Instream Flow Standard Assessment Report

Island of Maui
Hydrologic Unit 6006
Launiupoko

August 2017 **DRAFT PR-2017-03**

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

COVER
Satallite image of Launiupoko Gulch with the Launiupoko Stream flowing into the Pacific Ocean, West Maui [Google Earth, 2008].

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)
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)
DWS	Department of Water Supply (County of Maui)
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
HC&S	Hawaiian Commercial and Sugar Company
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
KAA	Kekaha Agriculture Association
KIUC	Kauai Island Utility Cooperative
LCA	Land Commission Award
LUC	Land Use Commission (State of Hawaii)
MECO	Maui Electric Company
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)
WMI	West Maui Investments, LLC
WML	West Maui Land Company
WQS	Water Quality Standards
WRPP	Water Resource Protection Plan (Commission on Water Resource Management)
WTF	water treatment facility

1.0 Introduction

General Overview

The hydrologic unit of Launiupoko is located in West Maui, on the the southwest flank of Puu Kukui Mountain which forms the western part of the Hawaiian island of Maui (Figure 1-3 and 1-4). It covers an area of 6.317 square miles from 4,680 feet elevation to the sea with a mean basin elevation of 1,960 feet and a mean basin slope of 79.9 percent (Figure 1-5). Eighty percent of the basin has a slope greater than 30 percent. The longest flow path in Launiupoko is 5.06 miles in length, traversing in a southwest-southernly direction from its headwaters to the ocean. The Launiupoko Stream is composed of one main stem and one tributary which flows only intermittently in the upper sections in response to rainfall-runoff. Baseflow is supported by dike-impounded groundwater. The basin has a mean annual precipitation of 55.8 inches. There is no town but the 2010 census population identifies 559 people residing in Launiupoko (U.S. Census Bureau Office of Planning 2011). The population figure does not account for residents living outside of the hydrologic unit who may rely on water from within the unit but it does include properties that receive water from outside of the unit (such as from the Kauaula hydrologic unit). One state highway exists along the coastline, and a number of private roads provide access to large areas of the hydrologic unit, although the mauka land is limited by steep terrain and no roads (Figure 1-6). There is one registered diversion and a pipeline system that carries non-potable water to small scale commercial agriculture and agrigultural-zoned farm lots.

Current Instream Flow Standard

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

> Interim instream flow standard for West Maui. The Interim Instream Flow Standard for all streams on West Maui, 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 December 31, 1988. Streamflow was not measured on that date; therefore, the current interim IFS is not a measurable value.

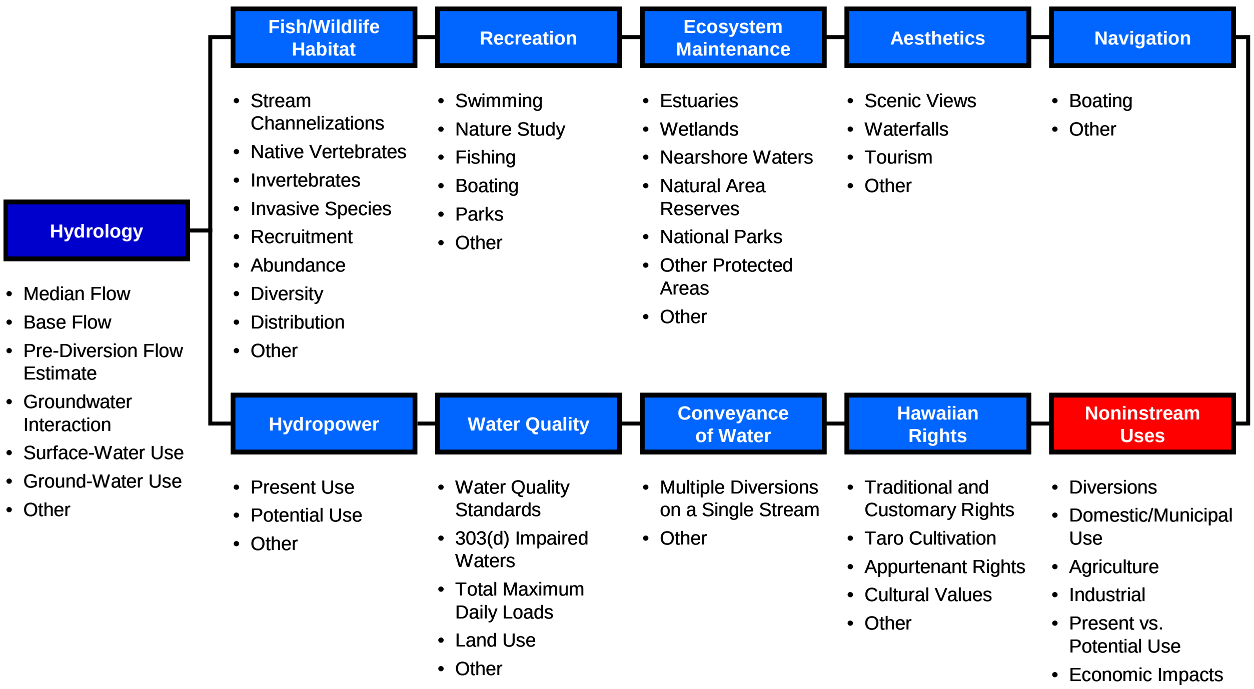
Instream Flow Standards

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.

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

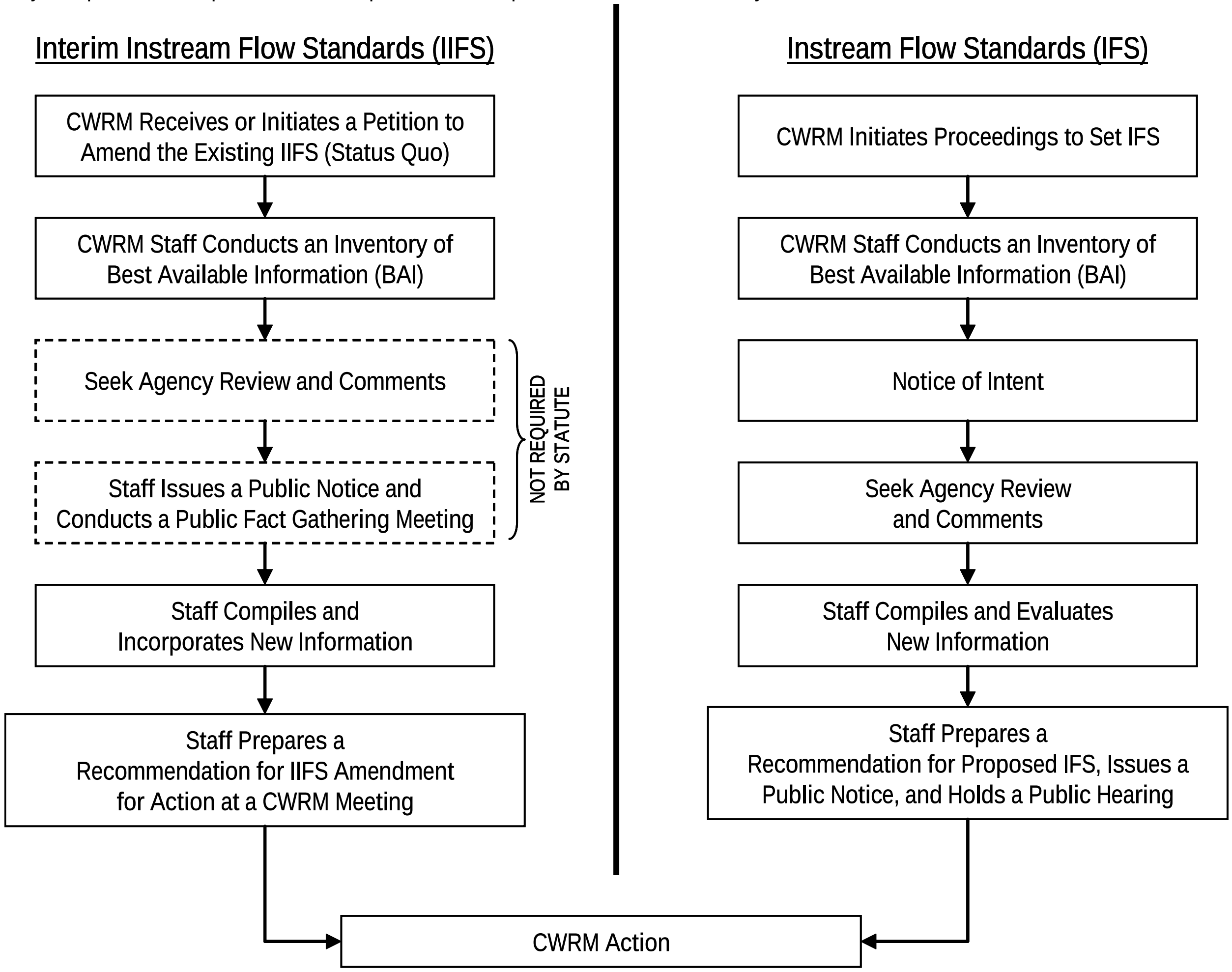


Interim Instream Flow Standard Process

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."

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.

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.



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.

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.

Noninstream uses are summarized in Section 13.0. Maps are provided at the end of each section to help illustrate information presented within the section's text or tables. Finally, Section 14.0 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. Quickbird satellite imagery of the Launiupoko hydrologic unit and streams in southwest Maui, Hawaii. (Source: U.S. Geological Survey, 1996; State of Hawaii, Commission on Water Resource Management, 2015c; State of Hawaii, Division of Aquatic Resources, 2005)

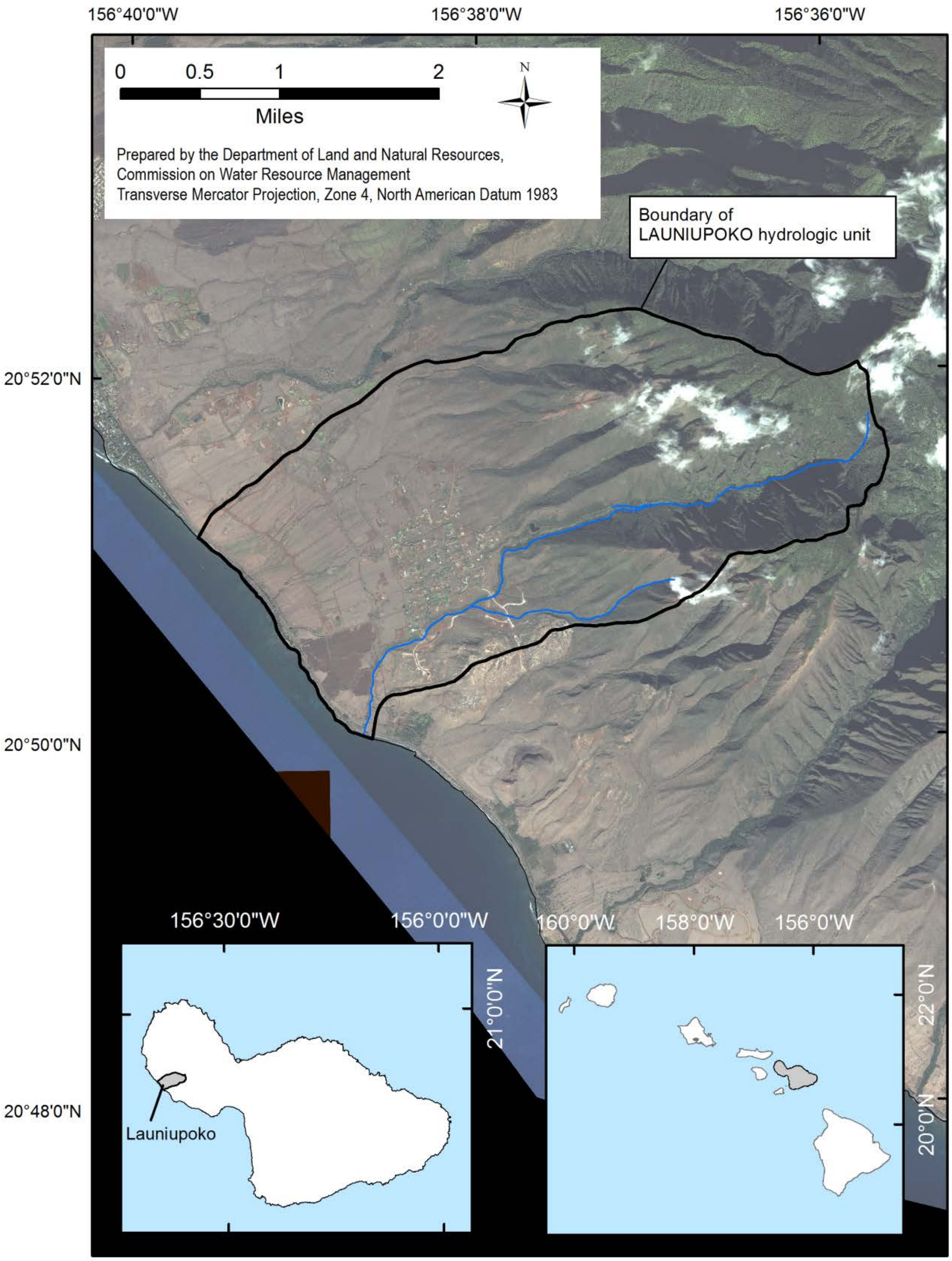


Figure 1-4. Elevation range of the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2004e; U.S. Geological Survey, 2001)

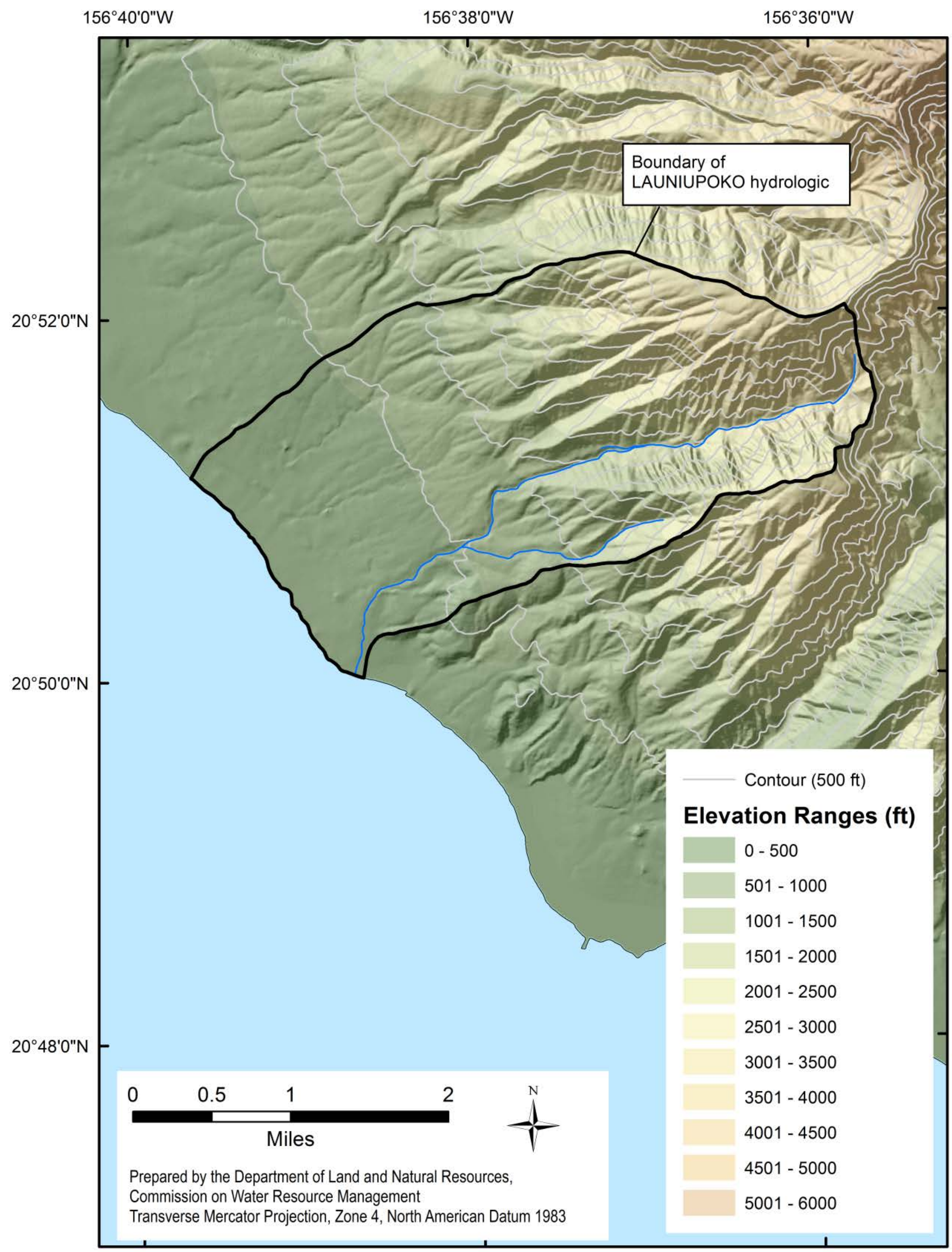


Figure 1-5. USGS topographic map of the Launiupoko hydrologic unit. (Source: State of Hawaii, Planning Department, 2004)

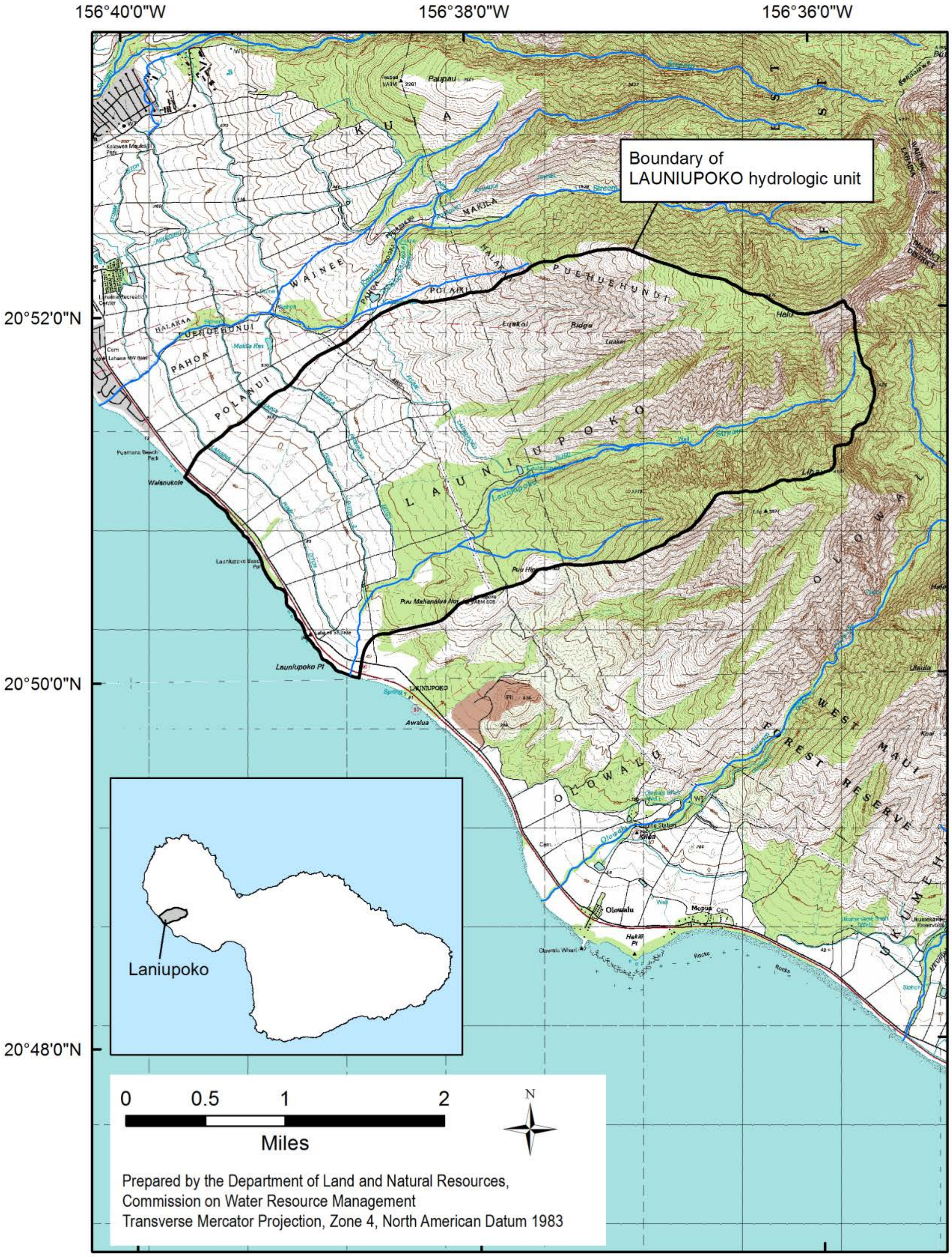
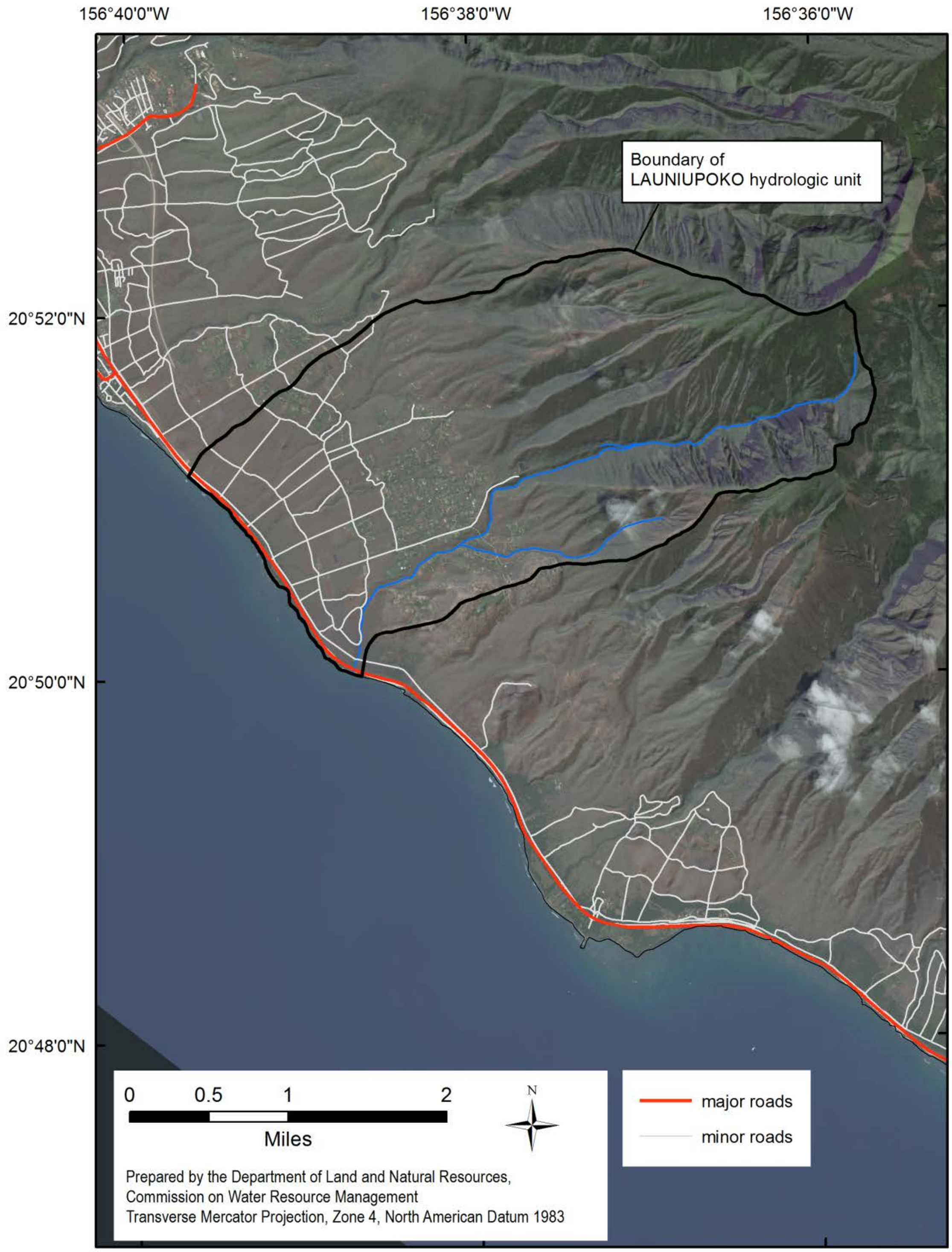


Figure 1-6. Major and minor roads for the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning 2015)



2.0 Unit Characteristics

Geology

Launiupoko is on the southern flanks of Puu Kukui, the West Maui volcano (Figure 2-2). There were three separate volcanic phases in West Maui (Stearns and Macdonald 1942). The first phase called the Wailuku Volcanic Series, makes up about 97% of the volume of the volcano, and consists of thin pahoehoe and aa flows of tholeiitic olivine basalt with minor plagioclase basalt as thick as 1700 meters (Table 2-1). The summit of this shield building phase eventually collapsed to form a caldera about 3.2 km across, with horizontal post-caldera lava flows. The Honolua Volcanic Series, the second phase, is dominated by alkali rocks that formed an incomplete cap to the volcano ranging from single flows less than 10 m thick to several flows as thick as 230 m on the northeastern slopes (Macdonald and abbott 1970). Occasionally viscuous trachytic magma formed domes with steeply sloping flow planes, especially in the Kahoma and Launiupoko areas. Many dike and vent formations were produced in the Honolua Series although due to the lack of well-developed rift zones, their distribution is somewhat irregular. The Honolua Series finished about 500 kya, followed by a brief third phase of activity which included four small eruptions occurring on the southwestern slope forming the Lahaina Volcanic Series. These lava flows were all silica undersaturated basanitoids or basanites. The rapid erioson and valley incision of West Maui has produced broad alluvial fans with unconsolidated dunes of lithified to semi-lithified calcareous sand on the Eastern slopes. The generalized geology of the Launiupoko hydrologic unit is depicted in Figure 2-2.

