Instream Flow Standard Assessment Report

Island of Oahu
Hydrologic Unit 3028
Heeia

June 2020 **DRAFT PR-2020-02**

State of Hawaii
Department of Land and Natural Resources
Commission on Water Resource Management

COVER
Satallite image of Heeia hydrologic units with the Heeia stream flowing into the Heeia Marsh, Heeia fish pond and Kaneohe Bay, Oahu [Google Earth, 2015].

Note: This report is intended for both print and electronic dissemination and does not include diacritical marks in spelling of Hawaiian words, names, and place names due to problems associated with its use electronically. However, Commission staff has made attempts to include diacritical marks in direct quotations to preserve accuracy.

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Acronyms and Abbreviations

AG	agricultural
ALISH	Agricultural Lands of Importance to the State of Hawaii
ALUM	agricultural land use maps [prepared by HDOA]
BFQ	base flow statistics
BLNR	Board of Land and Natural Resources (State of Hawaii)
BWS	Board of Water Supply (City & County of Honolulu)
C-CAP	Coastal Change Analysis Program
cfs	cubic feet per second
Code	State Water Code (State of Hawaii)
COM	commercial
Commission	Commission on Water Resource Management (DLNR)
CPRC	Compilation of Public Review Comments (PR-2008-07, CWRM
CWA	Clean Water Act (EPA)
CWRM	Commission on Water Resource Management (State of Hawaii)
DAR	Division of Aquatic Resources (State of Hawaii)
DHHL	Department of Hawaiian Home Lands (State of Hawaii)
DLNR	Department of Land and Natural Resources (State of Hawaii)
DOH	Department of Health (State of Hawaii)
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency (Department of Homeland Security)
FILEREF	File Reference [in the Commission's records of registered diversions]
ft	feet
gad	gallons per acre per day
GIS	Geographic Information Systems
G.L.	Government Lease
GOV	government
gpm	gallons per minute
Gr.	Grant
HAR	Hawaii Administrative Rules
HDOA	State Department of Agriculture (State of Hawaii)
HI-GAP	Hawaii Gap Analysis Program
HOT	hotel
HSA	Hawaii Stream Assessment
IFS	instream flow standard
IFSAR	Instream Flow Standard Assessment Report
IND	industry
IRR	irrigation requirements
IWREDSS	Irrigation Water Requirement Estimation Decision Support System
LCA	Land Commission Award
LUC	Land Use Commission (State of Hawaii)
MF	multi-family residential
mgd	million gallons per day
Mgal/d	million gallons per day
mi	mile
MOU	Memorandum of Understanding
na	not available
NAWQA	National Water Quality Assessment (USGS)
NHLC	Native Hawaiian Legal Corporation
NIR	net irrigation requirements
NPDES	National Pollutant Discharge Elimination System

NPV	Net Present Value
NRCS	Natural Resource Conservation Service (USDA)
NVCS	National Vegetation Classification System
por.	Portion
REL	religious
RMT	R.M. Towill Corporation
SCS	Soil Conservation Service (United States Department of Agriculture)
	Note: The SCS is now called the Natural Resources Conservation Service (NRCS)
SF	single family residential
SPI	Standardized Precipitation Index
sq mi	square miles
TFQ	total flow statistics
TFQ_{50}	50 percent exceedence probability
TFQ_{90}	90 percent exceedence probability
TMDL	Total Maximum Daily Load
TMK	Tax Map Key
UHERO	University of Hawaii's Economic Research Organization
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service (Department of the Interior)
USGS	United States Geological Survey (Department of the Interior)
WQS	Water Quality Standards
WRPP	Water Resource Protection Plan (Commission on Water Resource Management)
WTF	water treatment facility

1.0 Introduction

General Overview

The surface water hydrologic unit of Heeia is located on the windward side of the island of Oahu (Figure 1-3). The hydrologic unit includes the ahupuaa of Heeia in the Moku of Koolaupoko. Heeia is 4.417 square miles on the eastern flank of the Koolau Mountain Range just north of the former Koolau volcanic caldera. Heeia hydrologic unit includes Haiku Valley, Iolekaa Valley, and Heeia and Iolekaa streams that flow into Heeia Marsh, the Heeia fish pond, and Kaneohe Bay. Mean annual precipitation for Heeia is 83.6 inches. The geology and water resources are heavily influenced by the underlying Koolau volcanic series, with its dike complexes and marginal dike zone affecting the movement of groundwater. Subsequent weathering and later phases of volcanism overtopping the Koolau series have influenced the distribution of soils, topography, and flow of water. Much eroded alluvial material has been transported downstream into Haiku Valley, Heeia Marsh, and Kaneohe Bay. The Haiku Valley starts at the amphitheater-shaped watershed featuring the high cliffs of the Koolau Range, generated by the southeast to northwest oriented rift zone, and opens into the Heeia Marsh and Kaneohe Bay. Haiku Valley above the confluence with Iolekaa stream covers an area of 1.27 square miles from a maximum of 2,790 feet elevation to a minimum of 144 feet, with a mean basin elevation of 917 feet and a mean basin slope of 69 percent (Figures 1-4 and 1-5). Sixty-six percent of the basin has a slope greater than 30 percent, with a mean annual precipitation of 97.8 inches. Iolekaa Valley above the confluence with Heeia Stream covers an area of 0.57 square miles. The longest flow path in Heeia is 4.43 miles in length, traversing in a northeasterly direction from its headwaters to Kaneohe Bay. Two volcanic ridges extend from the Koolau cliffs in a northeasterly direction, separating Heeia from Kaneohe to the south, and Kahaluu to the north. Iolekaa Valley includes Iolekaa and the North Branch of Heeia Stream. While lava flows of the Koolau series greatly influence the movement of groundwater, pyroclastic and basaltic rocks from the late phase Honolulu Series compose a substantial percentage of the exposed surface rock. Alluvium forms an apron at the base of the cliffs and extends into the valleys, with younger alluvial deposits on top of older alluvium, Honolulu Volcanics, and Koolau Volcanics. There is a single substantial tributary (Iolekaa Stream) that converges with Heeia Stream, with many smaller tributaries fed by spring flow from high-elevation groundwater seepage and springs produced by dike complexes in the Koolau Volcanics and mid-elevation groundwater springs produced from seepage from the Honolulu Volcanics. Landcover in the Heeia hydrologic units is dominated by urban development in the lower elevations and non-native vegetation including scrub, shrub, and evergreen forest, in the middle and upper eleveations. The higher elevation portions of the hydrologic unit are made up of conservation land owned by the Department of Hawaiian Home Lands, Kamehameha Schools, and the Honolulu Board of Water Supply (HBWS), with other lands owned by the Department of Land and Natural Resources. Heeia is a census designated place located along the coast with a total population of 4,963 people (U.S. Census Bureau Office of Planning 2011). There are two highways that pass through Heeia between Kaneohe and Kahaluu (Figure 1-6).

The Heeia marsh once supported hundreds of acres of wetland taro, but many were lost with the decline in Hawaiian cultural practices and converted to rice paddies around World War I. In 1941, the HBWS started removing high elevation groundwater from Heeia Tunnel (well 3-2450-001) above Heeia Marsh at an elevation of 550 feet. In 1989, HBWS built well 3-2450-002. Reductions in flow and a discontinuation of large-scale management of Heeia Marsh led to the invasion of california grass, hau bush, and mangrove, altering the hydrology and ecology of the marsh. The restoration of the Heeia fish pond and the recent (since 2010) resurgence in kalo loi cultivation combined with attempts at removing invasive vegetation in the estuarine, marsh, and upland riparian corridors (since 2015) have successfully restored much of the biocultural landscape. Today, the Heeia marsh is an important wetland, where traditional food production and habitat restoration support endangered waterbirds, estuarine fish, and native wetland plants. However, the continued reduction of streamflow from high-elevation groundwater pumpage has affected the flow of water supporting cultural, eductional, and ecological value of Heeia Marsh and fish pond.

Current Instream Flow Standard

The current interim instream flow standard (IFS) for Heeia Stream was established by way of Hawaii Administrative Rules (HAR) §13-169-44, which, in pertinent part, reads as follows:

> <u>Interim instream flow standard for Windward Oahu</u>. The Interim Instream Flow Standard for all streams on Windward Oahu, as adopted by the commission on water resource management on June 15, 1988, shall be that amount of water flowing in each stream on the effective date of this standard, and as that flow may naturally vary throughout the year and from year to year without further amounts of water being diverted offstream through new or expanded diversions, and under the stream conditions existing on the effective date of the standard.

The current interim IFS became effective on July 31, 1987. Streamflow was not measured on that date; therefore, the current interim IFS is not a quantifiable value.

Instream Flow Standards

Under the State Water Code (Code), Chapter 174C, Hawaii Revised Statutes (HRS), the Commission on Water Resource Management (Commission) has the responsibility of establishing IFS on a stream-by-stream basis whenever necessary to protect the public interest in the waters of the State. Early in its history, the Commission recognized the complexity of establishing IFS for the State's estimated 376 perennial streams and instead set interim IFS at "status quo" levels. These interim IFS were defined as the amount of water flowing in each stream (with consideration for the natural variability in stream flow and conditions) at the time the administrative rules governing them were adopted in 1988 and 1989.

The Hawaii Supreme Court, upon reviewing the Waiahole Ditch Contested Case Decision and Order, held that such "status quo" interim IFS were not adequate to protect streams and required the Commission to take immediate steps to assess stream flow characteristics and develop quantitative interim IFS for affected Windward Oahu streams, as well as other streams statewide. The Hawaii Supreme Court also emphasized that "instream flow standards serve as the primary mechanism by which the Commission is to discharge its duty to protect and promote the entire range of public trust purposes dependent upon instream flows."

To the casual observer, IFS may appear relatively simple to establish upon a basic review of the Code provisions. However, the complex nature of IFS becomes apparent upon further review of the individual components that comprise surface water hydrology, instream uses, noninstream uses, and their interrelationships. The Commission has the distinct responsibility of weighing competing uses for a limited resource in a legal realm that is continuing to evolve. The following illustration (Figure 1-1) was developed to illustrate the wide range of information, in relation to hydrology, instream uses, and noninstream uses that should be addressed in conducting a comprehensive IFS assessment.

Interim Instream Flow Standard Process

The Code provides for a process to amend an interim IFS in order to protect the public interest pending the establishment of a permanent IFS. The Code, at §174C-71(2), describes this process including the role of the Commission to "weigh the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses."

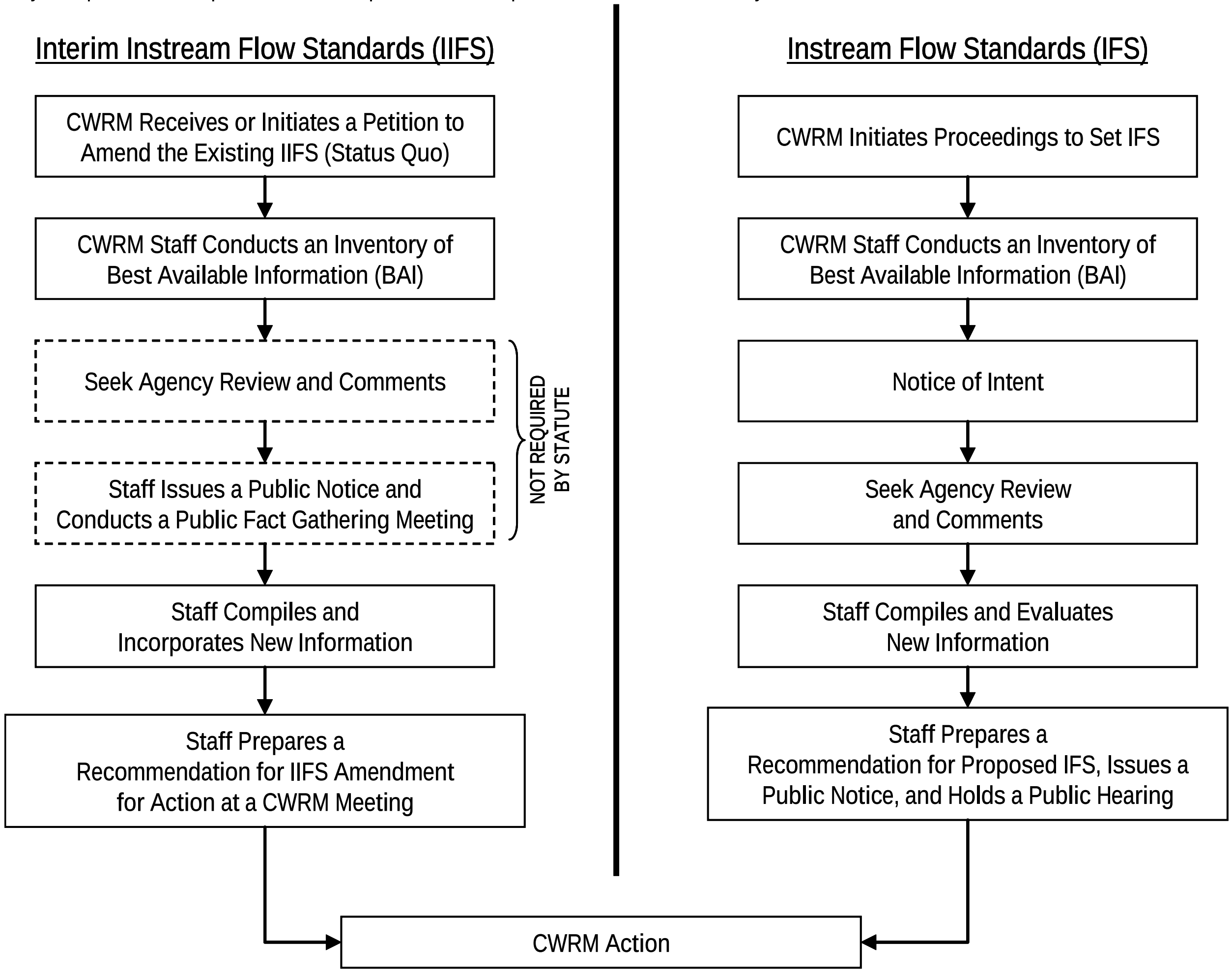
Figure 1-1. Information to consider in setting measurable instream flow standards.

Recognizing the complexity of establishing measurable IFS, while cognizant of the Hawaii Supreme Court's mandate to designate interim IFS based on best available information under the Waiahole Combined Contested Case, the Commission at its December 13, 2006 meeting authorized staff to initiate and conduct public fact gathering. Under this adopted process (reflected in the left column of Figure 1-2), the Commission staff will conduct a preliminary inventory of best available information upon receipt of a petition to amend an existing interim IFS. The Commission staff shall then seek agency review and comments on the compiled information (compiled in an Instream Flow Standard Assessment Report) in conjunction with issuing a public notice for a public fact gathering meeting. Shortly thereafter (generally within 30 days), the Commission staff will conduct a public fact gathering meeting in, or near, the hydrologic unit of interest.

Instream Flow Standard Assessment Report

The Instream Flow Standard Assessment Report (IFSAR) is a compilation of the hydrology, instream uses, and noninstream uses related to a specific stream and its respective surface water hydrologic unit. The report is organized in much the same way as the elements of IFS are depicted in Figure 1-1. The purpose of the IFSAR is to present the best available information for a given hydrologic unit. This information is used to determine the interim IFS recommendations, which is compiled as a separate report. The IFSAR is intended to act as a living document that should be updated and revised as necessary, thus also serving as a stand-alone document in the event that the Commission receives a subsequent petition solely for the respective hydrologic unit.

Figure 1-2. Simplified representation of the interim instream flow standard and permanent instream flow standard processes. Keys steps of the adopted interim IFS process are depicted in the left column by the boxes drawn with dotted lines.



Each report begins with an introduction of the subject hydrologic unit and the current IFS status. Section 2.0 is comprised of the various hydrologic unit characteristics that, both directly and indirectly, impact surface water resources. Section 3.0 contains a summary of available hydrologic information, while Sections 4.0 through 12.0 summarize the best available information for the nine instream uses as defined by the Code. Section 13.0 describes public trust uses of water not covered in other sections. Noninstream uses are summarized in Section 14.0. Maps are provided at the end of each section to help illustrate information presented within the section's text or tables. Finally, Section 15.0 provides a comprehensive listing of cited references and is intended to offer readers the opportunity to review IFSAR references in further detail.

An important component of the IFSAR and the interim IFS process is the Compilation of Public Review Comments (CPRC). The CPRC serves as a supporting document containing the oral and written comments that are submitted as part of the initial public review process. Comments referred to within the IFSAR will identify both the section and page number where the original comment can be located in the CPRC. For example, a reference to "8.0-3" indicates the third page of comments in Section 8.0 of the CPRC.

Following the preparation of the IFSAR and initial agency and public review, information may be added to the IFSAR at any time. Dates of revision will be reflected as such. Future review of the IFSAR, by agencies and the public, will only be sought when a new petition to amend the interim (or permanent) instream flow standard is pending. Recommendations for IFS amendments are prepared separately as a stand-alone document. Thus, the IFSAR acts solely as a compendium of best available information and may be revised further without the need for subsequent public review following its initial preparation.

Surface Water Hydrologic Units

Early efforts to update the Commission's Water Resource Protection Plan (WRPP) highlighted the need for surface water hydrologic units to delineate and codify Hawaii's surface water resources. Surface water hydrologic units served as an important first-step towards improving the organization and management of surface water information that the Commission collects and maintains, including diversions, stream channel alterations, and water use.

In developing the surface water hydrologic units, the Commission staff reviewed various reports to arrive at a coding system that could meet the requirements for organizing and managing surface water information in a database environment, and could be easily understood by the general public and other agencies. For all intents and purposes, surface water hydrologic units are synonymous with watershed areas. Though Commission staff recognized that while instream uses may generally fall within a true surface drainage area, noninstream uses tend to be land-based and therefore may not always fall within the same drainage area.

In June 2005, the Commission adopted the report on surface water hydrologic units and authorized staff to implement its use in the development of information databases in support of establishing IFS (State of Hawaii, Commission on Water Resource Management, 2005a). The result is a surface water hydrologic unit code that is a unique combination of four digits. This code appears on the cover of each IFSAR above the hydrologic unit name.

Surface Water Definitions

Listed below are the most commonly referenced surface water terms as defined by the Code.

Agricultural use. The use of water for the growing, processing, and treating of crops, livestock, aquatic plants and animals, and ornamental flowers and similar foliage.

Channel alteration. (1) To obstruct, diminish, destroy, modify, or relocate a stream channel; (2) To change the direction of flow of water in a stream channel; (3) To place any material or structures in a stream channel; and (4) To remove any material or structures from a stream channel.

Continuous flowing water. A sufficient flow of water that could provide for migration and movement of fish, and includes those reaches of streams which, in their natural state, normally go dry seasonally at the location of the proposed alteration.

Domestic use. Any use of water for individual personal needs and for household purposes such as drinking, bathing, heating, cooking, noncommercial gardening, and sanitation.

Ground water. Any water found beneath the surface of the earth, whether in perched supply, dike-confined, flowing, or percolating in underground channels or streams, under artesian pressure or not, or otherwise.

Hydrologic unit. A surface drainage area or a ground water basin or a combination of the two.

Impoundment. Any lake, reservoir, pond, or other containment of surface water occupying a bed or depression in the earth's surface and having a discernible shoreline.

Instream Flow Standard. A quantity of flow of water or depth of water which is required to be present at a specific location in a stream system at certain specified times of the year to protect fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses.

Instream use. Beneficial uses of stream water for significant purposes which are located in the stream and which are achieved by leaving the water in the stream. Instream uses include, but are not limited to:

(1) Maintenance of fish and wildlife habitats;
(2) Outdoor recreational activities;
(3) Maintenance of ecosystems such as estuaries, wetlands, and stream vegetation;
(4) Aesthetic values such as waterfalls and scenic waterways;
(5) Navigation;
(6) Instream hydropower generation;
(7) Maintenance of water quality;
(8) The conveyance of irrigation and domestic water supplies to downstream points of diversion; and
(9) The protection of traditional and customary Hawaiian rights.

Interim instream flow standard. A temporary instream flow standard of immediate applicability, adopted by the Commission without the necessity of a public hearing, and terminating upon the establishment of an instream flow standard.

Municipal use. The domestic, industrial, and commercial use of water through public services available to persons of a county for the promotion and protection of their health, comfort, and safety, for the protection of property from fire, and for the purposes listed under the term "domestic use."

Noninstream use. The use of stream water that is diverted or removed from its stream channel and includes the use of stream water outside of the channel for domestic, agricultural, and industrial purposes.

Reasonable-beneficial use. The use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the state and county land use plans and the public interest.

Stream. Any river, creek, slough, or natural watercourse in which water usually flows in a defined bed or channel. It is not essential that the flowing be uniform or uninterrupted. The fact that some parts of the bed or channel have been dredged or improved does not prevent the watercourse from being a stream.

Stream channel. A natural or artificial watercourse with a definite bed and banks which periodically or continuously contains flowing water. The channel referred to is that which exists at the present time, regardless of where the channel may have been located at any time in the past.

Stream diversion. The act of removing water from a stream into a channel, pipeline, or other conduit.

Stream reach. A segment of a stream channel having a defined upstream and downstream point.

Stream system. The aggregate of water features comprising or associated with a stream, including the stream itself and its tributaries, headwaters, ponds, wetlands, and estuary.

Surface water. Both contained surface water--that is, water upon the surface of the earth in bounds created naturally or artificially including, but not limited to, streams, other watercourses, lakes, reservoirs, and coastal waters subject to state jurisdiction--and diffused surface water--that is, water occurring upon the surface of the ground other than in contained water bodies. Water from natural springs is surface water when it exits from the spring onto the earth’s surface.

Sustainable yield. The maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source as determined by the Commission.

Time of withdrawal or diversion. In view of the nature, manner, and purposes of a reasonable and beneficial use of water, the most accurate method of describing the time when the water is withdrawn or diverted, including description in terms of hours, days, weeks, months, or physical, operational, or other conditions.

Watercourse. A stream and any canal, ditch, or other artificial watercourse in which water usually flows in a defined bed or channel. It is not essential that the flowing be uniform or uninterrupted.

Figure 1-3. World View 2 satellite imagery of the Heeia hydrologic units and streams in East Oahu, Hawaii. (Source: State of Hawaii, Planning Department, 2004; State of Hawaii, Commission on Water Resource Management, 2015c)

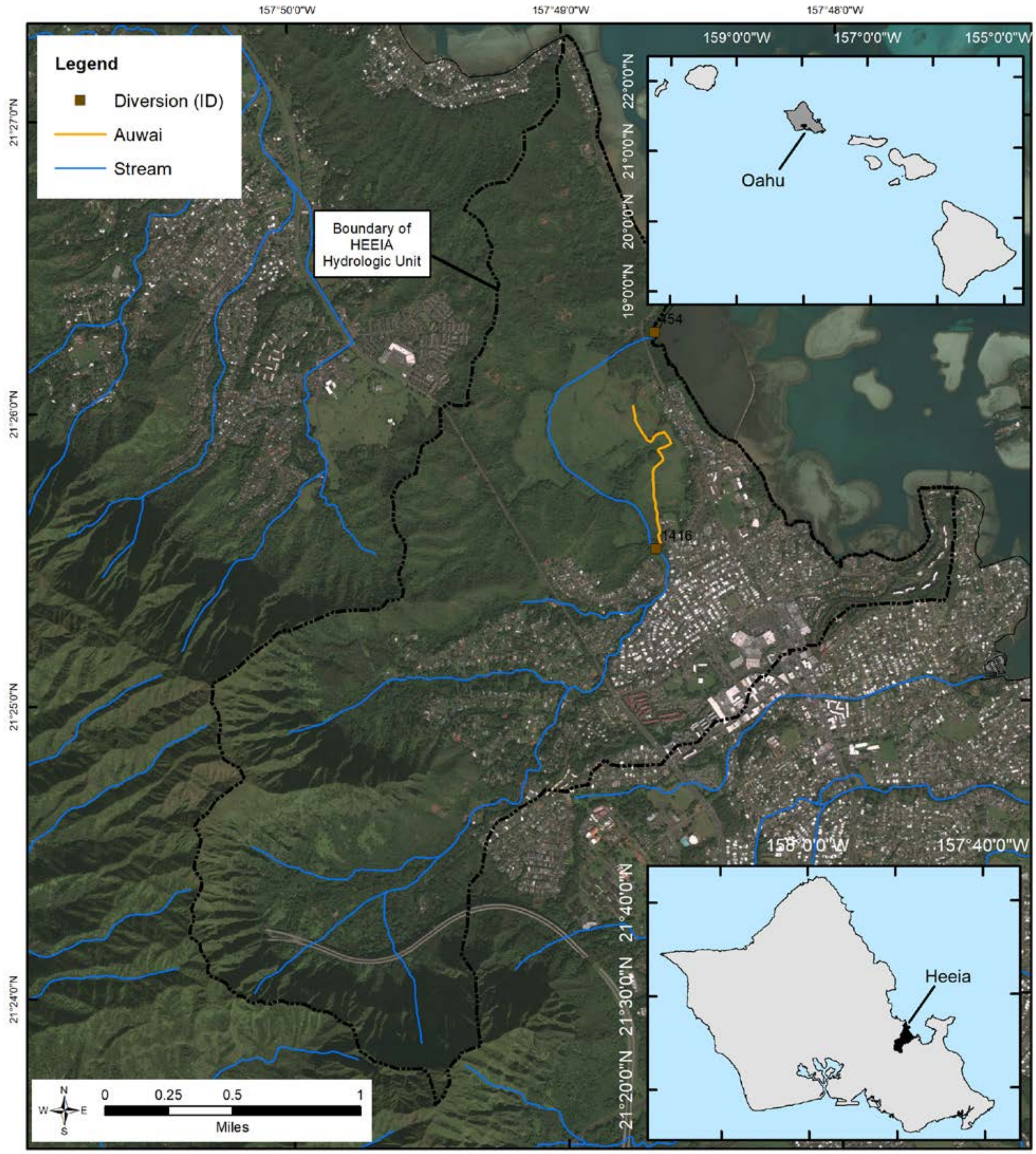


Figure 1-4. Elevation range and contours of the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2004e; U.S. Geological Survey, 2001)

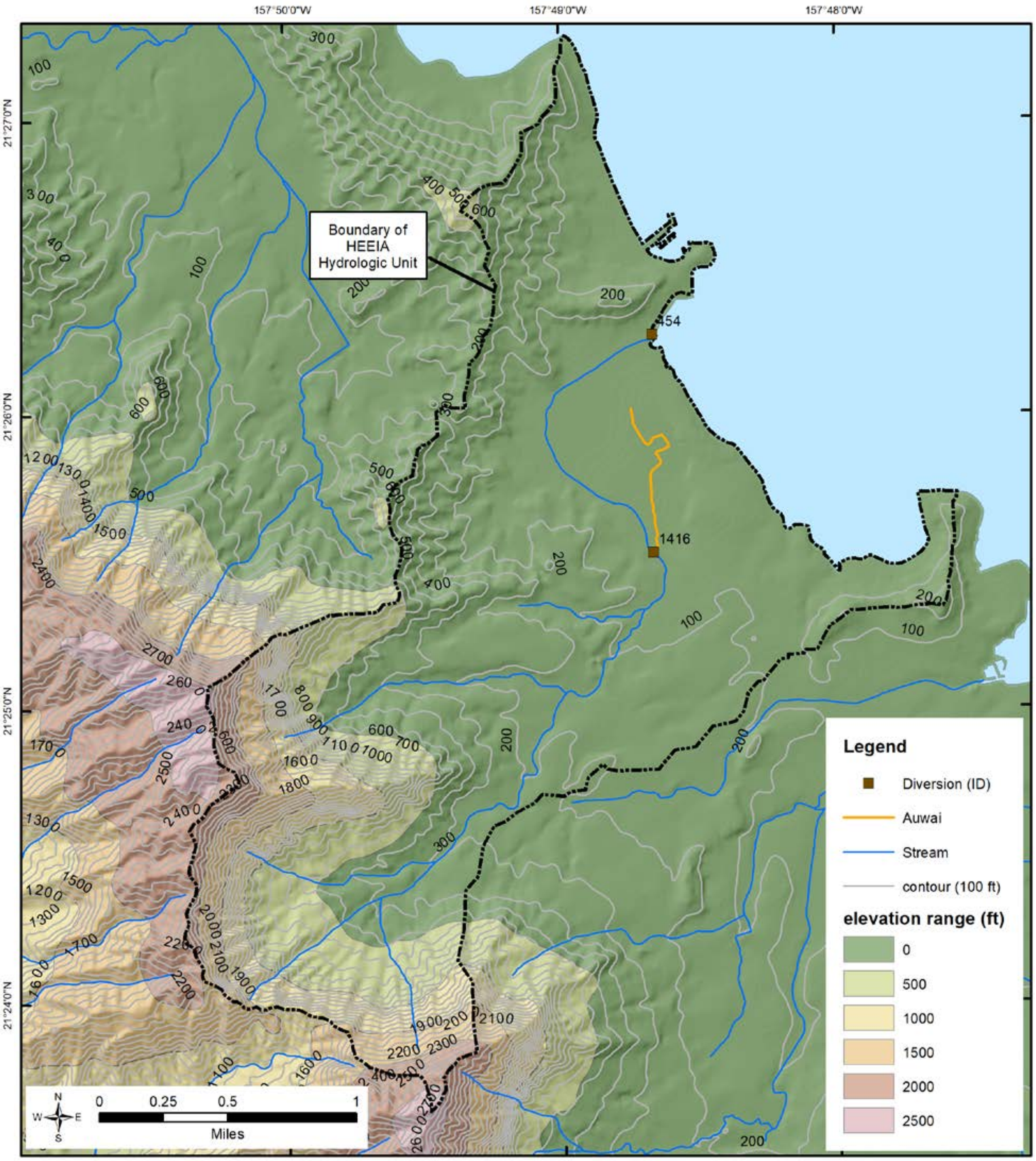


Figure 1-5. USGS topographic map of Heeia hydrologic unit, Oahu. (Source: U.S. Geological Survey, 1996)

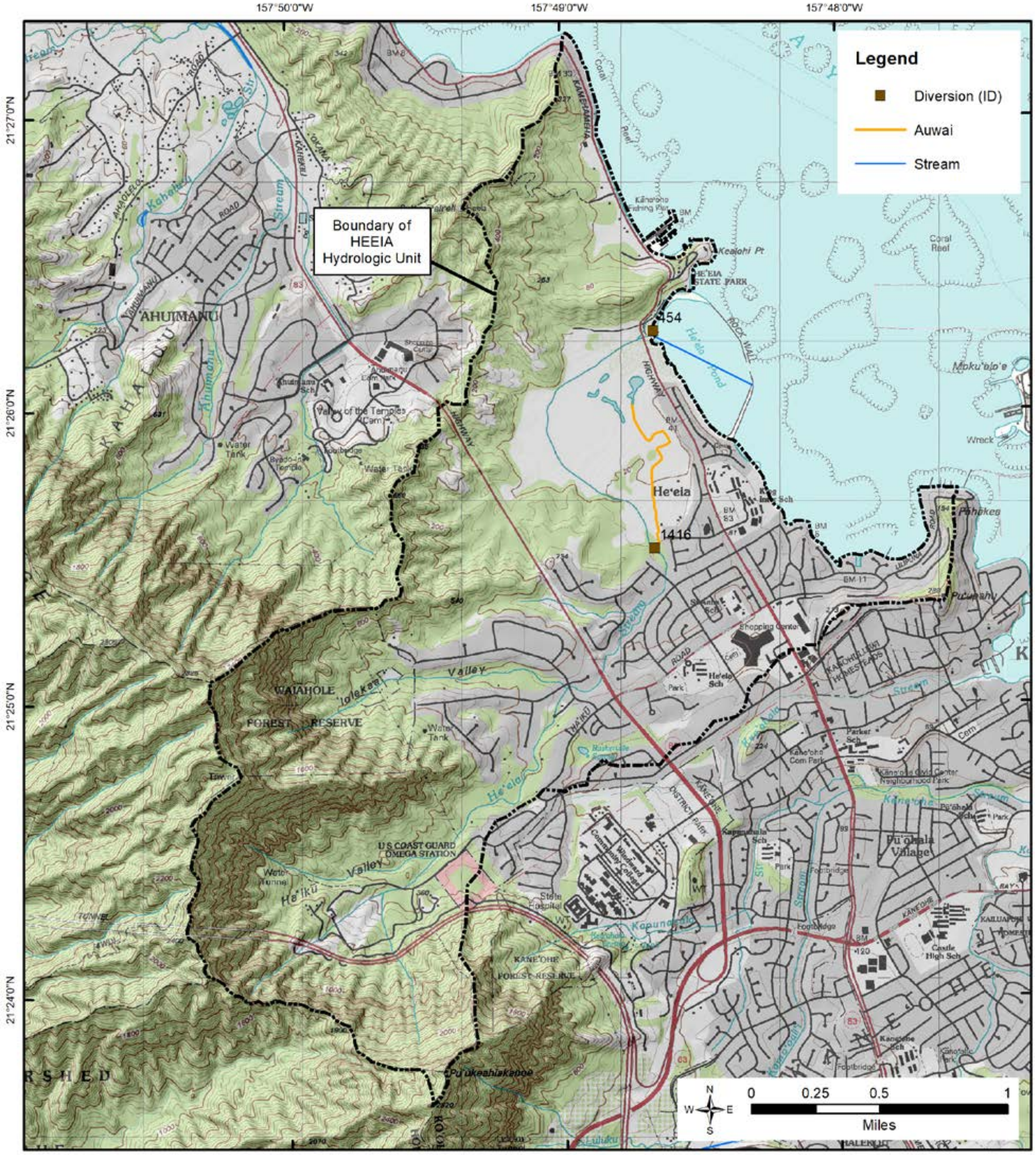
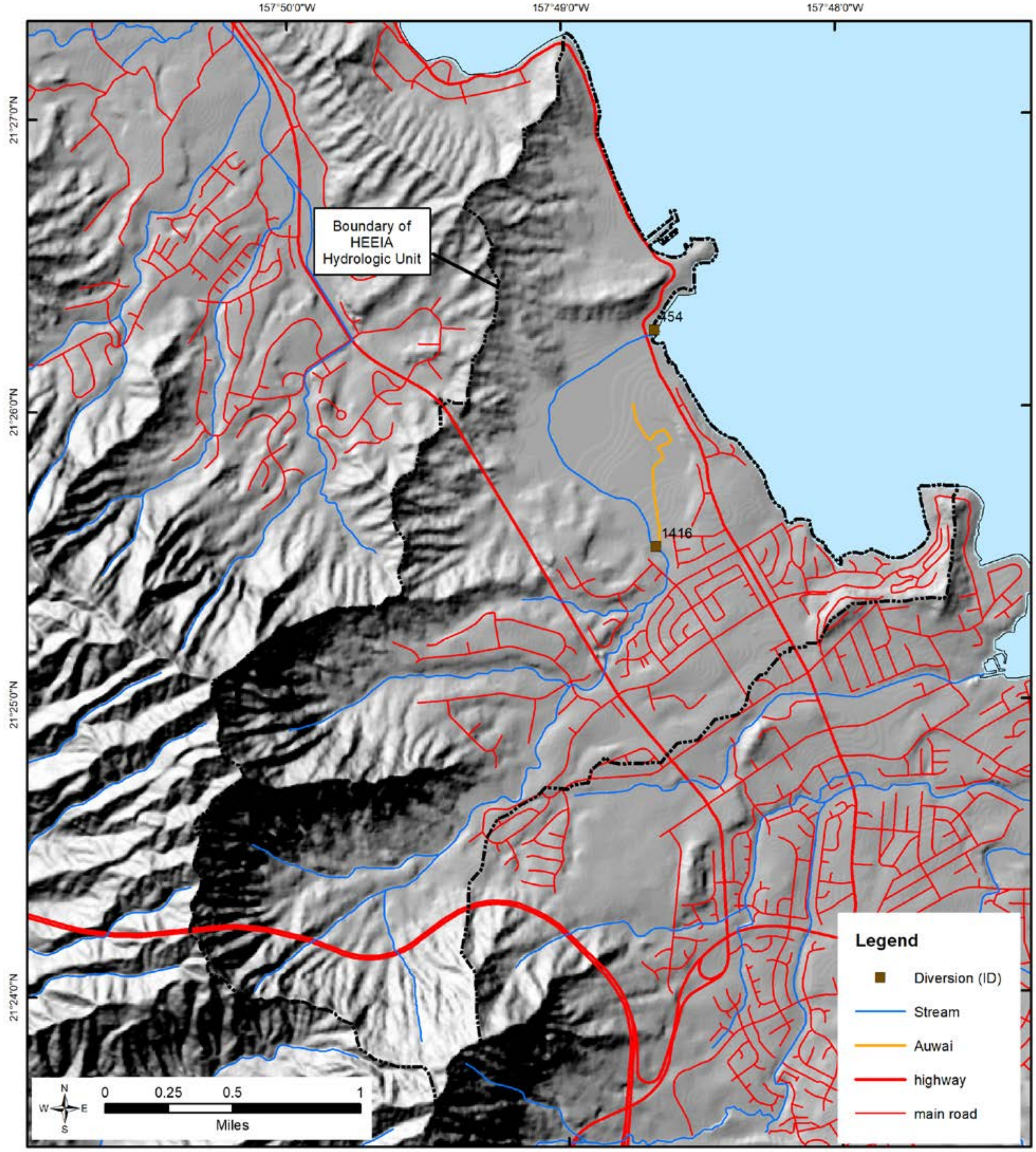


Figure 1-6. Major and minor roads for Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning 2020)



2.0 Unit Characteristics

Geology

The island of Oahu was built by the coalescence of two shield volcanoes: Waianae volcano on the western side and Koolau volcano on the eastern side (Stearns, 1946). The Waianae volcano became dormant before the Koolau volcano, resulting in Koolau lava flows overtopping the eroded remains of the eastern facing slopes of the Waianae volcano. The former caldera of the Koolau volcano, centered in what is now Kailua, extended from Kaneohe town in the North to Waimanalo in the South. To the west, the lava flows were ponded by the preexisting Waianae Range, forming the Schofield Plateau with slopes generally less than 5 degrees. By contrast, to the east, lava flowed unobstructed into the ocean, building a much steeper slope. The principal shield-building phase of the Koolau Volcano is comprised of the Koolau Volanic Series. This phase constitutes a series of highly permeable flank lava flows extruded from fissures intruded with low-permeable dikes. Factors that influence the permeability of these flows include secondary mineralization, proximity to vents, and weathering. The last eruption phase of the Koolau volcano concluded during the late Pleistocene, producing many cinder and tuff cones with several laval flows with rocks of the Honolulu Volcanic Series (Table 2-1).

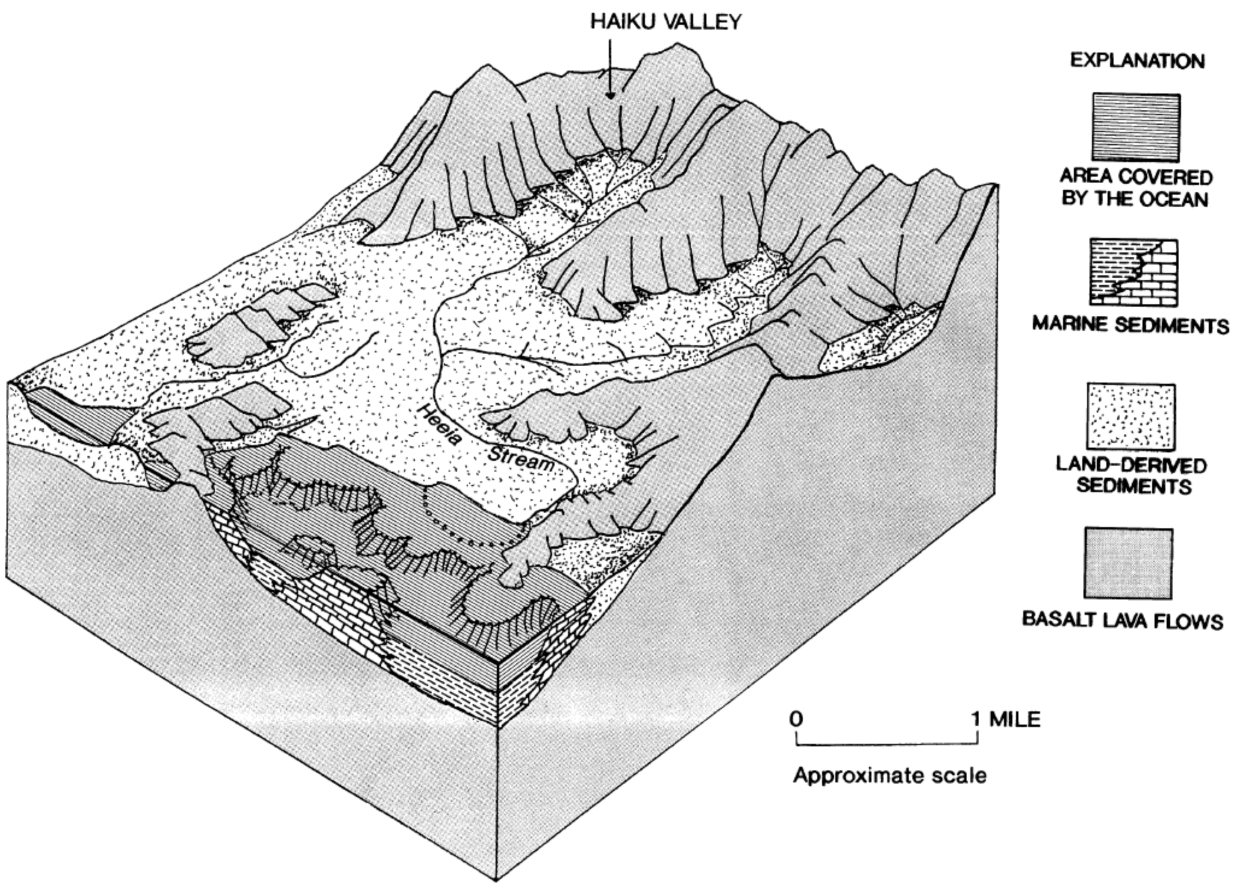
The primary Koolau rift zone extends along what is now the Koolau mountain range on an axis from southeast to northwest (Takasaki et al., 1969). The rift zone is a narrow zone of parallel fissures and adjacent vents marking repeated eruptions from the active volcano. Most of the Koolau eruptions produced thin-bedded pahoehoe and aa lava flows. Where erosion has incised the landscape to an appreciable extent, the rift zone and its associated dike complexes are exposed. The conspicuous Mokapu Penisula at the southern end of Kaneohe Bay and the less conspicuous cinder and tuff cones between the lava-filled valleys now dot the landscape. Post-volcanism, widespread erosion and subsequent depositional features are common, producing substantial alluvial plains along the coast. Shifts in climate and sea level have influenced the development of sand dunes and marshes, prominent features before urban development whose remnants are still visible. During the Pleistocene, substantial fluvial and marine erosion occurred, with the island submerged as much as 1,200 feet during the global cycles of sea level rise and fall with the feezing and thawing of the polar ice caps (Stearns and Vaksvik, 1935).

