

# WAIULAULA WATERSHED MANAGEMENT PLAN

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Mauna Kea Soil and Water Conservation District

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# Acronyms

ac.	acres
ALISH	Agricultural Lands of Importance to the State of Hawai'i
ASEA	Aquifer Sector Area
BMP	best management practice
CDP	community development plan
CDUA	Conservation District Use Application (DLNR)
CDUP	Conservation District Use Permit (DLNR)
CES	University of Hawai'i's Cooperative Extension Service
cfs	cubic feet per second
CNPCP	Hawai'i Coastal Nonpoint Pollution Control Program
CREP	Conservation Reserve Enhancement Program
CWDA	DOH's Critical Wastewater Disposal Areas
CWRM	Hawai'i Commission on Water Resource Management
CZM	coastal zone management
DAR	DLNR's Division of Aquatic Resources
DEM	digital elevation model
DHHL	Department of Hawaiian Homelands
DLNR	Hawai'i Department of Land and Natural Resources
DOA	Hawai'i Department of Agriculture
DOBOR	DLNR's Division of Boating and Ocean Recreation
DOH	Hawai'i Department of Health
DOT	Hawai'i Department of Transportation
DPW	Hawai'i County Department of Public Works
DWS	Hawai'i County Department of Water Supply
EA	environmental assessment
eFOTG	NRCS's electronic Field Office Technical Guide
EIS	environmental impact statement
EMC	event mean concentration
EPA	US Environmental Protection Agency
ER	enrichment ratios
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft/d	feet per day (movement of groundwater)
FUDS	Formerly Used Defense Sites
GIS	geographic information system
gpd	gallons per day
HAR	Hawai'i Administrative Rules
HBS	Bishop Museum's Hawai'i Biological Survey
HCC	Hawai'i County Code
HRS	Hawai'i Revised Statutes

HWMO	Hawai'i Wildfire Management Organization
LCC	large capacity cesspool
LID	Low Impact Development
LSB	University of Hawai'i's Land Study Bureau
LUC	Hawai'i Land Use Commission
LUPAG	Hawai'i County General Plan Land Use Pattern Allocation Guide
MG	million gallons
mgd	million gallons per day
MKSWCD	Mauna Kea Soil and Water Conservation District
MSD	marine sanitation device
MV	mass-volume (curve)
N	nitrogen
NARS	Hawai'i Natural Area Reserve System
NH <sub>4</sub>	ammonium
NPDES	National Pollutant Discharge Elimination System (permit)
NRCS	USDA's Natural Resources Conservation Service
N-SPECT	Nonpoint Source Pollution and Erosion Comparison Tool
OSDS	onsite disposal system
P	phosphorus
SCAP	CWRM's Stream Channel Alteration Permit
SLH	Session Laws of Hawaii
SMA	Special Management Area (permit)
TBD	to be determined
TMK	tax map key
TN	total nitrogen
TP	total phosphorus
TSS	total suspended sediment
UIC	Underground Injection Control (line or program)
USACOE	US Army Corps of Engineers
USCG	US Coast Guard
USDA	US Department of Agriculture
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
UST	underground storage tank
UXO	unexploded ordnance
WWMP	Wai'ula'ula Watershed Management Plan



# Executive Summary

The Wai'ula'ula Stream watershed encompasses over 18,000 acres in the South Kohala District on Hawai'i Island. The streams within this watershed flow more frequently than any other stream system in West Hawai'i, creating important habitat for the native aquatic species. The nearshore waters of Kawaihae Bay, into which Wai'ula'ula flows, provide an important nursery ground not only for the native stream fishes but also for species important to the marine recreational, subsistence, and commercial fisheries. The upper reaches of the streams also provide water for both domestic and agricultural uses.

The watershed supports a variety of land and water uses, ranging from agriculture to urban to commercial to conservation. The South Kohala District which encompasses this watershed has experienced tremendous population and residential growth over the past 20 years. Much of this growth has occurred within the watershed. In addition, the Hawai'i County General Plan projects that this area will experience significant urban and suburban expansion over the next several decades. No studies have been done on the impacts of this cumulative and ongoing development on the riparian, stream, and coral reef habitats, and stream and coastal water quality. It is generally thought that the water quality within the watershed remains good. However, water quality monitoring undertaken by the Mauna Kea Soil and Water Conservation District (MKSWCD) indicates that, in some areas and for some pollutants, State water quality standards are exceeded.