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

Name	Rock Type	Area (mi^2)	Percent (%)
Wailuku Volcanics	Lava flow	3.56	54.5
Older alluvium	Lithified sand and gravel	2.33	35.6
Honolua Volcanics	Lava flows, bulbous dome of massive lava	0.35	5.4
Alluvium	Sand and gravel	0.30	4.5

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 Launiupoko hydrologic unit, soils are largely dominated by Wainee soils and rough mountainous lands, with 43.3% of soils in Group B, 6.3% of soils in Group C and 40.5% of soils in Group D (Table 2-2). Most of the unit consists of soils in Group B, silty loam or loam with moderate infiltration rates, or Group D, clay loam, silty clay loam, or clay, with high runoff potential. The less sloping tops of ridges and interfluves (regions of higher land between valleys in the same hydrologic unit) are poorly drained but still support moderate infiltration. The lowlands are composed of well-drained clay and rough broken land – very steep land broken by numerous intermittent drainage channels (Figure 2-3). The numerous gulches and mountainsides have slopes of 40 to 70 percent, leading to high rates of slopewash. Runoff is rapid in these soils and geologic erosion is active. The soils of rough broken land are not uniform. The clay is moderately permeable with slow to medium runoff and a slight to moderate erosion hazard (U.S. Department of Agriculture, Soil Conservation Service, 1972).

Table 2-2. Area and percentage of soil types for the Launiupoko hydrologic unit.

Map Unit	Description	Area (mi^2)	Percent (%)
rRO	Rock outcrop	2.708	41.4
WyC, WxC, WyB, WxB	Wainee	1.919	29.4
rSM	Stony alluvial land	0.621	9.5
rRT	Rough mountainous land	0.551	8.4
rRS	Rough broken & stony land	0.503	7.7
rRK	Rock land	0.232	3.6
W	Water	0.002	<0.1

The Wainee soils are deep, extremely stony silty clay, well drained, and weathered from basic igneous rock on alluvial fans of 3-15 percent slope (U. S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division, 1986). These soils are excellent for agriculture. The center of the hydrologic unit consists of rough broken and rough mountainous soils while stony alluvial land (riverwash) dominates the lower reaches (Figure 2-3).

Rainfall

The West Maui Mountains are the driving force affecting the distribution of rainfall in Launiupoko with rainfall affected by both the orographic[1] effect and the rain shadow effect (Figure 2-1). 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 at the windward mountain slopes. The temperature inversion zone typically extends from 6,560 feet to 7,874 feet. This region is influenced by a layer of moist air below and dry air above, making climate extremely variable (Giambelluca and Nullet, 1992). The fog drip zone occurs below the elevation where cloud height is restricted by the temperature inversion, where temperature increases with elevation (Sholl et al., 2002). Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al, 2002) and can contribute significantly to ground water recharge. Above the 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.

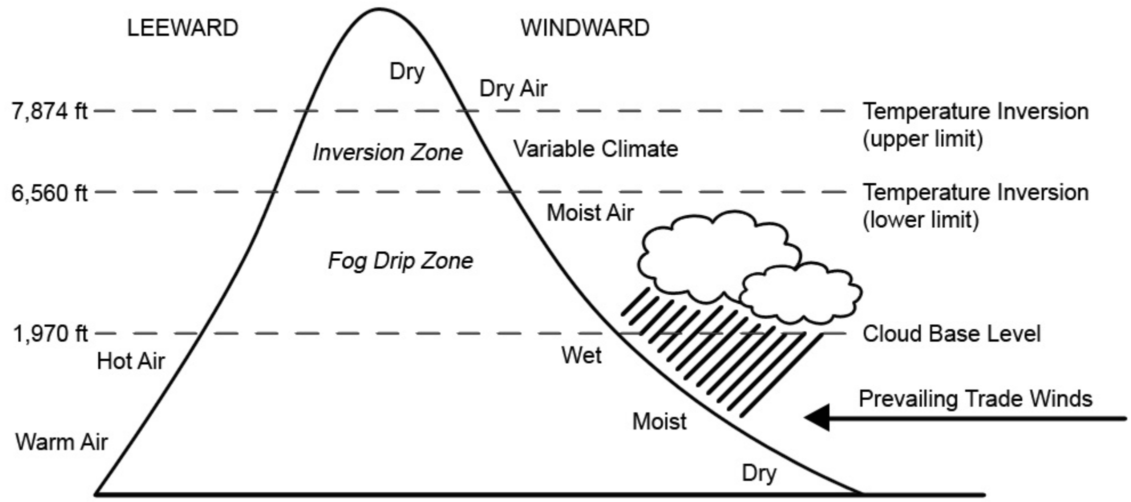
A majority of the mountains in Hawaii peak in the fog drip zone, where cloud-water is intercepted by vegetation. In such cases, air passes over the mountains, warming and drying while descending the leeward mountain slopes. Precipitation on Puu Kukui is influenced by its position relative to the trade winds. The highest position lies in the cloudy layer below the trade wind inversion resulting in peak rainfall for the region. Mean annual rainfall on Puu Kukui measured by the USGS (station 380.0) and Maui Land & Pineapple since 1928 is about 362 inches. 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). 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 in one location. Finally, the relatively round, conical shape of the West Maui Mountains exposes all sides of the peak to wind and moisture.

The Launiupoko hydrologic unit is situated on the leeward flank of the West Maui Mountains and as such receives less orographic rainfall than windward slopes and is impacted by the rain shadow effect. Wind will blow rainfall over the interfluve from east/northeast facing hydrologic units, contributing to higher

[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.

rainfall in the upper elevations (Figure 2-4). 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 just 39.5 inches. Above 2000 ft, rainfall is highest during the months of December and January, where the mean monthly rainfall is 9.41 inches and 9.52 inches, respectively. Irregular southernly Kona storm systems may produce localized intense rainfall on south facing slopes.

Figure 2-1. Orographic precipitation in the presence of mountains higher than 6,000 feet.



Currently, fog drip data for leeward slopes are non-existant. 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 Launiupoko hydrologic unit, which is calculated by multiplying the ratios with the monthly rainfall values (Giambelluca et al, 2013). Calculations show that approximately 32 percent of Launiupoko lies in the fog drip zone based on elevation. The total contribution from fog drip to the water budget based on percent of fog drig from monthly rainfall is about 31%, assuming the same ratios apply to leeward slopes (Table 2-3).

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 Launiupoko Hydrologic Unit based on an elevation range of 2000-4680 ft.

Month	Ratio (%)	Mean Rainfall (in)	Contribution (in)
January	13	9.52	1.24
February	13	7.49	0.97
March	13	8.32	1.08
April	27	7.07	1.91
May	27	5.05	1.36
June	27	4.74	1.28
July	67	4.44	2.97
August	67	4.71	3.16
September	67	3.38	2.26
October	40	5.08	2.03
November	40	7.67	3.07
December	27	9.41	2.54

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 Launiupoko, average annual solar radiation is 202.2 W/m^2 per day with a range of 174.8 – 225.4 W/m^2 per day (Figure 2-5). 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 is 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.

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[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.

A common approach to estimating evaporation is to employ a relationship between potential evaporation and the available water in the watershed. Potential evaporation is the maximum rate of evaporation if 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 2-1). 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 (Nullet and Giambelluca, 1990). Above the inversion, clear sky and high solar radiation at the summits cause increased evaporation, with pan evaporation rates of about 50 to 70 inches per year (Shade, 1999, Fig. 9). 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. Potential annual evapotranspiration in the Launiupoko hydrologic unit (Figure 2-6) averages 106.4 inches per year and ranges from 60.9 to 475.3 inches per year (Giambelluca et al. 2014).

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 ground water resources, land use classification continues to serve as a valuable tool for long-range planning purposes.

As of 2014, the LUC designated 51 percent of the land in Launiupoko as conservation district and 49 percent as agricultural district (State of Hawaii, Office of Planning, 2015d). The conservation district is located in the upper part of the hydrologic unit, whereas the agricultural district lies in the lower part of the hydrologic unit (Figure 2-7). The primary agricultural use was sugarcane grown by Pioneer Mill Co., which operated until 1999. Large tracks of agricultural land in Launiupoko were sold to West Maui Land Company (WML). This land has been subdivided into a few small commercial farms, but mostly agrigultural-zoned farm lots.

[4] Temperature inversion is when temperature increases with elevation.

Land Cover

Land cover for the hydrologic unit of Lauiniupoko 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 Launiupoko, e.g. forest, grassland, shrub land, with minor developed areas, cultivated areas, and bare land (Table 2-4, Figure 2-8). 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 2-9**).** The land cover maps provide a general representation of the land cover types in Launiupoko. 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.

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

Land Cover	Description	Area (mi^2)	Percent of Unit
Scrub/Shrub	Areas dominated by woody vegetation less than 6 meters in height	3.070	47.0
Grassland	Natural and managed herbaceous cover	1.198	18.3
Evergreen Forest	Areas where more than 67% of the trees remain green throughout the year	0.874	13.4
Paature/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops	0.590	9.0
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	0.303	4.6
Developed Open Space	Areas with a mixture of constructed materials, grasses or low-lying vegetation planted in developed areas for recreation, erosion control, and aesthetic purposes	0.264	4.0
Cultivated Crops	Areas intensely managed for the production of annual crops	0.142	2.2
Medium Intensity Developed	Areas with a mixture of constructed materials (50-79%) and vegetation	0.055	
Open Water	Areas of water with less than 25% vegetation	0.019	0.3
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.016	0.2
High Intensity Developed		0.006	0.1

Community members have reported lands cultivated with tropical flowers, coconuts, banana, and papaya, primarily in the lower-middle portions of the hydrologic unit. Some lots have horses or livestock. Along the coast, a number of typical native and alien species have been reported. Some of those native species include ulei, naupaka kahakai, akia, lau’we, and hala.

Table 2-5. HI-GAP land cover classes and area distribution in Launiupoko hydrologic unit. (Source: HI-GAP, 2005)

Land Cover	Area (mi^2)	Percent of Unit
Alien Shrubland	2.549	38.98%
Cultivated Cropland	0.936	14.31%
Alien Grassland	0.890	13.61%
Alien Forest	0.564	8.62%
Native Dry Cliff Vegetation	0.408	6.24%
Uncharacterized Shrubland	0.295	4.51%
Open Ohia Forest	0.222	3.39%
Uncharacterized Forest	0.188	2.87%
Closed Ohia Forest	0.139	2.13%
Native Shrubland / Sparse Ohia (native shrubs)	0.130	1.99%
Uncharacterized Open-Sparse Vegetation	0.110	1.68%
Uluhe Shrubland	0.032	0.49%
Developed, Low Intensity	0.029	0.44%
Very Sparse Vegetation to Unvegetated	0.022	0.33%
Deschampsia Grassland	0.017	0.27%
Native Wet Cliff Vegetation	0.009	0.14%
Undefined	0.001	0.01%

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 the flood happening 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.

Peak floods in Launiupoko were modled by USGS using regression formulas and flow records at nearby USGS stations. The 2-, 5-, 10-, 50-, and 100-year flood magnitudes in Launiupoko are calculated as 88, 290, 517, 1260, and 1680 cfs. 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 identified most of the Launiupoko hydrologic unit as flood-risk zone X, outside of the the 1% annual chance of flood. There is a small region along the coastline in Launiupoko where the flood risk is considered zone VE, with the potential for shallow flooding of 1-3 feet annually or areas, but there are no areas with greater than a 0.2% chance (Figure 2-10).

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 ground water supplies due to reduced recharge from rainfall. 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. During this period, both mean annual flow and median flow in Kawaikoi Stream was 75% of normal.

Table 2-6. Drought risk areas for Maui. (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	Kula, Kahului, Wailuku, Hana, Lahaina	Kula, Hana	Kula
Agriculture and Commerce	--	--	--
Environment, Public Health and Safety	Kula	Kula	Kula

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 Maui are summarized in Table 2-6. Based on the 12-month SPI, the Kula and Hana regions have the greatest risk to drought impact on Maui 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. The Launiupoko region is vulnerable to drought in the agricultural sector and has substantial wildfire risk, but there is less risk to the general population.

Figure 2-2. Mean annual rainfall of the Launiupoko hydrologic unit. (Source: Giambelluca et al., 2013)

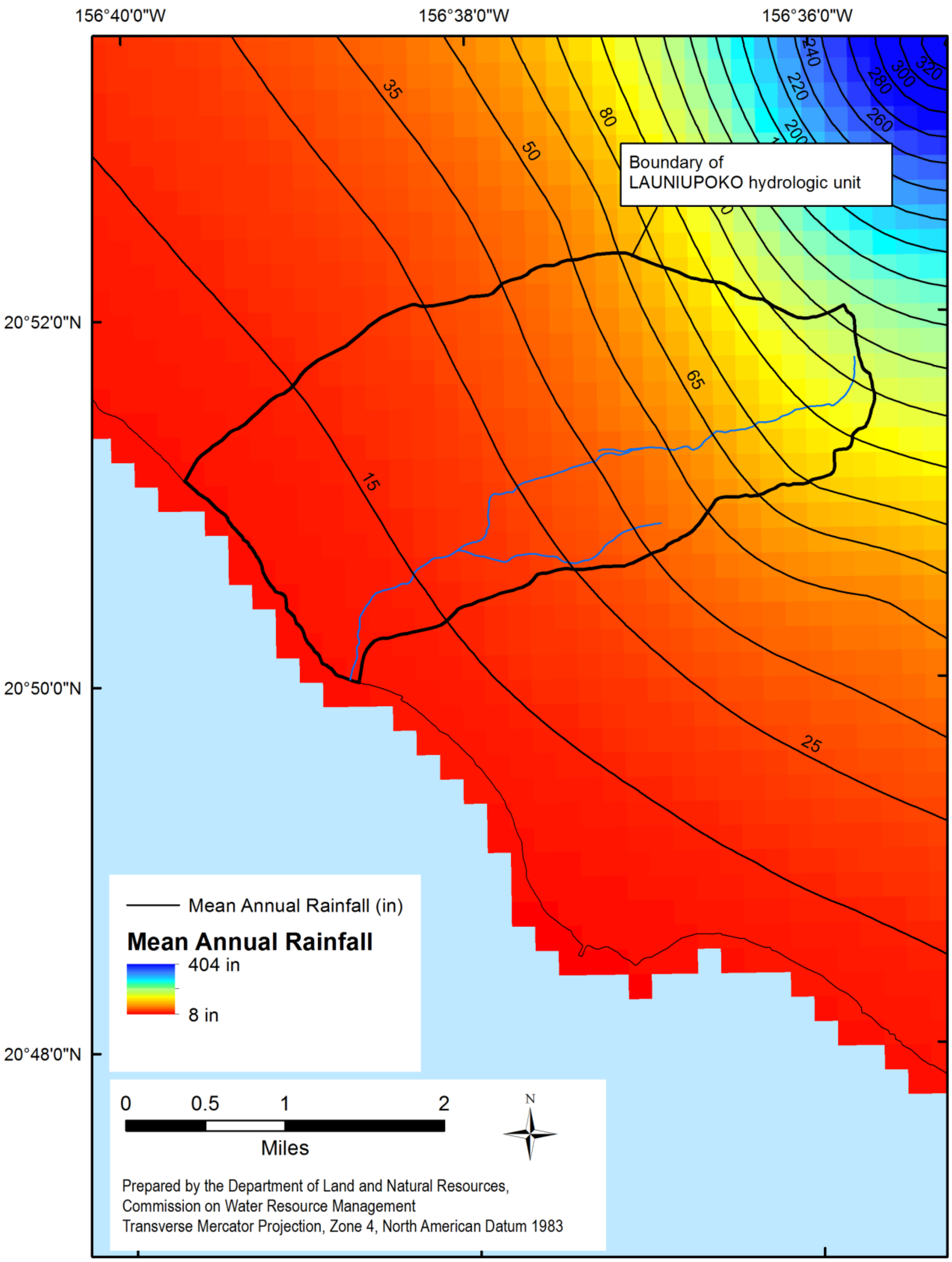


Figure 2-3. Mean annual solar radiation of the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015c)

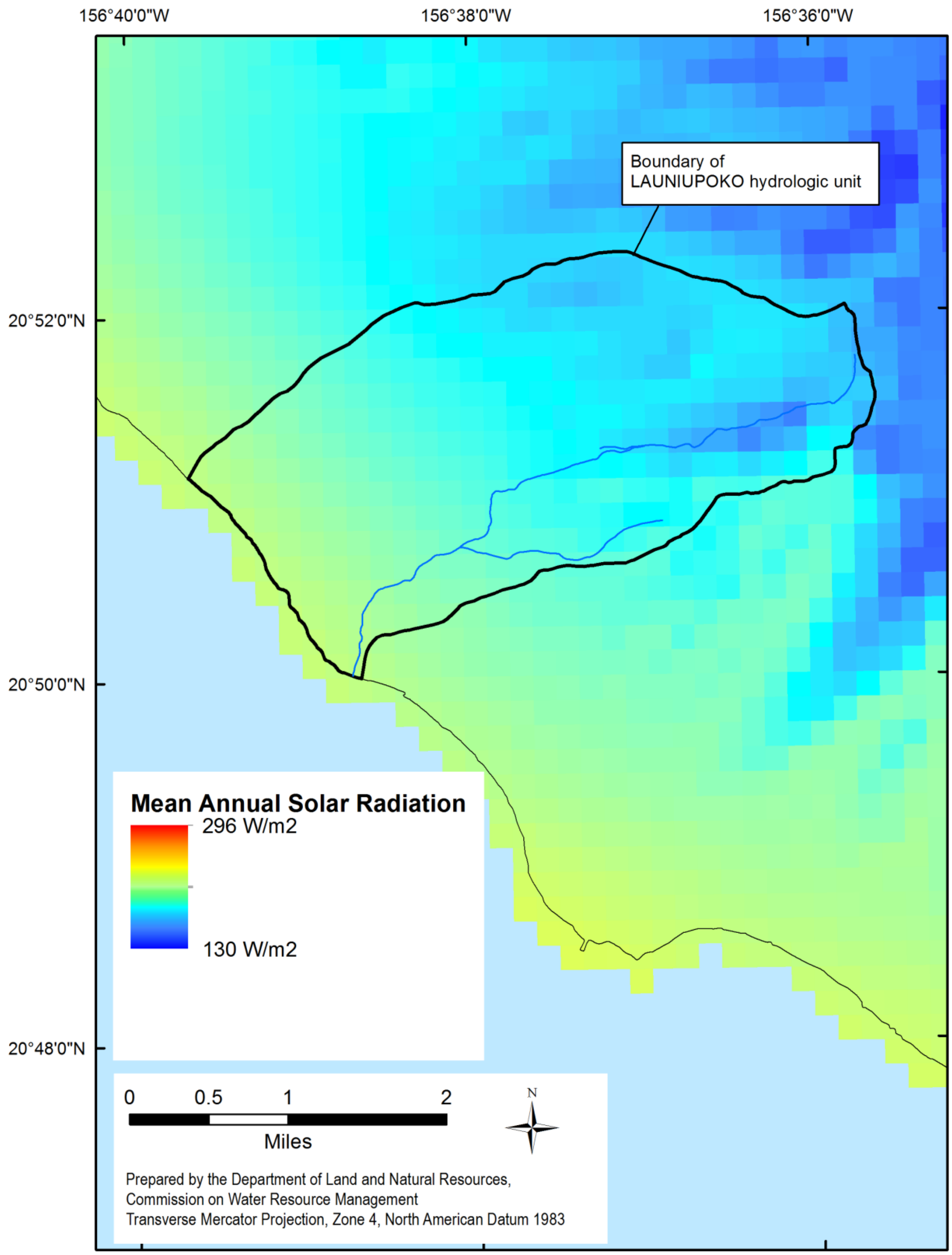


Figure 2-4. Mean annual potential evapotranspiration (Penman-Monteith method) of the Launiupoko hydrologic unit. (Source: Giambelluca et al., 2014)

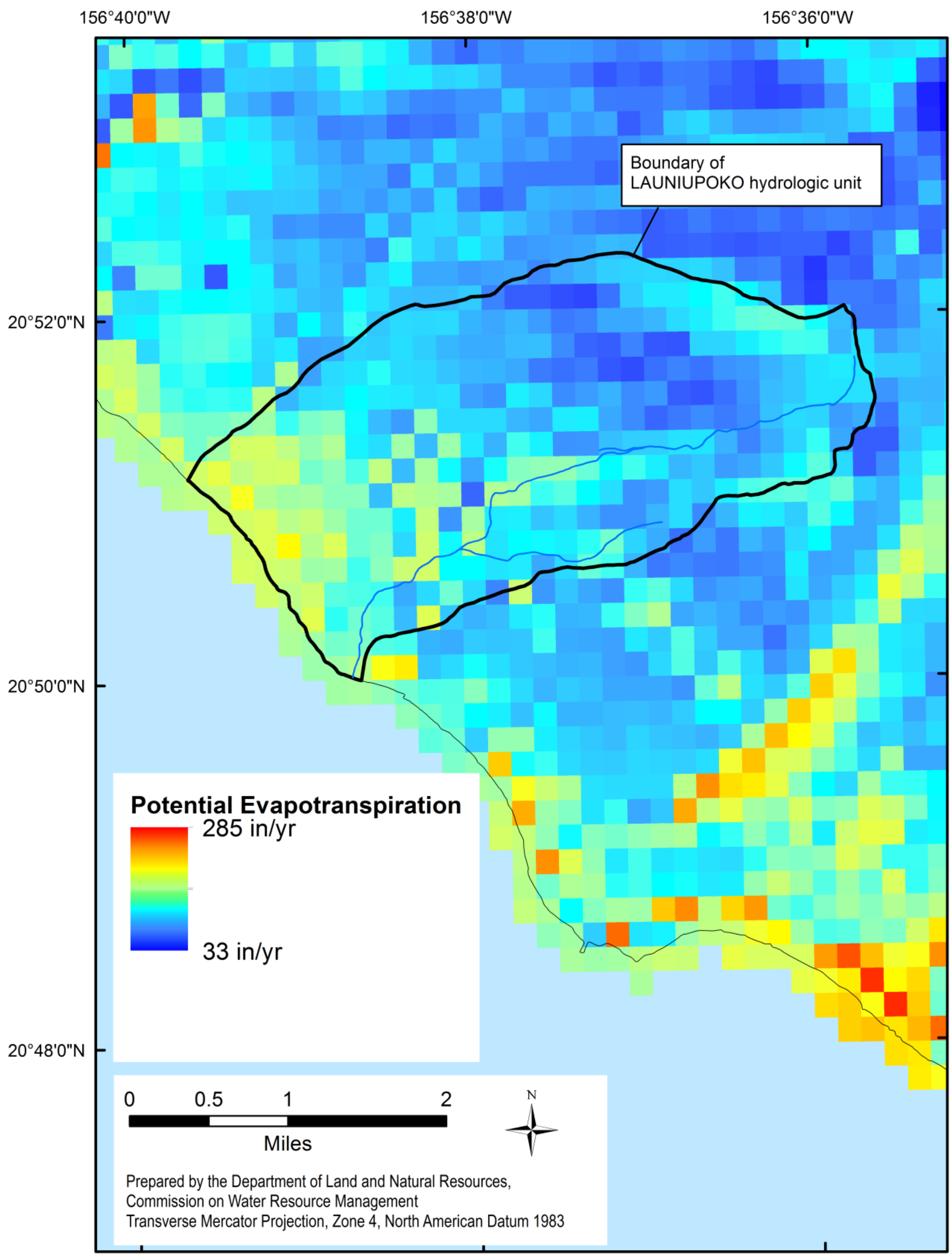


Figure 2-5. Generalized geology of the Launiupoko hydrologic unit. (Source: Sherrod et al., 2007)

