Instream Flow Standard Assessment Report

Island of Maui
Hydrologic Units 6043
Oopuola

November 2022 **PR-2022-08**

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

COVER
Satallite image of Oopuola hydrologic unit with Oopuola Stream flowing into the Pacific Ocean, Maui [Google Earth, 2014].

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.

Table of Contents

List of Figures

List of Tables

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
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
KLM	Kaanapali Land Management Company
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
MLP	Maui Land & Pineapple
MOU	Memorandum of Understanding

na	not available
NAWQA	National Water Quality Assessment (USGS)
NHLC	Native Hawaiian Legal Corporation
NIR	net irrigation requirements
NPDES	National Pollutant Discharge Elimination System
NPV	Net Present Value
NRCS	Natural Resource Conservation Service (USDA)
NVCS	National Vegetation Classification System
por.	Portion
REL	religious
RMT	R.M. Towill Corporation
SCS	Soil Conservation Service (United States Department of Agriculture) Note: The SCS is now called the Natural Resources Conservation Service (NRCS)
SF	single family residential
SPI	Standardized Precipitation Index
sq mi	square miles
TFQ	total flow statistics
TFQ_{50}	50 percent exceedence probability
TFQ_{90}	90 percent exceedence probability
TMDL	Total Maximum Daily Load
TMK	Tax Map Key
UHERO	University of Hawaii's Economic Research Organization
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service (Department of the Interior)
USGS	United States Geological Survey (Department of the Interior)
WQS	Water Quality Standards
WRPP	Water Resource Protection Plan (Commission on Water Resource Management)
WTF	water treatment facility

1.0 Introduction

General Overview

The surface water hydrologic unit of Oopuola is in the district of Koolau on the northeastern (windward) flank of the East Maui Volcano of Haleakala (Figure 1-3). Oopuola is a 1.227 square mile hydrologic unit whose watershed has a maximum elevation of 5210 feet and mean basin slope of 22.5 percent. Nineteen percent of the basin has a slope greater than 30 percent, with a mean basin elevation of 2780 feet and a mean annual precipitation of 152 (Figures 1-4 and 1-5). Oopuola Stream has one named tributary, Makanali Stream, and three unnamed tributaries, with the largest being the Westernmost tributary. The longest flow path of Oopuola Stream is 3.41 miles in length and drains a narrow, v-shaped watershed of 1.06 square miles from its headwaters to the Pacific Ocean. The geology and water resources are heavily influenced by the high permeability of the shield building phase making up the Honomanu Volcanic Series, which is exposed only in heavily incised valleys. From the coastline to about 2,000 feet inland, the thin-beded Honomanu basalt is exposed, resulting in a losing stream reach below a 50 foot waterfall formed by a thick post-erosional Kula Volcanic Series lava flow. About half of the hydrologic unit is composed of alien forest or grassland, with some closed and open ohia forest. The area is part of the Huelo census tract that has a total population of 2,173 people (U.S. Census Bureau, 2018).

Current Instream Flow Standard

The current interim instream flow standard (IFS) for Oopuola 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 East Maui. The Interim Instream Flow Standard for all streams on East 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 October 8, 1988. Streamflow was not measured on that date; therefore, the current interim IFS is not a quantifiable value.

Instream Flow Standards

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

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

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

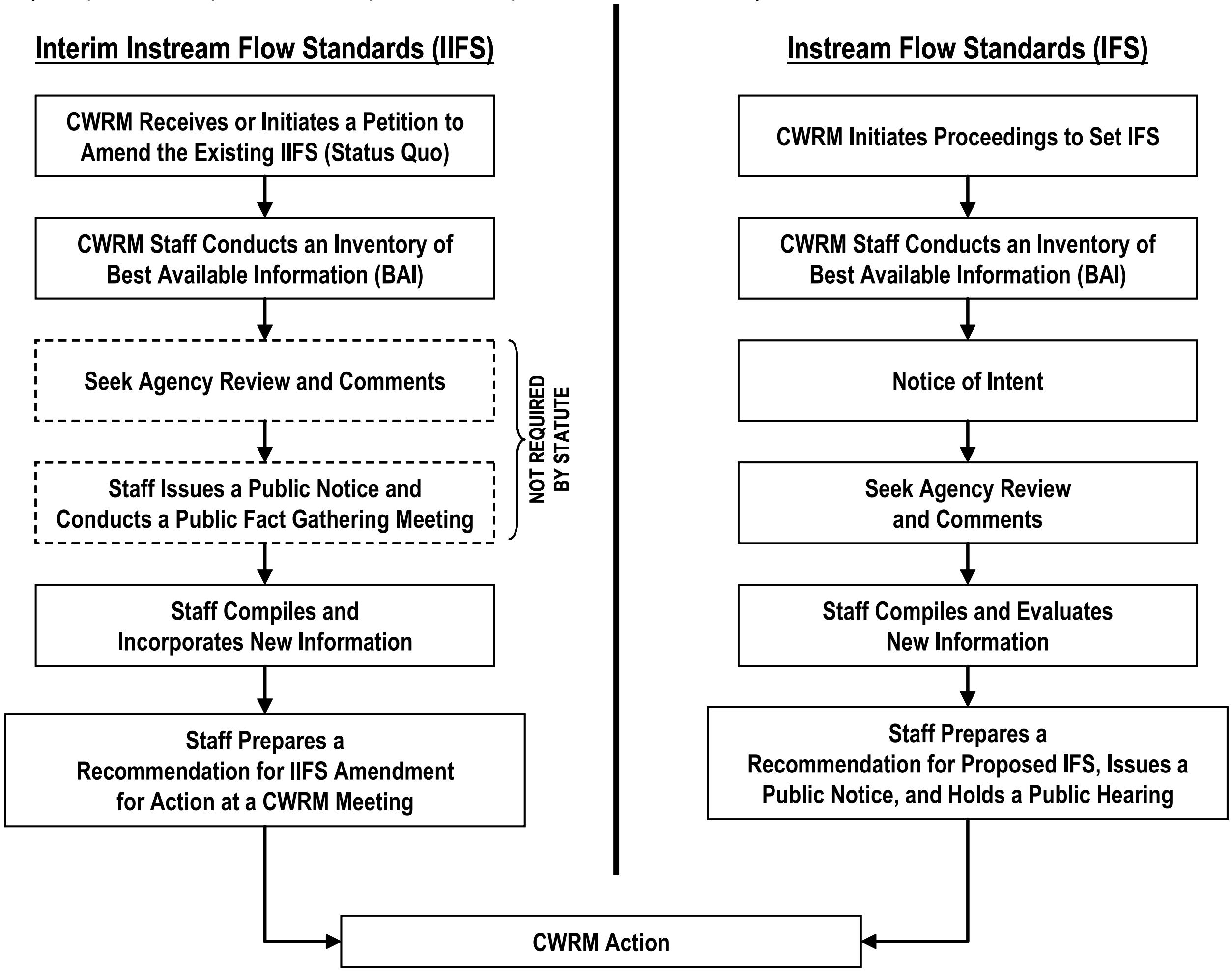
Figure 1-1. Information to consider in setting measurable instream flow standards.

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.

Section 13.0 describes public trust uses of water not covered in other sections. Noninstream uses are summarized in Section 14.0. Maps are provided at the end of each section to help illustrate information presented within the section's text or tables. Finally, Section 15.0 provides a comprehensive listing of cited references and is intended to offer readers the opportunity to review IFSAR references in further detail.

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

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

Surface Water Hydrologic Units

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

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

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

Surface Water Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Figure 1-3. Quickbird World View 2 satellite imagery of the Oopuola hydrologic unit and streams in East Maui, Hawaii.

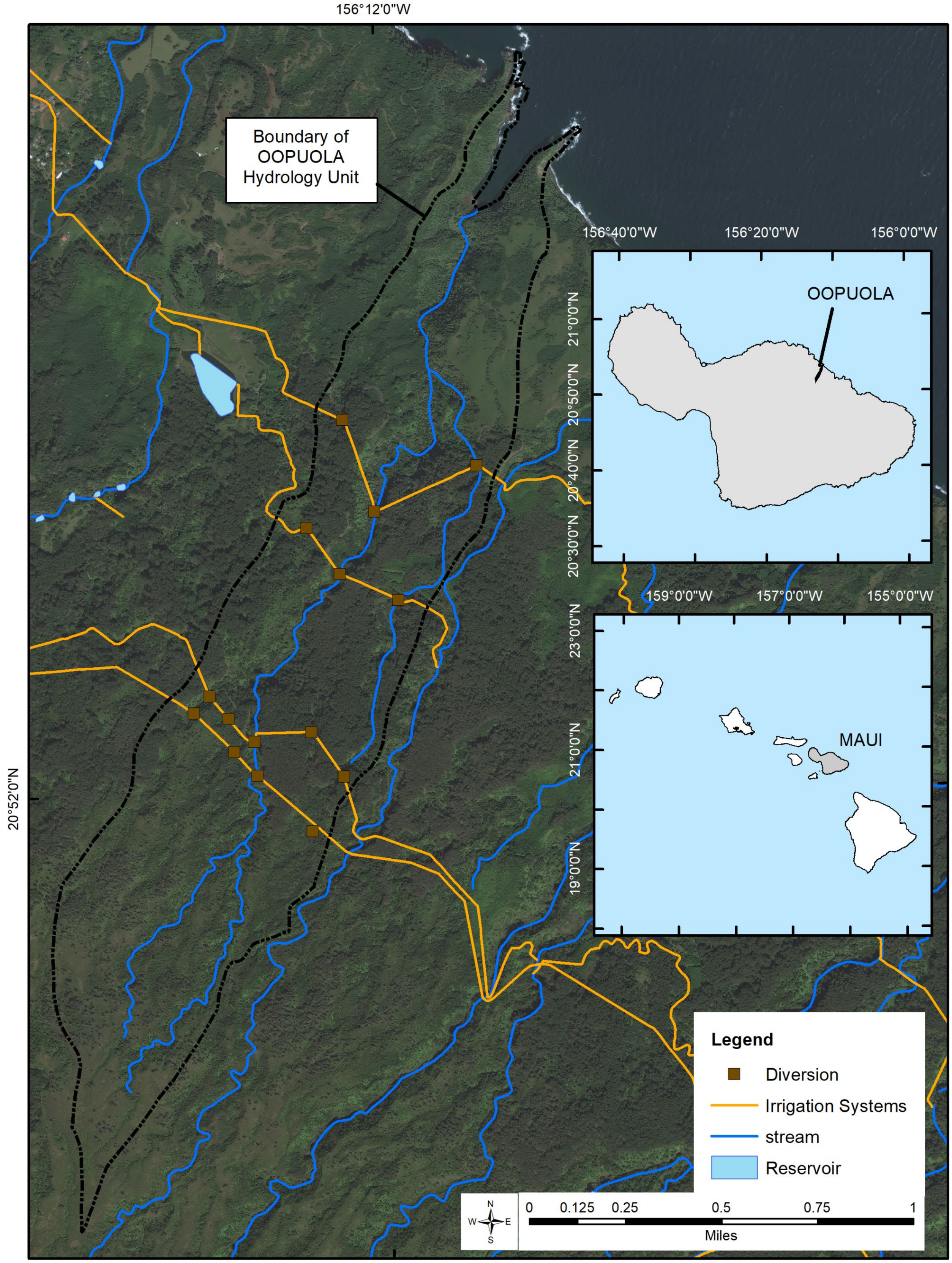


Figure 1-4. Elevation range of the Oopuola hydrologic unit, Maui. (U.S. Geological Survey, 2001)

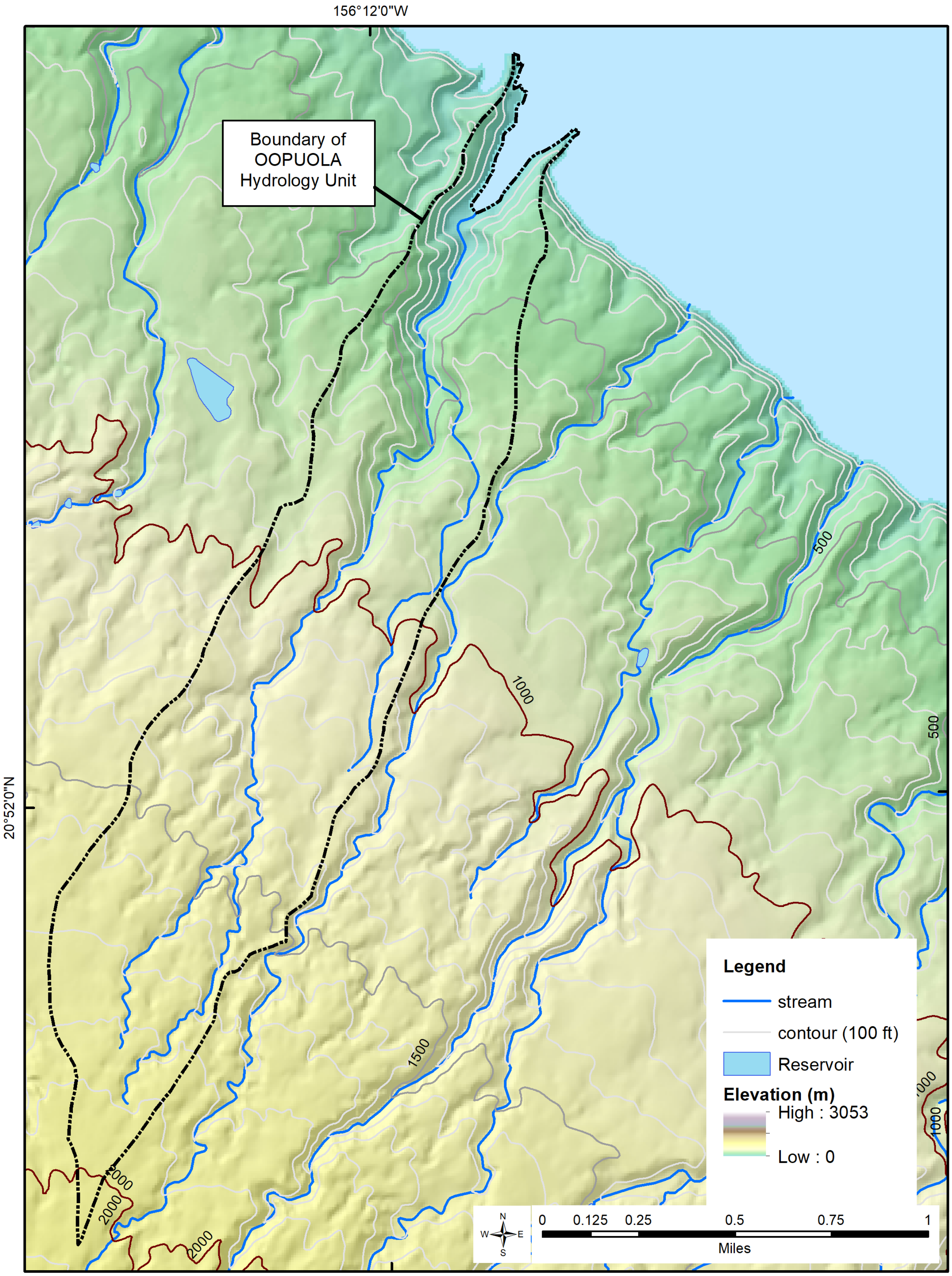


Figure 1-5. USGS topographic map of Oopuola hydrologic unit, Maui. (Source: U.S. Geological Survey, 1996)

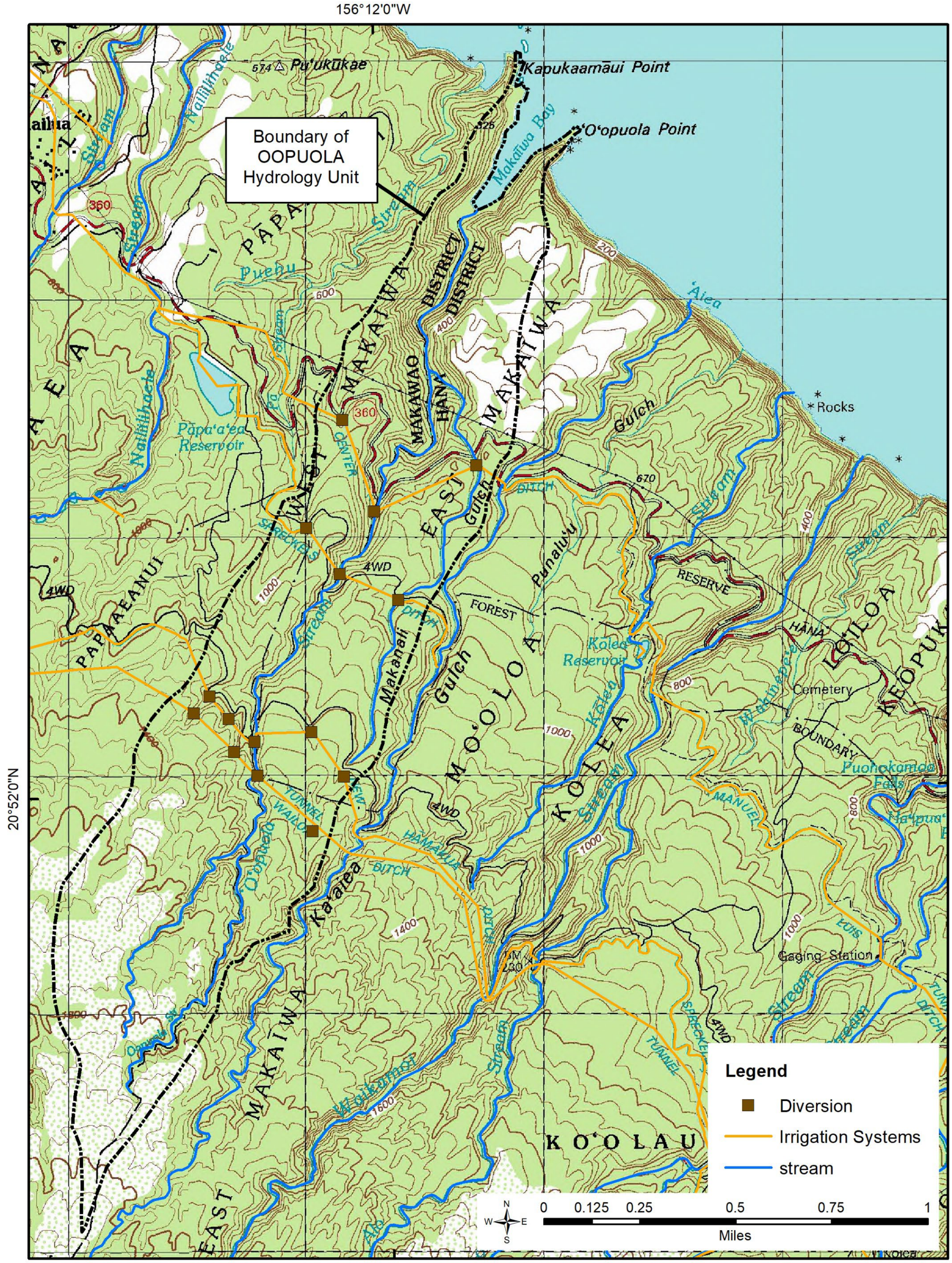
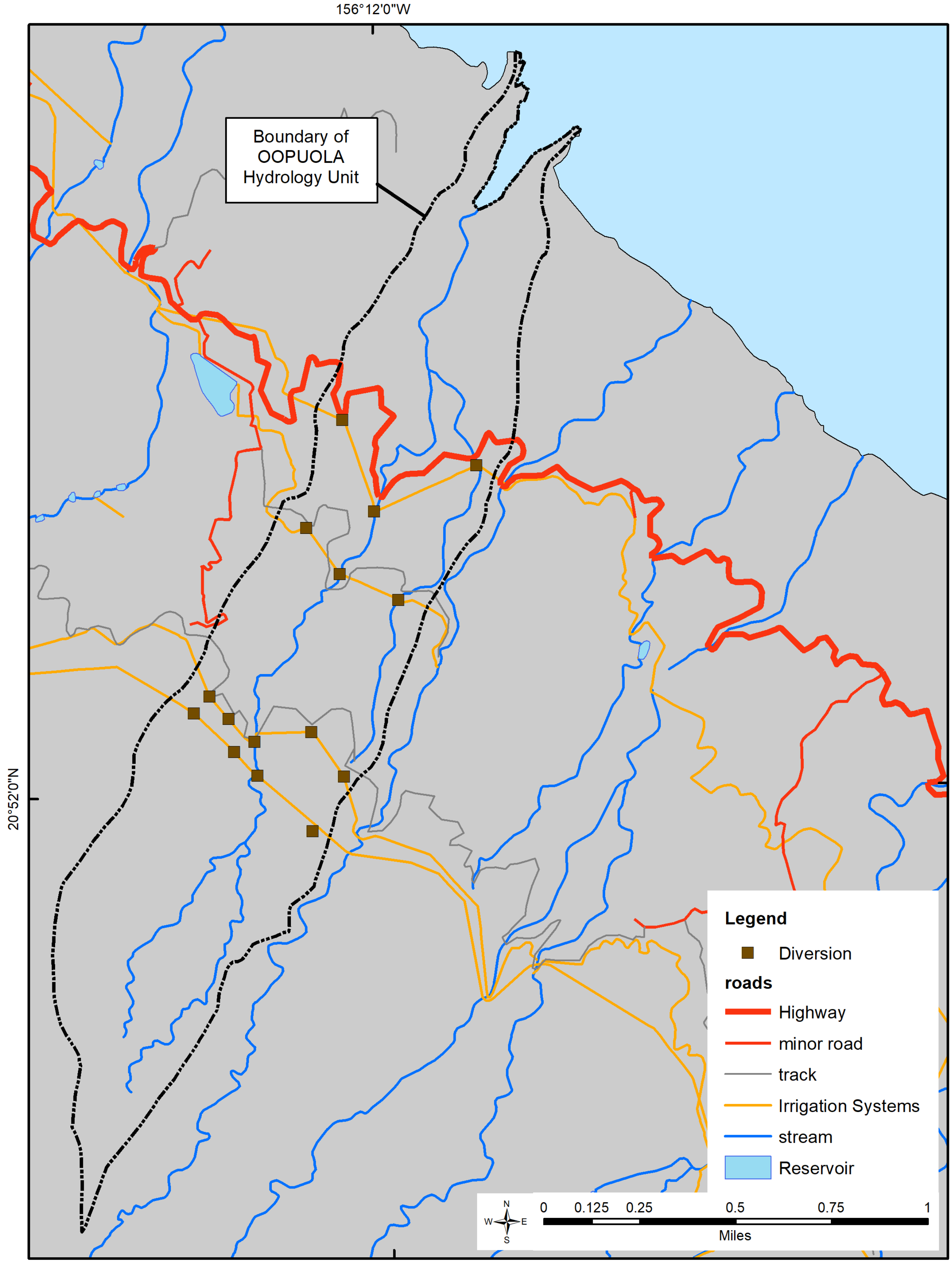


Figure 1-6. Major and minor roads for the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning 2020)



2.0 Unit Characteristics

Geology

The surface geology of the Oopuola hydrologic unit is primarily characterized by Kula volcanics, which are mainly aa flows (lava characterized by jagged, sharp surfaces with massive, relatively dense interior) that poured out at progressively longer intervals so that numerous valleys were cut between the younger lava flows (Figure 2-2). The older flows are massive, aggregating 2,000 feet thick on the summit and thin toward the isthmus where they are only about 50 feet thick. In the eastern end of the Haleakala near Nahiku, perched high-level ground water[1] is held up by the relatively low permeability[2] Kula volcanics and associated weathered soils and ash beds (Gingerich, 1999a). Elsewhere they contain fresh water at sea level, but it is brackish along the leeward shore. A small area near the head of the hydrologic unit includes geologic formations (weathered cinders, spatter, and pumice) originally built along fissures by firefountains (sprays of gases carrying magma from vents, spewing up to several hundred feet high, producing “spatter”) at the source of the lava flows, forming a few perched spring water systems. The Honomanu volcanic series, which predates the Kula volcanics, is believed to form the basement of the entire Haleakala mountain to an unknown depth below sea level. They are predominantly pahoehoe flows (lava characterized by a smooth or ropy surface with variable interior, including lava tubes and other voids), ranging from 10 to 75 feet thick and are very vesicular. The Honomanu basalts are extremely permeable and yield water freely (Stearns and MacDonald, 1942). The generalized geology of the Oopuola hydrologic unit is depicted in Figure 2-1.

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

Name	Rock Type	Lithology	Age Range (kya)	Area (mi^2)	Percent of Unit
Honomanu Basalt	Lava flows	Aa and pahoehoe	950-1,300	0.044	3.6
Kula Volcanics	Lava flows	Aa and pahoehoe	140-780/950	1.180	96.2

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 Oopuola hydrologic unit, soils are somewhat evenly distributed, with Group A (51%) soils the largest contributor, followed by Group D (43%) (Table 2-2). The soil orders for the Oopuola hydrologic unit are identified in Figure 2-2.

The mauka section of the hydrologic unit consists of permeable, well-drained soils, often occurring on the steeper slopes. The other 45 percent are poorly drained, occurring on the less sloping tops of ridges and interfluves (regions of higher land between valleys in the same hydrologic unit). In these areas, the substratum is soft, weathered basic igneous rock capped by a horizontal ironstone sheet 1/8 to 1 inch thick. Permeability is restricted by the ironstone sheet, which is impermeable except for cracks, meaning that rain water will infiltrate the top of the soil then move laterally until it either seeps out as springs or base flow[3] in streams; or reaches a more permeable soil type.

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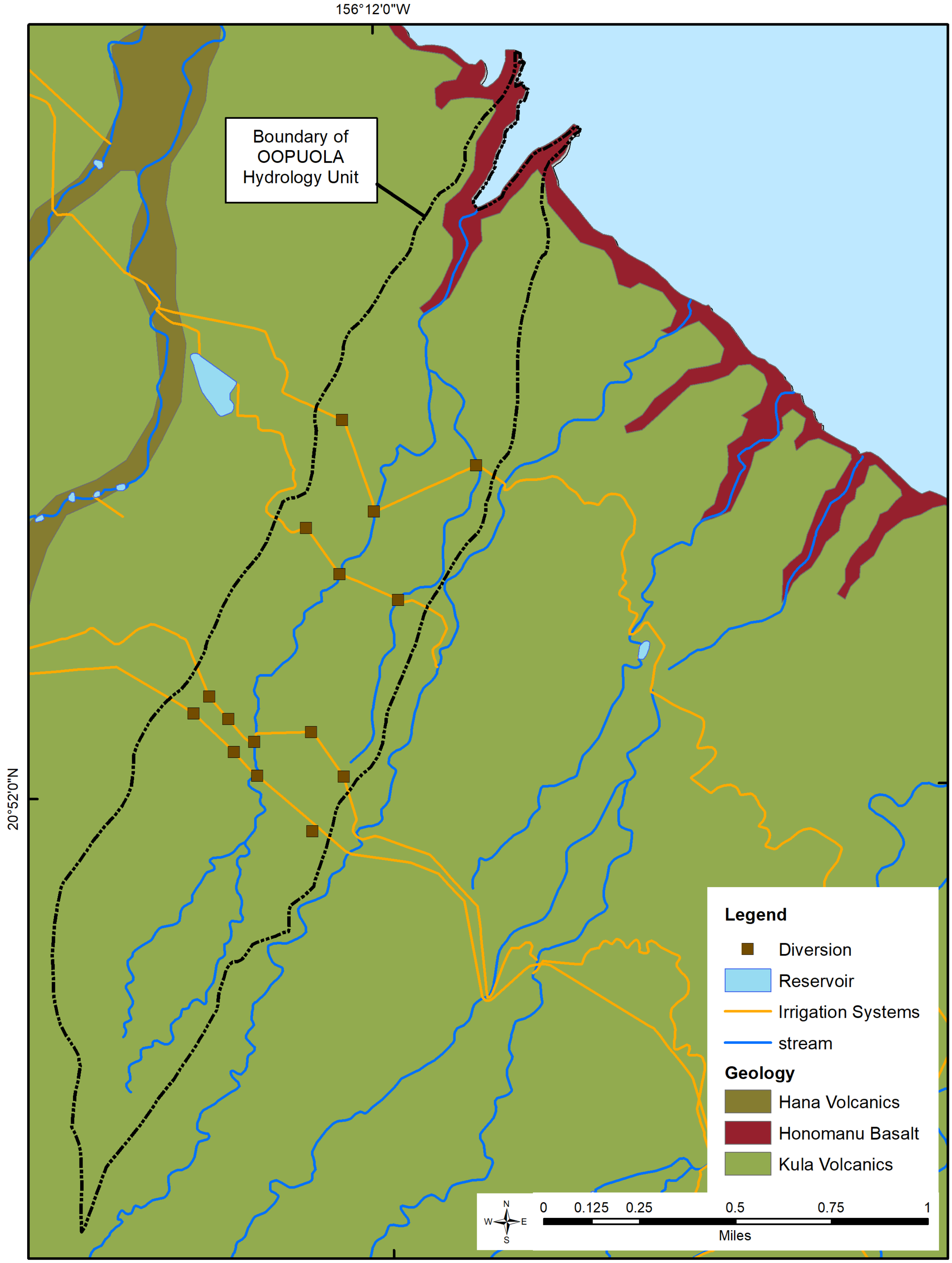
[1] Perched water is water confined by an impermeable or slowly permeable layer, thus accumulating in a perched water table above the general regional water table. It is generally near-surface, and may supply springs.
[2] Permeability is the ease with which water passes through material. It is a factor in determining whether precipitation runs off on the surface or descends into the ground.
[3] Base flow is the flow of water into a stream from the ground from persistent, varying sources and maintains stream flow between water-input events (i.e. during periods of no rainfall).

Figure 2-1. Generalized geology of the Oopuola hydrologic unit, Maui. (Source: Sherrod et al., 2007)



The soils along the course of Oopuola Stream continues in a gulch through rough mountainous land from the headwaters of the hydrologic unit to the coast. This is very steep land broken by numerous intermittent drainage channels with rapid runoff and active geologic erosion. The soils of rough mountainous land are not uniform (Soil Survey Staff, 2020).

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

Soil Series Unit	Hydrologic Soil Group	Area (mi^2)	Percent (%)
Honomanu	A	0.311	25.4
Rough Mountainous Land	D	0.535	43.6
Kailua	A	0.322	26.2
Pauwela	B	0.043	3.5

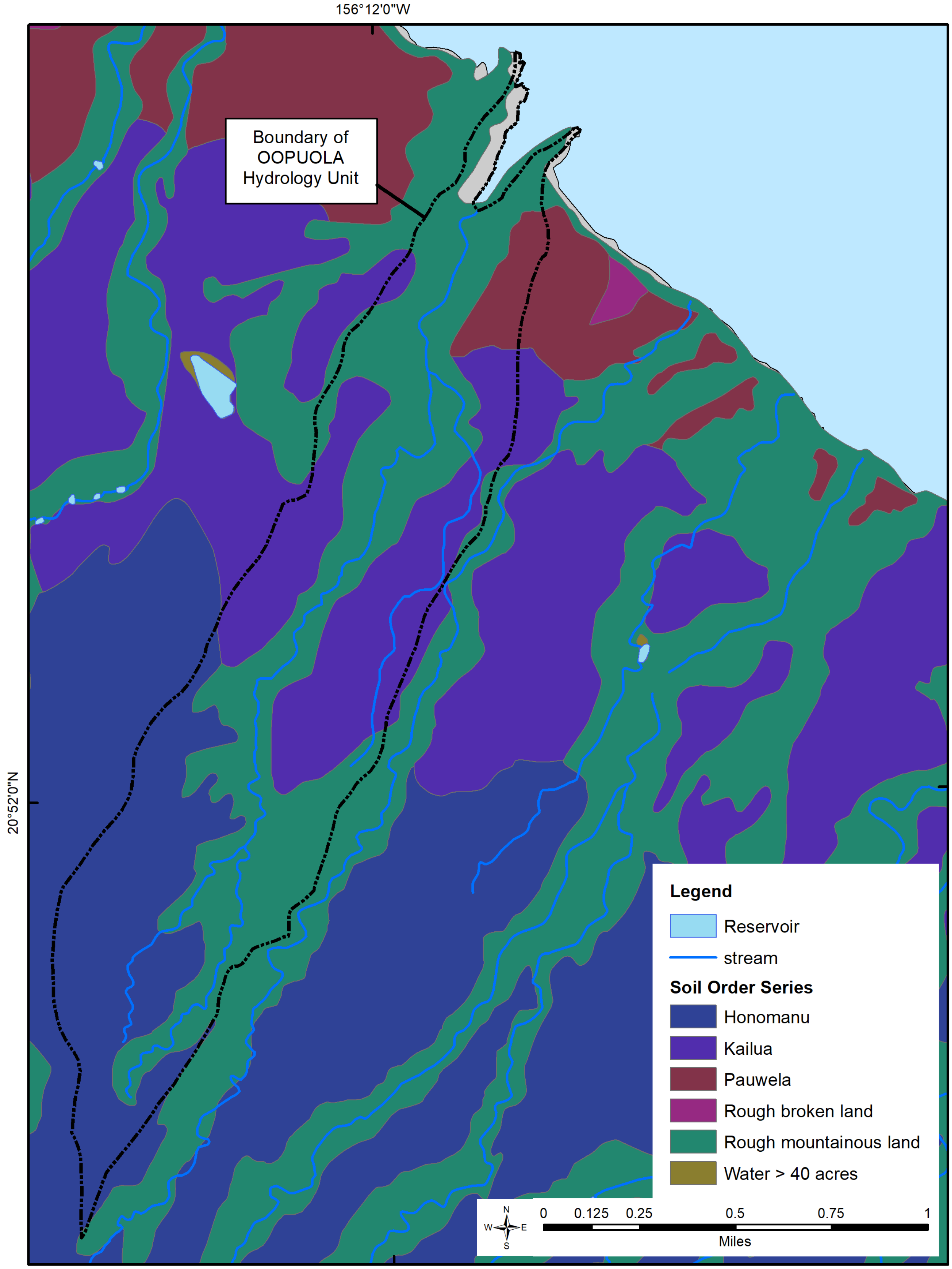
Rainfall

Haleakala and Puu Kukui are the driving force affecting the distribution of rainfall on Maui, with rainfall affected by the orographic[4] effect and the rainshadow effect (Figure 2-3). Orographic precipitation occurs when the prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. As moist air cools, water condenses and the air mass releases precipitation. As a result, frequent and heavy rainfall is observed on the windward mountain slopes. The temperature inversion zone, the range of elevations where temperature increases with elevation, typically extends from 6,560 feet to 7,874 feet. This region is identified by a layer of moist air below and dry air above (Giambelluca and Nullet, 1992). The fog drip zone on the windward side of islands extends from the cloud base level at about 2,000 feet to the lower limit of the most frequent temperature inversion base height at 6,560 feet (Giambelluca and Nullet, 1992). This zone occurs below the elevation where cloud height is restricted by the temperature inversion (Sholl et al., 2002). Fog drip is a result of cloud-water droplets impacting vegetation (Scholl et al., 2002) and can contribute significantly to groundwater 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. This region is found in the higher elevations of the largest volcanoes (e.g., Mauna Kea, Haleakala).