Most volcanic rocks on Oahu are typical of Hawaiian basalts, described as “microlithic or porphyritic igneous rock of a lava flow or minor intrusion, often vesicular or amygdaloidal.and composed essentially of plagioclase, and pyroxene, with or without interstitial glass.” (Holmes 1920). If olivine is present, then the rock is termed olivine-basalt and most of the rocks on Oahu contain olivine phenocrysts. Most of the lava flows on Oahu are fed by magma that rose through vertical cracks which then solidified to form dikes. The igneous rocks comprise most lava flows and dikes whereas the sedimentary rocks are formed by noncalcareous deposits of weathered igneous rocks as well as the calcareous sediments produced from reef limestone and abraded or corroded by wind or wave action. The lava flows range in thickness from 1 to 400 feet, but are usually less than 75 feet thick (Stearns and Vaksvik, 1935). There are few examples of soil beds more than a few inches think intercalated in the Koolau lavas suggesting that the volcano formed much more rapidly than others in Hawaii. As the magma cooled, the weight of the overlying rocks compressed the dike, which is then denser than the nearby extrusive and highly permeable flows. Such lava flows can support large amounts of basal and high-elevation (both perched and dike-confined) groundwater. The most appreciable dike complexes arc around the Koolau caldera from Waimanalo to Waialee (Takasaki et al., 1969). The location of dikes, and especially of dike complexes (many, closely spaced dikes), control the movement of groundwater in the Koolau region (Stearns, 1946). The dikes impound rain water infiltrating down from the high elevation forest, changing the direction of flow from seaward (i.e., downslope) to a perpendicular direction (i.e., parallel with the dike complex), creating high-elevation water bodies that discharge into other complexes, into the basal aquifer, or into streams where incision has exposed the dike complex. The transmissivity of these dike structures tend to range from

2,000 to 13,000 gallons per day per foot as compared to 1.4 to 4.0 million gallons per day per foot in dike-free aquifer zones (Ferris et al., 1962).

The original Koolau dome extended from just north of Puu Konahuanui to a location thousands of feet eastward into what is now the ocean. The steep northeast-facing cliffs in the southern Kaneohe area are the only remnants of the original caldera wall still visible (Stearns and Vaksvik, 1935). The Heeia hydrologic unit on the windward side of the Koolau mountain range, is in the northern portion of the former volcanic dome. Haiku Valley is eroded into the northeastern flank of the Koolau Range. The lava flows of the shield building Koolau Volcanics originated from the caldera or the rift zones and are characterized by high porosity and transmissivity (Visher and Mink, 1969). Koolau Basalt forms the basement rock into which Heeia Stream has eroded nearly 2,000 ft, and is exposed where the stream has incised through sedimentary cover (Figure 2-1). Numerous nearly vertical volcanic dikes are found along the rift zone, but have limited distribution in the lateral margins. The upper reaches of Haiku Valley are situated in the marginal dike zone, with fewer dikes.

Figure 2-1. Diagram of Heeia watershed and underlying geology on Oahu. (Source: Izuka et al., 1992)



The shield-building phase from the Koolau Volcano ended approximately 1.8 million years ago with erosion and subsidence modifying the original volcano. As Haiku Valley formed, eroded sediments filled the valley floor. About 800,000 years ago, lava flows from new rifts, tansverse to the former, erupted in the late-phase Honolulu Volcanics Series. These lava flows are distinguished by their massive, sparsely vesicular character and the presence of phenocrysts of the feldspathoid minerals (Winchell, 1947) mostly concealed beneath younger deposit formations described which impact the Heeia area. Haiku Valley was partially filled by these flows, cinder, and ash. The flows are thicker than average Koolau Basalt flows and have fewer vertical joints. The Kaneohe Volcanics phase formed a series of cinder cones in the Kaneohe region, the highest rising to 417 feet, with cinders visible where the main highway has cut through (Stearns and Vaksvik, 1935). Sediments and volcanic deposits fill the valley, with sediments thicker toward the center and mouth of the valley, although there is much irregularity.

The Heeia watershed and stream network are typical of windward facing watersheds, with steep upper reaches draining amphitheater-shaped valleys forming narrow valleys among hilly terrain in the middle reaches. As the streams reach less sloping, lower-elevation regions they produced broader alluvial fans. The main rocks in this region consist of lava flows, and alluvium sourced from volcanic material as well as beach deposits. The generalized geology of the Heeia hydrologic unit is depicted in Figure 2-2 and Table 2-1.

Table 2-1. Area and percentage of surface geologic features for Heeia hydrologic unit, Oahu. (Source: Sherrod et al, 2007)

Name	Rock Type	Area (mi^2)	Percent of Unit
Koolau Basalt	dike complex, lava flows	2.012	45.6%
Older alluvium	sand and gravel	1.658	37.5%
Alluvium	sand and gravel	0.587	13.3%
Beach deposits	beach deposits	0.022	0.5%

Soils

The U.S. Department of Agriculture's Natural Resources Conservation Service (formerly known as the Soil Conservation Service) divides soils into hydrologic soil groups (A, B, C, and D) according to the rate at which infiltration (intake of water) occurs when the soil is wet. The higher the infiltration rate, the faster the water is absorbed into the ground and the less there is to flow as surface runoff. Group A soils have the highest infiltration rates; group D soils have the lowest. In the Heeia hydrologic unit, soils are dominated by Lolekaa, rock outcrop, and Alaeloa (Table 2-2). Soils in the hydrologic unit are predominantly in Group B (66.8%) consisting of silty loam or loam with moderate infiltration rates while Group D soils (23.5%) make up the second the largest contributor, consisting of clay loam, silty clay loam, or clay, with high runoff potential. Group C soils (9.7%) are moderately permeable with slow to medium runoff and a slight to moderate erosion hazard composing the rest of the hydrologic unit (U.S. Department of Agriculture, National Resource Conservation Service, 1986). There are no Group A soils in Heeia. The soil series for this hydrologic groups are identified in Figure 2-3.

Rainfall

The Koolau Mountains are the driving force affecting the distribution of rainfall on Oahu, with rainfall affected by the orographic[1] effect (Figure 2-4). Orographic precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. As moist air cools, water condenses and the air mass releases precipitation. As a result, frequent and heavy rainfall is observed on the windward mountain slopes. The temperature inversion zone, the range of elevations where temperature increases with elevation, typically

[1] Orographic refers to influences of mountains and mountain ranges on airflow, but also used to describe effects on other meteorological quantities such as temperature, humidity, or precipitation distribution.

extends from 6,560 feet to 7,874 feet. This region is identified by a layer of moist air below and dry air above (Giambelluca and Nullet, 1992). The fog drip zone occurs below the elevation where cloud height is restricted by the temperature inversion (Scholl et al., 2002).

Figure 2-2. Generalized geology of the Heeia hydrologic unit, Oahu. (Source: Sherrod et al., 2007)

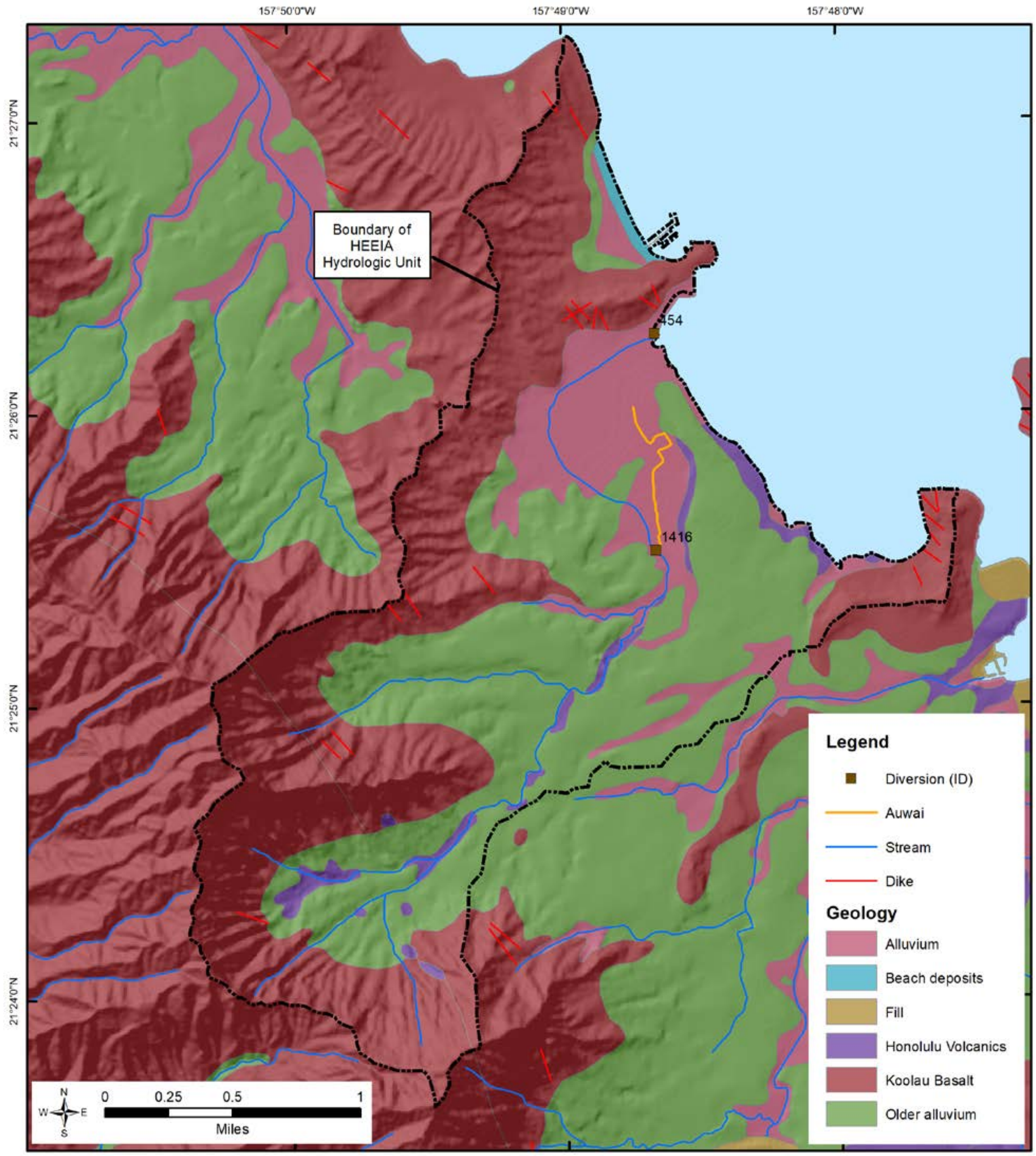


Table 2-2. Area and percentage of soil types for the Heeia hydrologic unit, Oahu. (Source: Soil Survey Saff, 2020)

Soil Series Unit	Hydrologic Soil Group	Area (mi^2)	Percent (%)
Alaeloa	B	1.194	13.52%
Ewa	B	0.03	0.34%
Hanalei	C	0.86	9.74%
Kaneohe	B	0.026	0.29%
Kokokahi	D	0.052	0.59%
Lahaina	B	0.108	1.22%
Lolekaa	B	3.732	42.25%
Marsh	D	0.348	3.94%
Mokuleia	B	0.012	0.14%
Pearl Harbor	D	0.022	0.25%
Rock land	D	0.052	0.59%
Rock outcrop	D	1.584	17.93%
Rough mountainous land	D	0.014	0.16%
Waikane	B	0.8	9.06%

Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al., 2002) and can contribute significantly to groundwater recharge (Engott et al., 2017). Above this inversion zone, the air is dry and the sky is frequently clear (absence of clouds) with high solar radiation, creating an arid atmosphere with little rainfall. This region is found in the higher elevations of the largest volcanoes (e.g., Mauna Kea, Haleakala).

Many mountains in Hawaii peak in the fog drip zone, where cloud-water is intercepted by vegetation. In such cases, air passes over the mountains, warming and drying while descending on the leeward mountain slopes. Puu Konahuanui is the tallest peak (3,150 feet a.s.l) in the Koolau range along the cliffs of Maunawili Valley and influences rainfall due to its position in the trade winds. The steep gradient around the island forces moisture-laden air to rapidly rise in elevation (over 3,000 feet) in a short distance, resulting in a rapid release of rainfall. The position of the peak lies in the cloudy layer below the trade wind inversion resulting in substantial rainfall in the region. The fog drip zone on the windward side of islands extends from the cloud base level at 1,970 feet to the lower limit of the most frequent temperature inversion base height at 6,560 feet (Giambelluca and Nullet, 1992). Mean annual rainfall measured at the nearby Hawaii State Hospital (Kaneohe Mauka station 781; elevation 200 feet; active from 1928-1998) is 74.21 inches and measured at Maunawili Hawaii State Agricultural Research Station (station 787.1; 417 feet; active from 1954-present) is 76.04 inches (Giambelluca et al. 2013).

The Heeia hydrologic unit is situated on the windward side of the Koolau Mountains and as such receives substantial orographic rainfall, contributing to higher rainfall in the upper elevations (Figure 2-5). The high spatial variability in rainfall is evident by the large variation in mean annual rainfall across the hydrologic unit. For the whole hydrologic unit, mean annual rainfall averages 74 inches. Above 2000 ft, rainfall is highest during the months of November to April, where the mean monthly rainfall varies from 9.26 to 12.76 inches, although there is a good distribution of rainfall across all months (Table 2-3).

Figure 2-3. Soil series classification of the Heeia hydrologic unit, Oahu. (Source: Soil Survey Staff, 2020)

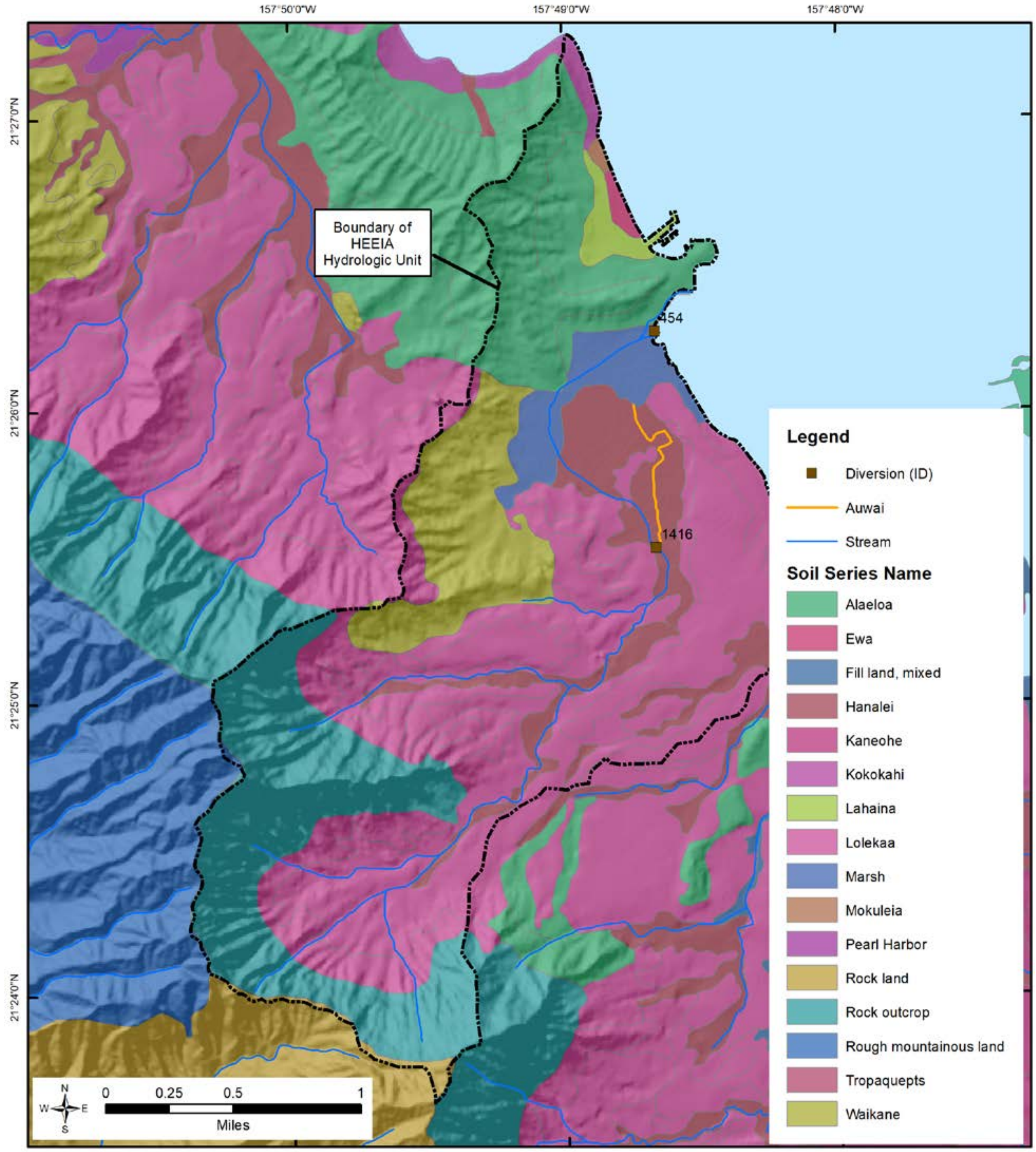
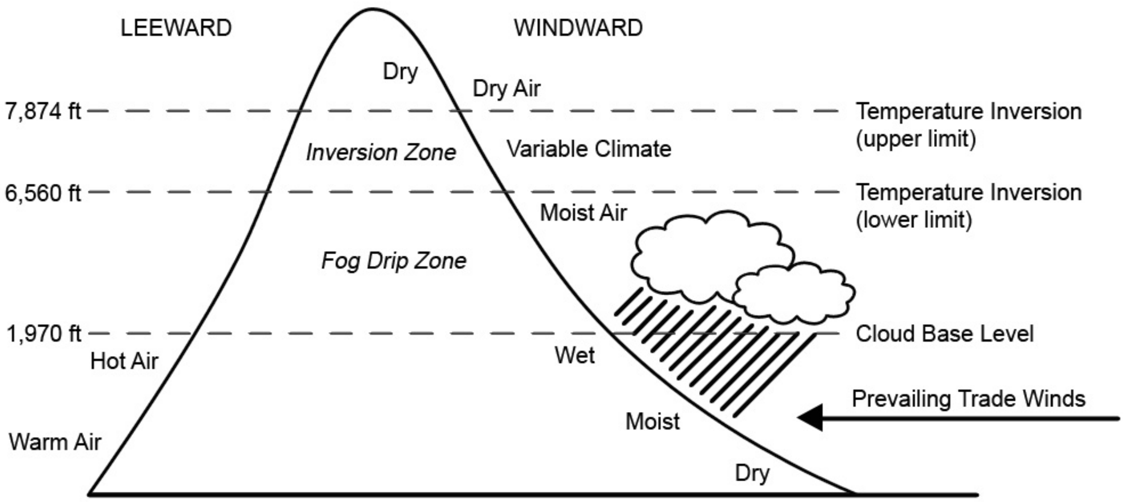


Figure 2-4. Orographic precipitation in the presence of mountains higher than 6,000 feet.



Shade (1999) used the monthly fog drip to rainfall ratios for the windward slopes of Mauna Loa on the Island of Hawaii (Table 2-3) to calculate fog drip contribution to the water-budget in windward East Maui. The fog drip to rainfall ratios were estimated using: 1) the fog drip zone boundaries for East Maui (Giambelluca and Nullet, 1991); and 2) an illustration that shows the relationship between fog drip and rainfall for the windward slopes of Mauna Loa, Island of Hawaii (Juvik and Nullet, 1995). This method was used to determine the contribution of fog drip in the Heeia hydrologic unit, which is calculated by multiplying the same ratios to the monthly rainfall values in the fog drip zone based on Giambelluca et al (2013). Calculations show that approximately 2.9 percent of Heeia (0.127 square miles) lies in the fog drip zone based on elevations greater than 2000 feet. The total contribution from fog drip to the water budget of the upper elevations based on percent of fog drig from monthly rainfall is about 24.8 percent (36.5 inches versus 147.2 inches) of the upper (>2,000 ft) watershed, assuming the same ratios apply here (Table 2-3). The total estimated mean annual contribution of fog drip to the Heeia hydrologic unit is about 32.36 millon gallons or about 0.089 mgd.

Table 2-3. Fog drip to rainfall ratios for the windward slopes of Mauna Loa on the island of Hawaii and approximate contributions to the Heeia Hydrologic Unit based on an elevation range of 2000-2160 feet and equivalent ratios.

Month	Ratio (%)	Mean Rainfall (in)	Contribution (in)
January	13	11.86	1.54
February	13	9.26	1.20
March	13	10.90	1.42
April	27	10.90	2.94
May	27	8.02	2.17
June	27	6.34	1.71
July	67	7.62	5.11
August	67	6.12	4.10
September	67	6.82	4.57
October	40	9.55	3.82
November	40	12.76	5.10
December	27	10.55	2.85

Solar Radiation

Solar radiation is the sun's energy that arrives at the Earth's surface after considerable amounts have been absorbed by water vapor and gases in the Earth's atmosphere. The amount of solar radiation to reach the surface in a given area is dependent in part upon latitude and the sun's declination angle (angle from the sun to the equator), which is a function of the time of year. Hawaii's trade winds and the temperature inversion layer greatly affect solar radiation levels, the primary heat source for evaporation. High mountain ranges block moist trade-wind air flow and keep moisture beneath the inversion layer (Lau and Mink, 2006). As a result, windward slopes tend to be shaded by clouds and protected from solar radiation, while dry leeward areas receive a greater amount of solar radiation and thus have higher levels of evaporation. In the Heeia hydrologic unit, average annual solar radiation ranged from 143.5 to 232.9 W/m^2 per day, with an average of 182.7 W/m^2 per day (Figure 2-6). It is greatest at the coast and decreases toward the uplands, where cloud cover is more of an influence (Giambelluca et al., 2014).

Evaporation

Evaporation is the loss of water to the atmosphere from soil surfaces and open water bodies (e.g. streams and lakes). Evaporation from plant surfaces (e.g. leaves, stems, flowers) is termed transpiration. Together, these two processes are commonly referred to as evapotranspiration, and it can significantly affect water yield because it determines the amount of rainfall lost to the atmosphere. On a global scale, the amount of water that evaporates is about the same as the amount of water that falls on Earth as precipitation. However, more water evaporates from the ocean whereas on land, rainfall often exceeds evaporation. The rate of evaporation is dependent on many climatic factors including solar radiation, albedo[2], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[3]. Higher evaporation rates are generally associated with greater net radiation, high wind speed and surface temperature, and lower humidity.

Potential evapotranspiration (PET) is the reate of water lost to the atmosphere when water is not a limiting factor, and it is often measured with evaporation pans. In Hawaii, pan evaporation measurements were generally made in the lower elevations of the drier leeward slopes where sugarcane was grown. These data have been compiled and mapped by Ekern and Chang (1985). Most of the drainage basins in Hawaii are characterized by a relatively large portion of the rainfall leaving the basin as evaporation and the rest as streamflow (Ekern and Chang, 1985). Based on the available pan evaporation data for Hawaii, evaporation generally decreases with increasing elevation below the temperature inversion[4] and the cloud layer (Figure 2-7). At low elevations near the coast, pan evaporation rates are influenced by sensible heat advection from the ocean (Nullet, 1987). Pan evaporation rates are enhanced in the winter by positive heat advection from the ocean, and the opposite occurs in the summer when pan evaporation rates are diminished by negative heat advection (Giambelluca and Nullet, 1992). With increasing distance from the windward coasts, positive heat advection from dry land surfaces becomes an important factor in determining the evaporative demand on the landscape (Nullet, 1987). Shade (1999, Fig. 9) estimated pan evaporation rates of 30 inches per year below 2,000 feet elevation to 90 inches per year near the coast.

Within the cloud layer, evaporation rates are particularly low due to the low radiation and high humidity caused by fog drip. Pan evaporation rates dropped below 30 inches per year in this area as reported in Shade (1999, Fig. 9). Near the average height of the temperature inversion, evaporation rates are highly variable as they are mainly influenced by the movement of dry air from above and moist air from below

[2] Albedo is the proportion of solar radiation that is reflected from the Earth, clouds, and atmosphere without heating the receiving surface.
[3] Sensible heat advection refers to the transfer of heat energy that causes the rise and fall in the air temperature.
[4] Temperature inversion is when temperature increases with elevation.

(Nullet and Giambelluca, 1990). Above the inversion, clear sky and high solar radiation at the summit causes increased evaporation, with pan evaporation rates of about 50 to 70 inches per year (Shade, 1999, Fig. 9). For example, Ekern and Chang (1985) reported evaporation increased to 50 percent more than surface oceanic rates near the Mauna Kea crest on the island of Hawaii. A common approach to estimating evaporation is to employ a relationship between potential evaporation and the available water in the watershed, estimated as potential evapotranspiration. The PET in Heeia (Figure 2-6) averages 127.5 inches and ranges from 65.8 to 242.3 inches (Giambelluca et al. 2014). Annual actual evapotranspiration for the Heeia hydrologic unit ranges 2.85 inches to 66.9 inches per year, with an average of 29.0 inches per year.

Land Use

The Hawaii Land Use Commission (LUC) was established under the State Land Use Law (Chapter 205, Hawaii Revised Statutes) enacted in 1961. Prior to the LUC, the development of scattered subdivisions resulted in the loss of prime agricultural land that was being converted for residential use, while creating problems for public services trying to meet the demands of dispersed communities. The purpose of the law and the LUC is to preserve and protect Hawaii's lands while ensuring that lands are used for the purposes they are best suited. Land use is classified into four broad categories: 1) agricultural; 2) conservation; 3) rural; and 4) urban.

Land use classification is an important component of examining the benefits of protecting instream uses and the appropriateness of surface water use for noninstream uses. While some may argue that land use, in general, should be based upon the availability of surface and groundwater resources, land use classification continues to serve as a valuable tool for long-range planning purposes.

As of 2014, 49.0 percent of the land in Heeia (2.165 square miles) was designated as conservation and 51.0 percent of the land is urban (State of Hawaii, Office of Planning, 2015d). None of the hydrologic unit is designated as rural or agriculture (Figure 2-8).

Land Cover

Land cover for the hydrologic units of Heeia is represented by two separate 30-meter Landsat satellite datasets. One of the datasets, developed by the Coastal Change Analysis Program (C-CAP), provides a general overview of the land cover types in Heeia, e.g., forest, shrub, developed areas, and wetlands (Table 2-4, Figure 2-9). The second is developed by the Hawaii Gap Analysis Program (HI-GAP), which mapped the National Vegetation Classification System (NVCS) associations for each type of vegetation, creating a more comprehensive land cover dataset (Table 2-5, Figure 2-10).

Based on the two land cover classification systems, the land cover of Heeia consists mainly of urban, evergreen forested, and scrub areas, dominated by alien vegetation. Low and medium intensity development and wetland also make up substantial portions of the region. Native wet cliff vegetation, native shurbland, and open ohia forest each make up small portions of the unit.

Figure 2-5. Mean annual rainfall and fog drip zone of the Heeia hydrologic unit, Oahu. (Source: Giambelluca et al., 2013)

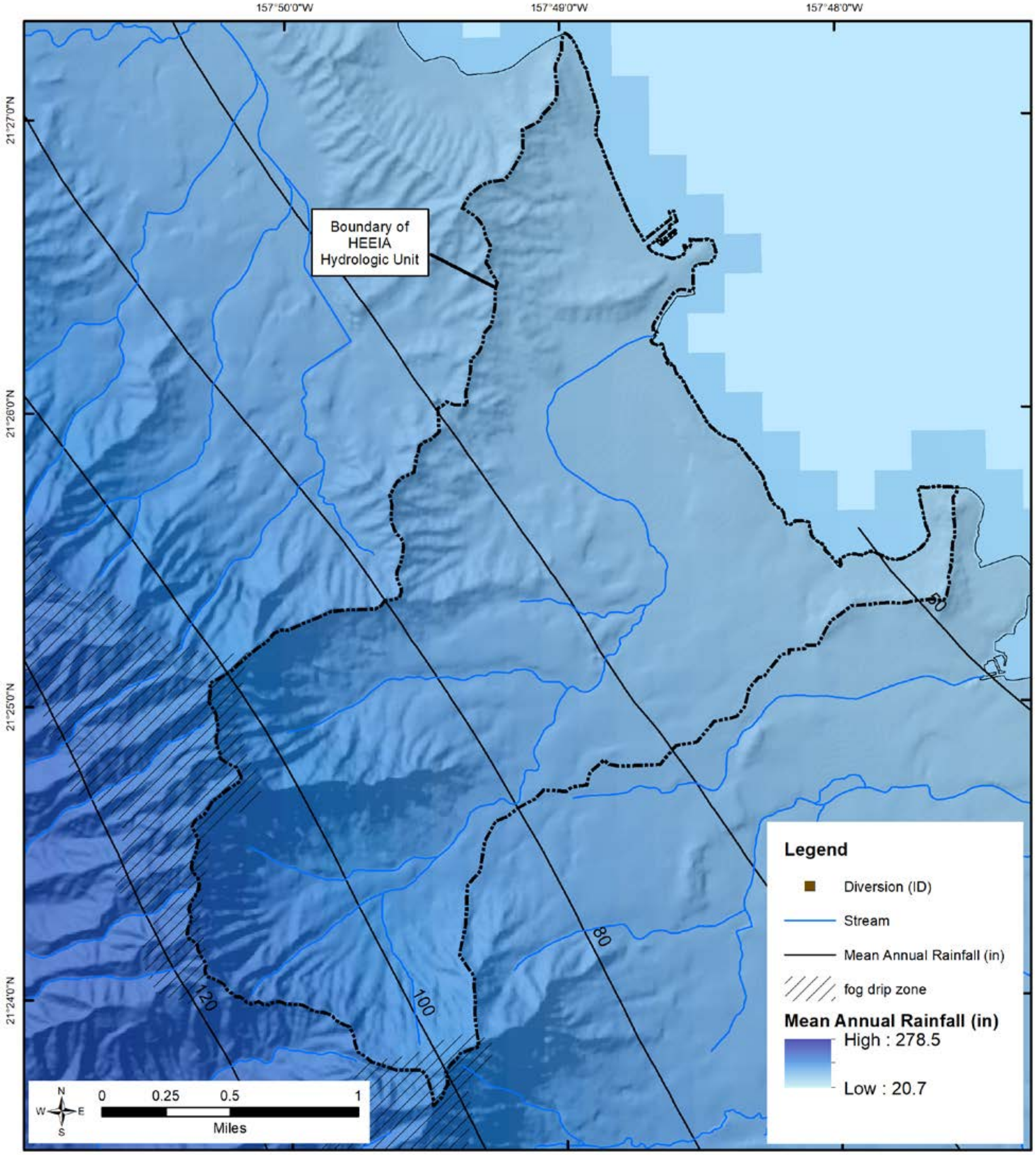


Figure 2-6. Mean annual solar radiation of the Heeia hydrologic unit, Oahu. (Source: Giambelluc et al., 2014)

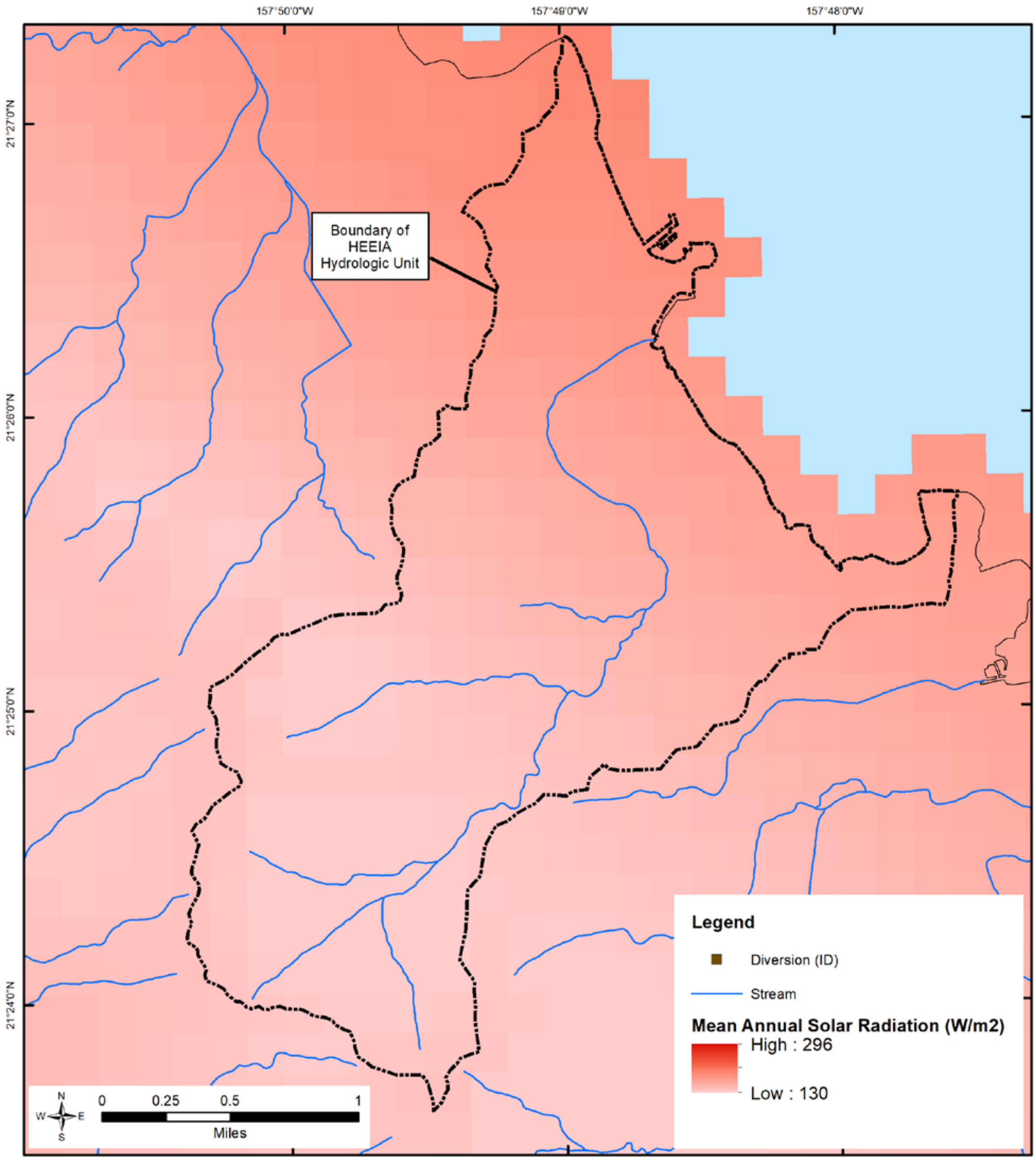
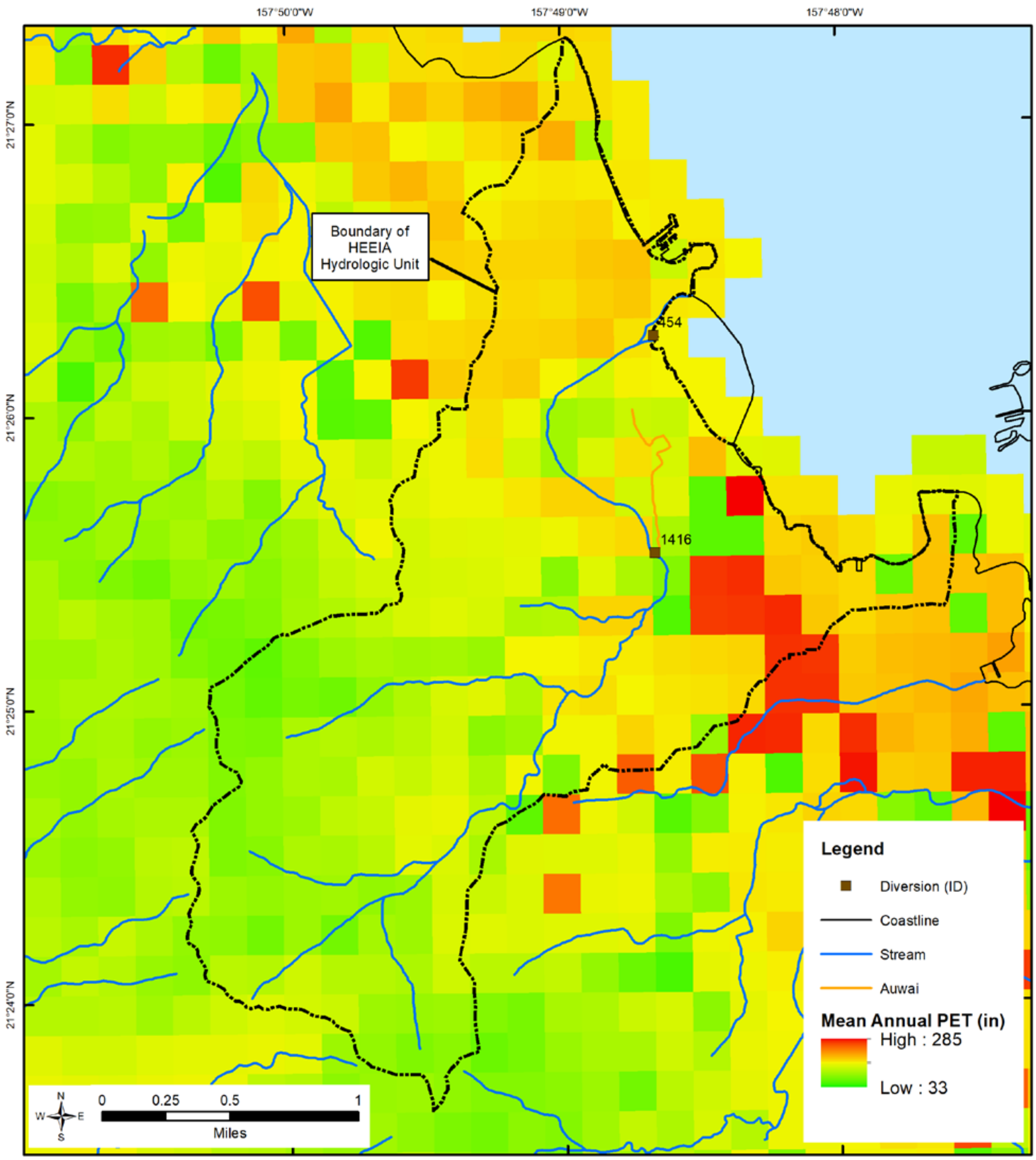


Figure 2-7. Mean annual potential evapotranspiration (Penman-Monteith method) for Heeia hydrologic unit, Oahu. (Source: Giambelluca et al., 2014)



The land cover maps (Figures 2-9 and 2-10) provide a general representation of the land cover types in Heeia hydrologic unit. Given that the scale of the maps is relatively large, they may not capture the smaller cultivated lands or other vegetation occupying smaller parcels of land. Land cover types may also have changed slightly since the year when the maps were published, particularly with reference to the cultivation of commercial crops. At small scales, community members have reported lands cultivated with tropical flowers, dryland and wetland taro, sweet potato, banana, and papaya. Along the stream in the upper elevations and in the marsh in the lower elevations, restoration of native species and the removal of invasive species has improved the ecological value of the hydrologic unit.

Table 2-4. C-CAP land cover classes and area distribution in Heeia hydrologic unit, Oahu. (Source: National Oceanographic and Atmospheric Agency, 2015)

Land Cover	Description	Area (mi^2)	Percent of Unit
Evergreen Forest	Areas where more than 67% of the trees remain green throughout the year	1.773	40.1%
Scrub	Areas dominated by woody vegetation less than 6 meters in height	0.970	21.9%
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	0.476	10.7%
Medium Intensity Developed	Areas with a mixture of constructed materials and substantial amounts of vegetation	0.463	10.5%
High Intensity Developed	Contains significant land area covered by concrete, asphalt and other constructed materials with less than 20% vegetation	0.309	7.0%
Palustrine Emergent Wetland	Includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, mosses or lichens	0.281	6.4%
Developed Open Space	Areas mostly managed grasses or low-lying vegetation planted for recreation, erosion control, or aesthetic purposes	0.068	1.5%
Estuarine Forested Wetland	Includes tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height; total vegetation cover greater than 20 percent	0.041	0.9%
Water		0.015	0.3%
Palustrine Scrub/Shrub Wetland	Includes tidal and nontidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity is below 0.5%	0.014	0.3%
Palustrine Forested Wetland	Included tidal and nontidal wetlands dominated by woody vegetation 5 meters in height or more	0.009	0.2%
Estuarine Scrub/Shrub Wetland	Tidal wetlands dominated by woody vegetation 5 meters or more in height; total vegetation cover is greater than 20 percent	0.006	0.1%
Cultivated	Areas intensely managed for the production of annual crops	0.000	0.0%
Grassland	Natural and managed herbaceous cover	0.000	0.0%

Table 2-5. HI-GAP land cover classes and area distribution for the combined Heeia hydrologic unit, Oahu. (Source: HI-GAP, 2005)

Land Cover	Area (mi^2)	Percent of Unit
Alien Forest	1.903	43.05%
Developed, Low Intensity	0.604	13.66%
Alien Grassland	0.421	9.52%
Alien Shrubland	0.312	7.07%
Developed, High Intensity	0.271	6.12%
Native Wet Cliff Vegetation	0.261	5.90%
Native Shrubland / Sparse Ohia (native shrubs)	0.167	3.79%
Uluhe Shrubland	0.116	2.63%
Mixed Native-Alien Forest	0.090	2.04%
Wetland Vegetation	0.079	1.78%
Open Ohia Forest	0.074	1.68%
Ohia Forest	0.070	1.58%
Open Water	0.024	0.55%
Very Sparse Vegetation to Unvegetated	0.019	0.44%
Closed Ohia Forest	0.005	0.10%
Undefined	0.004	0.09%

Flood

Floods usually occur following prolonged or heavy rainfall associated with tropical storms or hurricanes. The magnitude of a flood depends on topography, ground cover, and soil conditions. Rain falling on areas with steep slopes and soil saturated from previous rainfall events tends to produce severe floods in low-lying areas. Four types of floods exist in Hawaii. Stream or river flooding occurs when the water level in a stream rises into the flood plain. A 100-year flood refers to the probability of a given magnitude flood occuring once in a hundred years, or 1 percent chance of happening in a given year. Flash floods occur within a few hours after a rainfall event, or they can be caused by breaching of a flood safety structure such as a dam. Flash flooding is common in Hawaii because the small drainage basins often have a short response time, typically less than an hour, from peak rainfall to peak streamflow. They are powerful and dangerous in that they can develop quickly and carry rocks, mud, and all the debris in their path down to the coast, causing water quality problems in the near-shore waters. Some floods can even trigger massive landslides, blocking off the entire stream channel. Sheet flooding occurs when runoff builds up on previously saturated ground, flowing from the high mountain slopes to the sea in a shallow sheet (Pacific Disaster Center, 2007). Coastal flooding is the inundation of coastal land areas from excessive sea level rise associated with strong winds or a tsunami.