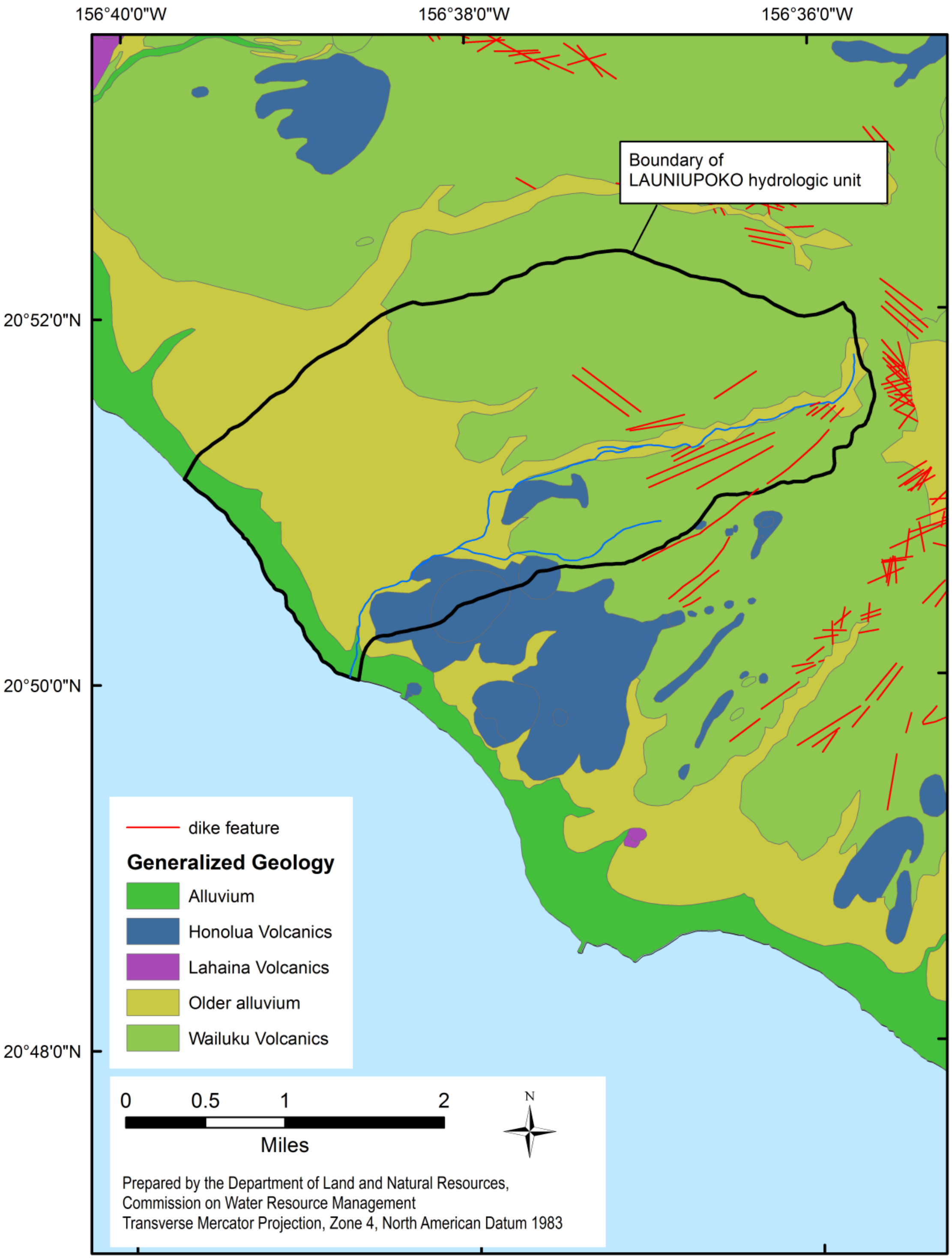


Figure 2-6. Soil classification of the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015m)

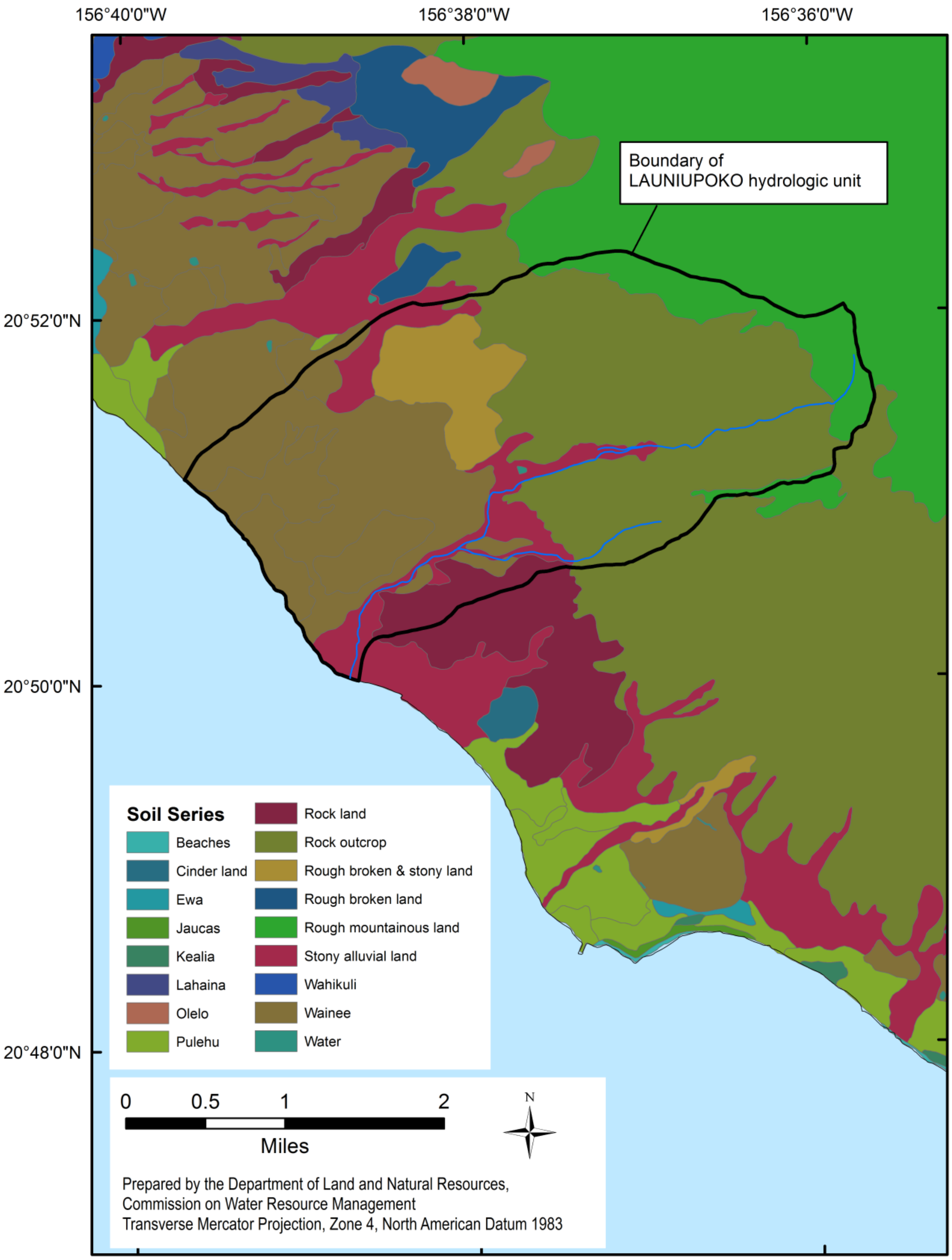


Figure 2-7. State land use district boundaries of the Launiupoko hydrologic unit (Source: State of Hawaii, Office of Planning, 2015d).

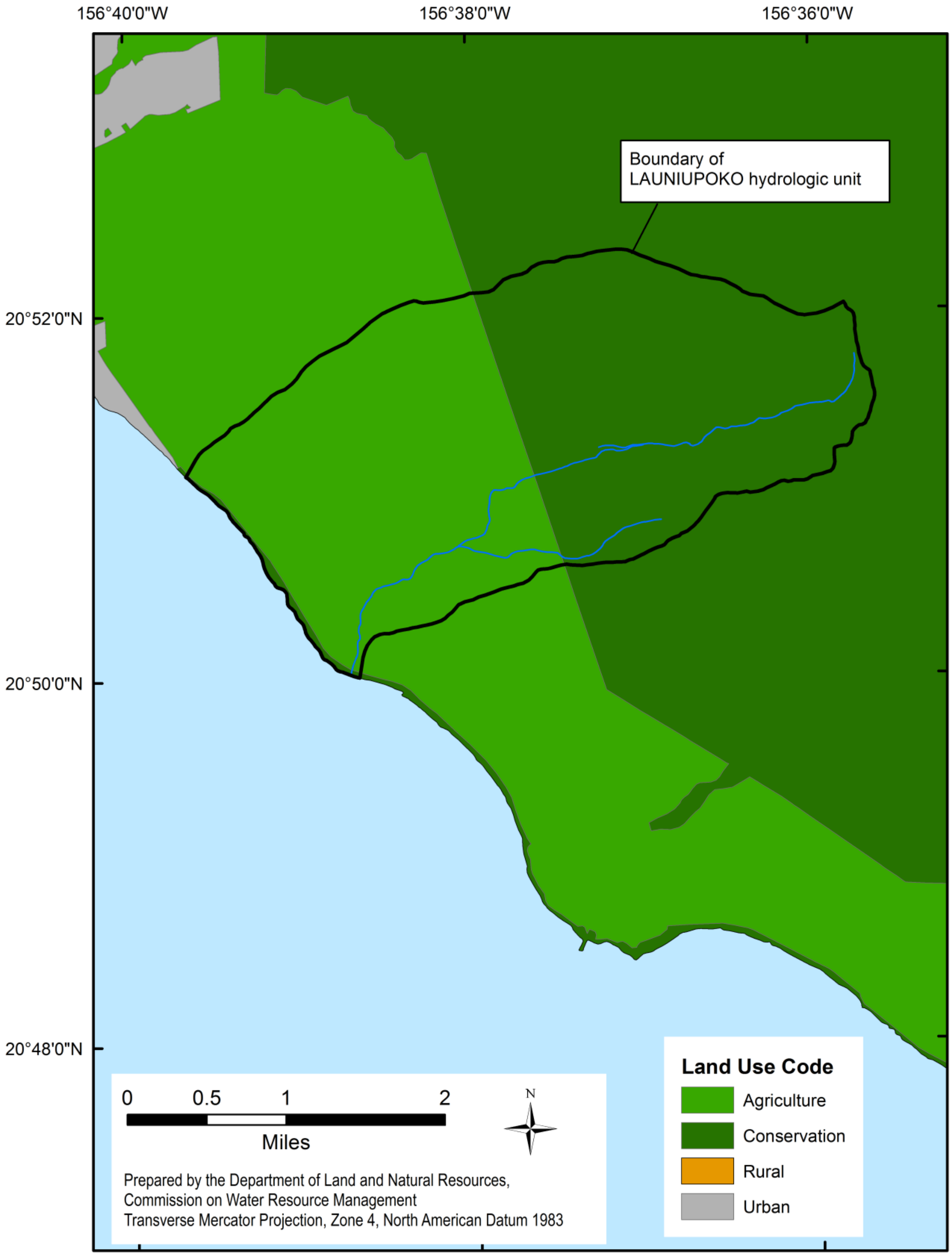


Figure 2-8. C-CAP land cover of the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015k).

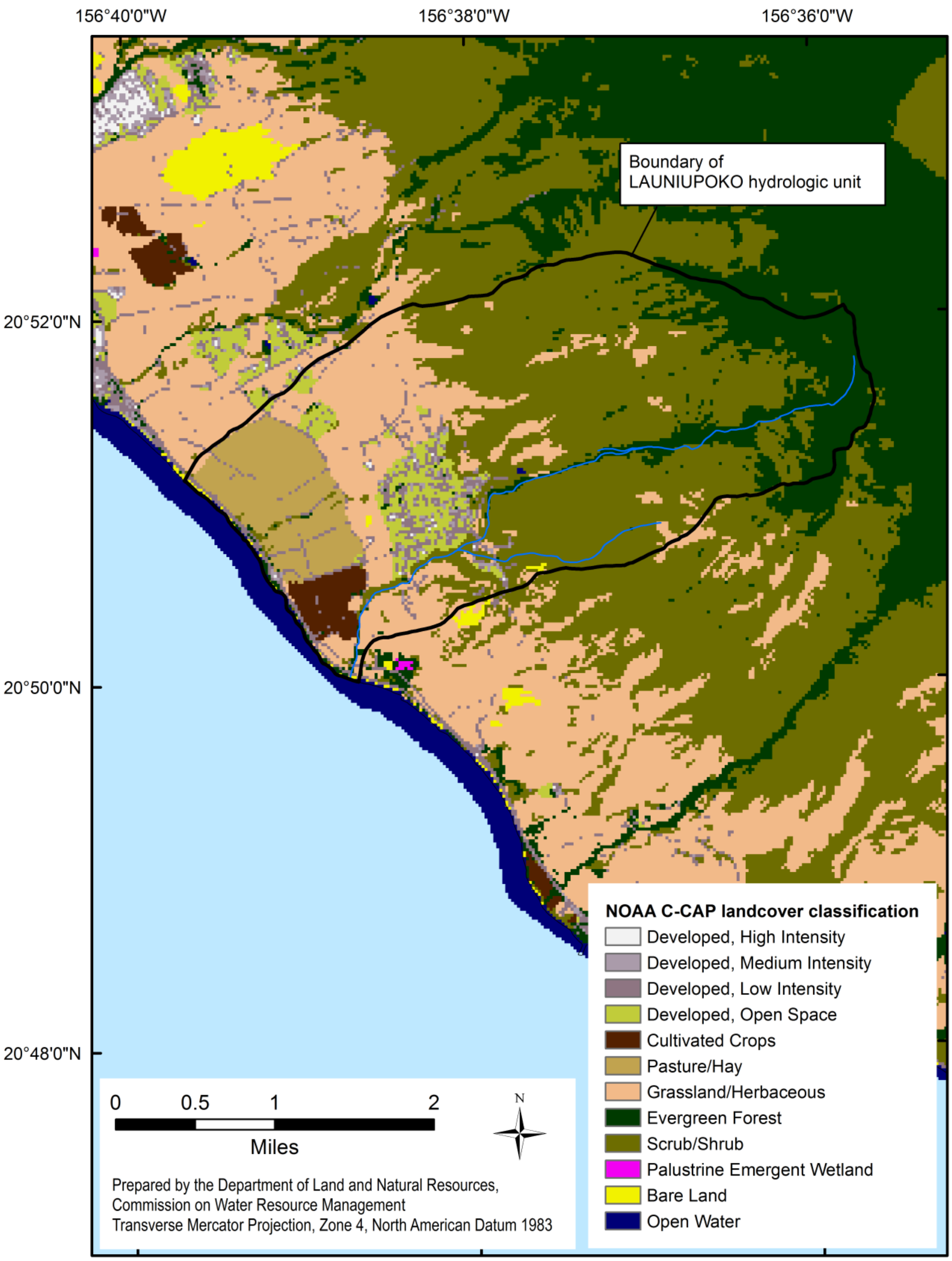


Figure 2-9. Hawaii GAP land cover classes of the Launiupoko hydrologic unit (Source: State of Hawaii, Office of Planning, 2015f).

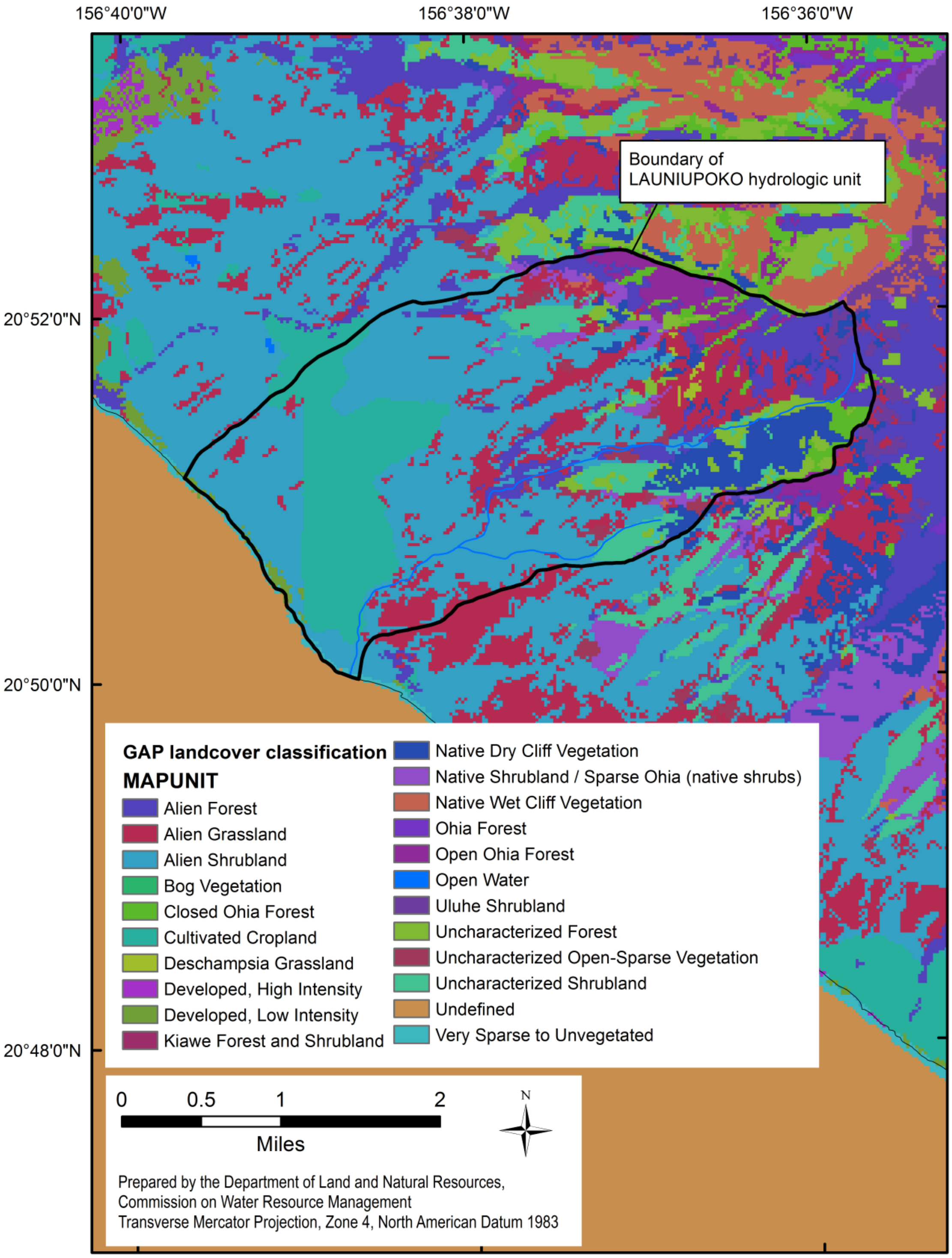
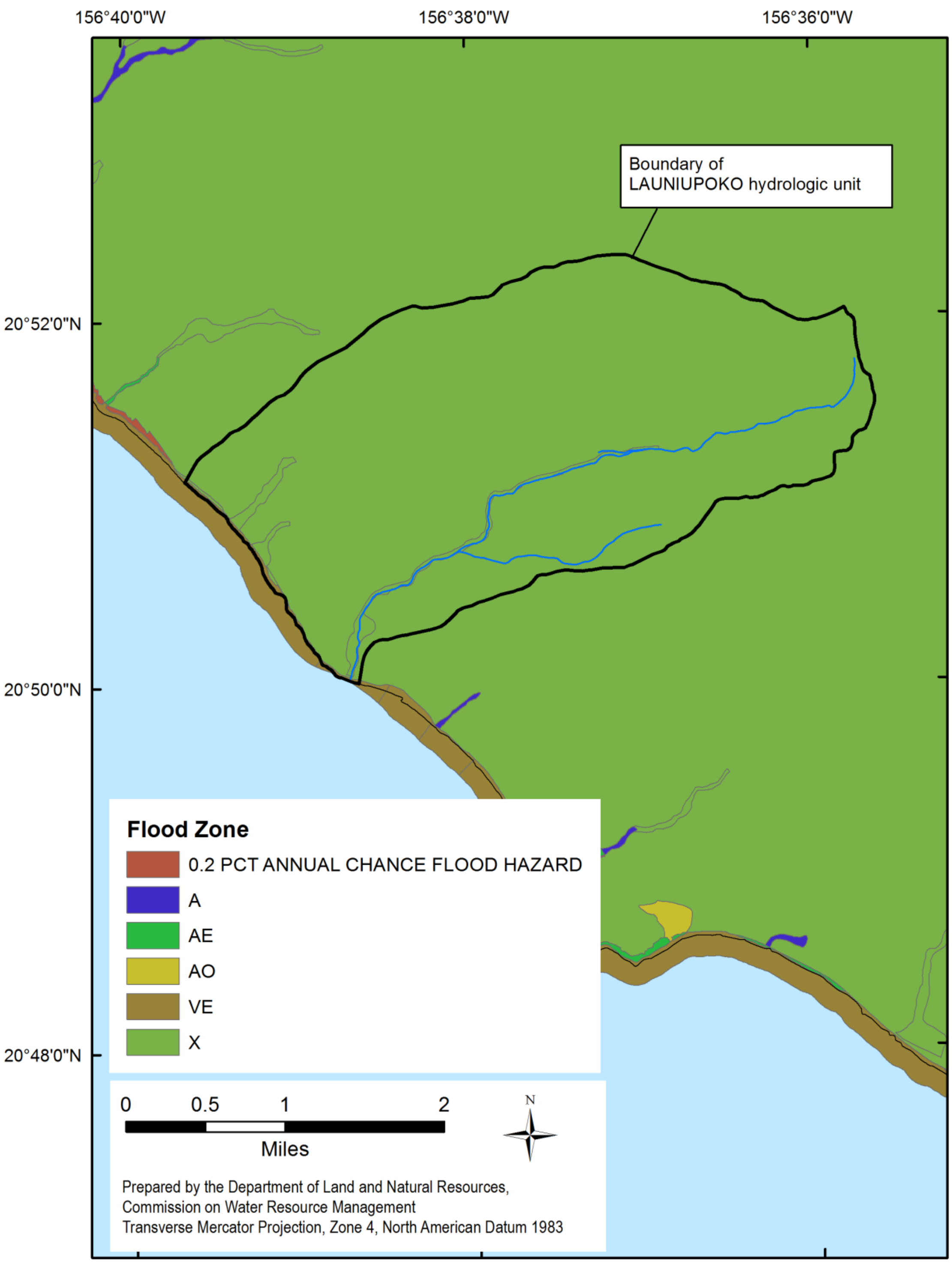


Figure 2-10. FEMA flood zone regions in the Launiupoko hydrologic unit (Source: Federal Emergency Management Agency, 2014).



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 Launiupoko Stream.

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 ground water is unlikely. Another way that ground water 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. It can discharge ground water onto the land surface, directly into the stream, or into the ocean. Figure 3-1 illustrates a valley that has been incised into a high-level water table, resulting in ground water discharges that contribute directly to streamflow and springs that contribute to streamflow. At places where erosion has removed the caprock, ground water discharges either as springs or into the ocean as seeps.

Ground Water

Ground water is an important component of streamflow as it constitutes the base flow[5] of Hawaiian streams. When ground water 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 ground water withdrawal can include the reduction of streamflow, which may cause a decrease in stream habitats for native species and a reduction in the amount of water available for irrigation. The interaction between surface water and ground water warrants a close look at the ground water recharge and demand within the State as well as the individual hydrologic units.

In Hawaii, ground water 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

[5] 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).

fresh ground water systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water-lens system 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. Vertically extensive fresh water-lens system can extend several hundreds or even thousands of feet below mean sea level. By contrast, a dike-impounded system is found in rift zones and caldera of a volcano where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. On Maui, dikes impound water to as high as 3,300 feet above mean sea level. 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 (Gingerich and Oki, 2000).

The hydrologic unit of Launiupoko occupies protions of the Launiupoko aquifer system. A general overview of the ground water occurrence and movement in Maui is described in Gingerich (1999b) and illustrated in Figure 3-1. Ground water is found in dike-impounded structures of Honolua and Wailuku Volcanics as well as in the fresh water-lens system making up the basal aquifer. Withdrawal from wells at or below sea level should not affect the high-elevation water table because the thick unsaturated zone will prevent any significant changes in the vertical flow gradient. However, during certain hydrologic conditions, there may be surface water-groundwater interactions, especially in the gaining reaches.

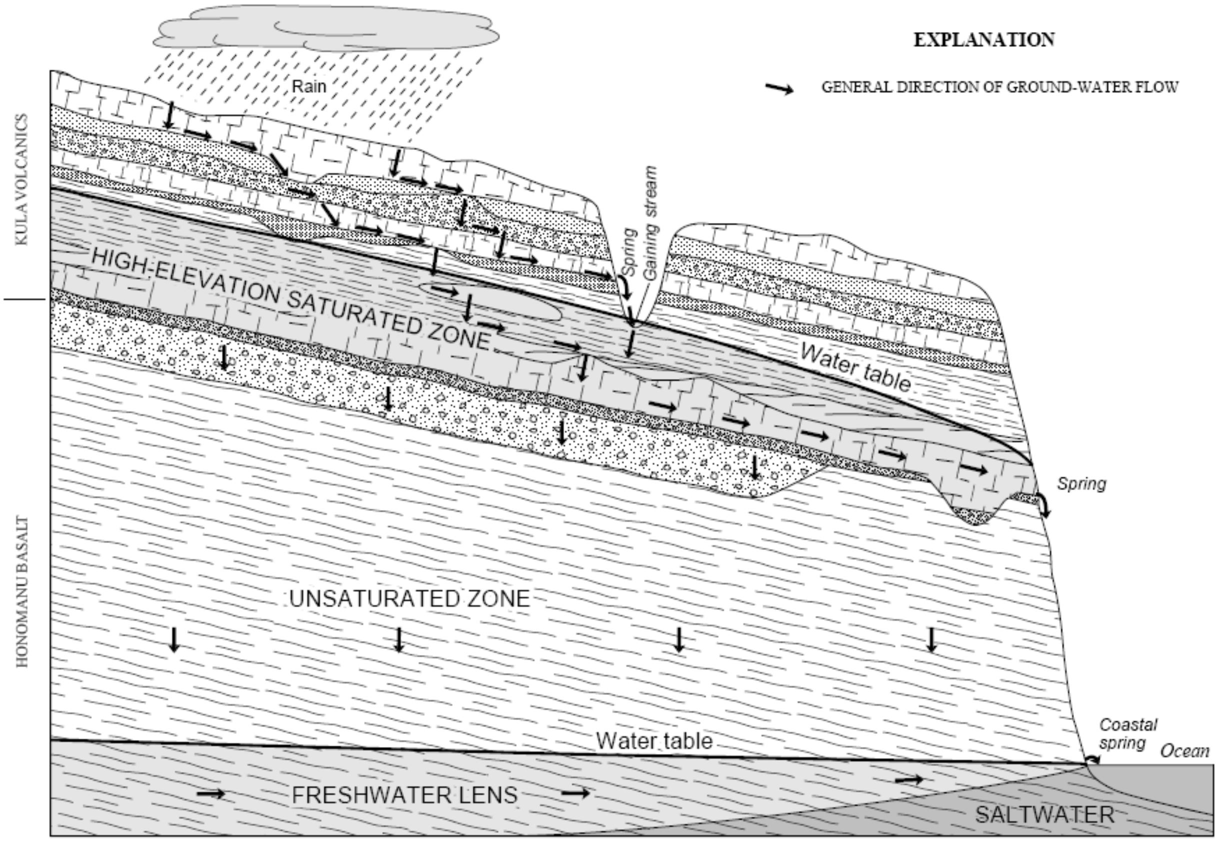
Pioneer Mill cut one development tunnel to supplement stream water to supply irrigation to sugarcane. Makila Land Company, a subsidiary of WML, has three functional wells in the Launiupoko Aquifer, two of which are in the Launiupoko hydrologic unit. Detailed information for each well is specified in Table 3-1. As of 2016, the 12-month moving average for existing groundwater withdrawals from the Launiupoko aquifer section was 0.375 mgd. This is well below the aquifer's current sustainable yield of 7 million gallons per day (State of Hawaii, Commission on Water Resource Management, 2015d). This potable water is for municipal use in domestic-residential single-family dwelling units or commercial use.