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 on the leeward mountain slopes. Haleakala, as the tallest peak (10,023 feet a.s.l) on Maui, influences the elevational distribution of moisture around the island. 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. Mean annual rainfall measured at Kailua (station 446; elevation 700 feet; active from 1904-present) is 122.2 inches and measured at Punaluu (station 447; 720 feet; active from 1906-1961) was 124.6 inches (Giambelluca et al. 2013).

[4] 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.

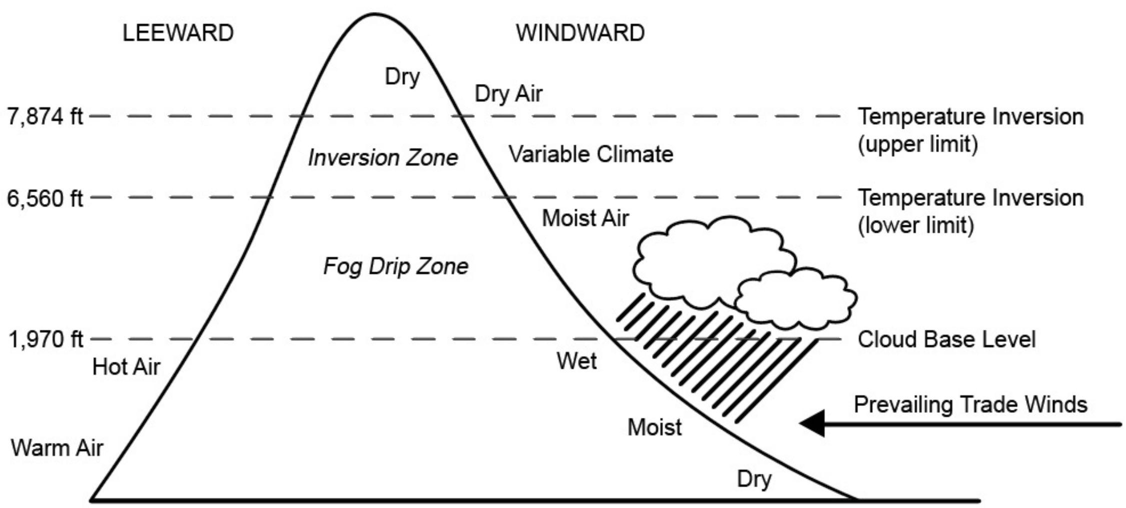
Figure 2-2. Soil order classification of the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015m)



The Oopuola hydrologic unit is situated on the windward side of Haleakala and as such receives substantial orographic rainfall, contributing to higher 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. Above 2000 ft, rainfall is highest during the months of March and April, where the mean monthly rainfall is approximately 22 inches (Table 2-3).

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 Oopuola hydrologic unit, which is calculated by multiplying the same ratios to the monthly rainfall values in the fog drip zone based on Giambelluca et al (2013). Calculations show that approximately 23 percent of Oopuola (0.277 square miles) lies in the fog drip zone based on elevations greater than 2000 feet. The total contribution from fog drip to the water budget based on percent of fog drig from monthly rainfall is about 25.6 percent (66.6 inches out of 260.1 inches) of the upper (>2,000 ft) watershed, assuming the same ratios apply here (Table 2-3).

Figure 2-3. Orographic precipitation in the presence of mountains higher than 6,000 feet.



Solar Radiation

Solar radiation is the sun's energy that arrives at the Earth's surface after considerable amounts have been absorbed by water vapor and gases in the Earth's atmosphere. The amount of solar radiation to reach the surface in a given area is dependent in part upon latitude and the sun's declination angle (angle from the sun to the equator), which is a function of the time of year. Hawaii's trade winds and the temperature inversion layer greatly affect solar radiation levels, the primary heat source for evaporation. High mountain ranges block moist trade-wind air flow and keep moisture beneath the inversion layer (Lau and Mink, 2006). As a result, windward slopes tend to be shaded by clouds and protected from solar radiation, while dry leeward areas receive a greater amount of solar radiation and thus have higher levels of evaporation. In the Oopuola hydrologic unit, average annual solar radiation ranged from 195.5 to 226.9 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 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[5], rainfall, humidity, wind speed, surface temperature, and sensible heat advection[6]. Higher evaporation rates are generally associated with greater net radiation, high wind speed and surface temperature, and lower humidity.

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 Oopuola hydrologic unit based on an elevation range of 2000-2160 feet and equivalent ratios.

Month	Ratio (%)	Mean Rainfall	Contribution (in)
January	13	15.7	2.04
February	13	13.58	1.77
March	13	22.65	2.94
April	27	21.73	5.87
May	27	14.62	3.95
June	27	12.45	3.36
July	67	17.5	11.73
August	67	14.05	9.41
September	67	11.48	7.69
October	40	14.88	5.95
November	40	18.66	7.46
December	27	16.25	4.39

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[7] and the cloud layer (Figure 2-6). 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.

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

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 summit causes increased evaporation, with pan evaporation rates of about 50 to 70 inches per year (Shade, 1999, Fig. 9). For example, Ekern and Chang (1985) reported evaporation increased to 50 percent more than surface oceanic rates near the Mauna Kea crest on the island of Hawaii. A common approach to estimating evaporation is to employ a relationship between potential evaporation and the available water in the watershed, estimated as potential evapotranspiration. Mean annual potential evapotranspiration in the Oopuola hydrologic unit (Figure 2-6) averages 132.9 inches per year and ranges from 99.1 to 172.4 inches (Giambelluca et al. 2014). Annual actual evapotranspiration for the Oopuola hydrologic unit ranges from 32.4 inches to 59.3 inches per year, with an average of 44.4 inches per year.

Land Use

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

Land use classification is an important component of examining the benefits of protecting instream uses and the appropriateness of surface water use for noninstream uses. While some may argue that land use, in general, should be based upon the availability of surface and groundwater resources, land use classification continues to serve as a valuable tool for long-range planning purposes. As of 2014, 77.5 percent (0.952 square miles) of the land in Oopuola is classified as conservation and 22.4 percent is classified as agriculture. None of the hydrologic unit is classified as rural or urban. The conservation districts are in the upper elevation sections of the hydrologic unit (Figure 2-7).

Land Cover

Land cover for the hydrologic units of Oopuola 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 Oopuola, 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).

Figure 2-4. Mean annual rainfall and fog drip zone in the Oopuola hydrologic unit, Maui. (Source: Giambelluca et al., 2013)

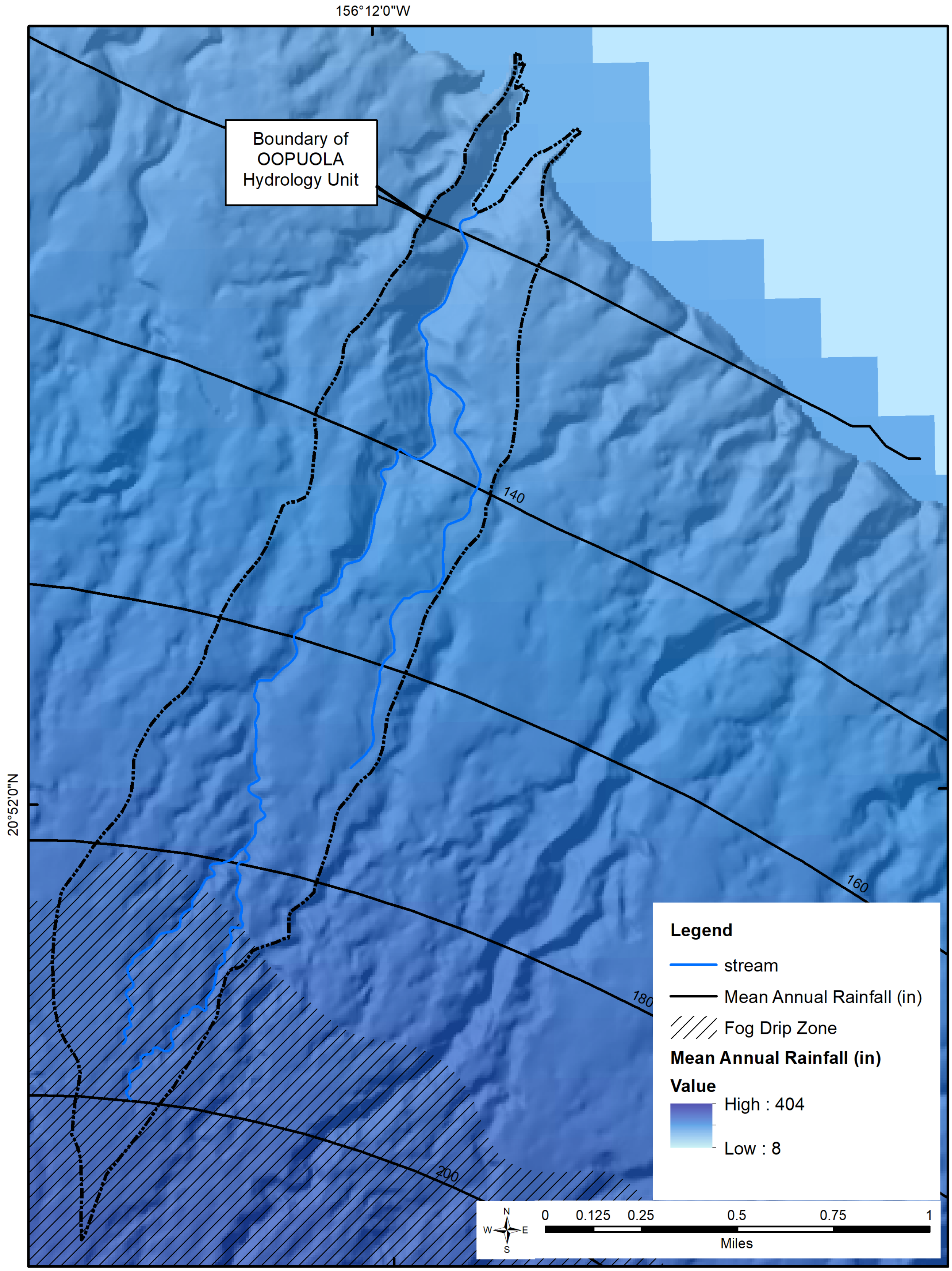


Figure 2-5. Mean annual solar radiation of the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015c)

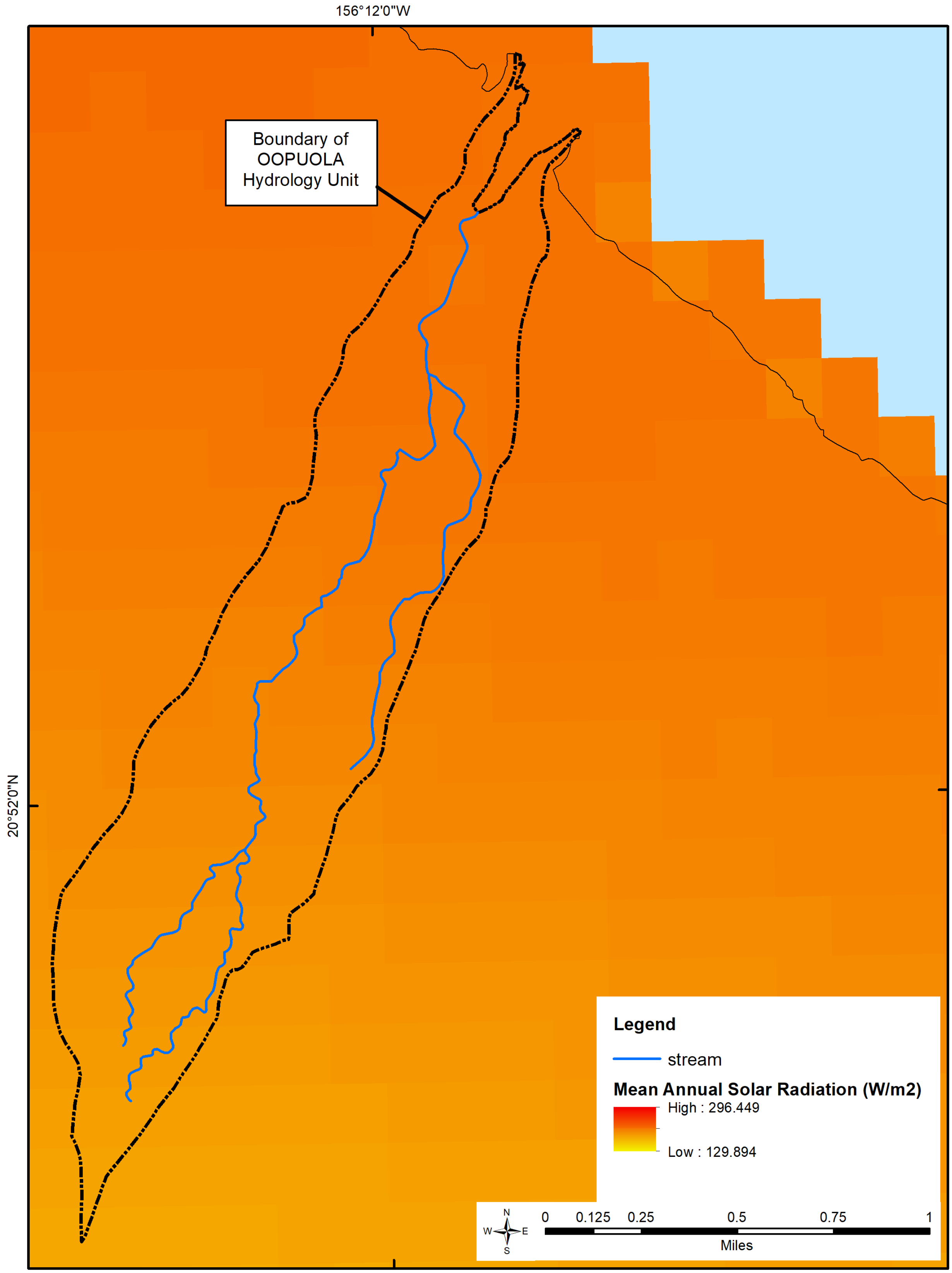
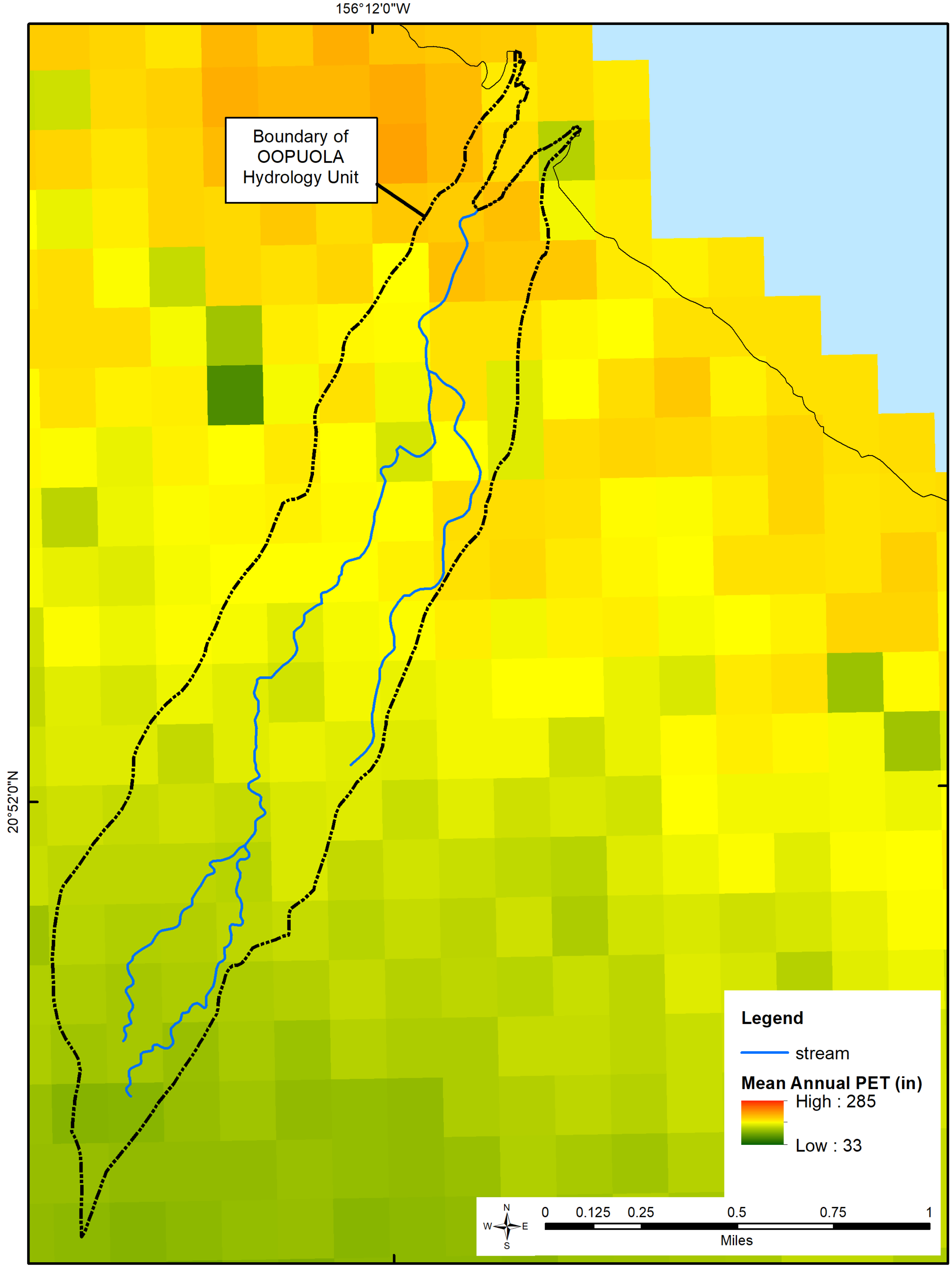


Figure 2-6. Mean annual potential evapotranspiration (Penman-Monteith method) of the Oopuola hydrologic unit, Maui. (Source: Giambelluca et al., 2014)



Based on the two land cover classification systems, the land cover of Oopuola consists mainly of evergreen forest, forested wetland, and scrub wetland. About half of the hydrologic unit is made up of alien forest, alien shrubland, or alien grassland. Native wet vegetation, open ohia forest or closed ohia forest make up less than 50 percent of the unit. The land cover maps (Figures 2-8, 2-9) provide a general representation of the land cover types in Oopuola hydrologic unit. At the middle to lower elevations, vegetation is generally dominated by alien species whereas the upper elevations are mixed native and non-native evergreen forest. Given that the scale of the maps is relatively large, they may not capture the smaller cultivated lands or other vegetation occupying smaller parcels of land. Land cover types may also have changed slightly since the year when the maps were published, particularly regarding the use of pasture lands and the extent of native or non-native vegetation.

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

Land Cover	Description	Area (mi^2)	Percent of Unit
Evergreen Forest	Areas where more than 67% of the trees remain green throughout the year	0.615	50.0%
Palustrine Forested Wetland	Included tidal and nontidal wetlands dominated by woody vegetation 5 meters in height or more	0.429	34.9%
Palustrine Scrub/Shrub Wetland	Includes tidal and nontidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity is below 0.5%	0.072	5.9%
Scrub	Areas dominated by woody vegetation less than 6 meters in height	0.063	5.1%
Low Intensity Developed	Constructed surface with substantial amounts of vegetated surface	0.025	2.1%
Grassland	Natural and managed herbaceous cover	0.015	1.2%
Open Water		0.007	0.6%
Bare Land	Bare soil, gravel, or other earthen material with little or no vegetation	0.002	0.2%

Flood

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

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

Land Cover	Area (mi^2)	Percent of Unit
Alien Forest	0.555	45.26%
Open Ohia Forest	0.273	22.25%
Closed Ohia Forest	0.227	18.51%
Uncharacterized Open-Sparse Vegetation	0.086	7.02%
Alien Grassland	0.030	2.41%
Uncharacterized Forest	0.026	2.15%
Very Sparse Vegetation to Unvegetated	0.022	1.78%
Uluhe Shrubland	0.006	0.48%
Uncharacterized Shrubland	0.001	0.11%
Undefined	0.000	0.03%

Peak floods in the Oopuola have been monitored at one location upstream in the watershed (Table 2-6). Using basin characteristics within the USGS Streamstats GIS-based program, it is possible to model the magnitude of floods at other locations, even if they are not monitored (Rea and Skinner, 2012). The 2-, 5-, 10-, 50-, and 100-year flood magnitudes in Oopuola Stream at Hana highway are estimated as 355, 632, 853, 1450, and 1740 cfs, respectively. The Federal Emergency Management Agency (FEMA) developed maps that identify the flood-risk areas in an effort to mitigate life and property losses associated with flooding events. Based on these maps, FEMA identified the entire hydrologic unit as having an area of minimal flood hazard flood-risk (Figure 2-10).

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

			peak flood magnitudes (cfs)				
station ID	station name	period of record	2-year	5-year	10-year	50-year	100-year
16566000	Oopuola Stream nr Huelo	1930-1957	416	510	560	647	676

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 or surface water due to reduced stream flow. The agriculture and commerce sector includes the reduction of crop yield and livestock sizes due to insufficient water supply for crop irrigation and maintenance of ground cover for grazing. The environmental, public health, and safety sector focuses on wildfires that are both detrimental to the forest ecosystem and hazardous to the public. It also includes the impact of desiccating streams, such as the reduction of instream habitats for native species.

Droughts have affected the islands throughout Hawaii's recorded history. The most severe events of the recent past years are associated with the El Niño phenomenon. In January 1998, the National Weather Service's network of 73 rain gauges throughout the State did not record a single above-normal rainfall, with 36 rain gauges recording less than 25 percent of normal rainfall (State of Hawaii, Commission on Water Resource Management, 2005b). The most recent drought occurred in 2000-2002, affecting all islands, especially the southeastern end of the State.

With Hawaii's limited water resources and growing water demands, droughts will continue to adversely affect the environment, economy, and the residents of the State. Aggressive planning is necessary to make wise decisions regarding the allocation of water at the present time, and conserving water resources for generations to come. The Hawaii Drought Plan was established in 2000 in an effort to mitigate the long-term effects of drought. One of the projects that supplemented the plan was a drought risk and vulnerability assessment of the State, conducted by researchers at the University of Hawaii (2003). In this project, drought risk areas were determined based on rainfall variation in relation to water source, irrigated area, ground water yield, stream density, land form, drainage condition, and land use. Fifteen years of historical rainfall data were used. The Standardized Precipitation Index (SPI) was used as the drought index because of its ability to assess a range of rainfall conditions in Hawaii. It quantifies rainfall deficit for different time periods, i.e. 3 months and 12 months. Results of the study for Maui are summarized in Table 2-7. Based on the 12-month SPI, the Kula region has the greatest risk to drought impact of the Maui regions because of its dependence on surface water sources, which is limited by low rainfall. The growing population in the already densely populated area further stresses the water supply.

Table 2-7. 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

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

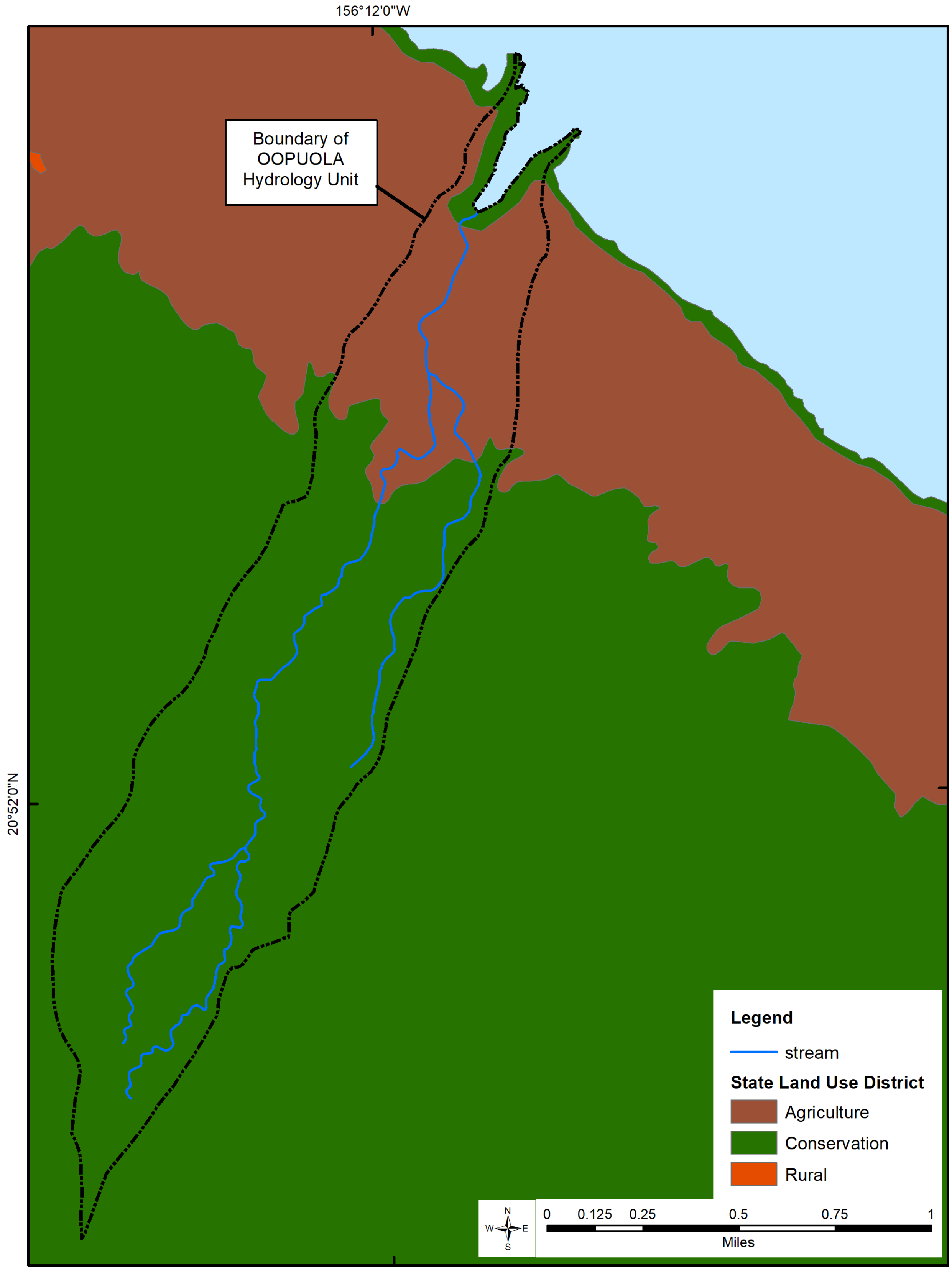


Figure 2-8. C-CAP land cover of the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015k).

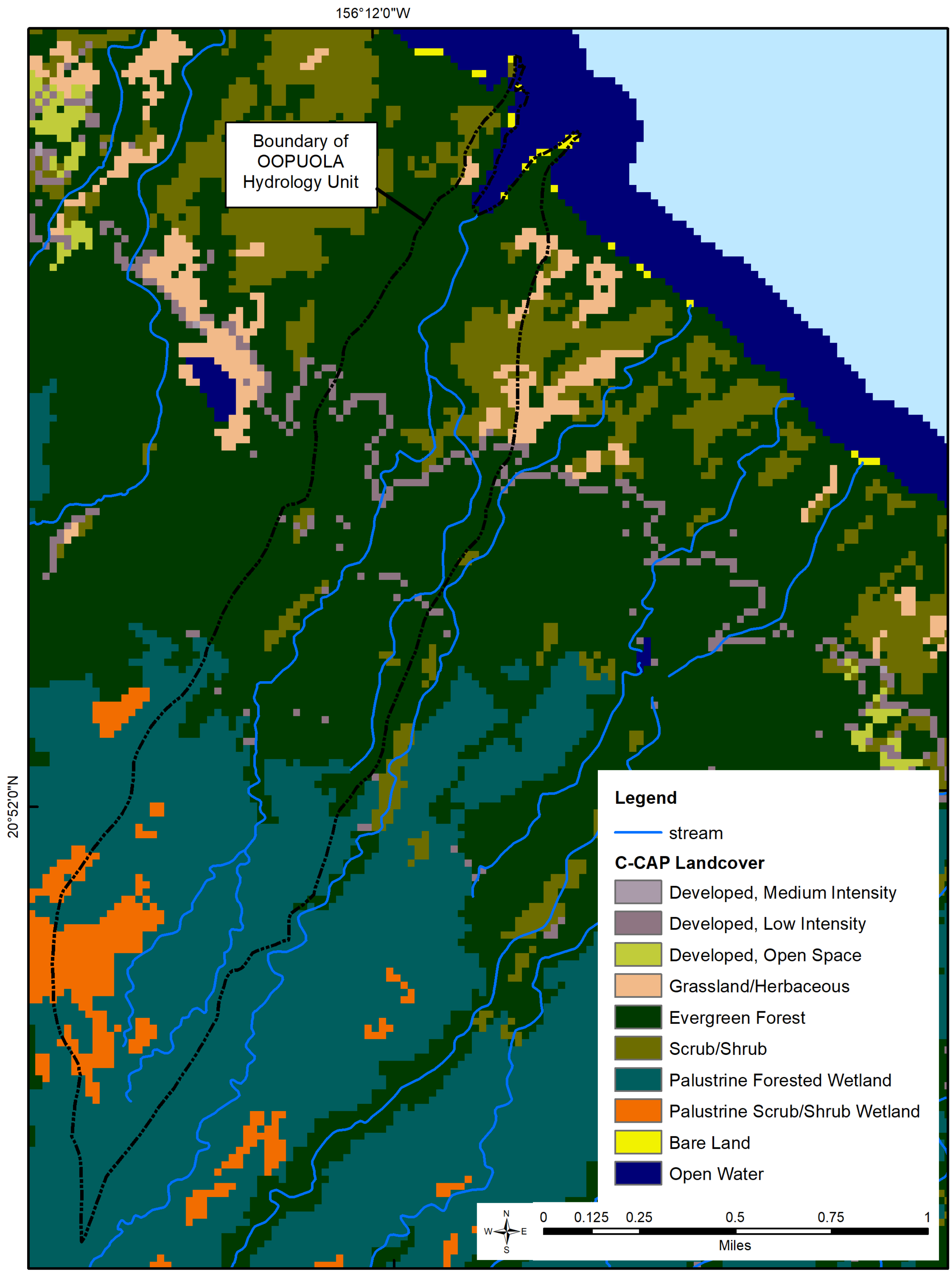


Figure 2-9. Hawaii GAP land cover classes of of the Oopuola hydrologic unit, Maui. (Source: USGS, 2001).