Through the Wai'ula'ula watershed management project, the MKSWCD seeks to be proactive in the management of this important watershed, focusing both on addressing existing sources of polluted runoff and threats to watershed health and preventing further degradation of the watershed resources as projected land use changes occur. The overall goal of the Wai'ula'ula watershed management plan is to maintain healthy stream and riparian environments, both in terms of water quality and habitat integrity, that sustain a healthy *mauka-makai* connection and promote community-based environmental stewardship.

Chapter 1 provides an overview of the Wai'ula'ula watershed management plan and its purpose, and describes the process used to develop the plan. MKSWCD took the leading role in developing the Wai'ula'ula Watershed Management Plan (WWMP), with significant stakeholder involvement and community input. The watershed planning process was a multi-year effort to develop relationships, educate residents of the watershed on water quality issues, and seek land users and community help to identify contributing pollution sources in the watershed and recommend specific actions needed to effectively control sources of pollution. In developing the watershed management plan, the MKSWCD consulted a number of documents for assistance, including EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA 2005), *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 1993), and *Updated Management Measures for Hawai'i's Coastal Nonpoint Pollution Control Program* (Stewart 2009).

Chapter 2 describes the natural and socio-cultural resources of the watershed. The primary tributaries of the Wai'ula'ula watershed are Waikoloa and Keanu'i'omanō streams, both of which originate at over 4,000-ft. elevation on Kohala Mountain and flow relatively parallel to one another until they join in a series of braided channels at about the 1,440-ft. elevation to form Wai'ula'ula, which terminates in the ocean in Kawaihae Bay. These streams flow year-round in their upper reaches but are intermittent in their lower reaches because of withdrawals upstream for domestic and agricultural purposes. There are permanent stream pools in the streams below Waimea that are apparently receiving some groundwater input. During storm events, stream levels and flows can increase rapidly, demonstrating the flashiness of Hawaiian streams.

The Wai'ula'ula watershed extends from the 5,260-ft. elevation on Kohala Mountain to sea level over a distance of 8.5 miles, if measured as a straight line from headwater to estuary. Because of this steepness, climate varies considerably by elevation. The upper elevations are typically wet and cool, while the coastline is hot and arid. The watershed is typically affected by a regular pattern of orographic cloud formation and precipitation. Lower reaches of the watershed typically receive most of their moisture during Kona storms and localized convection events during the winter months. Annual rainfall in the watershed varies from about 120 inches in the upper elevations to 7 inches at the coast. Drought conditions in the watershed in recent years have exacerbated the dry conditions in the lower watershed.

The lands of the Wai'ula'ula watershed comprise the geological substrates of both Kohala Mountain and Mauna Kea. This geology has implications for both soil types and hydrology. The Wai'ula'ula watershed comprises several broad types of vegetation: forest, grassland, scrub/shrub and cultivated land. With the exception of the forested headwaters, much of the watershed's vegetation has been altered over time. For the most part, plant and animal communities reflect this change.

In the Wai'ula'ula watershed, 69.4% of the lands are designated Agriculture, 21.2% Conservation, 0.5% Rural (small farms and low-density residential lots), and 8.9% Urban. Chapter 205, HRS, delegates the responsibility for zoning within the agricultural and rural districts to the counties. The urban district is entirely under county jurisdiction, and uses are controlled only by county zoning. While there is little urban or suburban development within the watershed at present, the County's Land Use Pattern Allocation Guide shows substantial areas designated for urban and suburban expansion. Lands in the Conservation District are managed by the Department of Land and Natural Resources. A permit is required prior to any use of land in the Conservation District. Conservation lands include the Kohala Watershed Forest Reserve, Pu'u o 'Umi Natural Area Reserve, and Kohala Restricted Watershed.

Chapter 2 also describes historic and current uses and the watershed's land and water resources. It also summarizes relevant authorities at the county, state and federal levels that affect the management of natural resources and regulate potential sources of polluted runoff in the watershed.