Table 3-1. Information of wells located in Lauiniupoko hydrologic unit (Source: State of Hawaii, Commission on Water Resource Management, 2015d).

[Negative elevation values indicate feet below mean sea level; positive elevation values indicate feet above mean sea level. Pump rate measured in gallons per minute (gpm); -- indicates value is unknown.]

Well number	Well Name	Well Owner	Year drilled	Use	Ground elevation (feet)	Well depth (feet)	Pump elevation (feet)	Pump depth (feet)	Pump rate (gpm)
5136-001	Launiupoko Tunnel	Pioneer Mill	--	IRR	1425	n/a	n/a	n/a	0
5137-001	Launiupoko 2	Launiupoko Water Co.	2000	Municipal	827	865	-34	861	100
5138-001	Launiupoko 1	Launiupoko Water Co.	1979	Municipal	633	677	-10	643	500
5238-001	Launiupoko 3	Launiupoko Water Co.	2003	Municipal	751	799	-9	760	500

Figure 3-1. Diagram illustrating the ground water system west of Keanae Valley, northeast Maui, Hawaii. Arrows indicate general direction of ground water flow (Source: Gingerich, 1999b).



Streamflow Characteristics

The USGS has maintained a variety of stream gaging stations over time, although none are currently active in Launiupoko (Figure 3-2). These stations have improved our understanding of water availability, the impacts of climate change of hydrology, flood frequency and intensity, and groundwater-surface water interactions. Flow in Launiupoko stream above the Launiupoko Ditch intake (station #16644000) was monitored from 1911 to 1917. Station 16641000 was only active a short period, with data missing from January, February, March and April of 1916 and historic streamflow characteristics are provided in Table 3-3. The closest long-term continuous stream flow monitoring stations maintained by the USGS are on Honokohau Stream (station #16620000) and Wailuku River (station #16604500). From 2012 to 2013, USGS established a partial-record gaging station above the diversion to develop low-flow discharge characteristics for the current period (1984-2013) as provided in Table 3-3. Differences in discharges between historic and current periods are likely due to a reduction of inflow from dike-impounded sources, differences in the phases of the Pacific Decadal Oscillation in which the data were collected, the influence of climate change, as well as the completeness of the actual datasets. Launiupoko stream is gaining immediately above the diversion, from about 1440 ft in elevation to the partial-record gaging station at 1,230 ft elevation (Figure 3-3). Dike-impounded groundwater supports continuous flow in the upper reaches of Launiupoko Stream with one-hundred percent of the low-flows diverted resulting in a dry stream below the diversion (Cheng 2014). The stream was also dry in the lowest reaches during every site visit by Commisstion staff from November 2016 to June 2017 (10 visits).

Table 3-2. Selected natural-flow duration discharge exceedance values from a historic (1911-1917) gaging station (#16644000) and current (1984-2013) partial record gaging station for the Launiupoko hydrologic unit. (Source: Cheng 2014)
[Flows are in cubic feet per second (cfs)]

	Discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded									
period	Q_{50}	Q_{55}	Q_{60}	Q_{65}	Q_{70}	Q_{75}	Q_{80}	Q_{85}	Q_{90}	Q_{95}
1911-1917	1.5	1.4	1.4	1.4	1.3	1.0	1.0	0.77	0.77	0.77
1984-2013	0.47	0.45	0.44	0.42	0.41	0.39	0.38	0.37	0.35	0.34

Long-term trends in flow

In a different study, 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 3-5 illustrates the results of the study for 7 long-term gaging stations around the islands. According to the analyses, 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. For example, mean annual streamflow in the nearby Honokohau Stream (USGS station 16620000) streamflow has slowly declined from the 1914 to 2015. At this station, the 10-year moving average annual streamflow was 43.65 cfs in 1926 and 32.91 cfs in 2015. 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 3-2. Ditches, diversions and gaging stations in the Launiupoko hydrologic unit (Source: State of Hawaii, Commission on Water Resource Management, 2015a).

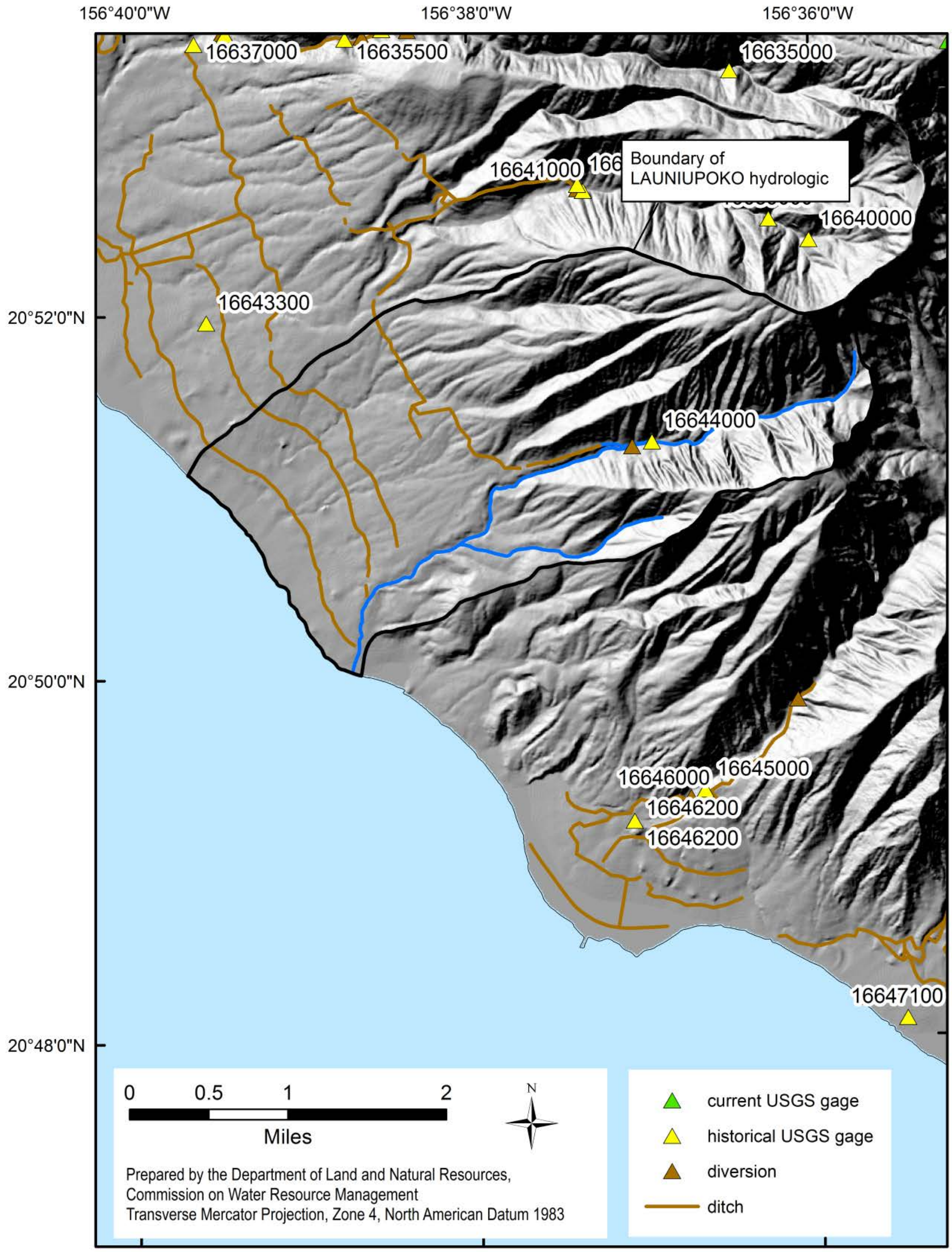


Figure 3-3. Seepage run results and median flow from partial record gaging stations of the Launiupoko hydrologic unit (Source: State of Hawaii, Commission on Water Resource Management, 2015a; Cheng, 2014).

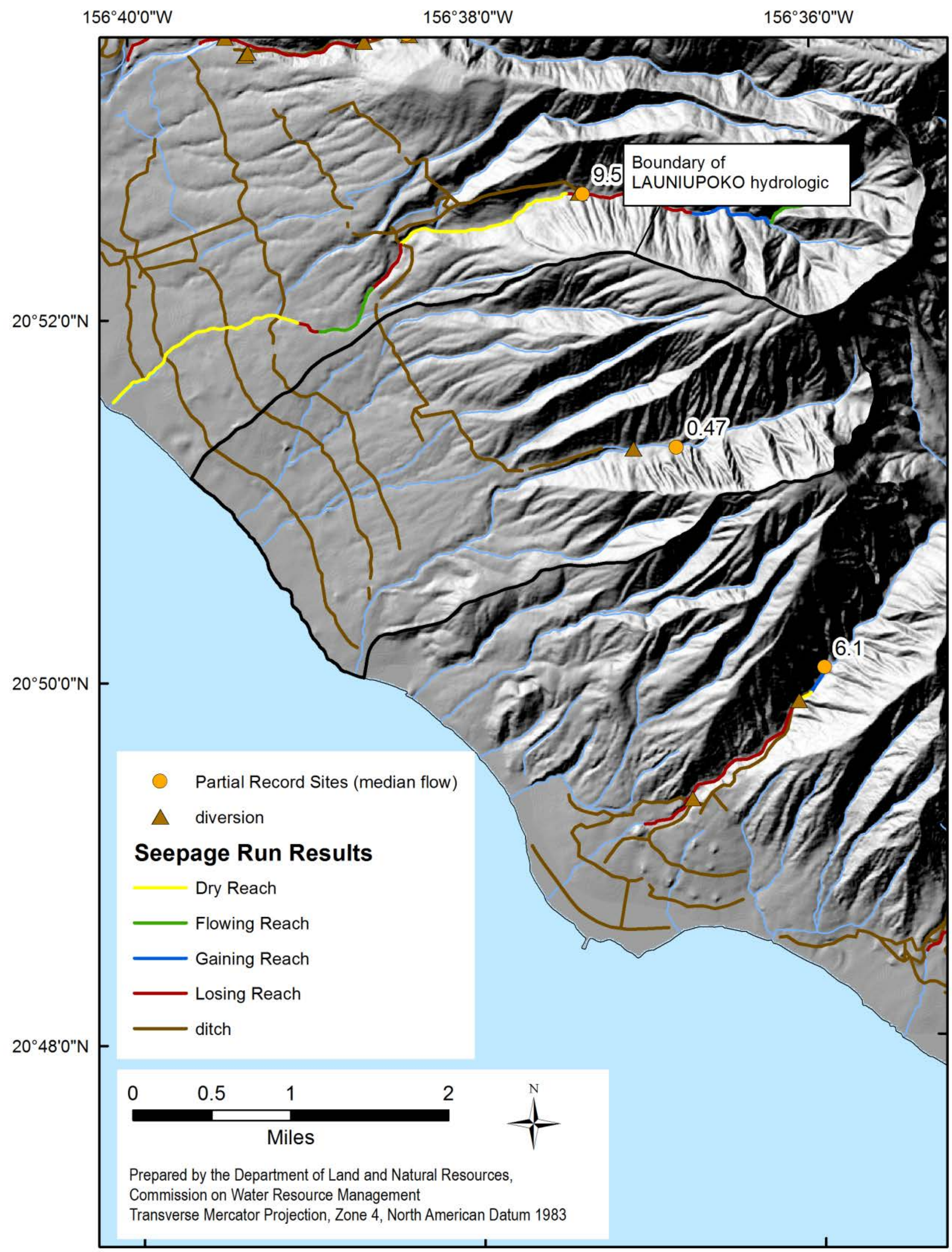


Figure 3-4. Aquifer system and well locations (with well numbers) of the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015d; State of Hawaii, Commission on Water Resource Management, 2015f)

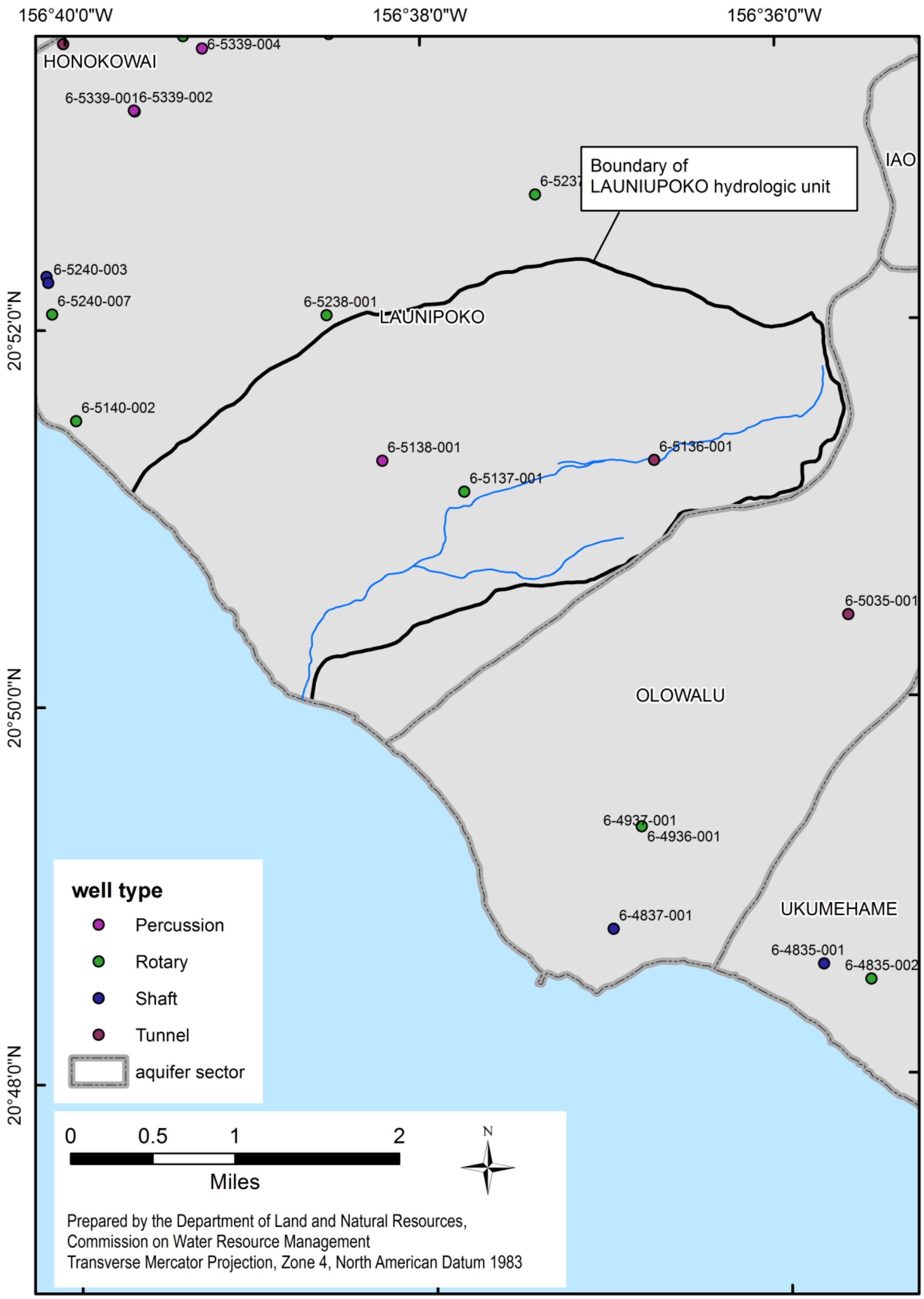
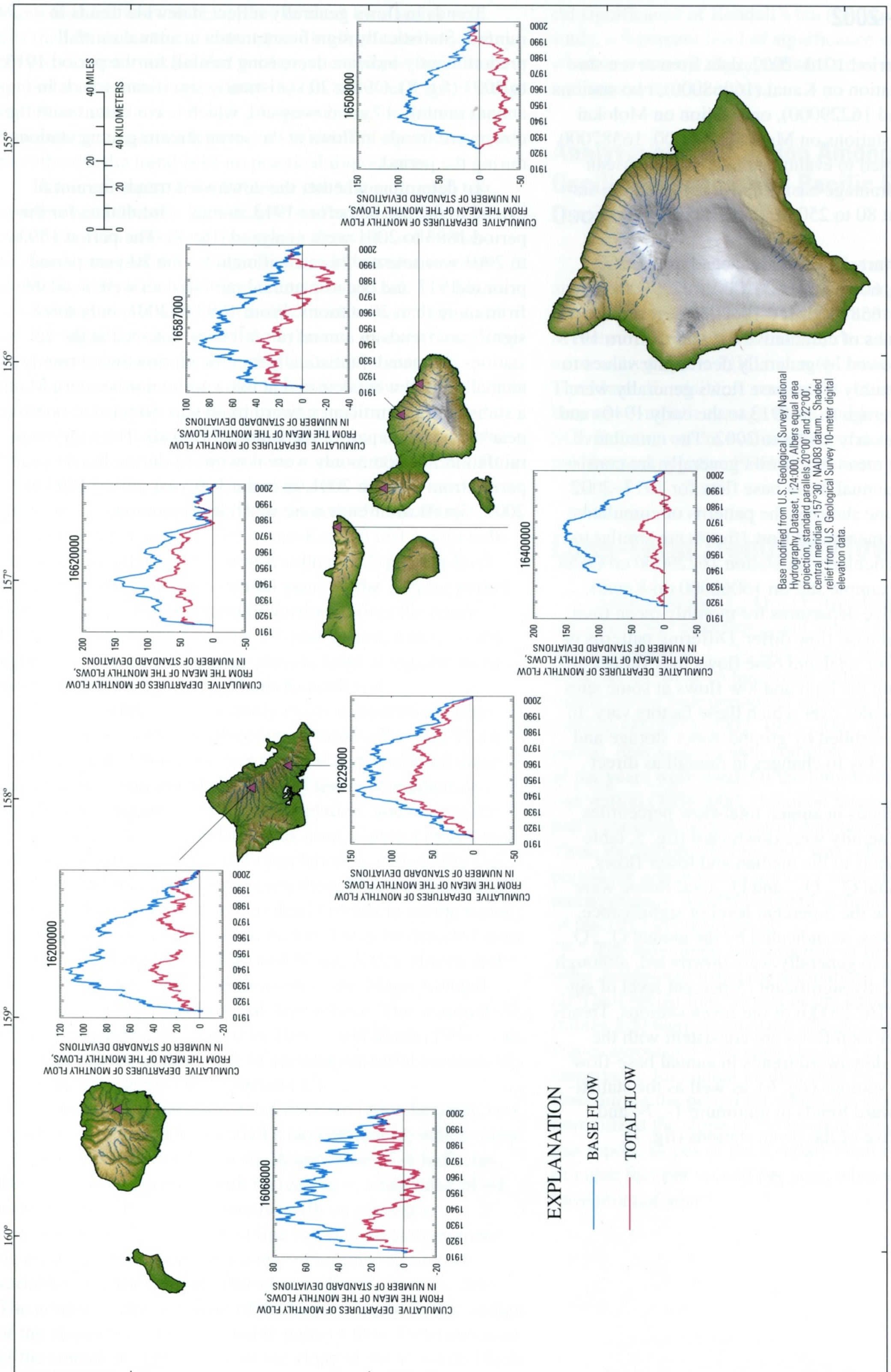


Figure 3-5. Cumulative departures of monthly mean flow from the mean of the monthly flows, Hawaii. This data is based on complete water years from 1913 through 2002. (Oki, 2004, Figure 4)



4.0 Maintenance of Fish and Wildlife Habitat

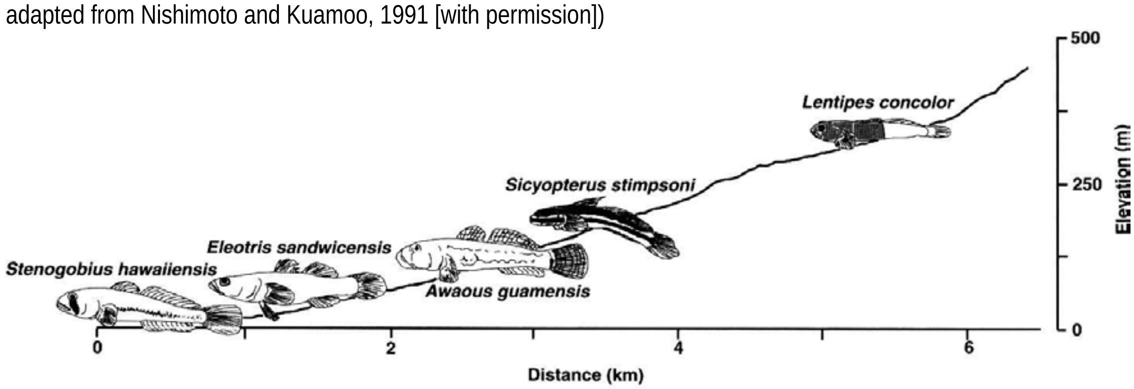
When people in Hawaii consider the protection of instream flows for the maintenance of fish habitat, their thoughts generally focus on just a handful of native species including five native fishes (four gobies and one eleotrid), two snails, one shrimp, and one prawn. Table 4-1 below identifies commonly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

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])



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.

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 Launiupoko hydrologic unit stream be listed as candidate streams for protection based on its riparian, aquatic, cultural or recreational resources. No native species have been observed in Launiupoko Stream due to its small size, lack of mauka to makai flow, and naturally low stream flow.

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. A copy of the updated inventory report for Launiupoko Stream is in Appendix A. The following is a brief summary of findings.

- **Point Quadrat Survey.** In Launiupoko Stream, no point quadrat surveys were conducted due to the lack of stream flow below the diversion. Tilapia and Micropterus species were found in the reservoirs in the 1960s. Although the post larval recruitment of native fish was not surveyed, diversions that fully dewater streams restrict the passage of larval and adult stream animals. It is unlikely that there is sufficient natural streamflow for restoration to benefit recruitment and survival of native species in the lower and middle reaches.

- **Insect Survey.** Launiupoko Stream did not meet the DAR qualification for native insect diversity (>19 spp) and native macrofauna diversity (>5 spp.) giving it a low score for native species likely due to a lack of streamflow. Streamflow restoration may increase insect biota diversity.

- **Watershed and Biological Rating.** The Launiupoko watershed has a below average ranking for Maui and an average rating statewide for land cover. The lack of estuarine and shallow marine areas associated with Launiupoko ranks it low for Maui and the state, while its stewardship rating is about average. Launiupoko Stream has a below average ranking for stream size resulting in a below average total watershed rating. The low number and diversity of native species found thoroughout the watershed gives it an low native species and total biological rating for the island and the state. These scores combined with Launiupoko Stream's relatively average rating for introduced genera, a low rating for all species, and resulted in its below average total biological and overall rating.

Another important consideration of fish and wildlife habitat is the presence of critical habitat. Under the Endangered Species Act, the U.S. Fish and Wildlife Service is responsible for designating critical habitat for threatened and endangered species. Though there are very few threatened or endangered Hawaiian species that are directly impacted by streamflow (e.g., Newcomb's snail), the availability of surface water may still have indirect consequences for other species..

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 did not find any stream recreational opportunities in the Launiupoko hydrologic unit and the regional committee classified the stream as "limited" (National Park Service, Hawaii Cooperative Park Service Unit, 1990). However both tourists and local residents are often seen recreating along the lower reaches of Launiupoko Stream and there is a hiking trail that follows the stream up the valley, although access to this trail is not easy.

Mammal hunting is permitted in Unit A on the island of Maui in the state-owned portions of the West Maui Forest Reserve that includes the Launiupoko hydrologic unit. Only a small portion the Launiupoko hydrologic unit is in this hunting area: approximately 0.742 square miles or 11.7 percent of the hydrologic unit (Figure 5-1).

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 Launiupoko Stream. A 1981 Maui 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, the Commission identified the following activities that were known to occur or observed at or near Launiupoko: pole and line fishing, gill netting, sport diving and throw netting, surfing, standup paddle boarding, and shell collecting, among others (Figure 5-2).