Figure 2-8. State land use district boundaries of the Heeia hydrologic unit, Oahu (Source: State of Hawaii, Office of Planning, 2015d).

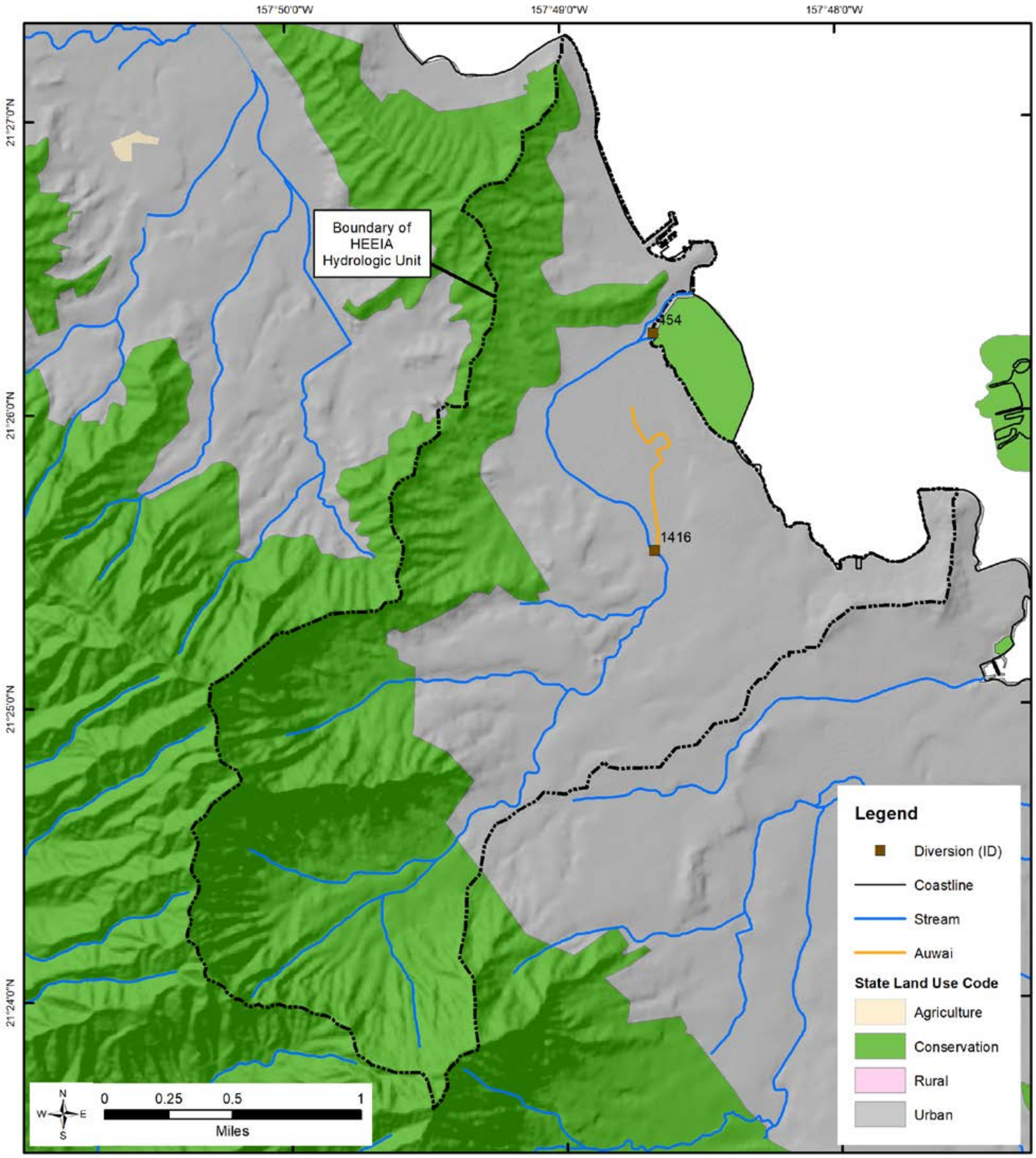


Figure 2-9. C-CAP land cover of the Heeia hydrologic unit, Oahu. (Source: NOAA, 2005).

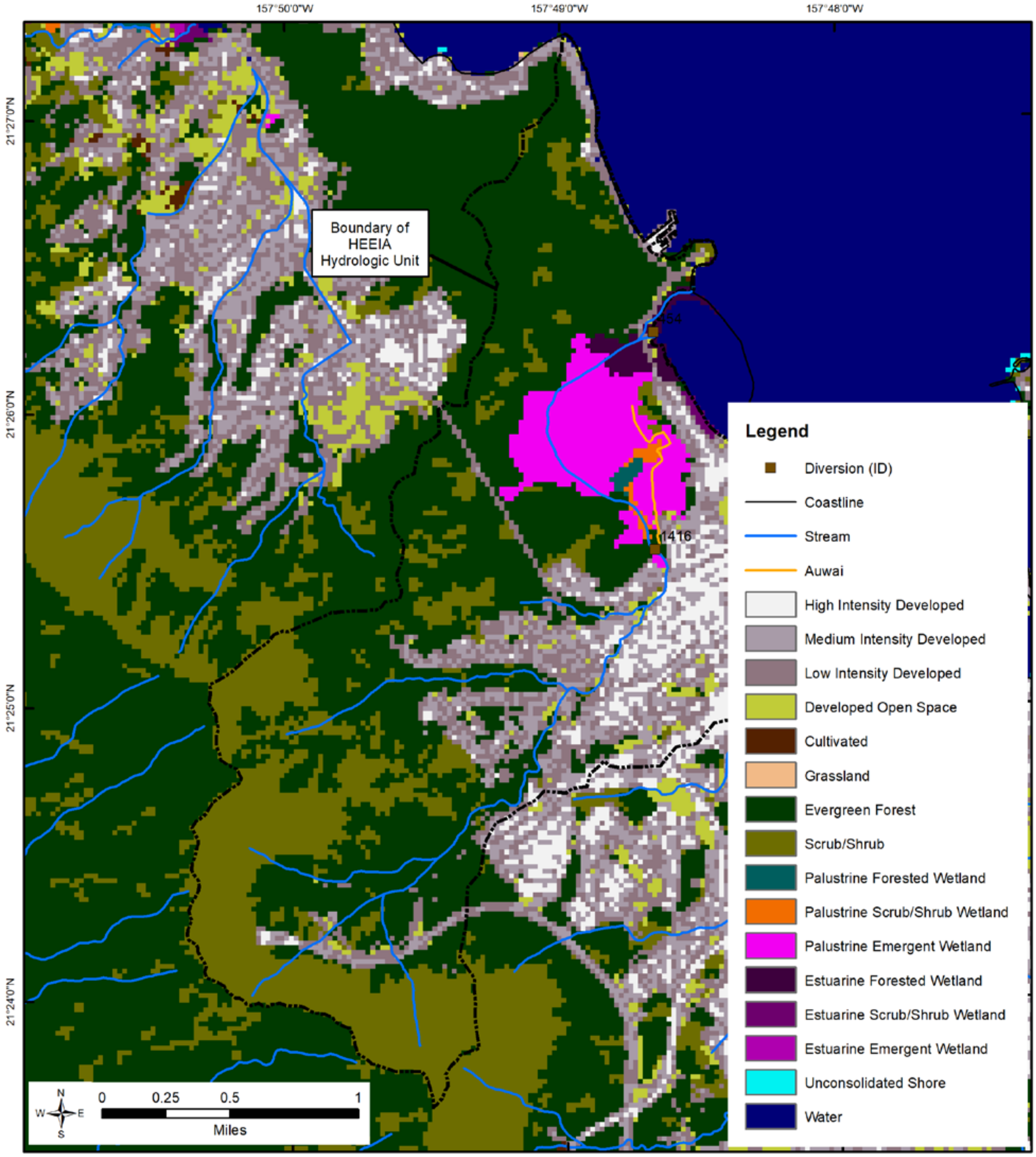
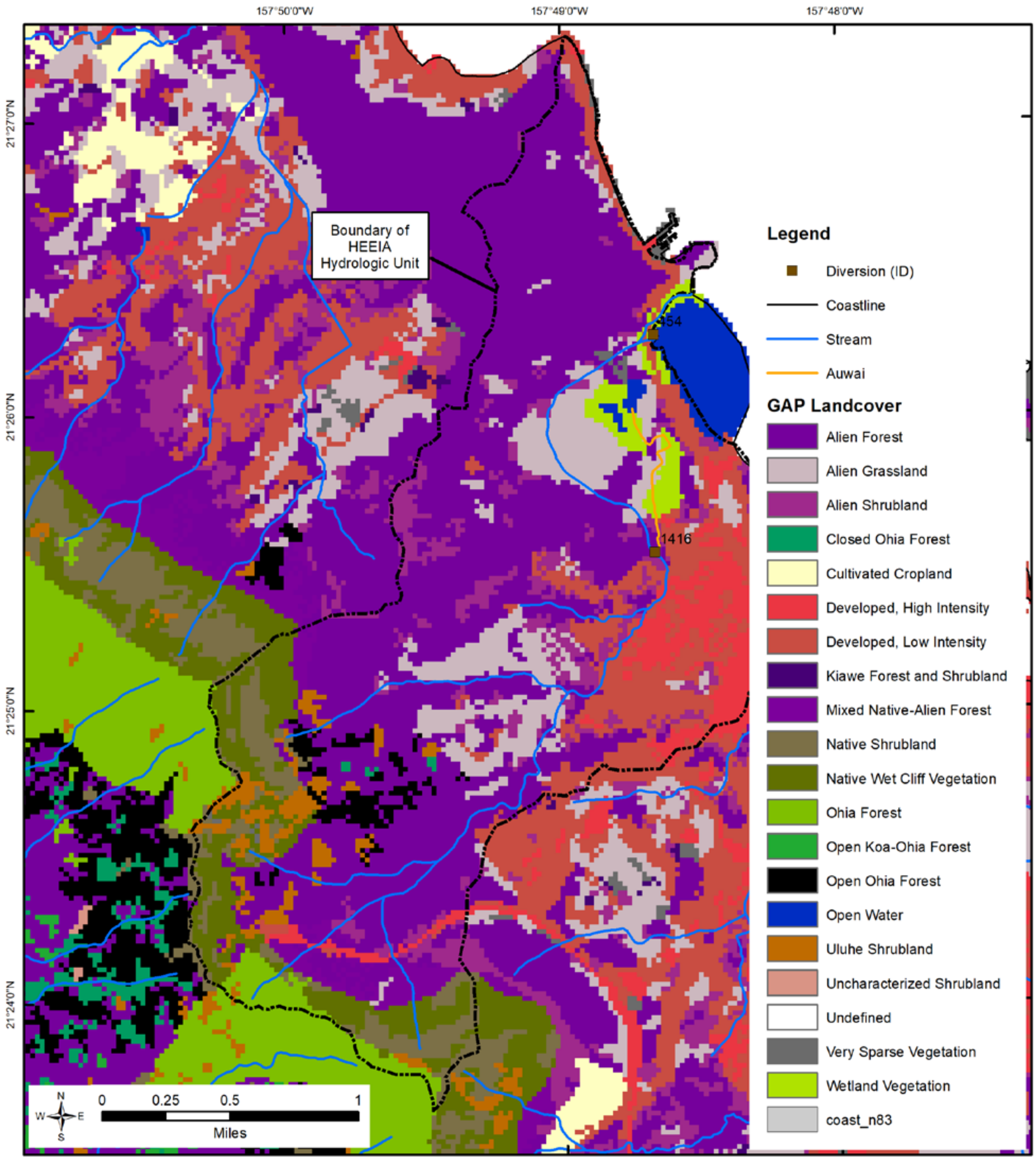


Figure 2-10. Hawaii GAP land cover classes of the Heeia hydrologic unit, Oahu (Source: USGS, 2001).



Peak floods in Heeia have been monitored at a few locations in the watershed (Table 2-6). Using basin characteristics within the USGS Streamstats GIS-based program, it is possible to model the magnitude of floods at the mouth of streams, even if they are not monitored (Rea and Skinner, 2012). The 2-, 5-, 10-, 50-, and 100-year flood magnitudes in Heeia Stream at the mouth are estimated as 1470, 2770, 3830, 6600, and 7920 cfs, respectively. The Federal Emergency Management Agency (FEMA) developed maps that identify the flood-risk areas in an effort to mitigate life and property losses associated with flooding events. Based on these maps, FEMA approximately 3.0 square miles (68.4%) as Flood Zone D, where there are possible but undetermined flood hazards occupies most (Figure 2-11). Another 1.07 square miles (24.3%) is designated Flood Zone X as an area of minimal flood hazard and 0.3 square miles (7.3%) designated as flood zone AE with a 1% chance of flooding floodplains or shallow flooding due to ponding (Figure 2-10).

Table 2-6. The magnitude of peak flows with specific recurrence intervals based on measured peaks flows at select monitoring locations in the Heeia hydrologic unit. (Source: Oki et al., 2010)

station ID	station name	period of record	peak flood magnitudes (cfs) 2-year	5-year	10-year	50-year	100-year
16275000	Heeia Stream at Haiku Valley	1915-P	571	1210	1830	3910	5150
16278000	Iolekaa Stream mauka near Heeia	1940-1970	43.1	108	181	484	701
16279500	Heeia Str at Kaneohe	1965-1997	956	2630	4370	10,300	13,800

Drought

Drought is generally defined as a shortage of water supply that usually results from lower than normal rainfall over an extended period of time, though it can also result from human activities that increase water demand (Giambelluca et al., 1991). The National Drought Mitigation Center (State of Hawaii, Commission on Water Resource Management, 2005b) uses two types of drought definitions — conceptual and operational. Conceptual definitions help people understand the general concept of drought. Operational definitions describe the onset and severity of a drought, and they are helpful in planning for drought mitigation efforts. The four operational definitions of drought are meteorological, agricultural, hydrological, and socioeconomic. Meteorological drought describes the departure of rainfall from normal based on meteorological measurements and understanding of the regional climatology. Agricultural drought occurs when not enough water is available to meet the water demands of a crop. Hydrological drought refers to declining surface and ground water levels. Lastly, socioeconomic drought occurs when water shortage affects the general public.

Impacts of drought are complex and can be categorized into three sectors: water supply; agriculture and commerce; and environment, public health, and safety sectors (State of Hawaii, Commission on Water Resource Management, 2005b). The water supply sector encompasses urban and rural drinking water systems that are affected when a drought depletes groundwater supplies due to reduced recharge from rainfall or surface water due to reduced stream flow. The agriculture and commerce sector includes the reduction of crop yield and livestock sizes due to insufficient water supply for crop irrigation and maintenance of ground cover for grazing. The environmental, public health, and safety sector focuses on wildfires that are both detrimental to the forest ecosystem and hazardous to the public. It also includes the impact of desiccating streams, such as the reduction of instream habitats for native species.

Droughts have affected the islands throughout Hawaii's recorded history. The most severe events of the recent past years are associated with the El Niño phenomenon. In January 1998, the National Weather Service's network of 73 rain gauges throughout the State did not record a single above-normal rainfall, with 36 rain gauges recording less than 25 percent of normal rainfall (State of Hawaii, Commission on

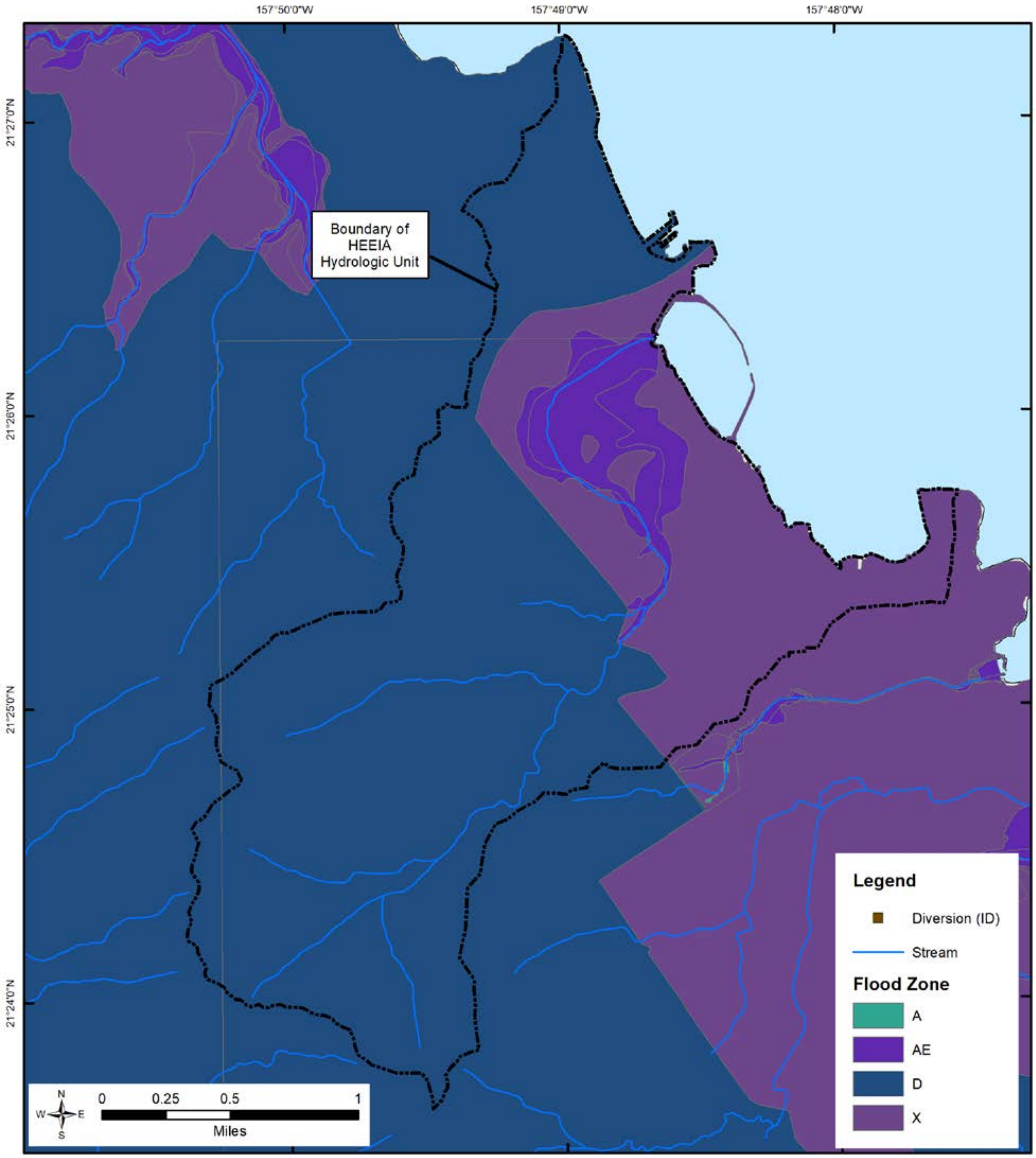
Water Resource Management, 2005b). The most recent drought occurred in 2000-2002, affecting all islands, especially the southeastern end of the State.

With Hawaii's limited water resources and growing water demands, droughts will continue to adversely affect the environment, economy, and the residents of the State. Aggressive planning is necessary to make wise decisions regarding the allocation of water at the present time, and conserving water resources for generations to come. The Hawaii Drought Plan was established in 2000 in an effort to mitigate the long-term effects of drought. One of the projects that supplemented the plan was a drought risk and vulnerability assessment of the State, conducted by researchers at the University of Hawaii (2003). In this project, drought risk areas were determined based on rainfall variation in relation to water source, irrigated area, ground water yield, stream density, land form, drainage condition, and land use. Fifteen years of historical rainfall data were used. The Standardized Precipitation Index (SPI) was used as the drought index because of its ability to assess a range of rainfall conditions in Hawaii. It quantifies rainfall deficit for different time periods, i.e. 3 months and 12 months. Results of the study for Oahu are summarized in Table 2-7. Based on the 12-month SPI, the Central Oahu regions have the greatest risk to drought impact on Oahu because of its dependence on surface water sources, limited rainfall, or relatively high drought frequency and high population density. The growing population in the already densely populated area further stresses the water supply. Flow in Heeia Stream may decline during low rainfall periods (hydrological drought), although the Heeia watershed is not considered vulnerable to drought, and the Heeia stream is not expected to stop flowing. There may be a small wildfire risk due to drought in Heeia hydrologic units, with dry invasive grasses or trees prone to wildfire, however there is less risk of drought to the general population.

Table 2-7. Drought risk areas for Oahu. (Source: University of Hawaii, 2003)
[Drought classifications of moderate, severe, and extreme have SPI values -1.00 to -1.49, -1.50 to -1.99, and -2.00 or less, respectively]

Sector	Drought Classification (based on 12-month SPI)		
	Moderate	Severe	Extreme
Water Supply	Central Oahu (Mililani/Waipio)	Central Oahu	Ewa, Haleiwa
Agriculture and Commerce	Central Oahu (Kunia to Helemano)	Central Oahu (Kunia)	North of Helemano
Environment, Public Health and Safety	Central Oahu (Mililani)	Central Oahu (Mililani and Kunia)	Waipio / Pearl City

Figure 2-11. FEMA flood zone regions in the Heeia hydrologic unit, Oahu (Source: Federal Emergency Management Agency, 2014).



3.0 Hydrology

The Commission, under the State Water Code, is tasked with establishing instream flow standards by weighing "the importance of the present or potential instream values with the importance of the present or potential uses of water for noninstream purposes, including the economic impact of restricting such uses." While the Code outlines the instream and offstream uses to be weighed, it assumes that hydrological conditions will also be weighed as part of this equation. The complexity lies in the variability of local surface water conditions that are dependent upon a wide range of factors, including rainfall, geology, and human impacts, as well as the availability of such information. The following is a summary of general hydrology and specific hydrologic characteristics for streams in the Heeia hydrologic unit.

Streams in Hawaii

Streamflow consists of: 1) direct surface runoff in the form of overland flow and subsurface flow that rapidly returns infiltrated water to the stream; 2) ground water discharge in the form of base flow; 3) water returned from streambank storage; 4) rain that falls directly on streams; and 5) additional water, including excess irrigation water discharged into streams by humans (Oki, 2003). The amount of runoff and ground water that contribute to total streamflow is dependent on the different components of the hydrologic cycle, as well as man-made structures such as diversions and other stream channel alterations (e.g. channelizations and dams).

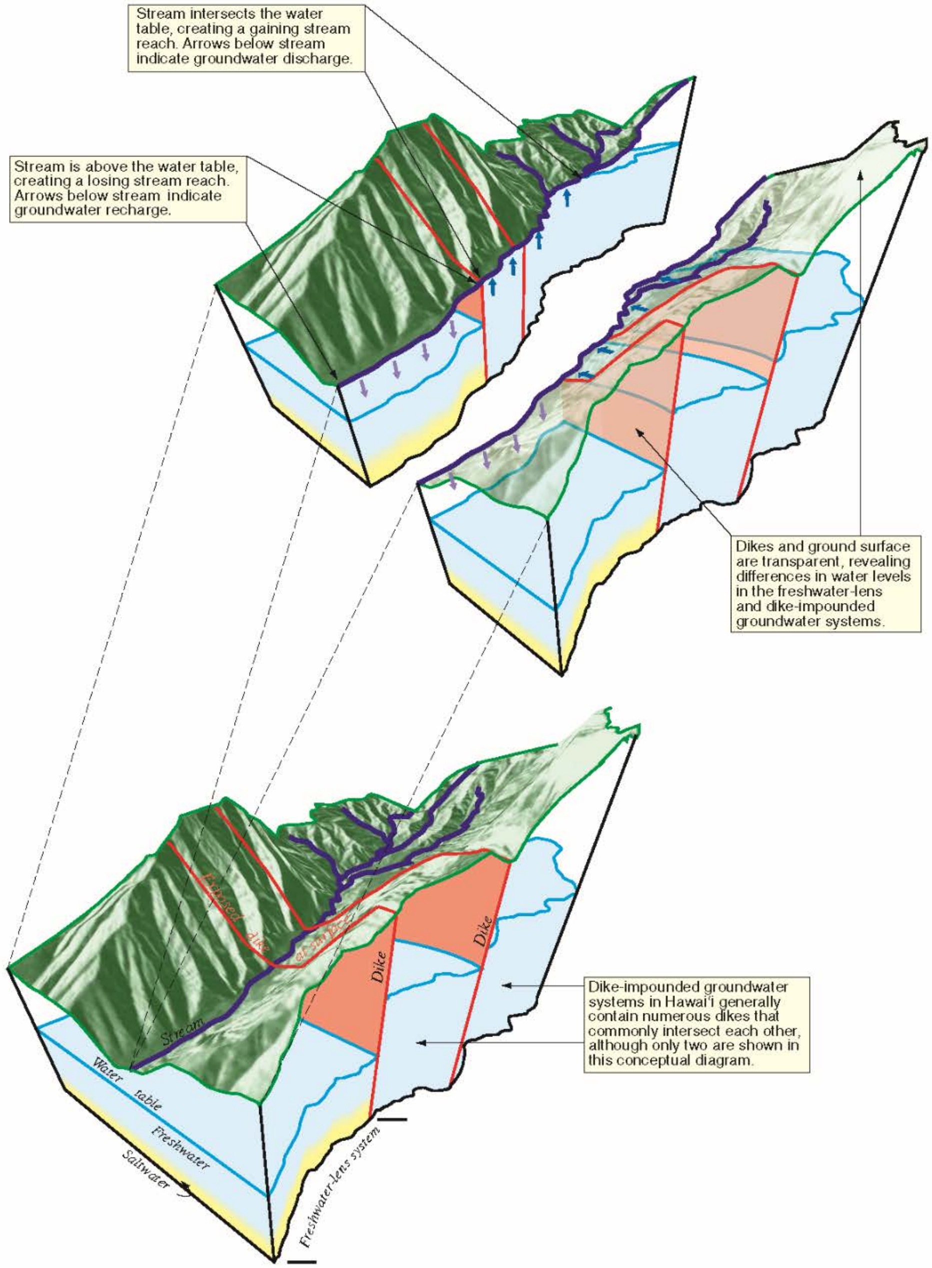
Streams in Hawaii can either gain or lose water at different locations depending on the geohydrologic conditions. A stream gains water when the ground water table is above the streambed. When the water table is below the streambed, the stream can lose water. Where the streambed is lined with concrete or other low-permeability or impermeable material, interaction between surface water and groundwater is unlikely. Another way that groundwater influences streamflow is through springs. A spring is formed when a geologic structure (e.g., fault or fracture) or a topographic feature (e.g., side of a hill or a valley) intersects ground water either at or below the water table. This can discharge groundwater onto the land surface, directly into the stream, or into the ocean. Figure 3-1 illustrates a valley that has been incised through erosion, exposing a high-level water table and resulting in ground water discharges that contribute directly to streamflow.

The USGS has maintained a variety of continuous stream gaging stations over time (Figure 3-8). These stations have monitored the flow of water in Heeia Stream (station 16275000), its headwater tributary (stations 16278000) or the flow of water in various ditches (stations 16270000, 16277000, 16280000, 16281000). In addition to these stations, peak streamflow values have been monitored at Heeia Stream (station 16279500). Historic flow data from these stations are available in Table 3-1.

Table 3-1. Selected streamflow parameters and duration discharge exceedance values for the given period of record in the Heeia hydrologic unit, Oahu, Hawaii. (Source: USGS, 2020)
[Flows are in cubic feet per second (million gallons per day)]

station ID	station name	period of record	mean daily flow	14-day low flow	discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded			
					Q_{50}	Q_{70}	Q_{90}	Q_{95}
16275000	Heeia Stream at Haiku Valley	1914-1919, 1939-1977, 1982-P	2.6 (1.67)	0.30 (0.19)	1.7 (1.10)	1.4 (0.90)	1.1 (0.71)	0.76 (0.49)
16278000	Iolekaa Stream nr Heeia	1940-1970	0.68 (0.44)	0.16 (0.10)	0.50 (0.32)	0.40 (0.26)	0.26 (0.17)	0.22 (0.14)

Figure 3-1. Conceptual diagram illustrating surface water-ground water interactions. (Source: Oki et al., 2010).



Groundwater

Groundwater is an important component of streamflow as it constitutes the base flow[1] of Hawaiian streams. Groundwater can also be an alternative source to diverting stream flow. When groundwater is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of groundwater withdrawal can include the reduction of streamflow, which may cause a

[1] Base flow is the water that enters a stream from persistent, slowly varying sources (such as the seepage of ground water), and maintains stream flow between water-input events (i.e., it is the flow that remains in a stream in times of little or no rainfall).

decrease in stream habitats for native species and a reduction in the amount of water available for irrigation. The interaction between surface water and groundwater warrants a close look at the groundwater recharge and demand within the State as well as the individual hydrologic units.

In Hawaii, groundwater is replenished by recharge from rainfall, fog drip, and irrigation water that percolate through the plant root zone to the subsurface rock. Recharge can be captured in three major groundwater systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water basal aquifer provides the most important sources of ground water. It includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water. The Ghyben-Herzberg principle describes the displacement of higher density saltwater by lower density fresh water in an aquifer for a condition where two fluids do not mix and the freshwater flow is primarily horizontal. In such a situation, for every one foot above sea level of freshwater, there are approximately 40 feet of freshwater below sea level. Thus, a vertically extensive fresh water-lens system can extend several hundreds of feet below mean sea level. By contrast, a dike-impounded system is found in rift zones or a caldera where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. On Oahu, dikes impound water to as high as 2,000 feet above mean sea level (Nichols et al. 1996). A perched system is found in areas where low-permeability rocks impede the downward movement of percolated water sufficiently to allow a water body to form in the unsaturated zone above the lowest water table (Engott et al., 2017). The water-bearing properties of various rock structures largly depends on their composition, and therefore their permeability. Where a dike complex exists, 100 or more dikes per mile, occupying 5% or more of the rock, is not uncommon and can hold substantial quantities of water in the permeable layers between the dikes. By contrast, in breccia deposits, the water-bearing properties are dependent on the degree of weathering and cementation. Lava flows of the Honolulu Series are much less permeable than of the Koolau Series. Thus, where the Koolau Series is overlain by the Honolulu Series, springs form at the toes of the Koolau lava flows. The most permeable rocks are of the Honolulu Series are the cinder beds, which are widely scattered but only found in small quantitites. Alluvium, deposited from erosional events upslope and from calcareous sedimentary material during swings in sea level, can be found to a thickness of more than 700 feet. Moderately consolidated and well consolidated alluvium is composed of silt and clay, forming an impermeable cap influencing the downward and lateral movement of water (Takasaki et al. 1969).

The hydrologic unit of Heeia is in the Koolaupoko aquifer system as part of the Windward Aquifer Sector. A general overview of the groundwater occurrence, movement, and interactions with surface water in this area is described in Izuka et al. (1992) and illustrated in Figure 3-2. Heeia is composed of Haiku Valley in the uplands, and Heeia Marsh in the lowlands. The geology of Haiku Valley is a heterogeneous composition of rocks from various volcanic events. The basement geology is composed of Koolau Basalt of high permeability, interlaced with low permeable interconnected dikes (Figure 3-2). On top of this is older alluvium of low permeability, then a massive lava flow of the Honolulu Volcanic Series with low permeability, pyroclastics of the Honolulu Volcanic Series of high permeability, and then deposits of younger alluvium, colluvium, and lava flows with high permeabilities (Stearns and Vaksvik, 1935). The low permeability of certain layers generates substantial lateral movement of groundwater in the valley. Further, the water accumulated in dike compartments commonly discharges into streams and has been developed by constructing horizontal tunnels. Izuka et al. (1992) provides an analysis of the drilling log of well 2450-002 in Haiku Valley completed in 1981. They describe two aquifers, one with a potentiometric surface above ground level in the alluvium or pyroclastics of the Honolulu Volcanics and a second at 170 feet below ground level (155 feet a.m.s.l.) in the dike compartment of the Koolau Basalt. The two aquifers are separated by the tick massive basalt lava flow of the Honolulu Volcanics.

Wells in the Heeia Hydrologic Unit

The Koolaupoko Aquifer System is located in the Windard Aquifer Sector on the windward side of Oahu and includes the surface water hydrologic units of Kaneohe, Heeia, Kahaluu, Waiahole, Waikane, and Kaawa. The 2019 update to the Water Resources Protection Plan revised the sustainable yield of the Koolaupoko Aquifer System based on updated information from 30 mgd to 28 mgd (State of Hawaii, 2019). The location of wells in the Heeia hydrologic unit are depicted in Figure 3-3 and detailed information for each well is specified in Table 3-2. The total installed pump capacity in the aquifer is 14.55 mgd, with 86 wells. Some of the high elevation groundwater withdrawals in Heeia are from development tunnels built by the Honolulu Board of Water Supply (BWS). The Honolulu BWS water distribution system can deliver water to urban areas outside of the hydrologic unit (e.g., Kaneohe, Kailua). Total monthly pumpage from the aquifer system by the Honolulu BWS is provided in Figure 3-4 and summarized in Tables 3-3. From 2010 to 2019, the Honolulu BWS mean pumpage from the aquifer system was 10.27 mgd, with a median of 10.20 mgd, and a maximum of 14.44 mgd.

Figure 3-2. Depiction of groundwater table in Haiku Valley in relation to geology with the elevation of springs and development tunnels dug through the overtopping Honolulu Volcanic Series in the marginal dike zone (Source: Izuka et al. 1992 modified from Takahashi and Mink, 1985)

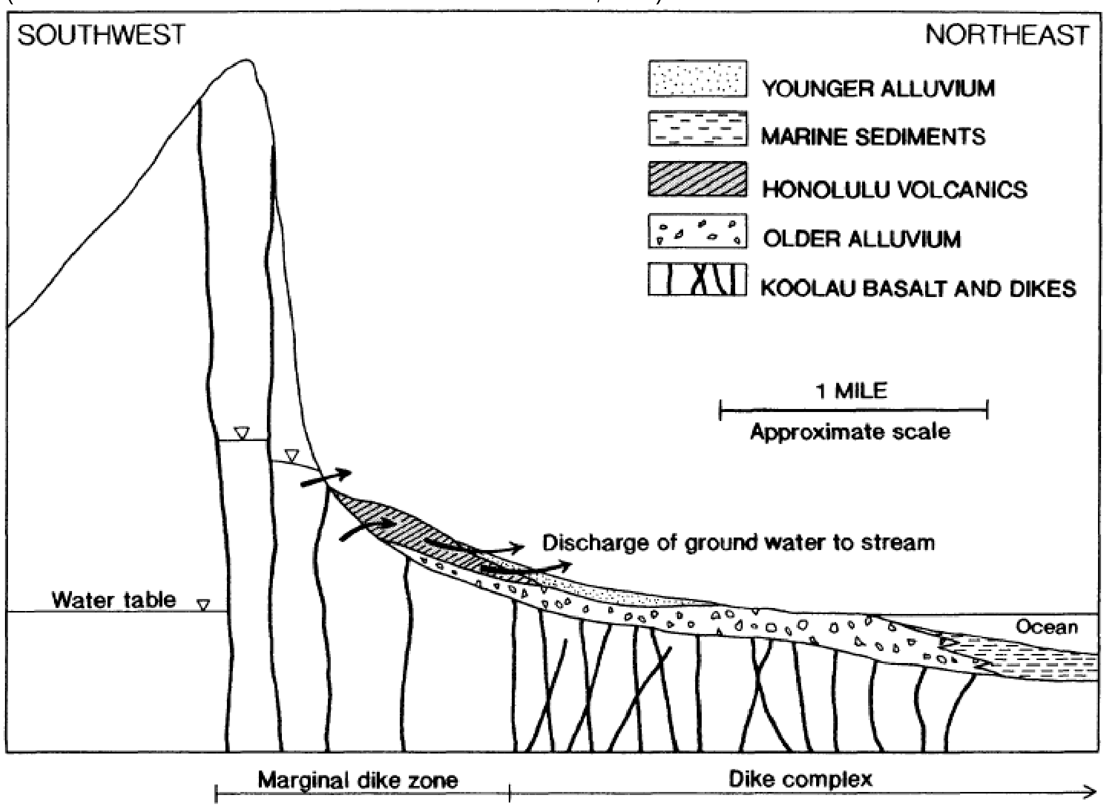


Figure 3-3. Well locations by well type and well numbers in and near the Heeia hydrologic unit, in the Windward aquifer sector, Oahu. (Source: State of Hawaii, Commission on Water Resource Management, 2018c).

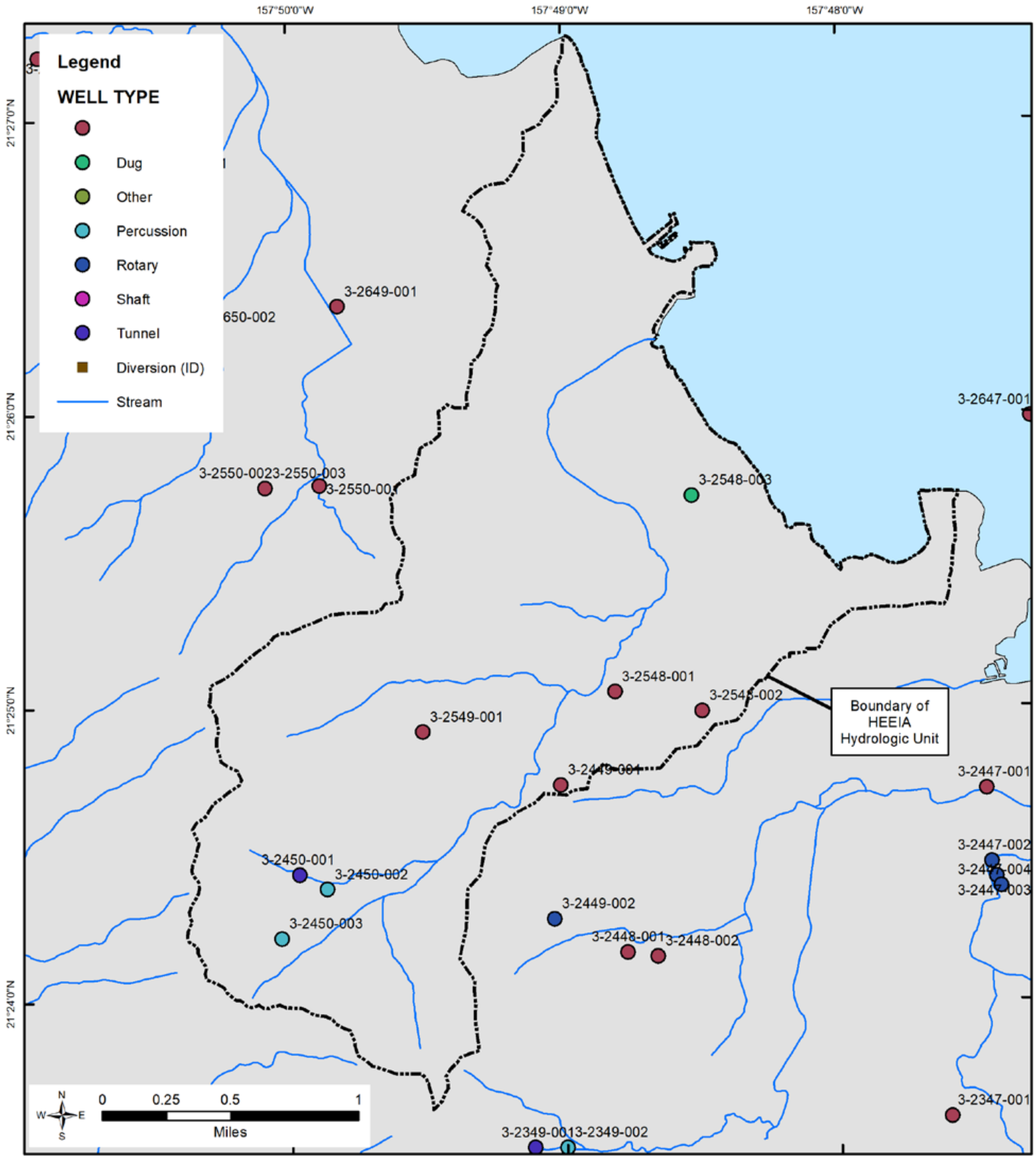


Figure 3-4. Total monthly reported pumpage (mgd) and 12-month moving average for Honolulu Board of Water Supply (BWS) wells and development tunnels in the Koolaupoko Aquifer system. (Source: Source: State of Hawaii, Commission on Water Resource Management, 2020c).