Chapter 3 provides water quality and biological data for the watershed, as well as estimations of pollutant loads. Autosamplers were used to collect stormwater runoff in three locations that was analyzed for nutrient and suspended sediment concentrations. At the Marine Dam site (where Waikoloa stream exits the high-elevation forest), the stream has relatively low concentrations of nitrate, ammonia, and orthophosphate ( $\text{PO}_4$ ). At the sampling site downstream of Waimea Town (Sandalwood site), ammonia concentrations doubled, total phosphorus concentrations (TP) more than doubled, and nitrate concentrations quadrupled. The average nitrate concentration just barely exceeded the water quality standard. The TP concentration was nearly twice the allowable amount. At the sampling site near the mouth of the watershed, total nitrogen was high, with measured concentrations nearly twice what is allowed by State water quality standards.

Nine samples of urban storm runoff were collected by taking grab samples of flowing water in parking lots, storm water running off of roads, or from pipes that collect parking lot/road runoff. All sites were located in Waimea, and samples were collected between November 2008 and April 2009. Based on this limited amount of data, it appears likely that runoff from high-use paved areas exceeds water quality criteria for sediment (by a factor of five), total phosphorus (by a factor of four), total nitrogen (by a factor of three) and nitrate (measured values are only slightly greater than the standard). These results are not surprising as urban storm runoff is usually high in sediment and nutrients.

During the period July 2006 through April 2008, the Department of Health (DOH) made frequent measurements of water quality at a number of coastal sites. Measurements in the nearshore waters of Kawaihae Bay at Wai'ula'ula were taken on 33 separate days. Comparison of measurement against the water quality standards shows that the Bay has too much ammonia (concentrations are 2.8 more than what is allowed) and too much chlorophyll (concentrations are double what is allowed). The high chlorophyll levels indicate that there is too much algae. It is likely the high ammonia levels are contributing to high excess algae. Because ammonia is rapidly converted to nitrate in the presence of oxygen, it is likely that the source of the ammonia is nearby. The measured nitrate and total nitrogen concentrations are near the standard. Total phosphorus concentrations are slightly above the standard.

“Loads” are the total amount of a pollutant that is exported from a watershed. Loads are usually measured in pounds (of Nitrogen, Phosphorus, or Sediment) per year. Existing loads can be measured, although obtaining data is very expensive. Modeling can be used to estimate loads for locations where measurements are not available. Annual loads were, therefore, estimated for this watershed management plan using NOAA's Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) model. One advantage of using a model is that it provides explicit estimates of the contributions of each landcover class. N-SPECT can also identify areas that are particularly susceptible to erosion or predict the change in loads resulting from land use changes.

The model's estimate of sediment concentration (TSS) was about 20% higher than the measured concentration at the Marine Dam autosampler and more than double the measured concentration at the lower edge of the town of Waimea. It is possible that NSPECT underestimated the amount of sediment that is re-deposited a short distance from where it was eroded. Or, it is possible that some of the RUSLE/MUSLE coefficients are not appropriate to Hawai'i. On an average annual basis, the model predicts that the nitrogen load from the watershed is approximately 23,000 kg or 1.4 kg/acre/year, while the predicted phosphorus load is 2,176 kg or 0.129 kg/acre/year (Gaut 2009). When compared to other watersheds in Hawai'i, N-SPECT produced reasonable estimates of nitrogen and phosphorus loads; however, the limited water quality data collected by autosamplers within the Wai'ula'ula watershed suggest these estimates may be high (Gaut 2009).

Assessment of ecosystem health can be based either on water quality or on biological populations. A healthy ecosystem is diverse and contains native species. Stream surveys reveal a wide array of native endemic and indigenous aquatic fish and macro-invertebrates in the watershed. According to Englund (2010), "[t]he relatively high 65% overall native aquatic insect biodiversity found within the entire Wai'ula'ula watershed is comparable to other high quality streams" (p. 12).

Chapter 4 describes the threats to the water quality of the watershed. At this time, there are insufficient data to conclusively prioritize threats by load contribution or impacts to resources. The following threats are present in the watershed:

- Nonpoint sources of pollution in the form of agriculture, urban/suburban runoff, onsite wastewater disposal systems, streambank erosion, disturbances by feral ungulates (pigs, goats), invasive plants, and atmospheric sources of nitrogen;
- Wildfire;
- Unexploded ordnance;
- Solid and hazardous waste;
- Flooding;
- Stream diversions; and
- Climate change.

