Ala Wai Canal project is designed to reduce the risk of just such a scenario, albeit for different purposes (i.e., protection of human life and property).

4. Water Quality Regulatory Framework

The passage above describes how the project and its potential to affect water quality will be subject to the requirements of Section 402 of the Clean Water Act and the NPDES. The State of Hawaii NPDES permit program is administered by the Department of Health Clean Water Branch; more information on this department and its mission is available at the website http://health.hawaii.gov/cwb/. Among other NPDES permit requirements, a SWPPP must be prepared and approved for the project activities, detailing the measures to be followed to control the introduction of sediment and pollutants into waterways. Because such sediment management measures must be closely integrated with the construction techniques and project sequence that will be developed by the construction contractor, the contractor is generally tasked with developing the project SWPPP as part of its pre-construction requirements. In other words, the exact best management practices (BMPs) and other sediment mitigation measures that will be employed during construction are not known at this time.

The State of Hawaii Clean Water Branch also administers the State’s Water Quality Certification (WQC) Program, under Section 401 of the Clean Water Act. The objective of the program is to ensure that any Federally permitted activity will not adversely impact the existing uses, designated uses, and applicable water quality criteria of the receiving State waters. A Section 401 WQC will be requested from the State prior to construction; generally, the State will not issue a WQC until the project technical design is at an advanced stage.

In addition to complying with these Clean Water Act requirements, the project will also undergo review under the Hawaii Coastal Zone Management (CZM) Program (http://planning.hawaii.gov/czm/). This review process examines, among other things, the project’s potential impact on water quality, erosion, and the coastal environment.

The Corps will be developing a Maintenance Plan at a later stage of pre-construction design. The O&M activities will be subject to applicable water quality regulations.

5. Sediment Management & Mitigation Measures

As stated above, the exact sediment management measures that will be employed during construction and maintenance have not yet been developed at this stage of project planning. However, the draft FR/EIS describes a number of measures that are likely to be incorporated into contract requirements and maintenance plans. One of the more important of these is the ability to temporarily divert stream-flow and dewater a chosen section of stream channel, so that construction machinery working within the stream channel are not disturbing stream sediments within flowing water. Sand bags or a cofferdam can be used to isolate the work area and to concentrate upstream flows into a large-diameter pipe. The pipe would extend downstream, thus allowing the stream flow to bypass the construction area and maintain downstream flows. The outfall of the pipe would be carefully sited to avoid the potential for erosion. This temporary dewatering tactic has been used to good effect on other projects, such as migration passage barrier removal on Waihe’e Stream by the State of Hawaii Division of Aquatic Resources.

Other measures and best management practices (BMPs) described in the draft FR/EIS or under consideration by the Corps include:

- Limiting construction activities within the stream channels to low-flow conditions/seasons. In addition to minimizing the extent of dewatering required, this would also serve to minimize the potential to disrupt migration of native species;

- Sequencing construction activities to limit the extent of exposed soil at any given time, and minimizing the extent and duration of work with stream channels;

- Using appropriate vehicles and equipment for all stages of construction and adequately training construction crews to avoid and minimize impacts to the aquatic environment;

- Requiring an adaptive management approach to sediment management, in which standard construction site BMPs such as silt fencing, coir logs, and mulch are continually evaluated, reinforced, or replaced as the construction progresses;

- Requiring an emergency response plan to protect exposed earth from an unexpected rainfalls.

6. Summary and Determination

- The Ala Wai Canal Project has the potential to adversely affect EFH only as an extension of its potential to affect water quality within the watershed.

- The project's potential to affect water quality will be strictly regulated under the Clean Water Act and other applicable requirements. The intent and expected effect of the sediment management measures applied to meet those requirements will be to reduce project impacts to water quality to insignificant levels.

The project activities will be short-term, closely controlled events in the context of an urban watershed that is subject to numerous uncontrolled, poorly assessed discharges. The connection between the project activities within the watershed and essential fish habitat in the marine environment will be tenuous to the point of being indiscernible. The Corps of Engineers determines that the project activities will not have an adverse effect on EFH.

7. References.

Goldberg, Stuart (NMFS). Email dated 14 March 2016, subject: Ala Wai EFH determination.

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