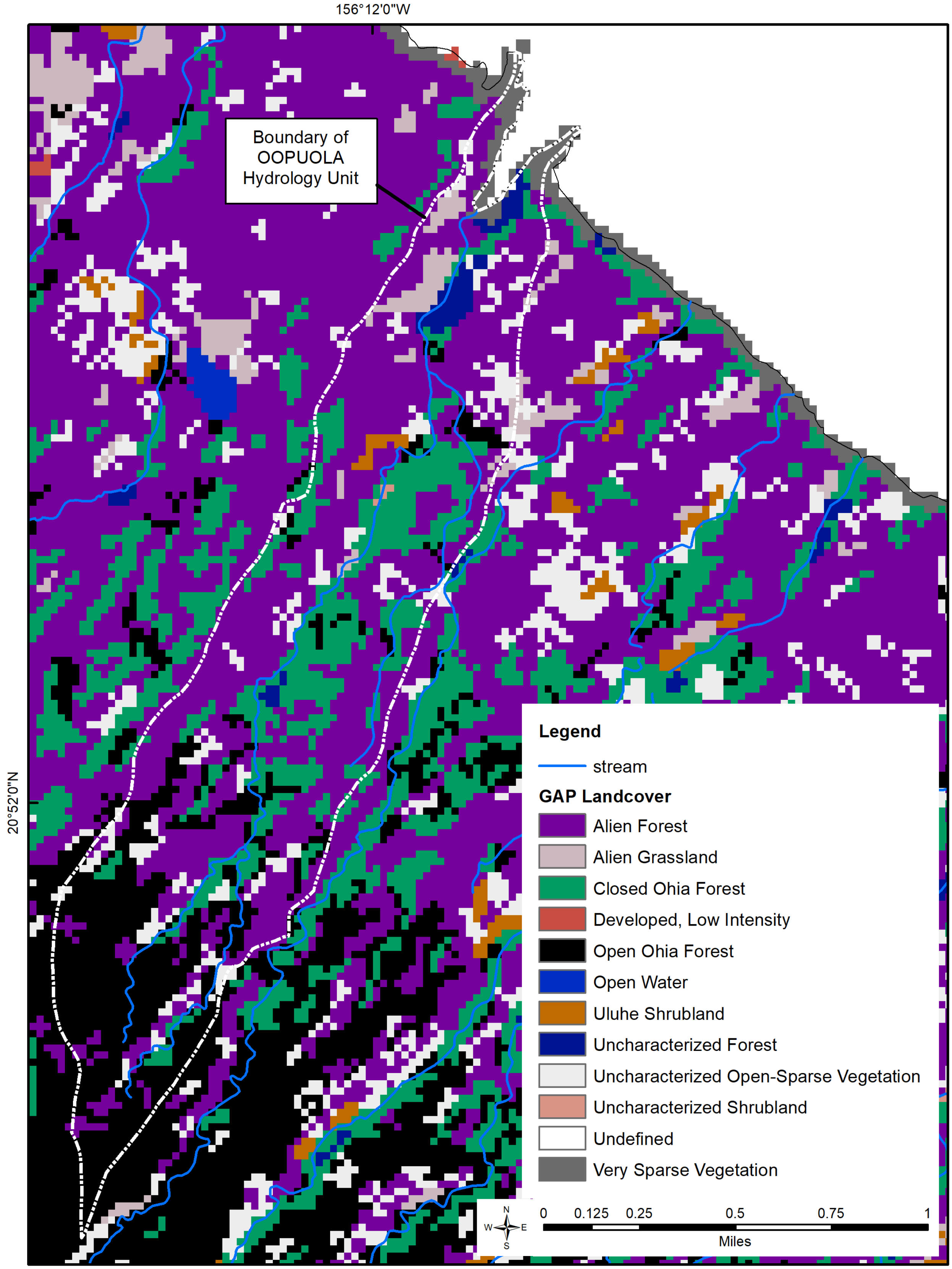
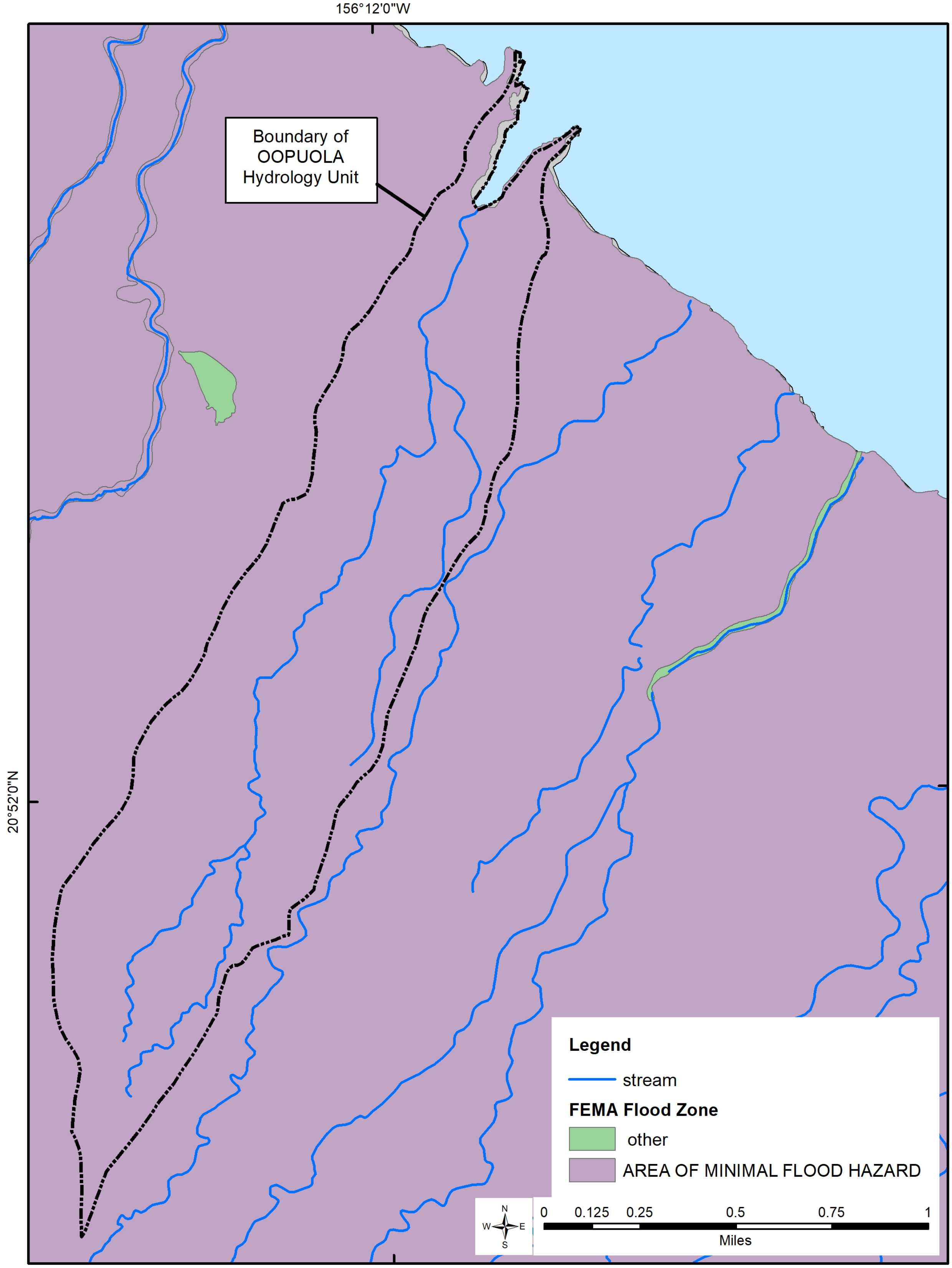


Figure 2-10. FEMA flood zone regions in the Oopuola hydrologic unit, Maui. (Source: Federal Emergency Management Agency, 2014)



3.0 Hydrology

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

Streams in Hawaii

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

Streams in Hawaii can either gain or lose water at different locations depending on the geohydrologic conditions. A stream gains water when the ground water table is above the streambed. When the water table is below the streambed, the stream can lose water. Where the streambed is lined with concrete or other low-permeability or impermeable material, interaction between surface water and 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.

The USGS has monitored both streams and ditches in Oopuola, although there are no currently active monitoring stations in the hydrologic unit. A long-term continuous stream monitoring station (station 16566000) was active from 1930-1957 on Oopuola Stream at an elevation of 1205 feet (Figure 3-5). A continuous gaging station at an elevation of 960 feet (station 16567000) was active from 1910-1915 on Oopuola Stream above Spreckels Ditch Crossing. Historic data from these stations are available in Table 3-1.

Table 3-1. Selected streamflow values for the period of record in the Oopuola hydrologic unit, Maui, Hawaii. (Source: USGS 2020) [Flows are in cubic feet per second (million gallons per day)]

station ID	station name	period of record	mean daily flow	14-day low flow	discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded			
					Q_{50}	Q_{70}	Q_{90}	Q_{95}
16566000	Oopuola Stream	1930-1957	2.7 (1.8)	0.12 (0.08)	1.1 (0.71)	0.62 (0.40)	0.32 (0.21)	0.28 (0.18)
16567000	Oopuola Stream ab Spreckels Ditch	1910-1915	9.7 (6.3)	0.47 (0.30)	2.7 (1.8)	1.2 (0.8)	0.70 (0.45)	0.62 (0.40)

Groundwater

Groundwater is an important component of streamflow as it constitutes the base flow[8] of Hawaiian streams. Groundwater can also be an alternative source to diverting stream flow. When groundwater is withdrawn from a well, the water level in the surrounding area is lowered. Nearby wetlands or ponds may shrink or even dry up if the pumping rate is sufficiently high (Gingerich and Oki, 2000). The long-term effects of groundwater withdrawal can include the reduction of streamflow, which may cause a decrease in stream habitats for native species and a reduction in the amount of water available for irrigation. The interaction between surface water and groundwater warrants a close look at the groundwater recharge and demand within the State as well as the individual hydrologic units.

In Hawaii, groundwater is replenished by recharge from rainfall, fog drip, and irrigation water that percolate through the plant root zone to the subsurface rock. Recharge can be captured in three major groundwater systems: 1) fresh water-lens system; 2) dike-impounded system; and 3) perched system. The fresh water basal aquifer provides the most important sources of ground water. It includes a lens-shaped layer of fresh water, an intermediate transition zone of brackish water, and underlying salt water. The Ghyben-Herzberg principle describes the displacement of higher density saltwater by lower density fresh water in an aquifer for a condition where two fluids do not mix and the freshwater flow is primarily horizontal. In such a situation, for every one foot above sea level of freshwater, there are approximately 400 feet of freshwater below sea level. Thus, a vertically extensive fresh water-lens system can extend several hundreds of feet below mean sea level. By contrast, a dike-impounded system is found in rift zones or a caldera where low-permeability dikes compartmentalize areas of permeable volcanic rocks, forming high-level water bodies. On 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 water-bearing properties of various rock structures largly depends on their composition, and therefore their permeability. Where a dike complex exists, 100 or more dikes per mile, occupying 5% or more of the rock, is not uncommon and can hold substantial quantities of water in the permeable layers between the dikes.

The hydrologic unit of Oopuola lies within the Waikamoi aquifer system. A general overview of the ground water occurrence, movement, and interactions with surface water in this area is described in Gingerich (1999b) and illustrated in Figure 3-1. Ground water is found at high elevations in the Kula Volcanics as well as a fresh water-lens system in the underlying Honomanu Basalt. A thick layer of unsaturated zone separates the high-elevation water body and the fresh water lens. The high-elevation saturated zone is not present near the coast because erosion has removed the low-permeability layers formed by the Kula Volcanics. 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, wells that remove water from the high-elevation water body can reduce streamflow and recharge into the fresh water lens.

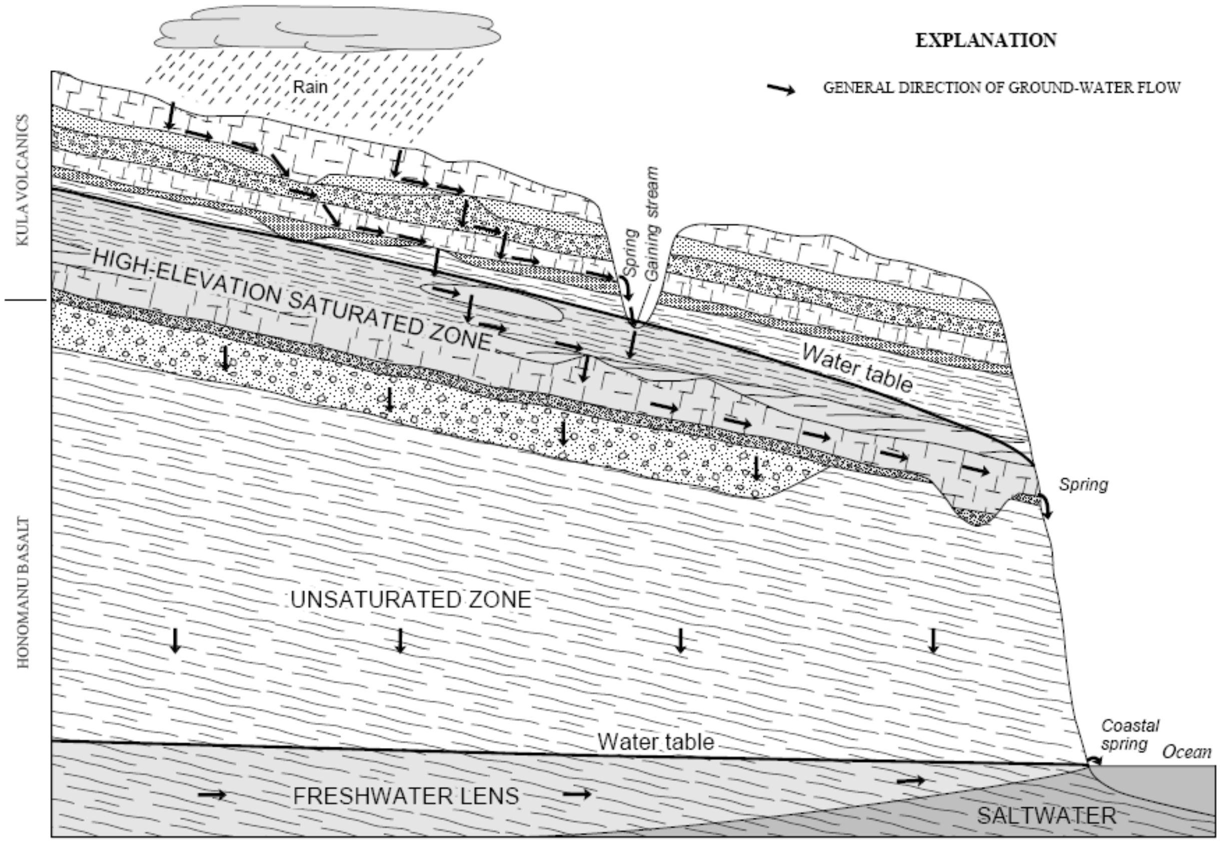
Wells in the Oopuola Hydrologic Unit

The Oopuola surface water hydrologic is located in the Waikamoi Aquifer System which is part of the Koolau Aquifer Sector on the windward side of Maui (Figure 3-2). The 2019 update to the Water Resources Protection Plan revised the sustainable yield of the Waikamoi Aquifer System based on updated information from 38 mgd to 37 mgd (State of Hawaii, 2019). There are no wells in the

[8] 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).

Waikamoi Aquifer System which are co-located within the Oopuola surface water hydrologic unit. The boundaries to the aquifer systems are depicted in Figure 3-2.

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).

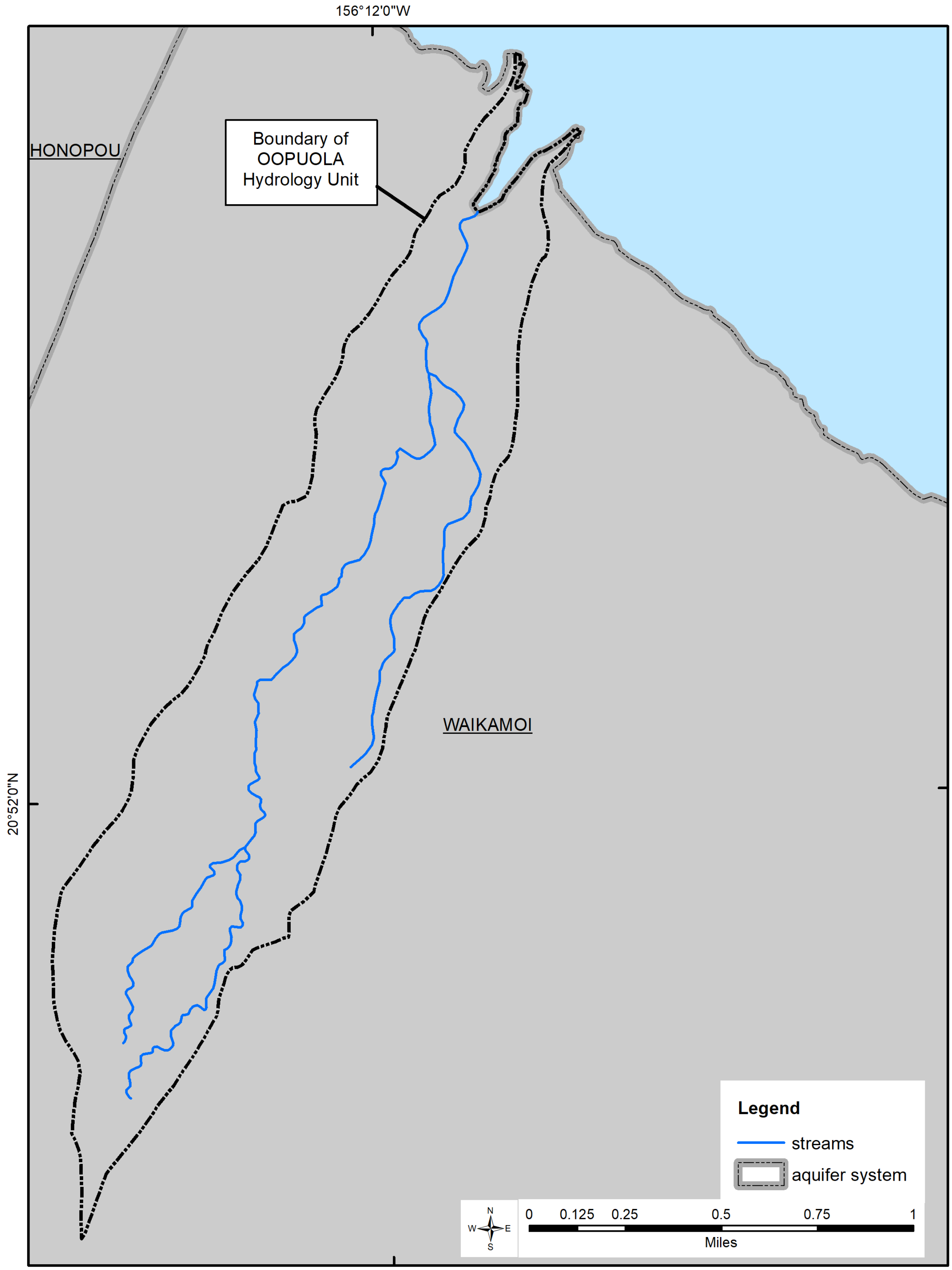


Streamflow Characteristics

One of the most common statistics used to characterize streamflow is the median flow in a particular time period. This statistic is also referred to as the flow at 50 percent exceedence probability, or the total flow that is equaled or exceeded 50 percent of the time (TFQ_{50}). The longer the time period that is used to determine the median flow value, the more representative of the flow conditions in the stream. Median flow is typically lower than the mean or average flow because of the bias in higher flows, especially during floods, present when calculating the mean flow. The flow at the 90 percent exceedence probability (TFQ_{90}) is commonly used to characterize low flows in a stream. In Hawaii, the baseflow is usually exceeded at least 90 percent of the time, and in many cases at least 70 percent of the time (Oki, 2003). The mean annual flow measured at station 16566000 on Oopuola Stream is provided in Figure 3-3.

Gingerich (1999) observed streamflow in Oopuola over the 50-foot waterfall approximately 2000 feet inland, but a dry streambed at the coast, suggesting a losing reach in the exposed thin-bedded lava flows of the Honomanu basalt. With water diverted at the Wailoa and New Hamakua ditches, CWRM staff measured a flow of 0.35 cfs above Center Ditch on December 14, 2020 and a flow of 0.27 cfs below the Center Ditch on January 22, 2021.

Figure 3-2. The Oopuola hydrologic unit in relation to the Waikamoi Aquifer System, Maui. (Source: State of Hawaii, Commission on Water Resource Management, 2020c).



The closest long-term continuous stream flow monitoring stations currently in operation is on Honopou Stream (USGS station 16587000). Using the period of overlapping data (1930-1957), flow duration exceedance values for station 16566000 on Oopuola can be estimated for the current climate period (1984-2013) as provided in Table 3-2 (Cheng 2016).

Figure 3-3. Mean annual flow in Oopuola Stream at USGS station 16566000 from 1930 to 1957. (Source: USGS, 2020)

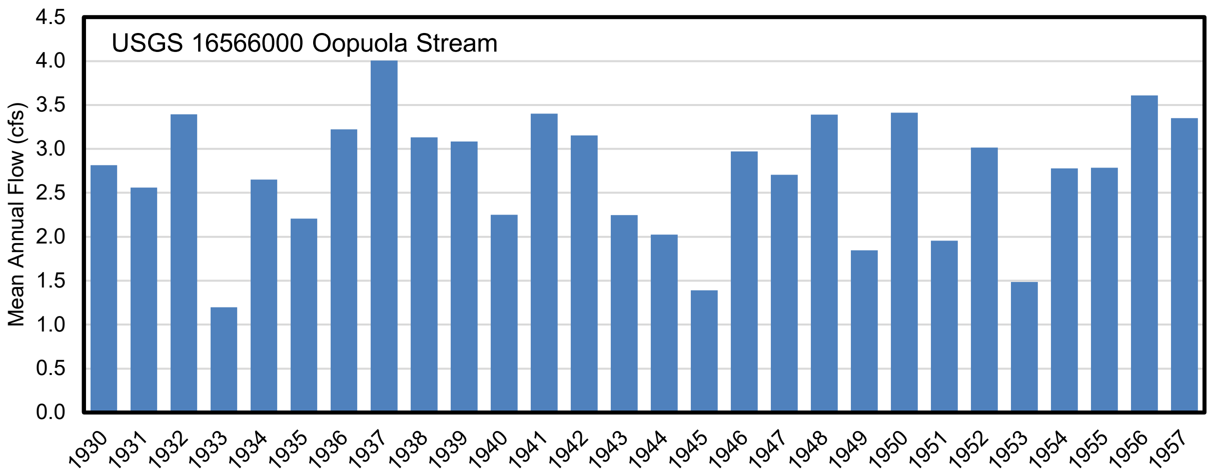


Table 3-2. Selected natural low-flow duration discharge exceedance values for the current (1984-2013) climate period based for Oopuola stream. (Source: Cheng, 2016) [Flows are in cubic feet per second (million gallons per day)]

station ID	stream name	drainage area (mi^2)	elevation (ft)	discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded			
				Q_{50}	Q_{70}	Q_{90}	Q_{95}
16566000	Oopuola Stream	0.25	1205	0.95 (0.61)	0.50 (0.32)	0.26 (0.17)	0.18 (0.12)

Watershed characteristics for estimating median and low-flow statistics at select locations

In cooperation with the Commission on Water Resource Management, the USGS conducted a study (Gingerich, 2005) to assist in determining reasonable and beneficial noninstream and instream uses of water in northeast Maui. The purpose of the study was to develop methods of estimating natural (undiverted) median streamflow, total flow statistics (TFQ), and base flow statistics (BFQ) at ungaged sites where observed data are unavailable. The study area lies between the drainage basins of Kolea Stream to the west and Makapipi Stream to the east. Basin characteristics and hydrologic data for the study area were collected and analyzed. One of the products of the study is a set of regression equations that can be used to estimate natural (undiverted) TFQ_{50}, BFQ_{50}, TFQ_{95}, and BFQ_{95} at gaged and ungaged sites. The subscripts indicate the percentage of time the flow, either total or base flow, is equaled or exceeded.

Although Oopuola lies outside of the study area, the regression equations are all the information that is available to estimate natural streamflow at ungaged locations in Oopuola hydrologic unit. The regression equations were applied at two selected ungaged sites and one formerly gaged site: 1) the Oopuola at mouth station is located near the outlet of the stream, at an elevation of 11 feet; 2) the Oopuola at Hana Hwy is in the middle reach of Oopuola at 675 feet elevation; 3) Oopuola at USGS 16566000 is at the former USGS station at 1205 feet in elevation.

While the Oopuola Stream was not included in the original study, the basin characteristics generally fall within the limits of the variables utilized by Gingerich (2005) and can be used to estimate median and low flow values for total flow and baseflow.

The regression analysis was evaluated to make sure that the general assumptions were met for each watershed: (1) the equation adequately describes the relation between the dependent and independent variables; (2) the mean residual error is close to zero; (3) the variance of residual error is constant and independent of input variables; (4) values of the residual error are normally distributed; (5) values of the residual error are independent of each other; (6) all independent variables selected are statistically significant at $\alpha = 0.05$); (7) independent variables are not correlated; and (8) the signs and magnitudes of the coefficients determined for the significant, independent variables are hydrologically reasonable (Fontaine et al. 1992). All streamflow and basin characteristics were log-transformed to satisfy the normality assumption. Due to correlation, certain basin characteristics were eliminated and a variable-selection algorithm was applie dot the remaining independent variables to aid in determining which combination of variables provides the best estimates of stream flow values. The final models were selected based on: (1) Mallow's *Cp* statistic; (2) the proportion of total variation explained, R^2; (3) the standard error of the estimates, SE; (4) the probability of significance for an independent variable, *p*; (5) that p had to be less than 5 percent for each independent variable to be included. The retransformed regression equations are bias in that they predict the median rather than the mean response of the dependent variable. To adjust, a bias-correction factor (BCF) was applied to the retransformed b_0 coefficient. The final regression equations are provided in Table 3-3.

A summary of the basin characteristics at select locations in the Oopuola hydrologic unit for each parameter needed for the regression equations are provided in Table 3-4.

Table 3-3. Summary of regression equations developed for estimating selected flow-duration statistics of perennial streams in East Maui. [**statistic:** TF is total flow; BF is base flow, Q_{xx} is the xx-percent flow duration; **statistic estimator:** Rainfall is area-weighted rainfall (cfs); **MAXELE** is maximum drainage basin elevation (feet); **ER** is elongation ratio (dimensionless); **R^2**: coefficient of determination, **SE:** average standard error of estimate; **MAD**: median absolute deviation (percent); **BCF**: Bias correction factor; n =17]

Statistic	Regression model	R^2	SE	MAD	BCF
TFQ_{50}	3184 x $RAINFALL^{1.338}$ x $MAXELE^{-1.366}$ x $ER^{-0.946}$	94.9	15.3	12	1.009
BFQ_{50}	25384 x $RAINFALL^{1.525}$ x $MAXELE^{-1.735}$ x $ER^{-0.937}$	91.0	22.5	17	1.019
TFQ_{95}	56267 x $RAINFALL^{1.478}$ x $MAXELE^{-1.750}$	76.6	38.1	21	1.059
BFQ_{95}	56267 x $RAINFALL^{1.620}$ x $MAXELE^{-2.054}$	75.3	43.0	28	1.073

Table 3-4. Summary of basin characteristics for selected locations in the Oopuola hydrologic unit used in regression equations for estimating selected flow-duration statistics of perennial streams in East Maui. (Source: USGS, 2020b)

Site name	elevation (ft)	rainfall (cfs)	drainage area (mi²)	basin length (mi)	maximum basin elevation (ft)	elogation ratio
Oopuola at mouth	11	13.43	1.06	3.41	*2060*	0.34
Oopuola at Hana Hwy	675	7.88	0.55	2.42	*2060*	*0.35*
Oopuola at USGS 16567000	940	7.40	0.51	2.15	*2060*	*0.37*
Oopuola at USGS 16566000	1250	*3.75*	0.25	1.56	*2060*	*0.36*

Note: values italicized fall outside of the range of the regression model

Estimated natural (undiverted) flow statistics for the ungaged sites are presented in Table 3-5. Compared to the estimated median baseflow from 1925-1971 the regression equations overestimated median total flow by 5 percent but estimated median baseflow within 1 percent at USGS 16570000. Gingerich (2005) found relative errors as high as 110 percent when the equations were applied outside of the study area. The difference in geology between the study area and the Oopuola hydrologic unit could account for some errors.

Table 3-5. Selected mediam (Q_{50}) and low (Q_{95}) total flow (TF) and baseflow (BF) statistics for Oopuola Stream at selected locations. [Flows are in cubic feet per second (million gallons per day]

Site name	TFQ_{50}	BFQ_{50}	TFQ_{95}	BFQ_{95}
Oopuola at mouth	8.4 (5.4)	6.4 (4.1)	3.9 (2.5)	0.55 (0.36)
Oopuola at Hana Hwy	4.1 (2.6)	2.8 (1.8)	1.8 (1.2)	0.23 (0.15)
Oopuola at USGS 16567000	3.5 (2.2)	2.4 (1.5)	1.6 (1.1)	0.21 (0.14)
Oopuola at USGS 16566000	0.89 (0.57)	0.86 (0.56)	0.59 (0.38)	0.07 (0.05)

Mathematical models and equations are commonly used to represent hydrologic occurrences in the real world; however, they are typically based on a set of assumptions that oftentimes render their estimates questionable in terms of accuracy and precision. This does not mean the public should entirely discount the estimates produced by these mathematical tools because they do provide quantitative and qualitative relative comparisons that are useful when making management decisions. Objections have been raised by several agencies in regards to the use of regression equations to estimate flow statistics. While the estimated statistics are presented to fulfill the purpose of compiling the best available information that will be considered in determining the interim IFS recommendations, the Commission staff does not intend to rely exclusively on the regression equations to make such important management decisions. The limitations and potential errors of the regression equations must also be considered.

One of the limitations of the regression equations is that they do not account for variable subsurface geology, such as those of intermittent streams and where springs discharge high flow to streams. The equations may overestimate flow statistics in intermittent streams as they do not account for losing reaches. On the other hand, the equations may underestimate the additional streamflow gained from springs. The equations tend to predict more accurately the higher flow statistics, TFQ_{50} and BFQ_{50}, rather than the lower flow statistics, TFQ_{95} and BFQ_{95}. The relative errors between observed and estimated flows ranged from 11 to 20 percent for TFQ_{50} and from 29 to 56 percent for TFQ_{95} and BFQ_{95}. According to Gingerich (2005), the most reliable estimates of natural and diverted streamflow duration statistics at gaged and ungaged sites in the study area were made using a combination of continuous-record gaging station data, low-flow measurements, and values determined from the regression equations. The study found that the average reduction in the low flow of streams due to diversions ranges from 55 to 60 percent.

Partial-record gaging stations

From 2021 to 2022, low-flow partial-record gaging stations were established at stations upstream of the Wailoa Ditch and natural-flow duration discharges were estimated for the current period (1984-2013) as provided in Table 3-5. Flow duration discharges were based on record augmentation using the MOVE.1 Model with concurrant daily streamflow at USGS 16570000 on Nailiilihaele Stream or USGS 16587000 on Honopou for 7 to 8 measurements. The MOVE.1 model accurately predicted streamflow in Makanali (NSE = 0.75), Oopuola (NSE = 0.85), Oopuola tributary (NSE = 0.89), and West Oopuola (NSE = 0.91) above Wailoa Ditch intakes.

Table 3-6. Selected flow duration discharge exceedance values for the current (1984-2013) climate period based on partial-record gaging station above Wailoa Ditch (natural flow) for the Oopuola hydrologic unit. [Flows are in cubic feet per second (cfs)]

	Discharge (Q) for a selected percentage ($_{xx}$) discharge was equaled or exceeded									
station	Q_{50}	Q_{55}	Q_{60}	Q_{65}	Q_{70}	Q_{75}	Q_{80}	Q_{85}	Q_{90}	Q_{95}
Makanali abv Wailoa Ditch	0.28	0.26	0.23	0.20	0.18	0.15	0.13	0.11	0.08	0.05
Oopuola abv Wailoa Ditch	1.0	0.92	0.82	0.72	0.63	0.55	0.48	0.42	0.35	0.28
Oopuola Tributary abv Wailoa Ditch	0.24	0.21	0.19	0.16	0.14	0.12	0.11	0.09	0.08	0.06
West Oopuola abv Wailoa Ditch	0.36	0.32	0.29	0.26	0.23	0.21	0.19	0.17	0.14	0.12

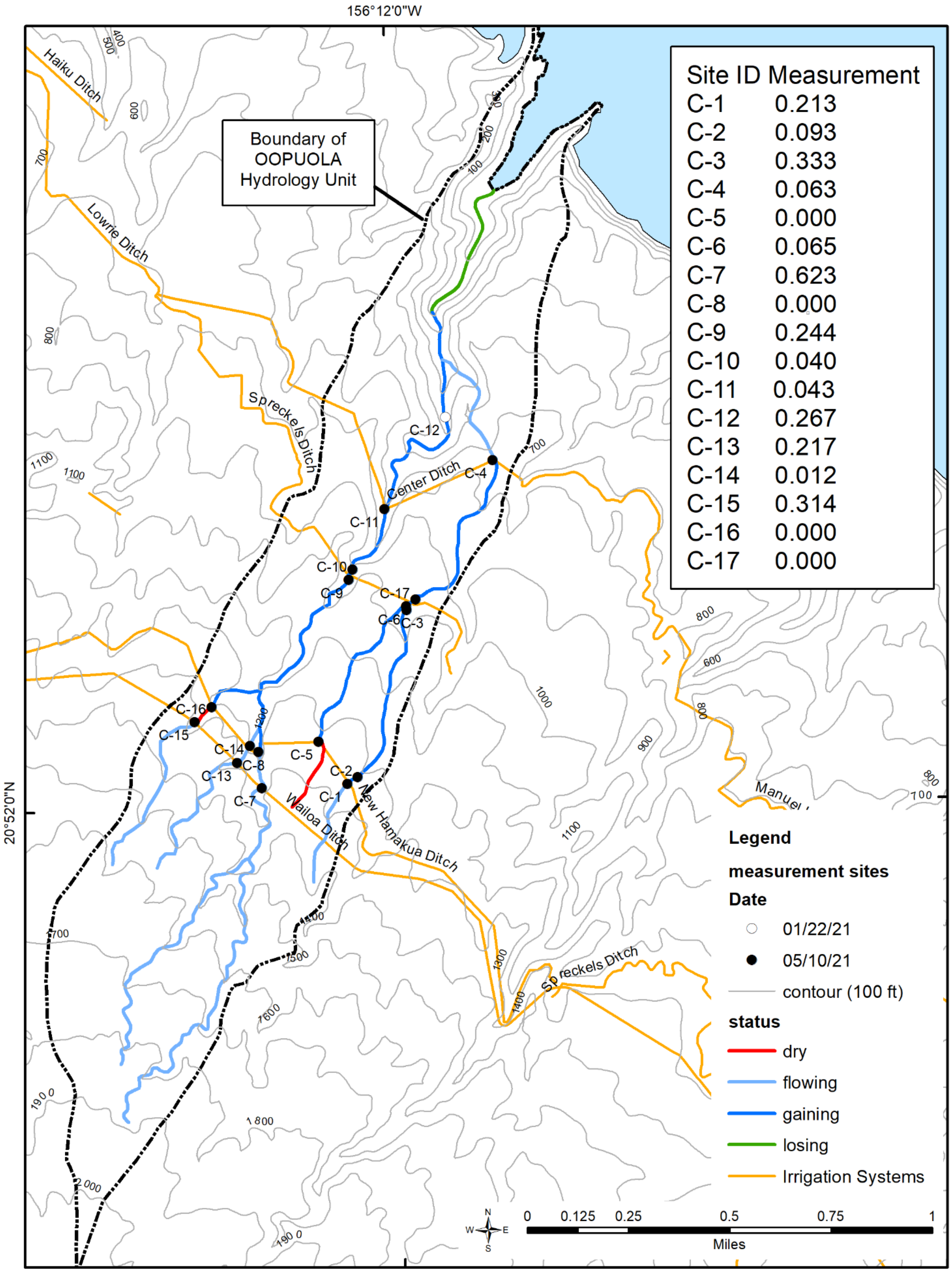
Seepage Run Results on Oopuola Stream

A seepage run was conducted under stable flow conditions on July 15, 2021 (Figure 3-4). Results suggest that Oopuola Stream is gaining from mauka to makai, with a streamflow gain rate of 0.36 $ft^3/s/mi$ above Spreckels Ditch and 0.01 $ft^3/s/mi$ between Spreckels ditch and Center Ditch. The mouth of Oopuola Stream has incised the Honomanu volcanics layer near the mouth and it is expected that Oopuola stream flows at the mouth less than 100% of the time due to seepage loss, as evidence from other streams with similar geology (i.e., Honomanu).

Long-term trends in rainfall and streamflow

The climate has profound influences on the hydrologic cycle and in the Hawaiian Islands, shifting climate patterns have resulted in an overall decline in rainfall and streamflow. Rainfall trends are driven by large-scale oceanic and atmospheric global circulation patterns including large-scale modes of natural variability such as the El Nino Southern Oscillation and the Pacific Decadal Oscillation, as well as more localized temperature, moisture, and wind patterns (Frazier and Giambelluca, 2017; Frazier et al, 2018). Using monthly rainfall maps, Frazier and Giambelluca (2017) identified regions that have experienced significant ($p<0.05$) long-term decline in annual, dry season, and wet season rainfall from 1920 to 2012 and from 1983 to 2012. On Maui, much of the windward side of Haleakala has experienced a significant decline in annual and seasonal rainfall in the from 1920 to 2012, and for most of the island from 1983-2012 (Figure 3-5).

Figure 3-4. Seepage run results for O‘opuola Stream in East Mau‘i, Hawai‘i.



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, one of which is located in Honopou Stream near the Wailoa (Koolau) Ditch (station 16587000). At station 16587000 on Honopou Stream, trends in mean annual flow provide some context for the variability in flow overtime (Figure 3-6). For the 90-year period 1913-2002, monthly mean base flows generally followed an increasing trend above the long-term average from 1913 to early 1940s, and a decreasing trend after the early 1940s to 2002 (Figure 3-7). Monthly mean total flows follow a similar pattern with the exception that the monthly mean total flow increased from mid-1980s to mid-1990s, and decreased from mid-1990s to 2002. Downward trends in the annual total low flow percentiles, TFQ_{75} and TFQ_{90}, were statistically significant at the 5 percent level of significance. This is consistent with the annual base flow percentiles (Oki, 2004).