The chapter describes each of these threats in detail. Addressing the effects of some of these threats is beyond the scope of this watershed management plan.

Chapter 5 describes management measures that can be implemented to achieve watershed restoration and protection goals and address the existing impairments and threats described in Chapters 3 and 4. This plan focuses efforts primarily in the riparian corridor and on the land immediately adjacent to the riparian zone because these areas most directly impact the quality of the stream and nearshore waters and habitats. The watershed management plan describes a coordinated program of effective actions to be implemented to prevent and abate polluted runoff within the watershed, as well as address other threats that have a direct impact of overall watershed health and habitat integrity.

Chapter 5 lays out watershed restoration and protection goals and objectives, as well as recommended projects and tasks to address the goals and objectives. It identifies implementing measures that will have the greatest likelihood of achieving the stated watershed goals. Under each goal, there is a brief description of the problem to be addressed, estimated pollutant load reductions expected, and a table listing criteria by which to measure success in achieving that particular goal, followed by one or more measurable objectives. Under each objective there are one or more projects to implement the objective. Under each project there is a list of tasks, which are interim measurable milestones to gauge progress toward project implementation. Worksheets for each project are provided in Appendix A, summarizing project tasks, implementation timeframe and schedule, pollutant load reduction estimates (if applicable), responsible entity and project partners, and an estimation of costs and technical assistance. Project timeframes and schedules assume a start date of 2012 for plan implementation.

<b>Goal 1: Reduce nutrient loads in the Wai'ula'ula watershed.</b>	
	<b>Objective 1a:</b> Reduce nutrient loads in agricultural runoff from Lālāmilo Farm Lots by 20% by 2019.
	<b><i>Project NUTR-1: Assist farmers in Lālāmilo Farm Lots with the development and implementation of Conservation Plans to reduce polluted runoff. This project also addresses objectives for sediment control and stormwater management.</i></b>
	<b>Objective 1b:</b> Fence 58,000-ft. of riparian corridors on Keanu'i'omanō Stream to exclude livestock from streams by 2023.
	<b><i>Project NUTR-2. Work with Parker Ranch and FR Cattle Co. to fence critical riparian areas that cattle are currently using to access water. This project will also address pathogens and sediment loads from eroding streambanks caused by cattle trampling.</i></b>
	<b>Objective 1c:</b> Increase inspections and maintenance (pumping) of onsite wastewater disposal systems (OSDS) within the watershed by 20% by 2019.
	<b><i>Project NUTR-3. By 2016, educate home owners about proper operation and maintenance of OSDS and the effects of failing OSDS on water quality, public health, and environmental conditions.</i></b>
	<b><i>Project NUTR-4. Work with local realtors and lenders to establish voluntary point-of-sale inspections of OSDS in critical areas of the watershed by 2017.</i></b>
<b>Goal 2: Prevent an increase in sediment loads in the Wai'ula'ula watershed.</b>	
	<b>Objective 2a:</b> Reduce sediment loads in agricultural runoff from Lālāmilo Farm Lots by 20% by 2019.
	<b><i>Project SED-1. Assist farmers in Lālāmilo Farm Lots with the development and implementation of Conservation Plans to reduce polluted runoff. (Implement concurrently with Project NUTR-1 above.)</i></b>
	<b>Objective 2b:</b> By 2020, improve grazing efficiency as a way to prevent overgrazing and limit wildfire size to an average of 100 acres burned per year in the fire prone area between 1,200-ft. and 2,600-ft. elevation.