Written comments received in response to the draft version of this report indicate:

Figure 5-1. Public hunting areas for game mammals in Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2002b)

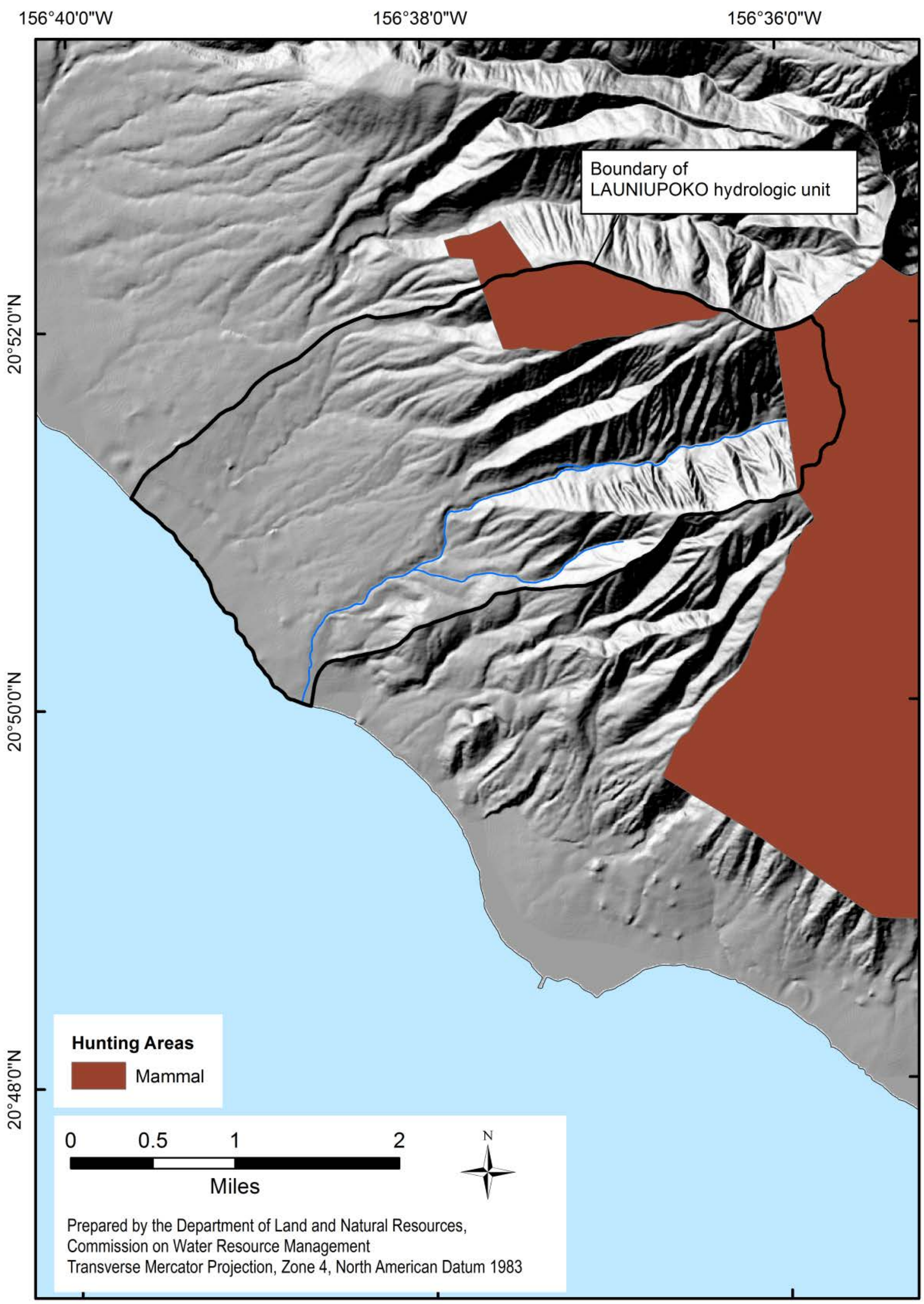
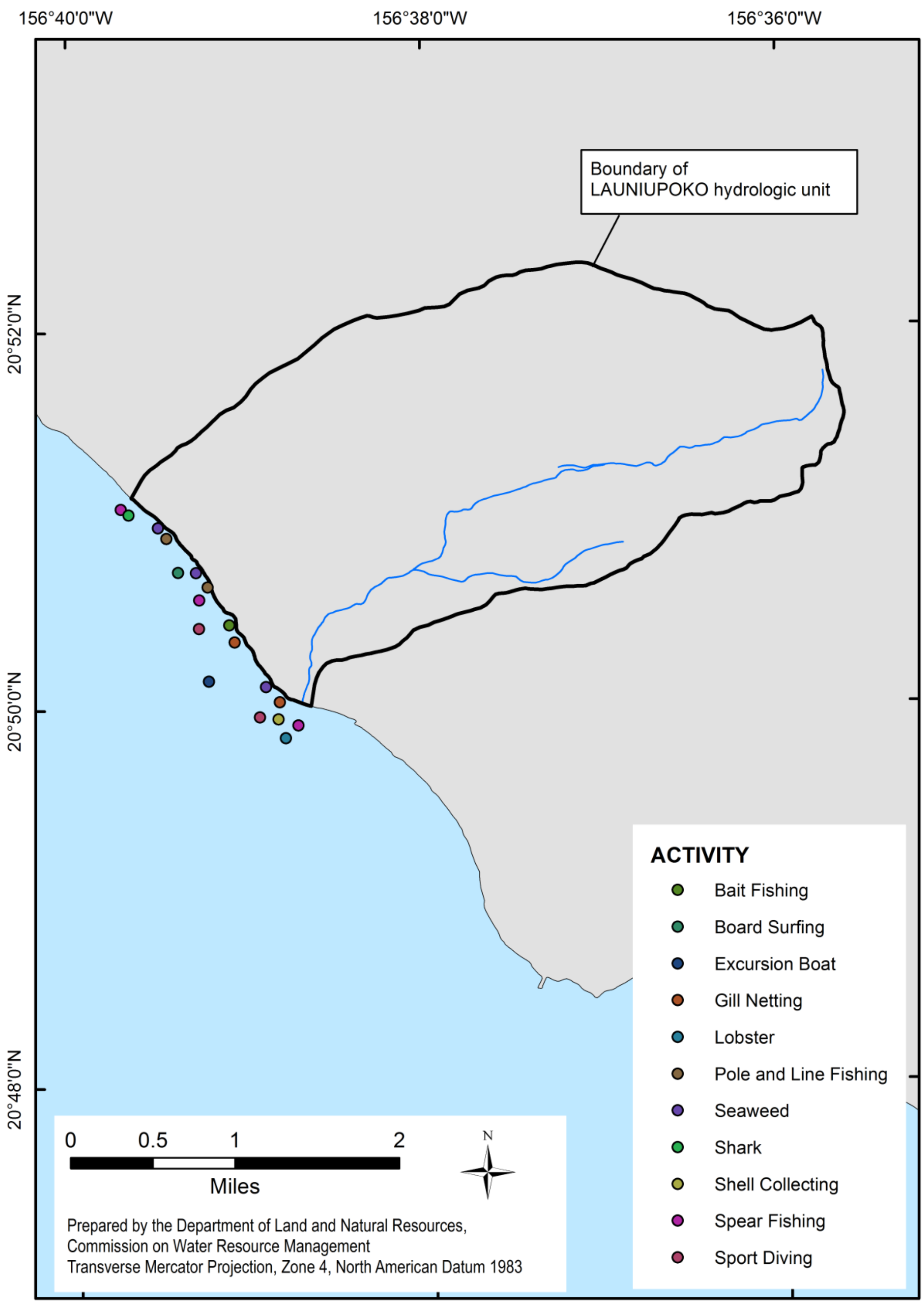


Figure 5-2. Recreational and aesthetic points of interest as well as coastal resources for Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 1999, 2002c; 2004a)

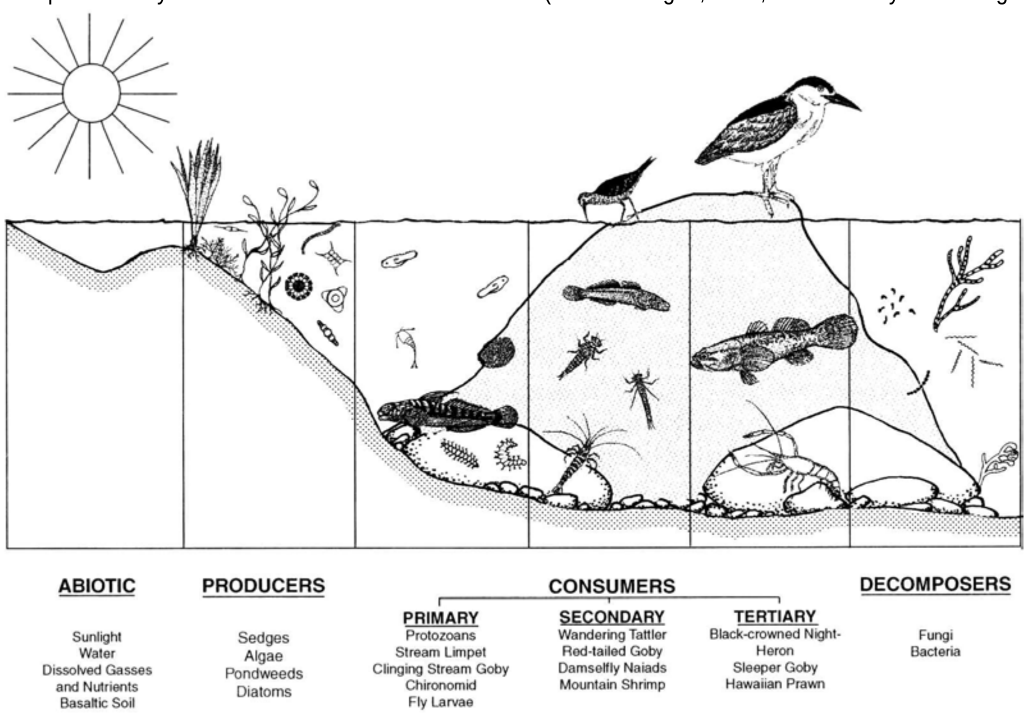


6.0 Maintenance of Ecosystems

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 Launiupoko Stream did not deserve to be a candidate stream for protection based on its lack of resources scoring (riparian, cultural, and recreational resources). Detrimental organisms (non-native species that have a negative effect on the ecosystem) were not considered in the final ranking; however their presence and abundance are considerable ecosystem variables. The destruction to both vegetation and soil resources in the Launiupoko hydrologic unit by determintal organisms is considered a major factor in alterations to the hydrology and water quality of the stream.

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 Launiupoko 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 Launiupoko hydrologic unit.

Category	Value
Listed threatened and endangered 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.	None
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.	None
Other rare organisms and communities: Many species that are candidates for endangered or threatened status have not been processed through all of the requirements of the Endangered Species Act. Also a number of plant communities associated with streams have become extremely rare. These rare organisms and communities were considered to be as indicative of natural Hawaiian biological processes as are listed threatened and endangered species.	None
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.	Palustrine
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.	10
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.	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, historic landmarks, and so on. In Launiupoko, 11 percent of the hydrologic unit falls within forest reserve (Table 6-2).

Table 6-2. Management areas located within Launiupoko hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008a).

Management Area	Managed by	Area (mi^2)	Percent of Unit
West Maui Forest Reserve	State Division of Forestry and Wildlife	21.815	11.7
The West Maui Forest Reserve is one of nine reserves on the Island of Maui that are managed by the State Department of Land and Natural Resources (DLNR)'s Division of Forestry and Wildlife. These reserves are established as multi-use land areas that incorporate various, and often competing, public uses and benefits. The management goals of the Forest Reserve System include: 1) Protect and manage forested watersheds for production of fresh water supply for public uses now and into the future; 2) Maintain biological integrity of native ecosystems; 3) Provide public recreational opportunities; and 4) Strengthen the economy by assisting in the production of high quality forest products in support of a sustainable forest industry. The primary goals of reserve are to manage the lands for sustainable game hunting, protect existing rare native biological resources and provide native and non-native timber resources.			

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 nine partnerships established statewide, three of which are on Maui. Table 6-3 provides a summary of the partnership area, partners, and management goals of the West Maui Mountains Watershed Partnership.

Table 6-3. Watershed partnerships associated with the Launiupoko hydrologic unit. (Source: State of Hawaii, Division of Forestry and Wildlife, 2008b)

Management Area	Year Established	Total Area (mi^2)	Area (mi^2)	Percent of Unit
West Maui Mountains Watershed Partnership	1998	78.125	50,000	47.5
The West Maui Mountains Watershed Alliance (WMMWA) is comprised of the County of Maui Department of Water Supply, Hawaii State Department of Land and Natural Resources (Division of Forestry and Wildlife, Kaanapali Land Management Corp., Kahoma Land Company L.L.C., Kamehameha Schools, Makila Land Company L.L.C., Maui Land Pineapple Company, Inc., and The Nature Conservancy of Hawaii, and Wailuku Water Company, L.L.C. The management priorities of the WMMWP include: 1) Baseline watershed forest health and threat assessments; 2) Establishment of forest health monitoring transects; 3) Fencing to control movement of feral animals, especially pigs and deer; 4) Staff control to remove pest animals from upper watershed; and 5) Pest plant control, particularly of priority weed species such as *Psidium cattleianum*. As of 2013, 19.44 miles of fencing have been built, of which 4.43 miles are pig and deer fencing (8-foot) and 14.91 miles are pig (4-foot) fencing resulting in 21,084 acres of protected lands.				

A major problem in Hawaiian watershed management is the presence of non-native vegetation. Table 6-4 describes the portion of the Launiupoko hydrologic unit dominated by native or alien plant species. 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). None of the Launiupoko hydrologic unit is classified as wetlands (Figure 6-2). Palustrine wetlands are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, or wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent.

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. Table 6-5 and Figure 6-3 present the portion of the hydrologic unit (~1000 feet above mean sea level) that was surveyed and the degree of disturbance of native forest. Over half of the unit is dominated by introduced species, while only 21 percent of the unit is dominated by native species.

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

Canopy Type	Area (mi^2)	Percent of Unit
Communities totally dominated by native species of plants	1.393	16.7
Communities that are totally dominated by introduced plants; virtually no native species remaining	4.925	59.0

The density of threatened and endangered plant species is high at elevations above 1,200 feet, resulting in the majority of the Launiupoko hydrologic unit, roughly 54 percent, covered in a high density of threatened and endangered plant species (Table 6-7).

Table 6-5. Density of threatened and endangered plants for Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015i)

Density	Area (mi^2)	Percent of Unit
Very High concentration of threatened and endangered species	2.128	33.6
High concentration of threatened and endangered species	0.565	8.9
Medium concentration of threatened and endangered species	2.308	15.8
Low or other concentration of threatened and endangered species	1.536	24.3

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 6-6.

Table 6-6. 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**	

In addition, certain areas of Launiupoko provide some of the last remaining critical habitat for particular native forest birds, plants, insects, and snails in Hawaii (Figure 6-3).

Figure 6-2. Reserves and wetlands for the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2007b; 2015n)

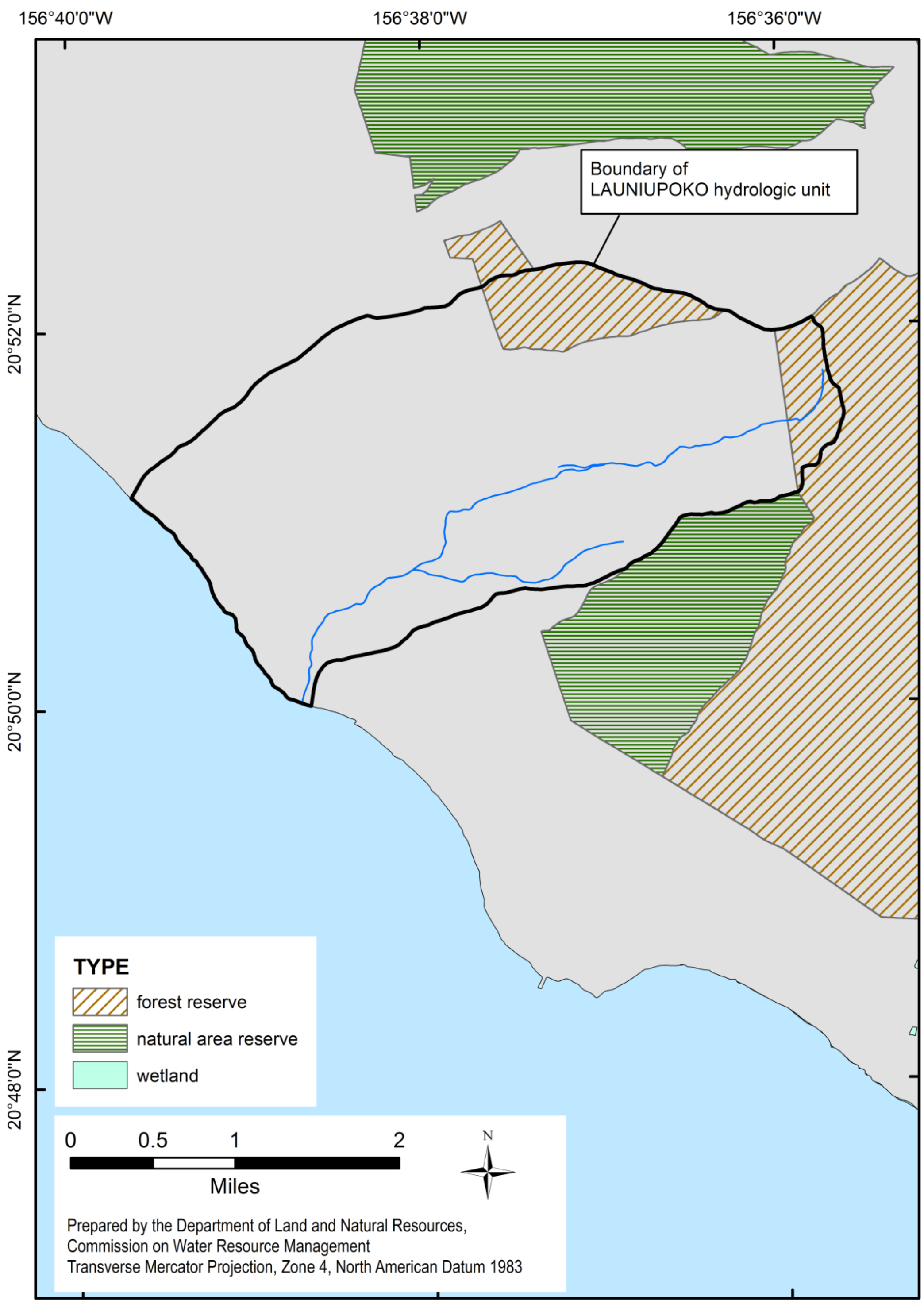


Figure 6-3. Distribution of critical habitat for plant, bird and snail species in the Launiupoko hydrologic unit. (Source: Scott et al., 1986; State of Hawaii, Office of Planning, 1996; 2004b)

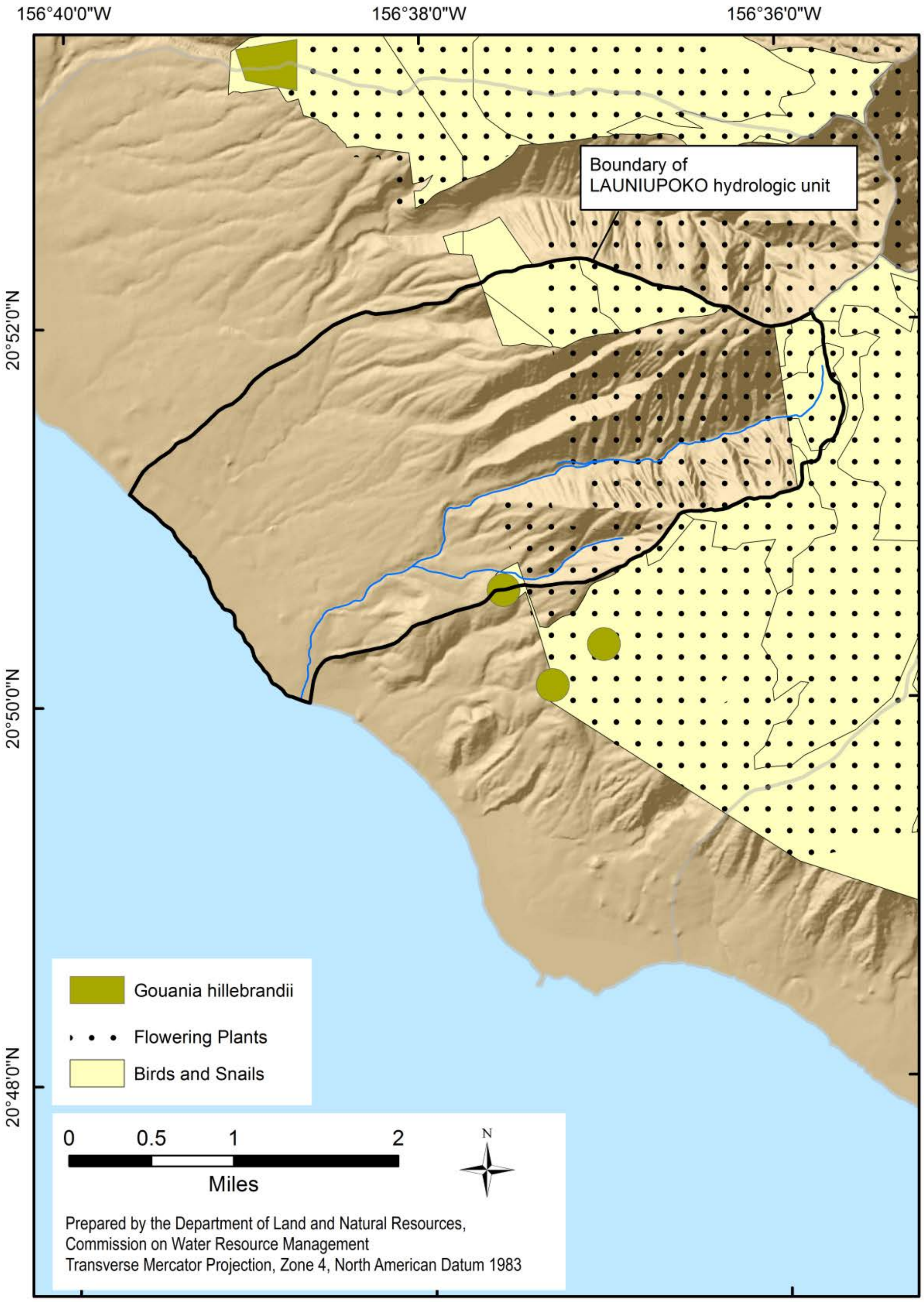
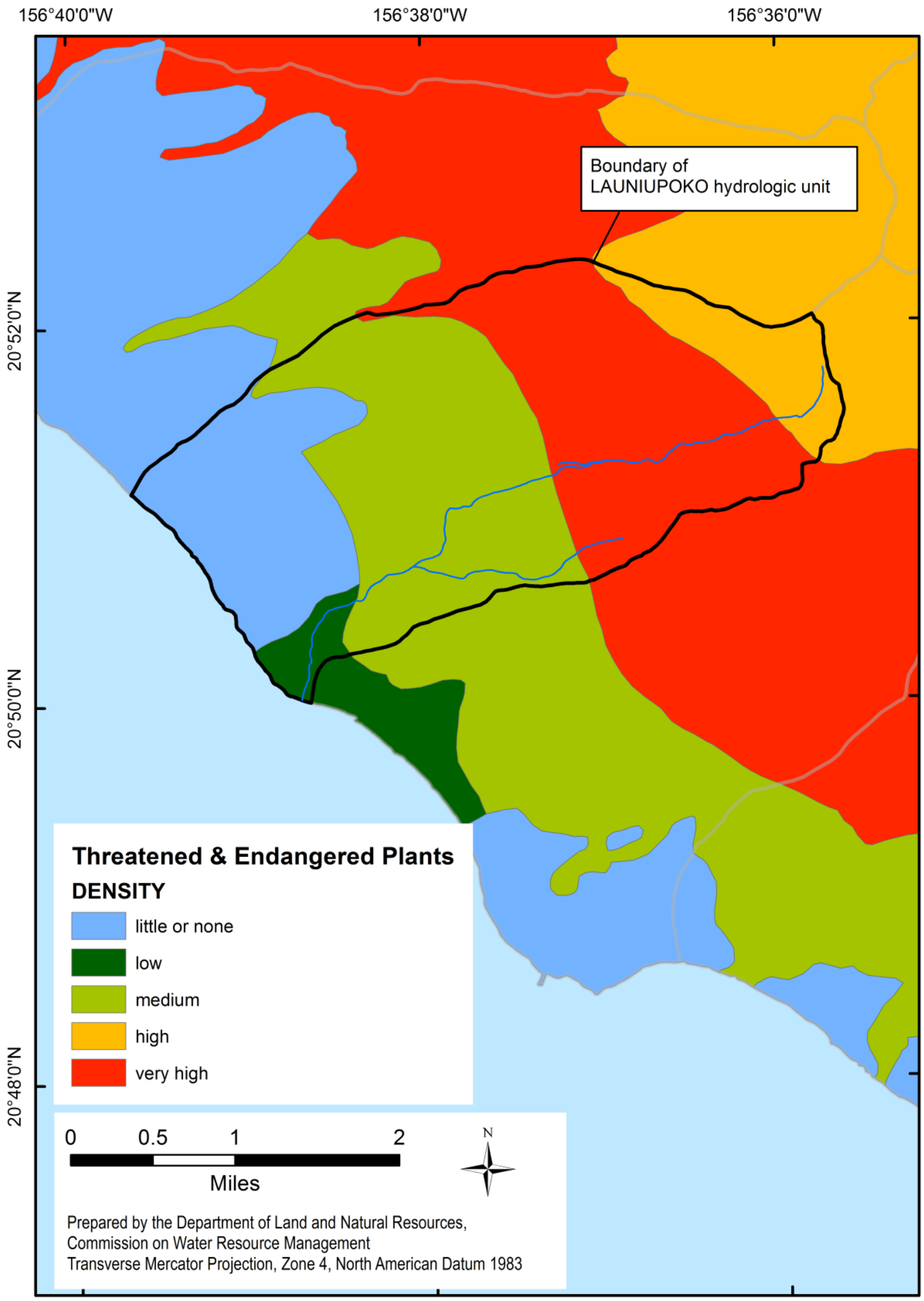


Figure 6-4. Density of threatened and endangered plants in the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015h)



7.0 Aesthetic Values

Aesthetics is a multi-sensory experience related to an individual's perception of beauty. Since aesthetics by definition 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 in Figure 5-2. However, the points listed are not exhaustive and it is beyond the scope of this report to list all potential aesthetic values.