Figure 3-5. Annual, wet season (Nov-Apr) and dry season (May-Oct) rainfall trends for the 1920-2012 (A) and 1983-2012 (B) periods, Maui. Hashed line areas represent significant trend over the period.
(with permission from Frazier and Giambelluca, 2017)

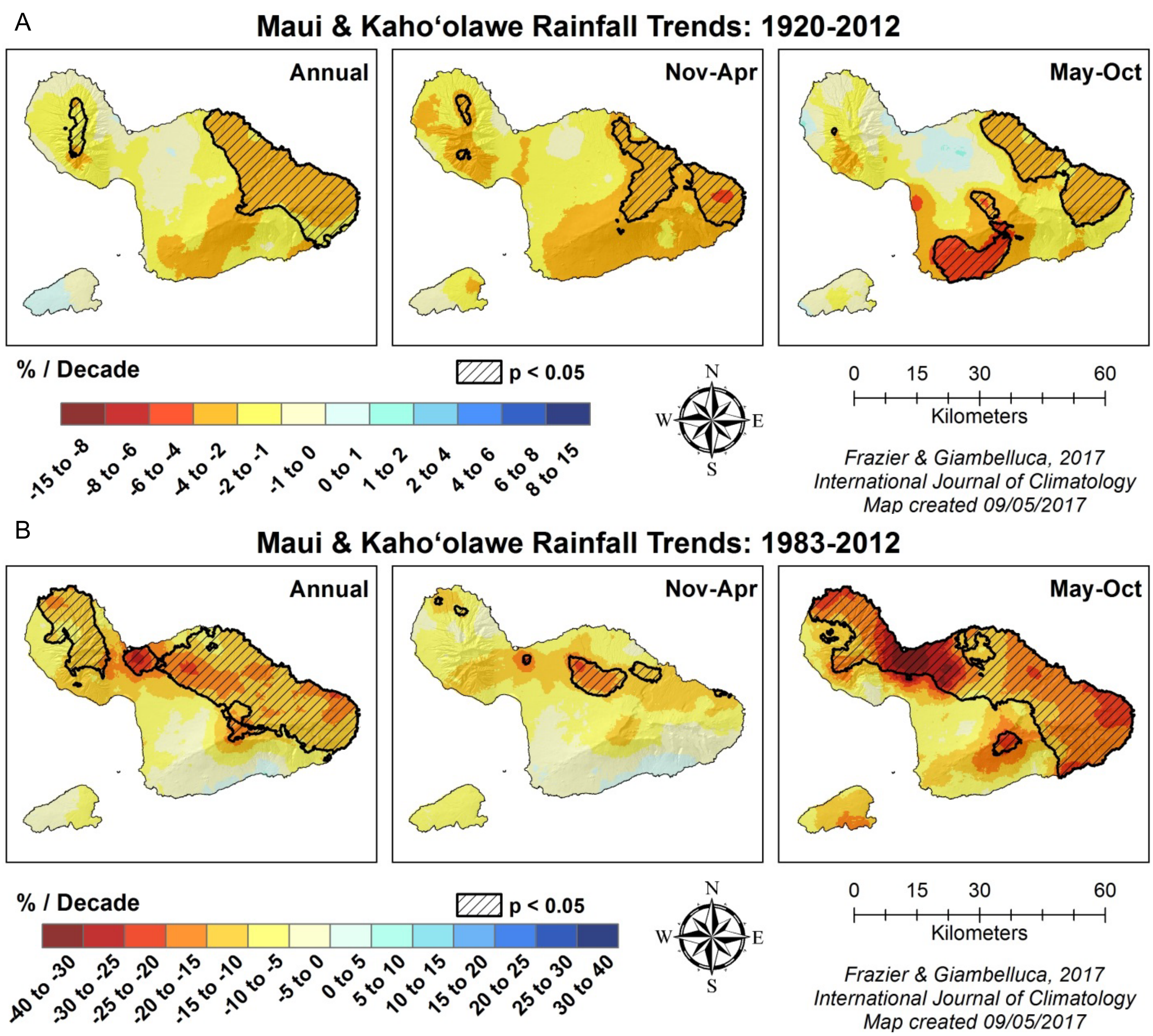
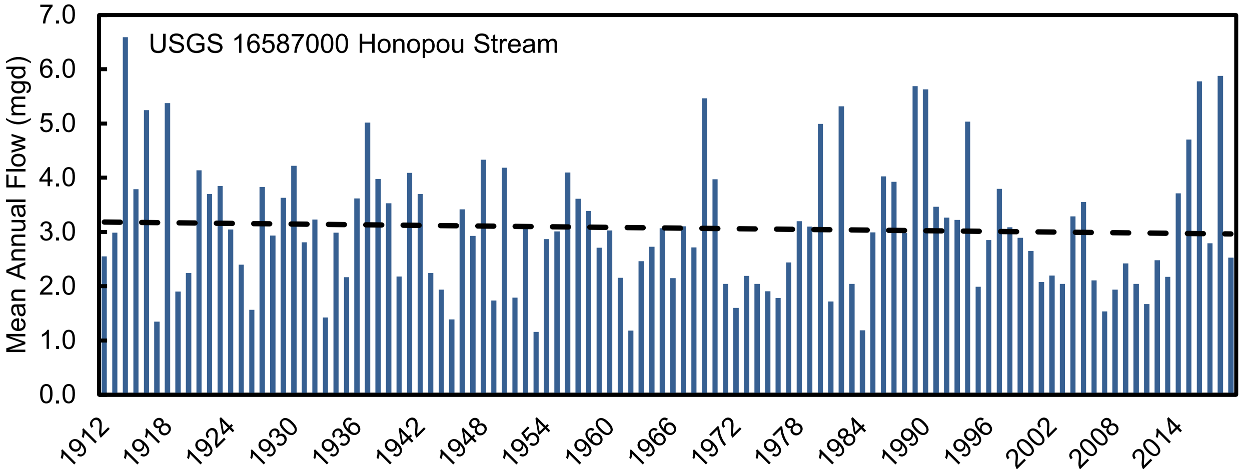
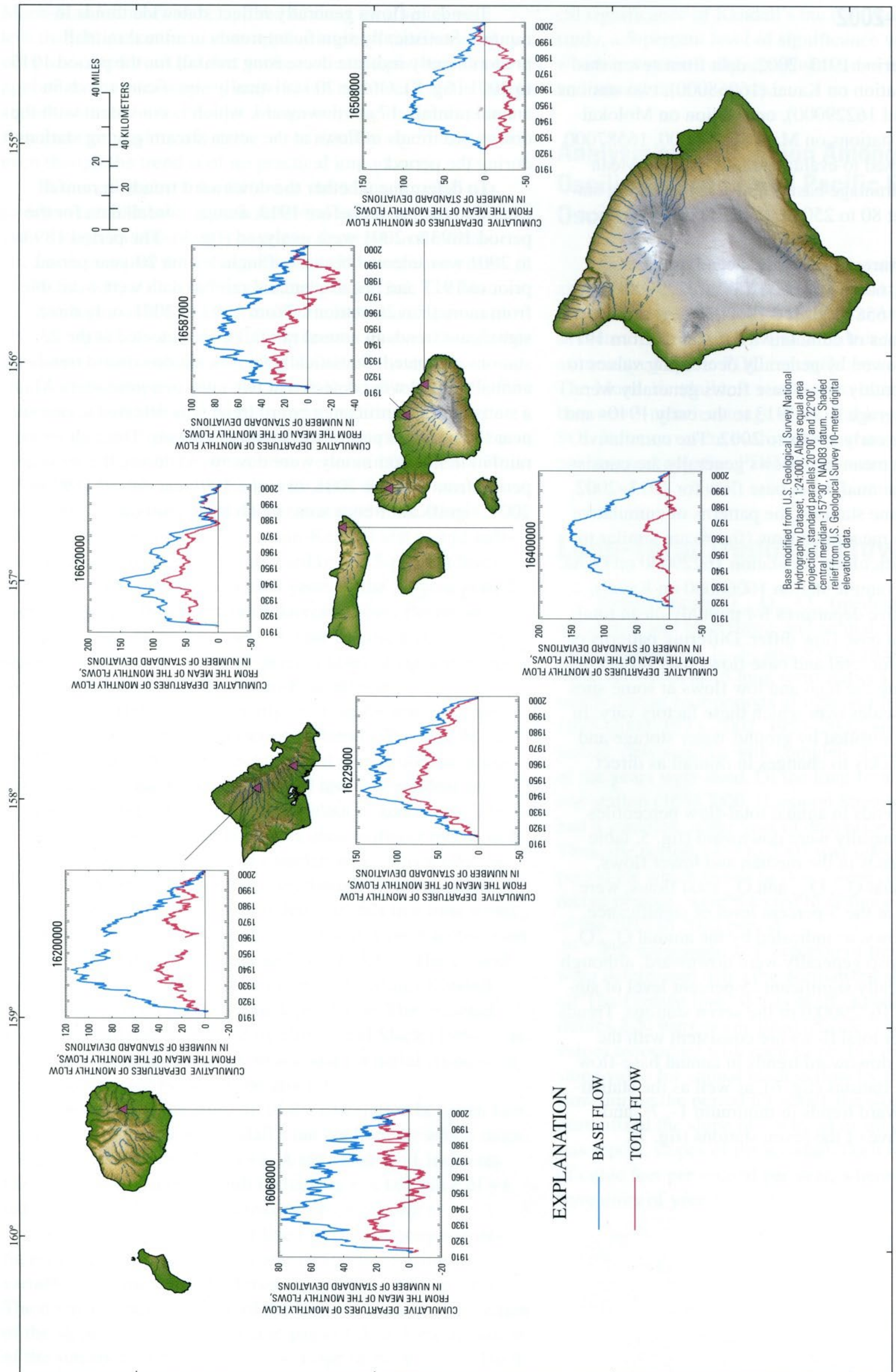


Figure 3-6. Mean annual flow (million gallons per day, mgd) at USGS station 16587000 on Honopou Stream, Maui. Line represents linear regression trend over the period of record. (Source: USGS, 2020)



The USGS examined the long-term trends and variations in streamflow on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai, where long-term stream gaging stations exist (Oki, 2004). The study analyzed both total flow and estimated base flow at 16 long-term gaging stations. Figure 3-**9** 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 groundwater contribution to streams. 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 3-7. 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.

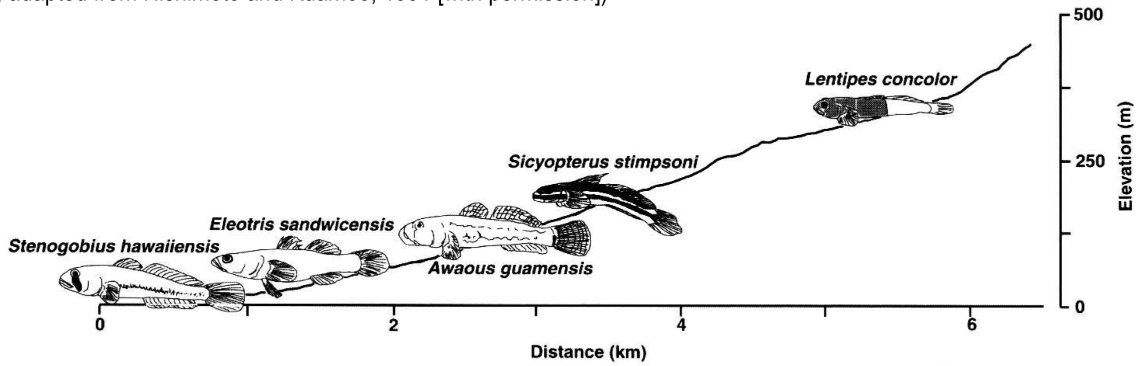
Table 4-1. List of commonly mentioned native stream organisms. (Source: State of Hawaii, Division of Aquatic Resources, 1993)

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

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

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

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



Hawaii Stream Assessment

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

Due to the broad scope of the HSA inventory and assessment, it continues to provide a valuable information base for the Commission's Stream Protection and Management Program and will continue to be referred to in various sections throughout this report. The HSA did not recommend that the Oopuola stream be listed as a candidate stream for protection based on its aquatic resources. Oopuola also did not have any "blue ribbon" resources identified by the HSA for protection.

DAR Atlas of Hawaiian Watersheds

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

- **Point Quadrat Survey.** In the Oopuola watershed, stream surveys were conducted in 2008 by DAR focusing on the upper reach. No native biota were found. In January 2021, DAR and CWRM staff conducted 20 point quadrat surveys below the Hana Highway and no native biota were found; however two *L. concolor* and one *A. stamineus* were observed outside of the surveys.

- **Insect Survey.** The Oopuola hydrologic unit did not meet the criteria as a biotic stream of importance for native insect diversity (>19 spp), native macrofauna diversity (>5 spp.), or abundance of any native species. It was not listed as a priority aquatic site for conservation.

- **Watershed and Biological Rating.** The Oopuola watershed has a high rating for Maui and statewide for land cover due to the high percentage of conservation land. The lack of wetland and estuarine reaches give the watershed a poor rating for shallow waters on Maui and statewide. However, the watershed rates medium for stewardship due to the degree of conservation, land use, and invasive species. Oopuola Stream has a low rating for stream size, a medium-high rating for wetness, and a medium-poor reach diversity resulting in a moderately high total watershed rating for Maui and statewide. The watershed was not rated for number of native species found or for introduced species. These scores combined gave Oopuola watershed a medium total watershed rating.

Parham (2019) modeled total habitat units for each stream based on stream surveys conducted in 2017 and 2018 and analyzed the consequences of the IIFS established by the CWRM 2018 Decision & Order on habitat (Table 4-2). DAR has also summarized the presence of native biota stream by stream which helps visualize the natural distribution of species (Table 4-4).

Table 4-2. Total modeled habitat units (m^2) and percentage of total in East Maui under natural and 2018 Decision & Order (D & O) IIFS values for the original 24 peititioned streams and the 12 non-petitioned streams.

Scenario	24 Petitioned Streams	12 non-petitioned streams	total
Natural Conditions	1,392,812 (66.0%)	717,242 (34.0%)	2,110,054 (100.0%)
2018 D & O IIFS	1,075,132 (51.0%)	94,092 (4.5%)	1,169,224 (55.5%)

Recent Biota Surveys

Staff from the Commission and DAR have surveyed many of the streams in the East Maui license area for habitat and freshwater biota. Recent interest in the habitat available in the non-petitioned streams as well as the temporary (since the closure of HC&S in 2016) discontinuation of the lower elevation ditches (e.g., Spreckels Ditch at various elevations, Center Ditch at the 750-foot elevation, Lowrie Ditch at the 700 foot elevation, and the Haiku Ditch at the 400 foot elevation) prompted an analysis of the effects of four years of continuous flow from the mid-elevation reaches to the ocean.

In Hoalua, one reach was surveyed at about the 10-foot elevation (stream mouth) and one reach was surveyed at about the 640-foot elevation (below Lowrie Ditch) to assess habitat and recruitment of native species. Each reach survey consisted of 20 point-quadrat biota and habitat surveys spaced at 10 m intervals randomly assigned to left, center, or right portions of the stream channel[1]. Raw data results from this survey are provided in Table 4-3.

[1] Higashi, G.R. and Nishimoto, R.T. (2007). The Point Quadrat Method: A Rapid Assessment of Hawaiian Streams. In: N.L. Evenhuis & J.M. Fitzsimons, Biology of Hawaiian Streams and Estuaries. Bishop Museum Bulletin in Cultural and Environmental Studies 3: 305-312.

Table 4-3. Occupancy and habitat characteristics from biota surveys in O'opuola Stream.

Date	01/22/2021	native aquatic species	
Elevation (ft)	480	*Eleotris sandwicensis* ('o'opu 'akupa)	0
Discharge (ft^3/s)	0.27	*Stenogobius hawaiiensis* ('o'opu naniha)	0
Mean wetted width (ft)	14	*Awaous guamensis* ('o'opu nākea)	0
Mean velocity (ft/s)	0.25	*Sicyopterus stimpsoni* ('o'opu nōpili)	0
Mean depth (cm)	37	*Lentipes concolor* ('o'opu alamo'o)	0
non-native aquatic species		*Neritina granosa* (hihiwai)	0
Poecilia reticulata (guppies)	1	*Kuhlia xenura* (āholehole)	0
Xiphophorus helleri (swordtail)	0		
Macrobrachium lar (tahitian prawn)	3		

Table 4-4. Total modeled habitat units, percent of total habitat units in license area streams, and presence of native stream biota by stream in East Maui.

tream	Habitat Units	Percent of Total	Kuhia	Eleotris sandwicensis	Stenogobius hawaiiensis	Awaous stamineus	Sicyopterus stimpsoni	Lentipes concolor	Neritina granosa	Neritina vespertinus	Macrobrachium grandimanus	Atyoida bisulcata
Makapipi	24,288	1.2%	X	X		X	X	X	X			X
Hanawi	126,408	6.0%	X	X	X	X	X	X	X			X
Kapaula	25,418	1.2%										
Waiaaka	0	0.0%										
Paakea	17,270	0.8%										
Waiohue	18,459	0.9%	X	X	X	X	X	X	X	X	X	X
Kopiliula	80,507	3.8%	X	X		X		X	X			X
E. Wailuaiki	60,737	2.9%	X	X		X		X	X			X
W. Wailuaiki	38,754	1.8%	X									X
Wailuanui	46,240	2.2%	X	X								X
Waiokamilo	37,792	1.8%										X
Piinaau	349,196	16.5%	X	X	X	X	X	X	X	X	X	X
Nuaailua	54,106	2.6%				X						X
Honomanu	108,859	5.2%										X
Punalau	14,527	0.7%				X	X	X				X
Haipuaena	40,496	1.9%						X				X
Puhokamoa	189,132	9.0%				X	X	X				X
Waihinepee	0	0.0%										
Waikamoi	40,068	1.9%										X
Kolea	5,940	0.3%										
Punaluu	0	0.0%										
Kaaiea	28,013	1.3%										X
Oopuola	20,616	1.0%										
Puehu	0	0.0%										
Nailiilihaele	275,924	13.1%										X
Kailua	130,209	6.2%					X					X
Hanawana	2,633	0.1%										
Hoalua	24,959	1.2%										
Hanehoi	28,009	1.3%										
Waipio	3,211	0.2%										
Mokupapa	0	0.0%										
Hoolawa	225,737	10.7%										X
Honopou	92,546	4.4%		X		X	X	X				

5.0 Outdoor Recreational Activities

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

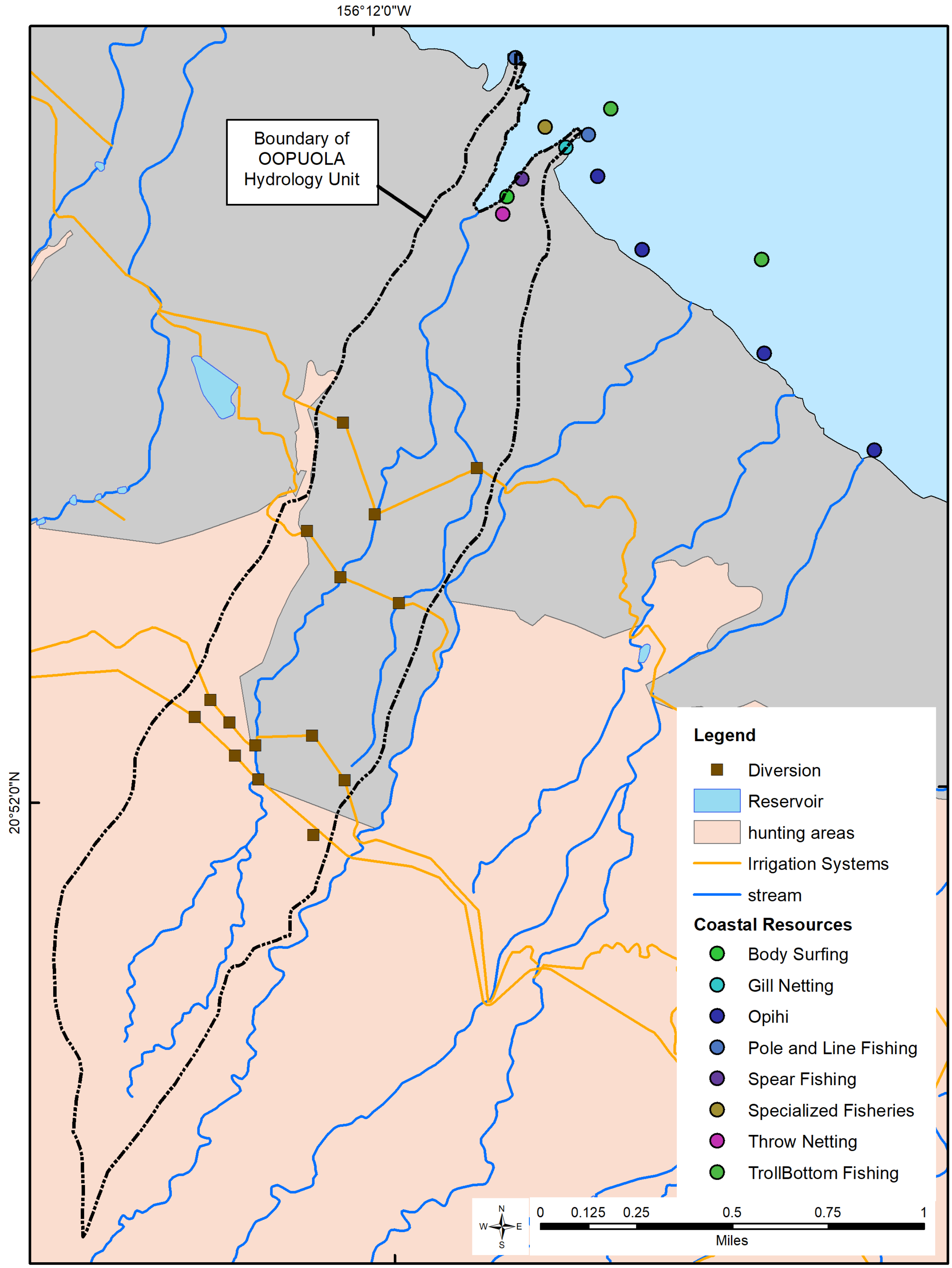
The Hawaii Stream Assessment identified hiking, hunting, and scenic views as recreational opportunities in the Oopuola hydrologic unit with two high quality experiences, providing a "substantial" regional ranking, but not recommending it for statewide ranking (National Park Service, 1990). 0.557 square miles (45 percent) in the Oopuola hydrologic unit are open for mammal hunting (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 Oopuola Stream. A 1981 Oahu Resource Atlas, prepared by the State of Hawaii Department of Transportation's Harbors Division, inventoried coral reefs and coastal recreational activities. Looking at available GIS data, some of the activities the Commission identified include spear fishing, throw netting and opihi collecting at or near Oopuola (Figure 5-1).

John Clark, in his book *The Beaches of Maui County* (1989), describes the Hoolawa area as follows:

> The shoreline from Maliko to Honomanū is characterized by high, steep sea cliffs. Within this long reach of cliffs are a number of bays that are usually little more than wide, moderately deep indentations in the shoreline, usually where streams meet the ocean. The beaches in these areas are narrow stretches of large boulders lying directly at the base of the sea cliffs. Many of these boulder beaches are not accessible at all by land, and if they are, it is only by a hazardous climb using a rope or cable to get down the cliffs. During the winter and spring months these bays are assaulted by heavy surf that sweeps completely across the boulders against the sea cliffs. There are no fringing reefs to check the advance of surf or strong currents. Over the years many fishermen have lost their lives along this dangerous coastline. These rough waters have long been excellent grounds for netting *akule* and *'ōpelu* and for hooking *'ū'ū*, *'āweoweo*, and *āhole*.
>
> There is no public access to any of these shoreline areas except from the ocean. Many of the bays are over one mile away from the Hāna Highway, and all of the land between the highway and the shoreline is private property replete with locked gates and No Trespassing signs.

Figure 5-1. Public hunting areas for game mammals and locations for coastal recreational activies in the Oopuola hydrologic units. (Source: State of Hawaii, Office of Planning, 2002h)

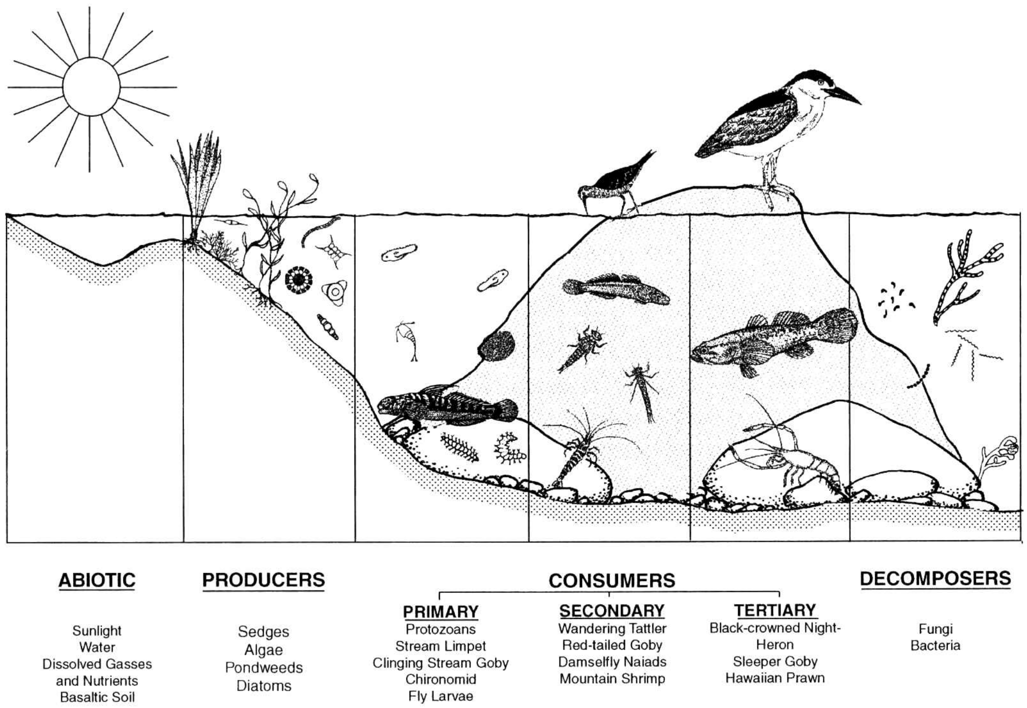


6.0 Maintenance of Ecosystems

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 Oopuola Stream did not deserve to be a candidate stream for protection based on its riparian resources.

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 Oopuola 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 Oopuola hydrologic unit, Maui. (National Park Service, 1990)

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.	None
Native forest: The proportion of a stream course flowing through native forest provides an indication of the potential "naturalness" of the quality of a stream's watershed; the greater the percentage of a stream flowing through native forest most of which is protected in forest reserves the more significant the resource. Only the length of the main course of a stream (to the nearest 10 percent) that passes through native forest was recorded.	0%
Detrimental organisms: Some animals and plants have a negative influence on streams. Wild animals (e.g., pigs, goats, deer) destroy vegetation, open forests, accelerate soil erosion, and contaminate the water with fecal material. Weedy plants can dramatically alter the nature of a stream generally by impeding water flow. Three species, California grass, hau, and red mangrove, are considered to have the greatest influence. The presence of any of these animals or plants along a stream course was considered a potentially negative factor, while the degree of detriment is dependent on the number of species present.	Hau, Pigs

For the purpose of this section, management areas are those locales that have been identified by federal, state, county, or private entities as having natural or cultural resources of particular value. The result of various government programs and privately-funded initiatives has been a wide assortment of management areas with often common goals. Such designated areas include forest reserves, private preserves, natural area reserves, wildlife sanctuaries, national parks, historic landmarks, and so on. In Oopuola, about 0.58 square miles (47 percent) falls within the Koolau Forest Rreserve

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. Approximately 0.92 square miles (75 percent) of the Oopuola hydrologic unit is part of the East Maui Watershed Partnership (Figure 6-2). Table 6-2 provides a summary of the partnership area, partners, and management goals of the East Maui Watershed Partnership.

Table 6-2. Watershed partnerships associated with the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Division of Forestry and Wildlife, 2020a)

Management Area	Year Established	Total Area (mi²)	Area (mi²)	Percent
East Maui Watershed Partnership	1991	186.73	0.92	75.0%
The East Maui Watershed Partnership (EMWP) is comprised of the County of Maui, State Department of Land and Natural Resources, East Maui Irrigation Co. Ltd., Haleakala National Park, Haleakala Ranch Company, Keola Hana Maui, Inc. (Hana Ranch Company), and The Nature Conservancy. The management priorities of the EMWP include: 1) Watershed resource monitoring; 2) Animal control; 3) Weed control; 4) Management infrastructure; and 5) Public education and awareness programs. The EMWP has conducted various projects including the construction of over seven miles of fence construction and on-going fence maintenance, the survey and removal of invasive plant species, eradication of animal species through an expanded hunting program, implementation of runoff and stream protection measures, water quality monitoring, and extensive public education and outreach campaigns.				

In 1974, the U.S. Fish and Wildlife Service (USFWS) initiated a National Wetlands Inventory that was considerably broader in scope than an earlier 1954 inventory that had focused solely on valuable waterfowl habitat. The inventory for Hawaii was completed in 1978 and utilized a hierarchical structure in the classification of various lands. The USFWS defines wetlands as “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water” (Cowardin et al., 1979). Cummulatively, less than 24 percent (0.294 square miles) of the Oopuola hydrologic unit is classified as wetlands (freshwater forested or estuarine), mostly occurring in the middle and upper elevation interfluves of the hydrologic unit (Table 6-3 and Figure 6-4).

Table 6-3. Wetland classifications for Oopuola hydrologic unit, Maui. (Source: US Fish and Wildlife Service, 2018)

System Type	Class	Area (mi²)	Percent of Unit
Palustrine	Freshwater Forested/Shrub Wetland	0.293	23.9%
Palustrine	Estuarine and Marine Deepwater	0.001	<0.01%

A series of vegetation maps describing upland plant communities was prepared as part of a USFWS survey in 1976 to 1981 to determine the status of native forest birds and their associated habitats. Figure 6-5 identifies critical habitat for plant species near Oopuola. Most of the unit is dominated by non-native vegetation and although a considerable native species exist in higher elevations. The Oopuola does not provides any critical ecosystem habitat critical habitat for plants. There is a high density of threatened and endangered plant species at elevations above 1,300 feet, which is about 40% of the Oopuola hydrologic unit (Table 6-4, Figure 6-6).

Coastal Areas of Biological Importance

To represent the connectivity of inland habitat to areas of Hawai‘i’s nearshore marine environment that support high levels of marine biodiversity, The Nature Conservancy used existing marine data, local ecological knowledge, and modeling to determine areas of biological significance (ABS) as part of TNC’s Marine Ecoregional Assessment of the Hawaiian Islands (Weiant, 2009). These nearshore areas in Hawai‘i serve as nursery or feeding grounds for many organisms (e.g., finfish, sea turtles, mok seals) and include valued and diverse habitat types (e.g., coral reefs, seagrass beds, salt marshes). Tsang et al. (2019) identified local catchments within stream networks that directly influence ABS as well as areas directly adjacent to an ABS and potentially hydrologically connected to these important nearshore marine habitats. Figure 6-7 depicts the Oopuola hydrologic unit in relation to all ABS for Maui Island. None of the ABS exist in the Oopuola hydrologic unit.

Figure 6-2. Reserves in or nearby the Oopuola hydrologic unit, Maui. (Source: State of Hawaii Division of Forestry and Wildlife, 2020b)

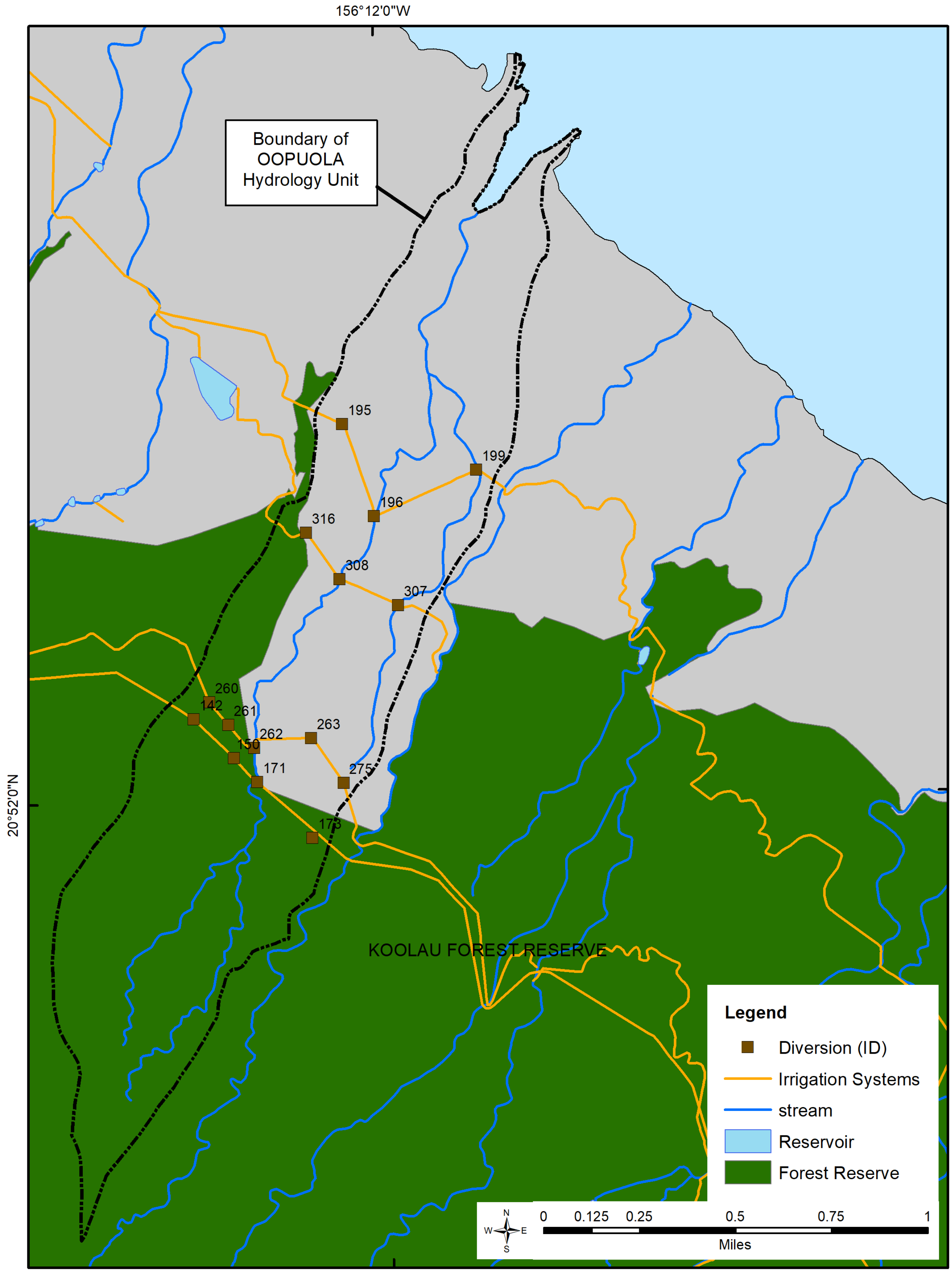


Table 6-4. Distribution of native and alien plant species for Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015f)

Canopy Type	Area (mi^2)	Percent
Very High concentration of threatened and endangered species	0.000	0.0%
High concentration of threatened and endangered species	0.485	39.5%
Medium concentration of threatened and endangered species	0.000	0.0%
Low concentration of threatened and endangered species	0.742	60.5%
Little or no threatened and endangered species	0.000	0.0%

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 6-7. Following the results of the Oahu Koolau case study, some of the most valuable aspects of the forested areas are believed to be ecotourism, aesthetic pleasure, species habitat, water quality, and water quantity. Oopuola provides no critical habitat for native forest birds, endangered plants or invertebrates.