	<b><i>Project SED-2. By 2013, extend the Waimea Irrigation Water System from Lālāmilo Farm Lots to the rock wall at the 1,200-ft. elevation.</i></b>
	<b><i>Project SED-3. Sub-divide large paddocks in the wildfire prone area between Lālāmilo and the rock wall at 1,200-ft. elevation into smaller paddocks by 2016 to improve grazing efficiency of fine fuels.</i></b>
	<b><i>Objective 2c:</i></b> By 2016, assess 100% of the watershed's riparian corridors to identify eroding or unstable streambanks and monitor at least 10 sites over 3 years to determine annual erosion rates.
	<b><i>Project SED-4. Identify eroding and unstable streambanks and install erosion pins in representative sites to monitor annual erosion rates.</i></b>
	<b><i>Objective 2d:</i></b> Following fencing projects (FIRE-1 and FIRE-2), remove all feral goats from the lower watershed (rock wall down to the coast) by 2020.
	<b><i>Project SED-5. Remove feral goats from the lower watershed between Queen Ka'ahumanu Highway and the rock wall at the 1,200-ft. elevation by 2014.</i></b>
	<b><i>Project SED-6. Remove goats from lower watershed below Queen Ka'ahumanu Highway by 2020. This project would only occur following the fencing of this area under Project FIRE-2.</i></b>
	<b><i>Objective 2e:</i></b> By 2022, restore 25% of bare land in the watershed contributing to erosion, using techniques described in the post-fire restoration manual (Project FIRE-6).
	<b><i>Project SED-7. Identify and re-vegetate 25% of priority bare land contributing to sediment load in the watershed by 2022.</i></b>
<b>Goal 3: Reduce wildfire occurrences and associated impacts to water quality and ecosystem health.</b>	
	<b><i>Objective 3a:</i></b> Reduce size of wildfires to an average of 100 acres burned per year by 2015 in the fire prone area between Queen Ka'ahumanu Highway and 1,200-ft. elevation by using grazing to manage fine fuel loads.
	<b><i>Project FIRE-1. Fence lower watershed between Queen Ka'ahumanu Highway and the rock wall at 1,200-ft. by 2013 to manage fine fuel loads with cattle grazing.</i></b>
	<b><i>Project FIRE-2. By 2018, develop a project to reduce the fuel load in the unfenced, ungrazed area below Queen Ka'ahumanu Highway (to sea level) in consultation with land owners, Hawai'i Wildfire Management Organization, NRCS, UH Cooperative Extension Service, and possible grazers.</i></b>
	<b><i>Objective 3b:</i></b> By 2020, install measures within the watershed to facilitate rapid response by fire suppression agencies in the event of a fire start, to include reducing fuel loads in a 150-ft. to 300-ft. buffer zone around neighborhoods and along roadways by 80%.
	<b><i>Project FIRE-3. Update fire resource maps that cover the Wai'ula'ula watershed by 2012.</i></b>

	<b><i>Project FIRE-4. Facilitate development and/or update of water use and access agreements between private land owners in the Wai'ula'ula watershed and fire response agencies by 2012.</i></b>
	<b><i>Project FIRE-5. Construct and/or maintain at least 6 miles of fuel breaks by 2017 to protect residential communities in fire-prone areas from wildfire and to slow spread of fire starts along roadways in the watershed.</i></b>
	<u>Objective 3c</u> : In cooperation with HWMO, develop a post-fire restoration manual of effective practices by 2015.
	<b><i>Project FIRE-6. In cooperation with HWMO, develop a post-fire restoration manual of effective practices by 2015.</i></b>
<b>Goal 4: Reduce the volume and increase the quality of stormwater runoff in the urban and suburban areas of the Wai'ula'ula watershed.</b>	
	<u>Objective 4a</u> : By 2020, treat 70% of urban stormwater runoff that is conveyed directly into streams and 30% of stormwater conveyed to dry wells in close proximity to stream channels.
	<b><i>Project STORM-1. Install storm drain and curbside catch basin filter inserts by 2016 on priority drains/ basins that discharge directly into streams.</i></b>
	<b><i>Project STORM-2. By 2018, install catch basin filter inserts on priority dry wells that are in close proximity to streams, where stormwater carrying pollutants may rapidly seep into stream channels.</i></b>
	<u>Objective 4b</u> : Conduct semi-annual educational events to engage residential property owners in managing stormwater onsite for three years before 2016.
	<b><i>Project STORM-3. Develop and implement a public education and outreach program for residential stormwater management.</i></b>
	<u>Objective 4c</u> : Decrease volumes flowing offsite and increase treatment of stormwater from existing commercial and residential developments by 15% by 2023.
	<b><i>Project STORM-4. Upgrade existing urban runoff control structures on a priority basis.</i></b>
	<u>Objective 4d</u> : Develop written pollution prevention procedures for the operation and maintenance of existing County roads, highways, and bridges by 2019 to reduce pollutant loadings to surface waters.
	<b><i>Project STORM-5. Work with the County to formalize operations and maintenance practices for County roads, highways, and bridges by developing written guidelines.</i></b>
	<u>Objective 4e</u> : By promoting use of Low Impact Development techniques, reduce the volume of stormwater runoff conveyed offsite from new large developments by 2025 so that total runoff volumes calculated by N-SPECT modeling of land use changes do not increase as urban and suburban expansion occurs.
	<b><i>Project STORM-6. Develop and implement a LID outreach program for large landowners, developers, State and county land managers and permitting agencies, and engineering and land use planning firms by 2015.</i></b>