The headwaters of Launiupoko Stream originate in the West Maui Mountains, a unique ecological region home to endemic and endangered birds, plants, and insects. However, access to this region is restricted to the general public.

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority (OmniTrak Group Inc., 2007), scenic views accounted for 21 percent of park visits statewide. Other aesthetic-related motivations include viewing famous landmarks (9 percent), hiking trails and walks (7 percent), guided tour stops (6 percent), and viewing of flora and fauna (2 percent). On the island of Maui, out-of-state visitors' most common reasons to visit state parks for scenic views (26 percent) was the number one reason for visiting a park above outings with family and friends (25 percent). By contrast, residents primarily used state parks on Maui for outings with family and friends (33 percent) followed by ocean/water activity (23 percent) and then scenic views (11 percent). Overall, Maui residents were very satisfied with scenic views giving a score of 9.7 (on a scale of 1 to 10, with 10 being outstanding), with out-of-state visitors giving a score of 9.3.

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.

The hydrologic unit of Launiupoko is not known to support any instream uses of navigation.

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.

Although offstream water from Launiupoko Ditch is combined with water from Kauaula Ditch, this is downstream of any hydropower facilities. There are no hydropower facilities on Launiupoko Stream.

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. Areas with more exposed soil, tend to generate higher quantities of sediment (Figure

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. According to the U.S. Environmental Protection Agency (USEPA), “[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,”

[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.

“aesthetic enjoyment,” and “compatible recreation” are among the designated uses of Class 1 inland 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. 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.

The sources for the 2014 Integrated Report are Hawaii’s 2012 §303(d) list, plus readily-available data collected from any State water bodies over the preceding 6 years (State of Hawaii, Department of Health, 2007). Per §303(d), impaired waters are listed after review of “‘all existing and readily available water quality-related data and information’ from a broad set of data sources” (State of Hawaii, Department of Health, 2004, p.57). However, available data are not comprehensive of all the streams in the State. According to the Hawaii Administrative Rules Title 11 Chapter 54 (HAR 11-54) all State waters are subject to monitoring; however, in the most recent list published (from the 2012 list that was published in 2014), only two streams statewide had sufficient data for evaluation of whether exceedence of WQS occurred. Launiupoko Stream did not appear on the 2012 List of Impaired Waters in Hawaii, Clean Water Act §303(d) but there was insufficient data for decision-making; therefore, no decision was made pertaining to the attainment of WQS or the applicable designated uses.

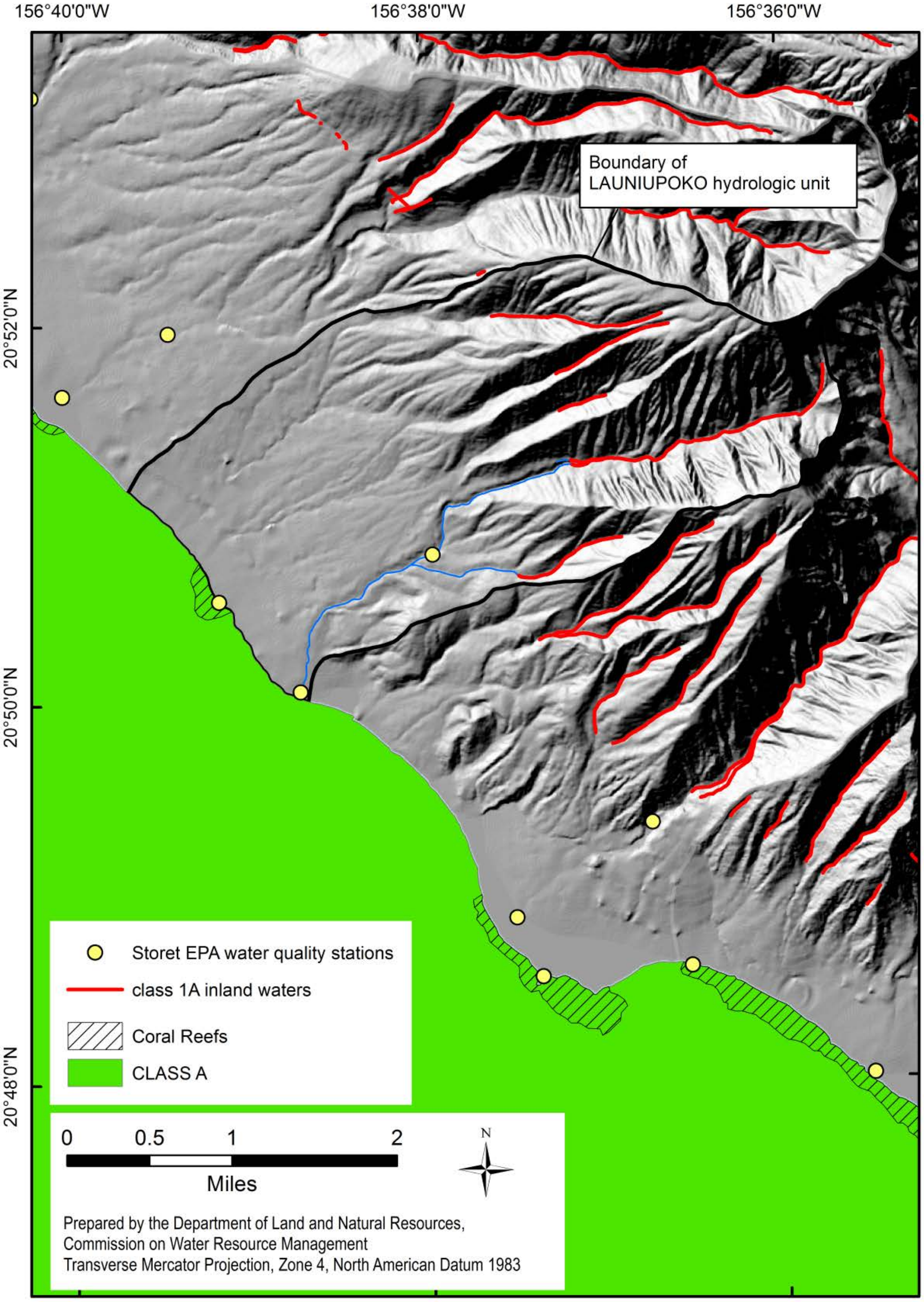
The 2006 Integrated Report indicates that the current WQS require the use of *Enterococci* as the indicator bacteria for evaluating public health risks in the waters of the State; however, no new data were available for this parameter in inland waters. As mentioned in Section 5.0, Outdoor Recreational 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 to be 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)."

Sections of Launiupoko Stream are classified as Class 1a inland waters from its headwaters to the boundary of the forest reserve as the surrounding land is in the conservation subzone "protective." Below this, the stream is classified as Class 1b inland waters to the coastline. 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.

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. The marine waters at the mouth of the Launiupoko hydrologic unit are Class A waters. Figure 10-1 shows the Launiupoko hydrologic unit, including inland and marine (coastal) water classifications.

Figure 10-1. Water quality standards for the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015e; 2008). The classifications are general in nature and should be used in conjunction with Hawaii Administrative Rules, Chapter 11-54, Water Quality Standards.



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 County of Kauai Department 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. The Launiupoko Irrigation Company supplies non-potable water to customers in the Kauaula and Launiupoko hydrologic units while the Launiupoko Water Company supplies potable water to customers in the Kauaula and Launiupoko hydrologic units.

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 ahupua‘a 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 ahupua‘a 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 the next section, 13.0 Noninstream Uses. 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 ahupuaa, and so the Commission's surface water hydrologic units often coincide with or overlap ahupuaa boundaries. The hydrologic unit of Launiupoko is shown in Figure 12-1. The ahupuaa 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.

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 established, future uses are not limited to the cultivation of traditional products approximating

[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.

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.

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.

Criteria for the provisional determination of appurtenant rights include submission of

1. proof of ownership or occupancy;
2. TMK map showing boundaries of all parcels for which an appurtenant right is being claimed;
3. TMK map showing current auwai(s)/ditches, loi, and source of water (i.e., stream or spring);
4. Documents demonstrating that the parcel was used as a residence or for cultivation at the time of the Mahele, including but not limited to:
    a. Legible copy of the Land Commission Award (LCA) and number;
    b. Royal Patent (RP) and number;
    c. Name of the original awardee.
5. Kamaaina testimony and/or other Mahele documents;
6. Other title history in support of the claim;
7. Map showing sources of water at the time of the Mahele;
8. 1800's tax records;
9. Current or historic photos of archeological features of historic uses;
10. Schematic maps or diagrams showing water flow in, through, and/or out of the parcel;
11. Current title or deed to the parcel clarifying any terms or conditions regarding water;
12. List of future crops and the water flow requirements (total and net flow) to supplement information in the application for a SWUPA; and
13. Other relevant information that may assist the Commission in making its determination.

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 Launiupoko. Table 12-2 presents the results of the Commission's assessment.

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

Table 12-1. Tax map key parcels with associated Land Commission Awards for the Launiupoko hydrologic unit.
[LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease]

TMK	Landowner	LCA	Grants/Leases	Notes
4-7-001-002	Pioneer Mill Co.	B2		
4-7-001-003	Pioneer Mill Co.			
4-7-001-004	State of Hawaii	9811, 6883:3, 9822:3, 6872:3, 6881:1, 4878:3		
4-7-001-016	Pioneer Mill Co.			
4-7-001-017	Pioneer Mill Co.			
4-7-001-018	State of Hawaii	8559-B:25		
4-7-001-021	Pioneer Mill Co.			
4-7-001-022	Pioneer Mill Co.	B2		

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).

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 12-5 (discharge measurements) and Table 12-6 (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

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	Area	Station	Period of	Temperature (ºC) Mean	Range	Mean	Temperature

designation			record			daily range	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

Historical uses can also provide some insight into the protection of traditional and customary Hawaiian rights. Without delving into the extensive archive of literature (refer to Kumu Pono Associates, 2001a), Handy and Handy, in *Native Planters of Old Hawaii* (1972), provide a limited regional description as follows:

> "Southeastward along the coast from the *ali'i* settlement were a nynber if areas where dispersed populations grew taro, sweet potato, breadfruit and coconut on slopes below and in the sides of valleys which had streams with constant flow…In and below the next valley, Launiupiko, there were no evidence of *lo'i*, and the people of 'Olowalu said there had never been any. But we think there must have been a few, although the ladn is, in general, dry and rough."

Individual cultural resources of Launiupoko 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 (Table 12-8).

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 are no fishponds present in the Launiupoko hydrologic unit (DHM, Inc., 1990).

Pre-European Contact Agriculture

Prior to European contact, Hawaiian irrigated wetland and dryland (rainfed) agriculture dominated river valleys and flood plains. Large systems of intensively cultivated taro required consistent and plentiful surface water diverted through an auwai (furrow or ditch) from a stream or spring with sufficient volume. Agriculture is an integral part of traditional Hawaiian culture and has also seen a resurgence of interest in recent years. Recently published datasets (see Ladefoged et al. 2009), have provided new insights in understanding the extent of both wetland and dryland agriculture pre-European contact (Figure 12-3). Due to the limited surface water supply, Launiupoko probably supported wetland taro only in the middle reaches in the valley, whereas dryland agriculture was more common in the lower reaches. This is consistent with conversations staff have had with current cultural practictioners in the area.

Table 12-4. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Launiupoko 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.	none
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.	n/a
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.	n/a
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.	n/a

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.	n/a
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.	n/a

Hawaiian Home Lands

Another component in the assessment of traditional and customary Hawaiian rights is the presence of Department of Hawaiian Home Lands (DHHL) parcels within 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). In June 2004, DHHL published the Muai Island Plan which served to examine infrastructure needs, provide development cost estimates, and identify priority areas for homestead development. Of the more than 31,000 acres of DHHL land on the island of Maui, no parcels occur within or nearby the Launiupoko hydrologic unit.

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

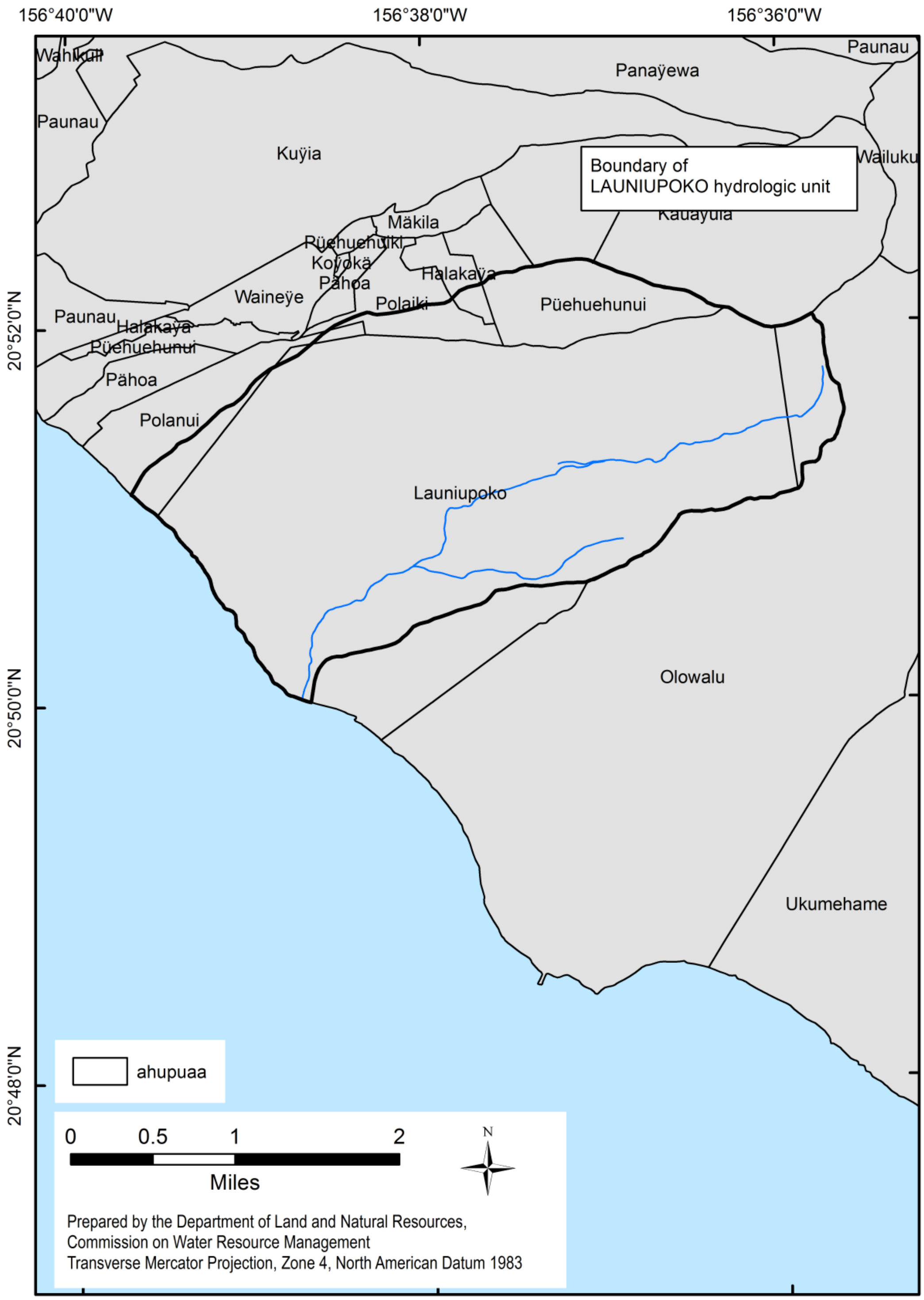
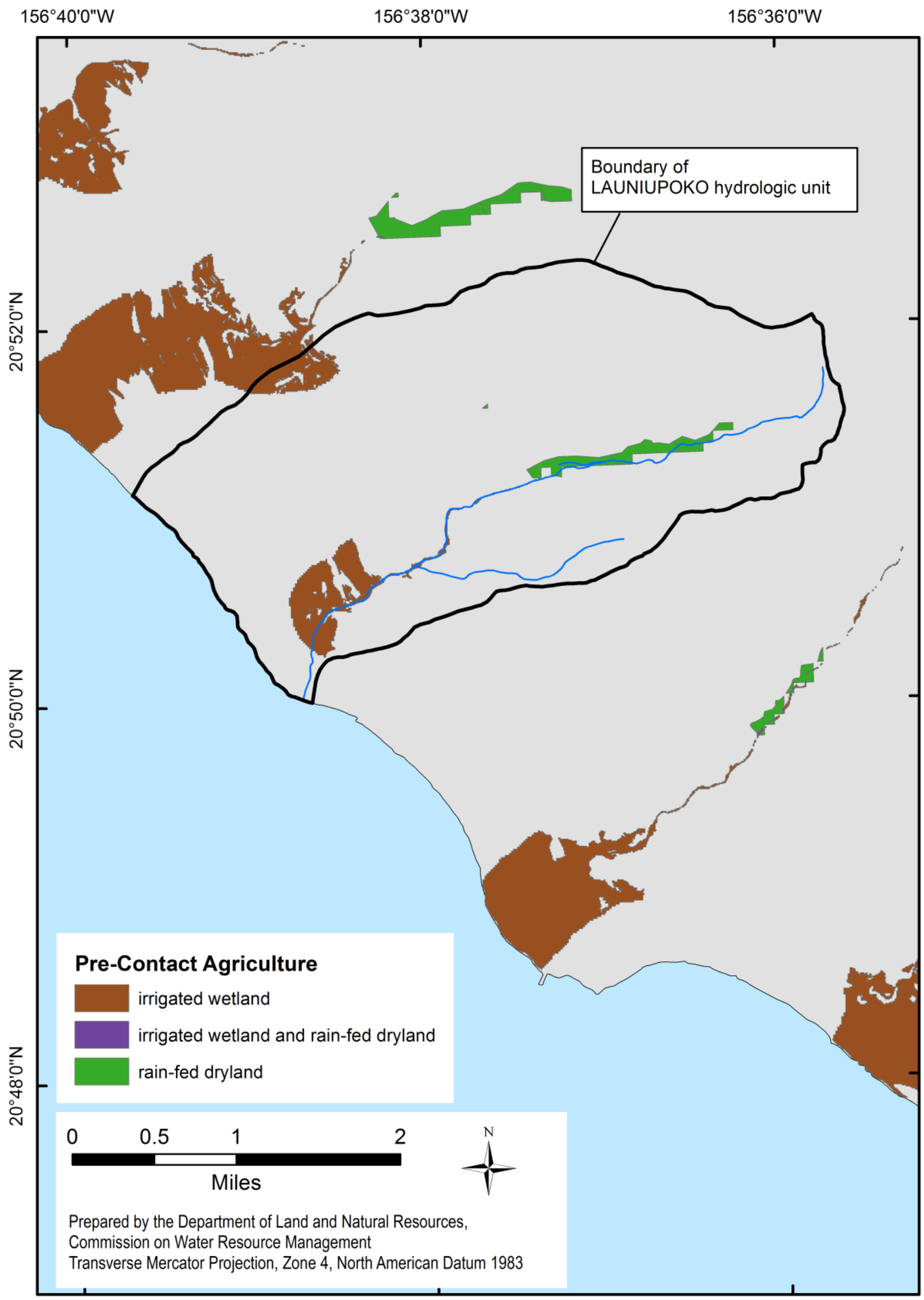

156°40'0"W
156°38'0"W
156°36'0"W
20°52'0"N
20°50'0"N
20°48'0"N
Paunau
Panaÿewa
Paunau
Kuÿia
Wailuku
Boundary of
LAUNIUPOKO hydrologic unit
Mäkila
Püehuehuiki
Koÿokä
Pähoa
Halakaÿa
Waineÿe
Polaiki
Püehuehunui
Paunau
Halakaÿa
Püehuehunui
Pähoa
Polanui
Launiupoko
Olowalu
Ukumehame
ahupuaa
0
0.5
1
2
Miles
N
Prepared by the Department of Land and Natural Resources,
Commission on Water Resource Management
Transverse Mercator Projection, Zone 4, North American Datum 1983

Figure 12-2. Zones of intensive agriculture in the Launiupoko hydrologic unit pre-European contact. (Source: Ladefoged, 2009)



13.0 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.

Launiupoko Stream Diversion

Water is most often used away from the stream channel and is not returned; however, as in the case of taro fields, water may be returned to the stream at some point downstream of its use. While the return of surface water to the stream would generally be considered a positive value, this introduces the need to consider water quality variables such as increased temperature, nutrients, and dissolved oxygen, which may impact other instream uses. In the Launiupoko hydrologic unit, there is one legacy plantation diversion registered to Pioneer Mill Co. (Table 13-1).

In addition to the amount of water currently (or potentially) being diverted offstream, the Commission must also consider the diversion structure and the type of use, all of which impact instream uses in different ways. The wide range of diversion structures, as noted above, is what makes regulation of surface water particularly difficult, since one standard method cannot be depended upon for monitoring and measuring flow. The ease of diverting streamflow, whether by gravity-flow PVC pipe, pump, or a dug channel, also plays a role in the convenience of diverting surface water and the abundance of illegal, non-permitted diversions.

Upon the enactment of the State Water Code and subsequent adoption of the Hawaii Administrative Rules, the Commission required the registration of all existing stream diversions statewide. The Commission categorized the diversions and filed registrations according to the registrant’s last name or company name. While it is recognized that the ownership and/or lease of many of the properties with diversions has changed since then, the file reference (FILEREF) remains the name of the original registrant file (Table 13-1) with locations are depicted in Figure 13-1. The Commission’s records for the hydrologic unit of Launiupoko indicate that the reported mean daily flow diverted from 1983 to 1988 was 0.66 mgd (range 0.35 mgd to 1.32 mgd). Based on plantation records, the median and mean flow diverted from 1956-1975 was 0.60 mgd and 0.78 mgd, respectively (Hatton 1967). Since the enactment of HAR

Title 13 Chapter 168, stream diversion works permits are required for the construction of new diversions or alteration of existing diversions, with the exception of routine maintenance.

Table 13-1. Current surface water diversions in Launiupoko Stream (Source: State of Hawaii, Commission on Water Resource Management, 2015)

FILE REF	Name	Operator	History	Current Use	Estimated Medium Flow
PIONEER MILL	Launiupoko Diversion	Launiupoko Irrigation Company	Pioneer Mill built in 1910s	Irrigation of commercial agriculture and agrigultural-zoned farm lots	0.60 mgd

Data from staff site visits may be found in Table 13-2.

Table 13-2. Registered diversions in the Launiupko hydrologic unit.
[Source of photos are denoted at the end of each description; CWRM, Commission on Water Resource Management;Arrows (⇨)indicate general direction of natural water flow to and out of diversions; Chevrons (⋗) indicate direction of diverted surface water flow]

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.955.6	PIONEER MILL		0.47	Yes	Yes	No	No

Launiupoko Stream is diverted by a concrete dam across the channel that captures 100% of base flow. Water is diverted through a gate into a pipe in the Launiupoko Ditch.

Photos. a) View of water flowing into Launiupoko Ditch from Launiupoko Stream from left bank (CWRM, 11/2016); b) Upstream view of Launiupoko Stream from diversion (CWRM, 11/2016); c) Launiupoko Diversion structure from downstream (CWRM, 11/2016); d) Downstream view of diversion and Launiupoko Stream from above diversion structure (CWRM, 11/2016); e) intake gate on diversion structure (CWRM, 11/2016); f) intake pipe in ditch (CWRM, 11/2016)

a)

b)

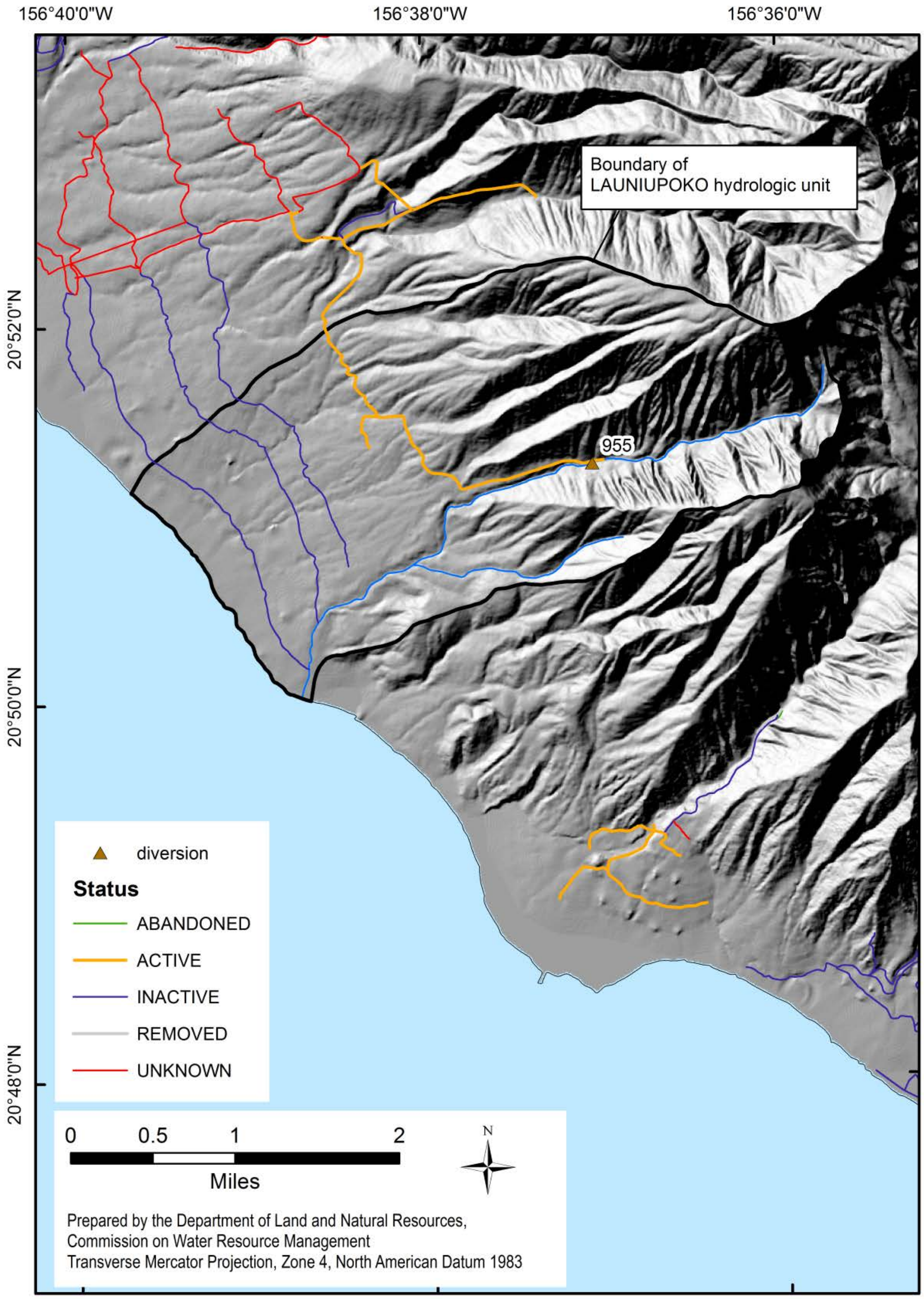
c)

d)

e)

f)

Figure 13-1. All registered diversions and ditches identified in the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2004d; State of Hawaii, Commission on Water Resource Management, 2015g)



Modifications of Ditch Systems and Groundwater Recharge

Following the establishment of instream flow standards, one of the proposed measures to increase streamflow may be to decrease the amount of water diverted from streams. Such a measure has important implications to ground water recharge because it affects the amount of water available for irrigation. The effects of irrigation water on ground water recharge can be analyzed using the water budget equation[1]. Engott and Vana (2007) at the USGS conducted a study that estimated each of the water budget components for west and central Maui using data from 1926 to 2004. Components of the water budget include rainfall, fog drip, irrigation, runoff, evapotranspiration, and recharge. Results of the study were separated into six historical periods: 1926-79, 1980-84, 1985-89, 1990-94, 1995-99, and 2000-04. From 1979 to 2004, ground water recharge decreased 44 percent from 693 million gallons per day to 391 million gallons per day (Figure 13-4). The low recharge rate in 2004 coincides with the lowest irrigation and rainfall rates that were 46 percent and 11 percent lower than those in 1979, respectively. During this period, agricultural lands decreased 21 percent from 112,657 acres in 1979 to 88,847 acres in 2004. Further analysis revealed that a 20 percent decrease in irrigation rate could result in a 9 percent reduction in recharge. A similar study by Izuka et al. (2005) reported that a 34 percent decrease in irrigation rate constituted a 7 percent reduction in recharge in the Lihue basin in Kauai, Hawaii.