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

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

Figure 6-3. The East Maui Watershed Partnership members in the the Oopuola hydrologic unit, Maui. (Source: State of Hawaii Division of Forestry and Wildlife, 2020a)

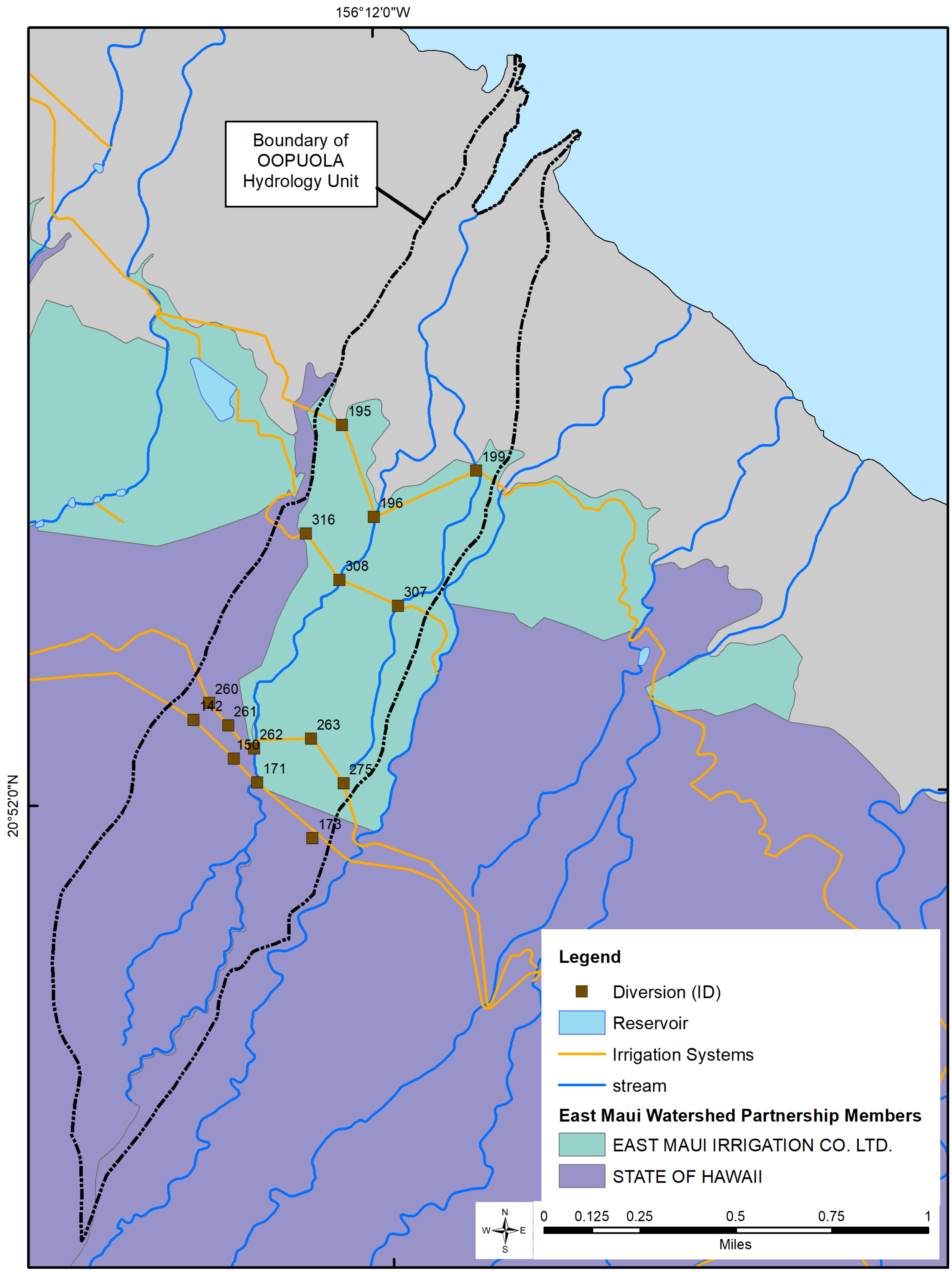


Figure 6-4. Wetlands in the Oopuola hydrologic unit, Maui. (Source: US Fish and Wildlife Service, 2018)

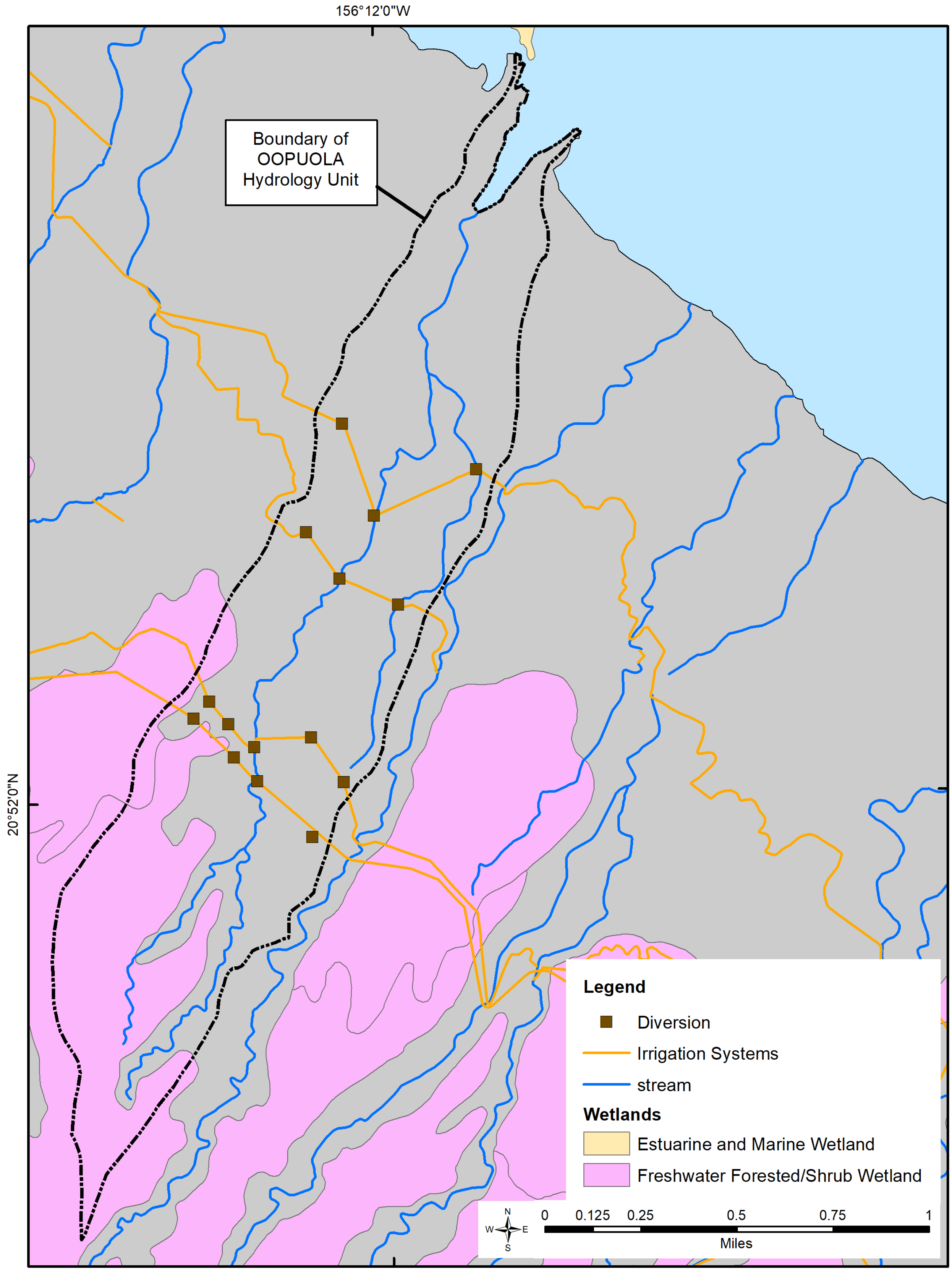


Figure 6-5. Distribution of critical habitat in the Oopuola hydrologic unit, Maui. (Source: US Fish and Wildlife Service, 2020)

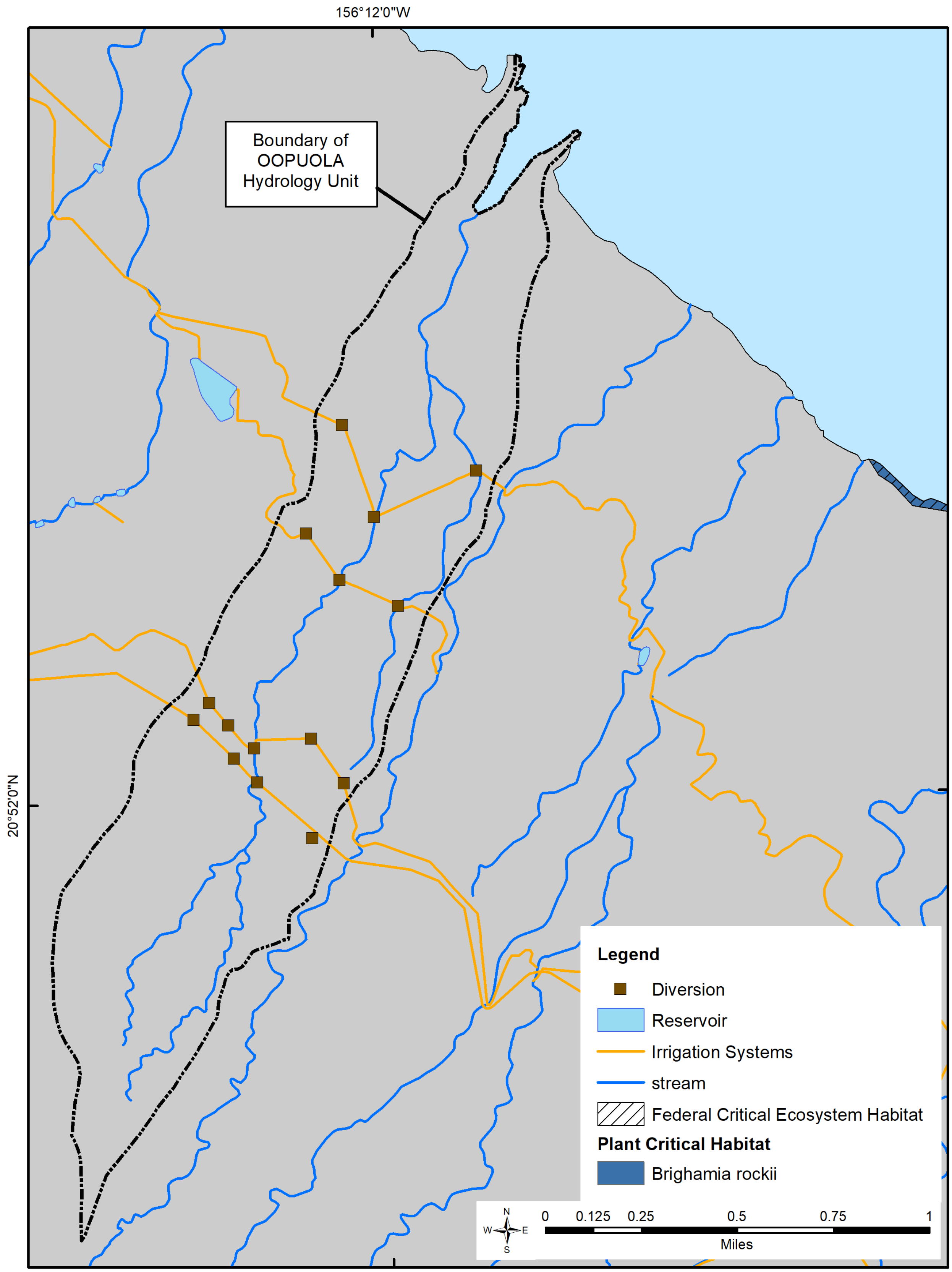


Figure 6-6. Density of threatened and endangered plants in Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015h)

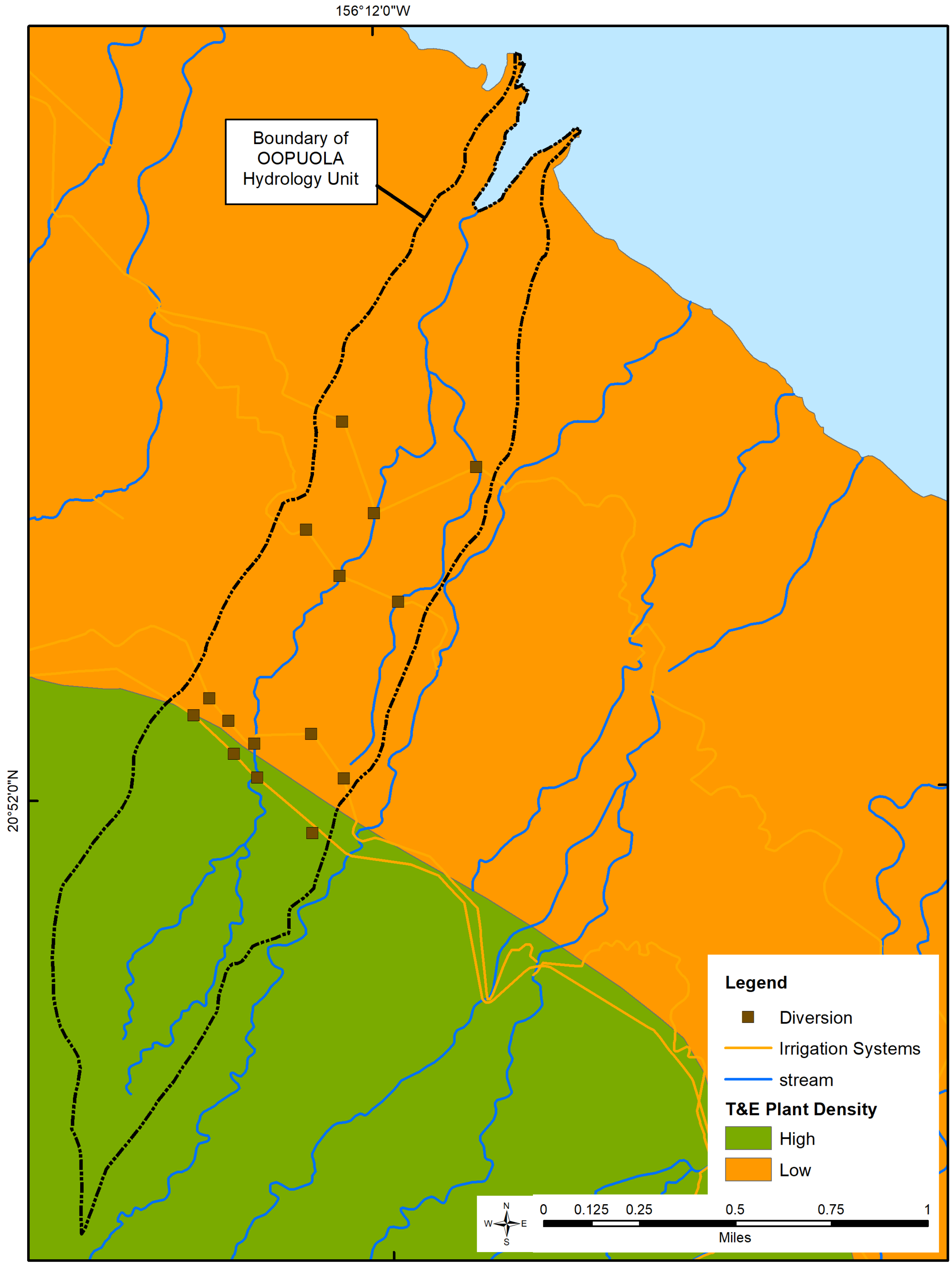
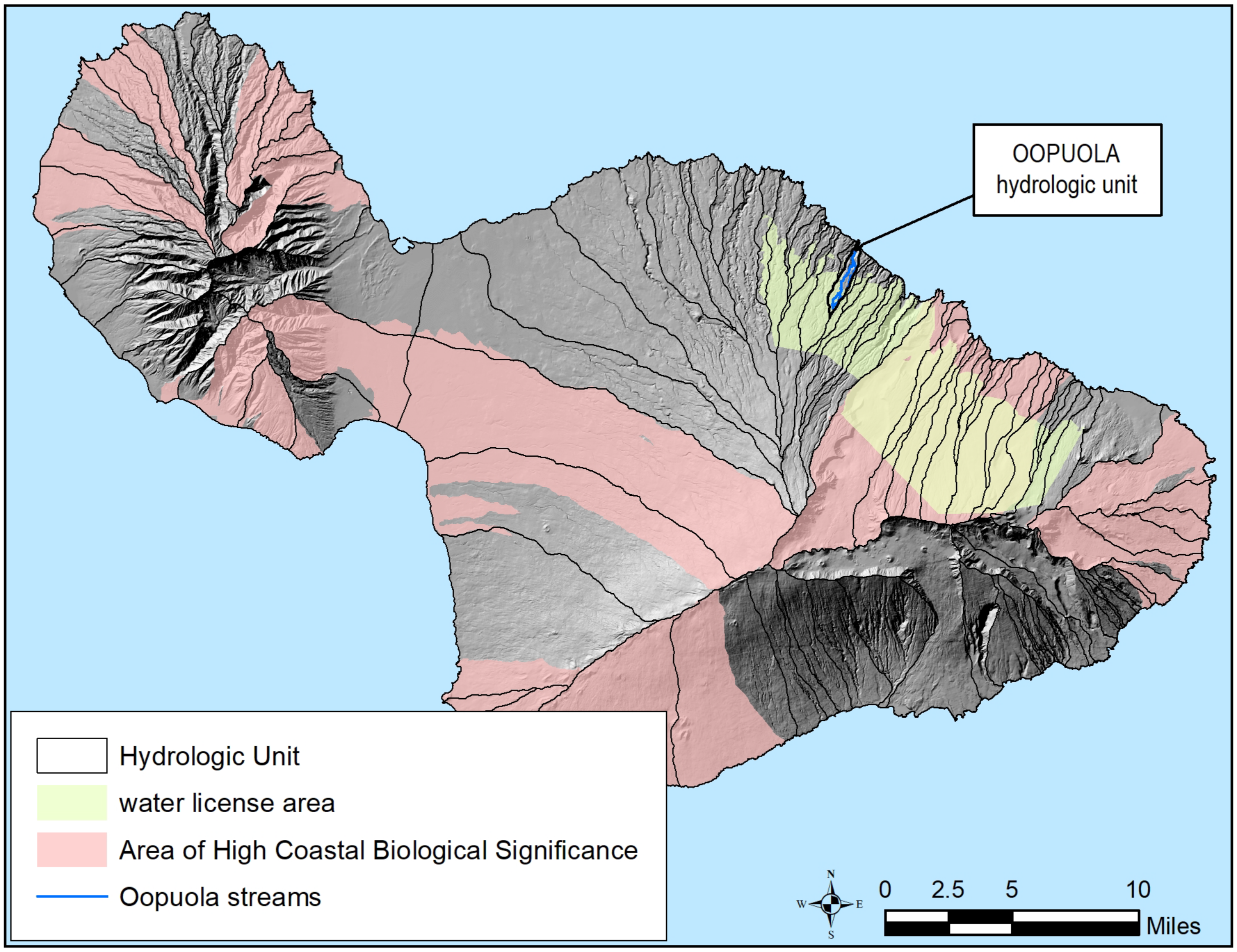


Figure 6-7. Catchment regions that are hydrologically connected to coastal areas of biological significance for the island of Maui. (Source: Tsang et al. 2019)



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. However, the points identified are not exhaustive and it is beyond the scope of this report to list all potential aesthetic values.

None of the Oopuola hydrologic unit supports endemic or endangered birds, plants, and insects. The stream provides minimal aesthetic value and it does not provide for wildlife viewing.

In a 2007 Hawaii State Parks Survey, released by the Hawaii Tourism Authority (OmniTrak Group Inc., 2007), scenic views accounted for 21 percent of the park visits statewide, though that was a decrease from 25 percent in a 2003 survey. 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, visitors' preference to visit state parks for scenic views (26 percent) was second only to uses for outings with family and friends (29 percent). In comparison, residents primarily used state parks for ocean/water activities (30 percent), followed by outings with friends and family (28 percent), and then scenic views (9 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. Though there are no state parks located in the hydrologic unit, it is assumed that where Oopuola Stream crosses Hana Highway there may be opportunities for scenic enjoyment.

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 Oopuola hydrologic unit does not provide any navigation opportunities.

9.0 Instream Hydropower Generation

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

There is no instream hydropower in the Oopuola hydrologic units.

10.0 Maintenance of Water Quality

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

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

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

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

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

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

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

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

Land use affects water quality because direct runoff (rainfall that flows overland into the stream) can transport sediment and its chemical contaminants into the stream. 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," "aesthetic enjoyment," and "compatible recreation" are among the designated uses of Class 1 inland

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

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

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

Once data are gathered and evaluated for quality and deemed to be representative of the waterbody segment, a decision is made as to whether the appropriate designated uses are being attained. This set of decisions are then tabulated into a report to the EPA that integrates two CWA sections; (§) 305(b) and §303(d). This Integrated Report is federally required every even-numbered year. 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 2012 Integrated Report are Hawaii’s 2010 §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 2010 list that was published in 2012), only 88 streams statewide had sufficient data for evaluation of whether exceedance of WQS occurred. Oopuola Stream did not appear on the 2018 List of Impaired Waters in Hawaii, Clean Water Act §303(d).

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)." The presence of on-site sewage disposal systems (OSSDS) is commonly linked to increased nutrient and bacterial contamination of nearby waters. There are no OSSDS in or nearby the Oopuola hydrologic unit.

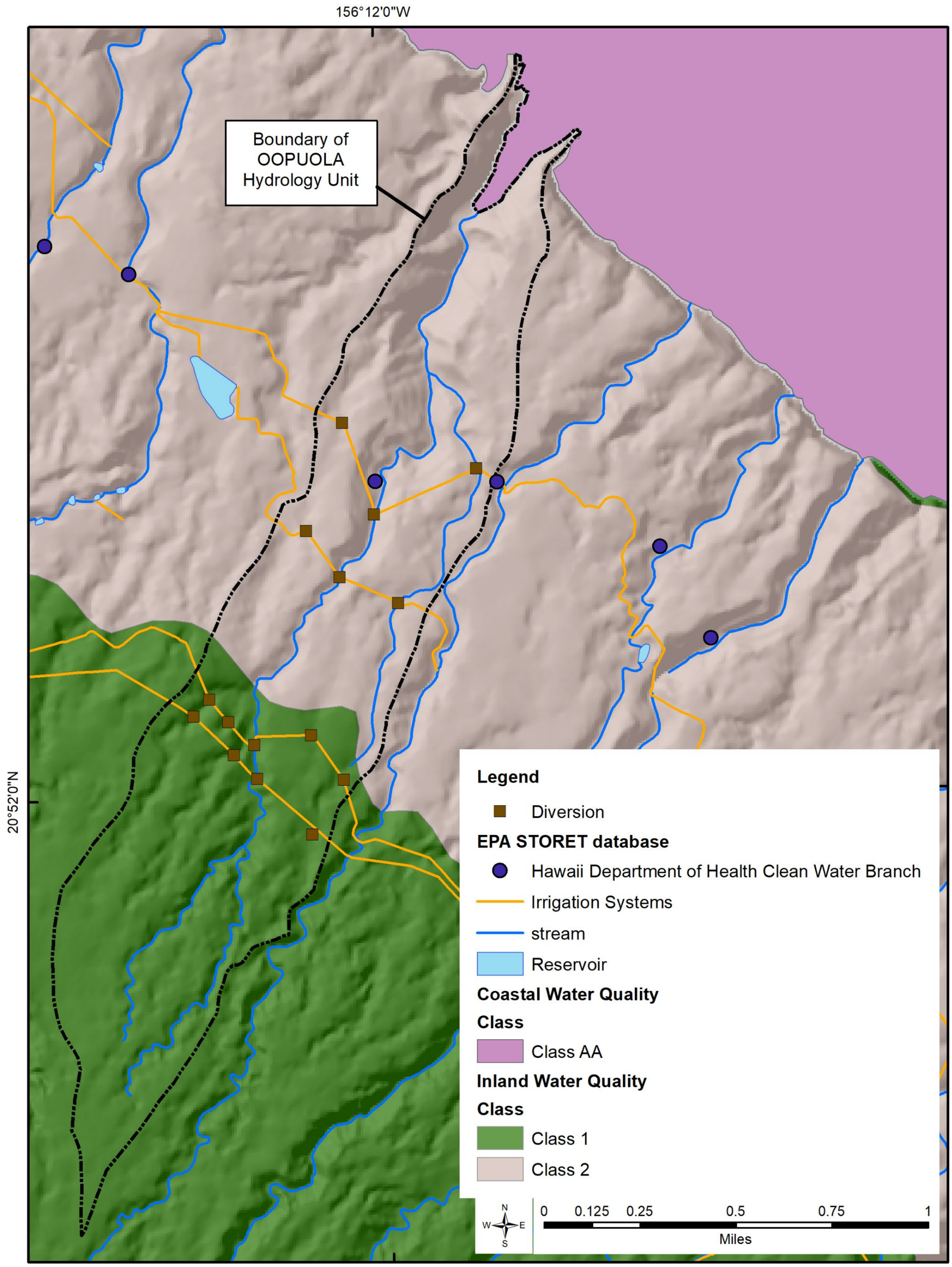
Oopuola Stream is classified as Class 1 inland waters from its headwaters to approximately the 700 ft elevation as the surrounding land is in the conservation subzone "protective." It should be noted that the conservation subzone map utilized for this interpretation is general and elevations are not exact. It should also be noted that there is no direct relationship between elevation and attainment of water quality standards.

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 only permitted under regulation. The marine waters at the mouth of the Oopuola Stream hydrologic unit are Class AA waters. Figure 10-1 shows the Oopuola hydrologic units, including inland and marine (coastal) water classifications.

Table 10-1. Water quality parameters for the State of Hawaii Department of Health Clean Water Branch stations in the Oopuola hydrologic unit (Source: EPA, 2020)

station name		elevation (ft)		sample date							
Oopuola Stream		510		7/16/2002							
temperature		Oxidation Reduction Potential		Ammonium at NH_4		Dissolved Oxygen		Salinity		Turbidity	
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
1	22.51	1	238	1	0.09	1	6.22	1	0.02	1	0.9
Nitrate as N		Specific Cond.		pH							
n	Mean (SD)	n	Mean (SD)	n	Mean (SD)						
1	0.46	1	0.0067	1	6.8						

Figure 10-1. Water quality standards and water quality sample sites for the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2015e; USEPA, 2020). 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 City and County of Honolulu Board of Water Supply does not have data for water users who are not on the county system and may be using catchment or surface water for domestic use. The State of Hawaii Department of Health Safe Drinking Water Branch administers Federal and State safe drinking water regulations to public water systems in the State of Hawaii to assure that the water served by these systems meets State and Federal standards. Any system which services 25 or more people for a minimum of 60 days per year or has at least 15 service connections is subject to these standards and regulations. Once a system is regulated by the Safe Drinking Water Branch, the water must undergo an approved filtration and disinfection process when it has been removed from the stream. It would also be subject to regulatory monitoring. However, there are no private water systems in the Oopuola hydrologic unit regulated by the DOH, Safe Drinking Water branch.

12.0 Protection of Traditional and Customary Hawaiian Rights

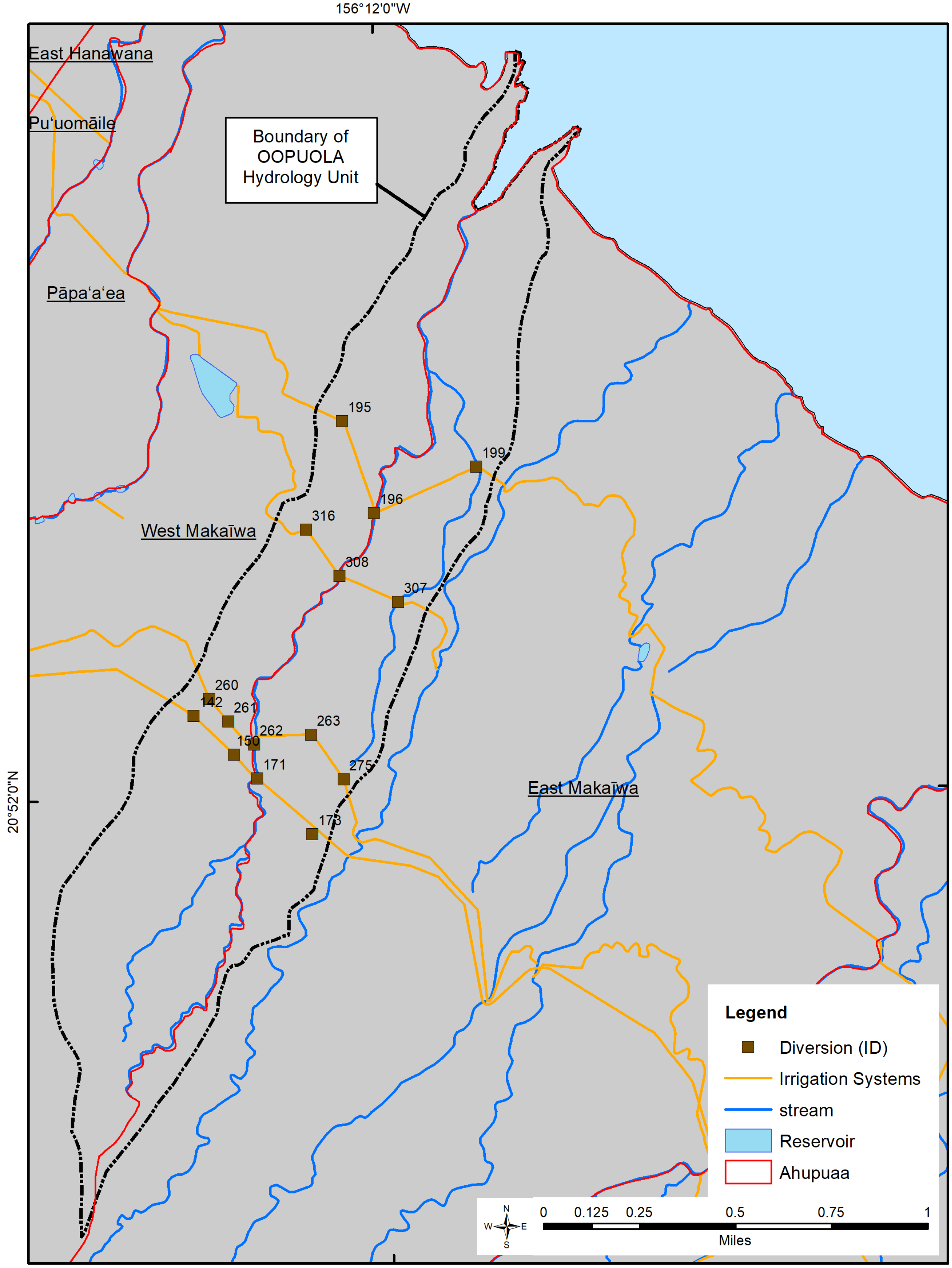
The maintenance of instream flows is important to the protection of traditional and customary Hawaiian rights, as they relate to the maintenance of stream resources (e.g., hihiwai, opae, oopu) for gathering, recreation, and the cultivation of taro. Article XII, Section 7 of the State Constitution addresses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

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

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

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

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



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 (Figure 12-2).

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

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

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

The Commission conducted a cursory assessment of tax map key parcels to identify their associated Land Commission Awards, in an attempt to identify the potential for future appurtenant rights claims within the Oopuola hydrologic unit. Table 12-1 presents the results of the Commission's assessment. The location of land commission awards agrees with the distribution of kuleana parcels in the hydrologic unit (Figure 12-3).