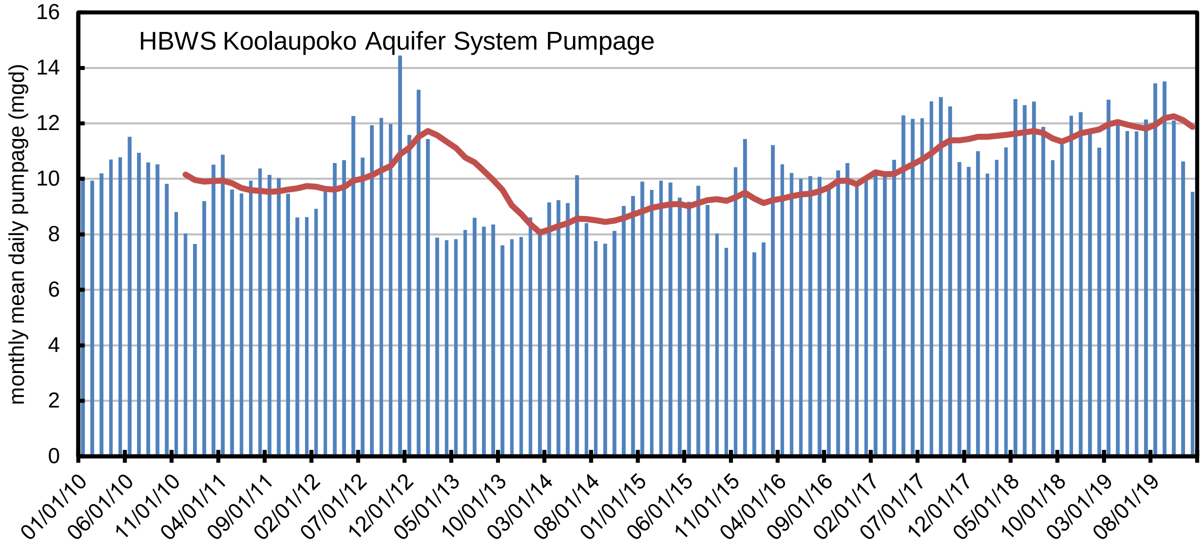


Table 3-2. Information of wells located in the Heeia surface water hydrologic units in the Koolaupoko Aquifer System (Source: State of Hawaii, Commission on Water Resource Management, 2020c).
[elevation values indicate feet above mean sea level; depth values indicate feet below ground elevation; -- indicates value is unknown; BWS = Board of Water Supply; ABD = abandoned; ABNLOS = abandoned lost; DON = domestic, DOA = Department of Agriculture; IRR = irrigation; IRRGC = golf course irrigation; MUNCO = municipal county; OBS = observation; SL = sealed; UNU = unused]

Well number	Well Name	Well Owner	Year drilled	Use	Ground elevation (feet)	Well depth (feet) or Tunnel Length (feet)	Installed pump capacity (mgd)	Average 2018 (mgd)
2450-001	Haiku Tunnel	Honolulu BWS	1940	MUNCO	550	1,300	n/a	n/a
2450-002	Haiku	Honolulu BWS	1981	MUNCO	497	600	1.008	
2450-003	Haiku-DOT	SOH DOT, Highways	1990	OTH	814	315	0.288	
2449-001	Kaneohe	Haiku Villa Community Association	1945	ABNLOS	238	92	n/a	n/a
2549-001	Iolekaa	Honolulu BWS	1966	MUNCO	485	423	0.302	
2548-001	Kaneohe	C&C of Honolulu	1945	ABNLOS	179	178	n/a	n/a
2548-002	Kaneohe	C&C of Honolulu	1945	ABNLOS	113	113	n/a	n/a
2548-003	Kaneohe-Patacsil	Josephine Patacsil	1960	ABNLOS	4	n/a	n/a	n/a

Groundwater Pumping and Salinity Levels

Of growing concern is the impact of increased groundwater pumpage on ground water salinity. As pumpage draws down the less dense freshwater lens, brachish ground water from the transition zone will mix, increasing the salinity (and thus chloride content) of the freshwater lens. Freshwater is water with a chloride content of less that 250 parts per million (ppm), or 1.3% of the chloride content of seawater. Hydrologists with the USGS and CWRM monitor the elevation of the freshwater lense, the transition zone to brachish water, and the elevation of sea water in deep monitoring wells across the state. In the Koolaupoko Aquifer System, the Honolulu BWS reports chlorides for wells that are being actively pumped on a monthly basis, although there are often lapses in reporting (Figure 3-5). Most groundwater pumpage in the Kookaupoko Aquifer System is from the marginal dike zone or high elevation water, which is less subject to saltwater intrusion.

Table 3-3. Groundwater pumpage from source wells for the Honolulu Board of Water Supply from the Koolaupoko Aquifer System from 2013-2020. [Flows in million gallons per day, mgd]

well ID	well name	Year drilled	Use	Pump capacity (mgd)	average monthly pumpage (mgd)	median monthly pumpage (mgd)	maximum monthly pumpage (mgd)
2247-001	Kamooalii II	1985	abandoned	n/a	n/a	n/a	n/a
2248-001	Kamooalii I	1985	unused	n/a	n/a	n/a	n/a
2348-002	Kuou I-1	1955	municipal	--	0.670	0.578	1.720
2348-003	Kuou I-2	1955	municipal	3.024	0.000	0.000	0.000
2549-001	Iolekaa	1966	municipal	0.302	0.057	0.000	0.257
2651-001	Kahaluu Tunnel	1947	municipal	n/a	1.846	1.842	2.575
2651-002	Waihee Tunnel	1955	municipal	n/a	3.770	4.260	7.721
2651-003	Kahaluu	1980	municipal	1.008	0.716	0.787	1.831
2652-002	Waihee Incline 1	1976	municipal	n/a	0.000	0.000	0.000
2652-003	Waihee Incline 2	1976	municipal	n/a	0.000	0.000	0.000
2652-001	Waihee Incline 3	1971	municipal	n/a	0.854	0.955	2.160
2652-004	Waihee Incline 4	1976	municipal	n/a	0.000	0.000	0.000
2751-002	Waihee I-1	1972	municipal	1.008	0.000	0.000	0.000
2751-003	Waihee I-2	1972	municipal	1.008	0.000	0.000	0.000
2348-005	Kuou II	1986	municipal	1.008	0.095	0.083	0.636
2348-006	Kuou III	1995	municipal	0.720	0.447	0.462	0.811
2349-001	Luluku Tunnel	1948	municipal	n/a	0.104	0.093	0.307
2349-002	Luluku	1984	municipal	1.008	1.001	1.006	1.180
2450-001	Haiku Tunnel	1940	municipal	n/a	0.525	0.594	2.064
2450-002	Haiku	1981	municipal	1.008	0.163	0.159	0.399
			Total =		10.248	10.819	21.661

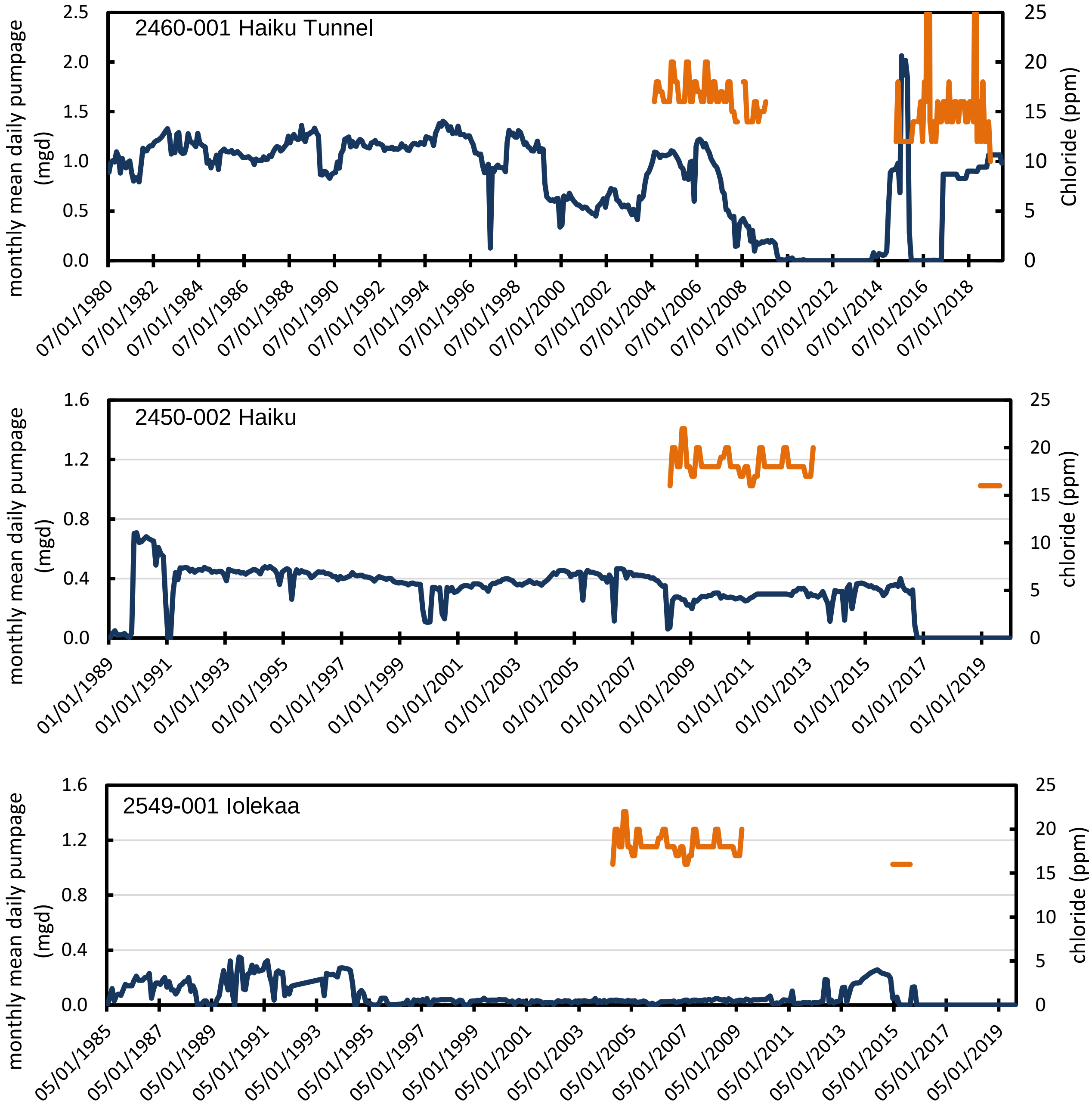
Streamflow Characteristics

Streamflow conditions have been monitored continuously in the Heeia hydrologic unit at USGS station 16275000 at an elevation of 272 feet (Figure 3-8). Other nearby long-term continuous stream flow monitoring stations are located on Waiakeakua Stream (USGS station 16240500). Izuka et al. (1992), summarized existing streamflow measurements and seepage measurements in streams to estimate the groundwater contributions to surface water for Heeia Stream. Izuka et al (1992) estimated that base flow for Heeia Stream at USGS station 16275000 in 1990 was between 1.0 and 2.0 cfs (0.64 and 1.3 mgd). However, in the period before the Haiku Tunnel was completed in 1940, the base flow was between 2.0 and 3.0 cfs (1.3 and 1.9 mgd) as depicted in Figure 3-6. Cheng (2016) estimated natural-flow duration discharges for the current period (1984-2013) and groundwater development as provided in Table 3-4.

Table 3-4. Selected natural low-flow duration discharge exceedance values for the current (1984-2013) climate period based for streams in the Heeia hydrologic unit, Oahu. (Source: Cheng, 2016)
[Flows are in cubic feet per second (million gallons per day]

		discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded			
station ID	stream name	Q_{50}	Q_{70}	Q_{90}	Q_{95}
16275000	Heeia Stream	1.7 (1.10)	1.5 (0.97)	1.3 (0.84)	1.2 (0.78)
16278000	Iolekaa Stream	0.52 (0.34)	0.38 (0.25)	--	--

Figure 3-5. Mean monthly groundwater pumpage (million gallons per day, mgd) and chloride concentration (parts per million, ppm) from wells and development tunnels operated by the Honolulu Board of Water Supply in the Heeia hydrologic unit. (Source: State of Hawaii, Commission on Water Resource Management, 2020c) [Note: x-axis scales differ between graphs]



Heeia Stream gains streamflow via groundwater seepage as it flows from mauka to makai. The Haiku Development Tunnel withdrawals water at an elevation of 550 feet. Based on Izuka et al. (1992), most, if not all the groundwater withdrawal from the tunnel would have supported surface flow during equilibrium conditions (pre-1940 tunnel construction). Figure 3-7 depicts the mean daily tunnel withdrawal and stream flow in Heeia Stream from 1982 to 2019 and Table 3-5 provides the annual and seasonal mean daily flow for this period. The difference between total wet season and dry season flow is due to seasonal differences in runoff.

Figure 3-6. Flow-duration curves for Heeia Stream at USGS 16275000 for different periods of time. (Source: Izuka et al. 1992)

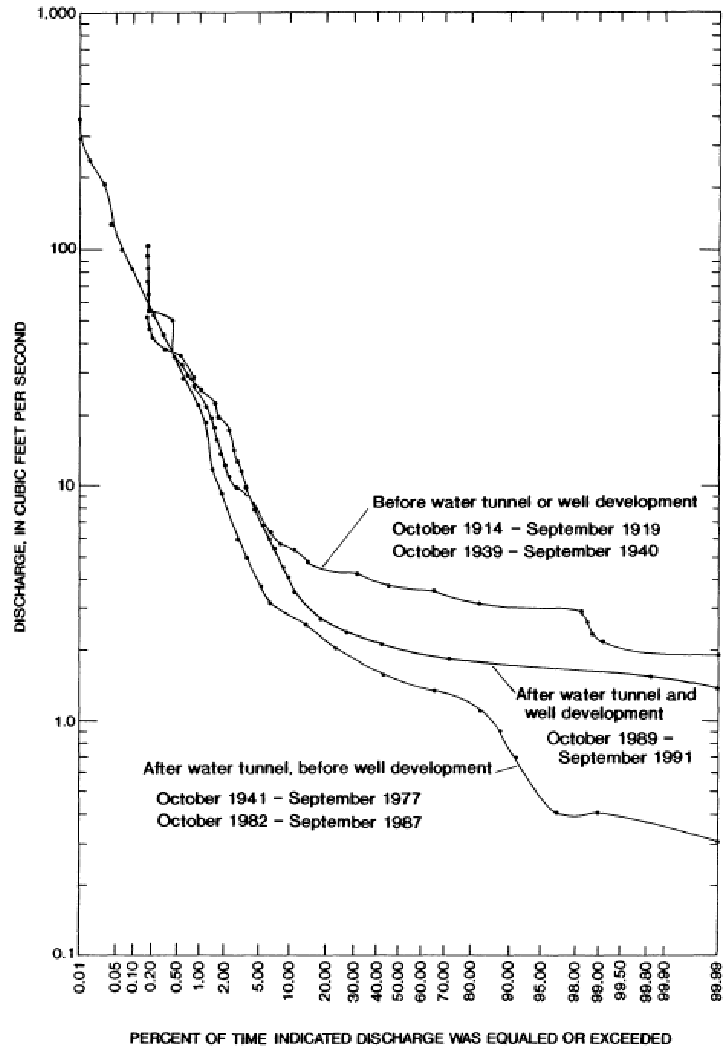


Figure 3-7. Monthly mean daily flow in Heeia Stream at (USGS station 16275000) and the total daily flow in Heeia hydrologic unit, Oahu. (Source: USGS, 2020)

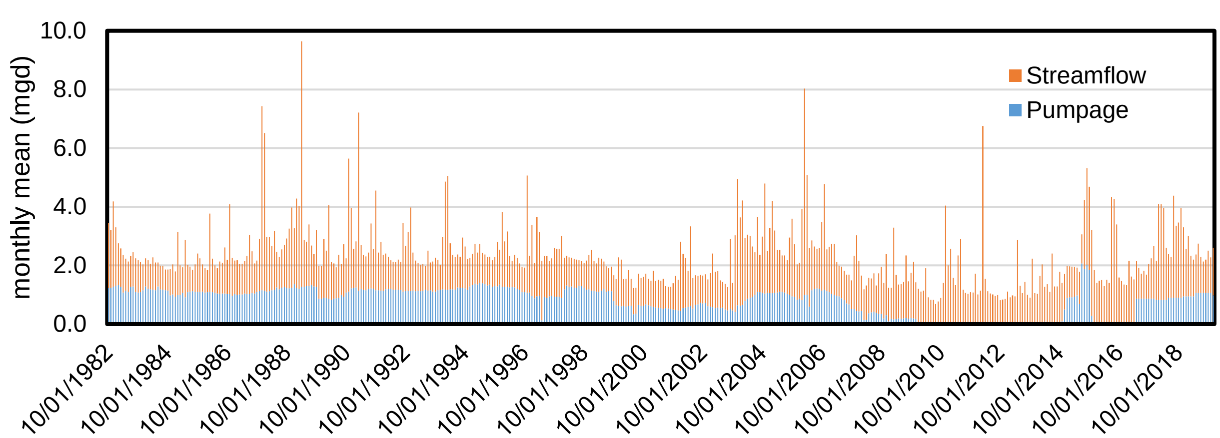


Table 3-5. Mean (standard deviation) total and seasonal statistics for seasonal streamflow at USGS 16275000 and development tunnel pumpage (Haiku Tunnel, well 2549-001) from October 1982 to December 2019 in the Heeia hydrologic unit, Oahu. [Flows are million gallons per day (mgd)]

source	Mean (SD)	Wet Season Mean (SD)	Dry Season Mean (SD)
Heeia Stream at USGS 16275000	1.55 (0.94)	1.78 (1.13)	1.33 (0.61)
Haiku Tunnel	0.80 (0.46)	0.77 (0.45)	0.83 (0.47)
Total	2.35 (1.06)	2.55 (1.26)	2.15 (0.76)

Seepage Gains and Losses

Point measurements of surface flow were made at various times throughout the Heeia hydrologic unit, although only one continuous streamflow monitoring station presently exists. During selected periods of time, the USGS made synoptic (point) measurements at many locations during low-flow conditions almost simultaneously. These "seepage" measurements are used to quantify the gains and losses of streamflow due to interactions with the groundwater system. Many measurements were made in the early 1940s and early 1960s, and again in the late 1980s. Using the upstream and downstream measurements, and the length of stream channel between the measurements, estimates of gains and losses of streamflow can be calculated. Overall, Heeia Stream is gaining flow from the Haiku Tunnel at an elevation of 570 feet to its confluence with the north branch of Heeia Stream at an elevation of 140 feet (Table 3-6). This corresponds to the stream channel incising the Honolulu Volcanics in Haiku Valley. Gains in streamflow ranged from 10.0 to 13.2 cfs per mile of channel (6.64 to 8.53 mgd per mile) at higher elevations and between 6.0 to 0.23 cfs per mile (4.0 to 0.16 mgd per mile) of channel at middle elevations. By contrast, the north branch of Heeia Stream was mostly a losing stream, with losses ranging from -0.34 to -3.2 cfs per mile (-0.22 to -2.1 mgd per mile) because the channel primarily incised older alluvium (Figure 3-11). The seepage gains and loses between specific elevations along stream reaches estimated from Izuka et al. (1992) are described in detail in Table 3-6.

Long-term trends in flow

The climate has profound influences on the hydrologic cycle and in the Hawaiian Islands, shifting climate patterns have resulted in an overall decline in rainfall and streamflow. Rainfall trends are driven by large-scale oceanic and atmospheric global circulation patterns including large-scale modes of natural variability such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation, as well as more localized temperature, moisture, and wind patterns (Frazier and Giambelluca, 2017; Frazier et al, 2018). Using monthly rainfall maps, Frazier and Giambelluca (2017) identified regions that have experienced significant ($p<0.05$) long-term decline in annual, dry season, and wet season rainfall from 1920 to 2012 and from 1983 to 2012. On Oahu, there is a substantial area that has experienced a significant decline in annual and seasonal rainfall in the northern Koolau Mountains from 1920 to 2012, and for most of the island from 1983-2012 (Figure 3-11).

Table 3-6. Distance between elevations (miles, mi), total mean gain/loss in flow (cubic feet per second, cfs), and mean seepage rate change (cfs per mi) for specific streams in the Heeia hydrologic unit, Oahu. (Source: USGS, 2020)

Heeia Stream				North Branch Heeia Stream/Iolekaa Stream			
Elevation (ft)	Distance (mi)	Seepage (cfs)	Seepage rate (cfs per mi)	Elevation (ft)	Distance (mi)	Seepage (cfs)	Seepage rate (cfs per mi)
570				430			
500	0.056	0.74	13.21	360	0.115	-0.04	-0.35
470				360			
430	0.077	0.86	11.11	320	0.237	-0.64	-2.70
430				320			
400	0.101	1.02	10.10	140	0.625	-0.21	-0.34
400							
340	0.06	0.36	6.00				
340							
272	0.299	0.07	0.23				
272							
240	0.293	0.75	2.56				
240							
160	0.413	1.26	3.05				
160							
150	0.799	1.99	2.49				
150							
95	0.263	-0.10	-0.37				

Figure 3-8. USGS gaging stations of streams and ditches in the Heeia hydrologic unit, Oahu (Source: USGS, 2020).

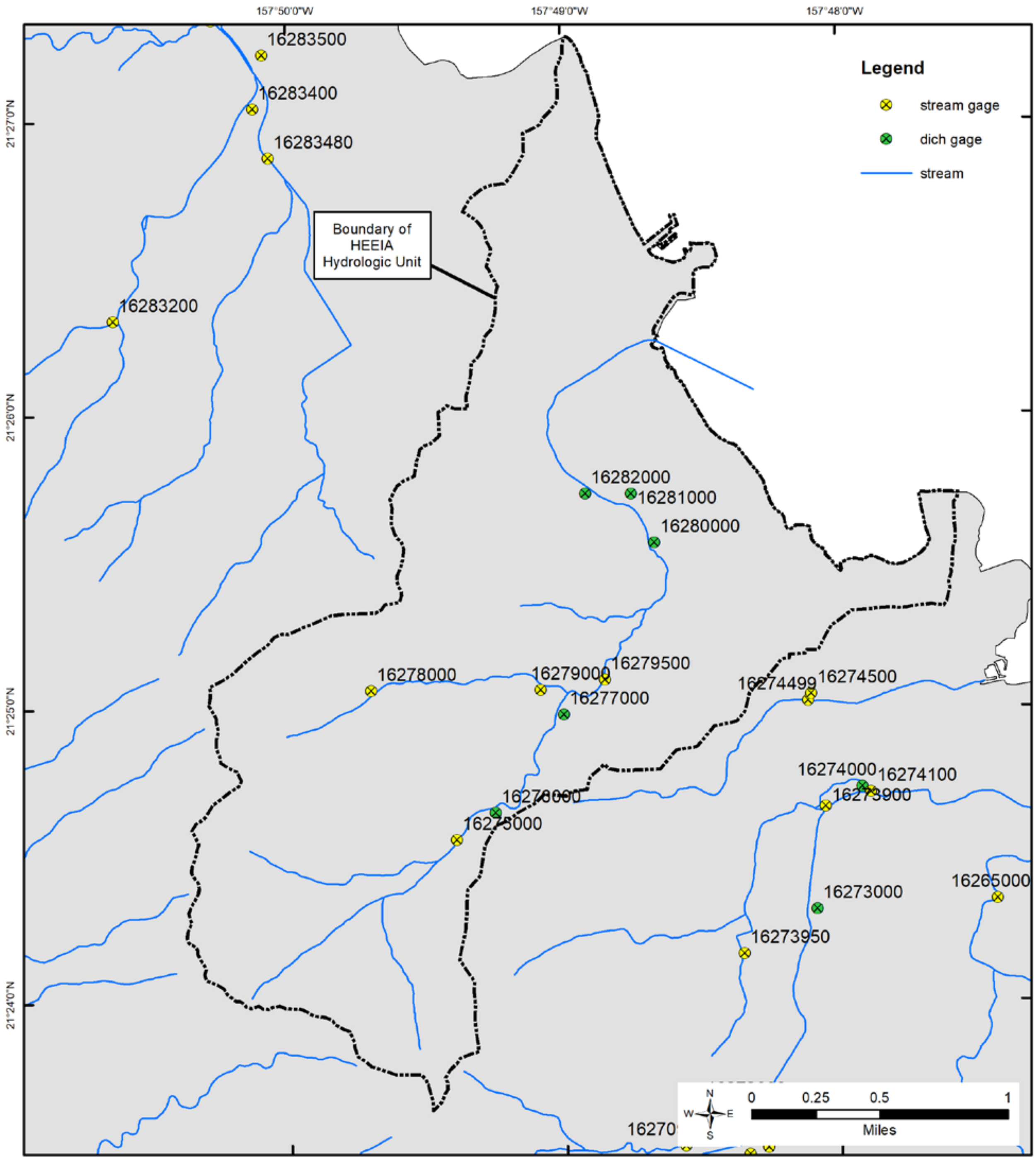
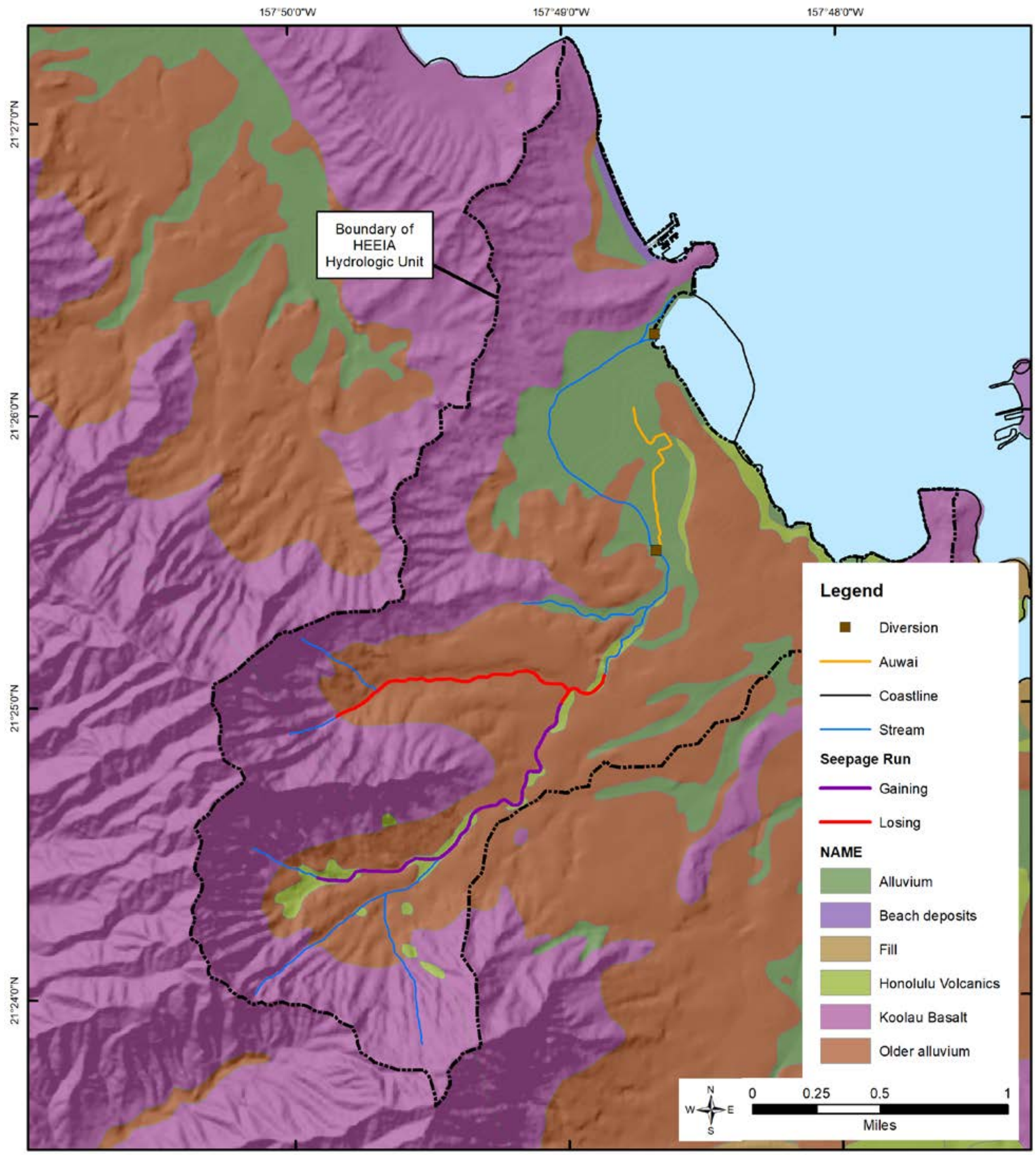


Figure 3-9. Seepage run results from near simultaneous point measurements in Heeia hydrologic unit, Oahu. (Source: USGS, 2020).



The USGS examined the long-term trends and variations in streamflow on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai, where long-term stream gaging stations exist (Oki, 2004). The study analyzed both total flow and estimated base flow at 16 long-term gaging stations. Figure 3-12 illustrates the results of the study for 7 long-term gaging stations around the islands. According to the analysis, low flows generally decreased from 1913 to 2002, which is consistent with the long-term downward trends in rainfall observed throughout the islands during that period. Monthly mean base flows decreased from the early 1940s to 2002, which is consistent with the measured downward trend of low flows from 1913 to 2002. This long-term downward trend in base flow may imply a reduction of ground water contribution to streams. At a nearby long-term gaging station on Kalihi Stream, which has been active almost continuously from 1913 to present day, trends in mean annual flow provide some context for the long-term decline in rainfall (Figure 3-13). Changing streamflow characteristics could pose a negative effect on the availability of drinking water for human consumption and habitat for native stream fauna (Oki, 2004).

Figure 3-10. Annual, wet season (Nov-Apr) and dry season (May-Oct) rainfall trends for the 1920-2012 (A) and 1983-2012 (B) periods, Oahu. Hashed line areas represent significant trend over the period.
(with permission from Frazier and Giambelluca, 2017)

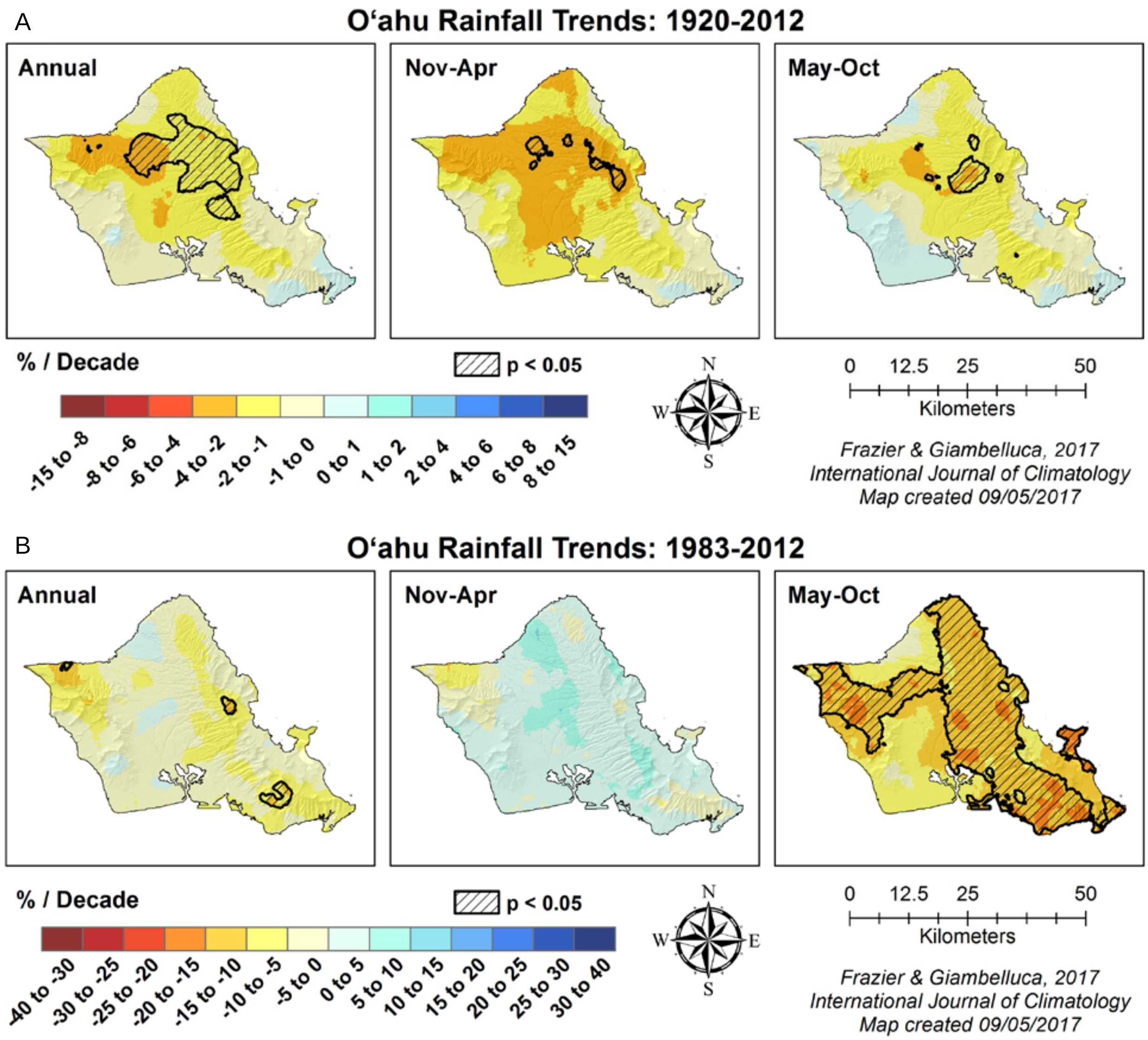


Figure 3-11. Cumulative departures of monthly mean flow from the mean of the monthly flows, Hawaii. This data is based on complete water years from 1913 through 2002. (Oki, 2004, Figure 4)

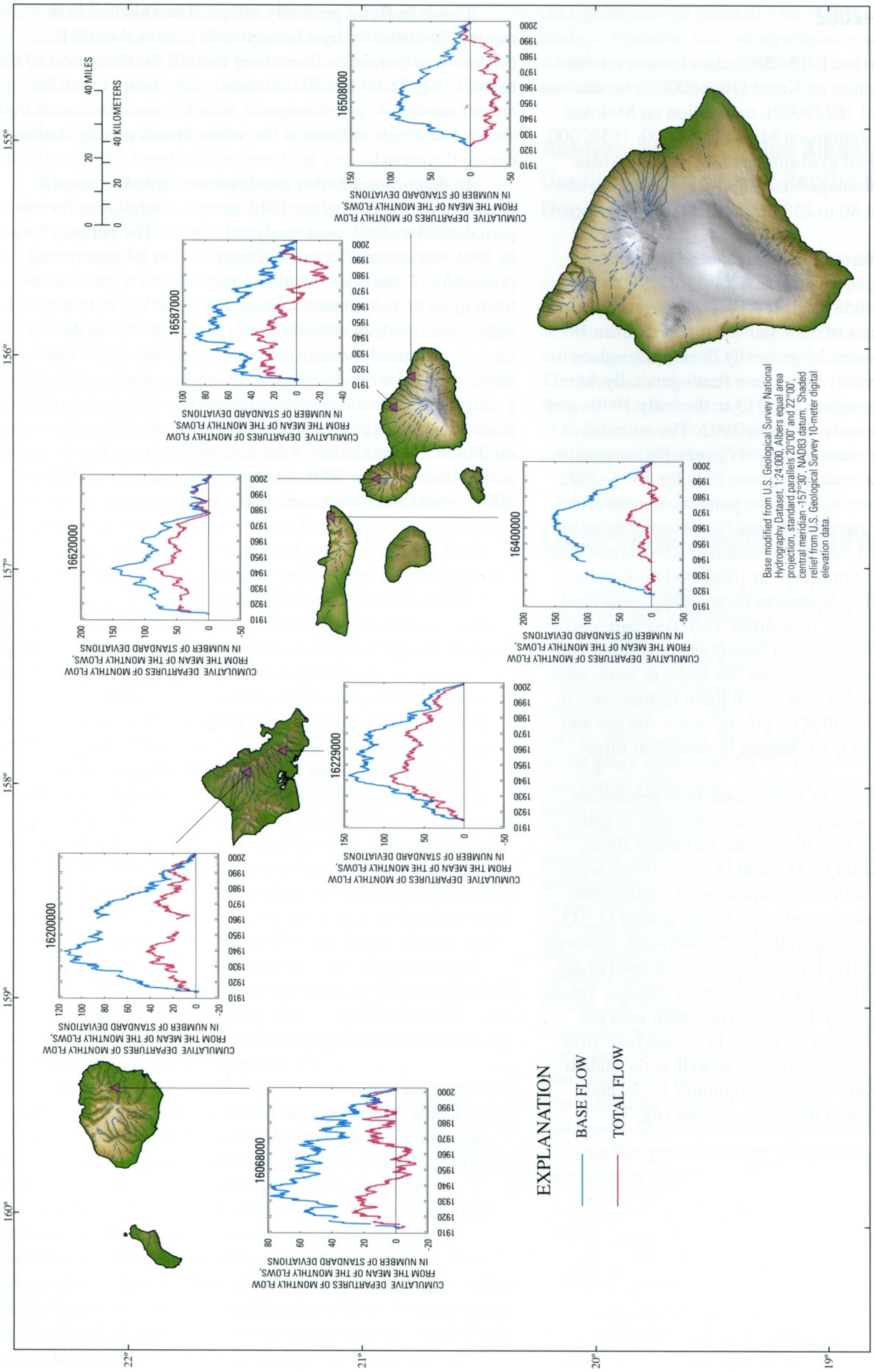
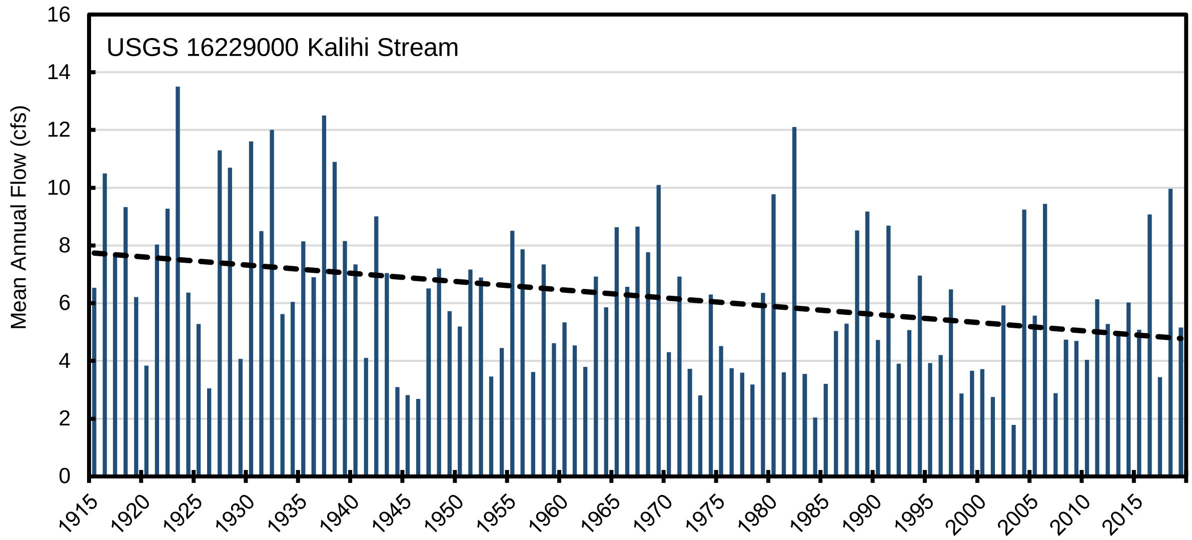


Figure 3-12. Mean annual flow (cubic feet per second, cfs) at USGS station 16229000 on Kalihi Stream, Oahu. Line represents linear regression trend over the period of record. (Source: USGS, 2020)



4.0 Maintenance of Fish and Wildlife Habitat

When people in Hawaii consider the protection of instream flows for the maintenance of fish habitat, their thoughts generally focus on just a handful of native species including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and one prawn. Table 4-1 below identifies commonly mentioned native stream animals of Hawaii.

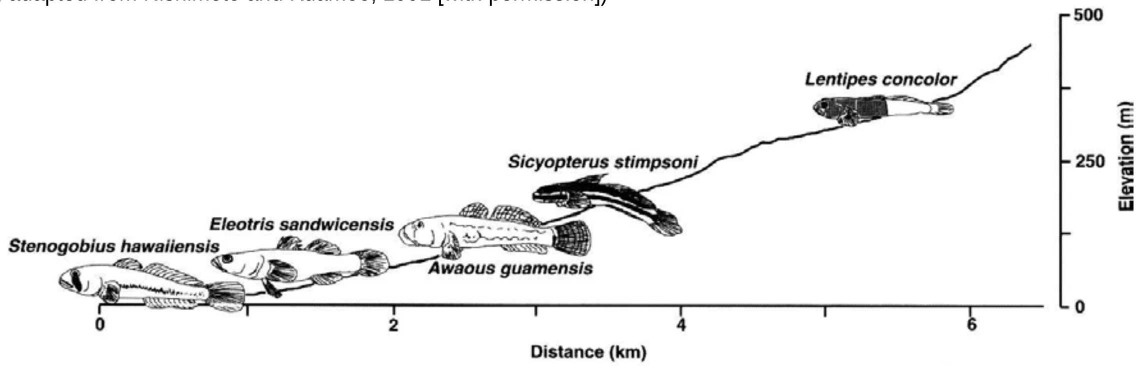
Table 4-1. List of commonly mentioned native stream organisms. (Source: State of Hawaii, Division of Aquatic Resources, 1993)

Scientific Name	Hawaiian Name	Type
Awaous stamineus	‘O‘opu nakea	Goby
Lentipes concolor	‘O‘opu hi‘ukole (alamo‘o)	Goby
Sicyopterus stimpsoni	‘O‘opu nopili	Goby
Stenogobius hawaiiensis	‘O‘opu naniha	Goby
Eleotris sandwicensis	‘O‘opu akupa (okuhe)	Eleotrid
Atyoida bisulcata	‘Opae kala‘ole	Shrimp
Macrobrachium grandimanus	‘Opae ‘oeha‘a	Prawn
Neritina granosa	Hihiwai	Snail
Neritina vespertina	Hapawai	Snail

Hawaii’s native stream animals have amphidromous life cycles (Ego, 1956) meaning that they spend their larval stages in the ocean (salt water), then return to freshwater streams to spend their adult stage and reproduce. Newly hatched fish larvae are carried downstream to the ocean where they become part of the planktonic pool in the open ocean. The larvae remain at sea from a few weeks to a few months, eventually migrating back into a fresh water stream as juvenile *hinana*, or postlarvae (Radtke et al., 1988). Once back in the stream, the distribution of the five native fish species are largely dictated by their climbing ability (Nishimoto and Kuamoo, 1991) along the stream’s longitudinal gradient. This ability to climb is made possible by a fused pelvic fin which forms a suction disk. *Eleotris sandwicensis* lacks fused pelvic fins and is mostly found in lower stream reaches. *Stenogobius hawaiiensis* has fused pelvic fins, but lacks the musculature necessary for climbing (Nishimoto and Kuamoo, 1997). *Awaous guamensis* and *Sicyopterus stimpsoni* are able to ascend moderately high waterfalls (less than ~20 meters) (Fitzsimons and Nishimoto, 1990), while *Lentipes concolor* has the greatest climbing ability and has been observed at elevations higher than 3,000 feet (Fitzsimons and Nishimoto, 1990) and above waterfalls more than 900 feet in vertical height (Englund and Filbert, 1997). Figure 4-1 illustrates the elevational profile of these native fresh water fishes.

The maintenance, or restoration, of stream habitat requires an understanding of and the relationships among the various components that impact fish and wildlife habitat, and ultimately, the overall viability of a desired set of species. These components include, but are not limited to, species distribution and diversity, species abundance, predation and competition among native species, similar impacts by alien species, obstacles to migration, water quality, and streamflow. The Commission does not intend to delve into the biological complexities of Hawaiian streams, but rather to present basic evidence that conveys the general health of the subject stream. The biological aspects of Hawaii’s streams have an extensive history, and there is a wealth of knowledge, which continues to grow and improve.

Figure 4-1. Elevational profile of a terminal-estuary stream on the Big Island of Hawaii (Hakalau Stream). (Source: McRae, 2007, adapted from Nishimoto and Kuamoo, 1991 [with permission])



Hawaii Stream Assessment

One of the earliest statewide stream assessments was undertaken by the Commission in cooperation with the National Park Service's Hawaii Cooperative Park Service Unit. The 1990 Hawaii Stream Assessment (HSA) brought together a wide range of stakeholders to research and evaluate numerous stream-related attributes (e.g., hydrology, diversions, gaging, channelizations, hydroelectric uses, special areas, etc.). The HSA specifically focused on the inventory and assessment of four resource categories: 1) aquatic; 2) riparian; 3) cultural; and 4) recreational. Though no field work was conducted in its preparation, the HSA involved considerable research and analysis of existing studies and reports. The data were evaluated according to predefined criteria and each stream received one of five ranks (outstanding, substantial, moderate, limited, and unknown). Based on the stream rankings, the HSA offered six different approaches to identifying candidate streams for protection: streams with outstanding resources (aquatic, riparian, cultural or recreational), streams with diverse or "blue ribbon" resources, streams with high quality natural resources, streams within aquatic resource districts, free flowing streams, or streams within the National Wild and Scenic Rivers database.

Due to the broad scope of the HSA inventory and assessment, it continues to provide a valuable information base for the Commission's Stream Protection and Management Program and will continue to be referred to in various sections throughout this report. The HSA did not recommend that the Heeia hydrologic unit streams be listed as candidate streams for protection based on riparian, cultural, aquatic and recreational resources. At the time of the assessment, only one of the four group one native species (*Awaous stamineus*) had been observed in Heeia Stream. Additionally, seven group two native species had been observed in the stream.

DAR Atlas of Hawaiian Watersheds

The HSA inventory was general in nature, resulting in major data gaps, especially those related to the distribution and abundance of aquatic organisms – native and introduced – inhabiting the streams. The State of Hawaii Division of Aquatic Resources (DAR) has since continued to expand the knowledge of aquatic biota in Hawaiian streams. Products from their efforts include the compilation and publication of an *Atlas of Hawaiian Watersheds and Their Aquatic Resources* for each of five major islands in the state (Kauai, Hawaii, Oahu, Molokai, and Maui). Each atlas describes watershed and stream features, distribution and abundance of stream animals and insect species, and stream habitat use and availability. Based on these data, a watershed and biological rating is assigned to each stream to allow easy comparison with other streams on the same island and across the state. The data presented in the atlases are collected from various sources, and much of the stream biota data are from stream surveys conducted by DAR. Currently, efforts have been focused on updating the atlases with more recent stream survey data collected statewide, and developing up-to-date reports for Commission use in interim IFS recommendations. Since the HSA was released, additional surveys have identified other group one native species (i.e., *Eleotris sandwicensis*, *Stenogobius hawaiiensis*). A copy of the updated inventory report for Heeia is in Appendix A. The following is a summary of the findings.

- **Point Quadrat Survey.** In the Heeia watershed, stream surveys were conducted in 1975, 1977, 1995, and 2003 by the Division of Aquatic Resources. A variety of native and invasive species have been identified in the hydrologic unit, mostly in the estuary, lower, and middle reaches (Table 4-2). However, no DAR surveys have been conducted in the headwaters or since estuarine restoration has taken place. Streamflow restoration would likely benefit recruitment and survival of native species in the estuary, lower, and middle reaches.

- **Insect Survey.** At least one native damselfly species (e.g., *Megalagrion nigrohamatum nigrolineatum*) has been identified in the Heeia hydrologic unit, meeting the criteria as a biotic stream of importance for native macrofauna diversity (>5 spp.). However, the watershed did not meet the DAR qualification for native insect diversity (>19 spp).

- **Watershed and Biological Rating.** The Heeia watershed has a average rating for Oahu and statewide for land cover due to the high percentage of conservation land. The extensive wetland and estuarine reaches give the watershed one of the highest ratings for shallow waters on Oahu and statewide. However, the watershed rates poorly for stewardship due to the degree of urbanization, channelization, and invasive species. Heeia Stream has a low rating for stream size, and for wetness, and an average reach diversity resulting in an average total watershed rating for Oahu and statewide. The watershed rates average for number of native species found and for introduced species, resulting in an average all species and total biological rating for the island and the state. These scores combined gave Heeia watershed an above average overall watershed rating.

Table 4-2. Present (P) of native species by stream reach for the Heeia Hydrologic unit, Oahu. (Source: DAR, 2006)

species	Estuary	Lower	Middle	Upper	Headwaters
Atyoida bisulcata			P		
Macrobrachium grandimanus		P			
Kuhlia sandvincensis		P			
Awaous stamineus					
Eleotris sandwicensis		P			
Sicyopterus stimpsoni					
Stenogobius hawaiiensis		P			

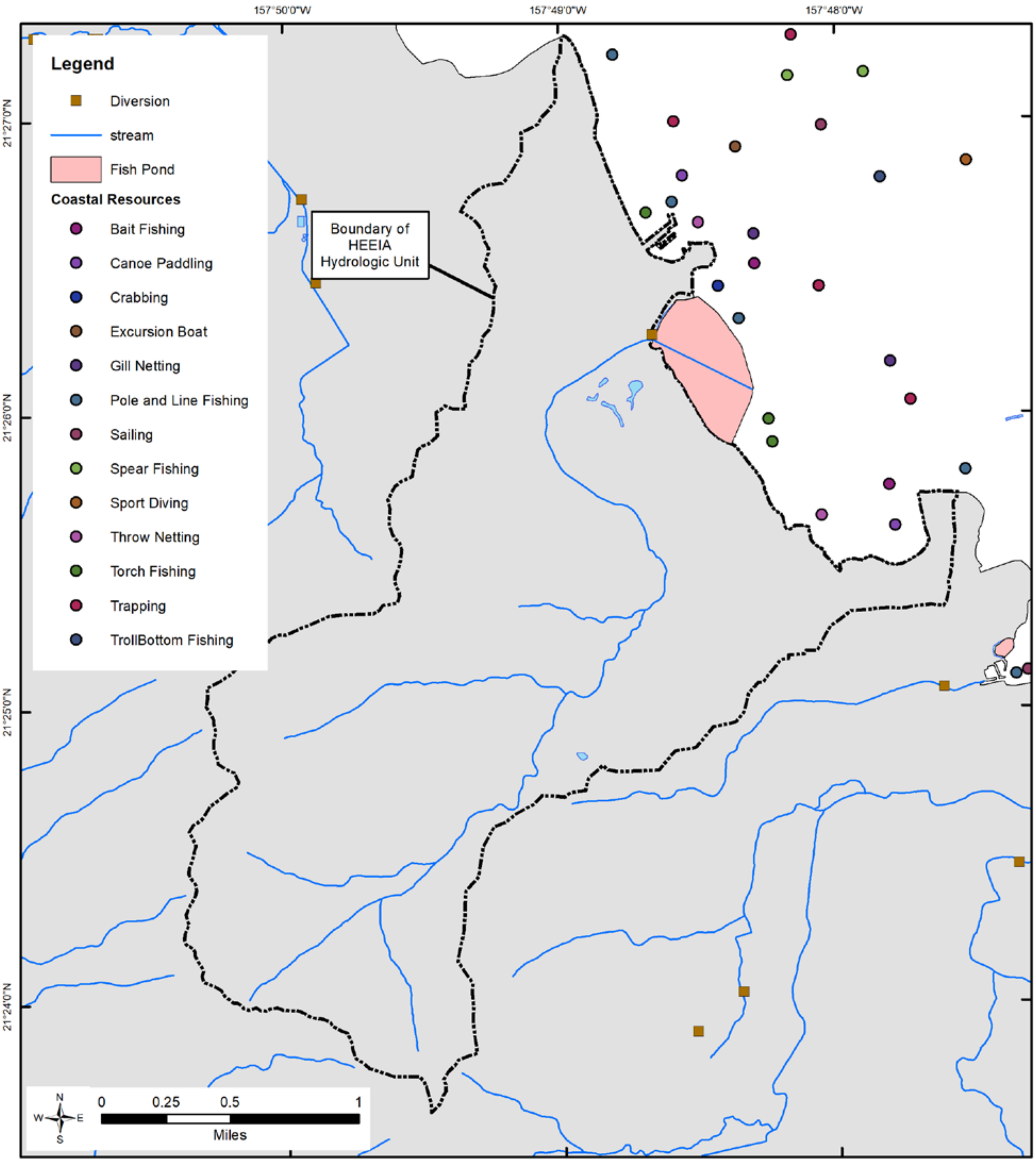
5.0 Outdoor Recreational Activities

Water-related recreation is an integral part of life in Hawaii. Though beaches may attract more users, the value of maintaining streamflow is important to sustaining recreational opportunities for residents and tourists alike. Streams are often utilized for water-based activities, such as boating, fishing, and swimming, while offering added value to land-based activities such as camping, hiking, and hunting. Growing attention to environmental issues worldwide has increased awareness of stream and watershed protection and expanded opportunities for the study of nature; however, this must be weighed in conjunction with the growth of the eco-tourism industry and the burdens that are placed on Hawaii's natural resources.

The Hawaii Stream Assessment identified fishing, swimming, boating, and parks as stream recreational opportunities in the Heeia hydrologic unit and the regional committee classified the streams as "substantial" (National Park Service, 1990). There are many additional near-shore and inland recreational opportunites, including hiking, swimming, scenic views, and cultural experiences (Figure 5-1). Mammal control is informally permitted in one portion of the Heeia marsh, but not in the rest of the hydrologic units. The Heeia stream, fish pond, and Heeia marsh are associated with recreational opportunities such as bird watching, fishing, hiking and standup paddle boarding.

Since changes to streamflow and stream configurations have raised concerns regarding their impact to on-shore and near-shore activities, the Commission attempted to identify these various activities in relation to Maunawili Stream. A 1981 Oahu Resource Atlas, prepared by the State of Hawaii Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available GIS data, some of the activities the Commission identified that were known to occur or observed at or near Heeia include: bait fishing, gill netting, torch fishing, sport diving, throw netting, crabbing, spear fishing (Figure 5-1).

Figure 5-1. Coastal resources and recreational activies in the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2002b)

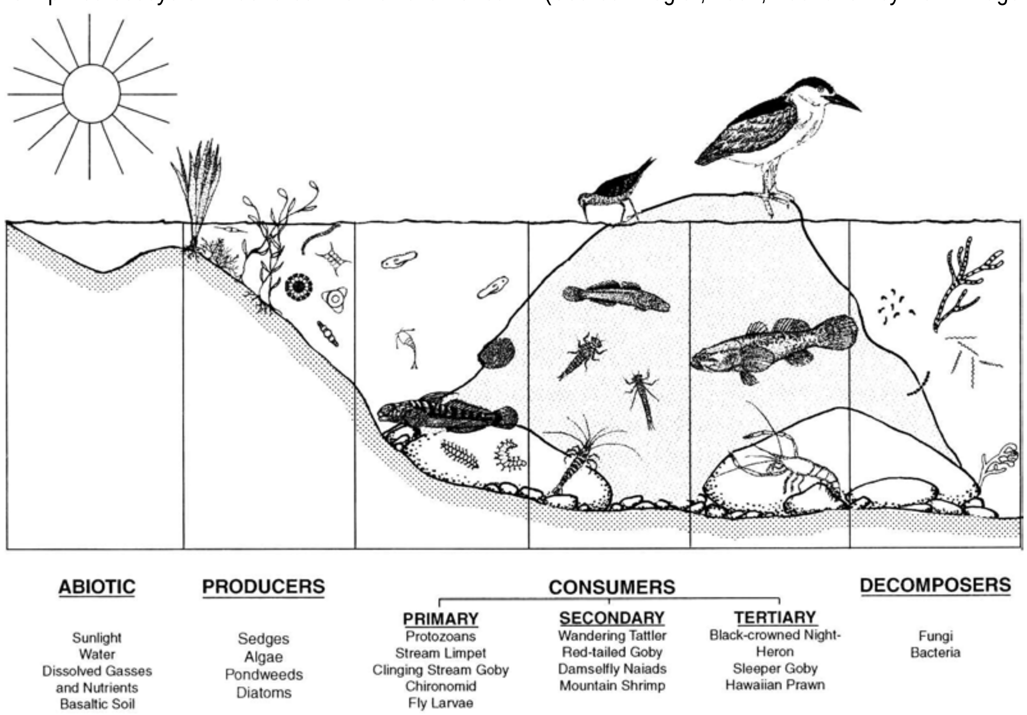


6.0 Maintenance of Ecosystems

An ecosystem can be generally defined as the complex interrelationships of living (biotic) organisms and nonliving (abiotic) environmental components functioning as a particular ecological unit. Depending upon consideration of scale, there may be a number of ecosystem types that occur along a given stream such as estuaries, wetlands, and stream vegetation, according to the State Water Code. Figure 6-1 provides a simplified ecosystem represented in a Hawaiian stream. The entire hydrologic unit, as it relates to hydrologic functions of the stream, could also be considered an ecosystem in a very broad context.

The HSA determined that Heeia Stream deserved to be a candidate stream for protection based on its Diversity of Resources scoring (scored well in Riparian, Cultural, and Recreational rankings) and had a Blue Ribbon Resources scoring (Cultural resources). The Heeia Marsh is one of the remaining wetland habitats from a once vast network of streams and wetlands that stretched along the windward coast. Restoration of the marsh, it’s estuarine habitat, the nearshore fish pond, and upland riparian vegetation has expanded the ecological and cultural values in recent (since 2015) years, although urbanization and invasive vegetation continues to affect water quality and habitat.

Figure 6-1. Simplified ecosystem illustrated in a Hawaiian stream. (Source: Ziegler, 2002, illustration by Keith Kruger).



The Hawaiian resource-use concept of ahupuaa is closely related to the Western concepts of ecosystem maintenance. Native Hawaiians generally utilized natural resources within the limits of their ahupuaa; therefore, it was important to manage and conserve these resources. Likewise, watershed resources must be properly managed and conserved to sustain the health of the stream and the instream uses that are dependent upon it.

The riparian resources of Heeia Stream were classified by the HSA (National Park Service, Hawaii Cooperative Park Service Unit, 1990) and ranked according to a scoring system using six of the seven variables (Table 6-1).

Table 6-1. Hawaii Stream Assessment indicators of riparian resources for Heeia hydrologic units, Oahu. (National Park Service, 1990)

Category	Value
Listed threatened and endangered bird species: These species are generally dependent upon undisturbed habitat. Their presence is, therefore an indication of the integrity of the native vegetation. The presence of these species along a stream course was considered to be a positive attribute; with the more types of threatened and endangered species associated with a stream the higher the value of the resource. Only federally listed threatened or endangered forest or water birds that have been extensively documented within the last 15 years were included.	4
Recovery habitat: Recovery habitat consists of those areas identified by the USFWS and DLNR as essential habitat for the recovery of threatened and endangered species. Streams that have recovery habitat anywhere along their length were included.	Present
Threatened and Endangered Birds: Eighteen species of birds of threatened or endangered birds are associated with streams, four of which are water birds exclusively. The remainder are forest birds whose habitat includes streams but the degree of relationship is unknown.	4
Protected areas: The riparian resources of streams that pass through natural area reserves, refuges and other protected areas are accorded special protection from degradation. Protected areas were so designated because of features other than their riparian resources. The presence of these areas along a stream, however, indicates that native processes are promoted and alien influences controlled.	none
Wetlands: Wetlands are important riparian resources. They provide habitat for many species and are often important nursery areas. Because they are often extensive areas of flat land generally with deep soil, many have been drained and converted to agricultural or urban uses. Those that remain are, therefore, invaluable as well as being indicators of lack of disturbance.	W+ (over ½ mi^2 of palstrine wetland)
Native forest: The proportion of a stream course flowing through native forest provides an indication of the potential “naturalness” of the quality of a stream’s watershed; the greater the percentage of a stream flowing through native forest most of which is protected in forest reserves the more significant the resource. Only the length of the main course of a stream (to the nearest 10 percent) that passes through native forest was recorded.	0%
Detrimental organisms: Some animals and plants have a negative influence on streams. Wild animals (e.g., pigs, goats, deer) destroy vegetation, open forests, accelerate soil erosion, and contaminate the water with fecal material. Weedy plants can dramatically alter the nature of a stream generally by impeding water flow. Three species, California grass, hau, and red mangrove, are considered to have the greatest influence. The presence of any of these animals or plants along a stream course was considered a potentially negative factor, while the degree of detriment is dependent on the number of species present.	Mangrove, California Grass, Hau, Pigs

For the purpose of this section, management areas are those locales that have been identified by federal, state, county, or private entities as having natural or cultural resources of particular value. The result of various government programs and privately-funded initiatives has been a wide assortment of management areas with often common goals. Such designated areas include forest reserves, private preserves, natural area reserves, wildlife sanctuaries, national parks, or historic landmarks. In Heeia, the Hawaii Community Development Authority manages the Heeia Marsh (0.625 square miles, 14 percent) in cooperation with the Kakoo Oiwi, a community-based non-profit corporation to support biological and cultural resources[1]. About 0.338 square miles (7.8 percent) of the hydrologic unit falls within the Waiahole Forest Rreserve (Iolekaa Section) under the jurisdiction of the Department of Land and Natural Resources Division of Forestry and Wildlife. Kamehameha Schools Bishop Estate, the State of Hawaii

[1] http://dbedt.hawaii.gov/hcda/discover-heeia/

Department of Hawaiian Home Lands, and the City & County of Honolulu all own and manage land in Heeia. In addition to the individual management areas outlined above, Watershed Partnerships are another valuable component of ecosystem maintenance. Watershed Partnerships are voluntary alliances between public and private landowners who are committed to responsible management, protection, and enhancement of their forested watershed lands. There are currently ten partnerships established statewide, two of which are on Oahu (Figure 6-2). Table 6-2 provides a summary of the partnership area, partners, and management goals of the Koolau Mountains Watershed Partnership.

Table 6-2. Watershed partnerships associated with the Heeia hydrologic units, Oahu. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008b)

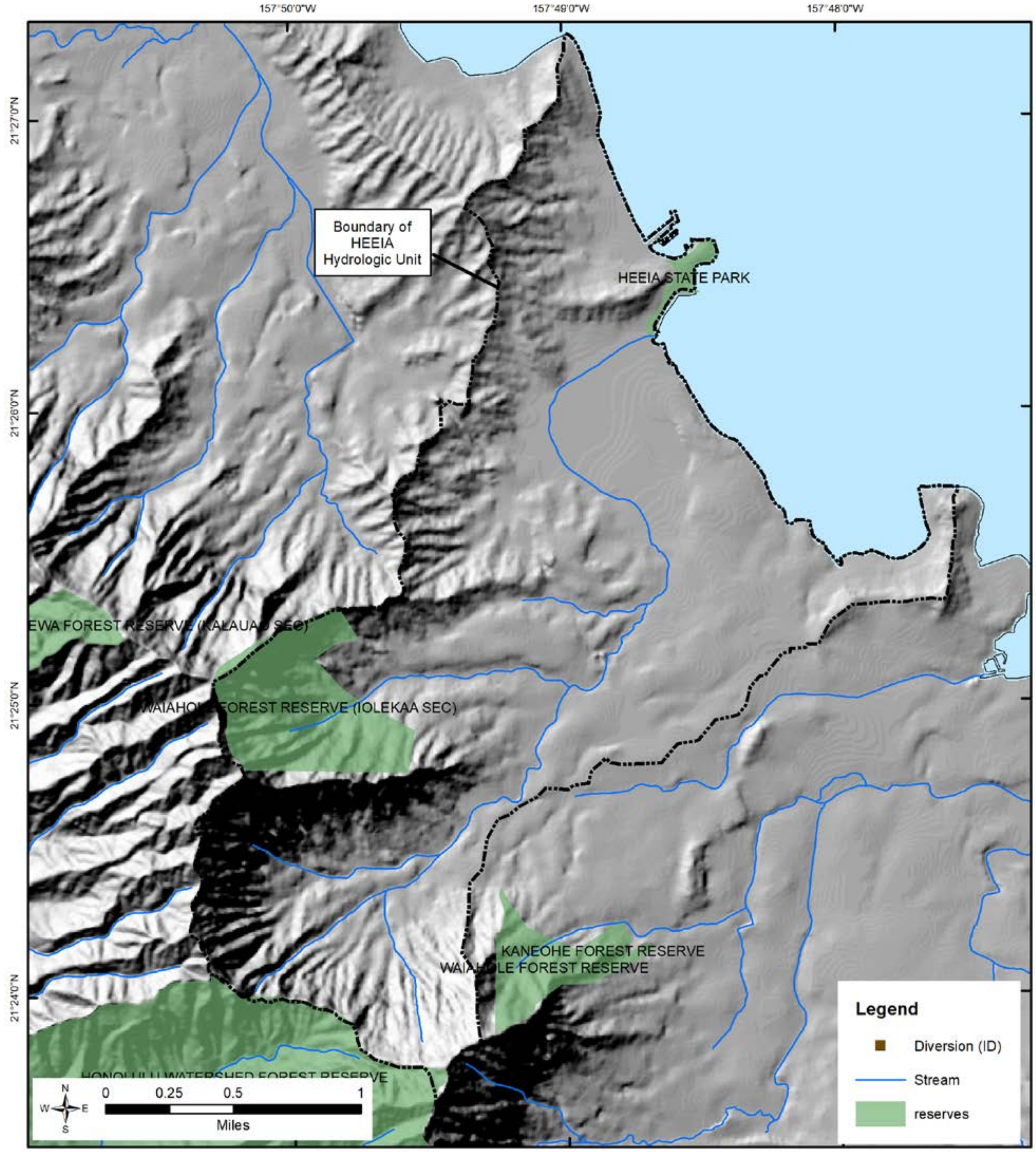
Management Area	Year Established	Total Area (mi^2)	Area (mi^2)	Percent of Unit
Koolau Mountains Watershed Partnership	1999	174.07	1.027	23.3%
The Koolau Mountains Watershed Alliance (KMWA) is comprised of the City and County of Honolulu Board of Water Supply, Dole Food Company Inc, Hawaii Reserves Inc, Waimea Valley (Hiipaka LLC), Kamehameha Schools, Kualoa Ranch, Oahu Country Club, Ohulehule Forest Conservancy LLC, Queen Emma Land Company, State Agribusiness Development Corp, State Department of Hawaiian Home Lands, the State Department of Land and Natural Resources, US Army, and US Fish and Wildlife Service. The management priorities of the KMWP include: 1) Baseline watershed monitoring of forest health and threat assessments; 2) installation of fencing to control movement of feral ungulates; 3) invasive weed control; and 4) light restoration activies.				

In 1974, the U.S. Fish and Wildlife Service (USFWS) initiated a National Wetlands Inventory that was considerably broader in scope than an earlier 1954 inventory that had focused solely on valuable waterfowl habitat. The inventory for Hawaii was completed in 1978 and utilized a hierarchical structure in the classification of various lands. The USFWS defines wetlands as “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water” (Cowardin et al., 1979). Cummulatively, 8.9 percent (0.391 square miles) of the Heeia hydrologic unit is classified as wetlands (estuarine, freshwater emergent, freshwater forested or pond), mostly occurring in the low elevation reaches of the hydrologic unit (Table 6-3 and Figure 6-4). The Heeia Marsh is critical wetland bird habitat. Heeia Watershed was also designated as a National Estuarine Research Reserve, supporting the restoration of a biocultural landscape. The wetlands provide a buffer to stormwater runoff, sediment and nutrients, while supporting habitat for endemic wetland birds as well as food production.

Table 6-3. Wetland classifications for Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2015n)

System Type	Class	Area (mi^2)	Percent of Unit
Palustrine	Freshwater Emergent Wetland	0.278	6.3%
Marine	Estuarine and Marine Wetland	0.052	1.2%
Palustrine	Freshwater Forested/Shrub Wetland	0.038	0.9%
Marine	Estuarine and Marine Deepwater	0.014	0.3%
Palustrine	Freshwater Pond	0.007	0.2%
Palustrine	Riverine	0.002	<0.1%

Figure 6-2. Reserves that include the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2007b; 2015n)



A series of vegetation maps describing upland plant communities was prepared as part of a USFWS survey in 1976 to 1981 to determine the status of native forest birds and their associated habitats. Figure 6-5 identifies critical habitat for plant species near Heeia. There is likely also native and potentially endangered damselfly species (*Megalagrion sp*) in the headwaters or in the Heeia Marsh, although their distribution is not well known. Most of unit is dominated by invasive vegetation and the considerable number of invasive aquatic species may limit their distribution. The density of threatened and endangered plant species is high at elevations above 1,200 feet, resulting in little of the Heeia hydrologic unit to be covered in a high or very high density of threatened and endangered plant species (Table 6-4, Figure 6-6).

Table 6-4. Distribution of native and alien plant species for Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2015f)

Canopy Type	Area (mi^2)	Percent
Very High concentration of threatened and endangered species	0.000	0.0%
High concentration of threatened and endangered species	0.624	14.1%
Medium concentration of threatened and endangered species	0.907	20.5%
Low concentration of threatened and endangered species	1.991	45.1%
Little or no threatened and endangered species	0.898	20.3%

At multiple elevations in Heeia watershed the removal of invasive species and replacement with native vegetation have been the focus of restoration efforts. In the tidally influenced portion of Heeia Stream and its adjacent estuary, the removal of a large stand of invasive riparian trees, including invasive mangrove and hau bush, was followed by soil preparation, erosion control and riparian forest restoration using native and Polynesian-introduced plant species starting in 2015. This estuary project was a joint effort lead by Hui O Ko'olaupoko (non-profit organization), Hawaii State Parks, and other community organizations. Further inland in Heeia Marsh, the removal of hau bush, mangroves, and California grass to restore historic loi and the ecological function of Heeia Marsh have been spearheaded by The Nature Conservancy. Several segments of Heeia Stream in the upland elevations (nearly 2-miles of riparian habitat restoration) have been the focus of efforts by Hui O Ko'olaupoko and partners Kamehameha Schools and Papahana Kuaola focused on building ecological, agricultural, and cultural resources. Together, these projects serve as a model for community-supported watershed restoration and complements other habitat improvement and wetland restoration efforts. The restoration of wetland and estuarine habitats will improve food security, aquaculture, habitat for endangered species, and cultural resource management.

A working paper is being developed by the University of Hawaii's Economic Research Organization (UHERO), entitled *Environmental Valuation and the Hawaiian Economy*, which discusses the use of existing measures of economic performance and alternative statistical devices to provide an economic valuation of threatened environmental resources. The paper focuses on the Koolau, Oahu watershed and illustrates three categories of positive natural capital (forest resources, shoreline resources, and water resources) against a fourth category (alien species) that degrades natural capital. In the case of the Oahu Koolau forests, a benchmark level of degradation is first defined for comparison against the current value of the Oahu Koolau system. The Oahu Koolau case study considers a hypothetical major disturbance caused by a substantial increased population of pigs with a major forest conversion from native trees to the non-indigenous Miconia (*Miconia calvescens*), along with the continued "creep" of urban areas into the upper watershed (Kaiser, B. et al., n.d.). Recognizing that in the United States, the incorporation of environmental and natural resource considerations into economic measures is still very limited, the paper provides the estimated Net Present Value (NPV) for "Koolau [Oahu] Forest Amenities." These values are presented in Table 6-5. Following the results of the Oahu Koolau case study, some of the most valuable aspects of the forested areas are believed to be ecotourism, aesthetic pleasure, species habitat, water quality, and water quantity. Most of Heeia provides no critical habitat for native forest birds with the forests in the uppermost elevations of Haiku valley and cliff vegetation supporting endangered plants or invertebrates.

Table 6-5. Estimated Net Present Value (NPV) for Koolau [Oahu] Forest Amenities. (Source: Kaiser, B. et al., n.d.)

Amenity	Estimated Net Present Value (NPV)	Important limitations
Ground water quantity	$4.57 to $8.52 billion NPV	Optimal extraction assumed.
Water quality	$83.7 to $394 million NPV	Using averted dredging cost estimates.
In-stream uses	$82.4 to $242.4 million NPV	Contingent valuation estimate for a single small fish species.
Species habitat	$487 to $1,434 million NPV	Contingent valuation estimate for a single small bird species.
Biodiversity	$660,000 to $5.5 million NPV	Average cost of listing 11 species in Koolaus.
Subsistence	$34.7 to $131 million NPV	Based on replacement value of pigs hunted.
Hunting	$62.8 to $237 million NPV	Based on fraction of hunting expenditures in state. Does not include damages from pigs to the other amenities.
Aesthetic values	$1.04 to $3.07 million NPV	Contingent valuation; Households value open space for aesthetic reasons.
Commercial harvests	$600,000 to $2.4 million NPV	Based on small sustainable extraction of koa.
Ecotourism	$1.0 to $2.98 billion NPV	Based on fraction of direct revenues to ecotourism activities.
Climate control	$82.2 million	Based on replacement costs of contribution of all tropical forests to carbon sequestration.
Estimated value of joint services:	**$7.444 to $14.032 billion**	

Figure 6-3. The Koolau Mountains Watershed Partnership boundaries in the the Heeia hydrologic unit, Oahu.

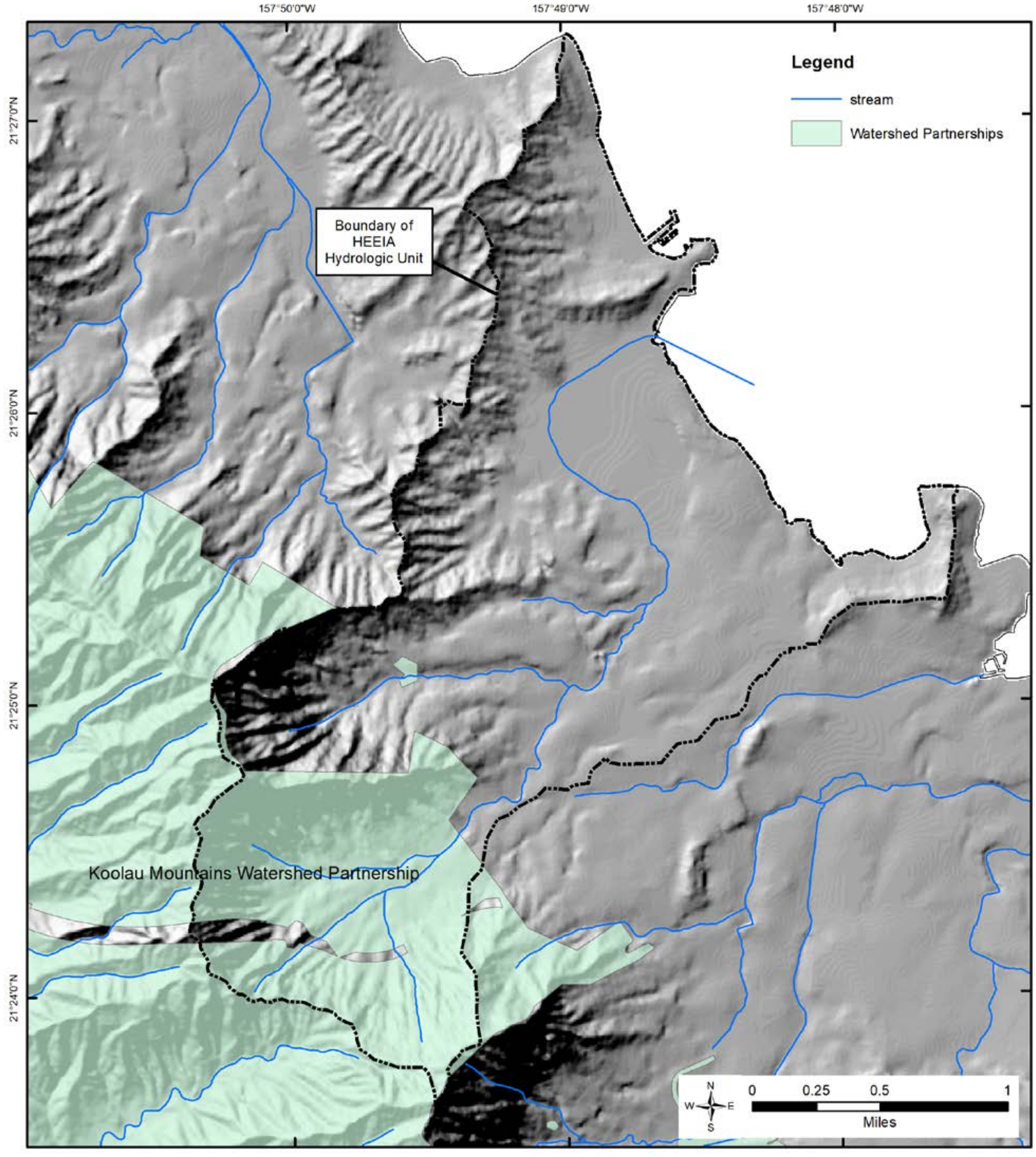


Figure 6-4. Wetlands in the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2007b; 2015c)

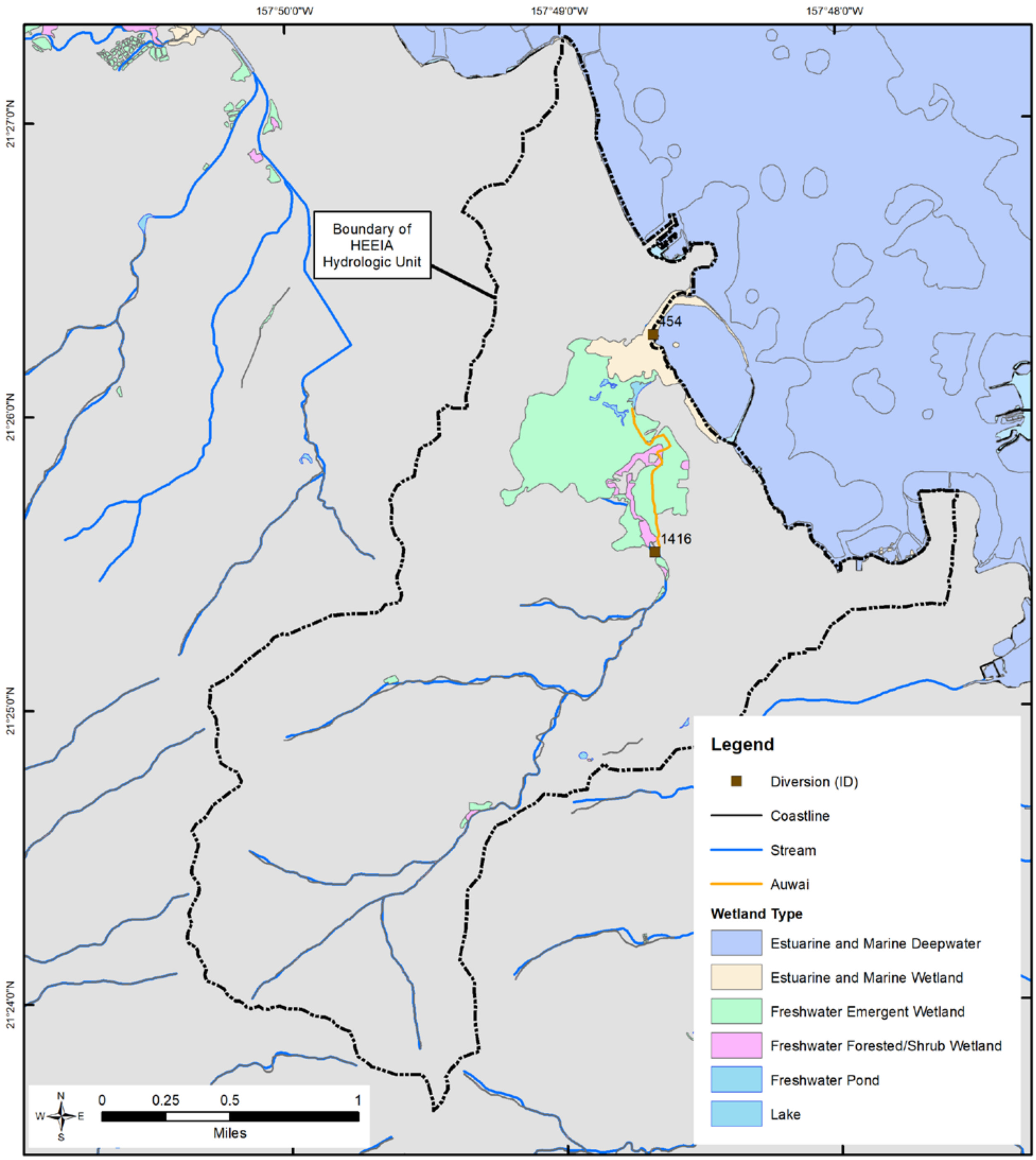


Figure 6-5. Distribution of critical ecosystem habitat in Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2004b)

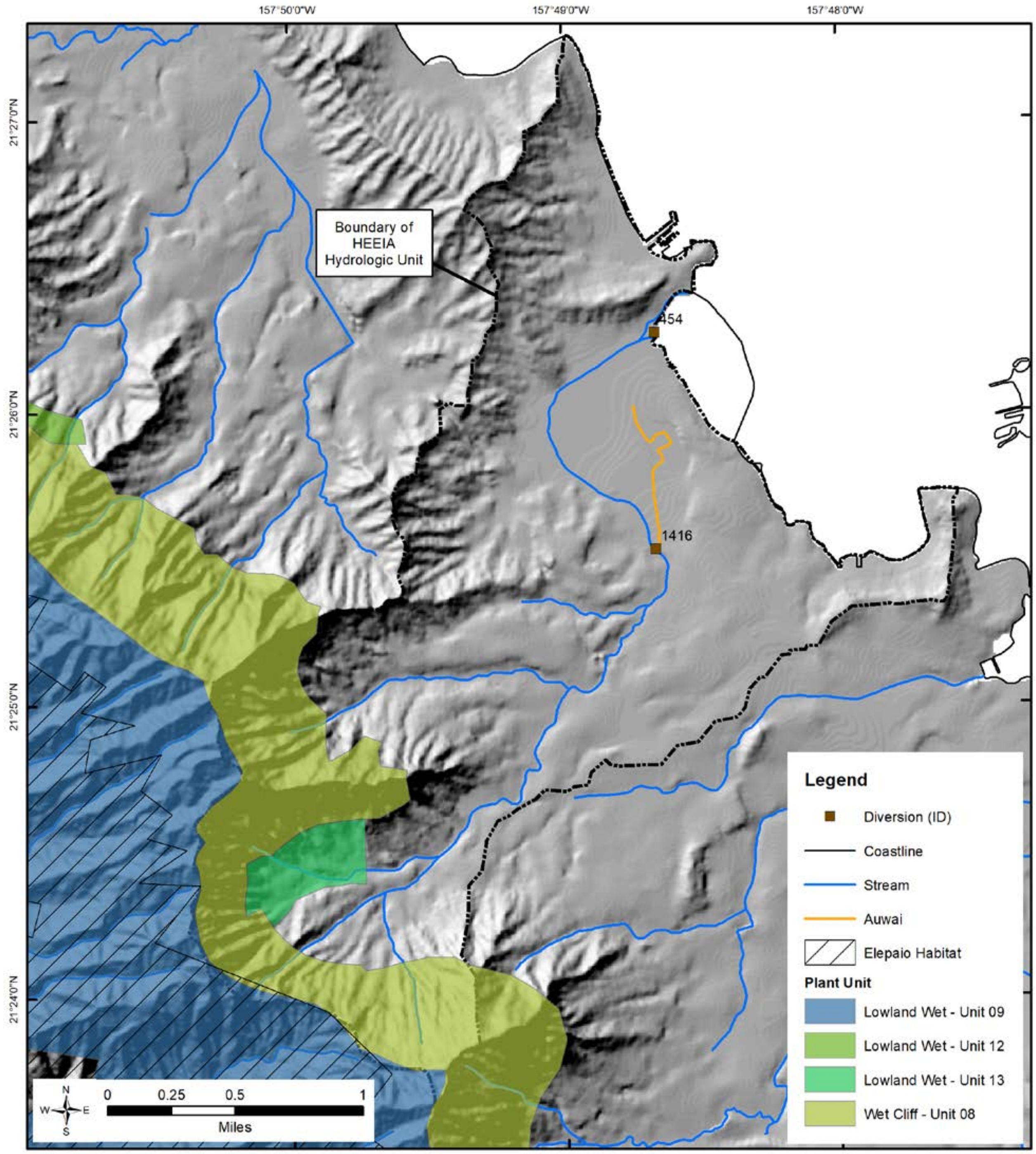
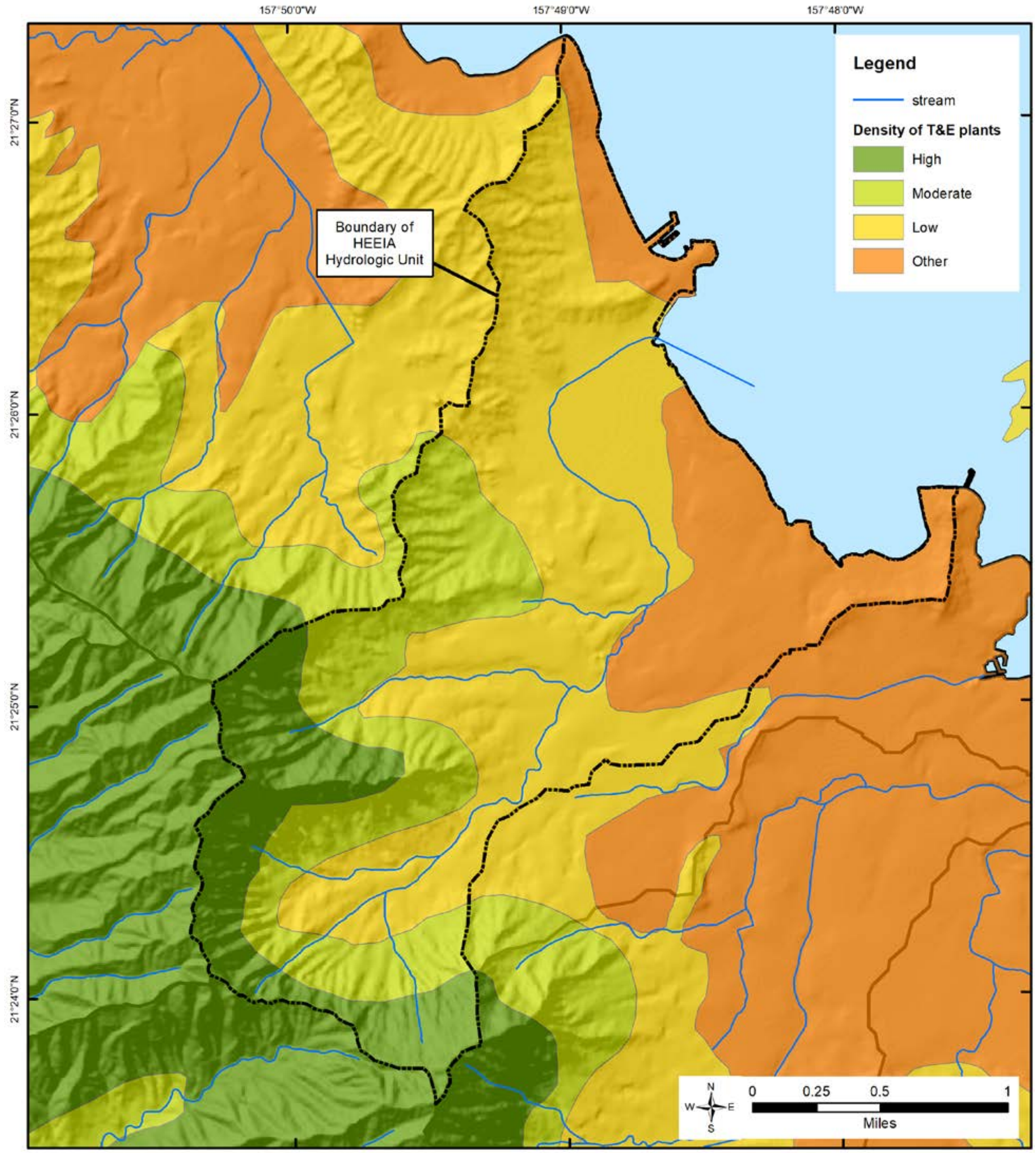


Figure 6-6. Density of threatened and endangered plants in Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2015d)



7.0 Aesthetic Values

Aesthetics is a multi-sensory experience related to an individual's perception of beauty. Since aesthetics is a subjective observation, a stream's aesthetic value cannot be determined quantitatively (Wilson Okamoto & Associates, Inc., 1983). However, there are certain elements, either within or surrounding a stream, which appeal to an observer's visual and auditory senses, such as waterfalls and cascading plunge pools. Visitors and residents can identify a point that has aesthetic value and continue to return to such a point to gain that value. Such points can potentially be identified, as maped. However, the points identified are not exhaustive and it is beyond the scope of this report to list all potential aesthetic values.

The Heeia hydrologic unit supports endemic and endangered birds in the marsh which is accessible to the general public. There are hiking, wildlife viewing, and viewpoint opportunities readily available to appreciate the aesthetic value of Heeia Marsh and Heeia Fish Pond.

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority (OmniTrak Group Inc., 2007), scenic views accounted for 21% of park visits statewide. Other aesthetic-related motivations include viewing famous landmarks (9%), hiking trails and walks (7%), guided tour stops (6%), and viewing of flora and fauna (2%). Out-of-state visitors' most common reasons to visit state parks for scenic views (26%) was the number one reason for visiting a park above outings with family and friends (25%). By contrast, residents primarily used state parks for outings with family and friends (33%) followed by ocean/water activity (23%) and then scenic views (11%). While scenic views accounted for 51% of park activities by residents, they accounted for 82% of visitor activities. Oahu residents were very satisfied with scenic views (9.1 out of 10, with 10 being outstanding), compared to out-of-state visitors giving a score of 9.6 out of 10.

8.0 Navigation

The State Water Code, Chapter 174C, HRS, includes navigation as one of nine identified instream uses; however, it fails to further define navigation. Navigational water use is largely defined as water utilized for commercial, and sometimes recreational, transportation. In the continental United States, this includes water used to lift a vessel in a lock or to maintain a navigable channel level. Under the provisions of the Clean Water Act, navigable waters also include wetlands (State of Nevada, Department of Conservation and Natural Resources, Division of Water Resources, n.d.).

Hawaii streams are generally too short and steep to support navigable uses. If recreational boating (primarily kayaks and small boats) is included under the definition of navigation, then there are only a handful of streams statewide that actually support recreational boating and even fewer that support commercial boating operations. Kauai's Wailua River is the only fresh water waterway where large boat commercial operations exist, and no streams are believed to serve as a means for the commercial transportation of goods.

Their may be stand-up paddle boarding opportunities in the Heeia Marsh and Heeia fish pond, but no general navigation by boats.

9.0 Instream Hydropower Generation

The generation of hydropower is typically accomplished through instream dams and power generators; however, the relatively short lengths and flashy nature of Hawaii's streams often require water to be diverted to offstream power generators. In these "run-of-river" (i.e., utilizes water flow without dams or reservoirs) designs, water is diverted through a series of ditches, pipes, and penstocks to the powerplant, and then returned to the stream. Some designs call for the powerplant to be situated such that the drop of water level (head) exiting the plant can be sent to fields for crop irrigation.

There is no instream hydropower in the Heeia hydrologic unit.

10.0 Maintenance of Water Quality

The maintenance of water quality is important due to its direct impact upon the maintenance of other instream uses such as fish and wildlife habitat, outdoor recreation, ecosystems, aesthetics, and traditional and customary Hawaiian rights. There are several factors that affect a stream's water quality, including physical, chemical, and biological attributes. The State of Hawaii Department of Health (DOH) is responsible for water quality management duties statewide. The DOH Environmental Health Administration oversees the collection, assessment, and reporting of numerous water quality parameters in three high-priority categories:

- Possible presence of water-borne human pathogens;
- Long-term physical, chemical and biological components of inland, coastal, and oceanic waters; and
- Watershed use-attainment assessments, identification of sources of contamination, allocation of those contributing sources, and implementation of pollution control actions.

The Environmental Health Administration is also responsible for regulating discharges into State waters, through permits and enforcement actions. Examples include federal National Pollutant Discharge Elimination System (NPDES) permits for storm water, and discharge of treated effluent from wastewater treatment plants into the ocean or injection wells.

Sediment and temperature are among the primary physical constituents of water quality evaluations. They are directly impacted by the amount of water in a stream. The reduction of streamflow often results in increased water temperatures, whereas higher flows can aid in quickly diluting stream contamination events. According to a book published by the Instream Flow Council, "[w]ater temperature is one of the most important environmental factors in flowing water, affecting all forms of aquatic life (Amear et al, 2004)." While this statement is true for continental rivers, fish in Hawaii are similar, but their main requirement is flowing water. Surface water temperatures may fluctuate in response to seasonal and diurnal variations, but only a few degrees Celsius in natural streams, mainly because streams in Hawaii are so short. However, temperatures in streams with concrete-lined channels, and dewatered streams, may fluctuate widely due to the vertical solar contact. Surface water temperatures may also fluctuate widely due to water column depth, channel substrate, presence of riparian vegetation, and ground water influx. Surface water also differs considerably from ground water, generally exhibiting lower concentrations of total dissolved solids, chlorides, and other major ions, along with higher concentrations of suspended solids, turbidity, microorganisms, and organic forms of nutrients (Lau and Mink, 2006). Findings of a 2004 USGS National Water Quality Assessment (NAWQA) Program report identified land use, storm-related runoff, and ground water inflow as major contributors of surface water contaminants (Anthony et al., 2004). Runoff transports large amounts of sediment from bare soil into surface water bodies, with consequences for in-stream and near-shore environments.

Water body types can be freshwater, marine, or brackish. They can be further delineated as inland fresh waters, estuaries, embayments, open coastal waters, and oceanic waters (HAR 11-54-5 to 11-54-6). Each water body type has its own numeric criteria for State of Hawaii Water Quality Standards (WQS).

Fresh waters are classified for regulatory purposes, according to the adjacent land's conservation zoning. There are two classes for the inland fresh waters. Class 1 inland waters are protected to "remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source." These waters are used for a number of purposes including domestic water supply, protection of native breeding stock, and baseline references from which human-caused changes can be measured.

Class 2 inland waters are protected for uses such as recreational purposes, support of aquatic life, and agricultural water supplies.

Class 1 waters are further separated into Classes 1a and 1b. Class 1a waters are protected for the following uses: scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other non-degrading uses which are compatible with the protection of the ecosystems associated with waters of this class. Streams that run through natural reserves, preserves, sanctuaries, refuges, national and state parks, and state or federal fish and wildlife refuges are Class 1a. Streams adjacent to the most environmentally sensitive conservation subzone, "protective," are Class 1b, and are protected for the same uses as Class 1a waters, with the addition of domestic water supplies, food processing, and the support and propagation of aquatic life (HAR 11-54-3). These classifications are used for regulatory purposes, restricting what is permitted on the land around receiving waters. For example, public access to Class 1b waters may be restricted to protect drinking water supplies.

Land use affects water quality because direct runoff (rainfall that flows overland into the stream) can transport sediment and its chemical contaminants into the stream. The U.S. Environmental Protection Agency (USEPA) defines "[a] TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards are set by States, Territories, and Tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing as well as ecological health), and the scientific criteria required to support those uses. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs (USEPA, 2008)."

The DOH, Environmental Health Administration maintains the State of Hawaii Water Quality Standards (WQS), a requirement under the Federal Clean Water Act (CWA) regulated by the EPA. The CWA aims to keep waters safe for plants and animals to live and people to wade, swim, and fish. Water Quality Standards are the measures that states use to ensure protection of the physical, chemical, and biological health of their waters. "A water quality standard defines the water quality goals of a water body, or portion thereof, by designating the use or uses to be made of the water and by setting criteria necessary to protect the uses (CWA §131.2)." Each state specifies its own water uses to be achieved and protected ("designated uses"), but CWA §131.10 specifically protects "existing uses", which it defines as "…those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards (CWA §131.3)."[1] Although the State WQS do not specify any designated uses in terms of traditional and customary Hawaiian rights, the "protection of native breeding stock," "aesthetic enjoyment," and "compatible recreation" are among the designated uses of Class 1 inland

[1] Existing uses as defined in the CWA should not be confused with existing uses as defined in the State Water Code, although there is some overlap and linkage between the two. Under the Water Code, if there are serious threats to or disputes over water resources, the Commission may designate a "water management area." Water quality impairments, including threats to CWA existing uses, are factors that the Commission may consider in its designation decisions. Once such a management area is designated, people who are already diverting water at the time of designation may apply for water use permits for their "existing uses." The Commission then must weigh if the existing use is "reasonable and beneficial." The Water Code defines "reasonable-beneficial use" as "the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the state and county land use plans and the public interest." The relationships between a Commission existing use and a CWA existing use can help determine the appropriateness of the use and its consistency with the public interest.

waters, and "recreational purposes, the support and propagation of aquatic life, and agricultural and industrial water supplies" are among the designated uses of Class 2 inland waters. This means that uses tied to the exercise of traditional and customary Hawaiian rights that are protected by the State Constitution and the State Water Code (Section 12.0, Protection of Traditional and Customary Hawaiian Rights), including but not limited to gathering, recreation, healing, and religious practices are also protected under the CWA and the WQS as designated and/or existing uses. Therefore, the Commission's interim IFS recommendation may impact the attainment of designated and existing uses, water quality criteria, and the DOH antidegradation policy, which together define the WQS and are part of the joint Commission and DOH obligation to assure sufficient water quality for instream and noninstream uses.

State of Hawaii WQS define: 1) the classification system for State surface waters, which assigns different protected uses to different water classes; 2) the specific numeric or narrative water quality criteria needed to protect that use; and 3) a general antidegradation policy, which maintains and protects water quality for the uses defined for a class. Quantitative and qualitative data are utilized. Numeric water quality criteria have specific concentrations (levels of pollutants) that must be attained based on water body type, e.g. fresh water stream. Qualitative standards are general narrative statements that are applicable to all State waters, such as "all waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants (State of Hawaii, Department of Health, 2004)." Conventional pollutants include nutrients and sediments. Toxic pollutants include pesticides and heavy metals. Indicator bacteria are utilized to assess bacterial levels. Biological assessments of aquatic communities are also included in the data collected.

Once data are gathered and evaluated for quality and deemed to be representative of the waterbody segment, a decision is made as to whether the appropriate designated uses are being attained. This set of decisions are then tabulated into a report to the EPA that integrates two CWA sections; (§) 305(b) and §303(d). This Integrated Report is federally required every even-numbered year[2]. CWA §305(b) requires states to describe the overall water quality statewide. They must also describe the extent to which water quality provides for the protection and propagation of a balanced population of shellfish, fish, and wildlife and allows recreational activities in and on the water. Additionally, they determine whether the designated uses of a water body segment are being attained, and if not, what are the potential causes and sources of pollution. The CWA §303(d) requires states to submit a list of Water-Quality Limited Segments, which are waters that do not meet state water quality standards and those waters' associated uses. States must also provide a priority ranking of waters listed for implementation of pollution controls, which are prioritized based on the severity of pollution and the uses of the waters. In sum, the §303(d) list leads to action. In 2018, the DOH Clean Water Branch published their biennial water quality monitoring and assessment report to meet the CWA §303(d) and CWA §305(b) requirements. In this report, Heeia Stream was removed from the list of impaired inland streams.

The sources for the 2018 Integrated Report are data collected from November 1, 2015 to October 31, 2017. The report identifies areas in need of restoration and serves as a baseline to validate the state's efforts to improve water quality. Impaired waters are listed after review of all existing and readily available water quality-related data and information. While available data are not comprehensive of all the streams in the State, all state waters are subject to monitoring (HAR 11-54).

The distribution of on-site sewage disposal systems (e.g., cesspools and septic systems) leads to high levels of pollution in nearby water bodies due to groundwater leaching and runoff. There are many cesspools in the upper elevations of the Heeia hydrologic unit which likely contribute to the high levels of contamination in surface waters at lower elevations (Figure 10-2). The current WQS require the use of

[2]Current and previous reports can be found at: https://health.hawaii.gov/cwb/clean-water-branch-home-page/integrated-report-and-total-maximum-daily-loads/

Enterococci as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational Activities, DOH maintains WQS for inland recreational waters based on the geo-mean statistic of *Enterococci*: 33 colony-forming units per 100 mL of water or a single-sample maximum of 89 colonies per 100 mL. This is for full-body contact (swimming, jumping off cliffs into waterfall pools, etc.). If *Enterococci* count exceeds those values, the water body is considered impaired. DOH Clean Water Branch efforts have been focused on coastal areas (State of Hawaii, Department of Health, 2006, Chapter II, p.20). The marine recreational zone, which extends from the shoreline seaward to 1,000 feet from shore, requires an *Enterococci* geo-mean of less than 7 colony-forming units per 100 mL of water to protect human health (HAR 11-54-8).

The 2012 Integrated Report also states: "Public health concerns may be underreported. *Leptospirosis* is not included as a specific water quality standard parameter. However, all fresh waters within the state are considered potential sources of *Leptospirosis* infection by the epidemiology section of the Hawaii State Department of Health. No direct tests have been approved or utilized to ascertain the extent of the public health threat through water sampling. Epidemiologic evidence has linked several illness outbreaks to contact with fresh water, leading authorities to issue blanket advisories for all fresh waters of the state (State of Hawaii, Department of Health, 2007, Chapter II, p.3)."

Heeia Stream is classified as Class 1a inland waters from its headwaters to approximately the 700 ft elevation as the surrounding land is in the conservation subzone "protective." It should be noted that the conservation subzone map utilized for this interpretation is general and elevations are not exact. It should also be noted that there is no direct relationship between elevation and attainment of water quality standards. Figure 10-1 shows the Heeia hydrologic unit, including inland and marine (coastal) water classifications.

Data from other sources are also available evaluate water quality problems in streams. In 1980s and 1990s, the US Geological Survey sampled vaious water quality parameters at USGS station 16275000 on Heeia Stream. Water quality data collected from multiple locations in Heeia are summarized in Table 10-1.

Marine water body types are delineated by depth and coastal topography. Open coastal waters are classified for protection purposes from the shoreline at mean sea level laterally to where the depth reaches 100 fathoms (600 feet). Marine water classifications are based on marine conservation areas. The objective of Class AA waters is that they "remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions." Class A waters are protected for recreational purposes and aesthetic enjoyment; and protection of fish, shellfish, and wildlife. Discharge into these waters is permitted under regulation. In the 2018 DOH report, only 108 marine water bodies were assessed with 81.5% not attaining water quality standards for at least one or more conventional pollutants (usually turbidity). Further, 66% of marine assessments failed to meet nutrient water quality standards, and 47% failed to meet the chlorophyll *a* standard. only 88 streams statewide had sufficient data for evaluation of whether exceedance of WQS occurred. The marine waters at the mouth of the Heeia hydrologic unit are Class A waters. In the 2018 DOH report, Heeia Stream was identified as not meeting inland water quality standards for dry season enterococci and total nitrogen, but attained the standard for wet season parameters. Similarly, for marine waters, Heeia Kea small boat harbor did not meet the standards for total nitrogen and chlorophyll *a* in 2018.

Following the designation of Heeia Stream as an impaired inland waterbody in 2004, the State of Hawaii Department of Health Clean Water Branch has funded multiple projects to improve runoff, soil erosion, and overall water quality, including some of the restoration efforts described in section 5.0. Additional work is needed to connect onsite sewage disposal systems to county sewer systems.

Table 10-1. Mean and standard deviation (SD) water quality parameters for various locations in the Heeia hydrologic unit, Oahu (Source: EPA, 2020)

station ID		**station name**		**elevation (ft):**							
21HI-322202											
temperature		Phosphorus		Silica		Salinity		DO		pH	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
55	22.8 (1.4)	55	0.04 (0.06)	55	27.96 (2.27)	55	0.09 (0.01)	55	7.62 (1.72)	55	8.07 (1.15)
Ammonia		Chlorophyll a		Nitrate + Nitrite		Nitrogen		Turbidity		TSS	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
47	0.01 (0.01)	55	0.00 (0.00)	55	0.23 (0.11)	55	0.36 (0.18)	55	3.42 (1.78)	54	5.19 (4.49)
station ID		**station name**		**elevation (ft):**							
21HI-322203											
temperature		Phosphorus		Silica		Salinity		DO		pH	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
54	21.1 (0.9)	53	0.05 (0.06)	53	27.55 (2.89)	54	0.08 (0.01)	54	8.11 (1.81)	54	7.90 (1.44)
Ammonia		Chlorophyll a		Nitrate + Nitrite		Nitrogen		Turbidity		TSS	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
35	0.01 (0.01)	53	0.00 (0.00)	53	0.09 (0.04)	53	0.13 (0.07)	54	1.32 (1.33)	51	3.69 (5.72)
16275000		Heeia Stream at USGS 16275000			**elevation (ft):** 272						
temperature		Phosphorus		Orthoposphate		Sodium		Alkalinity		pH	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
164	20.7 (0.84)	43	0.05 (0.07)	25	0.03 (0.04)	39	12.0 (0.61)	38	48.2 (7.9)	170	7.56 (0.40)
Nitrate		Organic N		Ammonia + Ammonium		Kjeldahl Nitrogen		Specific Cond.		TSS	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
21	0.09 (0.10)	2	0.15 (0.18)	8	0.02 (0.01)	12	0.35 (0.18)	170	152 (11.6)	31	13.9 (35.8)
Potassium		Calcium		Silica		Floride		Turbidity		Magnesium	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
39	0.87 (0.19)	39	9.05 (1.39)	39	25.5 (2.7)	14	0.14 (0.11)	118	6.3 (46.5)	39	5.8 (0.79)
Sulfate		Zinc		Strontium		Manganese		Nickel		Organic Carbon	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
39	3.32 (0.87)	16	35.6 (103.0)	26	53.4 (16.3)	57	28.3 (72.1)	13	5.08 (11.6)	24	1.04 (1.46)

Figure 10-1. Water quality standards and water quality sample sites for the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2020h; USEPA, 2020). The classifications are general in nature and should be used in conjunction with Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards.

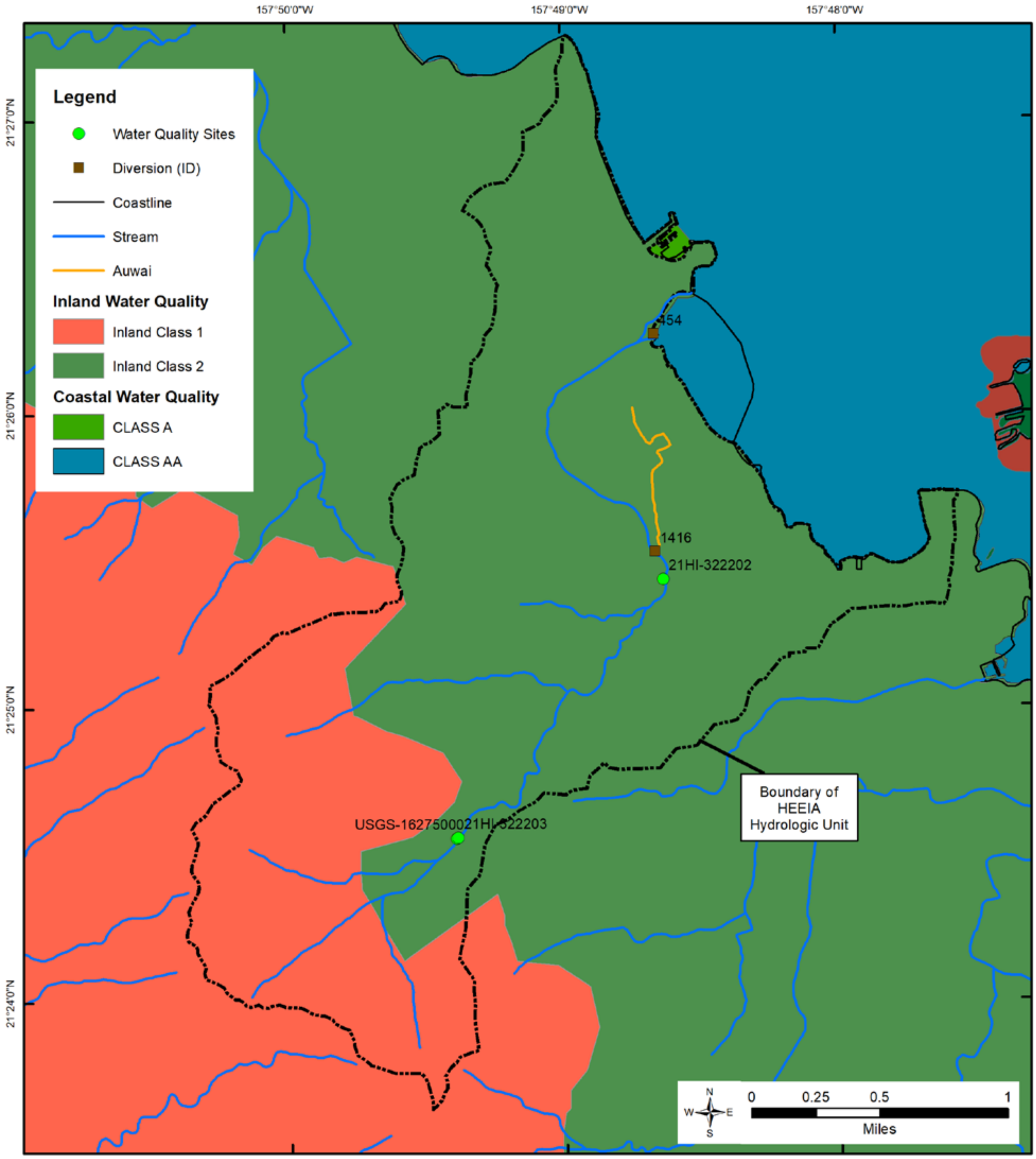
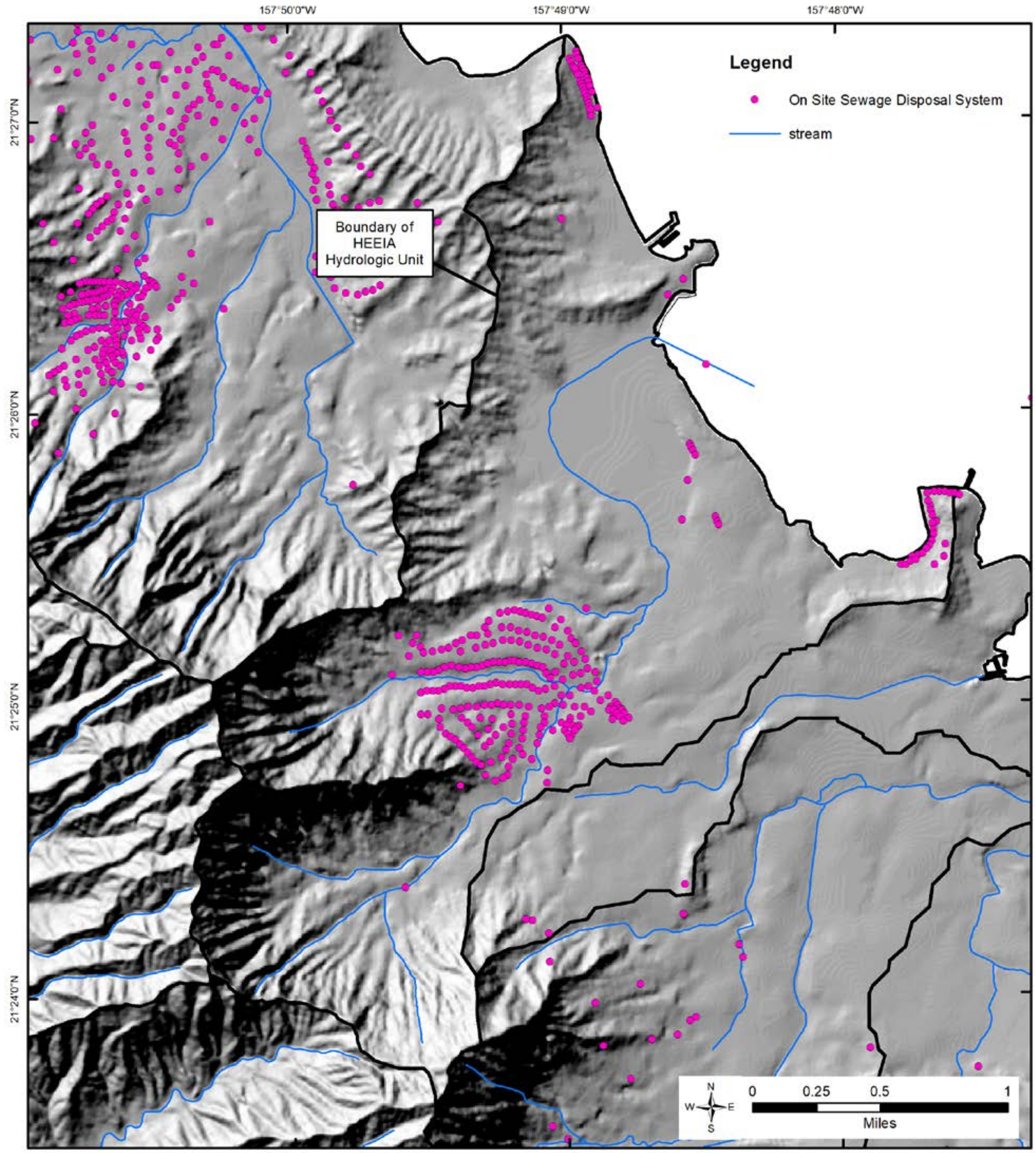


Figure 10-2. On-site sewage disposal systems and wastewater treatment facilities in the Heeia hydrologic units, Oahu. (Source: State of Hawaii Department of Health, 2020)



11.0 Conveyance of Irrigation and Domestic Water Supplies

Under the State Water Code, the conveyance of irrigation and domestic water supplies to downstream points of diversion is included as one of nine listed instream uses. The thought of a stream as a conveyance mechanism for noninstream purposes almost seems contrary to the concept of instream flow standards. However, the inclusion of this instream use is intended to ensure the availability of water to all those who may have a legally protected right to the water flowing in a stream. Of particular importance in this section is the diversion of surface water for domestic purposes. In its August 2000 decision on the Waiahole Ditch Combined Contested Case Hearing, the Hawaii Supreme Court identified domestic water use of the general public, particularly drinking water, as one of, ultimately, four trust purposes.

Neither the State nor the County keeps a comprehensive database of households whose domestic water supply is not part of a municipal system (i.e. who use stream and / or catchment water). The City and County of Honolulu Board of Water Supply does not have data for water users who are not on the county system and may be using catchment or surface water for domestic use. The State of Hawaii Department of Health Safe Drinking Water Branch administers Federal and State safe drinking water regulations to public water systems in the State of Hawaii to assure that the water served by these systems meets State and Federal standards. Any system which services 25 or more people for a minimum of 60 days per year or has at least 15 service connections is subject to these standards and regulations. Once a system is regulated by the Safe Drinking Water Branch, the water must undergo an approved filtration and disinfection process when it has been removed from the stream. It would also be subject to regulatory monitoring. However, there are no private water systems in the Heeia hydrologic units regulated by the DOH, Safe Drinking Water branch.

12.0 Protection of Traditional and Customary Hawaiian Rights

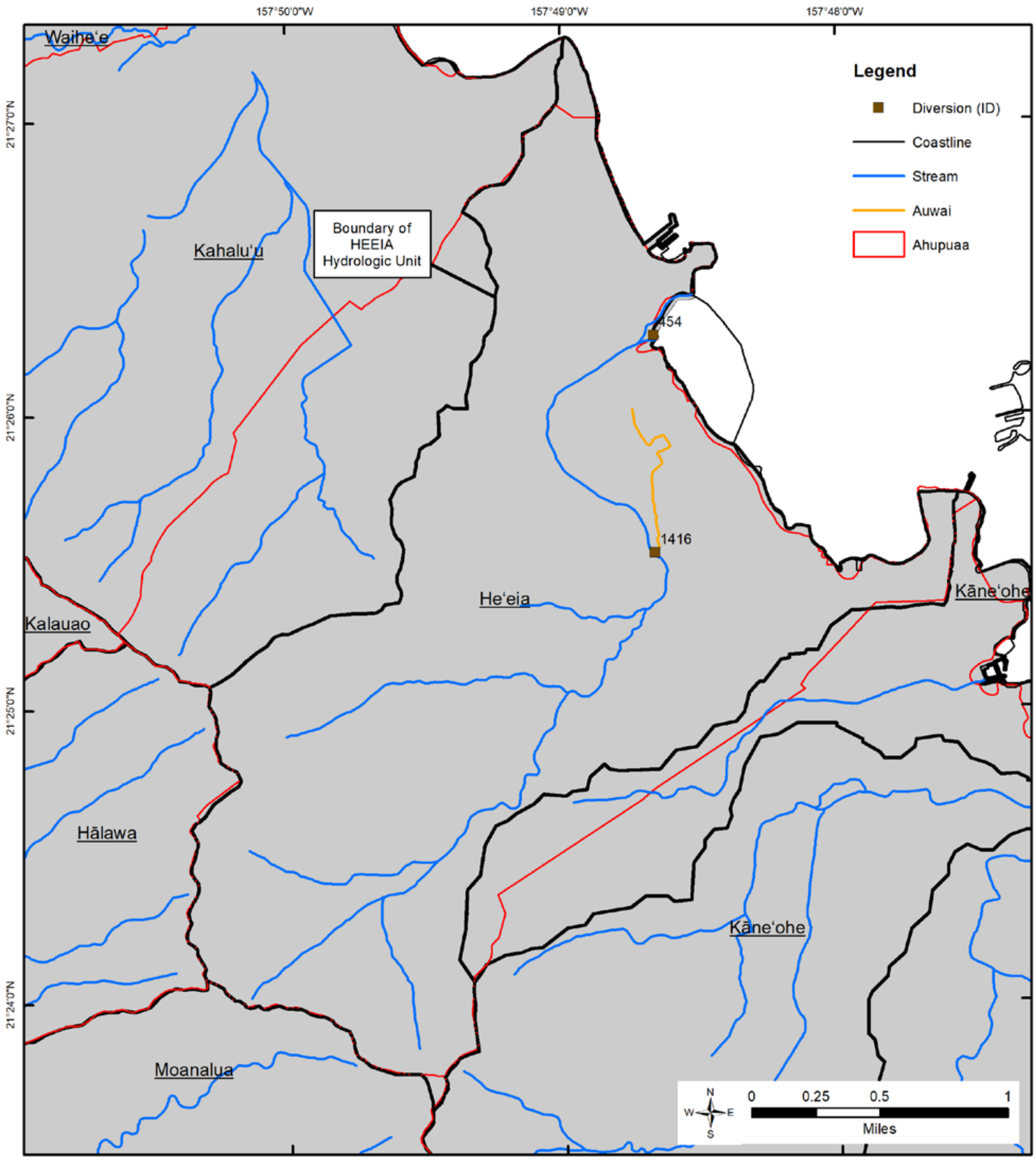
The maintenance of instream flows is important to the protection of traditional and customary Hawaiian rights, as they relate to the maintenance of stream resources (e.g., hihiwai, opae, oopu) for gathering, recreation, and the cultivation of taro. Article XII, Section 7 of the State Constitution addresses traditional and customary rights: "The State reaffirms and shall protect all rights, customarily and traditionally exercised for subsistence, cultural and religious purposes and possessed by ahupuaʻa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778, subject to the right of the State to regulate such rights." Case notes listed in this section indicate, "Native Hawaiian rights protected by this section may extend beyond the *ahupuaʻa* in which a native Hawaiian resides where such rights have been customarily and traditionally exercised in this manner. 73 H.578, 837 P.2d 1247."

It is difficult to fully represent in words the depth of the cultural aspects of streamflow, including traditions handed down through the generations regarding gathering, ceremonial and religious rites, and the ties to water that are pronounced in Hawaiian legend and lore. "There is a great traditional significance of water in Hawaiian beliefs and cultural practices…The flow of water from mountain to sea is integral to the health of the land. A healthy land makes for healthy people, and healthy people have the ability to sustain themselves (Kumu Pono Associates, 2001b, p.II:8)."

Taro cultivation is addressed in this section of the report as well as section 14. This is because instream flow standards take into account both social and scientific information. For sociological and cultural purposes, taro cultivation can be considered an instream use as part of the "protection of traditional and customary Hawaiian rights," that is specifically listed as an instream use in the Water Code. Taro cultivation can also be considered a noninstream use since it removes water from a stream (even if water from taro loi is later returned to the stream). It could be argued that for scientific analysis, taro cultivation is an instream use since taro loi provide habitat for stream biota, but because the water is physically taken out of the stream, it is also a noninstream use. Another way to look at the approach of indentifying taro cultivation as both instream and noninstream uses is that when the Commission addresses taro cultivation as an instream use, it is generally in the context of traditional and customary Hawaiian rights; whereas when the Commission addresses taro cultivation as a noninstream use, it is approaching the issue from the aspects of agriculture and water use.

In ancient Hawaii, the islands (*moku*) were subdivided into political subdivisions, or ahupuaa, for the purposes of taxation. The term ahupuaa in fact comes from the altar (*ahu*) that marked the seaward boundary of each subdivision upon which a wooden head of a pig (*puaa*) was placed at the time of the *Makahiki* festival when harvest offerings were collected for the rain god and his earthly representative (Handy et al., 1972). Each ahupuaa had fixed boundaries that were usually delineated by natural features of the land, such as mountain ridges, and typically ran like a wedge from the mountains to the ocean thus providing its inhabitants with access to all the natural resources necessary for sustenance. The beach, with its fishing rights, were referred to as *ipu kai* (meat bowl), while the upland areas for cultivation were called *umeke ai* (poi container hung in a net) (Handy et al., 1972). As noted earlier in Section 6.0, Maintenance of Ecosystems, Western concepts of ecosystem maintenance and watersheds are similar to the Hawaiian concept of *ahupuaʻa*, and so the Commission's surface water hydrologic units often coincide with or overlap ahupuaa boundaries. The hydrologic unit of Heeia and portions of neighboring hydrologic units are included in the *ahupuaʻa* of Heeia as shown in Figure 12-1. The *ahupuaʻa* boundaries are delineated based on the USGS Digital Line Graphs. These boundaries may be different from the information listed on legal documents such as deeds.

Figure 12-1. Traditional ahupuaa boundaries in the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2015j)



Appurtenant Water Rights

An appurtenant water right is a legally recognized right to a specific amount of surface freshwater – usually from a stream – on the specific property that has that right. This right traces back to the use of water on a given parcel of land at the time of its original conversion into fee simple lands: When the land allotted during the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water if water was being used on that land at or shortly before the time of the Mahele (State of Hawaii, Commission on Water Resource Management, 2007).

An appurtenant right is different from a riparian right, but they are not mutually exclusive. Riparian rights are held by owners of land adjacent to a stream. They and other riparian landowners have the right to reasonable use of the stream's waters on those lands. Unlike riparian lands, the lands to which appurtenant rights attach are not necessarily adjacent to the freshwater source (i.e., the water may be carried to the lands via auwai or ditches), but some pieces of land could have both appurtenant and riparian rights.

Appurtenant rights are provided for under the State Water Code, HRS §174C-101, Section (c) and (d) as follows:

- Section (c). Traditional and customary rights of ahupuaa tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778 shall not be abridged or denied by this chapter. Such traditional and customary rights shall include, but not be limited to, the cultivation or propagation of taro on one's own kuleana and the gathering of hihiwai, opae, oopu, limu, thatch, ti leaf, aho cord, and medicinal plants for subsistence, cultural, and religious purposes.

- Section (d). The appurtenant water rights of kuleana and taro lands, along with those traditional and customary rights assured by this section, shall not be diminished or extinguished by a failure to apply for or to receive a permit under this chapter.

The exercise of an appurtenant water right is still subject to the water use permit requirements of the Water Code, but there is no deadline to exercise that right without losing it, as is the case for correlative and riparian rights, which must have been exercised before designation of a water management area.

In August 2000, the Hawaii Supreme Court issued its decision in the Waiahole Ditch Combined Contested Case Hearing, upholding the exercise of Native Hawaiian and traditional and customary rights as a public trust purpose. These rights are described in the Commission's 2007 *Water Resource Protection Plan – Public Review Draft*, incorporating a later revision[1] as follows:

> Appurtenant water rights are rights to the use of water utilized by parcels of land at the time of their original conversion into fee simple lands i.e., when land allotted by the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water.[2] The amount of water under an appurtenant right is the amount that was being used at the time of the Land Commission award and is established by cultivation methods that approximate the methods utilized at the time of the Mahele, for example, growing wetland taro.[3] Once

[1] Although the final Water Resource Protection Plan had not been printed as of the date of this report, most edits had already been incorporated into the latest version, which the Commission utilized for this report.
[2] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[3] 65 Haw. 531, at 554; 656 P.2d 57, at 72.

established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[4], as long as those uses are reasonable, and if in a water management area, meets the State Water Code's test of reasonable and beneficial use ("the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the State and county land use plans and the public interest"). As mentioned earlier, appurtenant rights are preserved under the State Water Code, so even in designated water management areas, an unexercised appurtenant right is not extinguished and must be issued a water use permit when applied for, as long as the water use permit requirements are met (Figure 12-2).

The Hawaii Legislative Session of 2002 clarified that the Commission is empowered to "determine appurtenant rights, including quantification of the amount of water entitled to by that right," (HRS §174C-5(15)). In those cases, where a Commission decision may affect an appurtenant right, it is the claimant's duty to assert the appurtenant right and to gather the information required by the Commission to rule on the claim. The Commission is currently in the process of developing a procedural manual to aid in the understanding and assembling of information to substantiate an appurtenant rights claim.

In accordance with the State Water Code and the Supreme Court's decision in the Waiahole Ditch Combined Contested Case Hearing, the Commission is focused on the assertion and exercise of appurtenant rights as they largely relate to the cultivation of taro. Wetland kalo or taro (*Colocasia esculenta* (L.) Schott) is an integral part of Hawaiian culture and agricultural tradition. The preferred method of wetland taro cultivation, where terrain and access to water permitted, was the construction of loi (flooded terraces) and loi complexes. These terraces traditionally received stream water via carefully engineered open channels called auwai. The auwai carried water, sometimes great distances, from the stream to the loi via gravity flow. In a system of multiple loi, water may either be fed to individual loi through separate little ditches if possible, or in the case of steeper slopes, water would overflow and drain from one loi to the next. Outflow from the loi may eventually be returned to the stream.

The loi also served other needs including the farming of subsidiary crops such as banana, sugar cane, and ti plants that were planted on its banks, and the raising of fish such as oopu, awa, and aholehole within the waters of the loi itself. At least 85 varieties of taro were collected in 1931, each of which varied in color, locale, and growing conditions. The water needs of taro under wet conditions depend upon: 1) climate; 2) location and season (weather); 3) evaporation rate; 4) soil type; 5) ground water hydrology; 5) water temperature; and 6) agronomic conditions (crop stage; planting density and arrangement; taro variety; soil amendment and fertilization regime; loi drainage scheme; irrigation system management; and weed, pest, and disease prevalence and management).

The Commission conducted a cursory assessment of tax map key parcels to identify their associated Land Commission Awards, in an attempt to identify the potential for future appurtenant rights claims within the hydrologic unit of Heeia. Table 12-1 presents the results of the Commission's assessment. Of particular importance is the presence of terracing and oral testimony that indicates loi kalo existed throughout Heeia. There is evidence that loi kalo was also grown in Heeia wetland (Figure 12-3). The series of TMK parcels and associated land commission awards suggest extensive cultivation of the riparian areas of Heeia stream.

[4] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).

Figure 12-2. Generalized process for determining appurtenant water rights. This process is generalized and may not fully explain all possible situations. It does not apply to Hawaiian Homes Lands. If you are Native Hawaiian you may have other water rights.