Droughts, or periods of lower than average rainfall, have been shown to drastically decrease ground water recharge (Figure 13-5). The period of drought that occurred in 1998-2002, during which rainfall was at least 30 percent lower than the average annual rainfall was estimated to reduce recharge by 27 percent in west and central Maui (Engott and Vana, 2007). In the island of Kauai, the drought conditions reduced recharge in Lihue basin by 34-37 percent (Izuka et al., 2005). Even though droughts can have exacerbating effects on ground water recharge, these effects are transient and are usually mitigated by periods of higher than average rainfall (Engott and Vana, 2007). However, prolonged loss in irrigation water caused by decrease in the amount of water diverted at the ditches has greater effects on the long term trends of ground water levels.

[1] Water-budget is a balance between the amount of water leaving, entering, and being stored in the plant-soil system. The water budget method/equation is often used to estimate ground water recharge.

Figure 13-2. Estimated recharge for six historical periods between 1926 and 2004, central and west Maui, Hawaii. (Source: Engott and Vana, 2007)

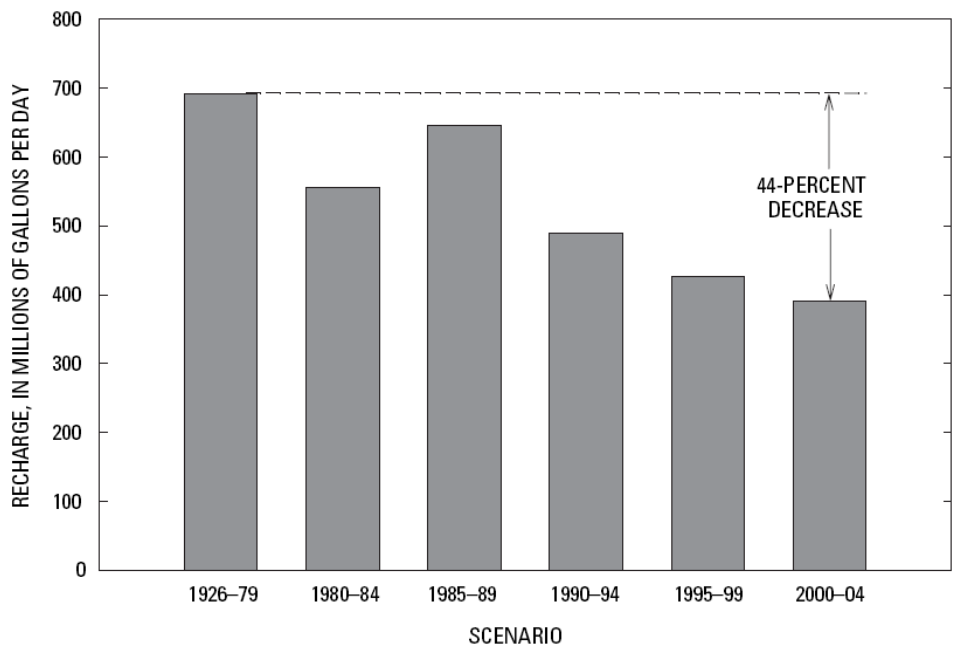
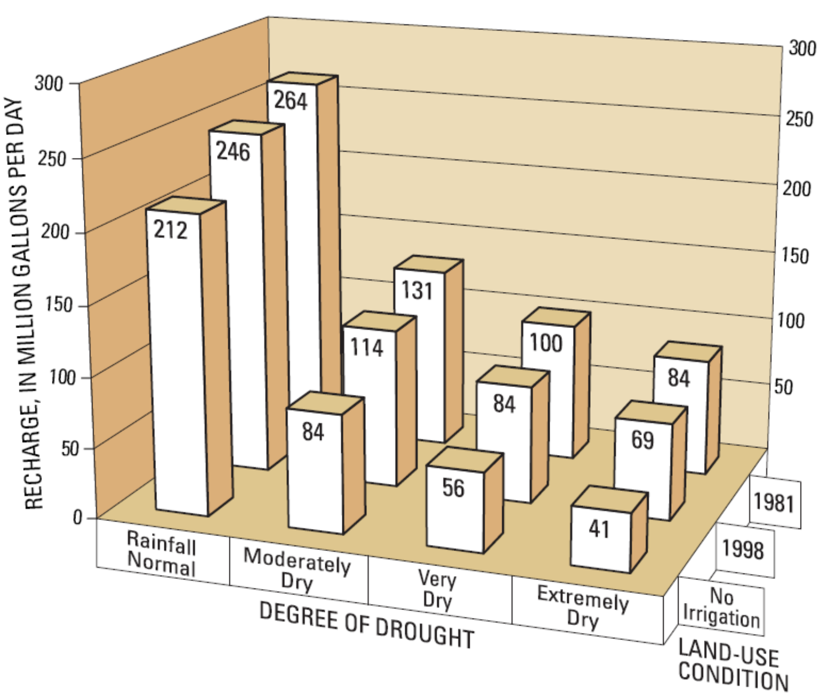


Figure 13-3. Summary of estimated recharge, in million gallons per day, for various land-use and rainfall conditions in the Lihue Basin, Kauai, Hawaii. (Source: Izuka et al., 2005)



Utilization of Important Agricultural Lands

The Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA) in 1977, with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the College of Tropical Agriculture, University of Hawaii. Three classes of agriculturally important lands were established for Hawaii in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide. 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. ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands. HDOA is currently in the process of developing agricultural incentives based on classifications of Important Agricultural Lands. While sugarcane was grown on 22 percent of designated agricultural land, only 3.5 percent of the hydrologic unit was designated in the Agricultural Lands of Importance database (Table 13-6). Decreasing the amount of water diverted at the ditches located affects the amount of water available for the irrigation of crops on these important agricultural lands.

Table 13-3. Agricultural Lands of Importance to the State of Hawaii and area distributions in the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015g)

Designation	Area (mi^2)	Percent of Unit
other	0.23	3.5

From 1978 to 1980, HDOA prepared agricultural land use maps (ALUM) based on data from its Planning and Development Section and from SCS. The maps identified key commodity areas (with subclasses) consisting of: 1) Animal husbandry; 2) Field crops; 3) Orchards; 4) Pineapple; 5) Aquaculture; 6) Sugarcane; and Wetlands (Table 13-7).

Table 13-4. Agricultural land uses and area distributions in the Launiupoko hydrologic unit. (Source: State of Hawaii, Office of Planning, 2015h)

Designation	Area (mi^2)	Percent of Unit
sugarcane	1.442	22.1

Though both ALISH and ALUM datasets are considerably outdated, many of the same agricultural assumptions may still hold true. The information is presented here to provide the Commission with present or potential noninstream use information (Figure 13-4 and 13-5).

Figure 13-4. Agricultural land use for the Launiupoko hydrologic unit based on the Agricultural Lands of Importance for the State of Hawaii (ALISH) classification systems. (Source: State of Hawaii, Office of Planning, 2015g)

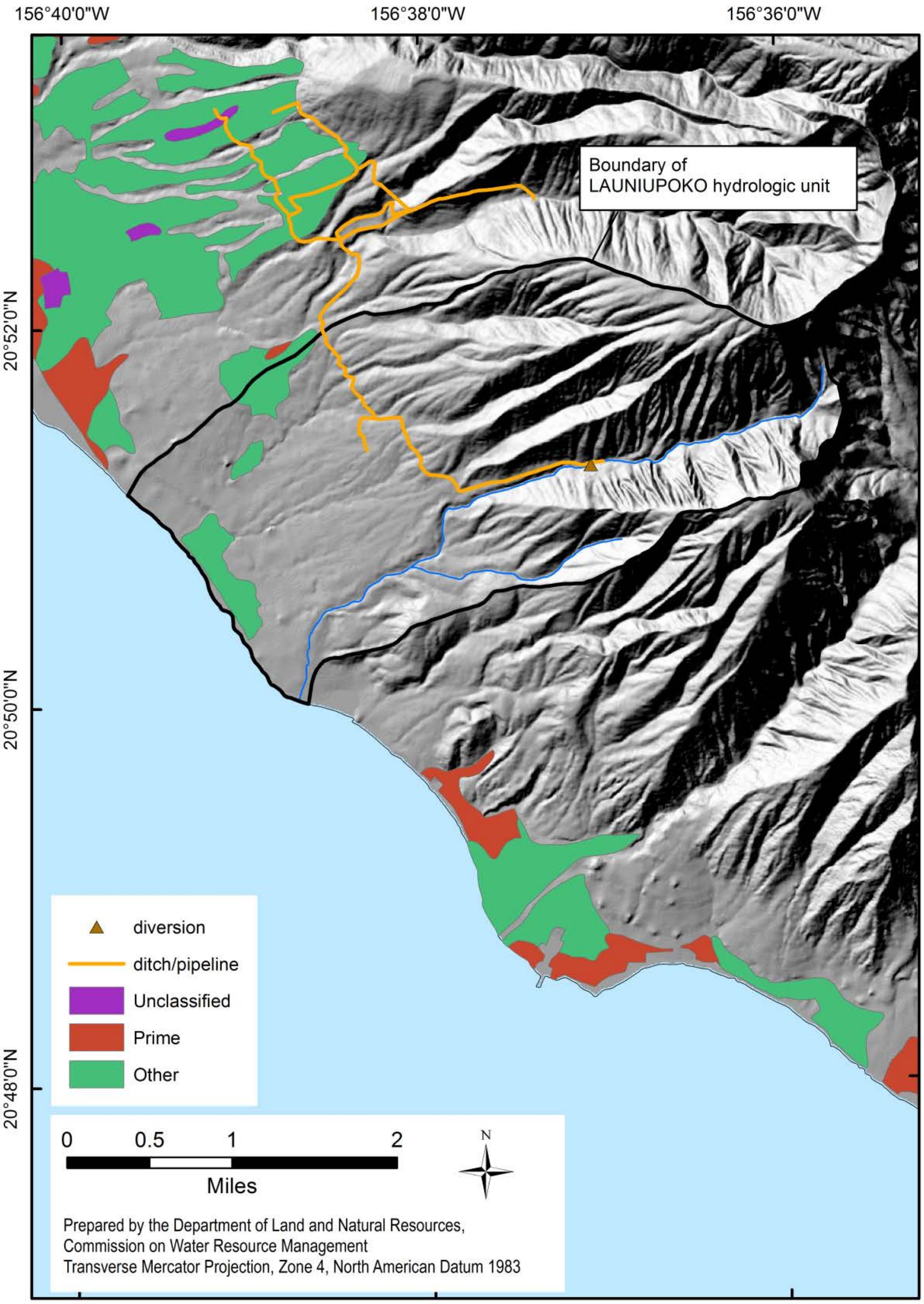
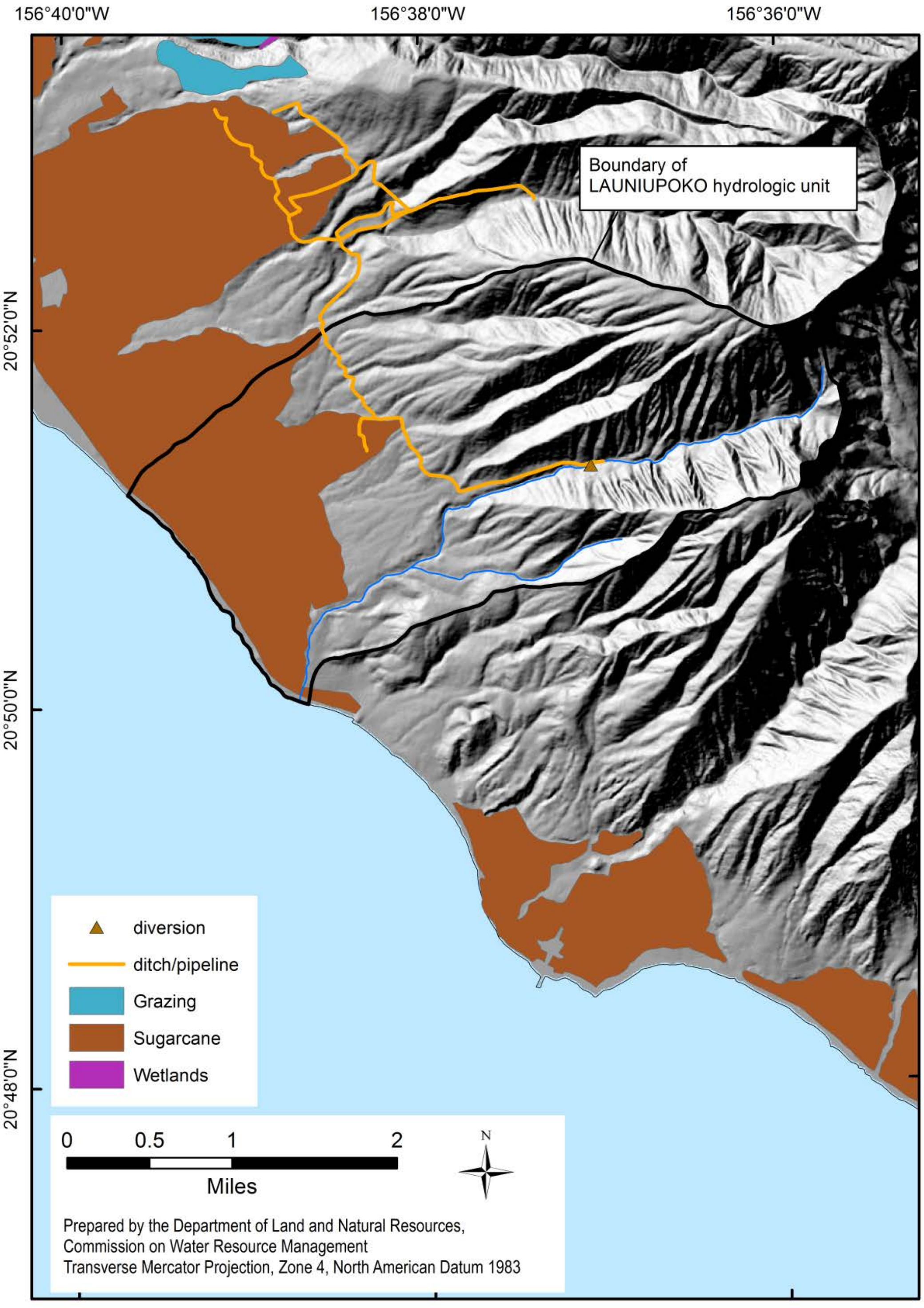


Figure 13-5. Designated gricultural land use for the Launiupoko hydrologic unit based on the Agricultural Land Use Map (ALUM). (Source: State of Hawaii, Office of Planning, 2015h)



Diverted Water from Launiupoko Stream

There are no years of overlapping records of natural streamflow at 1,230 ft (USGS station 16644000) and water diverted into the Launiupoko Ditch. During the sugarcane production era, Pioneer Mill Co. diverted an average of 0.78 mgd from Launiupoko Stream between 1956 and 1975. In their registration, Pioneer Mill Co. reported an average of 0.66 mgd diverted between 1983 and 1988 (Figure 13-6). By contrast, the average diverted flow for the most recent seven years is 0.41 mgd (Figure 13-7).

Figure 13-6. Mean daily flow (million gallons per day, mgd) diverted by Pioneer Mill from Launiupoko Stream into Launiupoko Ditch calculated from monthly data from 1983-1987. (Source: Pioneer Mill Co Registration, DIV.955.6)

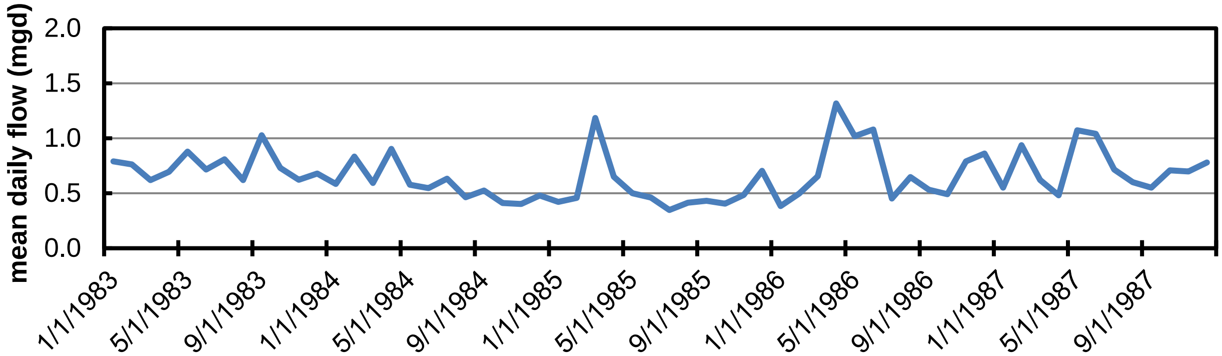
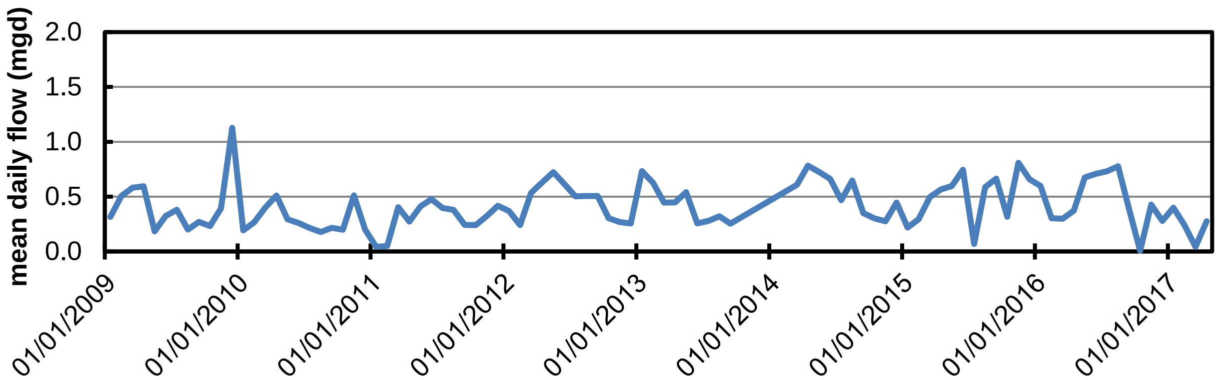


Figure 13-7. Mean daily flow (million gallons per day, mgd) diverted by Launiupoko Irrigation Co. from Launiupoko Stream to Launiupoko Ditch calculated from monthly data from 2009-2016. (Source: Lea Tamayose, West Maui Land Co.)



Irrigation Needs of the Launiupoko Service Area

The Commission funded the development of a GIS-based software program the utilizes the state of Irrigation Water Requirement Estimation Decision Support System, IWREDSS (State of Hawaii, Commission on Water Resource Management, 2015b) was developed by the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa for the State of Hawaii. IWREDSS is an ArcGIS-based numerical simulation model that estimates irrigation demand and water budget components for different crops grown in the Hawaiian environment. The model accounts for different irrigation application systems (e.g., drip, sprinkler, flood), and water application practices (e.g., field capacity versus fixed depth). Model input parameters include rainfall, evaporation, soil water holding capacities, depth of water table, and various crop water management parameters including length of growing season, crop coefficient[2], rooting depth, and crop evapotranspiration.

[2] Crop coefficient is an empirically derived dimensionless number that relates potential evapotranspiration to the crop evapotranspiration. The coefficient is crop-specific.

Calibration and validation of the model was based on the crop water requirement data for different crops from the Hawaii region United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS) Handbook 38 (NRCS-USDA, 1996). Relative errors between the net irrigation requirements (NIR) estimated by the model and those estimated by NRCS range from less than 1 percent to a 26 percent overestimate. This difference may be attributed to the general nature of the technique NRCS used in estimating NIR. Results of the regression analysis indicate a good correlation ($R^2 = 0.97$) between the two techniques; however, the NIR calculations by NRCS were consistently 8 percent higher than those of the IWREDSS model. Understanding that water demand is highly site, weather, application, and crop dependent, IWREDSS can still provide a useful approximation of water needs. Overall, the model is an appropriate and practical tool that can be used to assess the IRR of crops in Hawaii.

The Launiupoko Irrigation Company, a subsidiary of West Maui Land Company, currently operates the diversion, ditch, reservoir, and distribution system from Launiupoko Stream. This system supplies non-potable water for agrigultural-zoned farm lots, commercial agricultural operations, and landscaping within private and common use areas. Surface water from both Launiupoko and Kauaula streams supplies water for these demands. Using the existing TMK layer and remote sensing data (World View 2.0 satellite imagery, Google Earth, and Google Streetmaps), the approximate acerage of agriculture (and type where possible) and acerage of landscaping can be estimated. These data are summarized by TMK for the Kauaula and Launiupoko hydrologic units in Table 13-6 and visualized in Figures 13-9, Figure 13-10, and Figure 13-11. These data are summarized by TMK for the Kauaula and Launiupoko hydrologic units in Table 13-5 and visualized in Figures 13-9, Figure 13-10, and Figure 13-11. Based on remote sensing data, estimated acerage and irrigation water demand, total water demand is estimated as provided in Table 13-6.