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

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

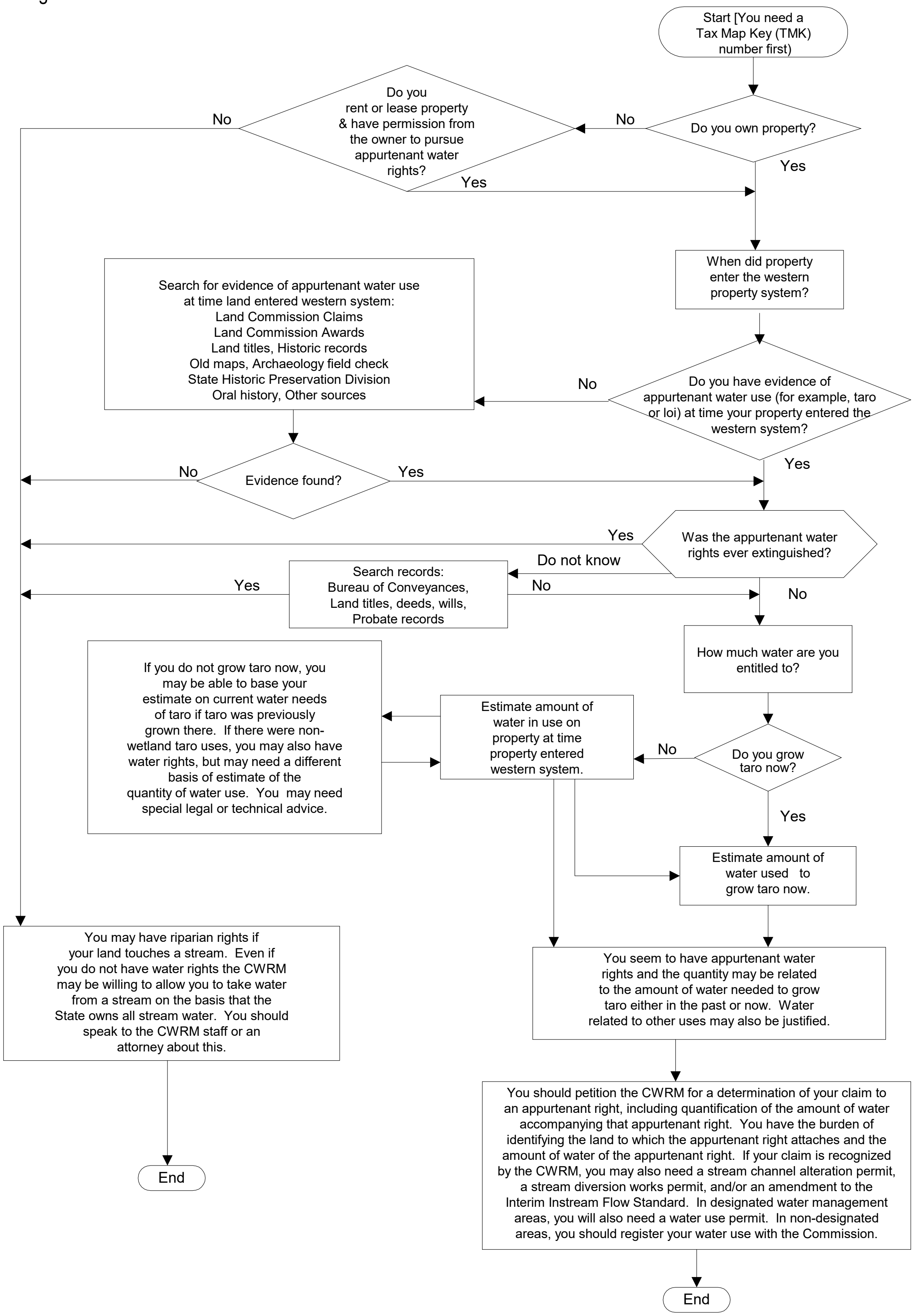


Table 12-1. Land Awards, claimants, associated tax map key (TMK) parcels, and landowners for the Oopuola hydrologic unit, Maui. [LCA is Land Commission Award; Gr. is Grant; por. is portion; and G.L. is Government Lease; BOE is Board of Education]

Land Award	TMK	Landowner	Claimant
Gr 1396	multiple	multiple	Luka & 10 others
LCA 3957 B:1	211001036	East Maui Irrigation	Luka
Gr 2140	211001042	East Maui Irrigation	Hikiau
Gr 1915	multiple	multiple	Mauna
Gr 2561	229013013	Rosario, Matilda	Kauhale
Gr 1677	229013013	Rosario, Matilda	Kauhale

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 12-3 (discharge measurements) and Table 12-4 (water-temperature statistics).

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

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

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

> Two *Kama'aina* at Ke'anae said that there were small loi developments watered by Ho'olawa, Waipi'o, Hanehoi, Hoalua, Kailua, and Na'ili'ilihaele streams, all of which flow in deep gulches. Stream taro was probably planted along the watercourse well up into the higher *kula* land and foret taro throughout the lower forest zone. The number of very narrow *ahupua'a* thus tuilitzed along the whole of the Hamakua coast indicates that there must have been a very considerable population. This would be despite the fact that it is an area of only moderate precipitation because of being too low to draw rain out of trade winds flowing down the coast from the rugged and wet northeast Ko'olau area that lies beyond. It was probably a favorable region for breadfruit, banana, sugar cane, arrowroot; and for yams and *'awa* in the interior. The slopes between gulches were covered with good soil, excellent for sweet-potato planting. The low coast is indented by a number of small bays offering good opportunity for fishing. The *Alaloa*, or "Long-road," that went around Maui passed through Hamakua close to the shore, crossing streams where the gulches opened to the sea. (p. 498)

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

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

Archaeological Evidence for Hawaiian Agriculture

Individual cultural resources of Oopuola hydrologic unit was 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 12-5). There are no identified archaeological sites in the Oopuola hydrological unit (Table 12-4). This is further supported by the lack of identified wetland or dryland pre-contact agriculture associated with the Oopuola hydrologic unit as modeled by Ladefoged et al. (2009) who modeled the extent of pre-contact agriculture across the Hawaiian Islands (Figure 12-3).

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

Historic Site #	State Site #	SHPD Library	Land Award	Description
none	none	none	none	

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 existing or historic fishponds present in the Oopuola hydrologic unit (DHM, Inc., 1990).

Figure 12-3. Kuleana parcels and zones of pre-contact intensive agriculture in Oopuola, Maui. (Source: Ladefoged et al., 2009)

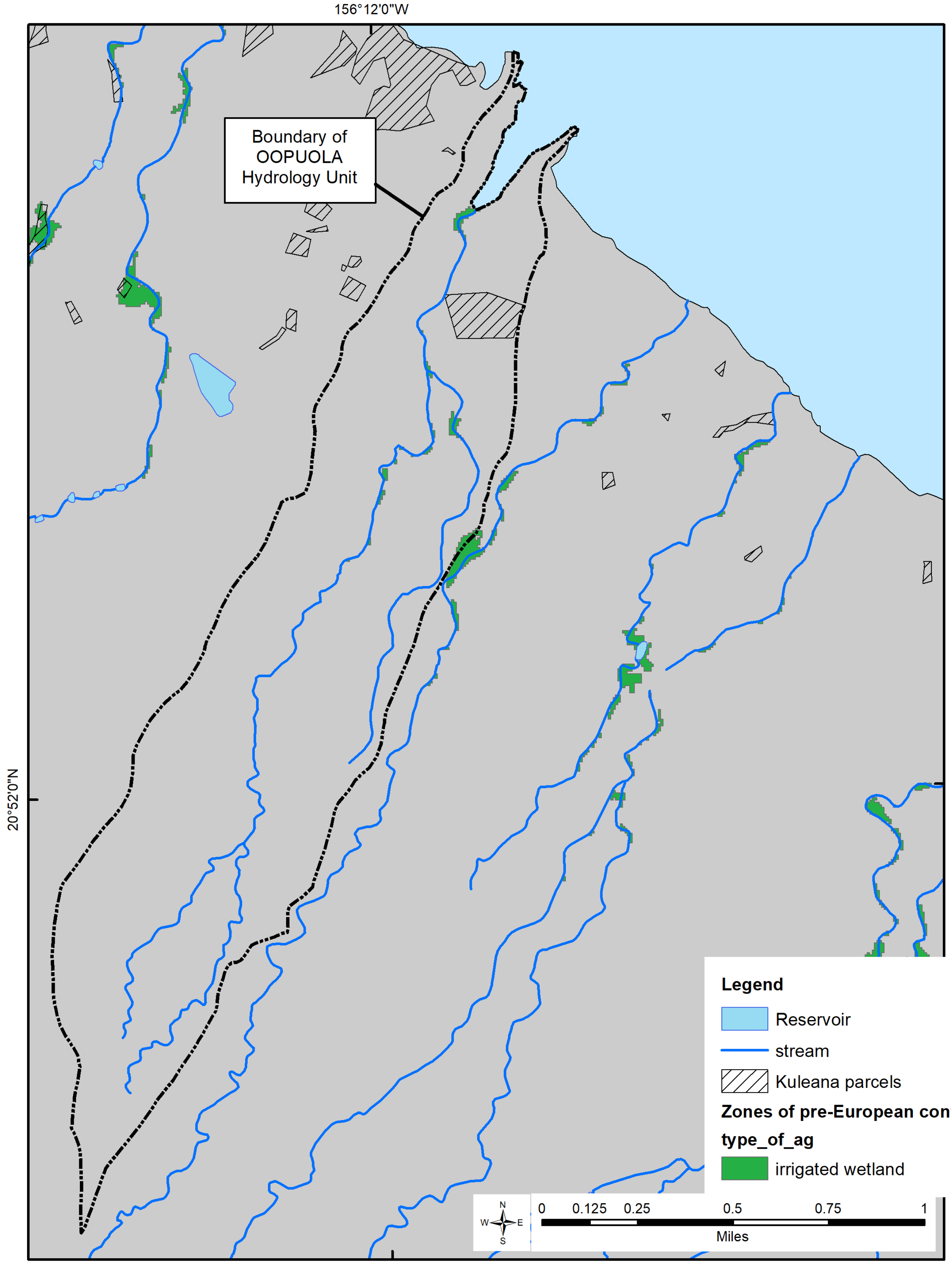


Table 12-5. Cultural resource elements evaluated as part of the Hawaii Stream Assessment for Oopuola stream, Maui.

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.	Yes
Taro Cultivation: Streams and stream water have been and continue to be an integral part of the Hawaiian lifestyle. The committee identified a number of factors important to current Hawaiian practices. These include current taro cultivation, the potential for taro cultivation, appurtenant rights, subsistence gathering areas, and stream-related mythology. The committee felt that a complete assessment of the cultural resources of Hawaii's streams should include these items but, due to limits of information, only the current cultivation of taro was included.	No

13.0 Public Trust Uses of Water

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

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

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

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

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

In the Oopuola hydrologic unit, the use of water for traditional and customary practices was covered in Chapter 12 and water in its natural state is covered in Chapters 3-7. The Maui County DWS municipal water system relies on water diverted from Oopuola Stream to support domestic and agricultural water uses in the Makawao, Haiku, Pukalani, and Kula regions. The following is an analysis of Maui County DWS's upcountry system and the reservations of water for Hawaiian Home Lands.

Maui County DWS Upcountry Municipal System

Of the five separate water systems operated by DWS, the Upcountry Maui (sometimes referred to as Makawao) system is the second largest system and is supported by Maui's largest surface water treatment facility (WTF), the Kamole Weir WTF. Surface water, for the most part, supplements the primary ground water sources (Haiku and Kuapakalua wells) for the region, but serves as backup in the event of pump failure or drought. The Kamole Weir WTF produces an average 3.6 million gallons per day, but is capable of producing 8 million gallons per day at maximum capacity. DWS also plans to increase capacity by 2.3 million gallons per day in 2015 (Findings of Fact, Conclusions of Law, and Decision and Order, 2007; Maui DWS, 2007e).

The Kamole Weir WTF receives water from the Wailoa Ditch and supplies water to approximately 6,571 water service connections and is capable of providing water to the entire Upcountry region (9,708 connections) if necessary (Maui DWS, 2007e). The EMI ditch system provides water to the Nahiku community, to Maui Land & Pine, and to the Maui County Board of Water Supply for use in upcountry Maui. There are three upcountry Maui County Department of Water Supply (DWS) water systems served by east Maui streams: Maui DWS Makawao is served by Wailoa Ditch, part of the EMI system; Maui DWS Upper Kula is served by Haipuaena and Waikamoi Streams; and Maui DWS Lower Kula by Honomanu, Haipuaena, and Waikamoi Streams. Maui DWS themselves divert the streams for the Upper and Lower Kula pipelines; it is only the Makawao system whose source is the EMI system (Mike Miyahira, DOH Safe Drinking Water Branch, personal communication, August 1, 2008.)

The Upcountry system includes the communities of Kula, Pukalani, Makawao, and Haiku, with an estimated population of 30,981 people (Findings of Fact, Conclusions of Law, and Decision and Order, 2007). Metered water usage in the Upcountry system has steadily climbed over the past 10 years, with the largest portion going towards potable water use (Table 13-1).

Table 13-1. Historical metered consumption for the Upcountry system, Maui (Source: Maui DWS, 2007d). [Data reported in million gallons per day]

Year	General	Agriculture Potable	Total Potable	Agriculture Non-potable	Total
2005	4.441	2.378	6.820	0.571	7.391
2004	4.387	2.138	6.525	0.575	7.100
2003	4.778	2.320	7.098	0.582	7.680
2002	4.461	1.908	6.368	0.433	6.801
2001	4.823	2.563	7.387	0.690	8.077
2000	4.370	2.504	6.873	0.505	7.379
1999	4.146	2.474	6.620	0.555	7.175
1998	4.003	2.382	6.384	0.512	6.897
1997	3.693	1.829	5.521	0.374	5.895
1996	4.083	1.923	6.007	0.481	6.487
1995	4.382	2.300	6.682	0.634	7.317
1994	3.871	1.931	5.802	0.504	6.306

For the Makawao-Pukalani-Kula Community Plan District, water use for agriculture and single-family residences has been very similar over the past 5 years. The two uses also have strong annual patterns, with water use rising approximately 1.5 million gallons per day during summer months versus winter months (Figure 13-1). Other water uses within the district are relatively low (County of Maui, 2018a). Upcountry metered consumption in 2014 was 6.263 mgd, with a three-year (2012-2014) average of 7.266 mgd, and a 10-year (2005-2014) average of 7.277 mgd. As of June 30, 2014, there were 1,822 requests for water meter service with an estimated demand of 7.284 mgd in the Kula, Makawao, Haiku, and Pukalani subdistricts.

The County of Maui, as part of its current effort to update the Maui County Water Use and Development Plan, is examining various resource options to meet the forecasted water needs and planning objectives of the Upcountry district over a 25 year planning period. Expansion of the Kamole Weir WTF is the primary long-term option affecting water delivered via the Wailoa Ditch; however, other options for the entire district include developing additional groundwater sources, expanding/upgrading interconnections (booster pumps) between systems, and increasing water storage capacity (Maui DWS, 2018a). Upcountry water demands are expected to increase, as depicted in Figure 13-2, based upon five water demand projections derived from varying growth scenarios (low, medium low, base, medium high, and high) to the year 2035.

Figure 13-1. Historical monthly water consumption by use class code for the Makawao-Pukalani-Kula Community Plan District, Maui (Source: Maui DWS, 2007d).

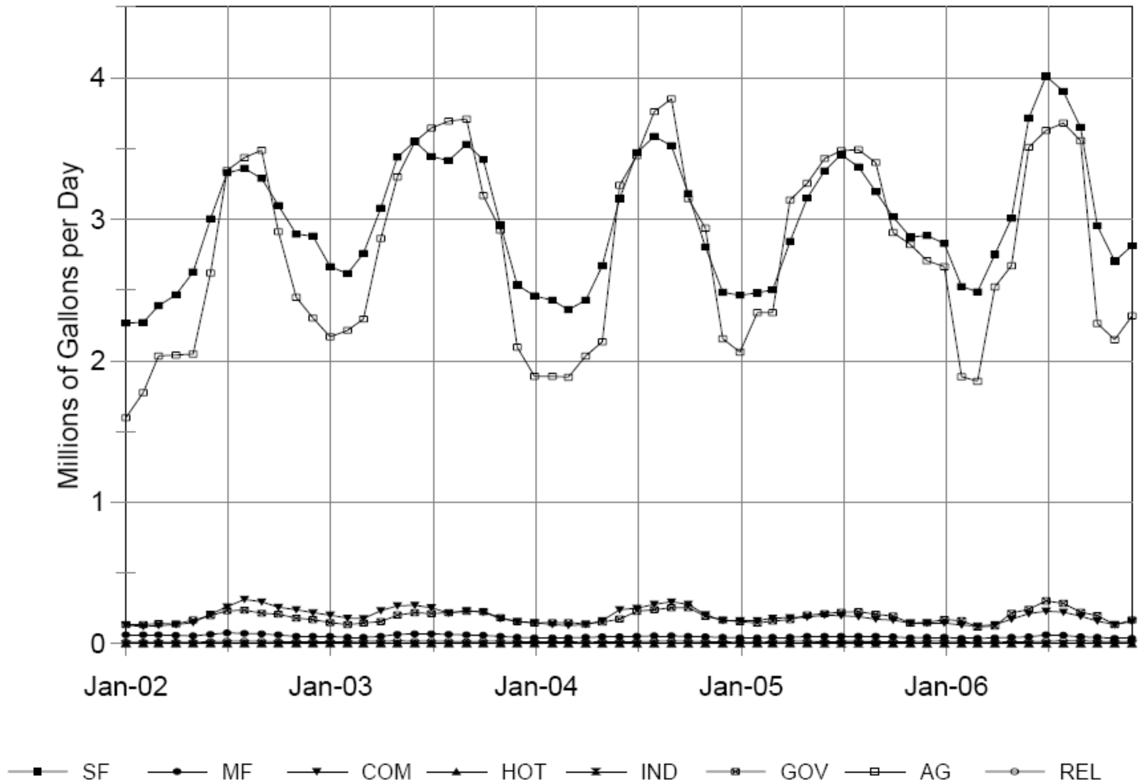
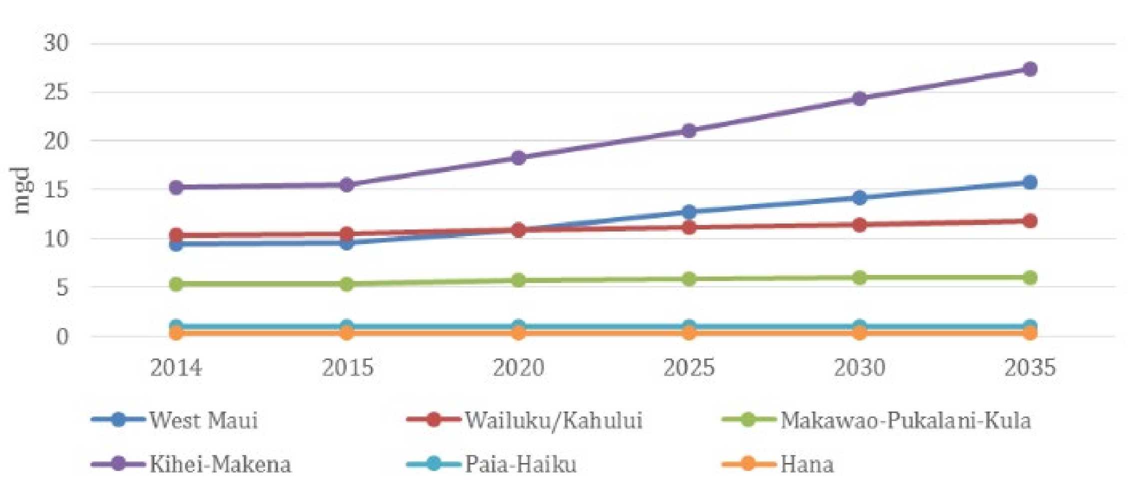


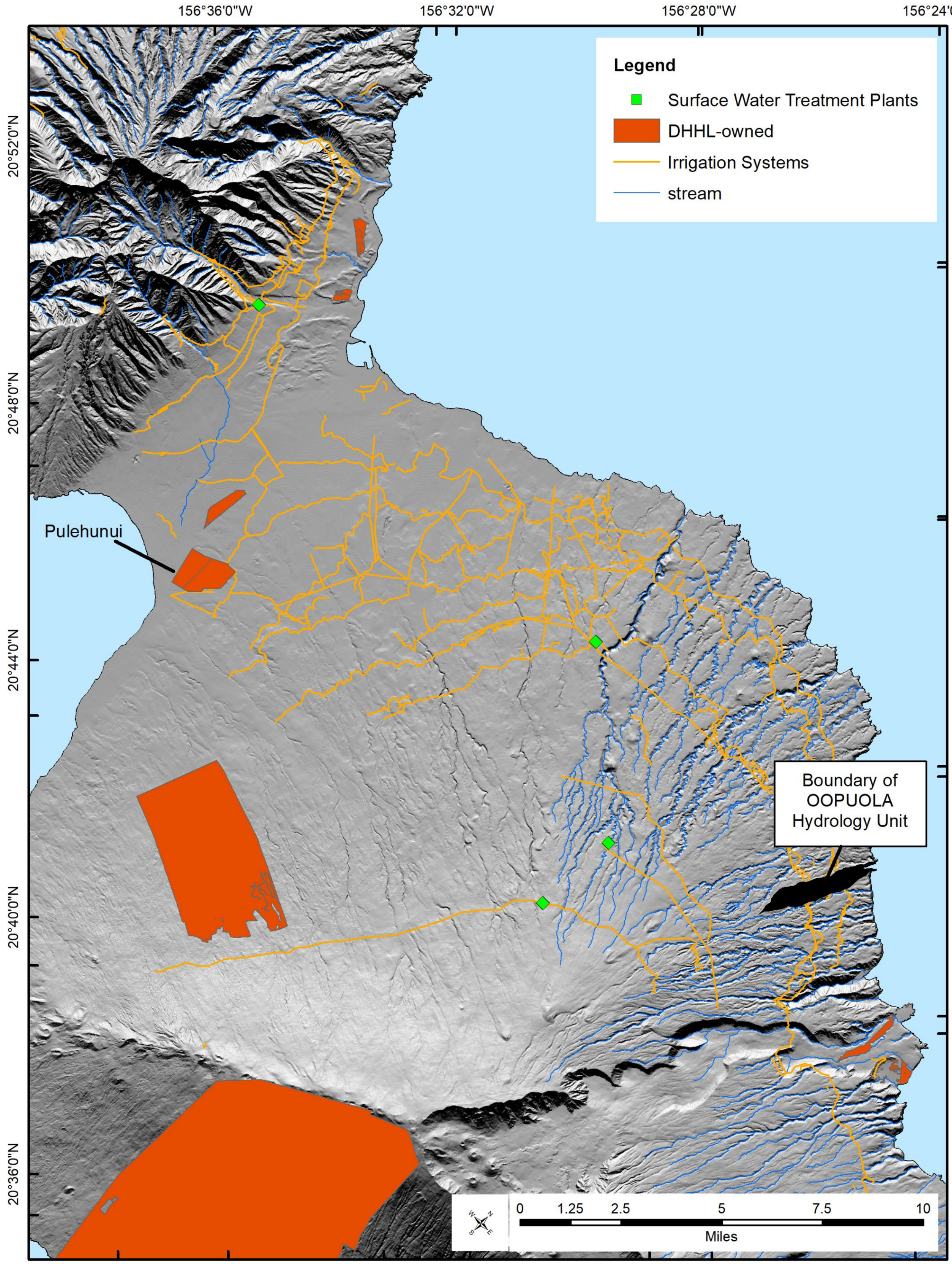
Figure 13-2. Population growth based demand by Community Plan Area, 2014-2035, Maui (Source: Maui County, 2020a)



Hawaiian Home Lands

A component in the assessment of water use includes an analysis of the presence of Department of Hawaiian Home Lands (DHHL) parcels within or near the surface water hydrologic unit. The mission of DHHL is to effectively manage the Hawaiian Home Lands trust and to develop and deliver land to native Hawaiians (PBR Hawaii, 2004). In June 2004, DHHL published the Maui 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, there are none in the Oopuola hydrologic unit. The Puunene Track of the Central Maui Region has over 700 acres which are not suitable for residential use. The recommendation was for 546 acres reserved for general agriculture. In the Pulehunui Master Plan, a joint development project between the DHHL, DLNR, Maui County Department of Public Safety, and the DAGS, 238 acres were reserved for agricultural homesteads (110 total), and 173 acres for general agricultural use. The source of water for these projects was assumed to be the Maui DWS, although non-potable water could be supplied by the East Maui Irrigation system (Figure 13-3).

Figure 13-3. Hawaiian Home Lands development parcels identified in the central valley, Maui. (Source: State of Hawaii, Department of Hawaiian Home Lands, 2011)



14.0 Noninstream Uses

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

In most cases, water is diverted from the stream channel via a physical diversion structure. Diversions take many forms, from small PVC pipes in the stream that remove relatively small amounts of water, to earthen auwai (ditches), hand-built rock walls, and concrete dams that remove relatively larger amounts of water. 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. Additionally, discharge of water from a ditch system into a stream may introduce invasive species.

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 it be 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.

Water Leaving the Oopuola Hydrologic Unit in Ditch Systems

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.

In 2007, the Commission initiated a contract for the purpose of conducting statewide field investigations to verify and inventory surface water uses and stream diversions, and update existing surface water information. Priority 1 Areas, under this contract, include all east Maui streams that are part of the pending Petition to Amend Interim Instream Flow Standards. Data from this study, along with information collected from Commission staff site visits, and information extracted from the original registration files are included in Table 14-2.

In the Oopuola hydrologic unit, East Maui Irrigation Company (EMI) operates four parallel ditch systems, running from east to west, as part of the larger East Maui Irrigation System. Though EMI registered all of its "major" diversions (included in Table 14-2), the Commission did not require EMI to register their "minor" diversions and instead were provided with a map, lists, and photographs. These minor diversions may vary widely in construction. One example consists of a small concrete basin collecting ground water seepage, which then transports the collected water via a gravity-flow PVC pipe to a larger ditch, ultimately joining one of the primary systems. The contribution of these small seeps and springs to total streamflow is unknown.

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. These permitted (as opposed to "registered") diversion works are not part of the Commission's verification effort, nor have any new diversions been permitted in the Oopuola hydrologic unit.

Continuous flow data are not available for the individual EMI diversions near Oopuola, rather, the entire system was monitored at Honopou. This allows for analysis via a flow duration curve, which is a cumulative-frequency curve that shows the percentage of time a daily median discharge is equaled or exceeded during a given time period. Flow duration curves are also common and effective way to assess streamflow variability and availability. Generally, flow duration curves for large streams with persistent input from ground water sources are flatter than those for streams where ground water inflow is minimal, making streamflow rather responsive to each rainfall event. The flows at 50 (Q_{50}) and 90 (Q_{90}) percent exceedence probability are common indices of median total flow and low flow, respectively. When a flow duration curve is plotted for measurements made at a ditch, it shows the variability in the amount of water diverted for agricultural or domestic uses. The Q_{50} flow indicates the median amount of water diverted during the period of record. Flow duration curves were plotted for each of the USGS gaging stations located at a ditch at Honopou Stream (Table 14-1).

Table 14-1. Selected off-stream water use statistics for each ditch in the East Maui Irrigation System, Maui, Hawaii. (Source: CWRM, 2018b) [Flows are in cubic feet per second (million gallons per day)]

Station ID	location	Period of record	Q_{50}	Q_{70}	Q_{90}
16588000	Wailoa Ditch at Honopou	2002-2016	168.4 (108.8)	112 (72.4)	65.7 (42.5)
16589000	New Hamakua Ditch at Honopou	2002-2016	4.47 (2.9)	1.31 (0.85)	0.42 (0.27)
16592000	Lowrie Ditch at Honopou	2002-2016	25.1 (16.2)	11.9 (7.7)	4.2 (2.7)
16594000	Haiku Ditch at Honopou	2002-2016	4.4 (2.8)	1.66 (1.07)	0.56 (0.36)

Hydropower Production

There are three hydropower generation plants that are run-of-the-ditch low-head hydropower which produces electricity from water diverted by the EMI system, including from Oopuola. Carol Wilcox, in her book *Sugar Water: Hawaii's Plantation Ditches* (1996), describes the use of surface water for generating hydroelectricity by Hawaiian Commercial and Sugar Company as follows:

> On Maui, Hawaiian Commercial and Sugar Company (HC&S) had three hydroelectric plants, all utilizing water collected by the East Maui Irrigation Company (EMI) irrigation system. The

earliest, Paia Hydro, was built by Maui Agricultural Company in 1912 with a 800-kilowatt capacity. In 1923, the penstock was extended to a higher elevation, thus increasing the capacity to 1000 kilowatts. HC&S built a 4000-kilowatt hydroplant at Kaheka in 1924. In 1982, a 500-kilowatt hydroelectric powerplant was installed at the Hamakua Ditch above Paia. Located only 50 feet below the Wailoa Forebay, this "low-head" hydroplant takes water through a 36-inch pipe and discharges it into the Hamakua Ditch.

Power generated from these facilities is used to satisfy agricultural power requirements with the remaining electricity not used sold to Maui Electric Company (MECO). During peak operation while sugarcane was grown and harvested, there was an estimated oil savings of 16,200 barrels per year according to MECO. The hydraulic turbine generators located at the Kaheka, Paia, and Hamakua facilities on the Wailoa Ditch are capable of producing 4.5, 0.9, and 0.4 megawatts, respectively (MECO, 2008b).

Figure 14-1. All registered diversions (ID) and ditches identified in the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Commission on Water Resource Management, 2015g)

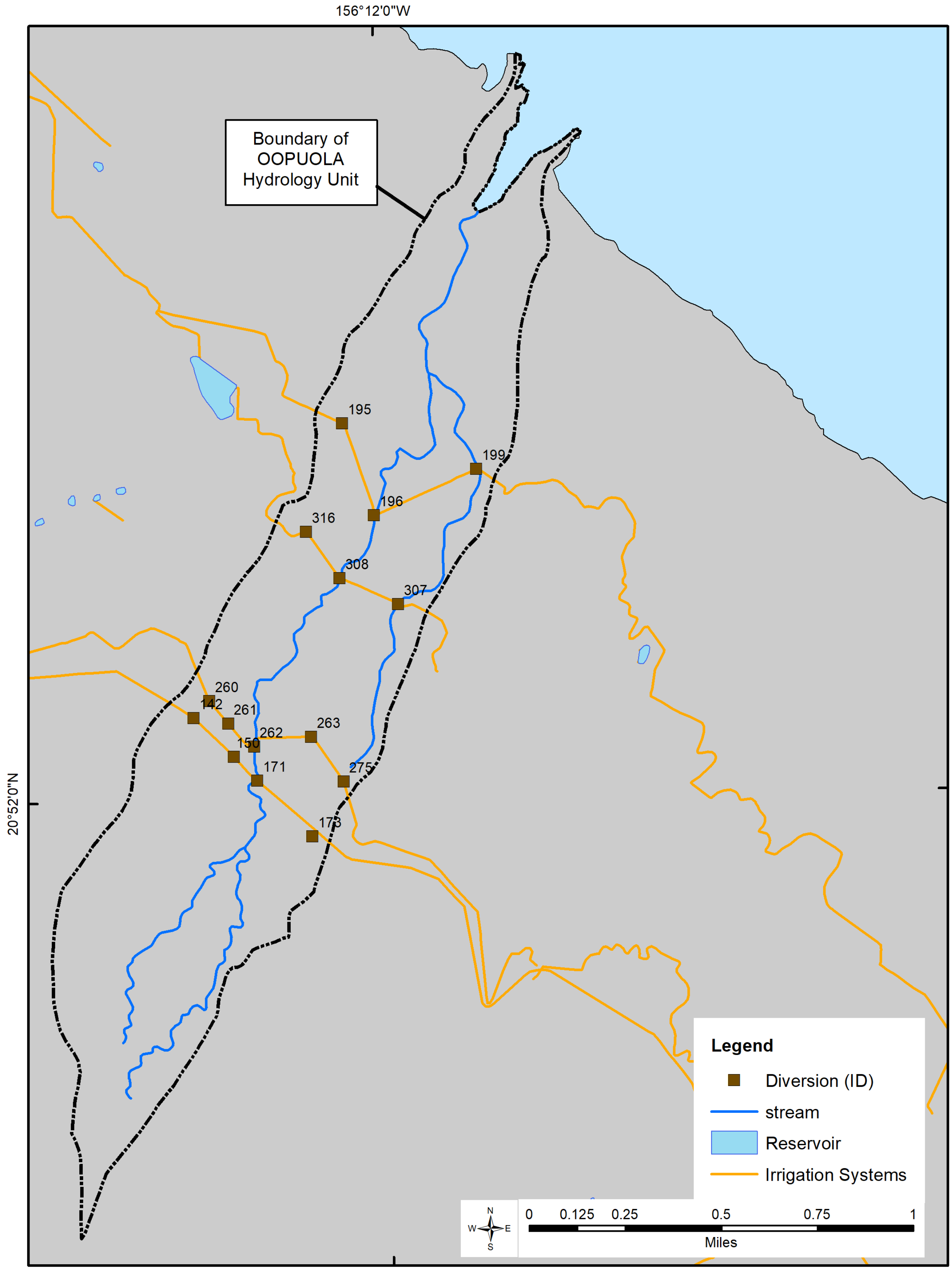


Table 14-2. Registered diversions in the Oopuola hydrologic unit, Maui.
[Source of photos are denoted at the end of each description; CWRM, Commission on Water Resource Management;Chevrons ( ) indicate general direction of natural water flow to and out of diversions; Arrows ( ) indicate direction of 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.173	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	Yes

Photos. a) Wailoa Ditch Intake (W-7) from Makanali Stream (unmapped Oopuola tributary) (EMI, 1989); 4" pvc pipe with capacity of 0.5 mgd; flow 0.67 cfs on 10/31/2007 (RM Towill); b) diversion from left bank (CWRM, 2020); c) upstream view of diversion and 4" pipe (CWRM, 2020); d) upstream view above diversion (CWRM, 2020); e) downstream view of diversion (CWRM, 2020); downstream view below diversion (CWRM, 2020)

a)

b)

c)

d)

e)

f)


Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.171	EAST MAUI IRR	1-1-001-050		Yes	Yes	Yes	Yes

Photos. a) Wailoa Ditch Intake (W-8) from Oopuola Stream (#1 Oopuola intake) (EMI, 1989); measured flow 0.29 cfs on 10/24/2007 (RM Towill); b) upstream view from left bank of diversion (CWRM, 2020); c) downstream view of diversion (CWRM, 2020); d) upstream view of intake (CWRM, 2020) e) upstream view above diversion (CWRM, 2020); f) diversion from right bank (CWRM, 2020); g) downstream view below diversion (CWRM, 2020); h) control gate on intake (CWRM, 2020)

a)

b)

c)

d)

e)

f)

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

g) 

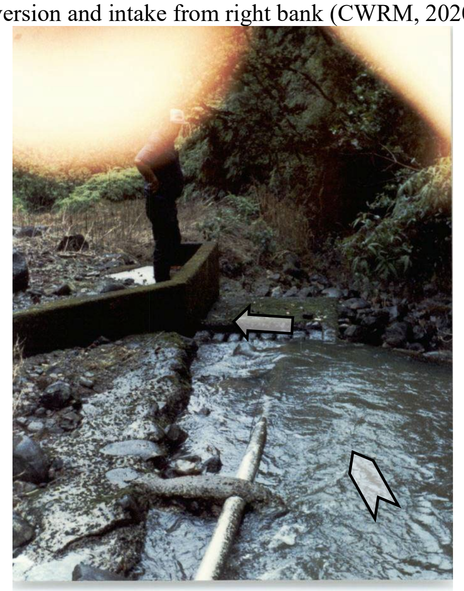
h) 

Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.150	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	Yes

Photos. a) Wailoa Ditch Intake (W-9) from Oopuola Stream (#2 Oopuola Tributary) (EMI, 1989); diversion capacity is 2 mgd; measured flow 0.33 cfs on 4/24/2009 (RM Towill); upper intake (CWRM, 2020); c) upstream of upper intake (CWRM, 2020); d) downstream view between upper intake and diversion (CWRM, 2020); e) stream above diversion (CWRM, 2020); f) diversion and intake from right bank (CWRM, 2020); g) upstream view of diversion (CWRM, 2020)

a)



b)

c)

d)

e)

f)

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

Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.142	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	Yes

Photos. a) Wailoa Ditch Intake (W-10) from Oopuola Stream (#4 Oopuola Tributary) (EMI, 1989); diversion capacity is 7 mgd; measured flow 0.067 cfs on 10/24/2007 (RM Towill); b) downstream view of intake (CWRM, 2020); c) upstream view of diversion (CWRM, 2020); d) upstream view of intake (CWRM, 2020); sluice basin on left bank (CWRM, 2020); upstream view from diversion (CWRM, 2020)

a)

b)

c)

d)

e)

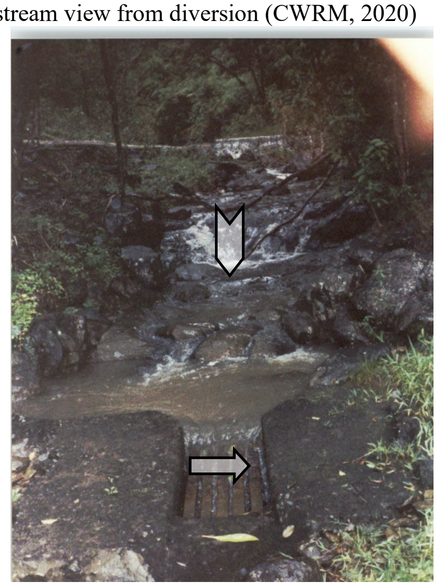
f)

Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.275	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	

Photos. a) New Hamakua Ditch Intake (NH-4) from Makanali Stream (EMI, 1989); diversion capacity is 1 mgd; measured flow 0.46 cfs on 10/31/2007 (RM Towill); b) upstream view of diversion and intake (CWRM, 2020); c) closeup of intake (CWRM, 2020), d) downstream view from diversion (CWRM, 2020); e) downstream view of diversion (CWRM, 2020); f) upstream view from diversion (CWRM, 2020)

a)



b)

c)

d)

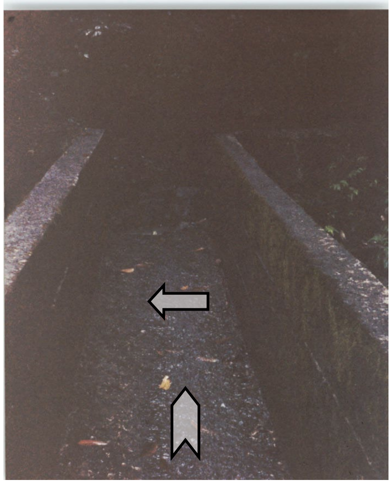
e)

f)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.263	EAST MAUI IRR	1-1-001-050		Yes	Yes		

Photos. a) New Hamakua Ditch Intake (NH-5) on unmapped tributary (Makanali intake/overpass) (EMI, 1989); diversion capacity is 1 mgd; measured flow 0.022 cfs on 10/31/2007 (RM Towill); b) upstream view of overpass (CWRM, 2020); c) upstream view of stream above diversion (CWRM, 2020); d) downstream view of overpass and intake (CWRM, 2020); e) overpass from right bank at ditch (CWRM, 2020)

a)


b)


c)

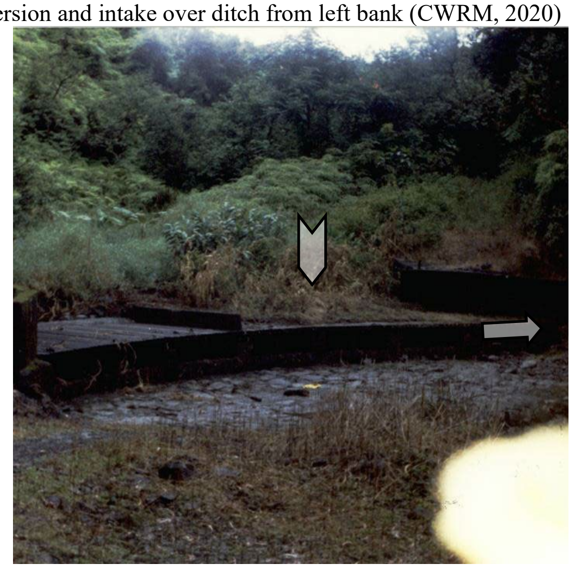

d)


e)


Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.262	EAST MAUI IRR	1-1-001-050		Yes	Yes	Yes	Yes

Photos. a) New Hamakua Ditch Intake (NH-6) on Oopuola Stream (Big strainer intake) (EMI, 1989); diversion capacity is 100 mgd; dry stream on 10/24/2007 (RM Towill); b) diversion and intake from right bank over ditch (CWRM, 2020); diversion and intake over ditch from left bank (CWRM, 2020)

a)



b)

c)

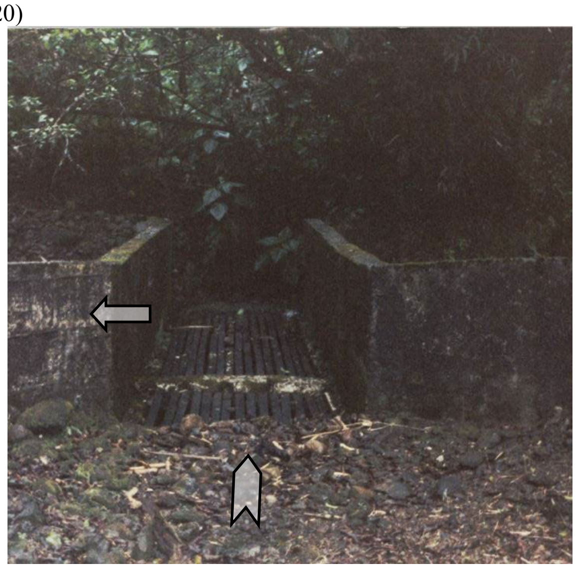
d)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.261	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	Yes

Photos. a) New Hamakua Ditch Intake (NH-7) on Oopuola Stream (#3 Oopuola Intake) (EMI, 1989); diversion capacity is 1 mgd; measured flow 0.01 cfs on 10/24/2007 (RM Towill); b) upstream view of overpass (CWRM, 2020); c) downstream view of intake (CWRM, 2020); d) upstream view above diversion (CWRM, 2020); e) downstream view of overpass (CWRM, 2020)

a)



b)

c)

d)

e)

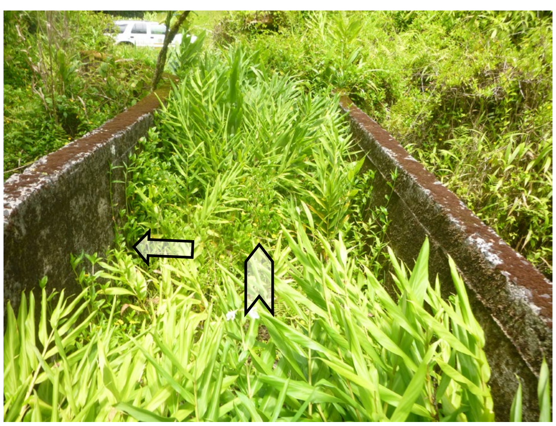
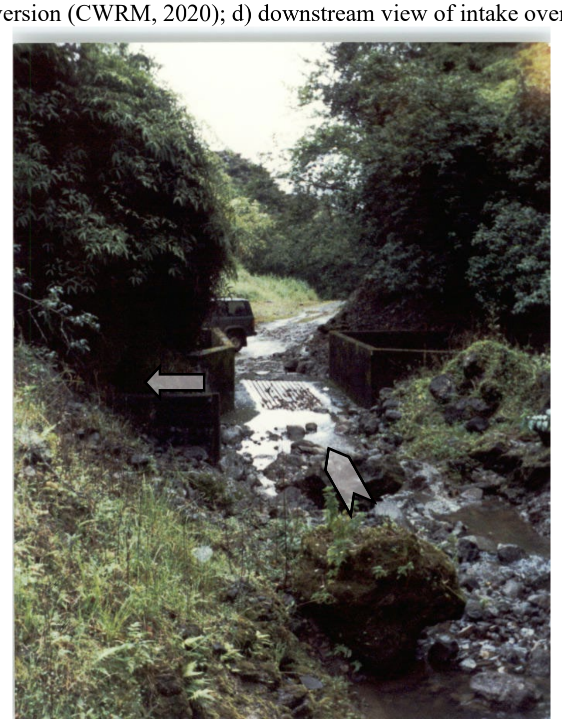


Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.260	EAST MAUI IRR	1-1-001-050		Yes	Yes	No	Yes

Photos. a) New Hamakua Ditch Intake (NH-8) on Oopuola Stream (#4 Oopuola Intake) (EMI, 1989); diversion capacity is 5 mgd; stream dry on 10/24/2007 (RM Towill); b) upstream view of intake overpass (CWRM, 2020); c) upstream view above diversion (CWRM, 2020); d) downstream view of intake over

a)



b)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.307	EAST MAUI IRR	1-1-001-050		Yes	Yes		

Photos. a) Spreckels Ditch Intake (S-12) on Makanali Stream (EMI, 1989); diversion capacity is uncontrolled; measured 0.22 cfs on 10/15/2007 (RM Towill); b) Spreckels Ditch at Makanali Stream (CWRM, 2020); upstream view of inflow from (CWRM, 2020); c) inflow from left bank (CWRM, 2020); d) downstream view below ditch (CWRM, 2020)

a)

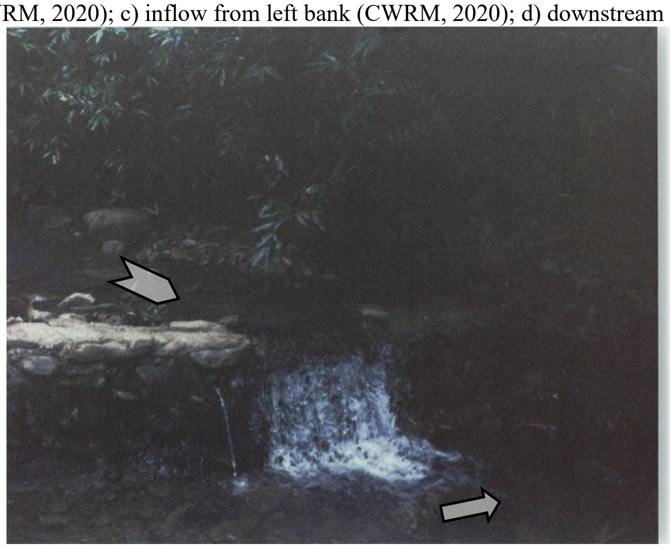


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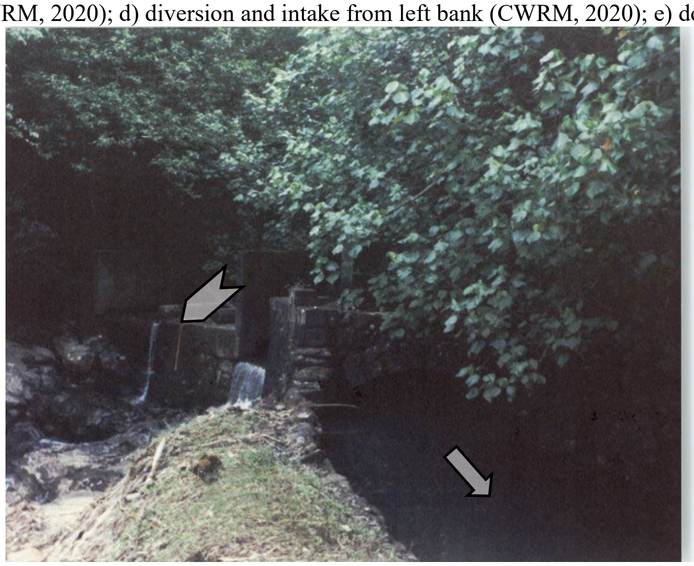
Table 14-2. Continued.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.308	EAST MAUI IRR	1-1-001-050		Yes	Yes	Yes	Yes

Photos. a) Spreckels Ditch Intake (S-13) on Oopuola Stream (EMI, 1989); diversion capacity is 60 mgd; measured 0.35 cfs on 10/15/2007 (RM Towill); b) upstream view above diversion (CWRM, 2020); c) diversion and intake from right bank (CWRM, 2020); d) diversion and intake from left bank (CWRM, 2020); e) downstream view from diversion (CWRM, 2020)

a)



b)

c)

d)

e)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.316	EAST MAUI IRR	1-1-001-050		Yes	Yes	Yes	Yes

Photos. a) Spreckels Ditch Intake (S-14) on West Oopuola Stream (EMI, 1989); diversion capacity is 70 mgd; measured 2.11 cfs on 10/15/2007 (RM Towill); b) comingled ditch and stream flow above diversion (CWRM, 2020); c) downstream view of diversion control on ditch (CWRM, 2020); d) upstream view of right bank with diversion dam (CWRM, 2020); e) downstream view below diversion (CWRM, 2020)

a)

b)

c)

d)

e)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.199	EAST MAUI IRR	1-1-001-050		Yes	Yes		

Photos. a) Center Ditch Intake (C-6) on Makanali Stream (EMI, 1989); diversion capacity is uncontrolled; measured 0.13 cfs on 10/15/2007 (RM Towill); b) downstream view below diversion (CWRM, 2020); c) view of ditch, diversion, and ditch control from right bank (CWRM, 2020); d) downstream view from diversion (CWRM, 2020); e) upstream view from diversion (CWRM, 2020); f) Center ditch with stream inflow from left bank (CWRM, 2020)

a)

b)

c)

d)

e)

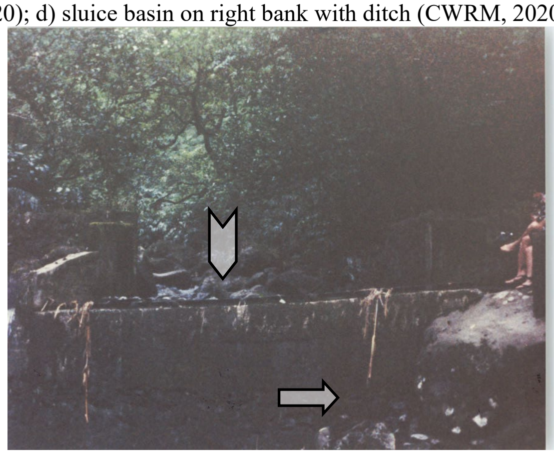
f)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.196	EAST MAUI IRR	1-1-001-050		Yes	Yes		

Photos. a) Center Ditch Intake (C-7) on Oopuola Stream (EMI, 1989); diversion capacity is 25 mgd; measured 0.45 cfs on 10/16/2007 (RM Towill); b) diversion intake from left bank (CWRM, 2020); c) intake across channel from left bank (CWRM, 2020); d) sluice basin on right bank with ditch (CWRM, 2020); e) upstream view above diversion (CWRM, 2020); f)

a)



b)

c)

d)

e)

Table 14-2. Continued. Registered diversions in the Oopuola hydrologic unit, Maui.

Event ID	File Reference	Tax Map Key	Diversion Amount (cfs)	Active (Yes/No)	Verified (Yes/No)	Riparian (Yes/No)	Rights Claim (Yes/No)
REG.195	EAST MAUI IRR	2-9-014-001	0.067	Yes	Yes		

Photos. a) Center Ditch Intake (C-8) on West Oopuola Stream (Small Oopuola Intake) (EMI, 1989); measured 0.04 cfs on 10/01/2007 (RM Towill); b) upstream view of flow into ditch (CWRM, 2020); center ditch below stream inflow (CWRM, 2020); d) upslope watershed of Oopuola tributary (CWRM, 2020); e) downslope view of Oopuola tributary above highway (CWRM, 2020); f) downslope view of Oopuola tributary below highway (CWRM, 2020)

a)

b)

c)

d)

e)

f)

Current Agricultural Demands

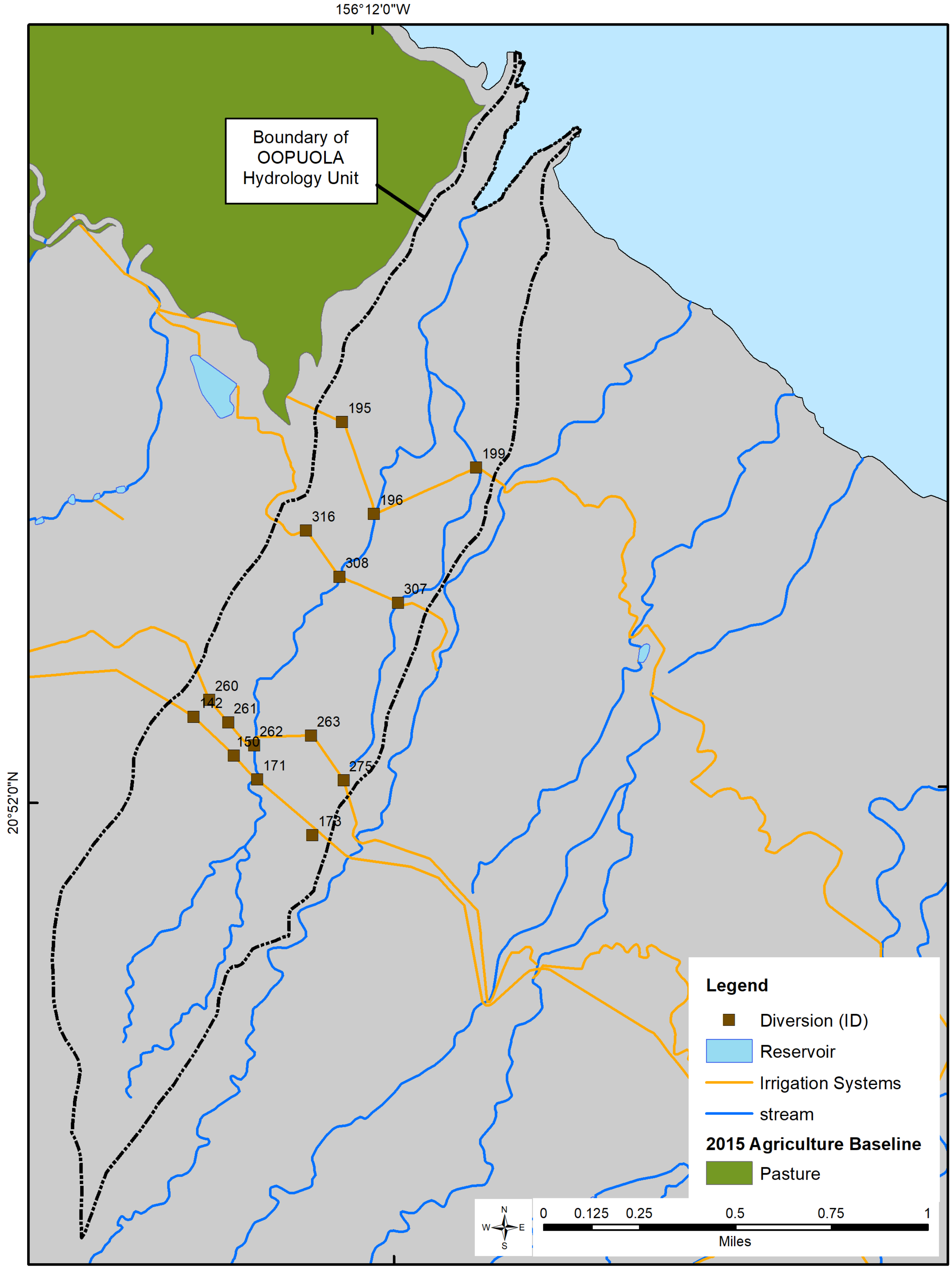
Using the 2015 Department of Agriculture Baseline Agriculture Survey (Perroy et al., 2015), the agriculturally zoned land occupies 22.4% of the Oopuola hydrologic unit however, none of it was in use in 2015 (Figure 14-3). Water from the EMI ditch system was used historically for sugarcane cultivation, domestic water supply, and small diversified agriculture. In 2016, Alexander and Baldwin closed the HC&S sugar plantation. Following the closure, irrigation demand dropped to approximately 20 mgd, as Alexander and Baldwin transitioned to a diversified agricultural plan, with 6-8 mgd used by Maui DWS, 1 mgd used by HC&S's cattle operation, 2 mgd used for bioenergy crops, and 6 mgd used to maintain reservoirs for fire protection.

The EMI system also services Maui DWS at Kamole Weir and the Kula Agricultural Park which services diversified agricultural needs. In 2018, the land owned by HC&S and EMI were sold by Alexander and Baldwin to Mahi Pono, a new diversified agricultural company, who also purchased a 50% stake in East Maui Irrigation Co. Currently, the transition to a larger diversified agriculture operation is ramping up with water demands increasing as more acerage is planted. Mahi Pono began planting orchard crops and growing diversified agricultural crops in 2018, with increased production each year (Table 14-3).

Table 14-3. Crop category, acerage, estimated irrigation demand, and water demand by crop in the 2019 Farm Plan proposed by Mahi Pono. (Perroy et al., 2015)

Crop Category	Acrage	Year to be planted	Irrigation Demand (gad)	Crop Water Demand (mgd)
Lemon	125	2019/2020	2407	0.301
Lime	800	2019/2020	2407	1.926
Mandarins	400	2020	2407	0.963
Orange	350	2019/2020	2407	0.842
Coffee	350	2020	2741	0.959
Community Farm Project	650	2020	3400	2.210
Cover crops	400	2019	2000	0.800
Sweet Potato	470	2019	2927	1.376
Nursery	510	TBD		
Row Crops	430	TBD		
Avocado	275	2019/2020	2773	0.763
Macadamia nut	1000	2019/2020	300	0.300
Dragon Fruit	25	2020	522	0.013
Guava	20	2019/2020	625	0.013
Lilikoi	35	2019	18	0.001
Papaya	15	2020	8690	0.130
White Pineapple	3	2019	3037	0.009
Total	5858			10.6

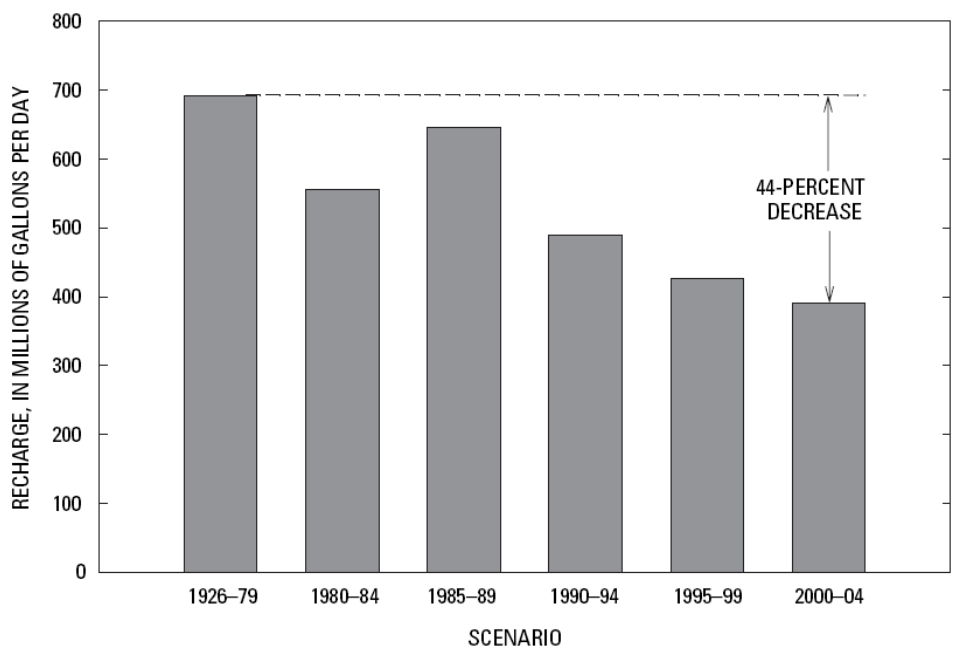
Figure 14-2. 2015 Baseline Agricultural Land Use map for the Oopuola hydrologic unit, Maui. (Source: (Perroy et al. 2016)



Modifications of Ditch Systems and Groundwater Recharge

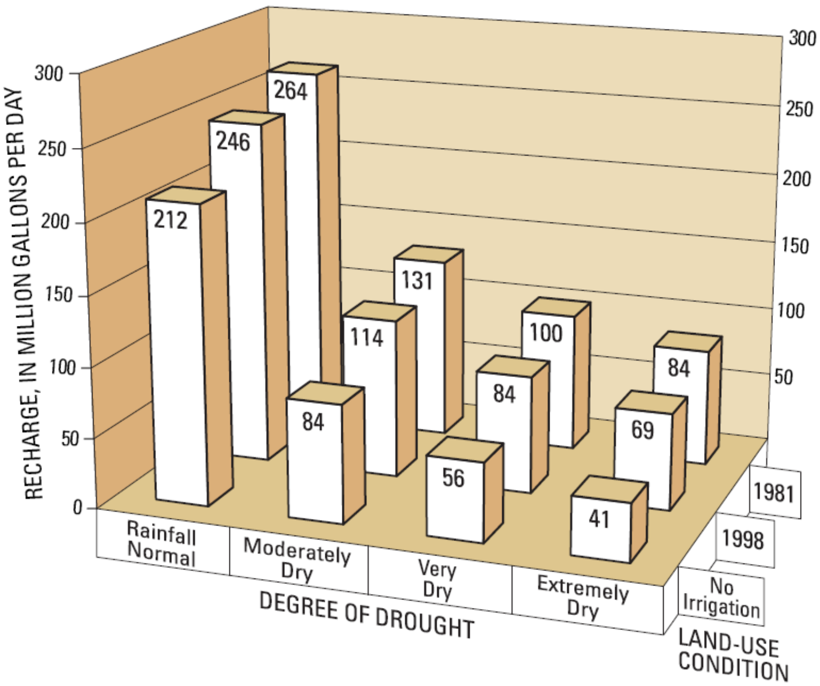
Following the establishment of instream flow standards, one of the proposed measures to increase streamflow may be to decrease the amount of water diverted from streams. Such a measure has important implications to groundwater recharge because it affects the amount of water available for irrigation. The effects of irrigation water on ground water recharge can be analyzed using the water budget equation[5]. 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 14-5). 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 (Figure 14-6). Droughts, or periods of lower than average rainfall, have been shown to drastically decrease ground water recharge. 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).

Figure 14-3. Estimated recharge for six historical periods between 1926 and 2004, central and west Maui, Hawaii. (Source: Engott and Vana, 2007)



5 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 14-4. 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

In 1977, the Agricultural Lands of Importance to the State of Hawaii (ALISH) were completed by the State Department of Agriculture (HDOA), with the assistance of the Soil Conservation Service (SCS), U.S. Department of Agriculture, and the University of Hawaii College of Tropical Agriculture and Human Resources. Three classes of agriculturally important lands were established for Hawaii in conjunction with the SCS in an effort to inventory prime agricultural lands nationwide (Figure 14-5). Hawaii's effort resulted in the classification system of lands as: 1) Prime agricultural land; 2) Unique agricultural land; and 3) Other important agricultural land. Each classification was based on specific criteria such as soil characteristics, slope, flood frequency, and water supply. The ALISH was intended to serve as a long-term planning guidance for land use decisions related to important agricultural lands. As agricultural commodities changed substantially with the closure of large-scale pineapple and sugarcane in the 1980s-2000s, the HDOA funded an updated baseline study of agricultural land use (ALUM) for 2015, although once sugarcane cultivation ended in 2016, the map was not relevant for central Maui. The HDOA is currently in the process of developing agricultural incentives based on classifications of Important Agricultural Lands. The burden of maintaining a non-potable water system can be more easily supported by large private landowners which have divested interests across their assets. The EMI ditch system is completely owned by East Maui Irrigation, although some portions of it exist on land owned by the State of Hawaii (Figure 14-8).

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. The Oopuola hydrologic unit has 0.067 square miles of land designated as "other" in the classification of ALISH. The ALISH designation provides some context for the water used out of the hydrologic unit. The East Maui Irrigation System supports the water needs of agriculture throughout the central valley (Figure 14-6, Table 14-4).

Table 14-4. Agricultural Lands of Importance to the State of Hawaii owned by Mahi Pono (formerly owned by Alexander & Baldwin) in the central valley, Maui. (Source: State of Hawaii, Office of Planning, 2015g)

Type	Square miles	Acres
Prime land	2.851	1824.6
Unique land	53.377	34161.3
Unclassified land	0.01	6.4
Other lands	10.832	6932.5

East Maui Irrigation System

The presence of the EMI system adds considerable complexity to the Commission's role in weighing instream and noninstream uses. While this is largely due to the transfer of water from one hydrologic unit to another, the importance of the system to both agriculture and municipal water supply in Upcountry and Central Maui play a pivotal role in the consideration of economic impacts. The complexity of the EMI system is detailed in Table 14-5 and illustrated in Figure 14-6.

In total, the EMI system consists of 388 separate intakes, 24 miles of ditch, 50 miles of tunnel, twelve inverted siphons, and numerous small feeders, dams, intakes, pipes, and flumes (Figure 14-7). Supporting infrastructure includes 62 miles of private roads and 15 miles of telephone lines. The system primarily captures surface water from multiple watersheds in east Maui with a combined area of approximately 56,000 acres, of which 18,000 acres are owned by EMI, and the rest by the State of Hawaii (Wilcox, 1996).

Leases and water licenses have been granted in this area as early as 1876, immediately after the signing and ratification of a Reciprocity Treaty between the Kingdom of Hawaii and the United States (Kumu Pono Associates, 2001a, p.443), thus making sugar cultivation a more reliable economic prospect. At one point there were five licenses issued for this area. Two were subsequently combined, resulting in the four license areas. As the licenses expired, they were not reissued; instead, revocable permits were issued to the license holders. The intent was to eventually issue one license to cover all areas once the existing licenses had all expired (Table 14-6). The licenses, and also the subsequent revocable permits, included clauses protecting the water rights of the native tenants for domestic use, including cultivation of taro. The licenses, and subsequent revocable permits, allow the taking of surface water and development of ground water via tunneling from state land. Commission staff reviewed 20 files pertaining to the water licenses/revocable permits that are housed in the Department of Land and Natural Resources' Land Division (State of Hawaii, Land Division, 2008). Documents in those files date from 1876 to present.

Figure 14-5. Agricultural Lands of Importance to the State of Hawaii (ALISH) for the Oopuola hydrologic unit, Maui. (Source: State of Hawaii, Office of Planning, 2020j)

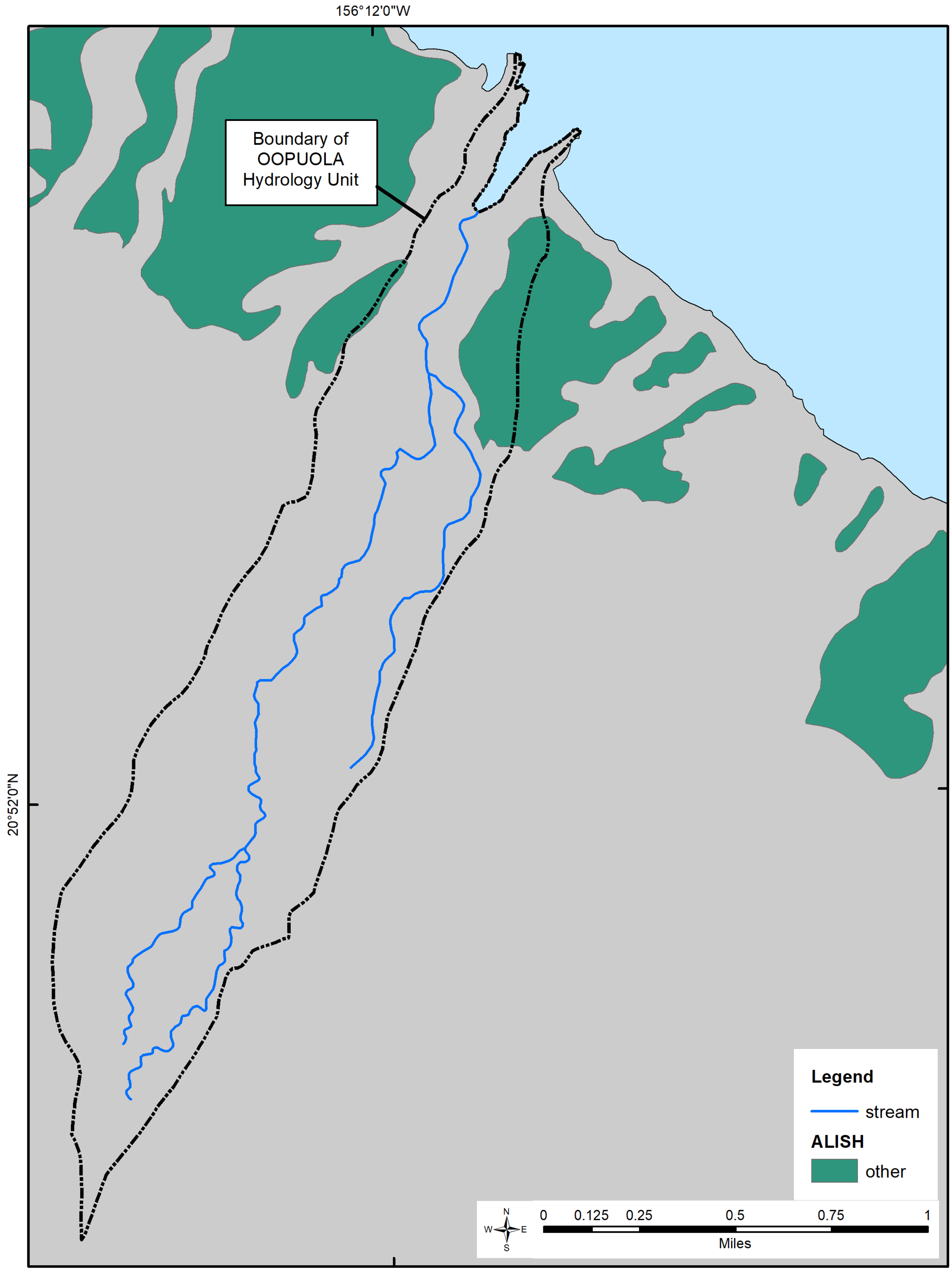


Figure 14-6. Agricultural Lands of Importance to the State of Hawaii (ALISH) designation for Alexander & Baldwin owned parcels (before sold) serviced by the East Maui Irrigation System. (Source: State of Hawaii, Office of Planning, 2020j)

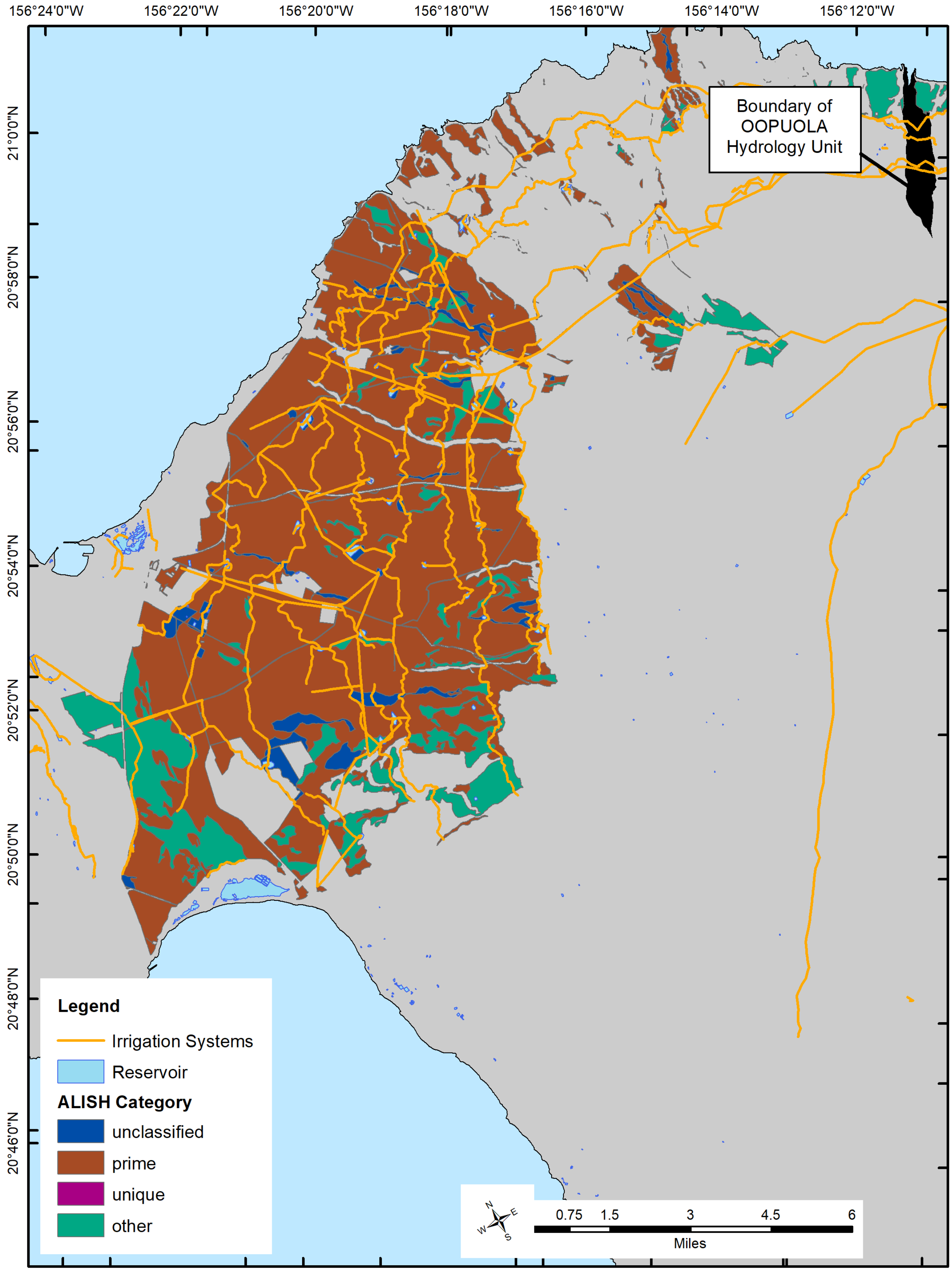


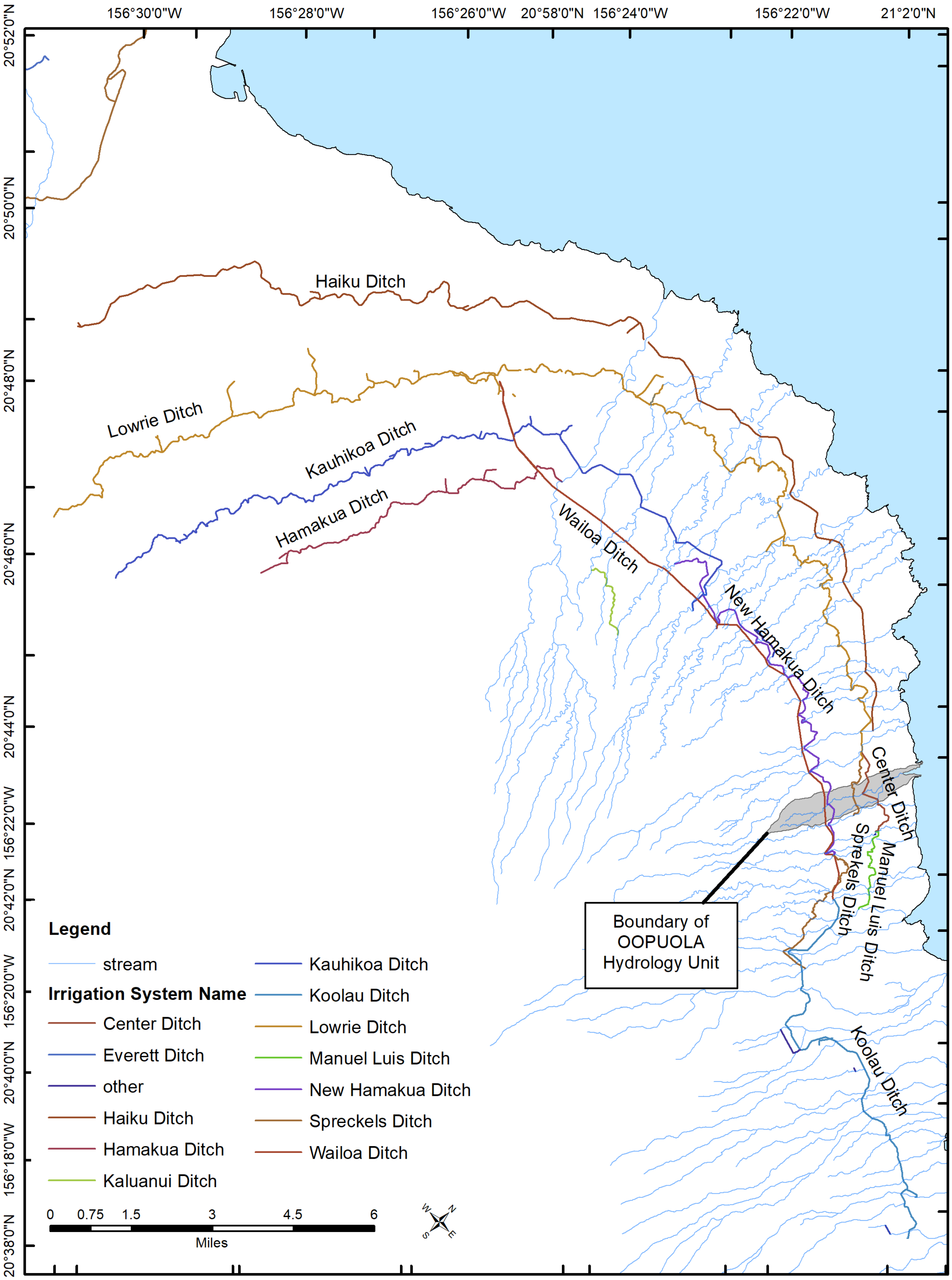
Table 14-5. Historic Timeline of the East Maui Irrigation System (Source: Wilcox, 1996)

1869	-	Samuel Alexander and Henry Baldwin partner to purchase 11.94 acres of Bush Ranch.
1876	-	Alexander and Baldwin form the Hamakua Ditch Company on Maui.
1878	-	Construction of the Hamakua Ditch is completed (not to be confused with the Upper and Lower Hamakua Ditches on the island of Hawaii).
1894	-	Alexander & Baldwin (A&B) is established as an agency.
1898	-	A&B gain control of Hawaiian Commercial & Sugar (HC&S), then become its agent shortly thereafter.
	-	Construction of Lowrie Ditch is started about this time. The Lowrie Ditch emanates from the Kailua watershed in the Makawao District, and receives water from a reservoir in Papaaea and Kailua Stream where the diversion intercepts the source of the older Haiku Ditch.
1900	-	A&B is incorporated with accumulated assets of $1.5 million, compared with a net profit of just $2,627.20 in 1895
	-	Lowrie Ditch is completed with a capacity of 60 million gallons per day and is able to irrigate 6,000 acres. The 22-mile system is 75 percent open ditch, but also includes 74 tunnels, 19 flumes, and a total of 4760 feet of siphons.
1904	-	Construction begins on Koolau Ditch, which extends the system 10 miles toward Hana.
1905	-	Koolau Ditch is completed with a capacity of 85 million gallons per day, and consists of 7.5 miles of tunnel and 2.5 miles of open ditch and flume.
1908	-	The East Maui Irrigation Company (EMI) is formed to develop and administer the surface water for all the plantations owned, controlled, or managed by A&B.
	-	A&B gains control of Kihei Plantation.
1912	-	The old Haiku Ditch is abandoned between 1912 and 1929.
1914	-	New Haiku Ditch is completed with a capacity of 100 million gallons per day. The system is mostly tunnel, partially lined, with a length of 54,044 feet.
1915	-	Kauhikoa Ditch is completed with a capacity of 110 million gallons per day and a length of 29,910 feet.
1918	-	Construction of Wailoa Ditch is started.
1923	-	Wailoa Ditch is completed with a capacity of 160 million gallons per day. The system is mostly tunnel, completely lined, with a length of 51,256 feet. Capacity was later increased to 195 million gallons per day (date unknown).

According to a collection of native traditions and historical accounts of east Maui, "While testimonies in some public hearings have expressed the sentiment that 'the waters were taken without permission'…, the initial development of the ditch system was authorized as a part of the Hawaiian Kingdom's program to promote prosperity for all the people of the Kingdom…Of importance to the native Hawaiian families of the land, each of the Water Licenses issued under the Kingdom included clauses which protected the pono wai (water rights) of native tenants of the respective lands through which the ditch system was developed (Kumu Pono Associates, 2001a, p.444)." Yet, as early as 1913, the USGS was reporting that "the present system of ditches takes practically the entire water supply of the region at times when the streams are low (Martin and Pierce, 1913, p.259).

In 1938, the "East Maui Water Agreement" was signed between the Territory of Hawaii and EMI, which by then had been incorporated (in 1908, through an Agreement between five agricultural companies) and which had consolidated the ditch system through leases of all ditches, water rights and easements, etc. (Kumu Pono Associates, 2001a, p.494). Under the terms of the East Maui Water Agreement, both parties granted to each other perpetual easements with a right to convey all waters, without charge, through any and all aqueducts owned respectively by EMI and the Territory, and over all lands owned by the two parties extending from Nahiku to Honopou inclusive. This agreement was made because the system traverses partly through government land and partly through EMI lands. Language in the Agreement allows for entities other than EMI to bid on the Water Licenses, but EMI has successfully bid on those licenses whenever they have been up for bid or renewal (State of Hawaii, Land Division, 2008).

Figure 14-7. Major ditches of the East Maui Irrigation System.



The licenses were for different terms and with different covenants, and were renewed and changed from time to time. The final terms of the licenses follow; after which revocable permits were issued. When the first of the four licenses expired, the State commissioned an appraisal to recommend rates to be charged for the Keanae License. The resulting report, published in 1972, summarizes some of the results of the 1938 Agreement. Because of the perpetual easements, "each party is assured of being able to convey its water through the aqueduct, with each paying the operation and maintenance cost in proportion to their respective use of it. So long as [EMI] is the successful bidder for all four State water licenses, it pays all the operation and maintenance costs…Subsequent to the agreement, the question of how much water was owned by each party was in effect settled by means of a study made in 1949 by Luna B. Leopold, Meteorologist…This map was used by [EMI] to determine the percentage of the rainfall on the government and private lands that are mauka of and tributary to the collection system for each of the four watersheds. It was assumed that the yields of the water collected in the aqueduct system are in proportion to the amount of rainfall on the respective land ownerships (Hull, 1972)." In other words, the ditch system collected water from both State and private lands. Ditch flow measurements were only collected at certain points, and included water originating on government as well as on private lands. In order to determine the amount of money to charge EMI for the water licenses, the State had to calculate the percentage of water in the ditch that came from government land and the percentage that came from private land (Table 14-7), and they did this using rainfall isohyets and acreage of the license areas. Those numbers were still in use as of 1972, and presumably until the end of all four water license agreements, as the other three (besides the then-recently expired Keanae License) were still in place at the time the 1972 report was published (Hull, 1972).

Table 14-6. Terms of last license, before they became revocable permits

License area	General Lease number	Term
Huelo	GL 3578	1960-1981
Honomanu	GL 3695	1962-1986
Keanae	GL 3349	1950-1971
Nahiku	GL 3505	1955-1976

Table 14-7. Percentage of water yield from the four license areas (as of 1972).

Watershed	Government (%)	Private (%)
Huelo	64.49	35.53
Honomanu	47.39	52.61
Keanae	79.19	20.81
Nahiku	95.02	4.98

The correspondence and discussions over the course of many years indicate that the water was viewed as a commodity and that water permitted to flow into the ocean was considered waste. Originally the rates charged for the water licenses were low, to allow for construction costs. For many years after construction, lease amounts were determined according to the price of sugar, the annual quantity of water carried through the system, and the percentages of government and private lands from which the water contributed to the system (State of Hawaii, Land Division, 2008). Water yields were measured for each license area. Rate of the licenses fluctuated with the price of sugar, but the licenses included minimum and maximum sugar prices that could be used in the calculations, e.g. if the price of sugar exceeded the price ceiling in the license, the rental rate would be frozen for the remainder of the license period, using that maximum amount to calculate rent. The terms of the long-term licenses were renegotiated at the expiration of the license period, i.e. roughly every 20-35 years. Under the long-term lease, A&B was required to pay for a minimal take of water even if it was not available due to low flow, or not necessary due to high rainfall on the plantations (State of Hawaii, Land Division, 2008 and Hull, 1972).

Water yield is no longer measured per license area; flow for all four license areas is totaled at the Honopou Boundary. Total water supply is classified either as water runoff from EMI land or water runoff from State-owned land. The water license areas are shown in Figure 14-8, along with other large landowners (Figure 14-9).

In 1965, HRS 171-58, as amended, required water rights to be leased through public auction or permitted on a month-to-month basis up to one year. The existing leases were grandfathered until their expiration. As mentioned above, the last water license agreement expired in 1986, after which all four license areas were disposed of as month-to-month revocable permits that were renewed annually, alternating in issuance to EMI and A&B. A&B proposed the consolidation of the four leases into a single lease, and in 1985 the Land Board approved a public auction sale for a 30-year water license incorporating the four licenses into a single license. In 1986, Native Hawaiian Legal Corporation (NHLC) challenged the Department of Land and Natural Resources (DLNR)'s decision that an Environmental Impact Statement (EIS) was not required and an Environmental Assessment (EA) was sufficient for the issuance of the 30-year lease. The Circuit Court agreed that an EA was adequate, and NHLC appealed to the Supreme Court, who remanded back to Circuit Court to conduct a hearing pursuant to HRS section 343-7(b) on the matter. Further discussions resulted in several decisions, including that the Board of Land and Natural Resources (BLNR) and DLNR must work towards long-term resolution; and that interested parties work together to develop a watershed management plan for the water lease areas. The latter resulted in the creation of the East Maui Watershed Partnership and development of the East Maui Watershed Management Plan.

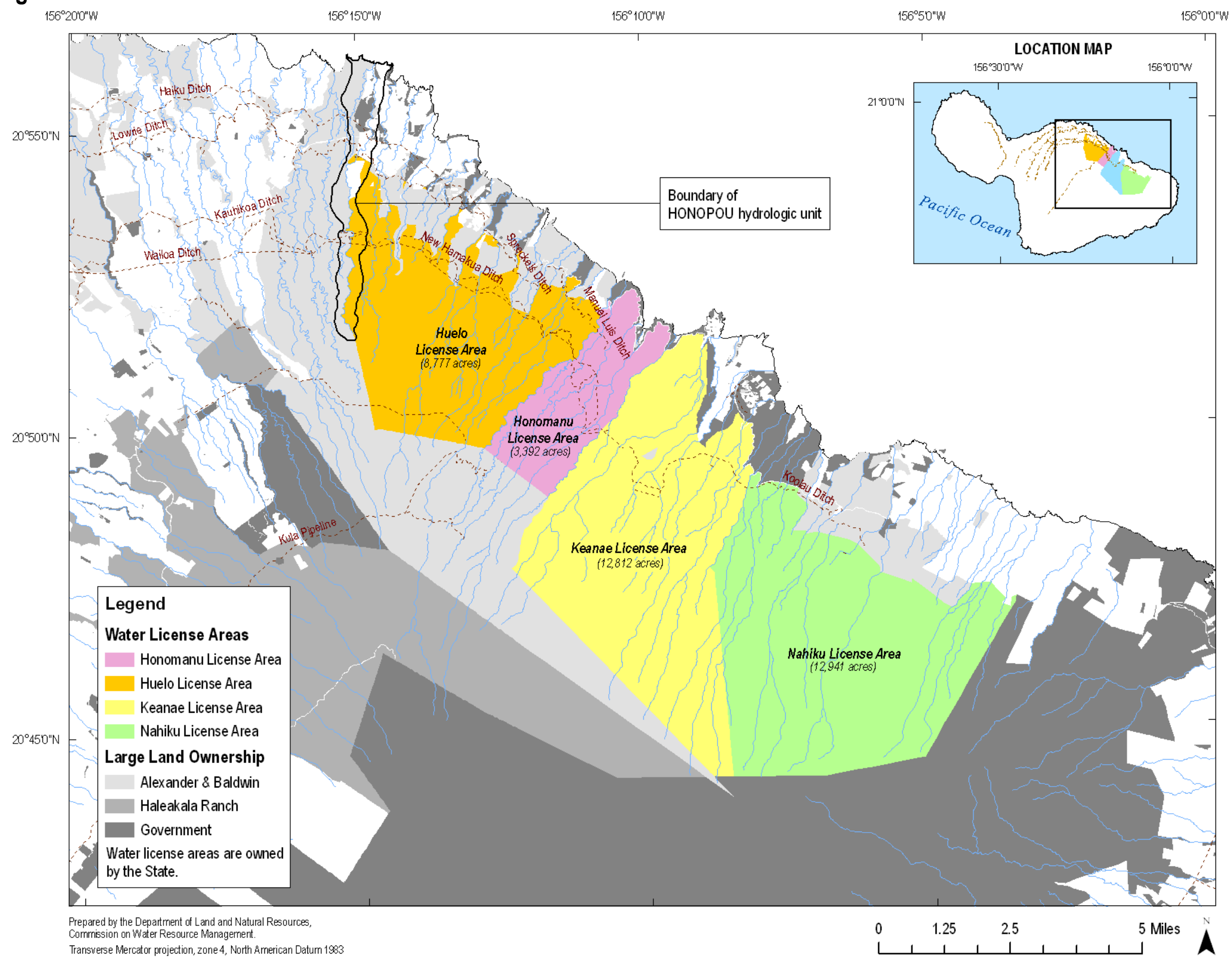
In 1987, the rate structure of the revocable permits was altered to a fixed flat fee independent of the amount of water diverted by A&B, and the rates were reduced by 25% to discount for the uncertainty that the annual permits would be renewed. However, the payments after 1987 were increased by 25% to remove the discount and convert the rates to long-term lease rentals. In 1988, the State performed an independent audit and set the benchmark rate based on the audit rate of five dollars per million gallons. In fiscal year 1999-2000, the permits were issued to A&B and EMI, with the fixed rates based on an assumed annual flow. The current revocable permits state that their rates are based on a staff appraisal dated May 7, 2001.

The revocable permits are currently regulated by the DLNR's Land Division, which collects fees for the permits. Those permits were most recently renewed in November 2018, with the following rental payments for 2019:

Table 14-8. Current revocable permits issued to A&B/EMI in 2019.

Revocable Permit No.	License Area	Area (acres)	Monthly Rent in 2019
S-7263	Honomanu	3,381.00	$2478.15
S-7264	Huelo	8,752.69	$9613.65
S-7265	Keanae	10,768.00	$5073.15
S-7266	Nahiku	10,111.22	$2082.07

Figure 14-8. East Maui Water License Areas.



In May 2001, A&B and EMI filed an Application for a Long Term Water License with the BLNR seeking a long-term 30-year lease rather than continue with year-to-year revocable permits. Shortly thereafter, Na Moku Aupuni O Koolau Hui, Inc. ("Na Moku") and Maui Tomorrow requested a contested case hearing, with NHLC filing on behalf of petitioners Na Moku, Elizabeth Lapenia, Beatrice Kekahuna, and Marjorie Wallett. (In May 2007, Elizabeth Lapenia withdrew from the case and is no longer represented in it.) Concurrently, the Petitioners filed with the Commission a Petition to Amend the Interim Instream Flow Standard for 27 Streams in East Maui.

In May 2002 the BLNR deferred the reissuance of interim revocable permits and granted a holdover of the existing revocable permits on a month-to-month basis pending the results of the contested case hearing. A January 2003 BLNR "Findings of Fact and Conclusions of Law and Order" indicates that the "BLNR may enter into a lease of water emanating from State lands for transfer outside of the watershed of origin provided that such lease is issued in accordance with the procedures set forth in HRS Chapter 171 and provided that all diversions of stream water shall remain subject to the Interim Instream Flow Standards set by CWRM, and to any judgment of a court of competent jurisdiction establishing appurtenant or riparian rights in favor of downstream users (p.12)." This part of the Order was reversed by Circuit Court in October 2003 and the BLNR advised that if it does not believe it has the requisite expertise, it should wait until CWRM has acted or make its own application to establish instream flows. However, the Court Order goes on to state that the BLNR cannot "rubber-stamp" any Commission determination, meaning that at any BLNR contested case hearing, any party may challenge a Commission decision "if its methodology is wrong or some other error is committed." The Order also indicates legal precedent suggests that an EA should be required for issuance of a long-term lease, and perhaps an EIS depending upon the result of the EA.

In March 2005, the Petitioners filed Motions For Summary Relief contesting the "Holdover Decision" that allowed continued renewal of the revocable permits. The motions for summary relief were denied. However, in the Order denying the motions for summary relief, the Hearings Officer indicated that an evidentiary hearing could be held upon request to determine if interim releases of water were required in order for the Board to fulfill its public trust duties pending the completion of an environmental assessment and determination of amendments to interim IFS. At an early pre-hearing conference the parties agreed the streams in issue in the evidentiary hearing concerning interim relief were Honopou, Puolua, and Hanehoi Streams in the Huelo license area, and Wailuanui, Waiokamilo, and Palauhulu Streams in Keanae. Accordingly, the evidentiary hearing was held in October and November 2005.

As mentioned above, it is not the intention of this IFSAR to enumerate all the details of the contested case; however, more detail, specifically contrasting claims by NHLC and HC&S, is provided in the recommendations to the Commissioners to amend the interim IFS.

There have been few changes to the EMI system since the Wailoa Ditch was completed in 1923. EMI continues to provide water to HC&S, which is the largest producer of raw sugar in Hawaii, and only one of two remaining sugar plantations in the state. In 2006, HC&S produced about 81 percent of the total raw sugar in Hawaii, or approximately 173,600 tons, amounting to about 3 percent of total U.S. sugar produced (A&B, 2007). HC&S also produces molasses, a by-product of sugar production, and specialty food grade sugars sold under their Maui Brand® trademark. Table 14-8 summarizes the harvest and production yields for HC&S from 2000 to 2006.

According to the Board findings in the contested case hearing regarding the east Maui water licenses, the total amount of water HC&S needs from EMI varies largely with weather and seasonal conditions, but ranges from a low of 134 million gallons per day in the winter months to a high of 268 million gallons per day during peak usage in the months of May to October (Findings of Fact, Conclusions of Law, and Decision and Order, 2007). From 2002 to 2004, HC&S received 71 percent of its water supply from EMI (surface water), while the remaining 29 percent was supplemental ground water. The EMI system was designed and constructed to take full advantage of the gravity flow of water from higher to lower elevations, thus minimizing pumping and the additional consumption of electrical power. As a result, HC&S attempts to divert the maximum possible amount of water into the EMI system at the Wailoa Ditch, which has a capacity of 195 million gallons per day.

In 2016, A&B closed the HC&S sugar plantation and then in 2018, the agricultural lands and East Maui Irrigation were sold to Mahi Pono, Inc. This new company proposes to develop a diversified agricultural plan to produce food crops for both local consumption and export.

In June 2018, the Commission issued its final Decision and Order regarding the petition to amend the interim instream flow standards for 27 streams in East Maui[6]. The Commission evaluated the best information currently available addressing the municipal water needs of Maui DWS and the reasonable and beneficial uses of water to conserve the State's agricultural land resource base and ensure the long-term availability of agricultural lands for agricultural uses, pursuant to article XI §3 of the Hawaii Constitution. As part of the Conclusions of Law, the Commission found that the current average daily

[6] https://dlnr.hawaii.gov/cwrm/newsevents/cch/cch-ma13-01/

use of 3.5 mgd at the Kula Agricultural Park and the current average daily use of 13 mgd treated at the three water treatment plants, will increase with expansion of the park and population growth (COL 93).

In addition to sugar crops, HC&S receives revenue from its sale of electricity to Maui Electric Company (MECO). The HC&S Puunene Sugar Mill continues to provide a renewable energy alternative in the form of sugar cane bagasse, a fibrous byproduct of the sugar extraction process. Bagasse is the primary fuel used in boilers to generate steam, a requirement for sugar processing and for driving steam turbine generators to produce electricity. The electricity that is not used by the sugar mill is sold to MECO for distribution. HC&S is under contract with MECO to supply, at specified rates, 12 megawatts of power from 7:00 a.m. to 9:00 p.m. daily except Sunday and 8 megawatts at all other times. The contract provides for monetary penalties if these requirements are not met by HC&S. The approximate oil savings is 44,700 barrels per year (MECO, 2008a).

HC&S also receives revenue from the delivery of water to the County of Maui Department of Water Supply's (DWS) Upcountry system and to the Haliimaile Pineapple Co (HPC). The HPC was created when Maui Gold Pineapple Co formed following the closure of Maui Land and Pineapple Co's hundred-year-old pineapple plantation. As of 2018, there were approximately 800 acres of land in Haliimaile under pineapple cultivation. The quantity of water used by the EMI system is unknown, as the pineapple fields also have their own sources of water from the Kaluanui and Opana systems.

The other major user of EMI surface water, Maui DWS, receives approximately 8.2 million gallons per day, a portion of which goes directly to the Kula Agricultural Park. Under a December 31, 1973 agreement between EMI, HC&S, and the County of Maui, EMI agreed to collect and deliver to the County 12 million gallons per 24-hour period for a term of 20 years, with an option for the County to receive an additional 4 million gallons after giving one year's written notice to EMI. Set to expire in 1993, this agreement was extended on several occasions, with the last extension expiring on April 30, 2000.

EMI currently delivers water to the County under a Memorandum of Understanding (MOU) that was executed on April 13, 2000, which provides for the County to continue to receive 12 million gallons per day from the Wailoa Ditch with an option to receive an additional 4 million gallons. However, the MOU also includes stipulations for periods of low flow, whereby the County will receive a minimum allotment of 8.2 million gallons per day while HC&S will also receive 8.2 millions gallons per day, or 9.4 million gallons per day should fire flow be required (Maui DWS, 2007b). The MOU has a term of 25 years and sets water delivery rates at $0.06 per thousand gallons. For the 2006 fiscal year, Maui DWS reported purchasing a total of 2,601 million gallons from EMI, at a cost of $156,848, which includes various other sources in addition to the Wailoa Ditch (Maui DWS, 2007a).

Irrigation Needs of Diversified Agriculture

The State of Hawaii Department of Agriculture uses a baseline irrigation rate of 3,400 gallons per acre per day (gad) to calculate the irrigation water demand for diversified agriculture. While this average may be applicable across a broad range of soil and climate conditions using particular irrigation practices with some crops, it does not help in the estimation of the actual water demands for crops frown in the field.

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 requirements (IRR) 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[7], rooting depth, and crop evapotranspiration.

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. Overall, the model is an appropriate and practical tool that can be used to assess the IRR of crops in Hawaii.

Understanding that water demand is highly site, weather, application, and crop dependent, IWREDSS can still provide a useful approximation of water needs. The simulation estimated that the IRR for various crops proposed for the central valley grown on TMK 2-3-8-003-005 (a randomly choosen parcel) ranges from 2250-3100 gallons per acre per day, depending on the drought scenario (Table 14-10). The model calculates IRR based on long-term rainfall records available at the weather stations located nearest to the fields. Thus, the estimated IRR represents an average value for given drought scenarios as opposed to average or wet year conditions. However, the estimated IRR for the relative drought year frequencies could be extrapolated to represent the highest demand scenarios. Alternatively, water demand per tree can be used based on the number of trees planted.

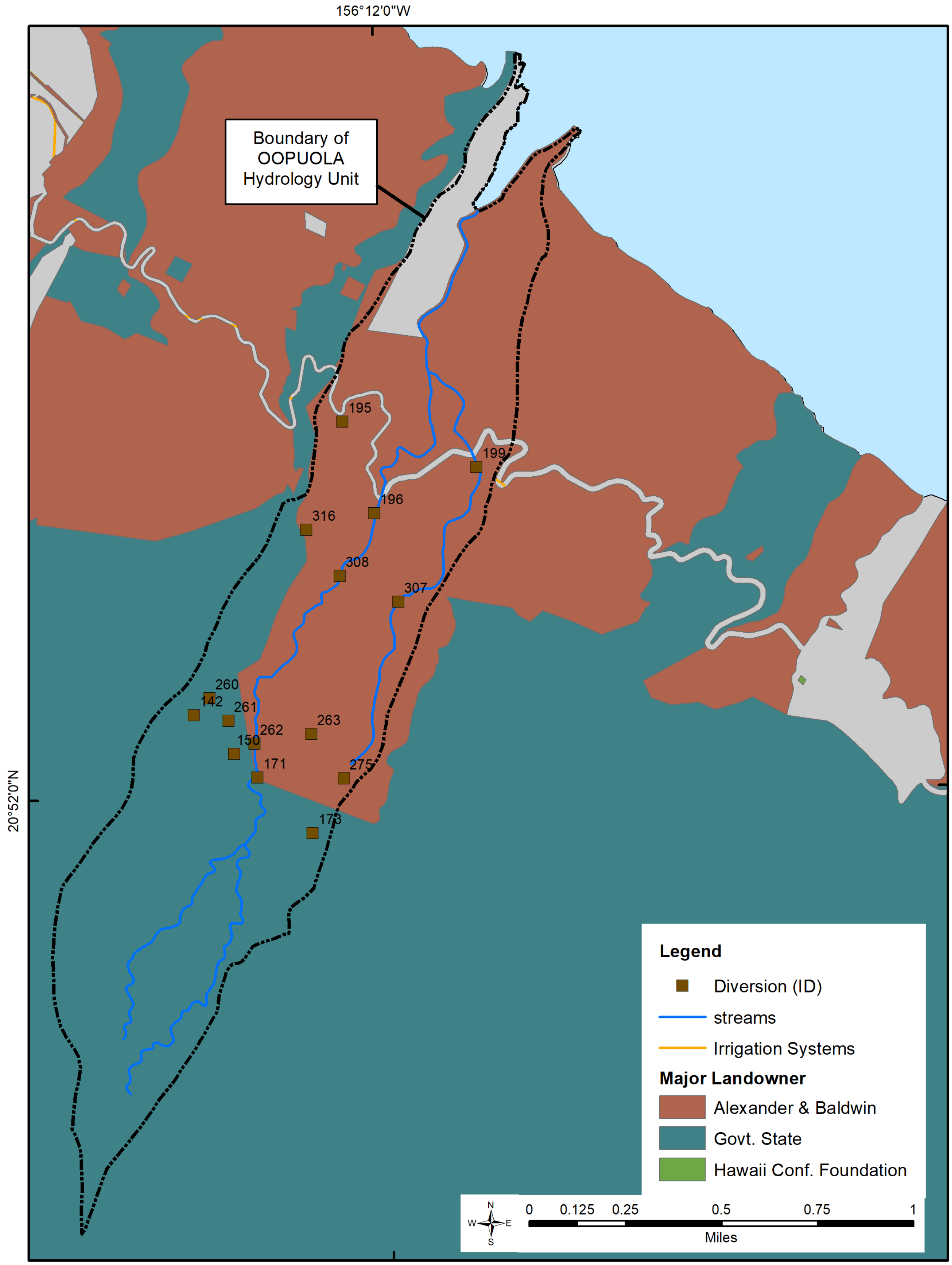
In the Commission's 2018 Decision and Order (CCH-MA-13-01), a balance of instream uses and sufficient water to meet non-instream agricultural and municipal needs was met. Based on long-term median flow estimates of water availability as well as the supply of water from non-petitioned streams, the Commission estimated that approximately 110.6 cfs (71.5 mgd) would be the median flow available for non-instream uses after 10.5 cfs were used by Maui DWS at the Kamole WTP and Kula Agricultural Park. The Draft EIS for the East Maui Water Lease[8] estimated that approximately 142.8 cfs (92.32 mgd) could be diverted while maintaining the interim IFS for use on the 22,254 acres of land designated as ALISH. Based on the IRR values for proposed crops (Table 14-9), this should be sufficient to meet the irrigation needs of the proposed diversified agricultural plan. Additional acerage (up to 36,000 acres are available) is also likely to be developed into pasture or row crops with variable water requirements.

Table 14-9. Mean drip irrigation demand estimates for various crops grown in central Maui based on IWREDSS scenarios modeled using the trickle drip irrigation method given a 10 ft depth to water table. Irrigation Requirement (IRR) value in gallons per acre per day.

		estimated irrigation demand (gallons/acre/day) for a given drought frequency			
crops	**irrigation method**	**1 in 2 (50%)**	**1 in 5 (20%)**	**1 in 10 (10%)**	**1 in 20 (5%)**
citrus	Trickle Drip	2258	2407	2474	2524
avocado	Trickle Drip	2516	2773	2891	2980
sweet potatos	Trickle Drip	2738	2927	3010	3073
coffee	Trickle Drip	2514	2741	2843	2921

[7] Crop coefficient is an empirically derived dimensionless number that relates potential evapotranspiration to the crop evapotranspiration. The coefficient is crop-specific.
[8] http://oeqc2.doh.hawaii.gov/EA_EIS_Library/2019-09-23-MA-DEIS-East-Maui-Water-Lease.pdf

Figure 14-9. Large landowners in the Oopuola hydrologic unit, Maui.



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16.0 Appendices

Appendix A ‘O‘opuola, Maui, Hawaii. June 2008. DAR Watershed Code: 64001
State of Hawaii, Department of Land and Natural Resources, Division of Aquatic Resources.

APPENDIX A

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

Atlas of Hawaiian Watersheds & Their Aquatic Resources ‘O‘opuola, Maui