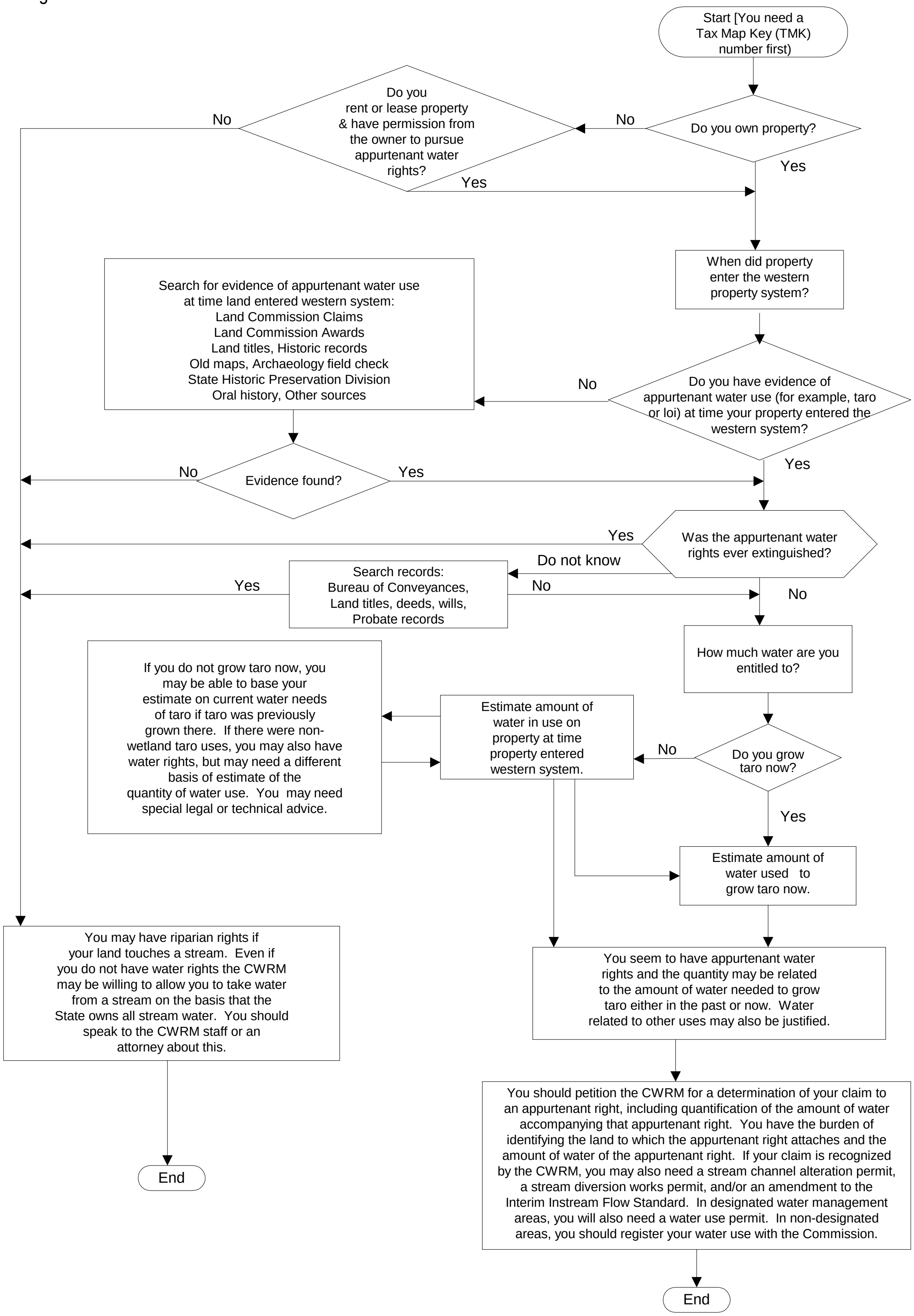


Table 12-1. Land Awards, claimants, associated tax map key (TMK) parcels, and landowners for the Heeia hydrologic units, Oahu. [LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease]

Land Award	TMK	Landowner	Claimant
LCA 10613:1	Many	Many	Paki, A
LCA 5821:1	146015004	Hawaiian Electric Co	Kaniaupio
LCA 1971:1	146036006	Helton, Russell G	Lihue
LCA 1971:2	146015005	Yang , Evelyn L et al.	Lihue
LCA 5969:1	146017022	Eden at Haiku Woods Incr A	Moalea
LCA 5969:2	146015001	C&C of Honolulu	Moalea
LCA 3307:1	146015014	State of Hawaii DHHL	Malalawalu
LCA 3307:2	146015014	State of Hawaii DHHL	Malalawalu
LCA 3307:3	146014001	BP Bishop Trust Estate	Malalawalu
LCA 3393:1	146015014	State of Hawaii DHHL	Pueokahi
LCA 3393:2	146012002	Haiku Gardens	Pueokahi
LCA 4240 B	146014002	Gingerridge LLC	Kauhane
LCA 5530:1	146014001	BP Bishop Trust Estate	Kauhane 2
LCA 5530:2	146017020	Aukai, Josheph Jr	Kauhane 2
LCA 5530:3	146017050	Eden at Haiku Woods Incr B	Kauhane 2
LCA 6047:3	146014004	Chong, Mary W Y Trust	Wahine
LCA 7511	146014006	BP Bishop Trust Estate	Kuweloula
LCA 6039:2	Many	Many	Elemakule
LCA 6039:3	146014006	BP Bishop Trust Estate	Elemakule
LCA 3579 B:1	Many	Many	Kane
LCA 3579 B:2	146014006	BP Bishop Trust Estate	Kane
LCA 3849:2	146017004	Sroat, Donald A Trust Est	Paaiea
LCA 10710:1	146017022	Eden at Haiku Woods Incr A	Paa
LCA 10424:1	146015002	BP Bishop Trust Estate	Naipu
LCA 4221:1	146013048	Kelling, Anthony K	Keakua
LCA 4221:2	146013048	Kwock, David A	Keakua
LCA 4221:3	146010006	Jain, Amod/Suha Trust	Keakua
LCA 6097:2	Many	Many	Unihepa
LCA 6097:1	146013049	Wery, Genie M	Unihepa
LCA 4238:1	146013033	Moriwake, Shigeto Trust	Kanakaoo
LCA 4238:2	146013035	Low, Curtis K H	Kanakaoo
LCA 2562	146026063	Loudat, Thomas A	Nauka
LCA 3347:2	146026063	Loudat, Thomas A	Nauka
LCA 5755:1	Many	Many	Kalaauhuakea
LCA 2370:1	146025095	Miner, Keith E	Komomua
LCA 2370:2	146025043	Siders, Kevin M	Komomua
LCA 2594:1	146025092	Tamanaha, Richard T Trust	Piena
LCA 3308:1	146014001	BP Bishop Trust Estate	Makakehau
LCA 3308:3	146025075	Miller, Marshall B	Makakehau
LCA 3574	146012053	Haiku Realty Ltd	Kahuhu
LCA 7514:2	146017046	Lee, Family Trust	Kupa

Table 12-1. continued.

Land Award	TMK	Landowner	Claimant
LCA 5821:2	146017047	Chinen, Amy E	Kaniaupio
LCA 3571	146012002	Haiku Gardens	Kalehuna
LCA 3306	146016001	State HCDA	Makahelu
LCA 3369 B:1	146016034	Kikukawa, Robert P/ Merle M Trust	Kalehua
LCA 3369 B:2	146016001	State HCDA	Kalehua
LCA 3369 B:3	146008033	Alii Cluster Park Association	Kalehua
LCA 2162:1	146016001	State HCDA	Kalei
LCA 2162:3	146016001	State HCDA	Kalei
LCA 5828:2	146016001	State HCDA	Kapaki
LCA 5828:3	146016034	Kikukawa, Robert P/ Merle M Trust	Kapaki
LCA 10425:1	146016034	Kikukawa, Robert P/ Merle M Trust	Nahuina
LCA 2515:1	146016013	BP Bishop Trust Estate	Makuawahine
LCA 2515:2	146016014	Patacsil, Josehpine E Trust	Makuawahine
LCA 2515:3	146008032	Saito, Dennis K	Makuawahine
LCA 5828:1	146016001	State HCDA	Kapakai
LCA 5828:3	146016034	Kikukawa, Robert P/ Merle M Trust	Kapakai
LCA 26889:1	146016001	State HCDA	Ehuiki
LCA 7523:1	146016001	State HCDA	Kalaau
LCA 7523:2	146016001	State HCDA	Kalaau
LCA 6047:1	146016013	BP Bishop Trust Estate	Wahine
LCA 3572:2	146016001	State HCDA	Kaniaa
LCA 2161:1	146016033	Estioko, Epipania Trust	Kaiwiwena
LCA 5755:2	146016033	Estioko, Epipania Trust	Kalaauhuakea
LCA 10192	146016016	Patacsil, Josehpine E Trust	Manuahi
LCA 10711	146016001	State HCDA	Pa
LCA 3573:1	146016001	State HCDA	Kailaa
LCA 8193:1	146016001	State HCDA	Hina
LCA 8194:1	146016001	State HCDA	Hoka
LCA 10423:1	146016010	Salado, Pedro Y	Napua
LCA 7736:1	146016001	State HCDA	Wahahee
LCA 7736:2	146016001	State HCDA	Wahahee
LCA 4468:1	146016001	State HCDA	Kana
LCA 4467:1	146016017	Sanchez, Pio	Keawe
LCA 3570:1	146016001	State HCDA	Kaauamoa
LCA 10977:1	146016001	State HCDA	Wiwi
LCA 10977:2	146033039	Alii Cluster Park Association	Wiwi
LCA 2161:2	146008004	Silva, Carol L Trust	Kaiwiwena
LCA 2608 B:1	146016001	State HCDA	Puhiki
LCA 2608 B:2	146016001	State HCDA	Puhiki
LCA 2163:1	146016001	State HCDA	Kawahine
LCA 6040:1	146016001	State HCDA	Ehu

Table 12-1. continued.

Land Award	TMK	Landowner	Claimant
LCA 7341:1	146016001	State HCDA	Papa
LCA 2608:1	146016001	State HCDA	Puahiki
LCA 2608:1	146005009	State DLNR	Puahiki
LCA 10713:1	146016001	State HCDA	Poohiwi
LCA 10713:2	146005009	State DLNR	Poohiwi
LCA 8143	146016001	State HCDA	Hoa
LCA 7515:1	146016001	State HCDA	Kekuamanaole
LCA 7515:2	146006051	C&C of Honolulu	Kekuamanaole
LCA 7165:1	146016001	State HCDA	Kahaku
LCA 7165:2	146006051	C&C of Honolulu	Kahaku
LCA 3833:1	146016001	State HCDA	Puhene
LCA 3833:2	146016001	State HCDA	Puhene
LCA 5537:1	146016001	State HCDA	Kealiiwahanui
LCA 5537:2	146005009	State DLNR	Kealiiwahanui
LCA 10713 B:1	146016001	State HCDA	Haalou
LCA 10713 B:2	146016001	State HCDA	Haalou
LCA 10613:1	146016001	State HCDA	Paki, A
LCA 7271	146016001	State HCDA	Hooulu
LCA 5534	146016001	State HCDA	Kahikamoku
LCA 4407	146016001	State HCDA	Kahulau
LCA 8194:2	146005009	State DLNR	Hoka

Taro Production

In 2002, the State Office of Hawaiian Affairs cosponsored a “No Ka Lo‘i Conference”, in the hopes of bringing together taro farmers from around the state to share knowledge on the cultivation of taro. An outcome of the conference was an acknowledgement that farmers needed to better understand the water requirements of their taro crops to ensure and protect their water resource interests. The result of this effort was a 2007 USGS wetland kalo water use study, prepared in cooperation with the State Office of Hawaiian Affairs, which specifically examined flow and water temperature data in a total of 10 cultivation areas on four islands in Hawaii.

The study reiterated the importance of water temperature in preventing root rot. Typically, the water in the taro loi is warmer than water in the stream because of solar heating. Consequently, a taro loi needs continuous flow of water to maintain the water temperature at an optimum level. Multiple studies cited in Gingerich, et al., 2007, suggest that water temperature should not exceed 77ºF (25ºC). Low water temperatures slow taro growth, while high temperatures may result in root rot (Penn, 1997). When the flow of water in the stream is low, possibly as a result of diversions or losing reaches, the warmer water in the taro loi is not replaced with the cooler water from the stream at a quick enough rate to maintain a constant water temperature. As a result, the temperature of the water in the taro loi rises, triggering root rot.

The 2007 USGS study noted that “although irrigation flows for kalo cultivation have been measured with varying degrees of scientific accuracy, there is disagreement regarding the amount of water used and needed for successful kalo cultivation, with water temperature recognized as a critical factor. Most studies have focused on the amount of water consumed rather than the amount needed to flow through the irrigation system for successful kalo cultivation (Gingerich, et al., 2007)." As a result, the study was designed to measure the throughflow of water in commercially viable loi complexes, rather than measuring the consumption of water during taro growth.

Because water requirements for taro vary with the stage of maturity of the plants, all the cultivation areas selected for the study were at approximately the same stage (i.e. near harvesting, when continuous flooding is required). Temperature measurements were made every 15 minutes for approximately 2 months. Flow measurements were collected at the beginning and the end of that period. Data were collected during the dry season (June – October), when water requirements for cooling kalo are higher. Surface water temperatures generally begin to rise in April and remain elevated through September, due to increased solar heating. Water inflow temperature was measured in 17 loi complexes, and only three had inflow temperatures rising above 27ºC (the threshold temperature above which wetland kalo is more susceptible to fungi and associated rotting diseases).

The average and median inflows from all 10 cultivation areas studied are listed in Table 12-4 below. The study indicated that the "values are consistent with previously reported inflow and are significantly higher than values generally estimated for consumption during kalo cultivation." It should also be noted that farmers were interviewed during field visits; most "believed that their supply of irrigation water was insufficient for proper kalo cultivation."

The study results are presented in Table 12-2 (discharge measurements) and Table 12-3 (water-temperature statistics).

Table 12-2. Summary of water use calculated from loi and loi complexes by island, and the entire state. (Source: Gingerich et al., 2007, Table 10) [gad = gallons per acre per day; na = not available]

Island	Complex				Loi			
	Number	Average water use (gad)	Average windward water use (gad)	Average leeward water use (gad)	Number	Average water use (gad)	Average windward water use (gad)	Average leeward water use (gad)
Kauai	6	120,000	97,000	260,000	2	220,000	220,000	na
Oahu	5	310,000	380,000	44,000	4	400,000	460,000	210,000
Maui	6	230,000	230,000	na	na	na	na	na
Hawaii	2	710,000	710,000	na	na	na	na	na
Average of all measurements		260,000	270,000	150,000		350,000	370,000	210,000
Median of all measurements		150,000	150,000	150,000		270,000	320,000	210,000

Historical uses can also provide some insight into the protection of traditional and customary Hawaiian rights. Handy and Handy in *Native Planters of Old Hawaii* (1972), provide a limited regional description as follows:

> Along the coast south and southeast of Waikane are five *ahupua'a* which topographically and environmentally are very much alike: Waiahole, Ka'alaea, Waihe'e, Kahalu'u, and He'eia. All face seaward on the broad calm bay that extends from Kualoa to Kane'ohe, a bay that is really a very long lagoon within a barrier reef that is far distant from the shore. At low tide a muddy bottom is exposed along the shore and there are no sandy beaches, for the coast line is too far in from the reef for coral sand to wash in, and the water along the landward side of the bay or lagoon is too shallow and too dirty for coral heads to

> grow, as they do at Kaneʻohe and northward from Kaʻaʻawa. Each of these districts has a broad coastal plain, which was converted by Hawaiians into an almost continuous expanse of *loʻi* irrigated with wter from large streams flowing out of the deep valleys that cut back into the Koʻolau range. (p. 452)

Further they recount the tremendous agricultural protential of these lowland coastal regions producing:

> …great quantities of sweet potato, yam, banana, upland taro, *wauke*, *olona*, and ʻ*awa*. (p. 452)

In recounting the ahupuaʻa of Heʻeia, Handy and Handy (1972) describe:

> The extensive salt marshes of Heʻeia inland from the fishponds (*loko*) were not suitable for cultivation, but fringing them to the souward, flanking both sides of Heʻeia Stream from which they are irrigated, lie the vast terraced lowland flast of this ahupuaa, which were in 1935 still largely planted in commercial taro. (p. 454)

The source of water for the loi was originally from two different streams:

> The southern portions of these *loʻi* were irrigated from Kalimukele Stream which turns southward and flows into Kaneʻohe; while the small stream named Puolena supplements the Heeia on the North. These terraces extend up the main steream to the junction of Haʻiku Stream and ʻIolekaʻa, flowing from the west and southwest, respectively. A small stream named Kaiwikeʻe flows into ʻIolekaʻa from southwestward in the Koʻolau range. Up all these valleys are old *loʻi*, now abandoned. (p. 454)

Each *ahupuaʻa* was associated with particular stories or legends, although this region of the moku was noticeably lacking in tradition or history according to Hand and Handy (1972). However,

> Heeia was named for the "washing away" of the primordial ancestor Wakea, his wife Haumea, and all their followers, in a tidal wave which overwhelmed their encampment in this place, during the epic wars with Kane-kumu-honua...It was near the small islet of Kapapa, in the bay, that the *kahuna* who had foretold this cataclysm taught Wakea to make a "*heiau*" of his clasped hands and an offering therin of a "pig"—a *humuhumu* fish caught in the waters beside him. In this district also lived one time Ma-ʻeli-ʻeli, known as the Dragon Woman of Heʻeia (Weservelt, 1915). (p. 454)

Individual cultural resources of Heeia hydrologic unit were not classified by the Hawaii Stream Assessment (HSA), but generally classified based on the Historic Preservation Division database. Data were collected in three general areas of: 1) archaeological; 2) historical; and 3) modern practices. Archaeological data were originally compiled by the State Historic Preservation Division and are only current to 1990, the date of the HSA. The Heeia hydrologic unit has archeological evidence addressing broad patterns in prehistory, with culturally significant sites including agricultural complexes, many heiau and potentially religious structures, and trails. The terracing and auwai system that supported loʻi kalo along streams are still evident in some regions.

Table 12-3. Water-temperature statistics based on measurements collected at 15-minute intervals for loi complexes on the island of Maui. (Source: Gingerich et al., 2007, Table 7) [ºC = degrees Celsius; na = not applicable]

Geographic designation	Area	Station	Period of record	Temperature (ºC) Mean	Range	Mean daily range	Temperature measurements greater that 27ºC (percent)
Windward	Waihee	Ma08A-CI	7/29/2006 - 9/22/2006	21.6	19.9 - 24.0	2.0	0.0
		Ma08B-CIL	7/29/2006 - 9/22/2006	24.9	20.3 - 34.0	7.6	25.4
		Ma08B-CO	7/29/2006 - 9/22/2006	25.5	20.0 - 35.5	5.7	27.0
Windward	Wailua (Lakini)	Ma09-CIT	7/30/2006 - 9/21/2006	20.7	18.5 - 23.4	2.3	0.0
		Ma09-CO	7/30/2006 - 9/21/2006	23.2	18.4 - 31.7	7.4	16.9
Windward	Wailua	Ma10-CI	7/30/2006 - 9/21/2006	22.5	20.5 - 25.9	1.9	0.0
Windward	Wailua (Waikani)	Ma11-CI	7/30/2006 - 9/21/2006	22.2	21.0 - 24.0	0.7	0.0
		Ma11-CO	7/30/2006 - 9/21/2006	26.1	22.1 - 31.8	3.3	29.1
Windward	Keanae	Ma12-CI	7/31/2006 - 9/21/2006	20.0	19.0 - 21.9	1.0	0.0
		Ma12-CO	equipment malfunction	na	na	na	na

Archaeological Evidence for Hawaiian Agriculture

There are many identified archaeological sites throughout the Heeia hydrological unit. In the middle and upper elevations, there is much terracing along the stream channels which indicate historical loi kalo was grown here. This is supported by Ladefoged et al. (2009) who modeled the extent of pre-contact agriculture across the Hawaiian Islands (Figure 12-3). There are many important cultural features includeing heiau, terracing, homesites, platforms, mounds, and walls consistent with irrigated agricultural complexes and cultural practices (Table 12-4).

Fishponds

Fishponds are another integral part of traditional Hawaiian culture, which speaks volumes of native Hawaiian skill and knowledge of aquaculture, which has also seen a resurgence of interest in recent years. Fishponds are found throughout the Hawaiian Islands and were either man-made or natural enclosures of water used for the raising and harvesting of fish and other aquatic organisms. Kikuchi (1973) identified six main types of fishponds, two of which are associated with streams (*loko wai, loko ia kalo*) and one type is associated with fresh water springs (*kaheka* or *hapunapuna*).

- Type III – *Loko Wai*: An inland fresh water fishpond which is usually either a natural lake or swamp, which can contain ditches connected to a river, stream, or the sea, and which can contain sluice grates. Although most frequently occurring inland, *loko wai* are also located along the coast near the outlet of a stream.

- Type IV – *Loko Ia Kalo*: A fishpond utilizing irrigated taro plots. *Loko ia kalo* are located inland along streams and on the coast in deltas and marshes.
- Type VI – *Kaheka* and *Hapunapuna*: A natural pool or holding pond. The majority, if not all of these types of ponds, are anchialine ponds with naturally occurring shrimp and mollusks.

According to a 1990 Hawaii Coastal Zone Management Program *Hawaiian Fishpond Study for the Islands of Hawaii, Maui, Lanai, and Kauai*, there was one existing fishponds present in the Heeia hydrologic units (DHM, Inc., 1990). This fishpond has been restored as described in Möhlenkamp et al. (2019).

Table 12-4. Archaeological sites in the Heeia hydrologic units, Oahu. (Source: Kipuka Database, 2020)
[LCA is Land Commission Award; Gr. is Grant;

Historic Site #	State Site #	SHPD Library	Land Award	Description
04135	50-80-10-04135	O-00856	10613:1	A roughly crescent-shaped terrace w/ a retaining wall consisting of stacked small cobbles & boulders of rough basalt; furros suggest historic pineapple cultivation
04136	50-80-10-04136	O-00856	10613:1	Roughly crescent to rectangular flat area cut into a ridgcrest
04137	50-80-10-04137	O-00856	10613:1	Roughly rectangular stone platform, constructed of boulders and cobbles
04138	50-80-10-04138	O-00856	10613:1	2 historic road cut retaining walls of stacked, rough basalt small boulders & cobbles, 6.0 m apart to stabilize the slope above the road
04139	50-80-10-04139	O-00856	10613:1	Roughly rectangular small boulder & cobble mounth; pineapple furrows present
04141	50-80-10-04141	O-00856	10613:1	Heeia Kea agricultural terrace; constructed of stacked orugh basalt small boulders & cobbles, possible ditch or trail upslope
04142	50-80-10-04142	O-00856	10613:1	Site complex w/ 3 temporal components: prehistoric habitation, tool manufacturing, and possible burial; historic agriculture; modern habitation & agriculture;; 37 features in small stream valley
04144	50-80-10-04144	O-00856	10613:1	An upright basalt boulder upon a small, oval, earthen mounth with a second small upright stone on west end of mound
04263	50-80-10-04263	O-00654	6047:1	Terrace site near the southern end of marsh and extending west along plant nursery
04264	50-80-10-04264	O-00654	10613:1	Historic auwai located at base of a slope
00329	50-80-10-00329	O-00409	10613:1	Leleahina Heiau, large heiau with 2 main platforms, one set below the other; more recent cemetery in center of upper' 4 smaller platforms on the lower end
05601			10613:1	none
05602			10613:1	none
05603			10613:1	none
05604			10613:1	none
02078	50-80-10-02078	O-01450	10613:1	House site comprised of 6 terraces and 1 depression; small patch of pia growning on it
02079	50-80-10-02079	O-01450	10613:1	Platform and alignments of uncertain function, possibly pre-contact or early post-contact
02081	50-80-10-02081	O-01450	10613:1	Two subsurface features, imu, containing cobble and boulder size cooking stones and abundant charcoal

Table 12-4. continued.

Historic Site #	State Site #	SHPD Library	Land Award	Description
02083	50-80-10-02083	O-01450	10613:1	2 earthen terraces for agriculture
04506	50-80-10-04506	O-01450	10613:1	Transmitter building for Haiku Naval Radio Station now used by Coast Guard for Omega signal
04509	50-80-10-04509	O-01450	10613:1	Remains of retaining wall that supported the foundationof the naval mess hall and several other buildings
02041	50-80-10-02041	O-01450	10613:1	Hale Manako; House site containing 2 stone-faced earthen terraces
02082	50-80-10-02082	O-01450	10613:1	Large subsurface imu
04667	50-80-10-04667	O-01450	10613:1	Groupe of large weathered boulders located on side of steep slope; concentrated and isolated cluster
02323	50-80-10-02323	O-01450	10613:1	Single surface firepit
02324			10613:1	none
04635	50-80-10-04635	O-01684	10613:1	Haiku Hale Kawala; limited surface remains consisting of a single depression and weathered boulders, basalt flakes
04495	50-80-10-04495	O-00971	10613:1	Terraced house site w/ 2 occupation components
04507	50-80-10-04507	O-01450	10613:1	Haiku substation; small electric substation first built in WWII
00332	50-80-10-00332	O-00409	10613:1	Kahekili/Kehekili Heiau; located on top of an oblong knoll
04508	50-80-10-04508	O-01450	10613:1	Remains of electrical substation
02042	50-80-10-02042	O-01450	10613:1	Haiku Loi system; 14 recorded features on an alluvial flot and additional featues on Kaiku stream banks; large loi complex of stone-faced terraces and associated non-terrace features, imu
04787	50-80-10-04787	O-01242	10613:1	Haiku Naval Radko Station Winch site
04788			10613:1	none
04495	50-80-10-04495	O-00971	10613:1	
00333	50-80-10-00333	O-004409	10613:1	Kane Ame Kanaloa Heiau

Figure 12-3. Zones of pre-contact intensive agriculture in Heeia, Oahu. (Source: Ladefoged et al., 2009)

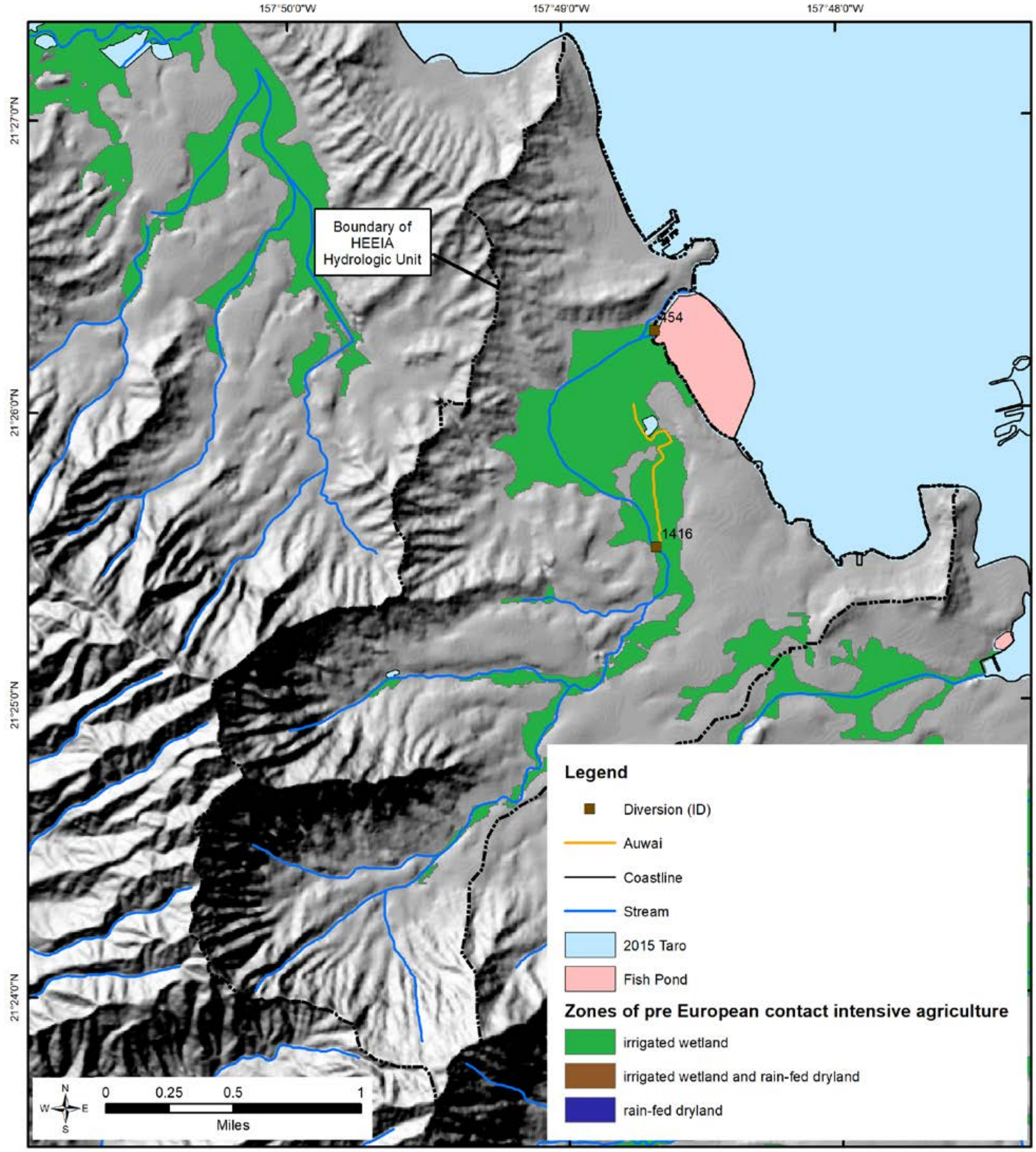


Table 12-5. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Heeia stream.

Category	Value
Survey coverage: The extent of archaeological survey coverage was analyzed and recorded as complete, partial, very limited, and none. Few valleys are completely surveyed. Many have little or no survey coverage.	Limited
Predictability: The ability to predict what historic sites might be in unsurveyed areas was scored as high, medium, or low predictability or unable to predict. A high score was assigned if archaeologists were able to predict likely site patterns in a valley given historic documents, extensive archaeological surveys in nearby or similar valleys, and/or partial survey coverage. A low score was assigned if archaeologists were unable to predict site patterns in a valley because of a lack of historical or archaeological information. A medium score was assigned to all other cases.	Limited
Number of Sites: The actual number of historic sites known in each valley is straightforward yet very time consuming to count. Instead, archaeologists used survey information to estimate the number of sites in each valley. These figures, adequate for this broad-based assessment, are only rough estimates.	1
Valley significance as a Whole District: The overall evaluation of each valley’s significance was made considering each valley a district. The significance criteria of the National and Hawaii Registers of Historic Places were used. Criterion A applies if the district is significant in addressing broad patterns of prehistory or early history. Criterion B applies if the district is associated with important people (rulers) or deities. Criterion C applies if the district contains excellent examples of site types. Criterion D applies if the district is significant for information contained in its sites. Finally, Criterion E applies if the district is culturally significant for traditionally known places or events or for sites such as burials, religious structures, trails, and other culturally noteworthy sites.	none
Site Density: The density patterns of historic sites make up a variable extremely important to planners. Three ranks were assigned: low for very few sites due either to normal site patterning or extensive land alteration, moderate for scattered clusters of sites, and high for continuous sites. Valleys with moderate or high density patterns are generally considered moderate or high sensitivity areas.	n/a
Site Specific Significance: The site specific significance variable was developed for valleys that had low densities of sites (very few sites) due either to normal site patterning or to extensive land alteration. An example of the first type might be a valley with housing sites on the side but too narrow for taro or housing sites on the valley floor. The second type might be a valley in which there had been sugar cane cultivation but a large heiau was left. The site specific significance of these valleys was categorized as either: 1) sites significant solely for information content which can undergo archaeological data recovery; or 2) sites significant for multiple criteria and merit preservation consideration. Those categorized as meriting preservation consideration would likely include large heiau, burial sites, and excellent examples of site types.	n/a
Overall Sensitivity: The overall sensitivity of a valley was ranked very high, high, moderate, low, or unknown. Very high sensitivity areas have moderate or high densities of sites with little or no land alteration. They are extremely important archaeological and/or cultural areas. High sensitivity areas have moderate or high densities of sites with little or no land alteration. Moderate sensitivity areas have very few sites with the sites meriting preservation consideration due to multiple criteria or moderate densities of sites with moderate land alteration. Low sensitivity areas have very few sites due to normal site patterning or due to extensive land alteration. The sites present are significant solely for their informational content, which enable mitigation through data recovery. Those valleys where no surveying had been undertaken and the ability to predict what might be found was low were ranked unknown.	n/a

Historic Resources: Several types of sites were considered by inclusion in this section, particularly bridges, sugar mills and irrigation systems. Those that are listed on the State or National register were inventoried, but none of them assessed.	none
Taro Cultivation: Streams and stream water have been and continue to be an integral part of the Hawaiian lifestyle. The committee identified a number of factors important to current Hawaiian practices. These include current taro cultivation, the potential for taro cultivation, appurtenant rights, subsistence gathering areas, and stream-related mythology. The committee felt that a complete assessment of the cultural resources of Hawaii's streams should include these items but, due to limits of information, only the current cultivation of taro was included.	No*

*none identified by the Hawaii Stream Assessment published in 1990; currently, there is kalo cultivated in the upper reaches of Haiku Valley and in Heeia Marsh.

13.0 Public Trust Uses of Water

The State Water Code (Hawaii Revised Statutes 174C-2) states that:

> The state water code shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes such as domestic uses, aquaculture uses, irrigation and other agricultural uses, power development, and commercial and industrial uses. However, adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance and scenic beauty, and the preservation and enhancement of waters of the State for municipal uses, public recreation, public water supply, agriculture, and navigation.

Article 11, Section 1 of the Hawaii State Constitution maintains that the:

> State and its political subdivisions shall conserve and protect Hawaii's natural beauty and all natural resources, including land, water, air, minerals, and energy sources, and shall promote the development and utilization of these resources in a manner consistent with their conservation and in furtherance of the self-sufficiency of the State. All public natural resources are held in trust by the State for the benefit of the people.

This solidified the Public Trust Doctrine as constitutional law. Further, Article 11, Section 7, states that the "State has an obligation to protect, control, and regulate the use of Hawaii's water resources for the benefit of its people." The Public Trust Doctrine now identifies four priority uses of water as: (1) water for traditional and customary practices, including the growing of taro; (2) reservations of water for Hawaiian Home Land allotments; (3) water for domestic use of the general public; (4) maintenance of waters in its natural state.

In the Heeia hydrologic unit, the use of water for traditional and customary practices was covered in Chapter 12 and water in its natural state is covered in Chapters 3-7.

Domestic Use of Water

The Honolulu BWS municipal system provides domestic and agricultural water use from groundwater sources in and nearby the Heeia hydrologic unit. Individual Honolulu BWS wells are covered in Chapter 3. Figure 13-1 depicts the Honolulu BWS wells and distribution systems in the Koolaupoko Aquifer System as they relate to the Heeia surface water hydrologic unit.

Hawaiian Home Lands

A component in the assessment of water use includes an analysis of the presence of Department of Hawaiian Home Lands (DHHL) parcels within or near the surface water hydrologic unit. The mission of DHHL is to effectively manage the Hawaiian Home Lands trust and to develop and deliver land to native Hawaiians (PBR Hawaii, 2004). The DHHL manages one 140 acre parcel within the Heeia hydrologic unit (Figure 13-2). However, DHHL's long-range plan for the parcel assumes loi kalo development supplied by surface water (State of Hawaii Department of Hawaiian Home Lands, 2011). The DHHL has a projected water need for potable water from the Koolaupoko Aquifer System of 0.0535 mgd and a need of 15.4125 mgd non-potable water from Heeia Stream for loi kalo.

Figure 13-1. Location of wells servicing the Honolulu Board of Water Supply municipal water distribution system in relation to the Heeia hydrologic unit, Oahu.

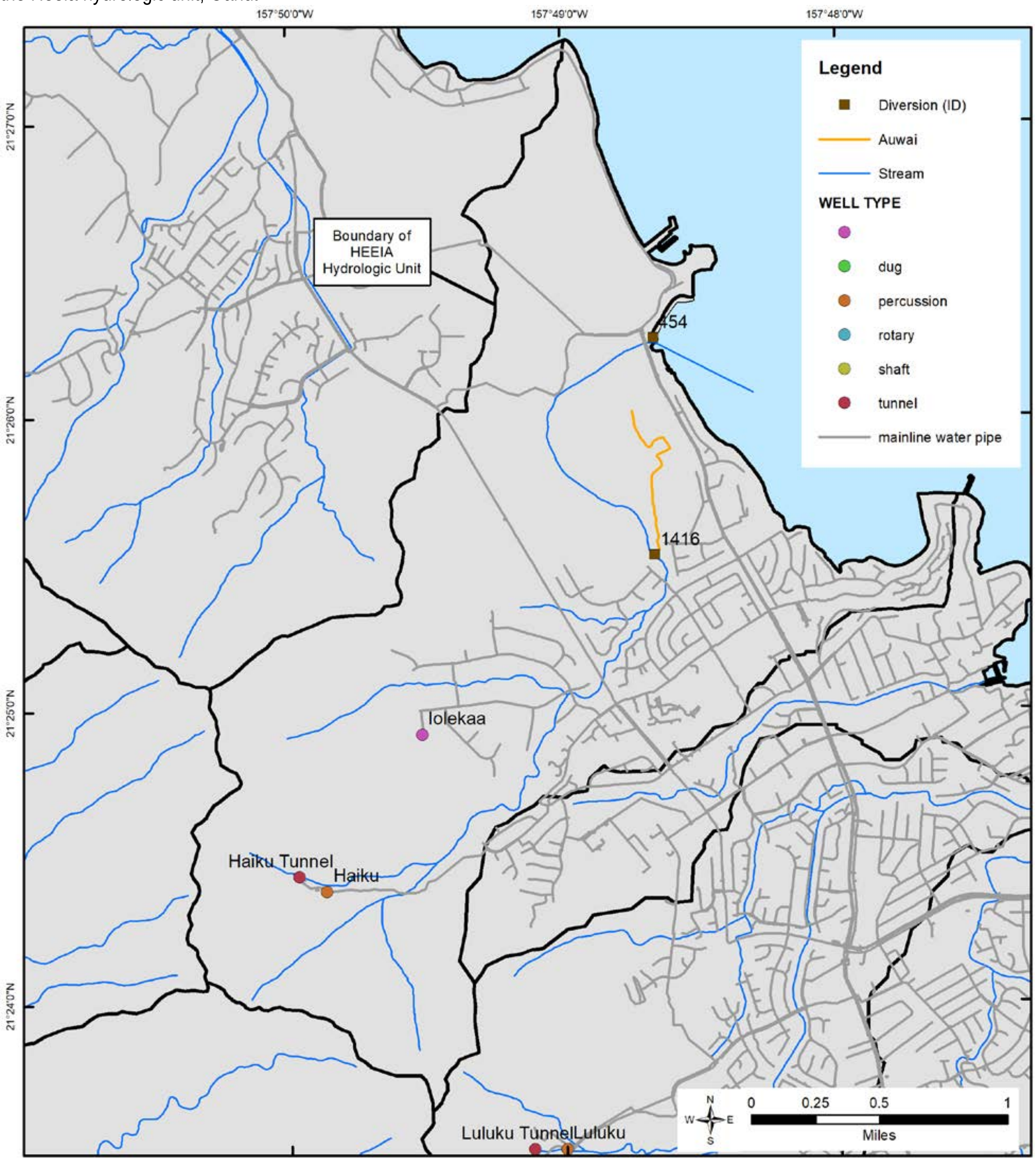
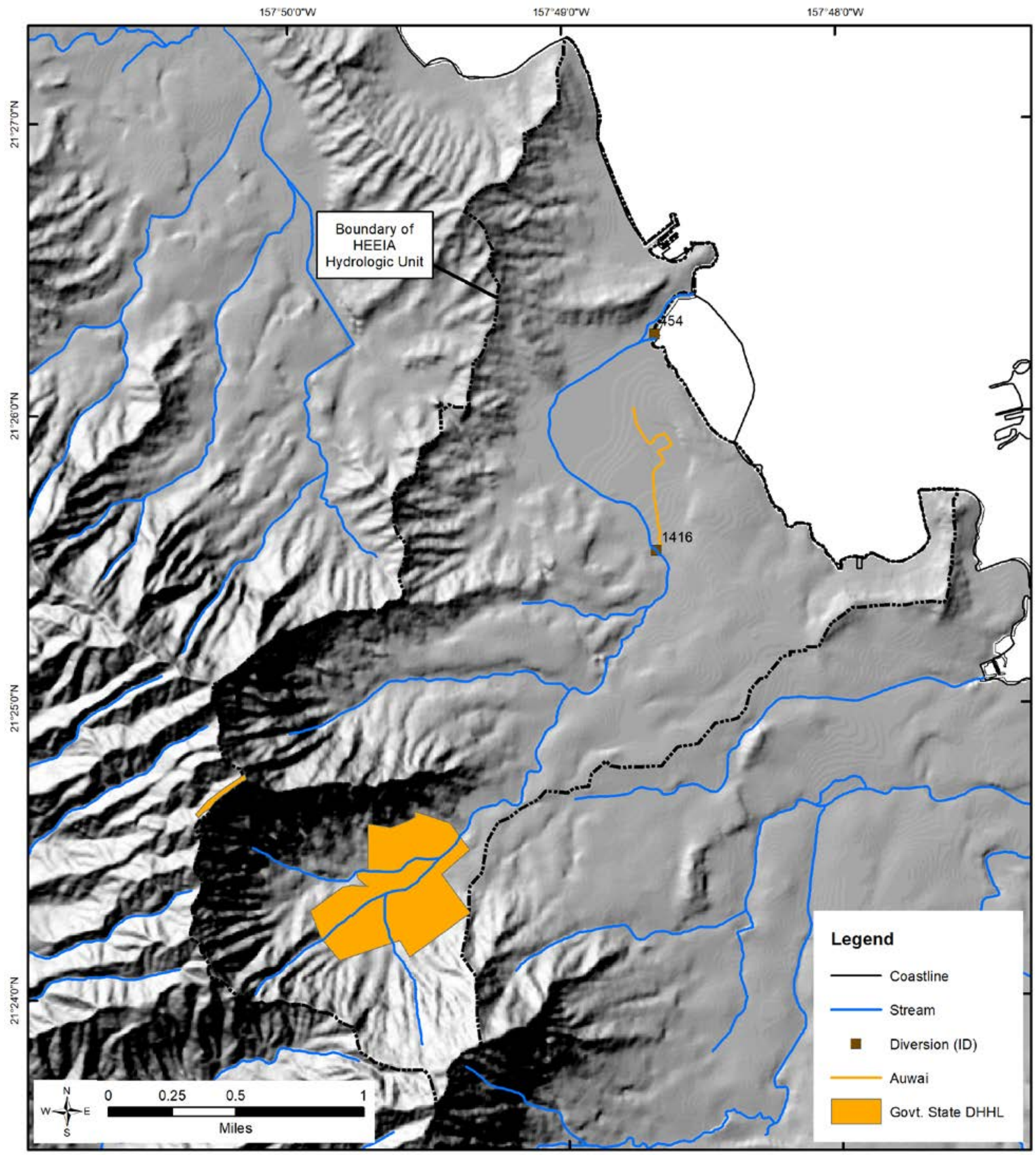


Figure 13-2. Hawaiian Home Lands development parcels identified in the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Department of Hawaiian Home Lands, 2011)



14.0 Noninstream Uses

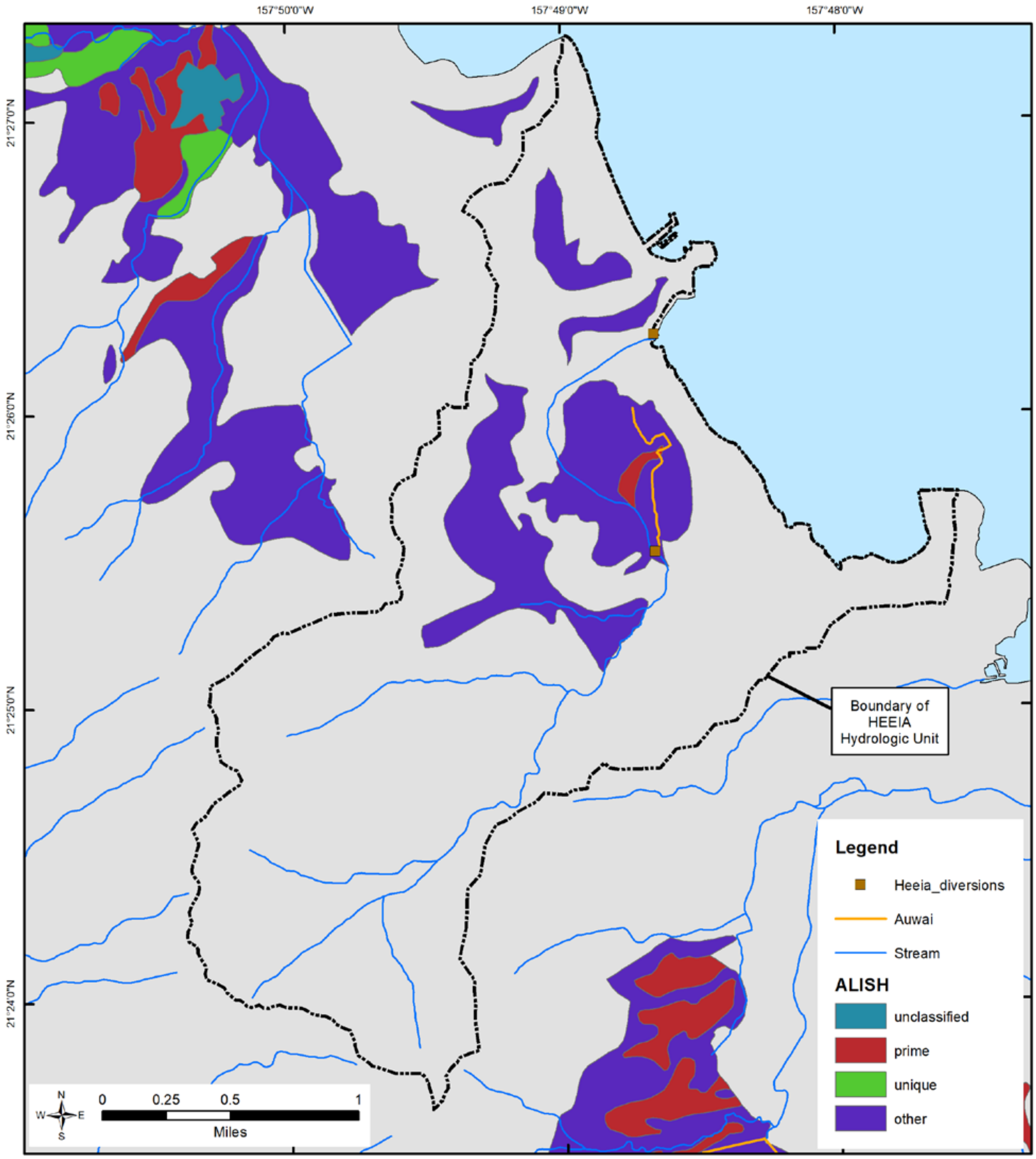
Under the State Water Code, noninstream uses are defined as "water that is diverted or removed from its stream channel…and includes the use of stream water outside of the channel for domestic, agricultural, and industrial purposes." Article XI, Section 3 of the State Constitution states: "The State shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally sustainable lands." Water is crucial to agriculture and agricultural sustainability. Article XI, Section 3 also states, "Lands identified by the State as important agricultural lands needed to fulfill the purposes above shall not be reclassified by the State or rezoned by its political subdivisions without meeting the standards and criteria established by the legislature and approved by a two-thirds vote of the body responsible for the reclassification or rezoning action. [Add Const Con 1978 and election Nov 7, 1978]." It is the availability of water that allows for the designation of Important Agricultural Lands. The Hawaii Farm Bureau Federation, Hawaii's largest advocacy organization for general agriculture, states that agriculture is a public trust entity worthy of protection, as demonstrated in its inclusion in the State Constitution. They, on behalf of farmers and ranchers, point to the importance of large-scale agriculture to sustainability and self-sufficiency of our islands, particularly in times of catastrophe when imports are cut off.

In most cases, water is diverted from the stream channel via a physical diversion structure. Diversions take many forms, from small PVC pipes in the stream that remove relatively small amounts of water, to earthen auwai (ditches), hand-built rock walls, and concrete dams that remove relatively larger amounts of water. Many of the diversions registered with the Commission in 1989 have been abandoned or gone unused for many years, as determined by follow-up site visit verifications. An inventory of stream diversions is provided in Table 14-1.

Utilization of Important Agricultural Lands

In 1977, the Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA), with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the University of Hawaii College of Tropical Agriculture and Human Resources. Three classes of agriculturally important lands were established for Hawaii in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide (Figure 14-1). Hawaii's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique agricultural land; and 3) Other important agricultural land. Each classification was based on specific criteria such as soil characteristics, slope, flood frequency, and water supply. The ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands. As agricultural commodities changed substantially with the closure of large-scale pineapple and sugarcane in the 1980s-2000s, the HDOA funded an updated baseline study of agricultural land use for 2015 (Figure 14-1). No land in Heeia is designated as agricultural land based on the State Land Use Commission designation, although agriculture was historically practiced on many parcels in Heeia. Water diverted from surface water sources in Heeia supply the irrigation needs of loi along the stream in Haiku Vally and from the Hop Tuck Ditch and Wing Wo Tai auwai in Heeia Marsh. These units have a much greater portion of prime agricultural lands. Large landowners (e.g., DHHL, Kamehameha Schools, State of Hawaii Community Development Authority) in the Heeia hydrologic unit are supporting the restoration of traditional agricultural practices which increase cultural, ecological, and economic resilience (Figure 14-2).

Figure 14-1. Agricultural Lands of Importance to the State of Hawaii (ALISH) for the Heeia hydrologic unit, Oahu. (Source: State of Hawaii, Office of Planning, 2015g)



Current and Future Agricultural Demands

Using the 2015 Department of Agriculture Baseline Agriculture Survey, very little of the land designated as important agricultural lands in the Heeia hydrologic unit is being used for agriculture (Figure 14-2). Taro was grown in some restored loi in Heeia Marsh in 2015. Since this study, loi kalo production has expanded to 1.853 acres (0.0029 square miles). Water is diverted from Heeia Stream using water from the Wing Wo Tai Ditch and the Hop Tuck Ditch in the marsh. Kakoo Oiwi anticipates expanding the production of banana, breadfruit, and taro in Heeia Marsh fed by Heeia Stream by 2037 to 12.4 acres, 12.4 acres, and 31 acres. The water demand for banana and breadfruit will be dependent on the location of the plantings, especially as the depth to the water table at low elevations is likely to reduce the irrigation demand of adult trees with mature root systems. In Haiku Valley, as of 2015, there was approximately 1.2 acres (0.0019 square miles) of loi kalo. Based on a generalized water demand of 150,000 gallons per acre per day for taro, there will be approximately 4.65 mgd of water use for taro in Heeia Marsh and 0.3 mgd in Haiku Valley. However, actual water deliveries may vary substantially over time. Some loi are watered directly from springs flowing from the base of the Koolau cliff face.

Table 14-1. Diversions in the Heeia hydrologic unit, Oahu.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.454	ST STEPHEN DC	4-6-005-001	0.02	Yes	Yes	No	

Diversion system is three wai (intakes) into Paepae O Heeia (Heeia fishpond) from Heeia Stream at its mouth in Kaneohe Bay. Diversion structure is a concrete flume with wooden gates that control the inflow of freshwater into the fishpond to regulate salinity and temperature seasonally.

Photos. a) downstream view of wai 1 diversion intake with screen; b) upstream view of ouflow of wai 1 into fishpond; c) downstream view of outflow into fishpond; d) fishpond; e) upstream view of wai 2 diversion; f) channel of Heeia stream before mangrove removal (HBWS December 2009)

a)

b)

c)

d)

e)

f)

Table 14-1. continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.1416	Wing Wo Tai	4-6-014-001	2.3	Yes	Yes	No	

Groundwater seepage and stream flow from Wing Wo Tai diversion supports loi complex in lower Heeia Marsh on east side. **Photos.** a) upstream view of spring in Heeia Marsh; b) downstream view of spring discharge; c) Wing Wo Tai loi complex; kalo in Heeia Marsh (HBWS December 2009)

a)

b)

c)

d)

Table 14-2. continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
n/a		4-6-014-001	0.65	Yes	Yes	No	

Kapuna Spring diversion (not registered) supplying water for loi area of approximately 3 acres at 240 feet elevation on land owned by KSBE.

Photos. a) upstream view of Kapuna Spring; b) downstream view from springs; c) upstream view of diversion; d) diversion intake to pipeline; e) pipeline from spring to loi; f) old diversion on tributary; g) outflow from pipeline; h) loi (HBWS January 2011)

a)

b)

c)

d)

e)

f)

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)

g)

h)

Table 14-3. continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
n/a	n/a	4-6-014-001	0.15	Yes	Yes	No	

Spring diversion (not registered) supplying water for loi area of approximately 0.5 acres at 260 feet elevation on land owned byGinger Ridge LLC and operated by Hui Ku Maoli Ola.

Photos. a) upstream view of auwai from spring; b) downstream view of loi; c) spring flow into stream (HBWS January 2011)

a)

b)

c)

d)

Figure 14-2. 2015 Baseline agricultural land use survey for the Heeia hydrologic unit, Oahu. (Source: Perroy et al., 2015)

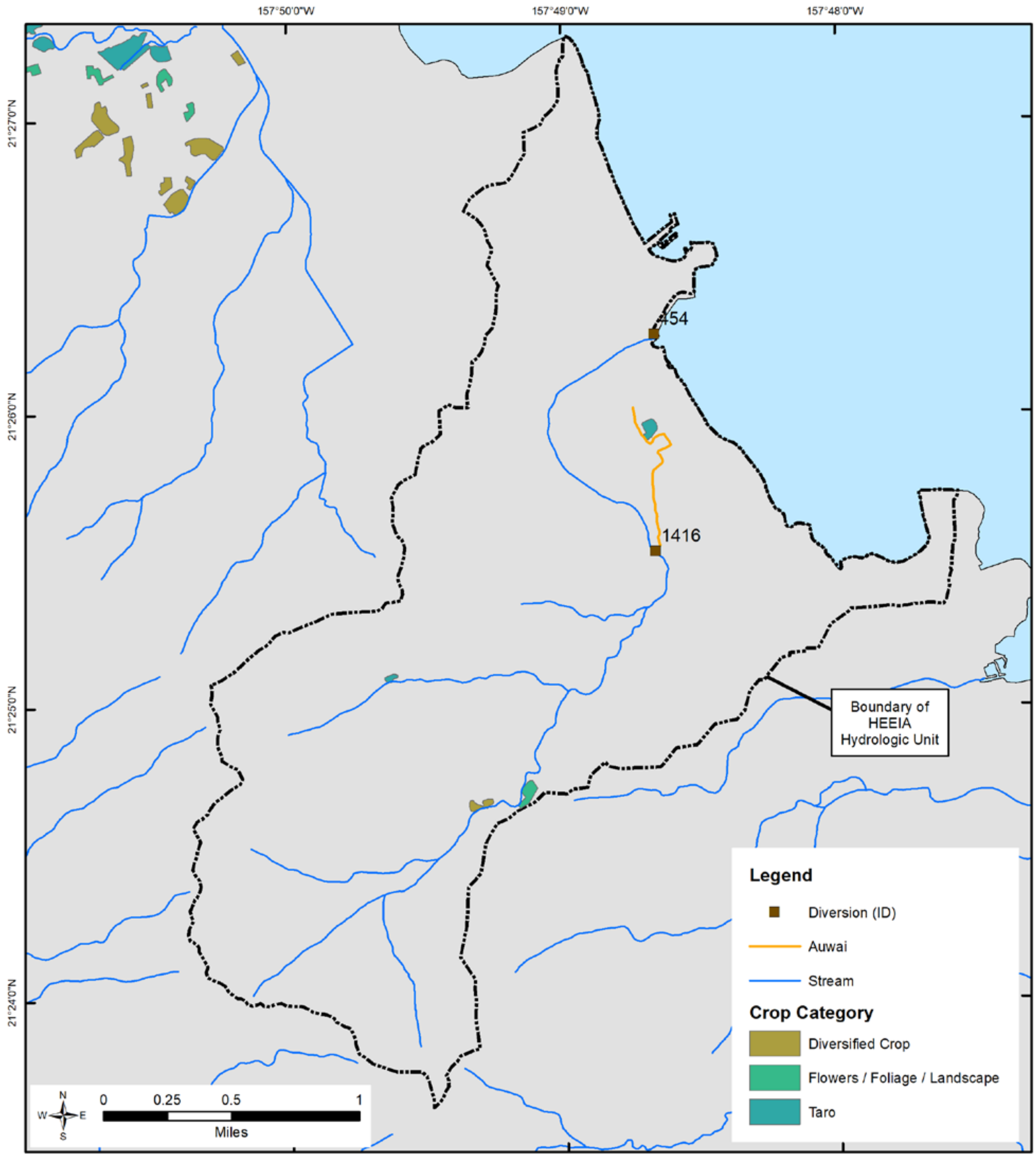
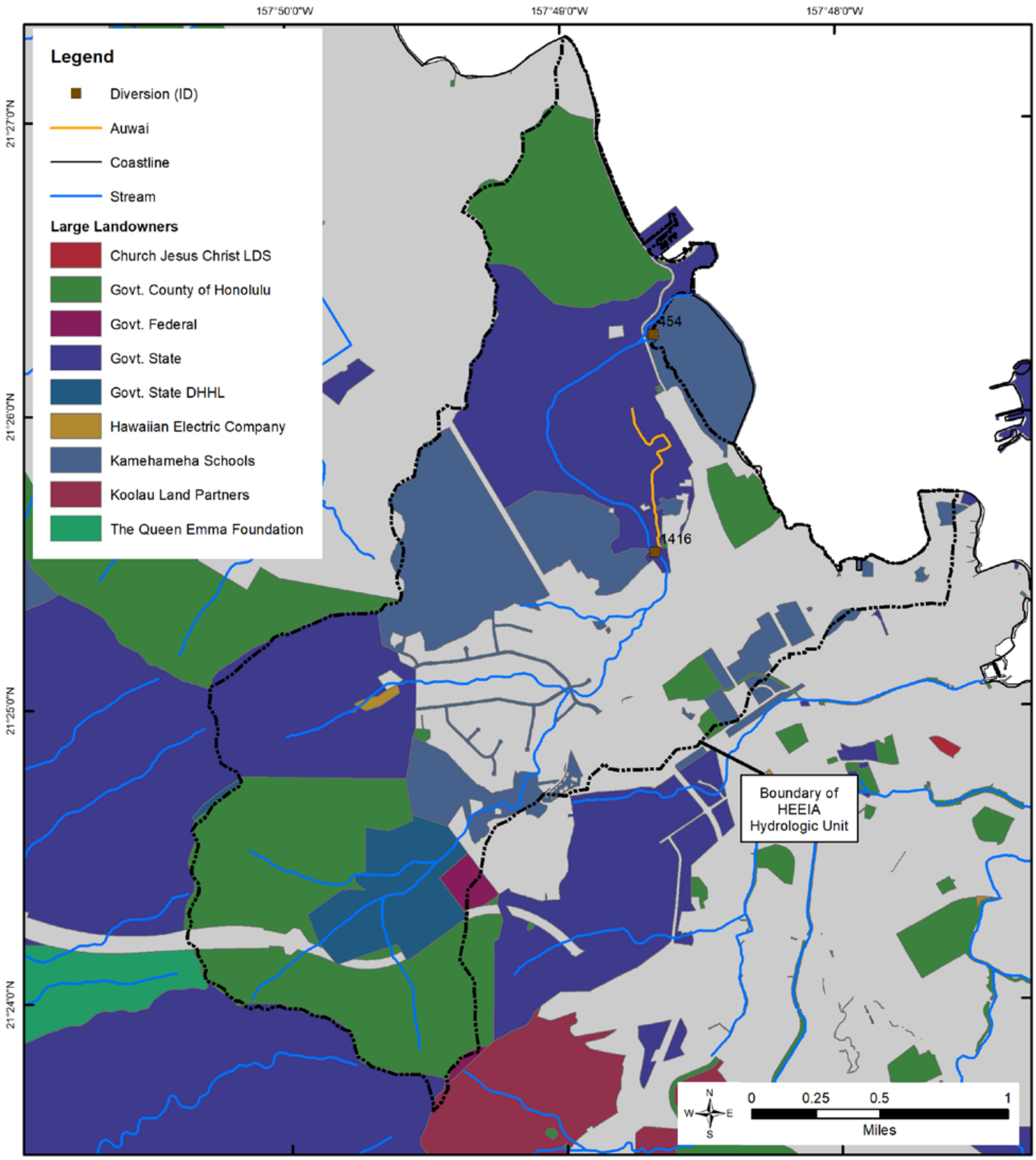


Figure 14-3. Distribution of large landowners in the Heeia hydrologic unit, Oahu.



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16.0 Appendices

Appendix A Heeia, Oahu, Hawaii. June 2008. DAR Watershed Code: 32008
State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources.

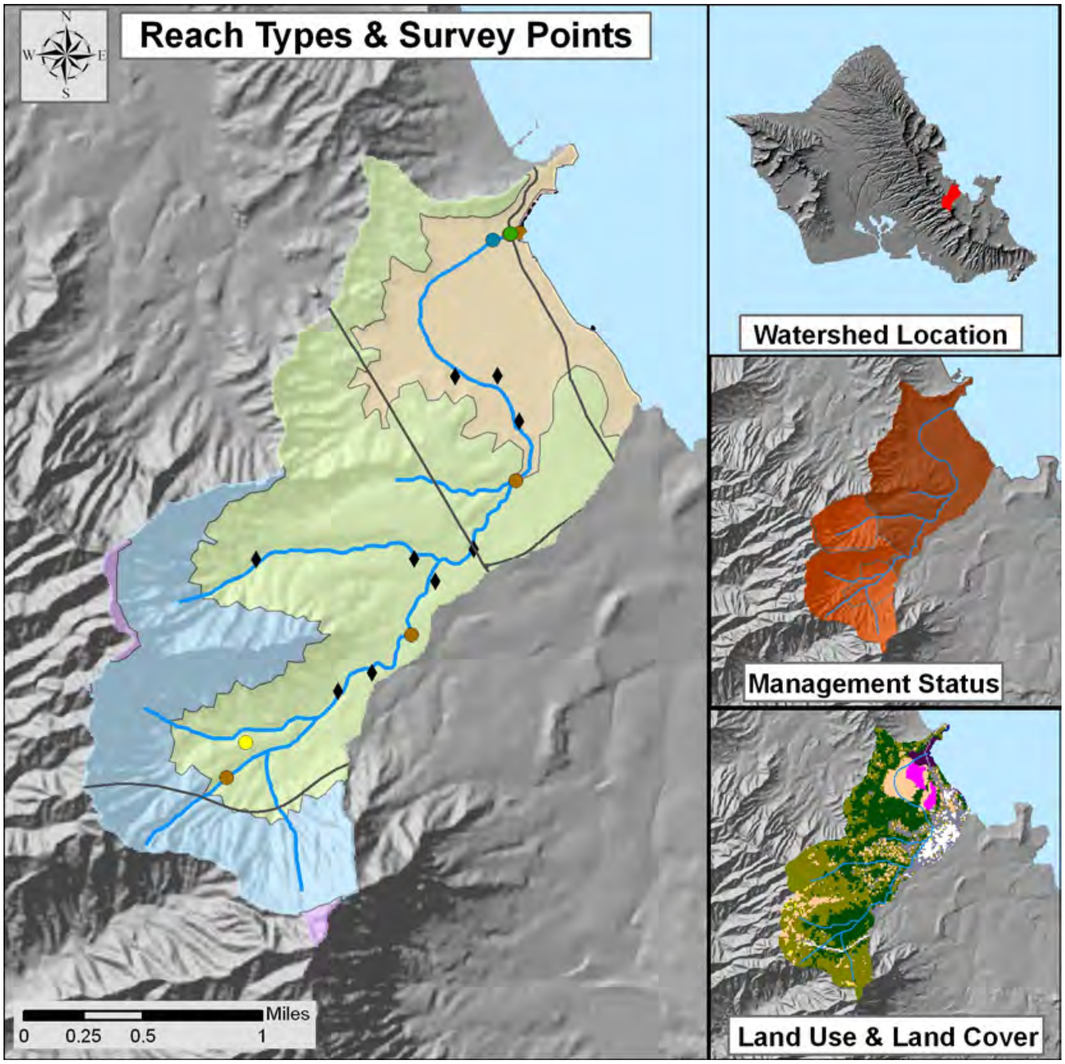
APPENDIX A

State of Hawai‘i, Department of Land and Natural Resources, Division of Aquatic Resources

Atlas of Hawaiian Watersheds & Their Aquatic Resources He‘eia, O‘ahu

DAR Watershed Code: 32008

He‘eia, O‘ahu



WATERSHED FEATURES

He‘eia watershed occurs on the island of O‘ahu. The Hawaiian meaning of the name is "washed (as being swept to sea)". The area of the watershed is 3.5 square mi (9.1 square km), with maximum elevation of 2723 ft (830 m). The watershed's DAR cluster code is 4, meaning that the watershed is medium size, steep in the upper watershed, and with embayment. The percent of the watershed in the different land use districts is as follows: 0% agricultural, 56.6% conservation, 0% rural, and 43.4% urban.

Land Stewardship: Percentage of the land in the watershed managed or controlled by the corresponding agency or entity. Note that this is not necessarily ownership.

Military	Federal	State	OHA	County	Nature Conservancy	Other Private
0.0	6.6	12.1	0.0	23.6	0.0	57.7

Land Management Status: Percentage of the watershed in the categories of biodiversity protection and management created by the Hawaii GAP program.

Permanent Biodiversity Protection	Managed for Multiple Uses	Protected but Unmanaged	Unprotected
0.0	0.0	42.3	57.7

Land Use: Areas of the various categories of land use. These data are based on NOAA C-CAP remote sensing project.

	Percent	Square mi	Square km
High Intensity Developed	4.0	0.14	0.36
Low Intensity Developed	8.6	0.30	0.79
Cultivated	0.0	0.00	0.00
Grassland	11.7	0.41	1.07
Scrub/Shrub	39.2	1.38	3.58
Evergreen Forest	31.9	1.13	2.91
Palustrine Forested	0.0	0.00	0.00
Palustrine Scrub/Shrub	0.0	0.00	0.00
Palustrine Emergent	2.2	0.08	0.20
Estuarine Forested	1.5	0.05	0.14
Bare Land	0.4	0.02	0.04
Unconsolidated Shoreline	0.0	0.00	0.00
Water	0.3	0.01	0.03
Unclassified	0.0	0.00	0.00

STREAM FEATURES

He‘eia is a perennial stream. Total stream length is 7.1 mi (11.5 km). The terminal stream order is 2.

Reach Type Percentages: The percentage of the stream's channel length in each of the reach type categories.

Estuary	Lower	Middle	Upper	Headwaters
0.0	21.7	66.1	12.2	0.0

The following stream(s) occur in the watershed:
He‘eia

BIOTIC SAMPLING EFFORT

Biotic samples were gathered in the following year(s):
1975 1977 1995 2003

Distribution of Biotic Sampling: The number of survey locations that were sampled in the various reach types.

Survey type	Estuary	Lower	Middle	Upper	Headwaters
Damselfly Surveys	0	0	1	0	0
DAR General Surveys	0	1	0	0	0
Published Report	0	1	0	0	0
Unpublished Report	0	3	2	0	0

BIOTA INFORMATION

Species List

Native Species

Cnidarians	*Mastigias sp.*
Crustaceans	*Atyoida bisulcata*
	Copepod sp.
	Macrobrachium grandimanus
	Palaemon debilis
	Palaemonetes sp.
	Podophthalmus vigil
Fish	*Caranx ignobilis*
	Congrid(?) species
	Eleotris sandwicensis
	Kuhlia sandvicensis
	Kuhlia xenura
	Mugil cephalus
	Sphyraena barracuda
	Stenogobius hawaiiensis
Snails	*Ferrissia sharpi*
	Littoraria scabra
	Melampus parvulus
	Neritina vespertina
Worms	Hirudinean sp.
	Scolelepis sp.

Native Species

Insects	*Megalagrion nigrohamatum nigrolineatum*

Introduced Species

Crustaceans	*Macrobrachium lar*
	Procambarus clarkii
	Scylla serrata
Fish	*Clarias fuscus*
	Gambusia affinis
	Misgurnus anguillicaudatus
	Poecilia reticulata
	Tilapia sp.
	unidentified poeciliid
	Xiphophorus helleri
Snails	*Melania sp.*

Introduced Species

Insects	*Cheumatopsyche analis*
	Crocothemis servilia
	Pantala flavescens
	Psorophora signipennis

Species Distributions: Presence (P) of species in different stream reaches.

Scientific Name	Status	Estuary	Lower	Middle	Upper	Headwaters
Atyoida bisulcata	Endemic			P		
Macrobrachium grandimanus	Endemic		P			
Eleotris sandwicensis	Endemic		P			
Kuhlia xenura	Endemic		P			
Stenogobius hawaiiensis	Endemic		P			
Megalagrion nigrohamatum nigrolineatum	Endemic			P		
Ferrissia sharpi	Endemic		P	P		
Neritina vespertina	Endemic		P			
Mastigias sp.	Indigenous		P			
Palaemon debilis	Indigenous		P			
Podophthalmus vigil	Indigenous		P			
Caranx ignobilis	Indigenous		P			
Congrid(?) species	Indigenous		P			
Kuhlia sandvicensis	Indigenous		P			
Mugil cephalus	Indigenous		P			
Sphyraena barracuda	Indigenous		P			
Littoraria scabra	Indigenous		P			
Melampus parvulus	Indigenous		P			
Scolelepis sp.	Indigenous		P			
Macrobrachium lar	Introduced			P		
Procambarus clarkii	Introduced		P	P		
Scylla serrata	Introduced		P			
Clarias fuscus	Introduced		P	P		
Gambusia affinis	Introduced		P	P		
Misgurnus anguillicaudatus	Introduced		P	P		
Poecilia reticulata	Introduced		P			
Tilapia sp.	Introduced		P			
unidentified poeciliid	Introduced		P			
Xiphophorus helleri	Introduced		P	P		
Cheumatopsyche analis	Introduced		P	P		
Crocothemis servilia	Introduced		P			
Pantala flavescens	Introduced		P			
Psorophora signipennis	Introduced		P			
Melania sp.	Introduced		P			
Copepod sp.	Undetermined		P			
Palaemonetes sp.	Undetermined		P			
Hirudinean sp.	Undetermined			P		

HISTORIC RANKINGS

Historic Rankings: These are rankings of streams from historical studies. "Yes" means the stream was considered worthy of protection by that method. Some methods include non-biotic data in their determination. See Atlas Key for details.

Multi-Attribute Prioritization of Streams - Potential Heritage Streams (1998): No

Hawaii Stream Assessment Rank (1990): Moderate

U.S. Fish and Wildlife Service High Quality Stream (1988): No

The Nature Conservancy- Priority Aquatic Sites (1985): No

National Park Service - Nationwide Rivers Inventory (1982): No

Current DAR Decision Rule Status: The following criteria are used by DAR to consider the biotic importance of streams. "Yes" means that watershed has that quality.

Native Insect Diversity > 19 spp.	Native Macrofauna Diversity > 5 spp.	Absence of Priority 1 Introduced
No	Yes	No

Abundance of Any Native Species	Presence of Candidate Endangered Species	Endangered Newcomb's Snail Habitat
No	Yes	No

CURRENT WATERSHED AND STREAM RATINGS

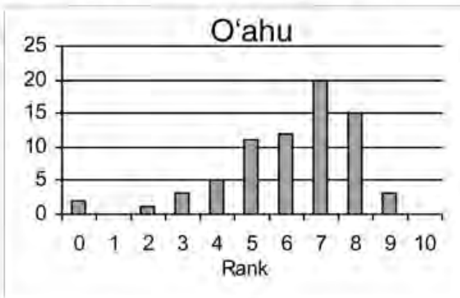
The current watershed and stream ratings are based on the data contained in the DAR Aquatic Surveys Database. The ratings provide the score for the individual watershed or stream, the distribution of ratings for that island, and the distribution of ratings statewide. This allows a better understanding of the meaning of a particular ranking and how it compares to other streams. The ratings are standardized to range from 0 to 10 (0 is lowest and 10 is highest rating) for each variable and the totals are also standardized so that the rating is not the average of each component rating. These ratings are subject to change as more data are entered into the DAR Aquatic Surveys Database and can be automatically recalculated as the data improve. In addition to the ratings, we have also provided an estimate of the confidence level of the ratings. This is called rating strength. The higher the rating strength the more likely the data and rankings represent the actual condition of the watershed, stream, and aquatic biota.

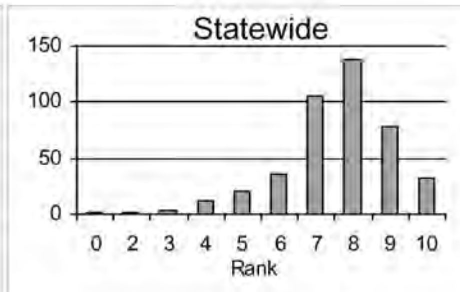
WATERSHED RATING: He‘eia, O‘ahu

Land Cover Rating: Rating is based on a scoring sytem where in general forested lands score positively and developed lands score negatively.

Watershed Rating

7

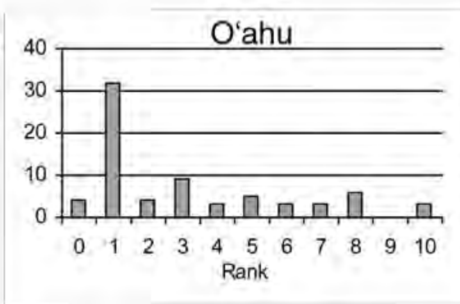


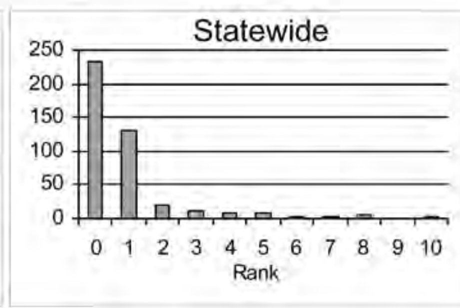


Shallow Waters Rating: Rating is based on a combination of the extent of estuarine and shallow marine areas associated with the watershed and stream.

Watershed Rating

7

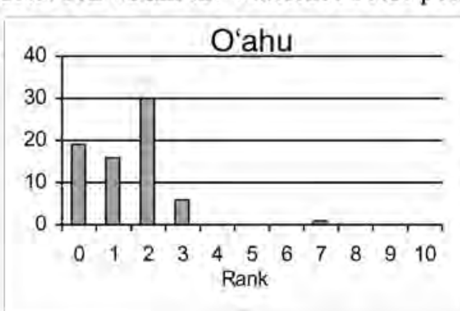


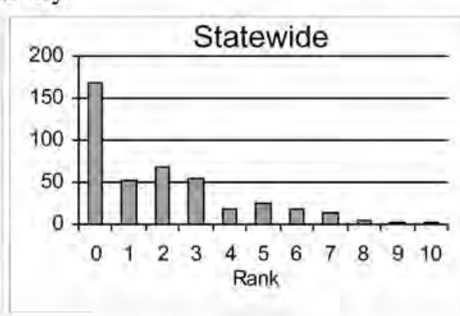


Stewardship Rating: Rating is based on a scoring system where higher levels of land and biodiversity protection within the watershed score positively.

Watershed Rating

1



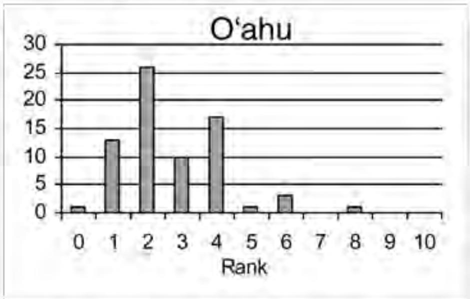


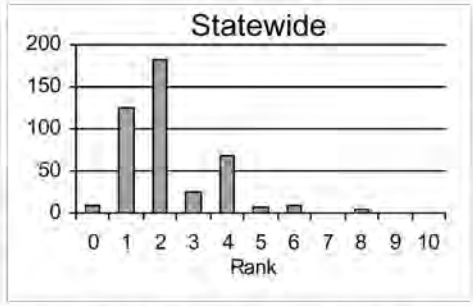
WATERSHED RATING (Cont): He‘eia, O‘ahu

Size Rating: Rating is based on the watershed area and total stream length. Larger watersheds and streams score more positively.

Watershed Rating

2

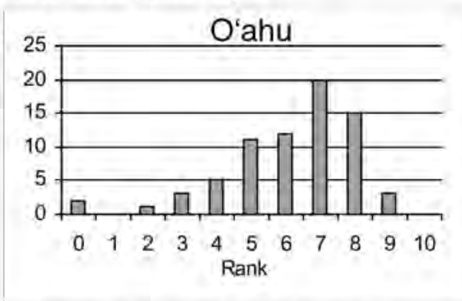


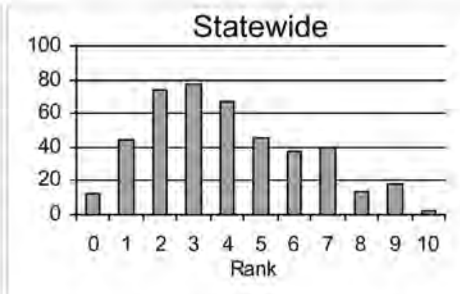


Wetness Rating: Rating is based on the average annual rainfall within the watershed. Higher rainfall totals score more positively.

Watershed Rating

3

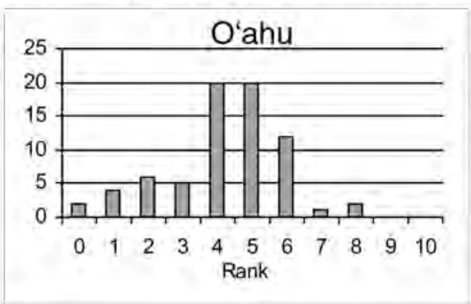


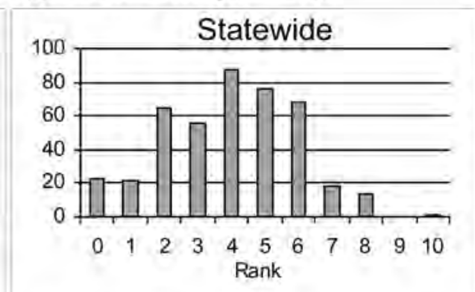


Reach Diversity Rating: Rating is based on the types and amounts of different stream reaches available in the watershed. More area in different reach types score more positively.

Watershed Rating

5

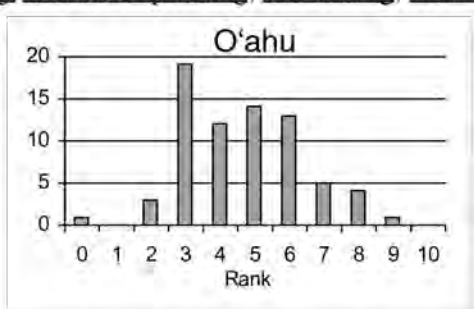


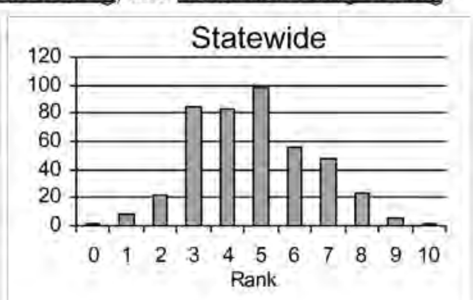


Total Watershed Rating: Rating is based on combination of Land Cover Rating, Shallow Waters Rating, Stewardship Rating, Size Rating, Wetness Rating, and Reach Diversity Rating.

Watershed Rating

6



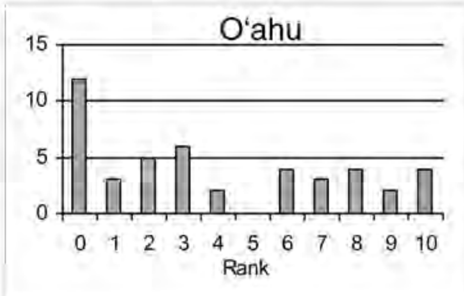


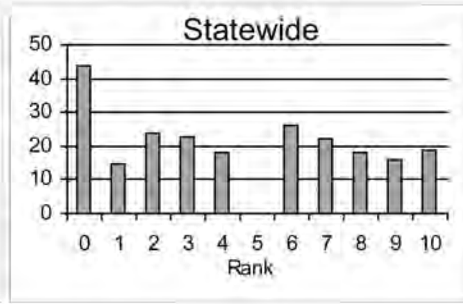
BIOLOGICAL RATING: He‘eia, O‘ahu

Native Species Rating: Rating is based on the number of native species observed in the watershed.

Stream Rating

6

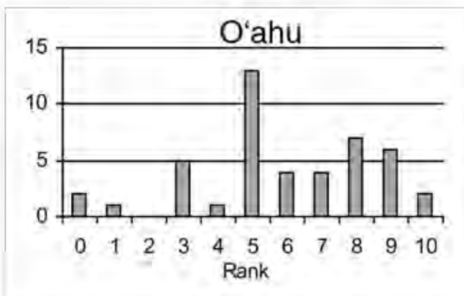


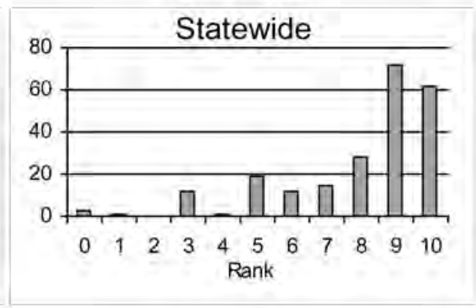


Introduced Genera Rating: Rating is based on the number of introduced genera observed in the watershed.

Stream Rating

5

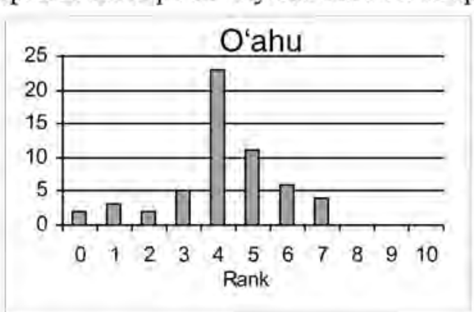


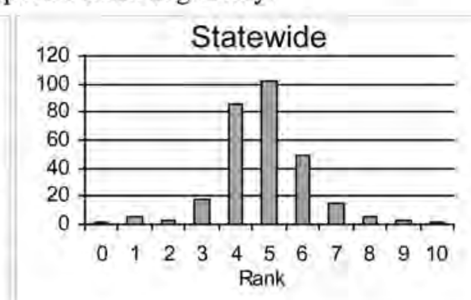


All Species' Score Rating: Rating is based on the Hawaii Stream Assessment scoring system where native species score positively and introduced species score negatively.

Stream Rating

5

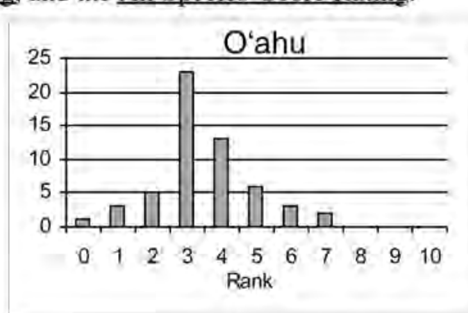


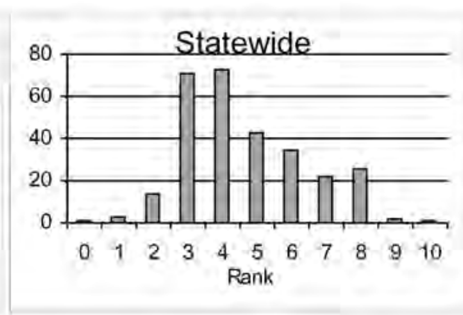


Total Biological Rating: Rating is the combination of the Native Species Rating, Introduced Genera Rating, and the All Species' Score Rating.

Stream Rating

4



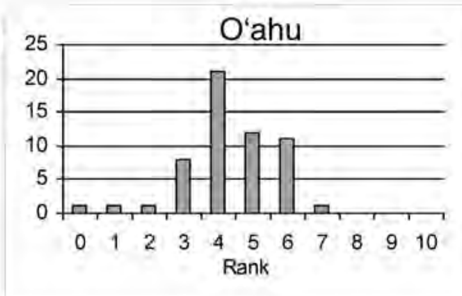


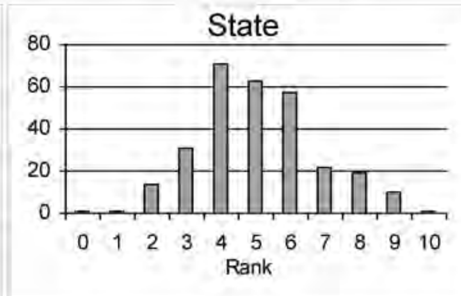
OVERALL RATING: He‘eia, O‘ahu

Overall Rating: Rating is a combination of the Total Watershed Rating and the Total Biological Rating.

Watershed Rating

5



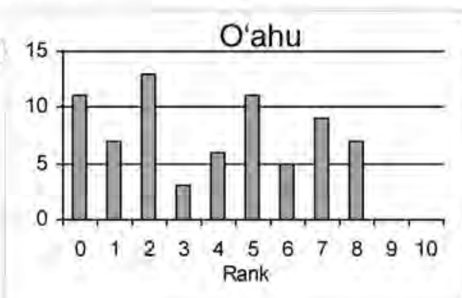


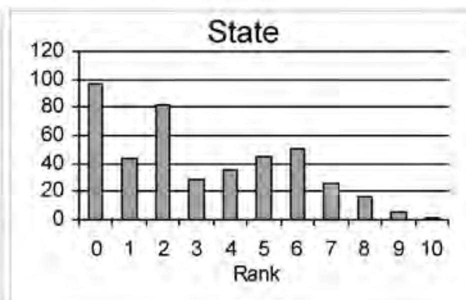
RATING STRENGTH: He‘eia, O‘ahu

Rating Strength: Represents an estimate of the overall study effort in the stream and is a combination of the number of studies, number of different reaches surveyed, and the number of different survey types.

Information Rating

5





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