Table 13-5. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247001002	91.75203	unoccupied		0		0	0
247001008	0.055491	unoccupied		0		0	0
247001011	25.65331	stables		0		0	0.784
247001018	2.378424	unoccupied		0		0	0
247001023	10.25434	unoccupied		0		0	0
247001025	26.21749	unoccupied		0		0	0
247001026	218.2363	unoccupied		0		0	0
247001029	122.0248	commercial	dragonfruit	14.51712		0	1.16544
247001030	148.409	commercial	diversified ag	1.88864		0	
247001031	27.11417	private	diversified ag	1.63904		0	2.65856
247001032	25.9317	unoccupied		0		0	0
247001033	28.07679	private	coconuts	0.29888		0	4.87232
247001034	25.26668	unoccupied		0		0	0
247001035	29.4474	none		0		0	1.20512
247001036	63.58255	unoccupied		0		0	0
247001037	42.83449	private	coconuts	0.45888		0	1.1936
247001038	52.31193	private	orchard	0.8192		0	1.23904
247001039	165.7356	commercial		0.63616		0	0
247001045	50.07061	none		0		0	2.64448
247001046	42.35658	unoccupied		0		0	0
247001047	26.45398	unoccupied		0		0	0
247001048	48.28882	unoccupied		0		0	0
247001049	69.84359	none		0		0	0
247001050	41.26209	unoccupied		0		0	0
247001051	25.5525	unoccupied		0		0	0
247001052	25.72212	none		0		0	0.65728
247001053	61.17673	none		0		0	0.20288
247001055	6.598421	road		0		0	0
247001056	41.07133	unoccupied		0		0	0
247001057	51.66702	unoccupied		0		0	0
247001999	28.34042	road		0		0	0
247002004	0.910732	unoccupied		0		0	0
247002011	0.076911	unoccupied		0		0	0
247002012	1.9416	unoccupied		0		0	0
247003001	5.015105	private	coconuts	1.02272	nursery	0.24256	1.2992
247003002	2.68661	unoccupied		0		0	0
247003003	0.093948	unoccupied		0		0	0
247003004	6.701242	none		0		0	1.7024
247003005	5.242377	private	coconuts	2.93888		0	
247003006	4.999313	private	coconuts	1.00096		0	1.37088

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247003007	4.928568	unoccupied		0		0	0
247003008	5.03491	unoccupied		0		0	0
247003009	5.477947	unoccupied		0		0	0
247003010	5.113108	private	pasture	2.02944		0	1.60128
247003011	6.032047	private	coconuts	0.63168		0	0.84224
247003012	5.597829	unoccupied		0		0	0
247003013	5.523616	private	orchard	0.64512		0	0.4448
247003014	5.162416	private	coconuts	0.8704		0	1.21728
247003015	5.169519	stables	pasture	3.63776		0	0
247003016	4.992098	private	orchard	0.75968		0	3.53856
247003017	5.656835	private	orchard	2.35456		0	0.7424
247003019	5.478119	none		0		0	3.72288
247003020	4.825436	unoccupied		0		0	0
247003021	4.726235	none		0		0	0
247003022	5.087197	none		0		0	2.448
247003023	5.09625	unoccupied		0		0	0
247003024	5.114799	commercial	diversified ag	5.0976		0	0
247003025	4.903347	unoccupied		0		0	0
247003026	4.979165	private	diversified ag	0.35584		0	0.28032
247003027	8.553706	unoccupied		0		0	0
247003028	37.32168	commercial	diversified ag	2.56128		0	0
247003029	15.07569	unoccupied		0		0	0
247003030	14.88611	commercial	nursery	3.70688		0	0
247003031	22.74105	unoccupied		0		0	0
247003032	8.918741	road		0		0	0
247003033	0.530573	road		0		0	0
247004001	1.209145	none	industrial	0		0	0
247004004	1.60377	unoccupied		0		0	0
247004005	0.627896	unoccupied		0		0	0
247004006	0.285421	unoccupied		0		0	0
247004007	0.197354	unoccupied		0		0	0
247004009	0.027896	unoccupied		0		0	0
247004010	0.239459	unoccupied		0		0	0
247005001	3.861176	unoccupied		0		0	0
247005003	0.326348	unoccupied		0		0	0
247005004	0.565715	unoccupied		0		0	0

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247005005	0.389359	unoccupied		0		0	0
247005006	0.466904	unoccupied		0		0	0
247005007	1.184654	unoccupied		0		0	0
247005008	0.356062	unoccupied		0		0	0
247005009	3.224439	unoccupied		0		0	0
247006001	5.36942	unoccupied		0		0	0
247006003	1.273876	unoccupied		0		0	0
247006004	18.02773	unoccupied		0		0	0
247009001	2.397836	none		0		0	0.86976
247009002	2.616891	none		0		0	0.46016
247009003	2.293709	none		0		0	1.47712
247009004	2.486802	none		0		0	1.22368
247009005	2.05972	none		0		0	1.5776
247009006	2.193699	none		0		0	1.28384
247009007	2.570035	none		0		0	0.32768
247009008	2.147771	none		0		0	0.52672
247009009	2.574314	none		0		0	0.41664
247009010	2.410804	private	coconuts	1.30496		0	0.56448
247009011	2.380024	none		0		0	0.5216
247009012	2.516773	none		0		0	0.56768
247009013	2.033969	private	orchard	0.60736		0	0
247009014	2.306584	none		0		0	0.16064
247009015	2.505953	none		0		0	0.84608
247009016	2.618457	none		0		0	1.42208
247009017	1.971543	none		0		0	0.79296
247009018	2.098194	unoccupied		0		0	0
247009019	1.993174	none		0		0	0
247009020	1.984012	none		0		0	0.44992
247009021	1.990439	none		0		0	1.16224
247009022	2.099259	none		0		0	1.03616
247009023	2.143264	none		0		0	0.9088
247009024	2.153043	none		0		0	0.47552
247009025	1.962646	none		0		0	0.90432
247009026	2.119471	none		0		0	0.30144
247009027	2.088458	none		0		0	1.18912
247009028	2.096029	none		0		0	1.25568

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247009029		none		0		0	1.17504
247009030		none		0		0	0.7584
247009031		none		0		0	0.45248
247009032		private	orchard	0.49664		0	1.02784
247009033		none		0		0	0.91072
247009034		unoccupied		0		0	0
247009035		private	orchard	0.60416	diversified ag	0.17472	0.48256
247009036		unoccupied		0		0	0
247009037		unoccupied		0		0	0
247009038		private	coconuts	0.15104		0	1.3824
247009039		private	diversified ag	0.19904		0	1.40416
247009040		none		0		0	1.63456
247009043		none		0		0	0.55424
247009044		none		0		0	0.70592
247009045		none		0		0	1.22368
247009046		none		0		0	0.64256
247009047		none		0		0	0.94848
247009048		private	coconuts	0.1312		0	0.75392
247009049		private	coconuts	0.93952		0	2.14272
247009050		private	coconuts	0.20096		0	0.79808
247009051		none		0		0	0.40192
247009052		none		0		0	0.69824
247009053		none		0		0	1.13088
247009054		none		0		0	0.59328
247009055		private	coconuts	0.23104		0	1.14176
247009056		unoccupied		0		0	0
247009057		none		0		0	0.58752
247009058		none		0		0	1.13088
247009059		none		0		0	0.912
247009060		none		0		0	0.34048
247009061		none		0		0	1.05728
247009062		none		0		0	0.81408
247009063		private	orchard	0.36608		0	0
247009065		none		0		0	1.0496
247009066		none		0		0	0.95488
247009067		none		0		0	1.17184

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247009068	3.744544	unoccupied				0	0
247009069	3.195715	private	coconuts			0	0.5344
247009070	2.335327	unoccupied				0	0
247009071	2.940796	none				0	1.06816
247009072	2.563319	none				0	0.64128
247009073	2.480625	none				0	0.58816
247009074	2.389657	none				0	0.84736
247009075	3.057093	none				0	1.74464
247009076	3.93921	none				0	1.32096
247009077	4.091127	unoccupied				0	0
247009078	3.994935	unoccupied				0	0
247009079	2.81178	private	coconuts			0	1.11552
247009080	2.454925	none				0	0.39104
247009081	2.042352	none				0	0.36096
247010001	2.231054	none				0	1.184
247010002	2.018044	private	coconuts			0	0.92288
247010003	2.627184	private	coconuts			0	0.71104
247010008	9.019377	none				0	1.31776
247010009	3.630511	none				0	1.4144
247010010	7.126205	none				0	1.232
247010012	2.17924	none				0	1.44512
247010013	2.255664	none				0	1.62112
247010014	2.3665	none				0	0.47936
247010015	2.35529	none				0	1.10144
247010016	2.249296	none				0	1.60064
247010017	2.240157	none				0	1.13856
247010018	3.433208	none				0	1.85856
247010019	3.351381	commercial	flowers			0	0.1856
247010020	2.789935	none				0	0.88064
247010021	2.333635	none				0	0.96
247010022	2.818654	none				0	1.97696
247010023	2.461139	private	diversified ag			0	1.0336
247010026	3.252948	none				0	0.38336
247010027	2.080079	none				0	0.64832
247010028	2.002084	none				0	0.81728
247010029	2.072069	unoccupied				0	0

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247010030		unoccupied		0		0	0
247010031		none		0		0	0.32128
247010032		none		0		0	1.04128
247010033		none		0		0	0.3712
247010034		none		0		0	1.16224
247010035		none		0		0	0.45056
247010036		none		0		0	1.16096
247010037		none		0		0	0
247010038		private	coconuts	0.51072		0	1.20768
247010039		none		0		0	0
247010040		none		0		0	0.65664
247010041		none		0		0	1.15392
247010042		none		0		0	0.73216
247010043		none		0		0	0.000998
247010044		none		0		0	0.31168
247010045		unoccupied		0		0	0
247010046		commercial	diversified ag	1.3696		0	0.2528
247010047		private		0.70912		0	0
247010048		private	diversified ag	0.70912		0	0.7744
247010049		private	orchard	0.31936		0	0.84352
247010050		none		0		0	0.72704
247010051		none		0		0	1.08416
247010052		private	coconuts	0.63552		0	0.18304
247010053		none		0		0	1.02464
247010054		none		0		0	0.33536
247010055		none		0		0	0.87296
247010056		none		0		0	1.0304
247010057		none		0		0	0.78208
247010058		unoccupied		0		0	0
247010059		private	diversified ag	0.69632		0	1.36448
247010060		none		0		0	1.26016
247010061		private	orchard	0.42304		0	0.5408
247010062		none		0		0	0.70336
247010063		none		0		0	1.43936
247010064		none		0		0	0.81728
247010065		private	orchard	0.42112		0	1.11296

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247010067	8.318937	unoccupied		0		0	0
247010068	4.268398	private	diversified ag	1.63264		0	0.50368
247010069	1.992884	stables	pasture	0.18368		0	0
247010070	2.168698	private	coconuts	0.304		0	1.44384
247010071	2.235894	none		0		0	1.50848
247010072	2.725142	none		0		0	0.71936
247010073	3.59609	none		0		0	1.47008
247010074	3.284164	none		0		0	0.47936
247010075	3.312827	unoccupied		0		0	0
247010076	3.182282	none		0		0	0.50304
247010077	2.72505	none		0		0	0.8704
247010078	3.656207	private	coconuts	0.49216		0	0.9056
247010079	3.208014	none		0		0	1.1392
247010080	5.755402	none		0		0	0.8096
247010081	5.476494	none		0		0	1.0816
247010082	1.966233	none		0		0	1.14752
247010083	2.386424	private	orchard	0.83392		0	0.47168
247010999	12.46055	Road		0		0	0
247011001	15.8856	industrial		0		0	0
247011002	16.89437	commercial		11.13344		0	0
247011003	15.39121	unoccupied		0		0	0
247011004	16.60308	none		0		0	0.95808
247011005	16.08845	none		0		0	0.60416
247011006	16.19301	none		0		0	1.35872
247011007	16.09453	commercial		9.9392		0	0.34624
247011008	15.58227	unoccupied		0		0	0
247011009	15.1927	none		0		0	1.86624
247011010	15.19147	unoccupied		0		0	0
247011011	15.26415	commercial	coconuts	2.28032		0	4.70208
247011012	16.04992	none		0		0	2.6976
247011013	12.91187	none		0		0	1.25696
247011014	12.76932	commercial	pasture	1.43232		0	0.89408
247011015	15.53564	none		0		0	0
247011016	15.91676	unoccupied		0		0	0
247011017	13.06103	commercial	coconuts	1.648		0	1.7728
247011018	13.2123	unoccupied		0		0	0

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247011019	500	unoccupied		0		0	0
247012001	4.973361	none		0		0	0
247012002	4.978238	private	coconuts	0.2048		0	3.07264
247012003	5.141767	none	unknown	1.06496		0	0
247012004	5.777885	private	unknown	1.35168		0	0.51392
247012005	5.402012	commercial	orchard	2.43264		0	2.02688
247012006	5.131663	private	coconuts	0.2624	diversified ag	0.5248	0.24192
247012007	5.072677	private	ornamentals	0.256		0	2.05248
247012008	5.756443	commerical	pasture	2.14272		0	0.56128
247012009	6.05012	private	none	0		0	1.25376
247012010	5.615555	private	unknown	0.6848		0	0.82752
247012011	5.075767	none		0		0	4.00768
247012012	5.083842	unoccupied		0		0	0
247012013	4.975928	private	coconuts	1.52		0	1.15968
247012014	5.691095	none		0		0	0.58112
247012015	5.022437	private	coconuts	1.22176		0	0.288
247012016	5.167997	private	coconuts	0.33664		0	0.36992
247012017	4.975729	none		0		0	0
247012018	5.346607	private	orchard	0.73664		0	0.62848
247012019	5.374511	unoccupied		0		0	0
247012020	5.579951	commercial	unknown	2.3232	coconut	0.82176	1.39264
247012021	4.386672	private	coconuts	0.54208		0	1.28896
247012022	4.454147	private	coconuts	0.43392		0	1.57376
247012023	4.249626	unoccupied		0		0	0
247012024	4.138264	private	diversified ag	0.81088	coconut	0.45504	1.64352
247012025	1.07172	pathway		0		0	0
247012026	0.818476	pathway		0		0	0
247012027	7.41671	Road		0		0	0
247013001	26.90325	unoccupied		0		0	0
247013002	27.28159	unoccupied		0		0	0
247013003	27.4535	unoccupied		0		0	0
247013004	25.95854	unoccupied		0		0	0
247013005	26.46094	unoccupied		0		0	0
247013006	27.50055	unoccupied		0		0	0
247013007	26.20531	unoccupied		0		0	0
247013008	27.03759	unoccupied		0		0	0

Table 13-5 [continued]. Agricultural operation, primary crop and acerage, secondary crop and acerage, and landscaping acerage by TMK in the Launiupoko Water Company service area.

TMK	TMK size (acres)	agricultural operation	primary agricultural crop	primary agricultural crop (acres)	secondary agricultural crop	secondary agricultural crop (acres)	landscaping (acres)
247013009	19.31249	unoccupied		0		0	0
247013010	17.49623	unoccupied		0		0	0
247013011	18.13812	industrial		0		0	0

Figure 13-8 Percent of each TMK in the Launiupoko Irrigation Company service area in agriculture as determined using remote sensing.

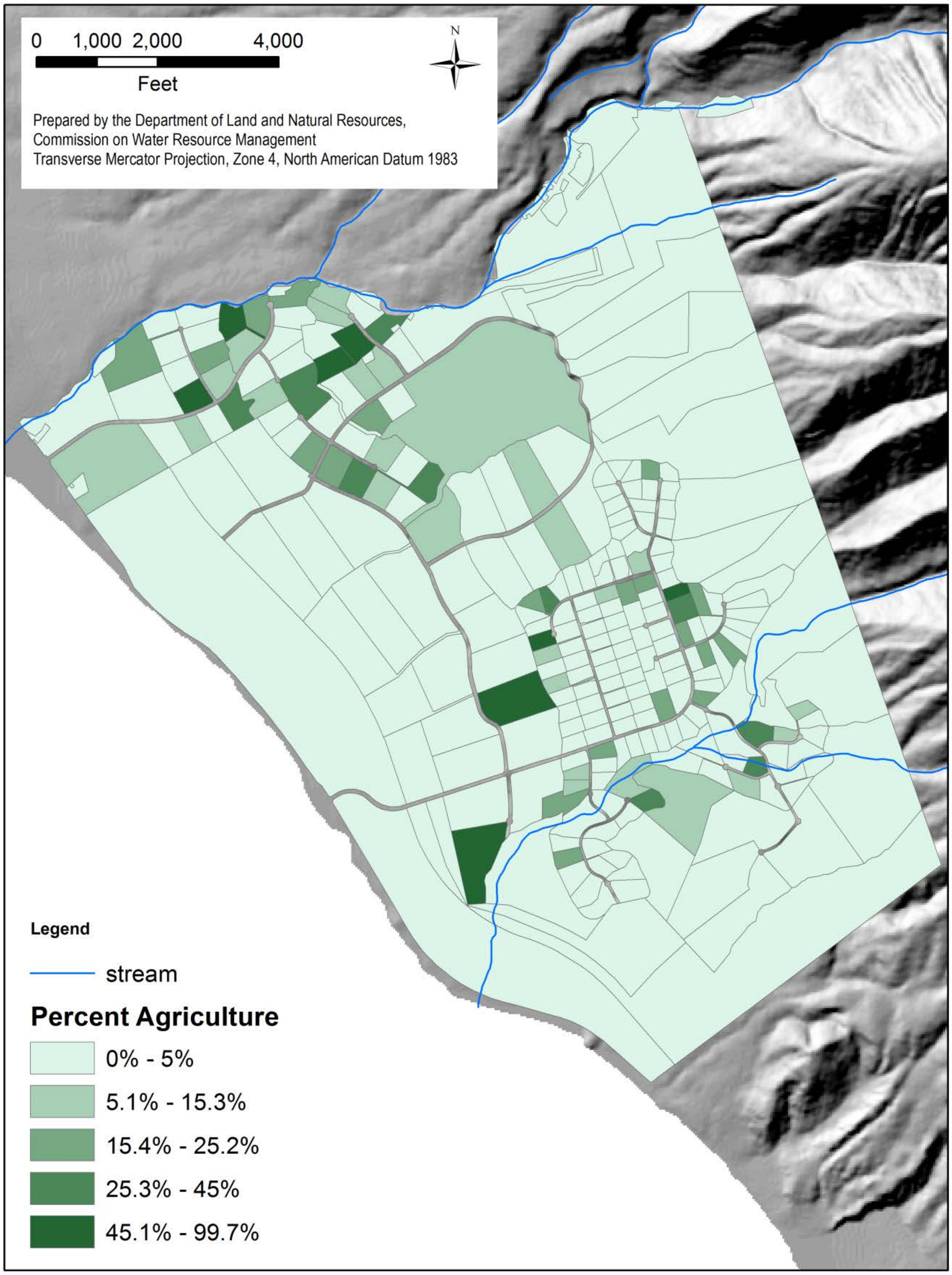


Figure 13-9. Percent of each TMK in the Launiupoko Irrigation Company service area in landscaping as determined using remote sensing.

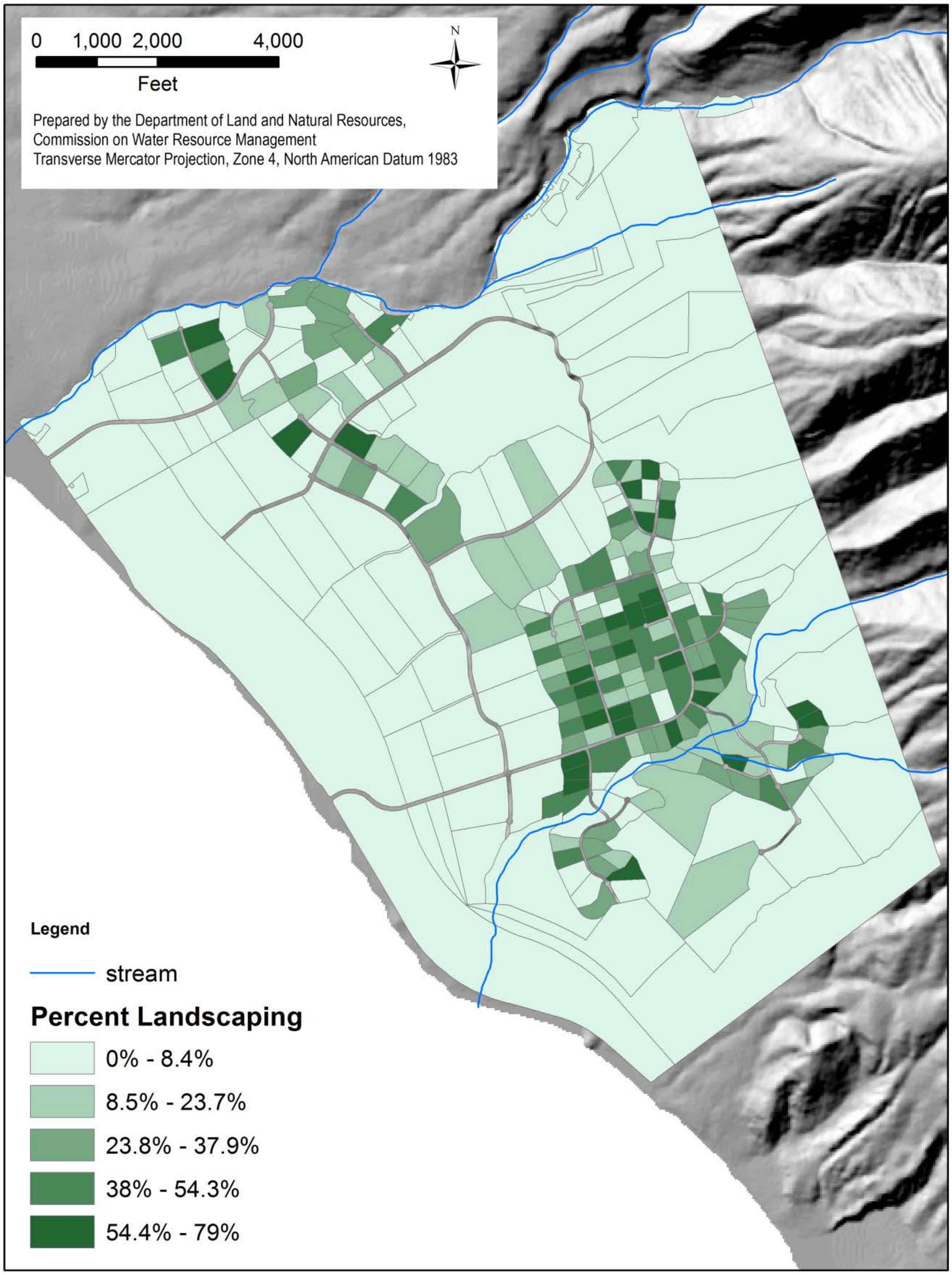
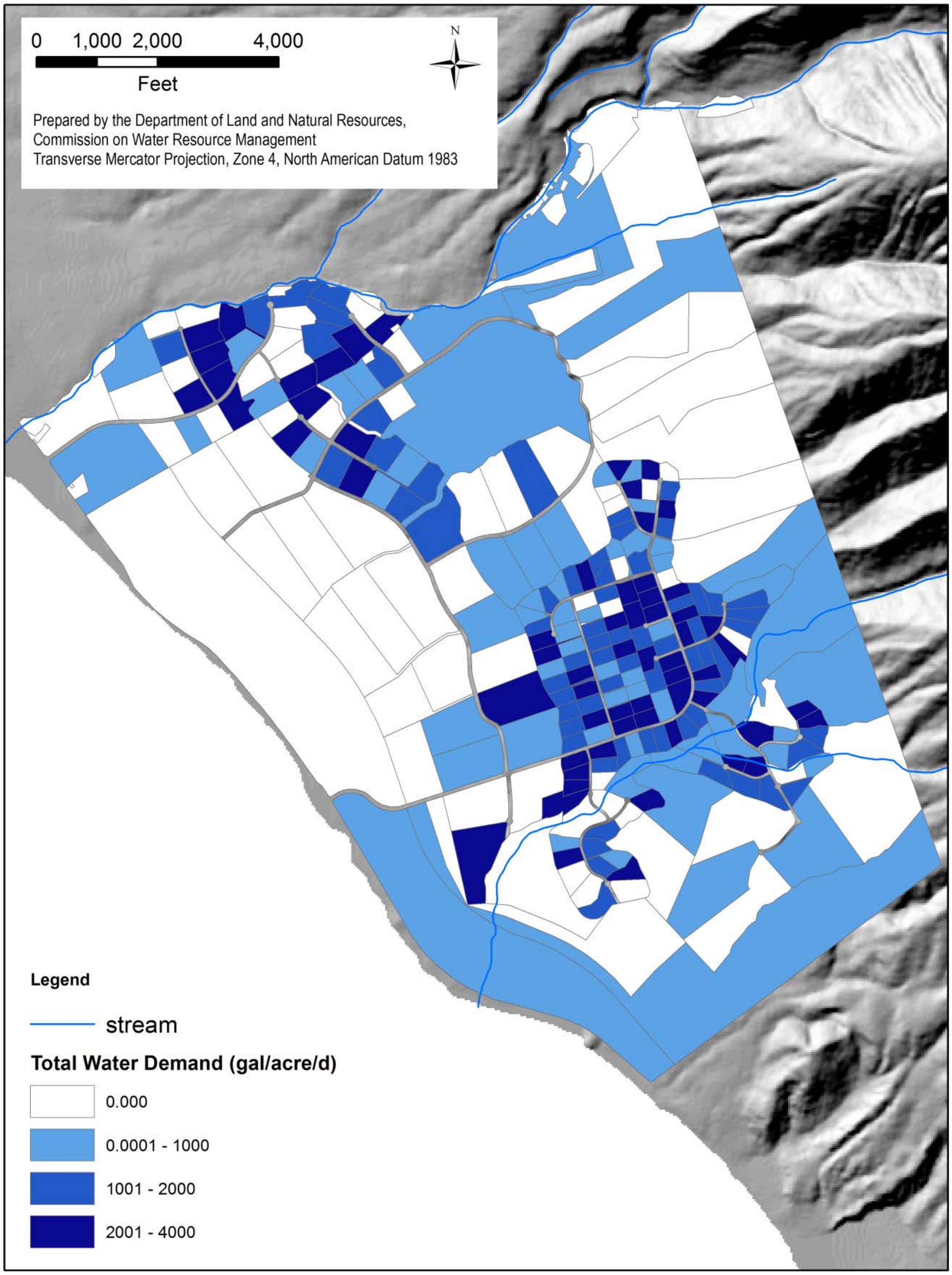


Table 13-5. Total cover (acres), estimated water demand (gallons per acre per day), and total water demand (million gallons per day, mgd) for all agricultural crops identified in the Launiupoko Irrigation Co. service area.

agricultural crop	total cover (acres)	estimated water demand (gal $acre^{-1}$ d^{-1})	total water demand (mgd)
Coconuts	23.7869	4077	0.0970
Diversified agriculture	17.8714	3400	0.0608
Dragonfruit	14.5171	3400	0.0494
Vine crop	3.1450	4754	0.0150
Nursery	3.7069	2500	0.0093
Orchard (assumed orange)	11.3869	2887	0.0329
Ornamental flower	0.8506	4754	0.0040
Pasture	9.8080	2500	0.0245
Unknown	3.1014	3400	0.0105
sum	88.1741		0.3033

Figure 13-10. Estimated water demand of each TMK in the Launiupoko Irrigation Company service area based on land cover (agriculture or landscaping) using remote sensing and modeled water demand for that land cover.



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15.0 Appendices

Appendix A Launiupoko River, Maui, Hawaii. June 2008.
State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources.