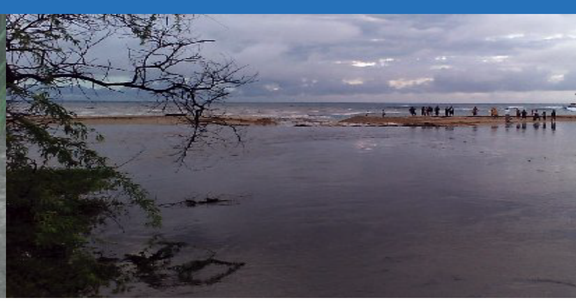
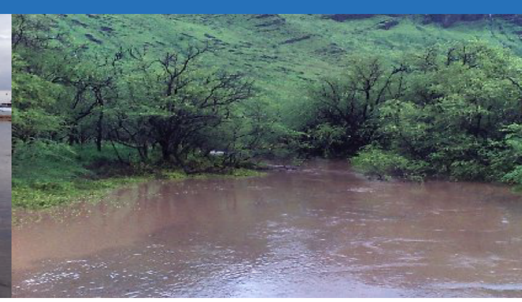
Mākaha Valley Flood Mitigation Study

PUBLIC REVIEW DRAFT REPORT
SEPTEMBER 2014

Volume I of III

Prepared for:
Department of Land and Natural Resources
Engineering Division

Prepared by:
Townscape, Inc.
with the assistance of
Okahara and Associates, Inc.

A special mahalo to community members who

contributed their time to share their mana'o.

Photographs on the cover page (from left to right):

Flooding behind homes on Manuku Street during December 2008 storm; Sand berm break at the mouth of Mākaha Stream; Stream flow at Mākaha Stream during heavy rains (facing upstream)

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LIST OF ACRONYMS

BMP	Best Management Practice(s)
BWS	Board of Water Supply
CDUP	Conservation District Use Permit
City	City and County of Honolulu
cfs	cubic feet per second
CWA	Clean Water Act
CWRM	Commission on Water Resource Management
DLNR	Department of Land and Natural Resources
DOH	Department of Health
DOT	Department of Transportation
EA	Environmental Assessment
EIS	Environmental Impact Statement
FEMA	Federal Emergency Management Agency
HEC-RAS	Hydrologic Engineering Center River Analysis System
hrs	hours
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OMPO	Oʻahu Metropolitan Planning Organization
ROH	Revised Ordinances of Honolulu
ROW	Right of Way
SCAP	Stream Channel Alteration Permit
SCD	State Civil Defense
SMA	Special Management Area
TMK	Tax Map Key
TR-55	Technical Release 55
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Executive Summary

Introduction

This study has been prepared by Townscape, Inc. for the Department of Land and Natural Resources, in fulfillment of the requirements set forth by Act 283, Session Laws of Hawaiʻi 2012. Okahara and Associates, Inc. contributed as sub-consultants for hydrology, hydraulics and civil engineering.

Over the years, Mākaha Valley has experienced numerous floods, including a 15-day rain event in November 1996 that resulted in 24 inches of rain in an area with an annual rainfall of 20 to 40 inches. A storm in December 2008 resulted in 12 inches of rain over the course of one day, which caused significant damage to roads and property.

Process

The study began with preliminary background research and information gathering. The study team met with community stakeholders, residents, business owners and large land owners to learn about historical flooding in the area, and also consulted with public agencies and elected officials. Hydrologic analysis was conducted to estimate the volume of water entering and passing through Mākaha during a rainfall event, specifically for the 10-, 25- and 100-year storms. Hydraulic modeling was done to determine the extent of flooding for "existing conditions" and for the "full build-out[1]" condition. Information from the stakeholder consultation process is included in Volume II of this report; and technical details from the hydrologic and hydraulic analysis are included in Volume III of this report.

Existing Watershed Conditions

Mākaha Valley is located on the leeward (west) side of the island of Oʻahu in the State of Hawaiʻi. It is approximately 5,914 acres in area and is comprised of two main watersheds, Mākaha and Kamaileʻunu. The Mākaha watershed covers about 4,659 acres—more than three-fourth of the valley—and drains into Mākaha Stream and West Mākaha Stream. A smaller drainage basin, about 1,255 acres in size, drains into Eku Stream (East Mākaha Stream).

Mākaha Stream and Eku Stream are the two main streams in the valley, with Mākaha as the primary stream. Mākaha Stream originates in the western slopes of the Waiʻanae mountain range and is fed by water that falls from Mount Kaʻala. The stream flows year-round in its upper reaches and intermittently at lower elevations. Eku Stream originates approximately 9,000 feet mauka (mountainside) of Farrington Highway on the eastern side of the valley from Kamaileʻunu Ridge and flows though the Mākaha East Golf Course.

Land elevations begin at sea level and rise to the highest peak of the valley, and of Oʻahu—Mount Kaʻala at an elevation of 4,015 feet above mean sea level. The majority of the valley walls and upper valley areas are covered with non-native grasses, shrubs, and trees. Soils vary throughout the valley, but the steep, mountainous areas are dominated by Rock Land (rRK), Stony Land (rST), and Tropohumults-Dystrandepts (rTP) soils.

[1] Full build-out assumes existing large undeveloped parcels are developed according to their city zoning designations.

More than one-third of the valley is designated as “Urban” within the State Land Use, while the remaining is designated as “Conservation.” The City & County of Honolulu, Board of Water Supply is the largest land owner in Mākaha. The lower Mākaha Valley consists of residential lots and single family homes. City zoning allows for apartment, agricultural, business, country, residential, preservation and resort use. There are at least thirteen large undeveloped parcels in the valley totaling more than 462 acres that could allow for more single family homes, hotels, and duplex units.

Flood Problems

Mākaha Valley lacks an overall interconnected drainage system. Rather, the drainage system in Mākaha is the result of “piecemeal” development without a master plan for the valley. A series of ditches, earthen berms, swales, catch basins, culverts, and underground pipes make up the drainage system for the developed areas of the valley. The majority of the runoff from these drainage systems is conveyed towards Mākaha Stream and some towards Eku Stream, but the stream capacities have not been improved. As a result, the streams overtop their banks during storm events and inundate surrounding areas where many of the homes are located.

Most of the flood problems were identified in the lower areas of the valley within the floodplain, including near Mākaha Stream, Eku Stream, and along Kili Drive, Mākaha Valley Road, Noholio Road and Lahaina Street. Some of the major flood problems and issues in Mākaha Valley are:

- Altered stream alignments
- Restrictions at the stream mouth contributing to flooding of properties near the mouth of Mākaha and Eku Streams
- “Unimproved” stream banks resulting in flooding of properties adjacent to Eku Stream
- Damaged drainage systems
- Lack of drainage infrastructure
- Clogged drainage infrastructure

Hydrologic Analysis

Hydrologic analysis, using the Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) method, determined the peak flows of Mākaha and Eku Streams. The calculated peak flows for a 10-, 25-, and 100-year storm for Mākaha Stream were 6,045 cubic feet per second (cfs), 8,166 cfs, and 11,413 cfs respectively. The calculated peak flows for a 10-, 25-, and 100-year storm for Eku Stream were 2,853 cfs, 3,792 cfs, and 5,201 cfs respectively.

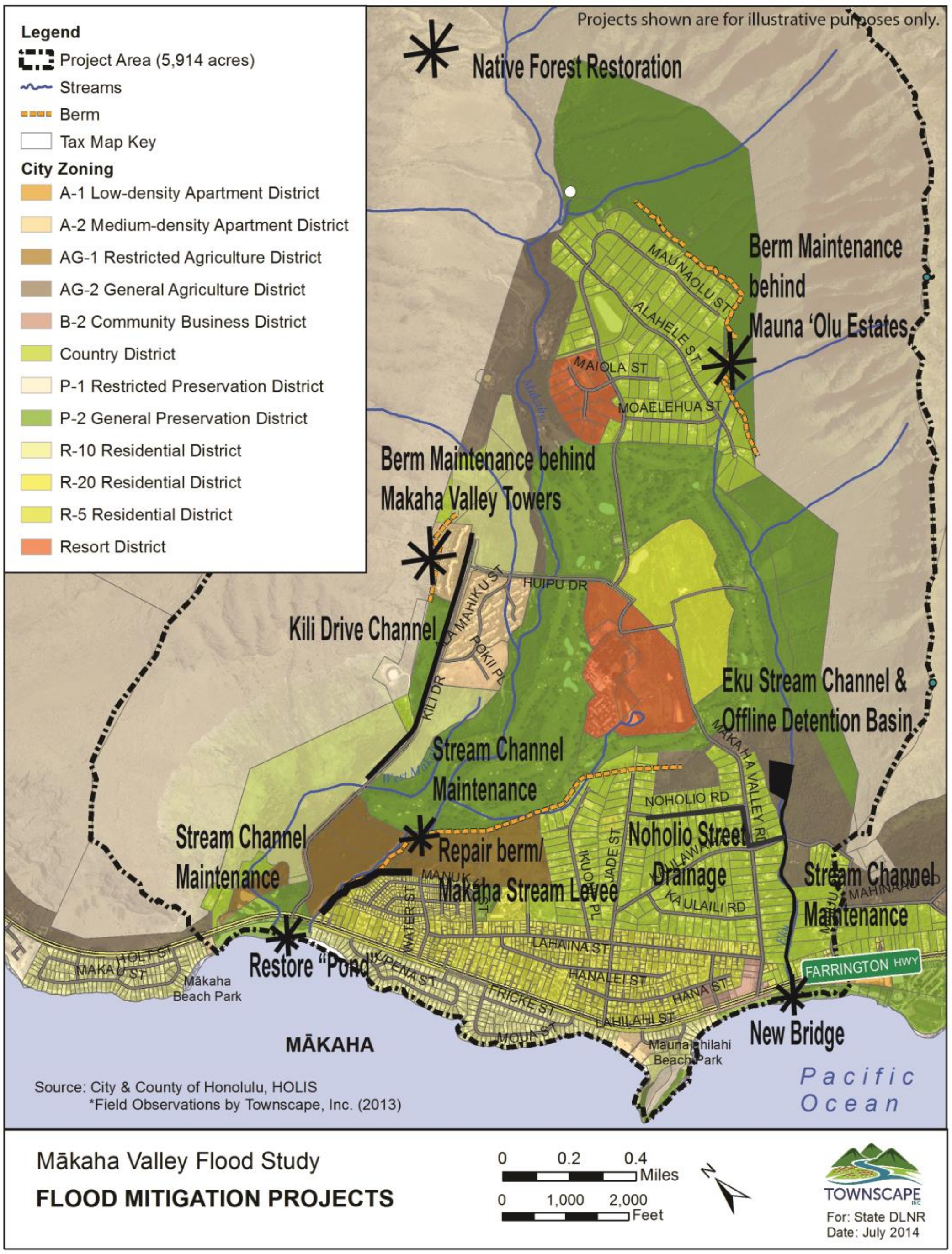
Hydraulic Analysis

Full build-out peak flows from WinTR-55[2] were inputted into the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) to analyze the extent of inundated areas from Mākaha and Eku Streams for the 10-, 25-, and 100-year storms.

Analysis showed that Eku Stream is well defined and contained until approximately 3,800 feet upstream of the mouth. For Eku Stream, the flood limits for the 10-,25- and 100-year storms in the upper

[2] Computer software program that applies the TR-55 model

elevations differ only slightly because of the deeper and more defined stream cross sections. As Eku Stream reaches the lower elevations, the flood limits of the 10-, 25-, and 100-year storms differ somewhat due to the very flat terrain found in some areas. For Mākaha Stream, the banks are more defined and therefore the flood limits differ only slightly for the 10-, 25-, and 100-year storms. The flood elevations range from two to seven feet within the streambed of Eku Stream, while the floodplain of Eku Stream can range from zero to three feet. Flood depths for Mākaha Stream range from five to over ten feet within the streambed and can range from zero to four feet in the Mākaha Stream floodplain.



Proposed Flood Mitigation Measures

Based on hydrologic and hydraulic analysis of the watersheds and discussions with community members, the structural projects and nonstructural programs recommended for Mākaha Valley are:

Structural Projects	Nonstructural Programs
1. Eku Stream Channel and Off-line Detention Basin 2. New Eku Stream Bridge at Farrington Highway 3. Repair the breach in the Mākaha Stream berm 4. Mākaha Stream Levee 5. Kili Drive Channel 6. Mauna ʻOlu Estates Drainage Improvements 7. Noholio Road Drain Line 8. Restore Mākaha Surfing Beach "Pond" 9. In-stream Detention Basins for Mākaha Stream	1. Forest Restoration 2. Stream Channel Maintenance 3. Storm Drain Maintenance 4. Enforcement of existing legislation 5. Education on Best Management Practices for Watersheds 6. Special care in permitting future development

Prioritization of Projects

Projects were grouped based on feasibility of implementation. Projects with relatively low cost and high implementation likelihood are categorized as Group 1. More complex and costly projects, but with large benefits relative to their cost are included in Group 2. Additional projects with high initial cost relative to their benefits are listed in Group 3.

Group 1	Group 2	Group 3
• Repair the breach in the Mākaha Stream berm • Restore Mākaha Surfing Beach "Pond"	• Eku Stream Channel and Off-line Detention Basin	• Kili Drive Channel • Mākaha Stream Levee • Noholio Road Drain Line • In-stream Detention Basins for Mākaha Stream • New Eku Stream Bridge at Farrington Highway

Summary of Environmental Impacts

No significant environmental impacts are anticipated from the proposed projects. Proposed projects will benefit public health and safety in terms of mitigating flood hazards, but may accelerate the velocity of runoff and reduce sedimentation of floodplain areas before discharging into the ocean. A more in-depth analysis of archaeological sites within the area may be required. Permits and approvals including a Special Management Area permit, Environmental Assessment or Environmental Impact Statement, Stream Channel Alteration Permit, National Pollutant Discharge Elimination System permit, Water Quality Certification, and Section 404 permit may be needed.

Next Steps

Significant funding will be needed to implement the proposed flood mitigation projects. A key strategy will be to secure funding for design and construction of projects incrementally. Identification of an entity that will assume ownership and/or perpetual maintenance of some of the improvements will be a challenge. The majority of the structural projects are located on privately-owned property.

1. Introduction

This study has been prepared by Townscape, Inc. for the Department of Land and Natural Resources (DLNR), in fulfillment of the requirements set forth by Act 283, Session Laws of Hawaiʻi 2012. Okahara and Associates, Inc. contributed as sub-consultants for hydrology, hydraulics and civil engineering. The requirements of the Act include the preparation of a flood study for Mākaha Valley, an investigation of all potential funding sources to finance flood mitigation projects, and provision of recommendations on improvements or repairs to mitigate flooding.

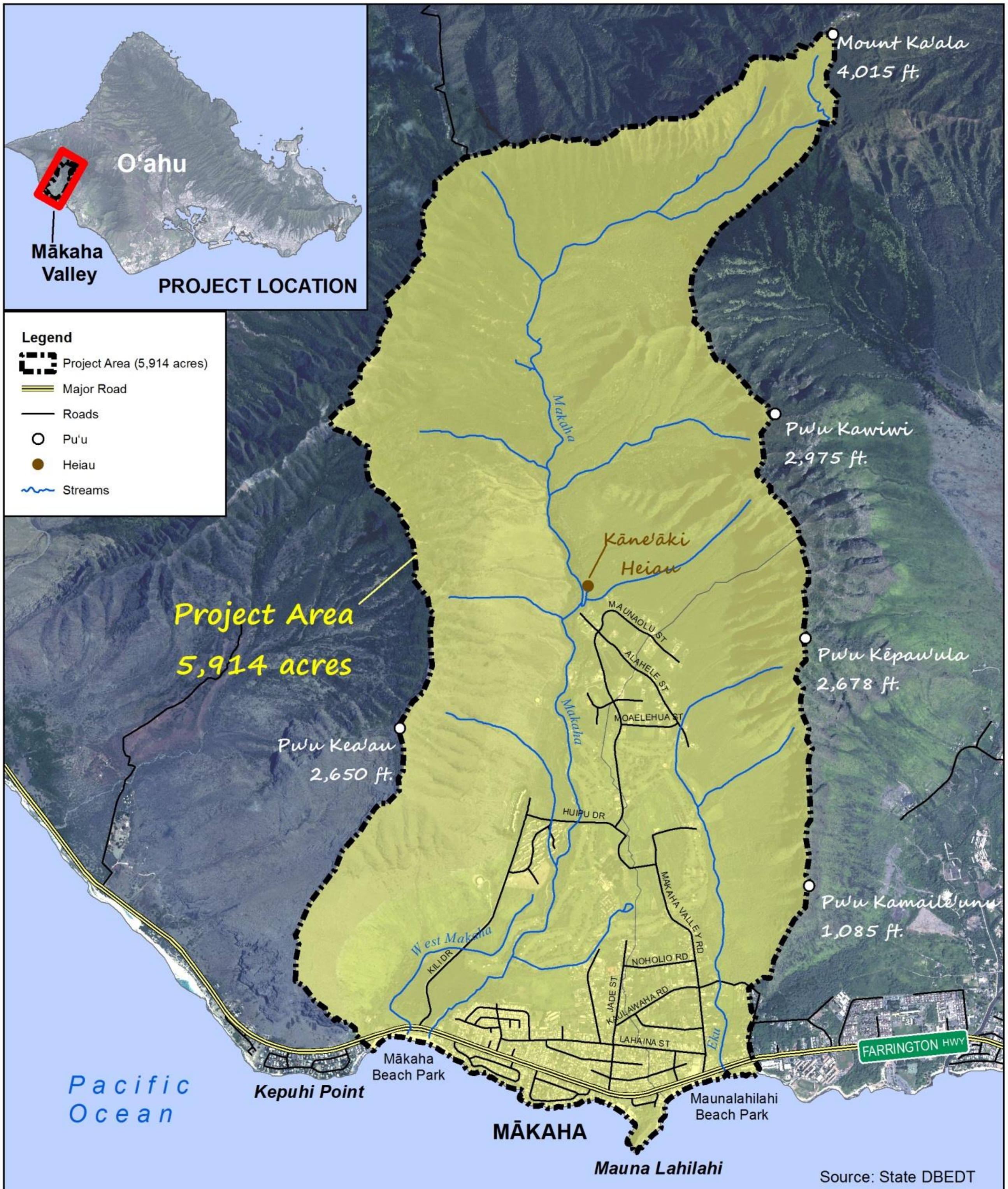
Over the years, Mākaha Valley has experienced numerous floods, including a 15-day rain event in November 1996 that resulted in 24 inches of rain in an area with an annual rainfall of 20 to 40 inches. A storm in December 2008 resulted in 12 inches of rain over the course of one day, which caused significant damage to roads and property.

Flooding in Mākaha Valley not only results in physical damage such as flooded roads, but it also affects the community socially and economically. These consequences include economic impacts, impacts on psychological and physical health, household disruption, evacuation, displacement and temporary accommodation.

The economic impacts include the cost of damage to property, as well as to roads, by a flood. Residents incur the cost of cleaning up after the storm and possibly the cost of temporary relocation. Residents living in floodplain areas already have to incur higher costs of purchasing flood insurance. Flooding on roads, particularly on Farrington Highway and heavily used roads such as Kili Drive and Mākaha Valley Road, can cause disruption to many residents who are unable to travel to and from their homes. Farrington Highway, which serves as the main road along the coast, is vulnerable to inundation by both riverine flooding and tidal waves. If the highway fails and closes, residents in Mākaha Valley and beyond could potentially be isolated from the rest of the island.

This report discusses the study process; provides an overview of existing watershed conditions; summarizes the flood problem areas; provides the hydrologic and hydraulic analysis; presents recommended flood mitigation projects and measures; and evaluates the effectiveness of each project to mitigate flooding. This report also provides a summary of environmental impacts of the proposed flood mitigation projects and concludes with future actions needed for implementation.

This report provides a succinct description of this flood study. Technical details have been documented in a separate volume of appendices.



Mākaha Valley Flood Study

Figure 1. Project Area

2. Process

The study began with preliminary background research and information gathering. The study team met with community stakeholders, residents, and government personnel to learn about historical flooding in the area. It was important for the team to understand some of the flooding issues from the perspective of those who have experienced the flooding problems "first-hand" and who throughout the years have observed the hydrologic changes in the valley due to land use changes, development, and urbanization. The project team also met with business owners and large land owners, public agencies, and elected officials. Meetings included one-on-one meetings, small group meetings, site visits to problem areas with stakeholders, and a community meeting to gather input and to share findings from the study. At the time of this writing, two additional community meetings are planned for this study. Information from the stakeholder consultation process is included in Volume II of this report.

Hydrologic analysis was conducted to estimate the volume of water entering and passing through Mākaha during a rainfall event, specifically for the 10-, 25- and 100-year storms. Hydraulic modeling was done to determine the extent of flooding for "existing conditions" and for the "full build-out[3]" condition. Community stakeholders, business owners, large land owners, and public agencies were consulted again after the project team developed concepts for preliminary flood mitigation projects.

First of three community meetings held at Wai'anae District Park

[3] Full build-out assumes existing large undeveloped parcels are developed according to their city zoning designations.

3. Existing Watershed Conditions

3.1 Physical Setting

Mākaha Valley is located on the leeward (west) side of the island of Oʻahu in the State of Hawaiʻi. One of the nine valleys on the leeward coast, Mākaha Valley is situated between Waiʻanae to its south and Keaʻau to its north. The valley is approximately five miles long and about two miles wide.

Aerial view of Mākaha Valley (1997)

Mākaha Valley is approximately 5,914 acres in area and is comprised of two main watersheds, Mākaha and Kamaileʻunu. The Mākaha watershed covers about 4,659 acres—more than three-fourth of the valley—and drains into Mākaha Stream and West Mākaha Stream. A smaller drainage basin, about 1,255 acres in size, drains into Eku Stream (East Mākaha Stream).

Mākaha Stream and Eku Stream are the two main streams in the valley, with Mākaha as the primary stream. Mākaha Stream originates in the western slopes of the Waiʻanae mountain range and is fed by water that falls from Mount Kaʻala. It flows southwesterly and terminates behind a large sand berm at Mākaha Beach Park. The stream flows year-round in its upper reaches and intermittently at lower elevations.

Eku Stream originates approximately 9,000 feet mauka of Farrington Highway on the eastern side of the valley from Kamaileʻunu Ridge and flows though the Mākaha East Golf Course. The stream is well defined and contained until approximately 3,800 feet upstream of the stream mouth.

Hydrology information is available from the two U.S. Geological Survey (USGS) stream gages (USGS Station Number 16211600 and 16211700) and the USGS rainfall gage (State Key number 842.1), all of which are located on Mākaha Stream. The stream gages provide data on annual peak streamflow[4], while the rainfall gage provides data on daily precipitation in inches.

The climate in Mākaha is generally reflective of conditions for leeward areas in Hawaiʻi, with rainfall ranging from about 25 inches per year in the coastal areas to about 80 inches per year at the highest elevations near Mount Kaʻala. The two seasons are distinguished by cooler temperatures and wet conditions during the winter months, generally between October and April, and drier and warmer conditions with northeasterly trade winds during the summer months. The leeward side is typically drier than the windward (east) side of Oʻahu. Most of the rainfall of the leeward areas is from major storms associated with the passage of a cold front or a Kona storm. These storms are more common in the winter and develop from the northwest and slowly move eastward, bringing extensive periods of rain to the leeward areas that may last for a week or more.

[4] USGS Gage No. 16211700 was discontinued in 2004 due to lack of funding.

3.2 Topography

Land elevations begin at sea level and rise to the highest peak of the valley, and of Oʻahu—Mount Kaʻala at an elevation of 4,015 feet above mean sea level. The valley consists of steep, nearly vertical ridges—with slopes greater than 200 percent—along both sides of the valley. From sea level to about 2.5 miles inland, the valley floor gradually increases to a 15 percent gradient and an elevation of about 600 feet. From there, the slope gradually becomes steeper until it reaches the top of the valley which is slightly less than five miles inland from the coast. The width of the valley floor varies from less than half a mile wide near Kāneʻāki Heiau, to nearly two miles wide near the coast.

3.3 Ground Cover

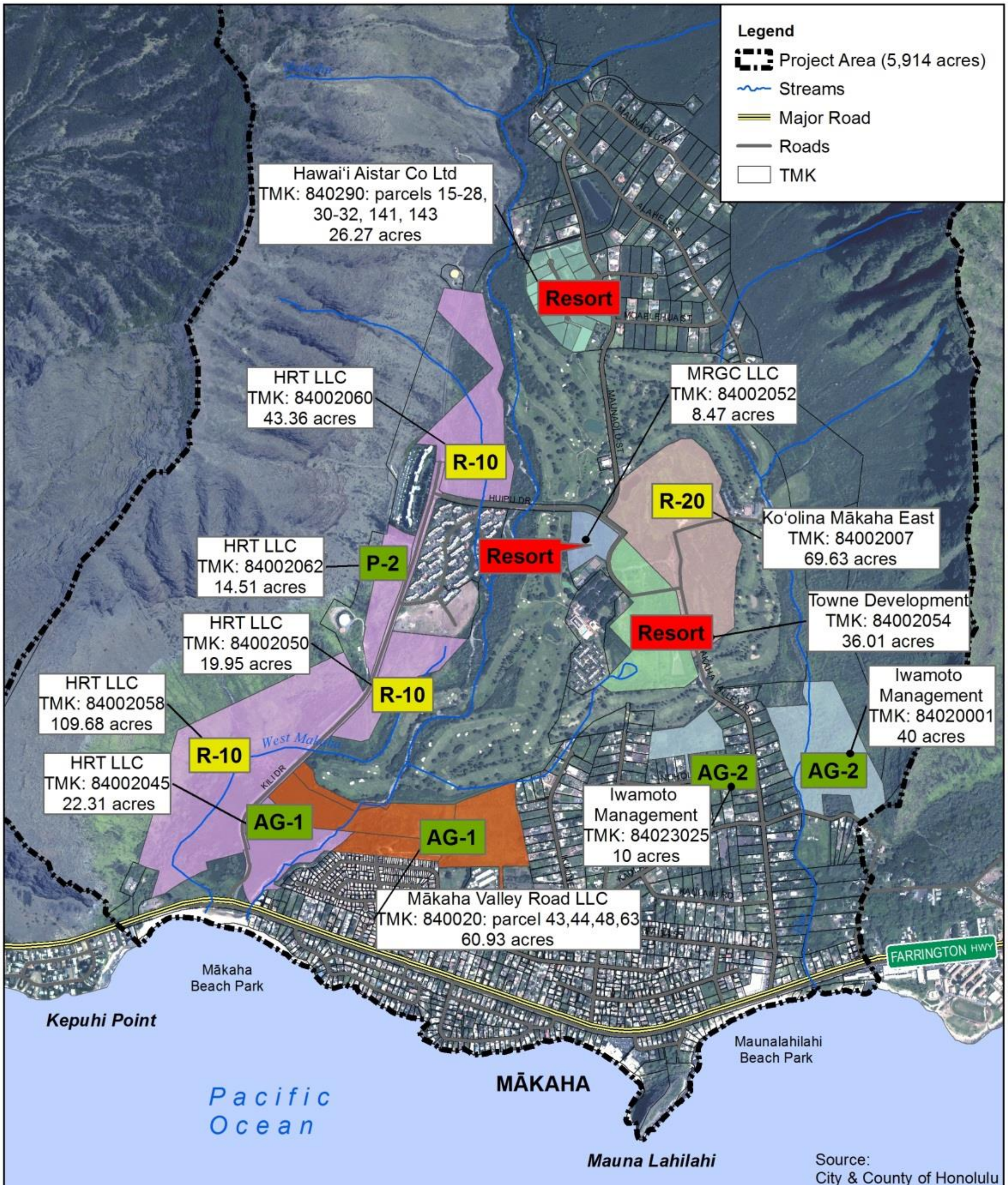
The majority of the valley walls and upper valley areas are covered with non-native grasses, shrubs, and trees. Invasive species such as coffee and strawberry guava are found throughout the forested areas. Native ʻōhiʻa trees and tropical uluhe fern shrubland cover a small portion of the upper valley near Mount Kaʻala. Kiawe forest and shrubland covers a significant part of the lower and mid-valley. The ridges are generally rocky outcrops with minimal vegetation cover. The majority of the streambeds, particularly from mid-valley to the ocean, are overgrown with vegetation.

Soils vary throughout the valley, but the steep, mountainous areas are dominated by Rock Land (rRK), Stony Land (rST), and Tropohumults-Dystrandepts (rTP) soils. Soils are also classified into hydrologic soil groups based on runoff potential and infiltration rates. There are four groups (A-D): Group A with the lowest runoff potential when thoroughly wet to Group D with the highest runoff potential when thoroughly wet. The majority of the soils near the streams are classified as Group B.

3.4 Land Use

More than one-third of the valley is designated as "Urban" within the State Land Use system, while the remaining area is designated as "Conservation." The urban designation extends at least half way into the valley and is the largest urban land designation along the Waiʻanae coast—allowing for concentrations of people and infrastructure. Storm water runoff from developed areas compared to undeveloped areas is generally greater since development results in more impervious surfaces such as roads and roofs and less water infiltrates into the ground.

Homes located at the base of steep valley walls



Mākaha Valley Flood Study

Figure 2. Undeveloped Parcels

The State does not own any land in Mākaha with the exception of the summit of the valley at Kaʻala Natural Area Reserve (less than 2 percent of the total valley). The City & County of Honolulu (City), Board of Water Supply (BWS) is the largest land owner in Mākaha—owning the majority of the forested lands designated as "Conservation" in the back of the valley and along the valley walls surrounding Mākaha.

Of the land designated as "Urban", city zoning allows for apartment, agricultural, business, country, residential, preservation and resort use. There are at least thirteen large undeveloped parcels in the valley totaling more than 462 acres that could allow for single family homes, hotels, duplex units and recreational facilities. The lower Mākaha Valley consists of residential lots and single family homes.

3.5 Climate Change

Scientists have already seen some of the impacts from climate change for Hawaiʻi including: an increase in air temperature, decrease in rainfall and stream flow, increase in rain intensity and an increase in sea level and sea surface temperatures. Major consequences of climate change that could intensify flooding issues are an increase in frequency and intensity of major storms and accelerated sea level rise. Global mean sea level is predicted to rise one foot in the next 40 years and up to three feet over the next century.

Impacts from climate change will contribute to greater vulnerability of communities, particularly those living along the coast. Even without future development in Mākaha contributing to the flooding conditions, the existing flooding conditions are anticipated to worsen due to climate change.

4. Flood Problems

Mākaha Valley lacks an overall interconnected drainage system. Rather, the drainage system in Mākaha is the result of "piecemeal" development without a master plan for the valley. A series of ditches, earthen berms, swales, catch basins, culverts, and underground pipes make up the drainage system for the valley (Figure 3). The majority of the runoff from these drainage systems is conveyed towards Mākaha Stream and some towards Eku Stream, but the stream capacities have not been improved. As a result, the streams have overtop their banks during large storm events and inundate surrounding areas where many of the homes are located. Some homes and apartments are located at the base of the mountains, close to very steep and almost vertical cliffs. Waterfalls cascade from the valley walls during large storms, similar to "streams" forming on the side of the mountains.

Below is an illustration of the impacts of past large storms that have resulted in heavy rain events for Mākaha Valley:

- Rapid storm water runoff in the upper areas of the valley because of the predominance of non-native vegetation like strawberry guava. Flood flows in the main channel of Mākaha Stream tear out large sections of stream bank and carry silt, boulders and forest debris downstream.
- Sections of Mākaha Stream become blocked by debris, such as tree limb and boulders, causing localized flooding and erosion of areas of the forest near the stream.
- Waterfalls form along the steep walls of the valley. On the east side of the valley, the waterfalls overwhelm the Mauna ʻOlu Estates ditch/berm system and roads and homes are flooded. On the west side of the valley, the waterfalls overwhelm the Mākaha Towers ditch/berm system and the parking lot and ground floor areas are flooded.
- The flood flows on the west side of the valley continue through the Mākaha Valley Towers property and flow across Kili Drive into the Mākaha Valley Plantation complex, flooding roads, parking lots and ground floor units. Flood flows continue down Kili Drive toward Farrington Highway and Mākaha Beach.
- Localized flooding occurs throughout the middle of the valley when drainage swales, channels and culverts are overwhelmed by storm water runoff.
- On the east side of the valley, the lower reaches of Eku Stream quickly fill and then overflow into nearby homes. Several blockages of the stream channel cause even more homes to be flooded. The Eku Stream Bridge at Farrington Highway is blocked by debris, increasing the severity of flooding. In all, over 100 homes experience significant flood damage from Eku Stream.
- Natural drainage swales in the lower-middle section of the valley are overwhelmed by large volumes of storm water runoff and some 50 to 100 homes in this area are damaged by these localized flood flows.
- The deeply incised channel of Mākaha Stream contains the flood flows of about 8000 cubic feet per second (cfs) until the vicinity of the Huipu Drive Bridge. Where the stream channel begins to widen, the flood waters may overtop the stream channel and cause flooding of the golf course and lands to the west of the stream. In the past, an earthen berm that was constructed to protect properties to the east of the stream failed in several places, and flood waters then flow

through homes on Water Street and Manuku Street and then on to Farrington Highway and Mākaha Beach.

- Homes located along Farrington Highway near Mākaha Beach are often flooded. Farrington Highway is flooded to a depth of three feet and is impassable for several hours. The flood flows, blocked by the large beach berm, run towards the West Mākaha Stream outlet, then flow seawards, break through the smaller beach berm and carry mud, litter, debris, trees, dead animals and trash onto Mākaha Beach and into the nearshore waters. Much of the sand in this section of the beach is torn away by the flood waters.

Most of the flood problems were identified in the lower areas of the valley within the floodplain, including near Mākaha Stream, Eku Stream, and along Kili Drive, Mākaha Valley Road, Noholio Road and Lahaina Street.

Some of the major flood problems and issues in Mākaha Valley are:

- Altered stream alignments
- Restrictions at the stream mouth contributing to flooding of properties near the mouth of Mākaha and Eku Streams
- "Unimproved" stream banks resulting in flooding of properties adjacent to Eku Stream
- Damaged drainage systems
- Lack of drainage infrastructure
- Clogged drainage infrastructure

Damages to Kili Drive after January 2011 storm

Historic land use in the valley, including uses from the plantation days, significantly altered the hydrology of the valley. The topography was changed in order to divert water for irrigation purposes. A number of these features are still in existence. In addition, the original stream alignment for Mākaha Stream has been altered as a result of development in the valley.

Properties located near the mouth of Mākaha Stream are exposed to higher flood risk due to the sand berm at the mouth of the stream that restricts the free flow of storm water to discharge into the ocean. Depending on wave action during the winter season, the beach berm can reach a height as high as the existing bridge along Farrington Highway. Storm water from Mākaha Stream is generally directed towards West Mākaha Stream as a result of the sand berm or may backwash into Mākaha Stream. When this condition occurs, the storm water contributes to flooding of adjacent properties and Farrington Highway due to the higher flood elevations.

Similarly, properties located near the mouth of Eku Stream are exposed to higher flood risk due to storm water that is constricted by Eku Stream Bridge. This bridge was built in 1989 and is inadequately sized to accommodate flows for a 100-year storm. Storm water that is constricted at the bridge may contribute to flooding of adjacent properties near the bridge.

Residents living in areas located near Eku Stream have described flooding of up to four feet on their properties during past rain events, from Eku Stream flooding and lack of drainage.

In addition to the absence of a comprehensive drainage system for the valley, some of the local drainage systems are damaged and have not been repaired. There is a breach in the berm located in the lower area of the valley near Mākaha Stream and also in the berm system located behind Mauna ʻOlu Estates. Past history of this area reveals that an earthen berm was constructed to reroute Mākaha Stream in order to develop a residential subdivision (homes that are located on Manuku and Nukea Streets). The earthen berm in the lower valley was damaged during the 2008 storm when storm flows broke through the berm in an area where the stream makes an abrupt change in direction. As a result of the breach, properties located downstream from the berm experience flooding and erosion to their property during large storms. With the breach in the berm, Mākaha Stream travels adjacent to the back yards of homes located on Manuku and Nukea Streets during large storms. Residents on these streets have reported flooding problems and property damage resulting from erosion and high velocity of runoff behind their properties since 2008.

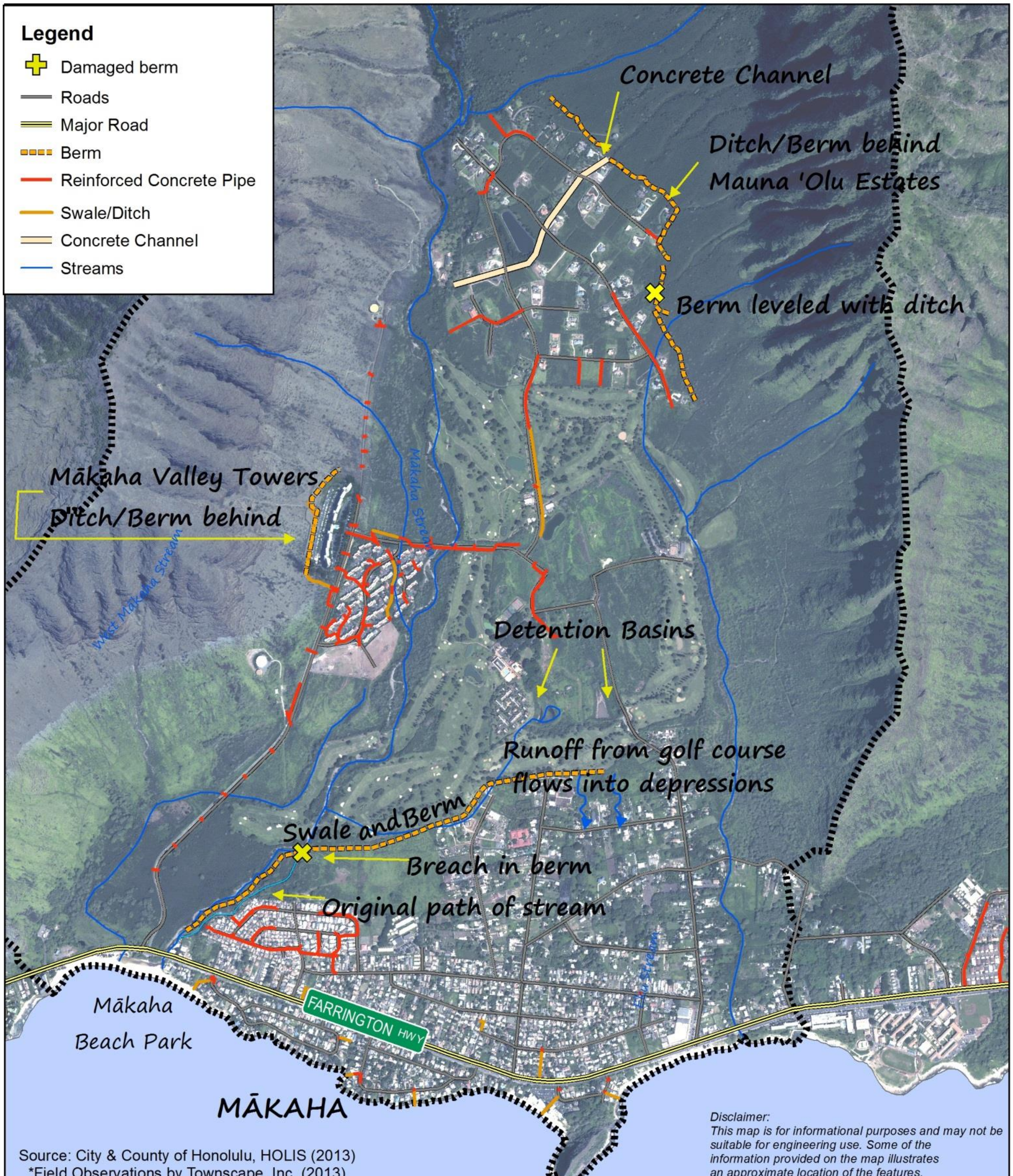
Sections of the existing system of ditches and berms above the Mauna ʻOlu Estates subdivision are not functioning as originally constructed. One part of the earthen berm is level with the ditch. The BWS is currently studying alternative measures to improve this system. This may include improving only certain problematic areas or improving the entire system with possibly a new lined drainage ditch or levee walls. Also being addressed is the adequate dissipation of hydraulic energy at the outlet of any improvements. The implementing entity for these potential improvements has not been identified.

The majority of the roads in the lower residential area are private roads that do not contain drainage infrastructure. Runoff disperses as sheet flow, but during large storms these areas are subject to ponding. This condition has been identified for Noholio Road, Lahaina Street, and Mākaha Valley Road. Additionally, two swales (depressions) from the Mākaha West Golf Course run towards the ocean and travel though residential properties, contributing to flooding in this area.

Storm drains are often clogged with small debris and rocks during a storm, which contributes to storm water backup and has resulted in extensive flooding and major road damages. Kili Drive is a private road located on the northern side of Mākaha Valley starting at Farrington Highway and ending near the Mākaha Valley Towers, where it forms an intersection with the Mākaha Valley Towers entrance, Huipu Drive, and an access road to a BWS reservoir. Kili Drive has experienced severe road damages from rocks, debris, and clogged drains that gouge out sections of the pavement. This issue has resulted in extensive flooding of Kili Drive and has closed the road off to residents during storms.

Storm drains clogged with rocks

There is an existing ditch and berm system behind the Mākaha Valley Towers which collects runoff from the valley walls and directs it to a culvert that travels under Kili Drive, under and through the Mākaha Valley Plantation complex, and into Mākaha Stream. During the 2008 storm, runoff traveling down the reservoir access road was extensive enough to damage the pavement near the intersection before spilling onto Kili Drive, which contributed to turning parts of Kili Drive into a "river." Kili Drive is often referred to as "Kili River" by community members.



Mākaha Valley Flood Study

Figure 3. Existing Drainage Systems

5. Hydrologic Analysis

Hydrologic analysis estimates the volume of water entering and passing through a drainage system from a rainfall event. The purpose of the hydrologic analysis was to determine the peak flows of Mākaha and Eku Streams in order to identify flooding problems for the smaller, sub-basin areas of the valley. Flows from the hydrologic analysis will be used in the hydraulic analysis in order to provide the proper flood mitigation measure. Peak flow discharges were calculated for the 10-, 25-, and 100-year flood events which correlate to the 10, 4, and 1 percent chance that a flood will occur in any given year.

While there are several methods to determine peak discharges, including using USGS regression equations, the Federal Emergency Management Agency's (FEMA) peak discharge-frequency drainage area curves, and Plate 6 from the City, the Technical Release 55 (TR-55) method published by the Natural Resources Conservation Service (NRCS) was used. The TR-55 method is recommended for estimating runoff and peak discharges for small watersheds. Win TR-55 (NRCS 2011), a computer software program that applies the TR-55 model, was used for this hydrologic analysis.

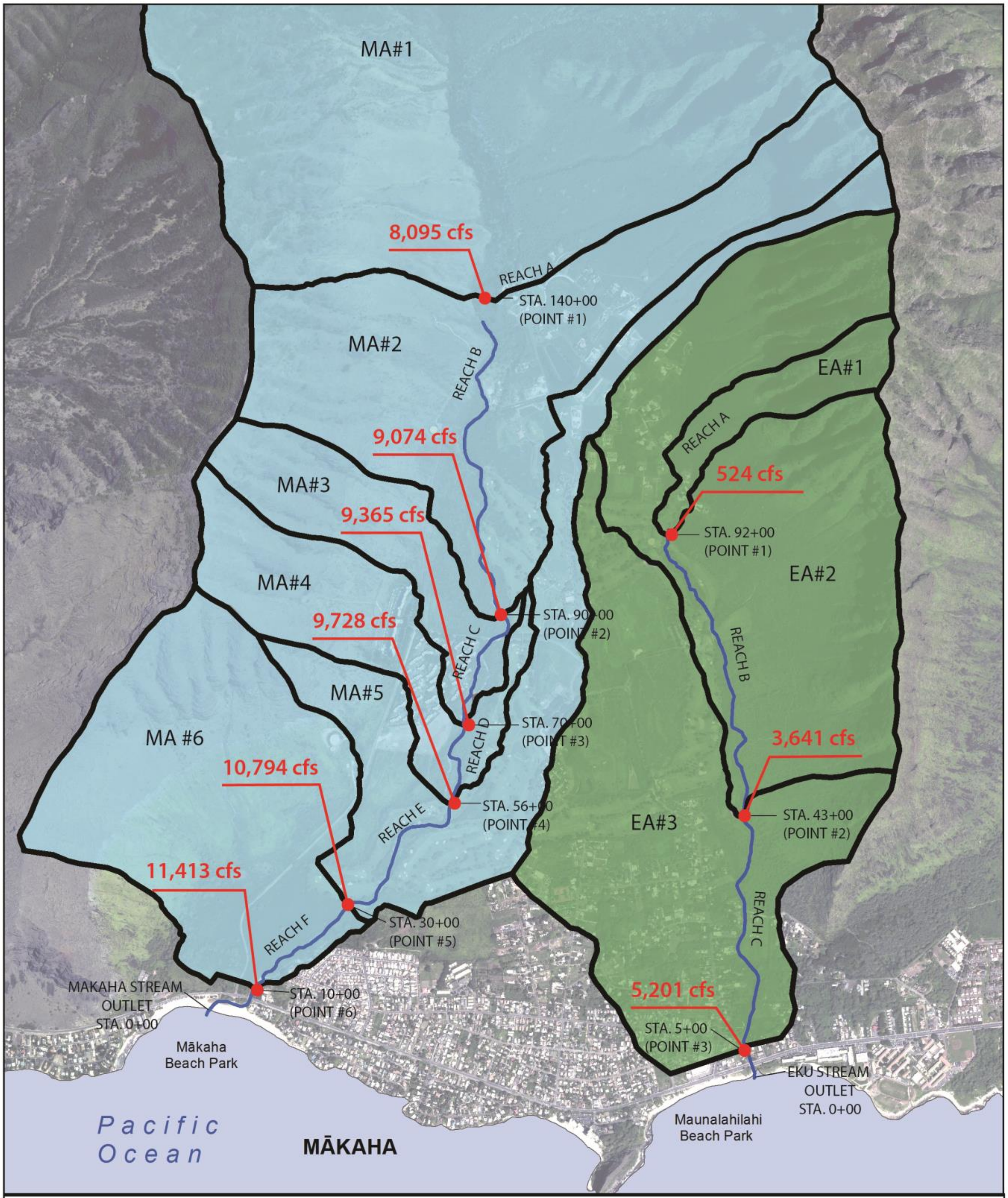
Mākaha and Eku Streams were delineated into subareas based on a tributary contributing runoff to the main stream. Note that Mākaha and West Mākaha Streams were modeled as a single stream in this analysis as was done by previous Flood Insurance Studies by FEMA. Centerline alignments—that defined the centerline of each stream—were created for both streams. Tributary points along the centerline alignment were then identified to delineate the tributary sub-areas and reaches. Tributary points for Mākaha Stream and Eku Stream are listed in Tables 1 and 2, respectively. A sub-area is defined as the land area that contributes runoff at a point along the flow path (stream); whereas a reach is defined as the major flow path (section of stream) through which runoff is routed. Six subareas were identified for Mākaha Stream and three for Eku Stream (Figure 4).

Table 1. Mākaha Stream Tributary Points

Point Number	Description	Stream Station
1	Beginning of study area	140+00
2	Existing limit of study	90+00
3	Intermediate point	70+00
4	Intermediate point	56+00
5	Intermediate point	30+00
6	End of study area	10+00

Table 2. Eku Stream Tributary Points

Point Number	Description	Stream Station
1	Beginning of study area	92+00
2	Existing limit of study	43+00
3	End of study area	5+00



Mākaha Valley Flood Study

Figure 4. Tributary Area Map

The WinTR-55 model includes inputting basin characteristics such as topography, soil type, land use, storm rainfall, and tributary area information. The other methods to determine peak discharges were felt to be too general because they only accounted for rainfall and area, whereas WinTR-55 accounted for differing land uses which is a significant factor for Mākaha. The results of the WinTR-55 peak flow calculations for the full build-out scenario for Mākaha Stream and Eku Stream are shown in Tables 3 and 4 respectively. The full build-out scenario assumes the development of the dozen or more large undeveloped parcels in Mākaha.

Table 3. Full build-out Peak Flows for Mākaha Stream

Sub-area or Reach	MĀKAHA STREAM: Peak flow (cfs) @peak time (hr)		
	10-year	25-year	100-year
Subarea 1 (MA#1)	4,285 cfs @ 10.59 hrs	5,783 cfs @ 10.58 hrs	8,095 cfs @ 10.55 hrs
Subarea 2 (MA#2)	1,458 cfs @ 10.11 hrs	1,966 cfs @ 10.12 hrs	2,737 cfs @ 10.13 hrs
Subarea 3 (MA#3)	601 cfs @ 10.06 hrs	799 cfs @ 10.07 hrs	1,100 cfs @ 10.06 hrs
Subarea 4 (MA#4)	626 cfs @ 10.09 hrs	826 cfs @ 10.09 hrs	1,124 cfs @ 10.10 hrs
Subarea 5 (MA#5)	598 cfs @ 10.40 hrs	809 cfs @ 10.38 hrs	1,138 cfs @ 10.40 hrs
Subarea 6 (MA#6)	1,585 cfs @ 10.02 hrs	2,120 cfs @ 10.02 hrs	2,931 cfs @ 10.01 hrs
Reach A @ Point #1	4,285 cfs @ 10.59 hrs	5,783 cfs @ 10.58 hrs	8,095 cfs @ 10.55 hrs
Reach B @ Point #2	4,809 cfs @ 10.54 hrs	6,496 cfs @ 10.52 hrs	9,074 cfs @ 10.55 hrs
Reach C @ Point #3	4,970 cfs @ 10.56 hrs	6,706 cfs @ 10.55 hrs	9,365 cfs @ 10.53 hrs
Reach D @ Point #4	5,163 cfs @ 10.54 hrs	6,964 cfs @ 10.55 hrs	9,728 cfs @ 10.53 hrs
Reach E @ Point #5	5,720 cfs @ 10.56 hrs	7,722 cfs @ 10.58 hrs	10,794 cfs @ 10.55 hrs
Reach F* @ Point #6	6,045 cfs @ 10.57 hrs	8,166 cfs @ 10.53 hrs	11,413 cfs @ 10.53 hrs

*Reach F is at end of the study. The study ended just above Farrington Highway due to limited available data.

To understand the peak flow calculations computed using WinTR-55 as shown above, for example for a 100-year storm for Mākaha Stream under the full build-out scenario, subarea 1 (identified on map as MA #1) generates 8,095 cfs at its peak flow and reaches its peak at about 10.55 hours from the start of the storm. Subarea 2 (identified on map as MA #2) generates 2,737 cfs at its peak flow at about 10.13 hours; 1,100 cfs, 1,124 cfs, 1,138 cfs, and 2,931 cfs for subareas 3 to 6 respectively.

Reach A is the section of the stream that flows through subarea 1 (MA#1). The amount of runoff that travels through the stream for this subarea is computed at Point #1 (Stream Station 140+00), which is equivalent to the amount of runoff generated by subarea A. Reach B is the section of the stream that flows through subarea 2 (MA#2) between Point #1 and Point #2. Similarly, the amount of runoff that travels though this section of the stream is computed at Point #2 (Station 90+00). The peak flow for Reach B at Point #2 is 9,074 cfs. Point #6 (10+00) is located at the end of the study area, located just above Farrington Highway, and measures the amount of runoff that travels though Reach F. The peak flow assuming full build-out of Mākaha Valley for a 100-year storm for Reach F at Point #6 is 11,413 cfs where peak flow is reached at about 10.53 hours from the start of the storm.

Table 4. Full build-out Peak Flows for Eku Stream

Sub-area or Reach	EKU STREAM: Peak flow (cfs) @peak time (hr)		
	10-year	**25-year**	**100-year**
Subarea 1 (EA#1)	277 cfs @ 9.97 hrs	375 cfs @ 9.97 hrs	524 cfs @ 9.96 hrs
Subarea 2 (EA#2)	1,716 cfs @ 10.13 hrs	2,300 cfs @ 10.13 hrs	3,181 cfs @ 10.13 hrs
Subarea 3 (EA#3)	1,146 cfs @ 10.40 hrs	1,497 cfs @ 10.36 hrs	2,029 cfs @ 10.40 hrs
Reach A @ Point #1	277 cfs @ 9.97 hrs	375 cfs @ 9.97 hrs	524 cfs @ 9.96 hrs
Reach B @ Point #2	1,967 cfs @ 10.12 hrs	2,631 cfs @ 10.11 hrs	3,641 cfs @ 10.11 hrs
Reach C* @ Point #3	2,853 cfs @ 10.18 hrs	3,792 cfs @ 10.18 hrs	5,201 cfs @ 10.18 hrs

*Reach C is at end of the study. The study ended just above Farrington Highway due to limited available data.

The calculated peak flows for a 10-, 25-, and 100-year storm for Mākaha Stream were 6,045 cfs, 8,166 cfs, and 11,413 cfs respectively. The calculated peak flows for a 10-, 25-, and 100-year storm for Eku Stream were 2,853 cfs, 3,792 cfs, and 5,201 cfs respectively. Note that the hydrologic analysis was completed just above Farrington Highway for both Mākaha and Eku Streams. Therefore, peak flows at the stream outlets into the ocean may be slightly higher. Complete peak flow calculations and hydrographs are provided in Volume III of this report.

Comparisons of full build-out versus existing conditions did not show a significant change in overall peak flows for Mākaha Stream. Peak flow for a 100-year storm at the end of the study area for Mākaha Stream for full build-out was 11,413 cfs compared to 11,326 cfs under existing conditions. Additionally, examination of the Mākaha Stream hydrograph generated by WinTR-55 shows subarea 1 (MA #1) as the major factor controlling the total peak flow at the downstream end of the stream. As shown in Table 3, subarea 1 generates 8,095 cfs at its peak flow. In other words, the majority of the runoff is contributed by subarea 1, which consists of forested lands owned by the BWS. Therefore, an increase in development within the lower reaches of Mākaha Stream will increase localized runoff rates and total runoff volumes, but total peak runoff rates for the stream will increase only by a relatively slight amount.

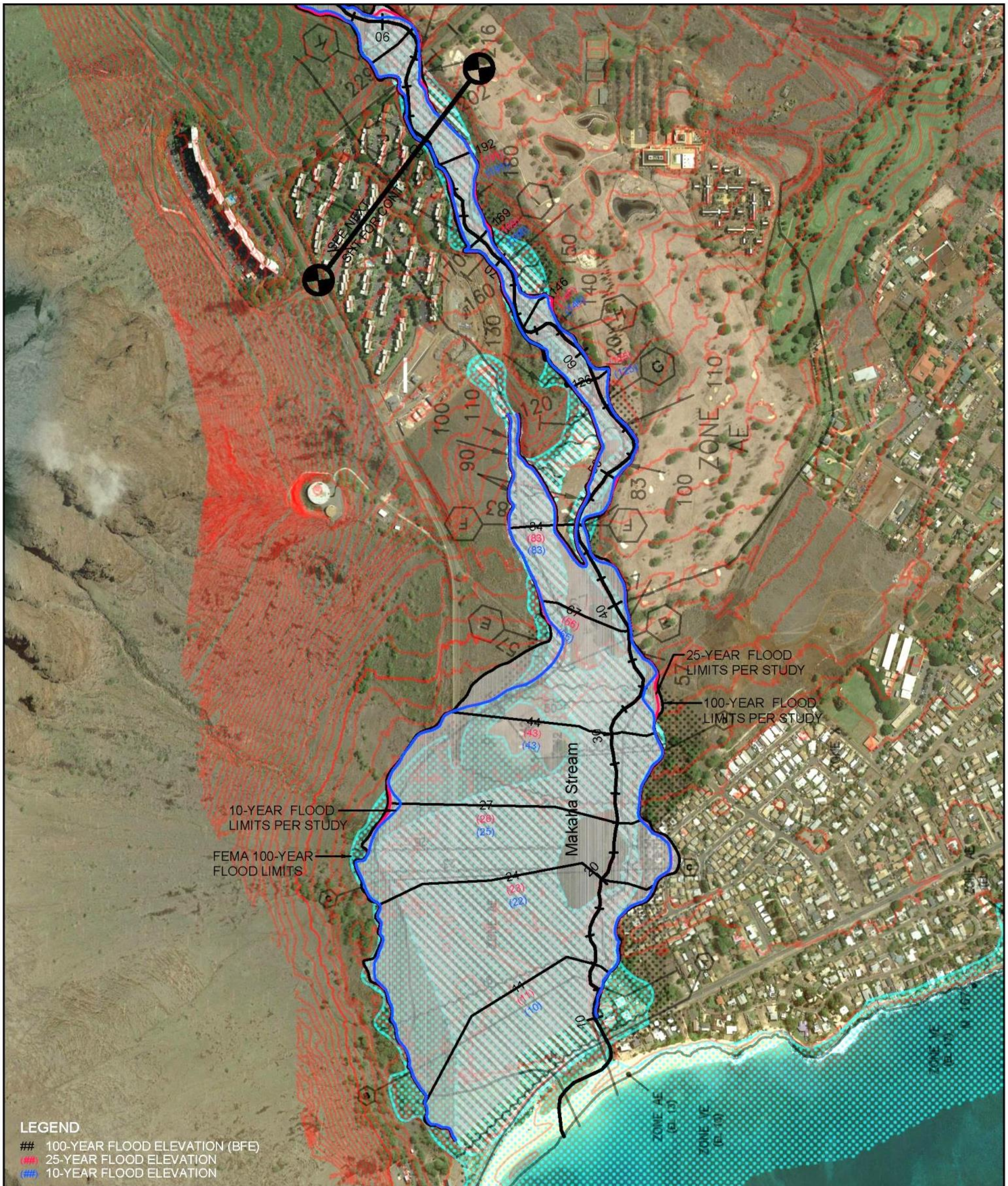
6. Hydraulic Analysis

The purpose of the hydraulic analysis is to identify flood areas based on the peak flow rates determined in the hydrologic analysis. Hydraulic analysis estimates the flow depths and points of overflow for a drainage system resulting from a known amount of water flow. Peak flow values determined from the hydrologic analysis were used in the Hydrologic Engineering Center River Analysis System (HEC-RAS), a computer program developed by the U.S. Army Corps of Engineers (USACE), to analyze the extent of inundated areas for Mākaha and Eku Streams including flood elevations for the 10-, 25-, and 100-year storms. Results from the HEC-RAS program are in Volume III of this report.

For Mākaha Stream, cross sections were generated along the stream alignment every 200 feet. For Eku Stream, cross sections were generated every 250 feet with the exception of the downstream flat areas where the cross sections were increased to every 50 feet to better analyze water flow paths. Note that the generated cross sections are only as accurate as the available topographic data. Full build-out peak flows from WinTR-55 were inputted into the HEC-RAS. Inundation areas and water levels were determined for both streams for the 10-, 25-, and 100-year storms.

Analysis showed that Eku Stream is well defined and contained until approximately 3,800 feet upstream of the mouth. The existing Eku Stream channel cannot contain the design storm, and as a result, runoff flows outside of the channel creating a path of shallow flooding which approaches 2,500 feet in width just upstream of Farrington Highway. For Eku Stream, the 10-, 25-, and 100-year flood limits in the upper elevations differ only slightly because of the deeper and more defined stream cross sections. As Eku Stream reaches the lower elevations, the limits differ somewhat due to the very flat terrain found in some areas. A ground elevation difference of six inches can result in a horizontal difference of 50 to 100 feet between flood limits of different recurrences. See Figures 5 and 6 for the 10, 25, and 100-year flood limits for Mākaha Stream and Figure 7 for Eku Stream. The figures also show the calculated water surface elevations at selected locations. For Mākaha Stream, the banks are more defined and therefore the flood limits differ only slightly for the 10-, 25-, and 100-year storms. The flood elevations range from two to seven feet within the streambed of Eku Stream, while the floodplain for Eku Stream can range from zero to three feet. Flood depths for Mākaha Stream range from five to over ten feet within the streambed and can range from zero to four feet in the Mākaha Stream floodplain.

Hydraulic analysis for this study did not account for anticipated sea level rise because the study area ended approximately 150 feet upstream of Farrington Highway. Further analysis will be required to incorporate impacts anticipated from sea level rise for proposed structural projects.



Mākaha Valley Flood Study

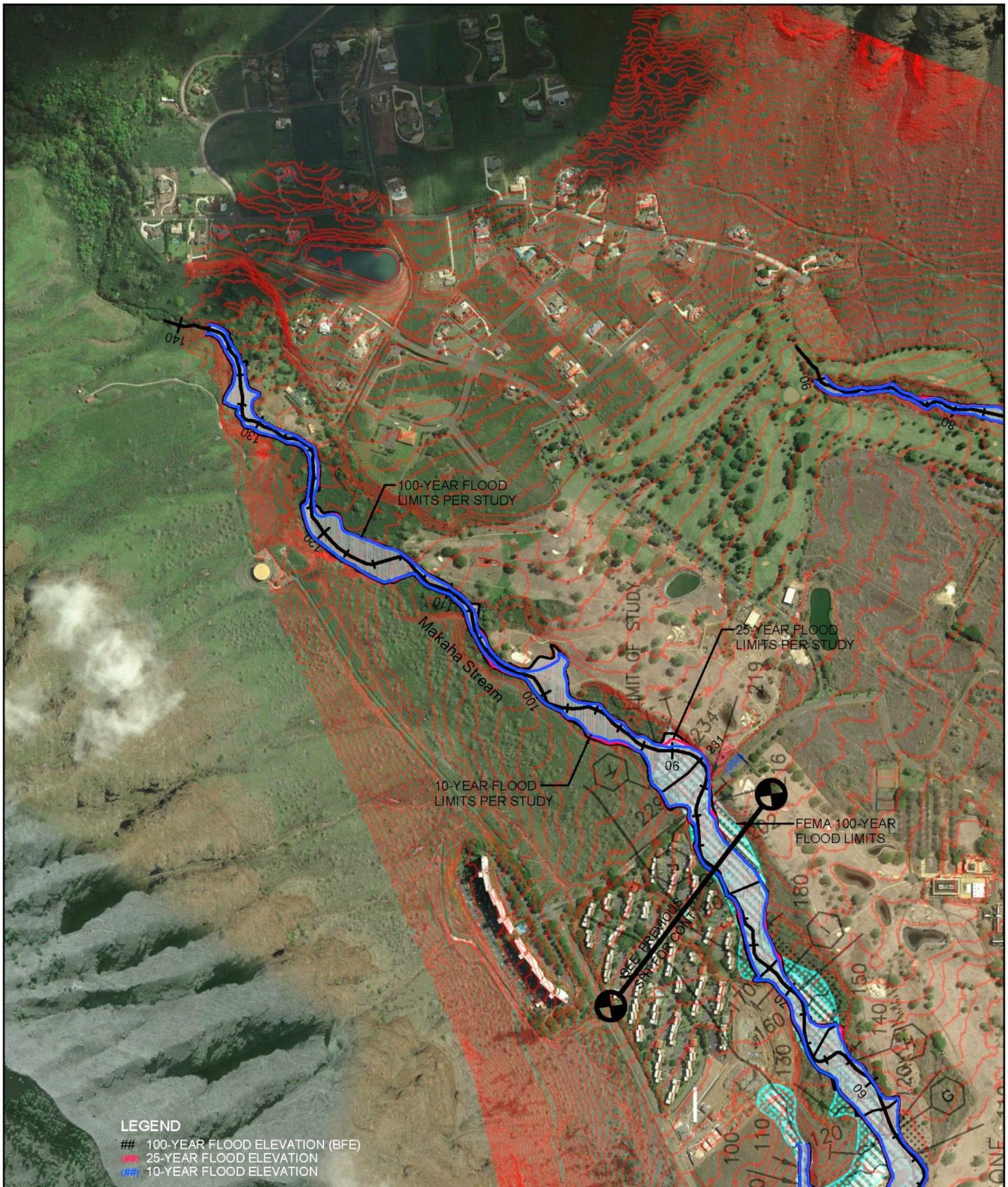
Figure 5. Mākaha Stream Flood Map

0 0.25 Miles

0 500 1,000 Feet

N

For: State DLNR
July 2014



Mākaha Valley Flood Study

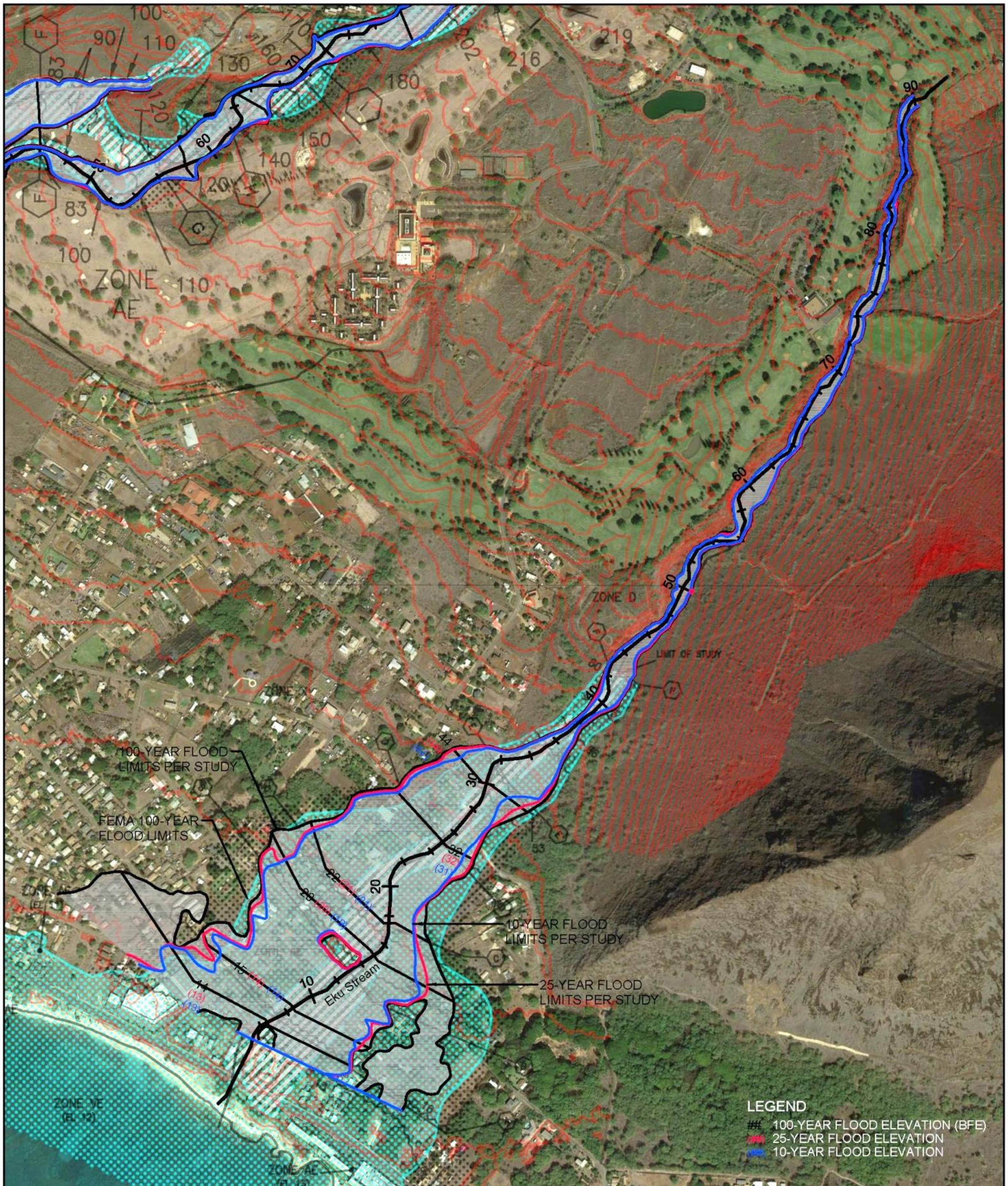
Figure 6. Mākaha Stream Flood Map

0 0.25 Miles

0 500 1,000 Feet

N

For: State DLNR
July 2014



Mākaha Valley Flood Study

Figure 7. Eku Stream Flood Map

0 0.25 Miles

0 500 1,000 Feet

N

For: State DLNR
July 2014

7. Proposed Flood Mitigation Measures

The purpose of this section is to recommend realistic flood mitigation projects for Mākaha Valley. These projects were developed based on hydrologic and hydraulic analysis of the area and discussions with community members. A general effectiveness analysis of each proposed flood mitigation project is included by examining estimated project cost, storm damages without the project, and benefits from implementation of the project. Estimated project cost includes costs associated with land acquisition and obtaining easements that may be required depending on the project location; environmental fees to complete an Environmental Assessment (EA) and any State and City approvals and permits; survey and design (includes topographic mapping, geotechnical work, and engineering); construction management; and construction of the project. A ten percent contingency is included in the construction cost estimate. Benefits may include, but are not limited to, avoided requirement to purchase flood insurance, avoided environmental impacts, avoided damage costs from flooding, and increased property values.

The recommended flood mitigation measures are grouped into two types of actions: structural projects and nonstructural programs. The structural projects require some type of construction while the nonstructural programs relate to an ongoing service with no foreseeable conclusion. Table 5 lists the proposed structural projects and nonstructural programs.

Table 5. Proposed Flood Mitigation Measures

Structural Projects	Nonstructural Programs
1. Eku Stream Channel and Off-line Detention Basin 2. New Eku Stream Bridge at Farrington Highway 3. Repair the breach in the Mākaha Stream berm 4. Mākaha Stream Levee 5. Kili Drive Channel 6. Mauna ‘Olu Estates Drainage Improvements 7. Noholio Road Drain Line 8. Restore Mākaha Surfing Beach “Pond” 9. In-stream Detention Basins for Mākaha Stream	1. Forest Restoration 2. Stream Channel Maintenance 3. Storm Drain Maintenance 4. Enforcement of existing legislation 5. Education on Best Management Practices for Watersheds 6. Special care in permitting future development

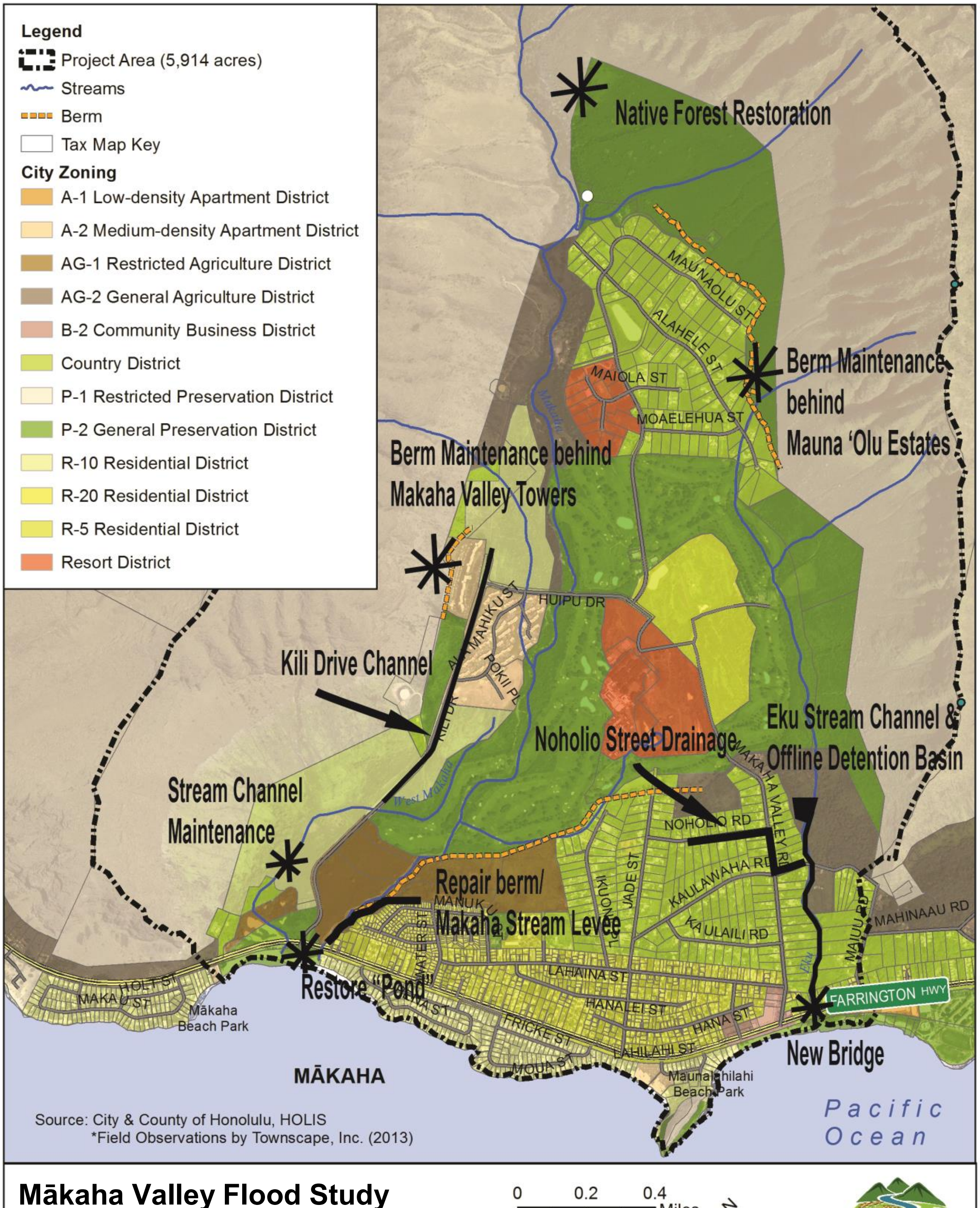


Figure 8. Flood Mitigation Projects

7.1 Structural Projects

Generally, the projects included in this section are "stand-alone" projects, which mean that the recommended project can be constructed independently of the other projects. Project designs may change slightly based on the implementation of another project.

Proposed improvements to Eku Stream include: widening the existing channel; lining the channel with concrete, gabion baskets, grouted rip-rap, or other methods; construction of an off-line detention basin; and widening of the Eku Stream bridge along Farrington Highway.

Proposed improvements to Mākaha Stream include: repairing the berm, protecting the area with a levee, and in-stream detention basins. The Kili Drive Channel would alleviate some of the runoff to Mākaha Stream. Table 6 provides a summary of total estimated cost for the structural projects.

Table 6. Summary of Estimated Cost for Structural Projects

Project No.	Mitigation Measure	Total Estimated Cost
1	Eku Stream Channel and Off-line Detention Basin	$27,774,000 to $34,774,000
2	New Eku Stream Bridge at Farrington Highway	$12,000,000 to $19,000,000
3	Repair the breach in the Mākaha Stream berm	$1,700,000 to $3,300,000
4	Mākaha Stream Levee	$17,025,000 to $24,025,000
5	Kili Drive Channel	$12,000,000 to $19,000,000
6	Mauna ʻOlu Estates Drainage Improvements	To be determined
7	Noholio Road Drain Line	$1,700,000 to $3,300,000
8	Restore Mākaha Surfing Beach "Pond"	To be determined
9	In-stream Detention Basins for Mākaha Stream	To be determined

7.1.1 Project No. 01: Eku Stream Flood Channel and Off-Line Detention Basin

Improvements to Eku Stream are recommended to extend upstream 3,800 feet to where the existing channel's capacity is exceeded. Calculations show that with the quantity of runoff, along with natural grades of the area, the velocity of the runoff will be too high for the channel to be unlined. The channel may be lined with concrete, gabion baskets, grouted rip-rap, or other methods. The channel will be 3,800 feet in length.

For a trapezoidal shaped concrete-lined channel, an 84-feet Right of Way (ROW) will be needed. The ROW includes a 16-foot wide maintenance road. The concrete channel will need to be approximately 40 feet wide at the base, 68 feet wide at the top of the channel, and five feet deep with side slopes of 2 to 1.

For a trapezoidal shaped gabion or grouted rip-rap channel, a 100-foot wide project easement will be needed. The ROW includes a 16-foot wide maintenance road. The gabion or grouted rip-rap channel will need to be approximately 50 feet wide at the base, 84 feet wide at the top of the channel, and 6.5 feet deep with side slopes of 2 to 1.

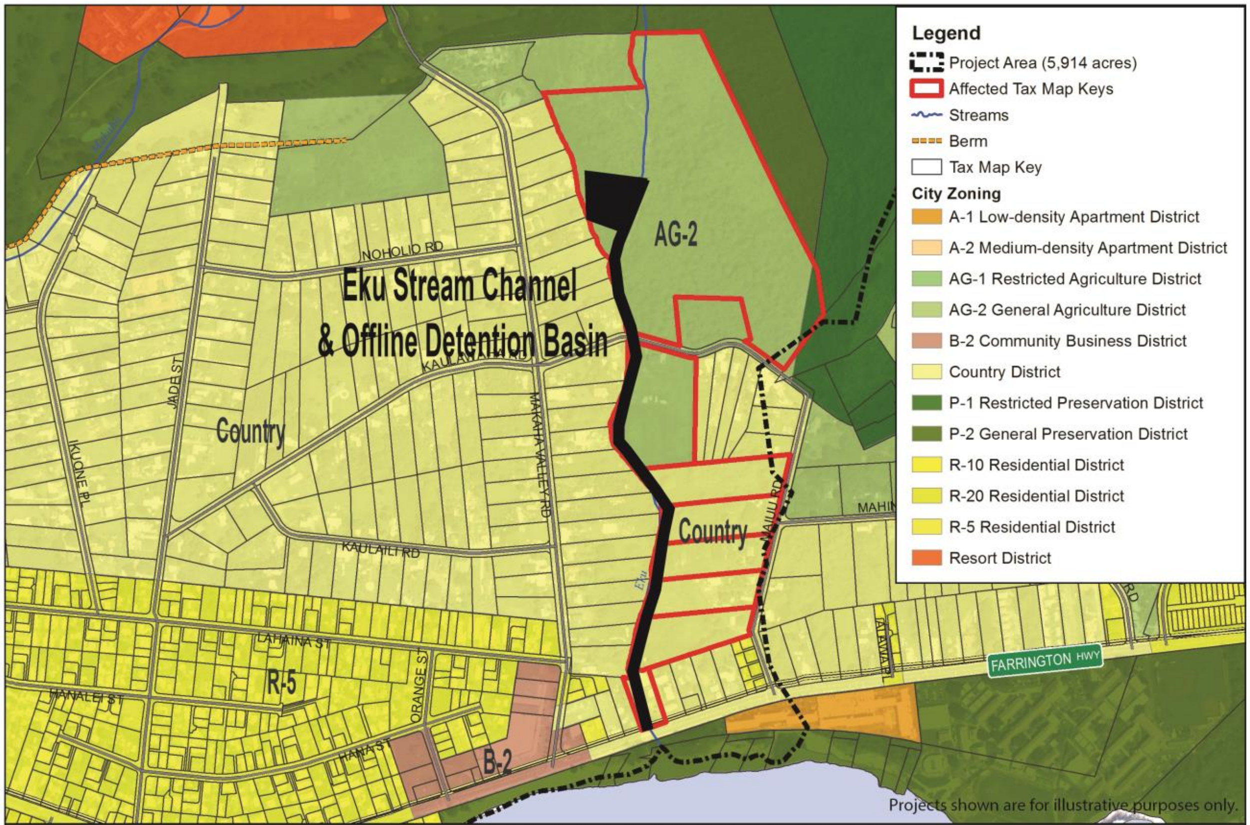
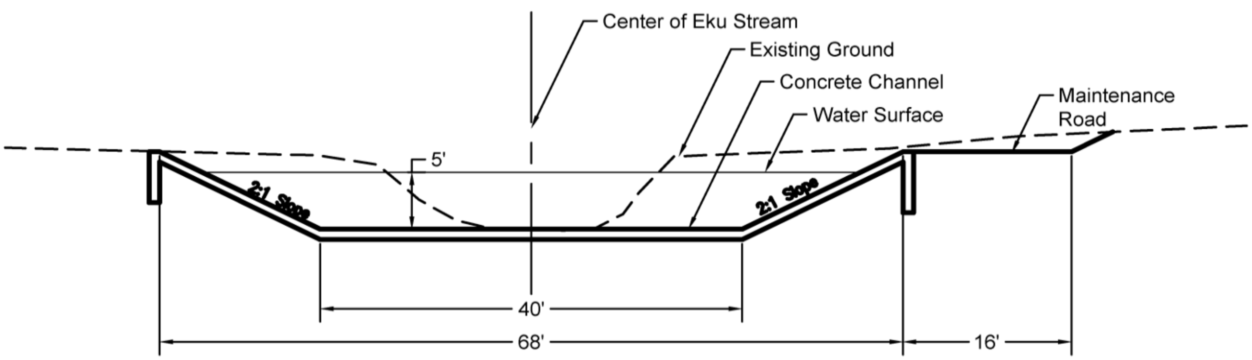


Figure 9. Eku Stream Flood Channel and Off-line Detention Basin Project Location

If the channel itself is used as a maintenance road, then the 16-foot wide maintenance road can be eliminated. Therefore, the ROW may only need to be 68 feet for the concrete channel and 84 feet for the gabion or grouted rip-rap channel.

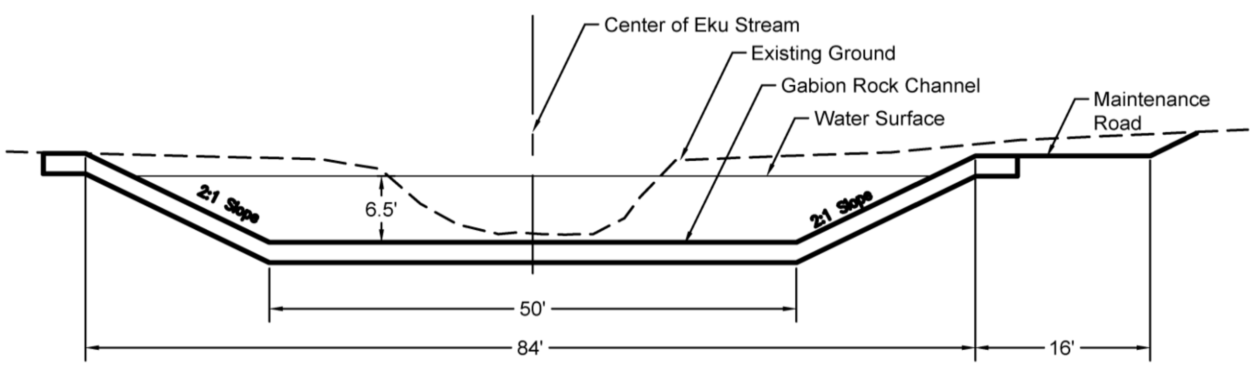
A 5.5-acre off-line detention basin will need to be constructed at the mauka end of the flood channel. The basin will have an average depth of 5.5 feet, which would contain approximately 1,555,000 cubic feet of runoff. The purpose of this basin is to limit the flow traveling along Eku Stream downstream of this point. Therefore, the design will include an overflow weir along the channel that will overtop once the flow in the channel reaches a certain rate (preliminary estimate is 2,000 cfs), and will direct the excess flow to the detention basin.

This project is designed to “contain” the 100-year storm. Useful life of the project is about 50 years.



Eku Stream - Concrete Channel

Looking Makai



Eku Stream - Gabion / Grouted Rip-Rap Channel

Looking Makai

Implementing Agency

To be determined

Ongoing Maintenance Agency

To be determined

Estimated Project Cost

The estimated cost to construct the Eku Stream Flood Channel and Off-line Detention Basin ranges from $27,794,000 to $34,794,000. This estimated cost includes acquiring one property (assessed building and land value of $310,000) on Farrington Highway adjacent to the stream and obtaining easements for eleven parcels ($464,000) from different landowners.

Cost Item	Estimated Cost
Acquisition	$310,000
Easements	$484,000[1]
Environmental	$500,000 - $1,000,000
Survey and Design	$1,000,000 - $2,000,000
Construction Management	$500,000 - $1,000,000
Construction	$25,000,000 - $30,000,000
Total	**$27,794,000 - $34,794,000**

[1] **Costs based on a 100-foot wide easement.**

Storm Damages w/o the Project

At least 80 parcels including residential and commercial properties will continue to be affected by the 100-year storm.

Benefits w/ the Project

The benefits of constructing the Eku Stream Flood Channel and Off-line Detention Basin are:

- Protecting both residential and commercial properties from property damages resulting from storms up to the 100-year storm
- Reducing or eliminating flood insurance costs
- Removing 57 residential units and business parcels from the 100-year flood zone with total assessed building value of $14,467,200
- Removing approximately 16 undeveloped parcels from the 100-year flood zone
- Increased property values from reduced flood risk

7.1.2 Project No. 02: New Eku Stream Bridge at Farrington Highway

Construct a new reinforced concrete bridge at Farrington Highway crossing Eku Stream. As-built plans of the existing bridge show that the 100-year peak flow used in the design of the bridge was 2,500 cfs. However, the calculated 100-year peak flow as part of this study that was noted in the previous section for a point just upstream of Farrington Highway is 5,201 cfs. Even with the use of the recommended off-line detention basin, the calculated 100-year peak flow as part of this project was found to be 3,900 cfs, which is a difference of 1,400 cfs from the capacity of the existing bridge for Eku Stream at Farrington Highway. The useful life of a new bridge would be 50 years.

Existing Eku Stream Bridge

While the State Department of Transportation (DOT) is mandated by the Federal Highway Administration to replace or retrofit bridges that are rated structurally deficient by inspection, the DOT has no mandate to replace bridges due to hydraulic deficiencies.

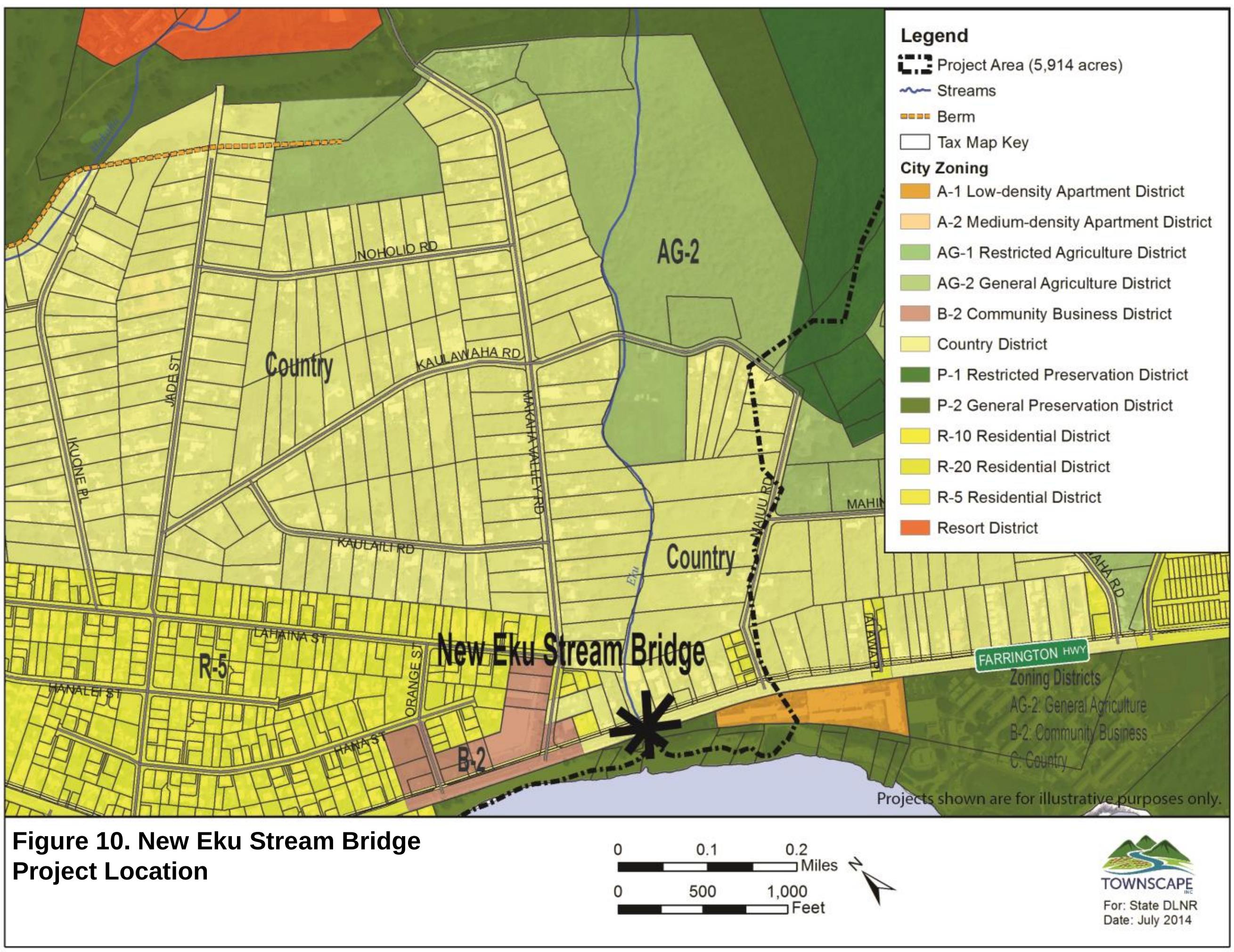


Figure 10. New Eku Stream Bridge Project Location

Implementing Agency
State Dept. of Transportation, Highways Division

Ongoing Maintenance Agency
State Dept. of Transportation, Highways Division

Estimated Project Cost
The estimated cost to construct the new Eku Stream Bridge is between $12,000,000 to $19,000,000.

Cost Item	Estimated Cost
Acquisition	To be determined
Easements	To be determined
Environmental	$500,000 - $1,000,000
Survey and Design	$1,000,000 - $2,000,000
Construction Management	$500,000 - $1,000,000
Construction	$10,000,000 - $15,000,000
Total	**$12,000,000 - $19,000,000**

Storm Damages w/o the Project
Properties upstream from the bridge and Farrington Highway will continue to be affected by flooding from storm water that is constricted at the existing Eku Stream Bridge since it does not have adequate capacity to handle a 100-year storm. Flooding on Farrington Highway near Eku Stream poses a great danger to vehicles and restricts access for residents and emergency vehicles into Mākaha Valley and beyond.

Benefits w/ the Project
The benefits of constructing a new Eku Stream Bridge are:

- Reduced flooding of properties upstream from the bridge and Farrington Highway because storm water can freely flow under the bridge and discharge into the ocean
- Minimized risk of flooding on Farrington Highway that poses a threat to public safety due to lack of accessibility into Mākaha Valley and beyond

7.1.3 Project No. 03: Repair the Breach in the Mākaha Stream Berm

Repair the earthen berm at the breach, located on Tax Map Key (TMK) 8-4-002:063, with a hard surface such as concrete because the breach is located at a point where the stream makes an abrupt change in direction. This project will return Mākaha Stream to pre-2008 conditions, but should only be considered as a temporary solution. Visual inspection of this berm system revealed that the earthen berms are eroding, and while they may last many more years, other breaks may occur in the future.

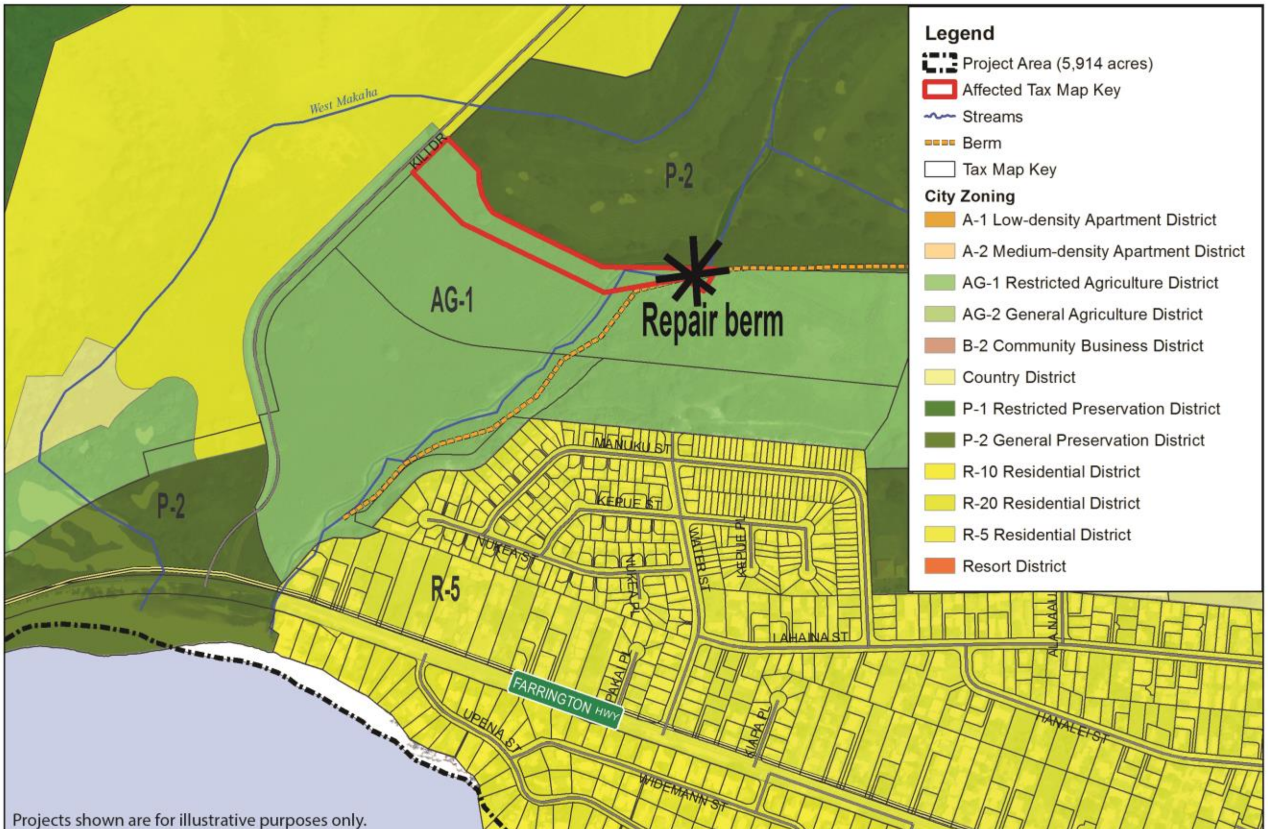
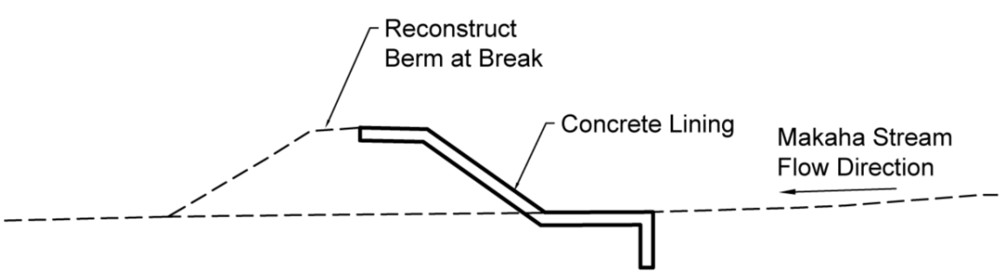


Figure 11. Repair the Breach in the Mākaha Stream Project Location

0 0.1 0.2 Miles
0 500 1,000 Feet
N
TOWNSCAPE
For: State DLNR
Date: July 2014



Repair Makaha Stream Berm

Looking Westerly

Implementing Agency
Mākaha Valley Road LLC[5]

Ongoing Maintenance Agency
Mākaha Valley Road LLC

Estimated Cost
The estimated cost to repair the breach in the berm is approximately $1,700,000 to $3,300,000. The recommended project is located on undeveloped land (TMK 8-4-002:063) owned by Mākaha Valley Road LLC. In accordance with Act 76 (2009), "the governor is authorized to designate state employees to enter on private property to mitigate hazardous situations after giving the landowner and occupier notice and a reasonable opportunity to mitigate the hazardous situation without assistance of the State."

Cost Item	Estimated Cost
Acquisition	None
Easements	None
Environmental	$200,000 - $400,000
Survey and Design	$300,000 - $500,000
Construction Management	$200,000 - $400,000
Construction	$1,000,000 - $2,000,000
Total	**$1,700,000 - $3,300,000**

Storm Damages w/o the Project
Properties downstream of the breach will continue to be flooded during large storms as storm water travels directly adjacent to some of the homes, and at times overflows into their backyards. Erosion of properties resulting from the velocity of storm water runoff will continue.

Additionally, from field observation, it appears that some residents have "extended" their "living space" into the area where storm water during a large storm would flow through the breach in the berm. For example, one household has a swing set in the area where flood waters will travel.

Benefits w/ the Project
The benefit of repairing the breach in the berm is to protect properties downstream of the breach that were previously protected from flooding before 2008. However, it is important to note that this mitigation measure should be considered a temporary solution as other breaks along the existing berm may occur in the future.

[5] Listed land owner of TMK 8-4-002:063 as of July 2014.

7.1.4 Project No. 04: Mākaha Stream Levee

Construct a reinforced concrete levee (flood wall) system along the northern and western side of affected properties located on Manuku and Nukea Streets. The levee will extend approximately 1,700 linear feet in length in an easterly/southeasterly direction near the rear boundary of these homes and the intent is to connect the proposed levee with the Department of Transportation's bridge replacement project for Mākaha Stream. A 30-foot wide easement is recommended, which includes a 16-foot wide maintenance road to be constructed on the southeastern side parallel to the flood wall. An additional 350 linear feet easement is recommended from the approximate end of the levee behind homes located on Manuku Street to Water Street. The purpose of this additional ROW is to provide maintenance access via Water Street to the approximate end of the levee. The height of the concrete levee will vary depending on the existing topography, but the levee will extend at least three times its height above ground into the existing ground for maximum stability.

This project will remove homes from the 100-, and possibly the 500-, year floodplain. The useful life of this project is 50 years.

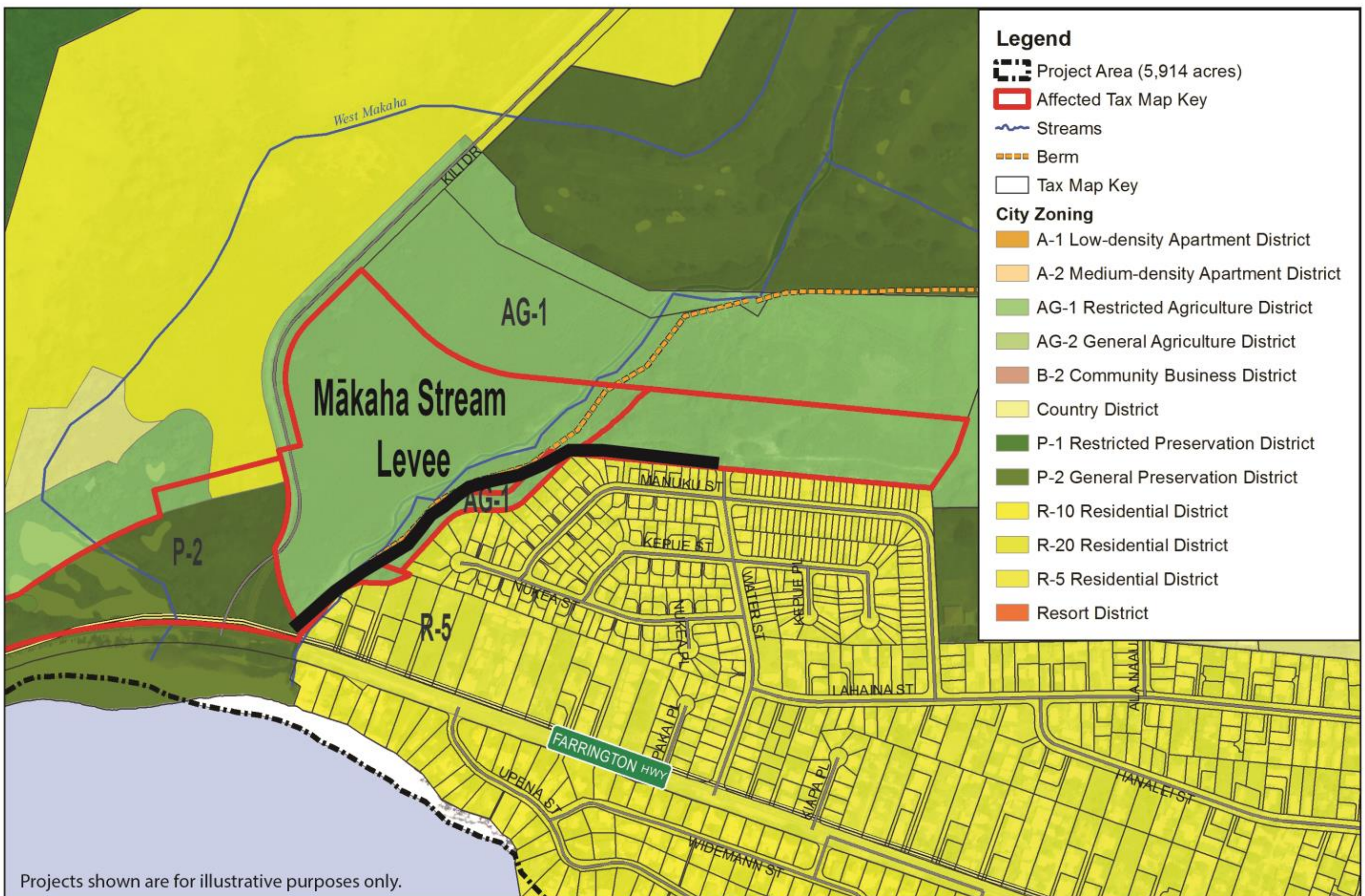
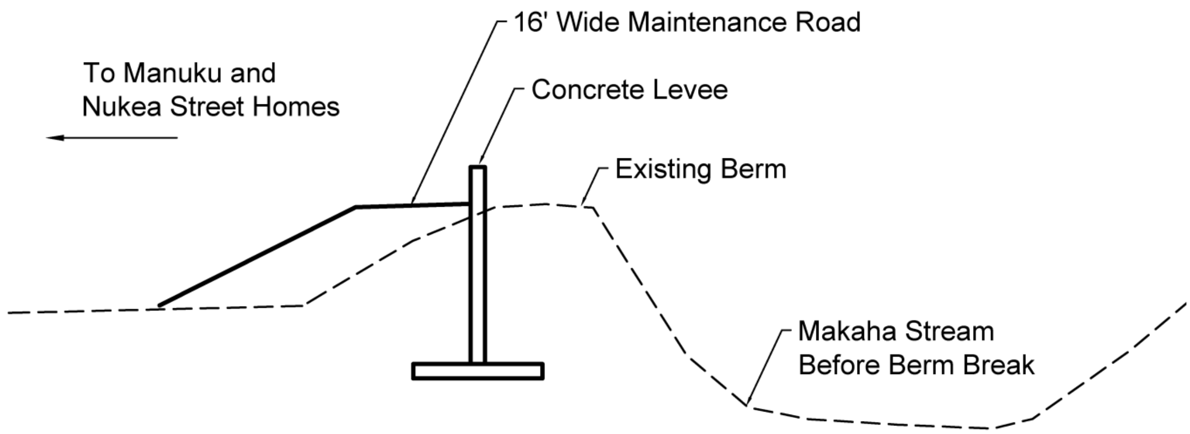


Figure 12. Mākaha Stream Levee Project Location



Makaha Stream Levee

Looking Makai

Implementing Agency

To be determined

Ongoing Maintenance Agency

To be determined

Estimated Project Cost

The estimated cost to construct the Mākaha Stream Levee is between $17,025,000 and $24,025,000. This estimated cost includes obtaining easements for four undeveloped parcels ($25,000) from four different landowners.

Cost Item	Estimated Cost
Acquisition	None
Easements	$25,000
Environmental	$500,000 - $1,000,000
Survey and Design	$1,000,000 - $2,000,000
Construction Management	$500,000 - $1,000,000
Construction	$15,000,000 - $20,000,000
Total	**$17,025,000 - $24,025,000**

Storm Damages w/o the Project

Homes and undeveloped parcels adjacent to Mākaha Stream near Manuku Street, Nukea Street, and Farrington Highway will continue to be flooded during large storms and edges of properties that are adjacent to the stream will slowly be eroded from the velocity of storm water runoff. Homes and undeveloped parcels will remain within the 100- and 500-year floodplains.

Benefits w/ the Project

The benefits of constructing the Mākaha Stream Levee are:

- Protecting residential properties from property damages resulting from storms up to the 100-year storm
- Alleviating flooding of at least 12 existing homes and 5 undeveloped parcels from the 100-year storm
- Protecting at least 40 homes from the 500-year storm
- Reducing or eliminating flood insurance costs

7.1.5 Project No. 05: Kili Drive Channel

Construct a trapezoidal shaped, open concrete-lined ditch that is ten feet wide at the base, 24 feet wide at the top of the channel, five feet deep, and with side slopes of 1-vertical to 1-horizontal. The channel will begin at the mauka end of the Mākaha Valley Towers complex and travel along the BWS Reservoir access road and Kili Drive to where West Mākaha Stream crosses Kili Drive at the existing cluster of 30-inch culverts. It may be possible to end the ditch before the West Mākaha Stream crossing, but that is dependent on more substantial survey and study of the area.

This ditch needs to be lined due to the high velocity of the runoff. In order to have the entire ditch as an open channel, it will require the removal of Monkey Pod trees fronting the entrance to the Mākaha Valley Towers complex. If removal of the trees will be an issue, an underground culvert system will need to be constructed in that area. However, use of an underground culvert system should be considered a last resort. The intent is to use Kili Drive as the maintenance road, therefore, an additional maintenance road is not needed. The useful life of this project is 50 years.

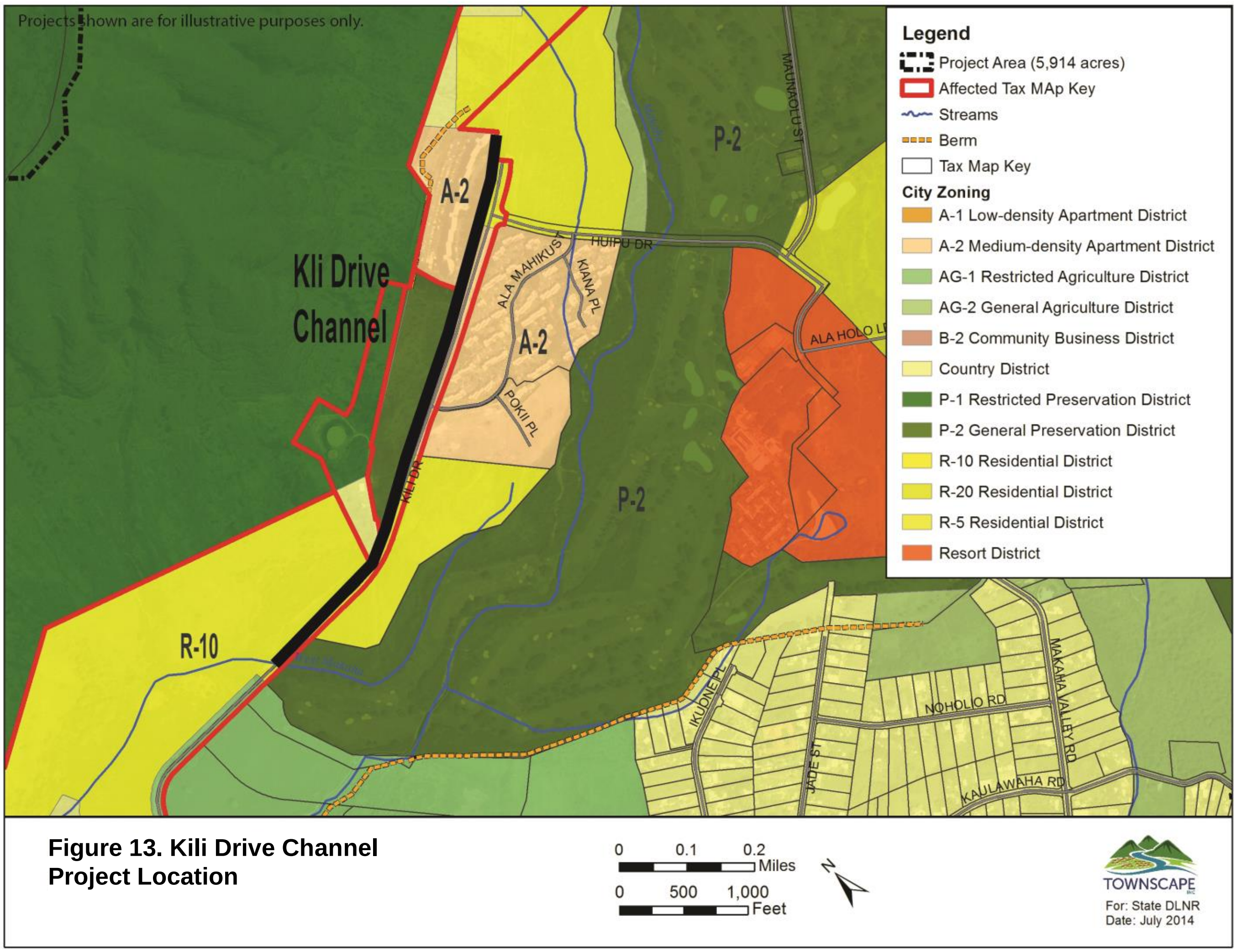
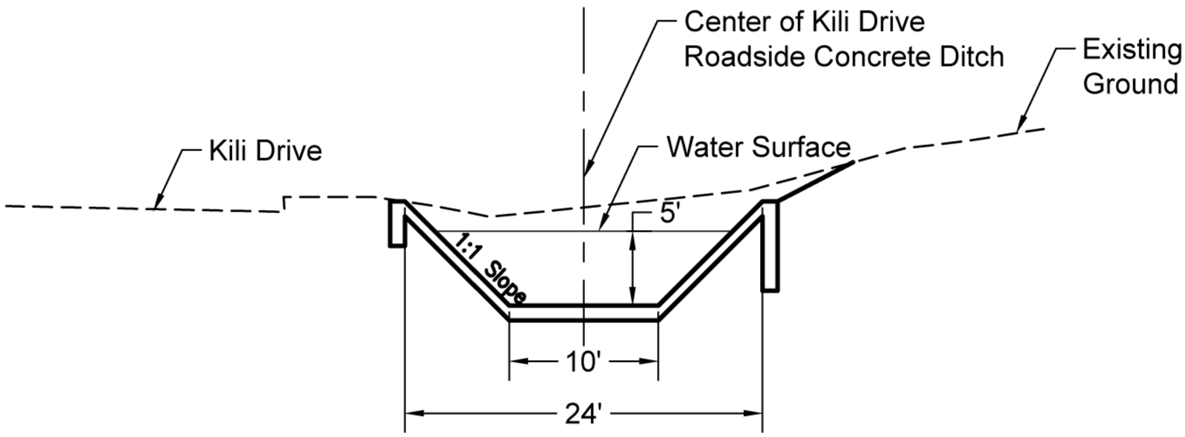


Figure 13. Kili Drive Channel Project Location



Kili Drive - Concrete Channel

Looking Makai

Implementing Entity
To be determined

Ongoing Maintenance Entity
To be determined

Estimated Project Cost
The estimated cost to construct the Kili Drive Channel is approximately $12,937,000 to $19,937,000. This estimated cost includes obtaining easements for 4 parcels ($937,000) from three different landowners.

Cost Item	Estimated Cost
Acquisition	None
Easements	$937,000
Environmental	$500,000 - $1,000,000
Survey and Design	$1,000,000 - $2,000,000
Construction Management	$500,000 - $1,000,000
Construction	$10,000,000 - $15,000,000
Total	**$12,937,000 - $19,937,000**

Storm Damages w/o the Project
Potential storm damages without the proposed Kili Drive Channel are:

- Road damages to Kili Drive
- Possible flooding of Mākaha Valley Plantations (a 572-condominium complex)
- Road damages to Huipu Drive
- Possible flooding of Mākaha Oceanview Estates (residential community)

Benefits w/ the Project

The benefits of constructing the Kili Drive Channel are:

- Reduced flooding of Kili Drive that has turned the road into a river in past storms, which has closed Kili Drive due to hazardous driving conditions and resulted in significant road damages
- Reduced runoff discharged into Mākaha Stream by collecting runoff from behind Mākaha Valley Towers and from the BWS Reservoir Road and redirecting it to West Mākaha Stream that would otherwise be conveyed under Kili Drive, Mākaha Valley Plantations, Mākaha Oceanview Estates complex and into Mākaha Stream

7.1.6 Project No. 06: Mauna 'Olu Estates Drainage Improvements

A separate study is being done by the BWS for the Mauna 'Olu Estates Drainage. Sections of the existing system of ditches and berms above the Mauna 'Olu Estates subdivision are not functioning as constructed.

The tributary area is divided into four areas ranging from 52 acres to 139 acres, with the total area slightly less than 400 acres. The TR-55 method was used to estimate peak flows for the 10-, 25-, 50-, and 100-year storms. A total of 2,776 cfs is generated during a 100-year storm event. Of this total, 1,264 cfs was intended by developers to go through the Mauna 'Olu Estates via the existing ditch system running through the subdivision and into the Mākaha Stream. The remaining 1,509 cfs was intended by developers to be conveyed along the mauka boundary of Mauna 'Olu Estates towards the golf course and flow into the Eku Stream. A total of 1,411 cfs, 1,945 cfs, and 2,356 cfs is generated during a 10-, 25-, and 50-year storm event respectively.

The BWS is currently reviewing the preliminary report, which includes recommendations on how to convey the offsite drainage. Recommendations may include improving only certain problematic areas or improving the entire system with possibly a new lined drainage ditch or levee walls. The intent of the overall design is to maintain the tributaries to Eku and Mākaha Streams as described above.

7.1.7 Project No. 07: Noholio Road Drain Line

Noholio Road is a private road within Mākaha Valley that connects Jade Street to Mākaha Valley Road. There are two depressions which collect runoff from the dwellings on the mauka side of the road as well as from some areas of the Mākaha East Golf Course. The property owners on the makai side of Noholio Road at these two depressions have both constructed solid walls along the frontage of their properties, which effectively act as dams trapping the water and causing localized flooding. There does not appear to be any drainage easements in the vicinity of these two depressions, therefore, the recommendation for this area is a closed culvert system.

Grated drain inlets will be installed along the makai shoulder at the low points of both depressions. A 36-inch culvert will connect these two inlets and travel along Noholio Road to Mākaha Valley Road, then to Kaulawaha Road, and finally empty into Eku Stream. The total length of this drain line will be approximately 2,500 feet. Because of the terrain in this area, the slope of the culvert will be minimal. Therefore, manholes should be placed at regular intervals for ease of maintenance. The grated inlet boxes will need to be maintained and cleaned before and after each storm event.

Improvements to Eku Stream are recommended prior to installing the Noholio Road drain line.

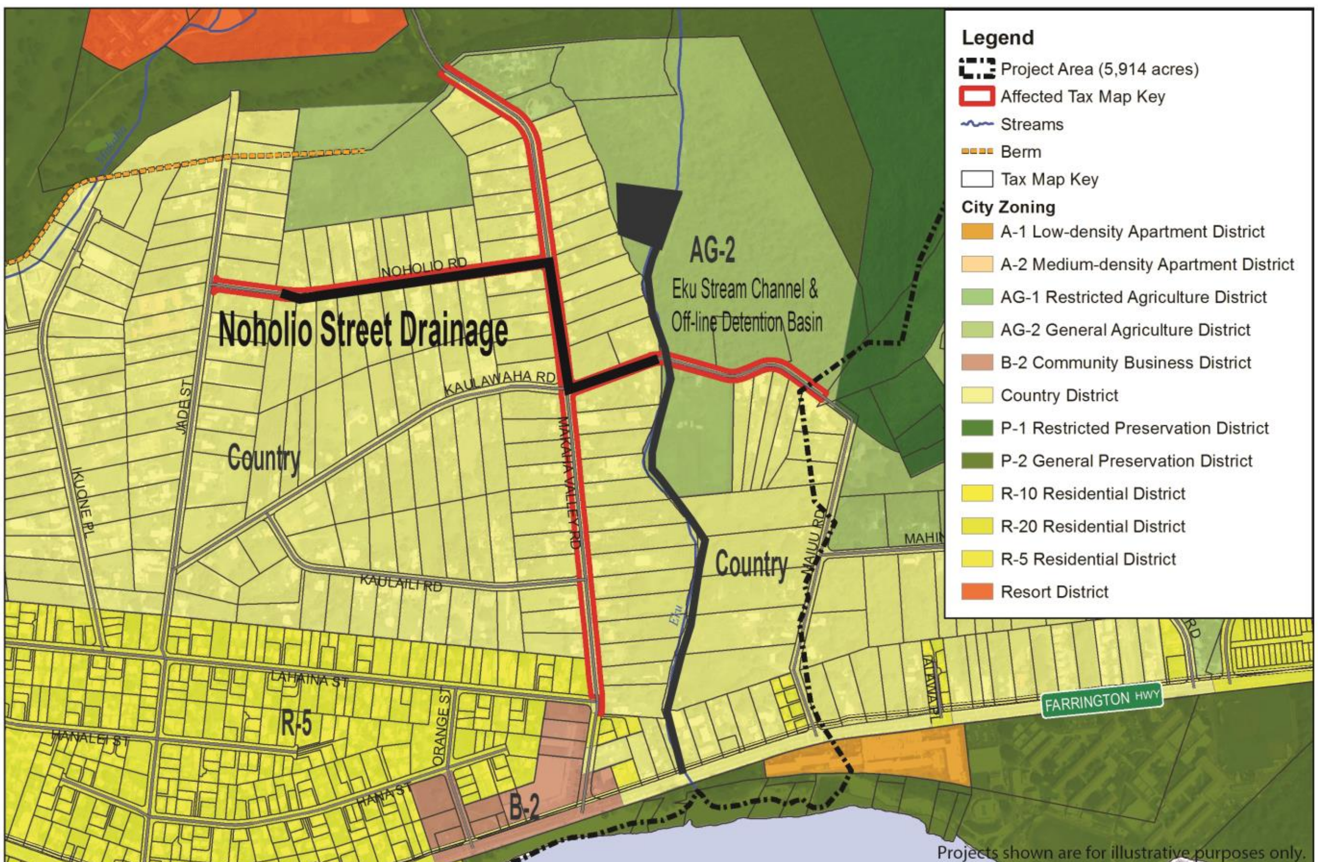


Figure 14. Noholio Street Drainage Project Location

0 0.1 0.2 Miles
0 500 1,000 Feet

TOWNSCAPE
For: State DLNR
Date: July 2014

Implementing Entity
To be determined

Ongoing Maintenance Entity
To be determined

Estimated Project Cost
The estimated cost to construct the Noholio Road drain line is approximately $1,700,000 to $3,300,000. Noholio Road (TMK 8-4-022:034) is a privately owned road. The listed owner (as of July 2014) based on the City's data is Mākaha Valley Farms Ltd.

Cost Item	Estimated Cost
Acquisition	None.
Easements	To be determined
Environmental	$200,000 - $400,000
Survey and Design	$300,000 - $500,000
Construction Management	$200,000 - $400,000
Construction	$1,000,000 - $2,000,000
Total	**$1,700,000 - $3,300,000**

Storm Damages w/o the Project
Homes on and makai of Noholio Road will continue to be affected by runoff locally and from mauka areas. Properties adjacent to the solid walls constructed by property owners will continue to be affected by localized flooding.

Benefits w/ the Project
The benefits of constructing the Noholio Road Drain Line are:

- Reduced flooding of Noholio Road and some areas of Mākaha Valley Road and Kaulawaha Road
- Reduced flooding of properties adjacent to solid walls constructed by properties owners

7.1.8 Project No. 08: Restore Mākaha Surfing Beach "Pond"

The USGS quadrangle map for "WAIANAE, HAWAII" (scale 1:24,000; 1983) shows a "depressional" 10-foot contour area at the Mākaha Surfing Beach. The depressional contour extends from the outlet of Mākaha Stream to the outlet of West Mākaha Stream, and is about 600 feet in length and about 150 feet in width = about 90,000 square feet = about 2 acres in area. Mākaha Surfing Beach in this area, from Farrington Highway to the waterline is about 300 to 350 feet in width, so this depression occupied about half of the width of the beach in this area.

Community members who are very familiar with conditions at Mākaha Surfing Beach say that there used to be a natural "pond" that extended from the outlet of Mākaha Stream to the outlet of West Mākaha Stream – more or less in the area that shows as a "depression" on the USGS map. These community members say that this "pond" functioned as a natural debris basin, catching and holding silt and debris from flooding of the streams and thus preventing this material from being deposited on the beach and in the near shore waters. After flood conditions abated, community members would clean out debris from the "pond." The "pond" would also hold water for some days after a storm, and the Mākaha Beach folks would stage "races" here with small model boats and engage in other kinds of recreation.

After the destructive storm of 2008 City crews worked to "restore" Mākaha Surfing Beach. Unfortunately, according to beach users, the City crews mistakenly filled in most of the "pond" area during this beach reconstruction project. As a result of the City work, there is now an area of the beach about 50 feet in width that provides a "channel" for flood waters to flow from Mākaha Stream, between the highway and the beach berm, to the West Mākaha Stream outlet, from which point flood waters flow toward the ocean. However, this channel is not low enough to serve the debris catchment function of the original "pond" area.

The Mākaha Surfing Beach "pond" should be restored – both to serve as a natural debris catchment feature and as a recreational amenity for beach users. City maintenance personnel from the Department of Facilities Maintenance could do the work at the request of the City Department of Parks and Recreation. Clearances would be required from the USACE and from the State Department of Health (DOH) and the State DLNR Office of Conservation and Coastal Lands. Since this work would be **corrective action** for an earlier beach reconstruction project, the full range of conservation and coastal permits may not be required.

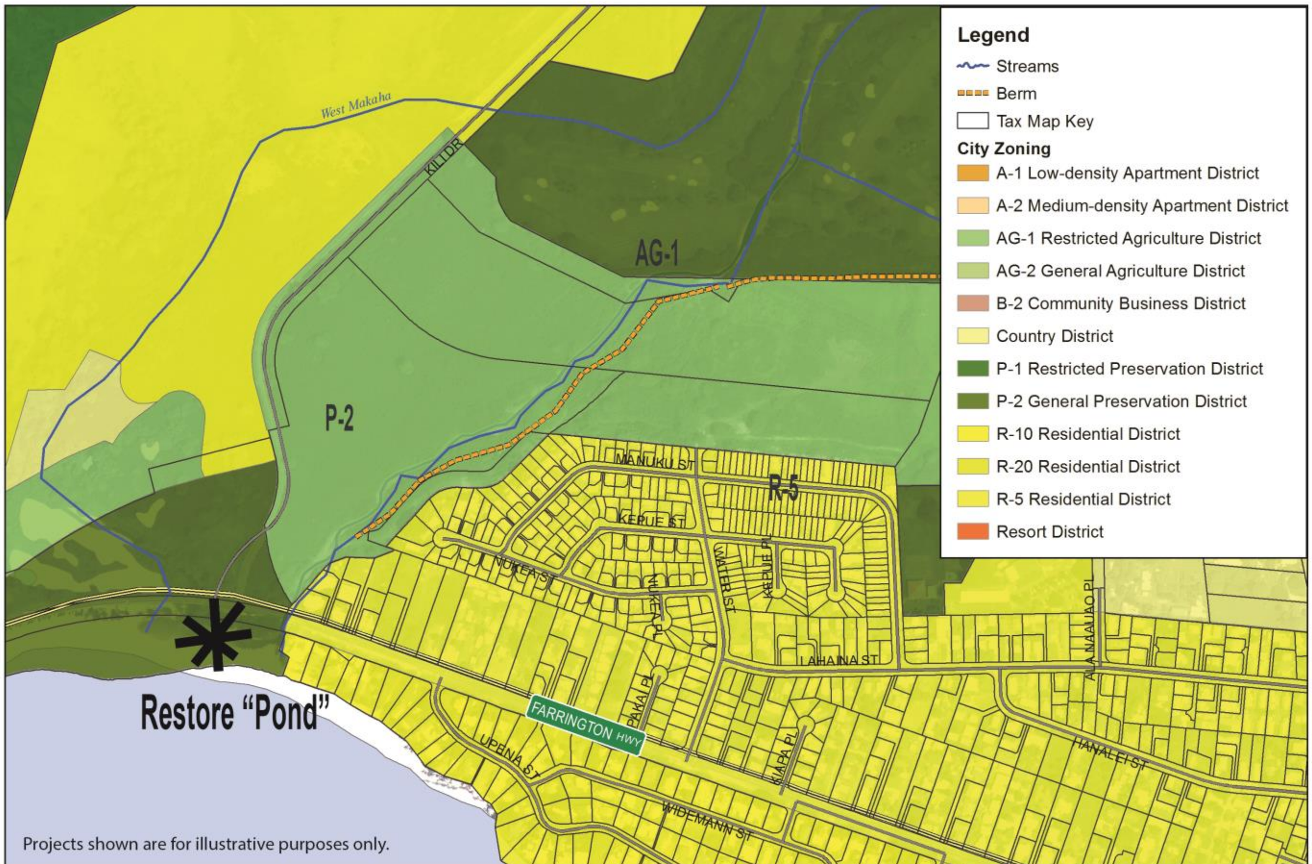


Figure 15. Restore "Pond" Project Location

Implementing Entity

City and County of Honolulu

Ongoing Maintenance Entity

Honolulu Department of Facilities Maintenance

Estimated Project Cost

"Maintenance Project"

7.1.9 Project No. 09: In-stream Detention Basins for Mākaha Stream

The highest amount of runoff contributing to 70 percent of the peak flow for Mākaha Stream is from subarea 1 (as shown in Figure 10). This drainage area consists of forested lands owned by the BWS. Construction of several detention basins in Mākaha Stream is needed in order to retain and hold back some of the runoff in the valley. The location where the detention basins will be built has yet to be determined.

Since the peak flow of subarea 1 is drawn out over a longer period and does not overlap with the other drainage areas for Mākaha Stream, detention basins in subarea 1 and other subareas will be required to reduce the total peak flow value.

Detention basins of approximately 6,550,000 cubic feet (about 7.5 acres by 20 feet deep) for subarea 1 and 2,250,000 cubic feet (about 2.6 acres by 20 feet deep) will reduce the total peak flow to about 9,844 cfs, which is approximately a fifteen percent reduction.

The location of one or more in-stream detention basin(s) for Mākaha Stream requires further research.

7.2 Nonstructural Measures

Nonstructural measures include ongoing programs that will help alleviate flooding in the valley.

The nonstructural programs recommended for Mākaha Valley are:

1. Watershed Restoration
2. Stream Channel Maintenance
3. Storm Drain Maintenance
4. Enforcement of existing legislation
5. Education on Best Management Practices for Watersheds
6. Drainage improvements required for future development

7.2.1 Watershed Restoration

In Hawaiʻi, watersheds are critically important—for water supply, water quality, air quality, natural habitats, scenic beauty, outdoor recreation and natural resource educational programs. They provide indirect services such as groundwater recharge by intercepting rainfall. Research shows that vegetation restoration can change soil hydraulic properties and that infiltration rates are two times greater in reforested areas compared to deforested areas[6]. But, most of our watersheds are also critically endangered and have been overrun by feral pigs and goats and by nonnative and invasive plants. The degraded condition of our watersheds has resulted in a host of negative environmental consequences, including increased runoff and erosion, poor water quality for streams and near shore waters, siltation of near shore reefs, decreased water infiltration and lower yields from aquifers, lower base stream flows, and increased stream flooding.

The BWS owns nearly two-thirds of the valley, which includes the majority of forested areas. The forested areas consist mostly of nonnative species such as strawberry guava and coffee. Improving the forests through native forest restoration will help to retain and absorb more water; thus reducing the peak amount of storm water that travels down the valley in the streams.

Forested areas in upper Mākaha Valley

Watershed restoration is a long-range project that will focus on incremental fencing of areas of the upper watershed to exclude feral pigs and goats, removal of invasive plants, planting native plants, restoration of traditional wet loʻi terraces

[6] Perkins,K.S., J.R. Ninmo, and A.C. Medieros (2012). Effects of native forest restoration on soil hydraulic properties, Auwahi, Maui, Hawaiian Islands. Geophys. Res. Lett.

and dry agricultural fields. The expected outcome after many years of these actions is the restoration of a healthy forest and a healthy watershed.

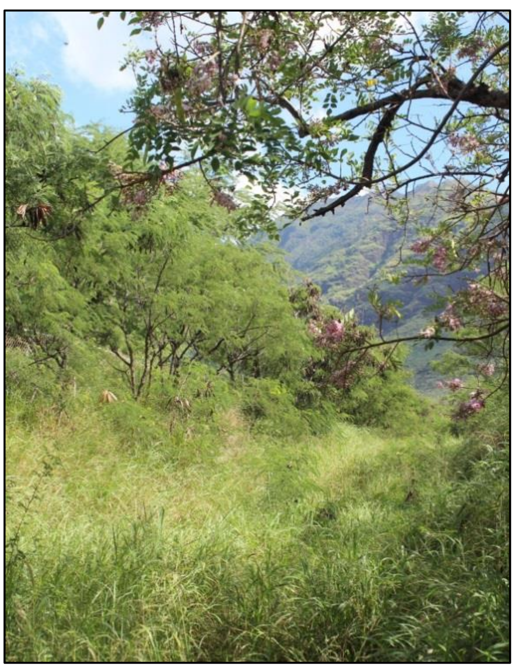
The U.S. Army Garrison-Hawaii, in partnership with the BWS, has constructed exclusion fences on land owned by the BWS in the upper reaches of Mākaha Valley. About 120 acres of native plant habitat has been enclosed. The purpose of the fence is to keep out goats and pigs that pose a threat to the endangered species and native forest resources. The BWS has worked with the Waiʻanae Watershed Partnership to remove invasive species in Mākaha Valley. In the past, groups such as the Youth Conservation Corps have volunteered to help with clearing invasive plants. More volunteer groups' involvement and community outreach are needed to support these forest restoration efforts.

Since all of the forested areas in the valley are owned by the BWS, significant commitment to forest restoration from the BWS is needed. Forest restoration will also require a significant amount of manual labor, some of which can be provided with the help of volunteers and forming partnerships with organizations, school groups, and community groups.

This recommended measure will provide long term benefits to the whole ecosystem. It will take many years to restore the watershed and many more years after that to observe significant improvement in reducing runoff.

A$500,000 Grant-in-Aid was approved by the 2014 Hawaiʻi State Legislature for forest restoration work in Mākaha Valley. Additionally, the BWS has committed to funding some of the forest restoration work and has submitted a grant application, in partnership with several other stakeholders, to the NRCS Regional Conservation Partnership Program for a long-range watershed restoration project.

7.2.2 Stream Channel Maintenance



Overgrown vegetation in Eku Stream Channel facing mauka

While vegetation within the stream channel can help absorb some of the storm water and reduce the velocity of storm water traveling down the stream, overgrown vegetation, debris, and large trees reduce the carrying capacity of the stream. Fallen trees act as a dam—preventing the natural flow of storm water. As a result, storm water collects in an area, overtops the stream banks and floods nearby properties.

Keeping the channel clear of excess vegetation, removing debris and any obstructions either natural or dumped can help maintain the carrying capacity of the stream. Additionally, garbage and debris within the stream channel are carried off during large storms and discharged into the ocean, which negatively impacts the quality of near shore waters.

On Oʻahu, the responsibility for maintaining a stream rests with the owner of the stream [Revised Ordinances of Honolulu (ROH) 41-26.3]. Both Mākaha and Eku Streams are not owned by one entity, but ownership is shared by many private landowners. Most of the property lines in Mākaha extend to the centerline of the stream, which means that Mākaha Stream is owned by at least four different landowners and Eku Stream is owned by more than twenty different property owners.

Maintaining the carrying capacity of the stream requires a coordinated effort amongst all property owners to maintain their section of the stream channel. A coordinating organization or government agency, such as a drainage district, may be able to assist landowners in maintaining their sections of the stream. Access into stream channels for maintenance may be a challenge since it requires getting permission from streamside property owners to enter into private property. Maintenance easements should be explored in exchange for a community stream channel maintenance program.

Additionally, the City's Department of Environmental Services Water Quality Branch sponsors the "Adopt-a-Stream" program, which is a volunteer program where participants commit to a minimum of four cleanups per year for two years. This program provides volunteers with supplies. Through this program, there are opportunities for school groups, businesses, organizations, and residents to Adopt Mākaha or Eku Streams. More information on the Adopt-a-Stream program can be found at http://www.cleanwaterhonolulu.com/storm/hero/adopt.html.While the City can enforce regulations requiring stream owners to maintain the stream, a Stream Channel Maintenance Program with regularly scheduled community-wide clean up dates would be more effective.

ROH 41-26.3 states that the owner of a stream:

"…has the duty to maintain, dredge, and clear such stream so that the natural flow of water runs unimpaired. The owner shall also be responsible for the removal of any debris, vegetation, silt or other items or material of any kind that may interfere with the natural flow of water."

7.2.3 Storm Drain Maintenance

Small rocks and debris clog up the storm drains, particularly catch basins near Kili Drive during storms, which prevent the discharge of storm water. As a result, roads are flooded—leading to significant road damages. Storm drains need to be cleaned out regularly of silt and trash. Storm drain maintenance includes clearing out culverts that fill up with debris and trash, and large rocks that pile up behind debris poles at the mouth of a culvert (i.e. makai of Mākaha Valley Towers).

While storm drains on City-owned roads are maintained by the City, maintenance responsibility for storm drains located on privately-owned roads rests with the owner of the road. The City can enforce maintenance of privately-owned storm drains to ensure that storm water can enter freely into them.

Three-foot debris poles filled with rocks to the top

However, regular storm drain maintenance for both City and privately owned roads are an issue due to budget constraints and manpower. “Adopt-a-Storm Drain” programs can be implemented for Mākaha Valley where volunteers take on the responsibility of removing debris from the storm drains. Cities such as the City of Superior in Wisconsin have successfully incorporated an Adopt-a-Storm Drain Program.

7.2.4 Enforcement

Enforcement of existing legislation that requires stream owners to maintain streams and waterways is a critical component to reducing flood risk. The City has the power to issue a Notice of Violation to the owner of any stream who has failed to maintain and clear the stream, which includes removing debris, vegetation, or silt. If the owner of the stream does not properly address the Notice of Violation to maintain and the clear the stream within 30 days of the notice, the City is then authorized to perform the necessary maintenance and clearing of the stream and charge the owner of the stream for the costs of such work. Failure to pay the bill will result in placement of a lien on their property.

It is illegal to litter in any stream and violators can be served with a citation by the City (ROH Article 4, Chapter 29). Enforcing existing legislation of “no dumping” in the streams should help to maintain streambeds free of bulky items dumped by residents that impede the flow of water and contribute to water contamination as the items decompose.

7.2.5 Education on Best Management Practices for Watersheds

The majority of residents in Mākaha are eager to learn about and be involved in flood risk management. Residents have varying levels of knowledge about flood risks, with various kinds of information shared with other community members. While it is good that the community members share information, there is the potential to spread misinformation as well. At the first Mākaha Flood Study community meeting, several residents voiced the need for public education and to provide information on how to prevent flooding of their homes, including specific instructions on what to do. Residents shared their willingness to help reduce flood risk particularly for their property, but lack the guidance on HOW to do it. Residents seek information and guidance on floodplain management and what actions they can take NOW.

Bringing general awareness of the flooding issues to the community is also beneficial, including providing educational information on Best Management Practices (BMPs) to minimize flood risks.

Community involvement could include starting a standing FLOOD COMMITTEE within the community's Neighborhood Board. Through the FLOOD COMMITTEE, residents can strategize and organize flood risk educational programs such as researching best practices, developing educational programs at Mākaha Elementary School, and starting community programs. Other programs may include developing a Neighborhood Watch program for illegal stream dumping, stream cleaning maintenance, and providing an informational campaign.

7.2.6 Drainage improvements required for future development

Our hydrologic analysis for Mākaha Stream and Eku Stream indicated that there was only a small increase in the 100-year flood flows when comparing flows for "existing conditions" and flows for "full build-out" conditions. For both streams, the "full build-out" scenario assumed that all as yet undeveloped land in these watersheds with residential or resort zoning would be developed.

However, the impact of future development on the 100-year storm peak flows is not the only issue of concern. We must also consider the following issues:

- ANY FUTURE DEVELOPMENT of zoned/undeveloped parcels has the potential of impacting adjacent downstream properties with increased flood flows. City drainage standards only require new developments to design their on-site drainage systems for a 10-year storm. Unlike drainage standards of the Hawaiʻi County Department of Engineering, which require new developments to DETAIN ON-SITE ANY INCREASE OF FLOOD FLOWS UP TO AND INCLUDING THE 100-YEAR FLOOD, City drainage standards allow a new development to discharge storm water from the property provided that downstream drainage systems can accommodate those flows. For Mākaha Valley, with its piecemeal and poorly maintained drainage systems, and with its two main streams experiencing significant flooding for 25-, 50- and 100-year storms, there is little or no "capacity" for existing drainage systems to accommodate increased flood flows from new developments.

  Our conclusion: any future development of zoned/undeveloped parcels should include a combination of on-site storm runoff detention and improvement of downstream drainage systems to prevent any increase in flooding of downstream parcels. Further, the ongoing maintenance of any drainage systems downstream from the new development should be the responsibility of the development company or of the home owners association or condominium association that maintains common facilities of the completed development.

- Recent conceptual plans developed by one of the major land owners in Mākaha Valley shows future development for several parcels in the Eku Stream watershed that are currently zoned AG-2 (General Agriculture) and P-2 (General Preservation). Any future development of these parcels and of other parcels that are currently zoned AG-1 or AG-2 or P-2 should also include a combination of on-site storm runoff detention and improvement of downstream drainage systems to prevent any increase in flooding of downstream parcels. As with the zoned/undeveloped parcels, the ongoing maintenance of any drainage systems downstream from the new development should be the responsibility of the development company or of the home owners association or condominium association that maintains common facilities of the completed development.

7.3 Other considerations

7.3.1 Stream erosion control

Sections of Mākaha and Eku stream banks are somewhat degraded in the lower reaches of the stream. One community resident pointed out a section of Mākaha Stream near Huipu Drive and east of the Mākaha Valley Plantations complex where the streambed has greatly expanded. Visual inspection of the stream in this area revealed that the carrying capacity of Mākaha Stream near Huipu Drive is adequate to contain flows during a large storm, but stream erosion control is recommended.

Measures such as streamside vegetation used to control stream bank erosion also can slow down storm water velocity and reduce amount of sediments transported into the ocean. Rock riprap or gabions may also help stabilize the stream banks. This erosion problem also occurs for property owners on Manuku and Nukea Streets.

7.3.2 Mākaha Stream Channel

Another possible flood mitigation project to address flooding in the lower reaches of Mākaha Stream is to construct a concrete-lined or gabion rock channel for the stream. A concrete-lined channel would need to be approximately 50 feet wide at the base, 75 feet wide at the top, 9.5 feet deep, and with side slopes of 1 to 1; whereas a gabion rock channel would need to be about 100 feet wide at the base, 125 feet wide at the top, ten feet deep, and with side slopes of 1 to 1. The entire length of the channel would run approximately 2,600 feet upstream from Farrington Highway to the damaged berm area. A 16-foot wide maintenance road is suggested, but may be eliminated if the channel is used as the maintenance access.

Project cost for the channel is estimated to be at least $27 million in addition to obtaining easements to construct the channel. Similar to the Mākaha Stream levee, benefits of the channel include protecting residential properties up to the 100-year storm, avoided insurance costs, and increased property values of nearby parcels from reduced flood risk. In addition, development of a channel for Mākaha Stream will protect several large undeveloped parcels from flooding up to the 100-year storm since the proposed channel will “contain” the 100-year storm. However, due to the high cost of this channel compared to the benefits it would provide, development of a channel for Mākaha Stream was not included in the previous recommended structural projects.

7.3.3 Farrington Highway, Replacement of Mākaha Bridges No. 3 and No.3 A

The State DOT is currently in the process of replacing the two wooden bridges that convey the Mākaha and West Mākaha stream flows under Farrington Highway with two larger capacity concrete bridges. The design work for the bridges and related up-stream and down-stream improvements has been completed. The existing bridges were found to be structurally deficient through bridge inspections conducted by the DOT. This evaluation was strictly for structural instability and not hydraulic inadequacy. However, the DOT did conduct a hydrologic study to determine what the bridge hydraulic openings should be. The 100-year flood flows calculated for the DOT project was 9,185 cfs, which differs from the FEMA flow of 11,561 cfs. This difference was stated in a public meeting for the bridges.

The detailed hydraulic study for this report ended approximately 150 feet upstream of Farrington Highway and does not tie into the DOT hydraulic calculations because of the difference in flow rates. The hydrologic study for this report yielded a flow of 11,413 cfs, which is comparable to the FEMA flow.

The combined hydraulic cross-sectional area of the planned new bridges is 1,295 square feet, which is 36 percent (or 950 square feet) more than that of the existing bridges. Theoretically, this cross-sectional area should handle the Mākaha Stream and West Mākaha stream flows. However, the Mākaha beach berm effectively turns the whole area into a large pond until the berm is breached by the stream or is mechanically opened by equipment operators. A program to open up the beach berm may be necessary and should include at minimum a definition of what is to be done, who will perform this work, how it will be physically done, and how it will be funded.

Some community members have expressed that the proposed bridge project should not move forward and that flooding of their properties will worsen with the current proposed plans.

7.3.4 Mākaha West Golf Course

Pacific Links Hawaiʻi is redesigning the Mākaha West Golf Course to a new 18-hole championship golf course. Work will include grubbing of existing vegetation and grading for new golf holes. Community members are concerned that the redesign of the golf course will lead to additional flooding in the valley. The engineers for the new golf course design have indicated that the new golf course will not increase runoff from the property.

7.3.5 Farrington Highway Realignment

The City and County of Honolulu developed a master plan for Mākaha Beach Park in 1996. The master plan included development of picnic areas, a new multi-purpose field, renovations to existing facilities, and realignment of the existing Farrington Highway to a mauka location.

Some community members are concerned with the safety of park users due to the existing location of the road. In addition to the public safety concern with park users and pedestrians crossing the highway, Mākaha Beach and Farrington Highway could become inaccessible due to beach erosion and wave damage due to high surf. The Oʻahu Metropolitan Planning Organization (OMPO) plans to fund a feasibility study for the relocation of Farrington Highway near Mākaha Beach Park in the current fiscal year.

8. Prioritization of Projects

Projects were grouped based on feasibility of implementation. Projects with relatively low cost and high implementation likelihood are categorized as Group 1. More complex and costly projects, but ones that demonstrate large benefits relative to cost are included in Group 2. Benefits were considered based on the following criteria: (1) public safety, (2) property and (3) infrastructure. Additional projects with high initial cost relative to their benefits are listed in Group 3.

Table 7. Prioritization of Projects

Group 1	Group 2	Group 3
• Repair the breach in the Mākaha Stream berm • Restore Mākaha Surfing Beach "Pond"	• Eku Stream Channel and Off-line Detention Basin	• Kili Drive Channel • Mākaha Stream Levee • Noholio Road Drain Line • In-stream Detention Basins for Mākaha Stream • New Eku Stream Bridge at Farrington Highway

Projects in Group 1 are considered "quick fixes." Repairing the breach in the Mākaha Stream berm is the least costly of the alternatives available to mitigate flooding predominately for homes near Manuku and Nukea Streets. As noted earlier, this mitigation measure would only be a temporary solution to reducing flood risk for homes near this area until another breach occurs along the berm. Constructing a levee (listed under Group 3) would be a longer-term, but relatively costly, solution to the flooding problem. Another option, yet the most expensive of the measures mentioned above, is to channelize Mākaha Stream. A Mākaha Stream Channel is not included in a priority group because of low implementation likelihood due to the high costs associated with the project. The other project included in Group 1 is restoring the "pond" at Mākaha Beach. This project would also mitigate some of the flooding problems that impact residents in the lower reaches of Mākaha Stream.

Of the remaining structural projects, only the Eku Stream Channel and Off-line Detention Basin project is listed in Group 2. This project would provide the most significant benefits, particularly for the well-being of residents near Eku Stream. The Eku Stream Channel could be built in phases; with the lower reaches of the channel built first, then constructing the remaining half of the channel, and finally the detention basin. Although a new Eku Stream bridge with adequate capacity for 100-year flows would also address flooding near Eku Stream, the project is listed in Group 3 due to the low likelihood of implementation.

Projects in Group 3 are projects that are recommended to mitigate flooding problems in the valley, but have a high cost relative to the potential benefits. The Kili Drive Channel would probably have highest priority within Group 3 because the channel would capture a significant amount of the runoff from behind Mākaha Valley Towers complex. The runoff also goes through the Mākaha Valley Plantation complex—which could potentially affect a lot of people and property. The Noholio drain line is included in Group 3 because it requires the lower half of the Eku Stream Channel to be built first. Without improvements done to the Eku Stream channel, runoff from Noholio Road conveyed to Eku Stream would be a detriment to properties near Eku Stream.

9. Summary of Environmental Impacts

This section provides a summary of environmental impacts of the proposed flood mitigation projects, and discusses potential regulatory constraints and requirements. A more detailed environmental impact assessment is included in Volume II of this report. The purpose of the assessment included in Volume II is to identify and evaluate potential impacts, including unintended effects in addition to the desired and intended effects, on the natural, socio-economic, cultural, and archaeological environment, that may result from proposed flood mitigation projects and measures for Mākaha Valley.

The proposed flood mitigation projects are generally consistent with the State and City designations for the land. No changes in land use will occur as a result of the proposed mitigation projects. Construction on conservation lands will require a Conservation District Use Permit (CDUP) from the DLNR. Proposed projects within the Special Management Area (SMA) will require an SMA permit from the City's Department of Planning and Permitting. Any proposed flood mitigation project that may be funded through State funds will require an EA or Environmental Impact Statement (EIS). Exclusion fencing for native forest restoration on the BWS land may also require an EA or EIS as well as a CDUP.

Proposed projects will benefit public health and safety in terms of mitigating flood hazards. At least 50 residential units and business parcels are protected from the 100-year storm with the proposed Eku Stream Channel, Off-line Detention Basin, and New Eku Stream Bridge. The proposed Kili Drive Channel would reduce the amount of runoff discharged into Mākaha Stream and the Mākaha Stream Levee would protect homes and several undeveloped parcels from the 100-year storm. While the proposed Mākaha Stream Levee would protect some homes from flooding, it may also unintentionally increase flooding on undeveloped properties located on the opposite side of the stream and levee.

Construction of proposed flood mitigation projects will require a more in-depth analysis of archaeological sites within the area. The analysis should include identifying areas that may not have been previously surveyed. An Archaeological Inventory Survey may need to be undertaken for one or more of the proposed project areas.

While the proposed projects would prevent flooding of properties, the structural measures may accelerate the velocity of runoff and reduce sedimentation of floodplain areas before discharging into the ocean. Under the Clean Water Act (CWA) and Hawaiʻi Revised Statutes Chapter 342D, Section 401 of the CWA requires a Water Quality Certification to be obtained for activities when proposed construction or operation may result in discharge of pollutants into state waters.

Proposed flood mitigation projects will involve construction within and immediately surrounding Mākaha and Eku Streams. A Stream Channel Alteration Permit from the DLNR Commission on Water Resource Management (CWRM) Stream Protection and Management Branch is required for any temporary or permanent activity within a stream bed or banks that may (1) obstruct, diminish, destroy, modify, 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.

Potential construction related impacts include discharge of construction materials into the stream and storm water runoff that mixes with sediments and construction materials. Proposed projects involving stream channel or stream bank alterations will require a Section 404 permit. Section 404 of the CWA is administered by the USACE and regulates the discharge of dredged or fill material into U.S. waters, including wetlands.

Pursuant to Section 402 of the CWA, the State DOH Clean Water Branch regulates discharge of pollutants into surface waters. Hawaiʻi Administrative Rules, Chapter 11-55 requires submittal of a complete National Pollutant Discharge Elimination System (NPDES) application for any construction activity that disturbs more than one acre of total land area. An NPDES permit may be required for the construction of proposed flood mitigation projects.

10. Next Steps

IMPLEMENTATION of the flood mitigation projects presented in this Flood Study will be challenging. Difficulties include:

- Most of the flood mitigation projects are located on privately-owned land. State and City agencies will typically NOT fund and implement projects that are located on privately-owned land.

- CIP funding from the Hawaii State Legislature and/or from Federal programs may be a possibility. However, most of the proposed flood mitigation projects will require significant capital funds – in the range of $15 to $30+ Million, and every year there are many competing projects that the Legislature and Federal agencies must consider.

- Ongoing maintenance of any flood mitigation projects like flood channels or levees will be another challenge. The maintenance of flood mitigation projects is typically performed by the City's Department of Facilities Management (DFM), but the City will not assume the responsibility of maintaining facilities on privately-owned land.

- One or more of the major land owners or home owners` associations may be able to implement and maintain flood mitigation projects in Mākaha Valley, perhaps with some assistance from public entities. As presented earlier in this Plan, any future development of land within Mākaha Valley should be conditioned with requirements for improvements of the overall drainage systems for Mākaha.

Most of the flood mitigation projects presented in this plan can be phased, and this strategy may mitigate some of the funding difficulties. For example, the Eku Stream channel and detention basin could be phased in 3 or 4 or more phases, with Phase 1 starting at Farrington Highway.

Overall, it will be critical for land owners, community groups, concerned citizens, elected officials and public agencies to continue to work together to implement flood mitigation projects to protect the health and safety of the Mākaha community.