<b>Goal 5: Restore and enhance riparian buffers that serve as protective filters for streams in the Wai‘ula‘ula watershed.</b>	
	<b>Objective 5a:</b> By 2025, restore 25,000-ft. of stream riparian corridor to provide an adequate buffer for managing stormwater, reducing pollutant loads by 10% from current levels, protecting from property loss due to flooding and erosion, and creating healthy habitat for native aquatic species.
	<b><i>Project STREAM-1. By 2017, convert marginal agricultural lands within a 15,000-ft. length of the stream corridor into native vegetation under the Hawai‘i Conservation Resource Enhancement Program.</i></b>
	<b><i>Project STREAM-2. Conduct semi-annual educational events, including hands-on events and demonstration projects, for three years before 2016 to educate the public about the importance of riparian buffers.</i></b>
	<b><i>Project STREAM-3. Prioritize riparian buffers for restoration, and work with land owner(s) to implement restoration project(s) on at least 10,000-ft. of priority stream corridors.</i></b>
	<b>Objective 5b:</b> By 2018, establish a county regulatory mechanism that specifically protects wetlands and riparian areas of perennial streams on Hawai‘i Island.
	<b><i>Project STREAM-4. Help draft policy language to enact an overlay district that explicitly protects wetlands and riparian areas.</i></b>
<b>Goal 6: Protect aquatic habitat and manage instream flows.</b>	
	<b>Objective 6a:</b> By 2021, ensure that instream flows for the streams within the Wai‘ula‘ula watershed balance permitted sustainable water use and protection of the biological, chemical, and physical integrity of these waters, and that annual diversions do not exceed half the combined flows at the Marine Dam and Kohākōhau stream gauges.
	<b><i>Project AQU-1. Work with landowners and the Water Commission to permit or remove 100% of illegal diversions by 2018.</i></b>
	<b><i>Project AQU-2. Evaluate need for specific instream flow standards for streams within the Wai‘ula‘ula watershed by 2019.</i></b>
	<b>Objective 6b:</b> Maintain or improve the current native species diversity of fish and invertebrate communities in the Wai‘ula‘ula watershed by 2025.
	<b><i>Project AQU-3. Consult with experts by 2016 to determine if existing dams and other instream structures are having a negative effect on ‘o‘opu instream migration.</i></b>
	<b><i>Project AQU-4. Prevent further introduction of invasive aquatic species into the streams and identify how to remove existing invasive species that threaten native species by 2020.</i></b>
	<b><i>Project AQU-5. By 2015, protect priority instream perennial pools that provide important habitat for native aquatic species.</i></b>
<b>Goal 7: Increase public education, understanding, and participation regarding watershed issues.</b>	



	<u>Objective 7a</u> : Increase stakeholder awareness and involvement by 15% by implementing an integrated watershed management information and education campaign by 2016.
	<b><i>Project EDUC-1: Develop/ adapt and distribute educational materials related to watershed issues to community members. The majority of these educational materials relate to projects described above.</i></b>
	<u>Objective 7b</u> : Recruit and engage volunteers to assist in at least two large community-based projects in the watershed every year beginning in 2013.
	<b><i>Project EDUC-2: Provide on-the-ground service learning opportunities for school children and community members.</i></b>
<b>Goal 8: Provide effective project administration and management to ensure long-term success.</b>	
	<u>Objective 8a</u> : Establish appropriate administrative framework by 2012 to allow for effective and timely implementation of the Wai'ula'ula watershed plan.
	<b><i>Project ADMIN-1: Hire Wai'ula'ula watershed coordinator.</i></b>
	<u>Objective 8b</u> : Implement monitoring program described in Chapter 6, following the timeframes established.
	<b><i>Project: MONIT-1: When management plan implementation begins, initiate monitoring components described in Chapter 6.</i></b>

Using best professional judgment, management actions were assessed and prioritized based on a number of criterion, including load reduction potential, acreage affected, landowner buy-in, cost, ease of implementation, and community exposure (to facilitate education and outreach). This process, described in more detail in Chapter 5, resulted in projects being placed in high, medium, and low priority levels for implementation. These priority levels translated into an implementation schedule spanning 15 years.

Chapter 6 outlines the monitoring component of the Wai'ula'ula watershed management plan. Monitoring is an essential part of watershed planning. Monitoring can identify emerging problems or document response to changes in land use or climate. Equally important, monitoring is needed to evaluate the effectiveness of implemented BMPs.

PURPOSE OF MONITORING	TYPE OF MONITORING
<b>Implementation Monitoring</b>	
Implementation monitoring determines whether the management strategies outlined in the work plan are being implemented as written.	
<b>Land Use Monitoring</b>	
Changes in land use have the potential to result in changes to water quality or integrity of riparian habitats. Such changes should be tracked and correlated with changes in baseline water quality	

PURPOSE OF MONITORING	TYPE OF MONITORING
<b>Long-Term Monitoring of Water Quality</b>	
Water quality monitoring will help identify whether new disturbances or management activities are having a negative or positive impact on water quality; measure whether there are progressive changes in water quality, either for better or for worse; evaluate, when fires occur, whether there are downstream impacts; and evaluate year-to-year variability in order to more realistically evaluate pre- and post- monitoring of BMPs.	<b>Long-Term Baseflow Monitoring</b>
	<b>Long-Term Marine Monitoring</b>
	<b>Stormflow Monitoring</b>
<b>Monitoring of Watershed Conditions</b>	
The purpose of the watershed condition monitoring is to assess the status and trend of watershed attributes to help determine if Wai'ula'ula watershed management efforts are achieving goals of maintaining and restoring a healthy watershed.	<b>Vegetation Monitoring</b>  <ul style="list-style-type: none"> <li>■ Stubble Height Monitoring</li> <li>■ Fuel Loads</li> <li>■ Vegetation Transects</li> </ul>
	<b>Stream Condition Assessment</b>
	<b>Erosion Monitoring</b>  <ul style="list-style-type: none"> <li>■ Infiltration Rates</li> <li>■ Erosion Rates</li> </ul>
	<b>Biological Surveys of Aquatic Species</b>

A detailed sampling and analysis plan that outlines parameters to be monitored, sampling location and frequency, roles and responsibilities, documentation and records, quality control requirements, and chain of custody will be developed prior to implementation of management projects.

Chapter 7 provides an extensive bibliography. The appendices provide additional information of interest. Appendix A provides stand-alone worksheets for each project, summarizing project tasks, implementation timeframe and schedule, responsible entity and project partners, and an estimation of costs and technical assistance. Appendix B describes the relevant Coastal Nonpoint Pollution Control Program management measures. Appendix C identifies EPA's nine key elements for developing an effective watershed management plan.

# Chapter 1: Introduction

The Wai'ula'ula Stream watershed encompasses over 18,000 acres in the South Kohala District on Hawai'i Island. The streams within this watershed flow more frequently than any other stream system in West Hawai'i, creating important habitat for the native aquatic species. The nearshore waters of Kawaihae Bay, into which Wai'ula'ula flows, provide an important nursery ground not only for the native stream fishes but also for species important to the marine recreational, subsistence, and commercial fisheries. The upper reaches of the streams also provide water for both domestic and agricultural uses.

The watershed supports a variety of land and water uses, ranging from agriculture to urban to commercial to conservation. The South Kohala District which encompasses this watershed has experienced tremendous population and residential growth over the past 20 years. Much of this growth has occurred within the watershed. In addition, the Hawai'i County General Plan projects that this area will experience significant urban and suburban expansion over the next several decades. No studies have been done on the impacts of this cumulative and ongoing development on the riparian, stream, and coral reef habitats, and stream and coastal water quality. It is generally thought that the water quality within the watershed remains good. However, water quality monitoring undertaken by the Mauna Kea Soil and Water Conservation District (MKSWCD) indicates that, in some areas and for some pollutants, State water quality standards are exceeded. Through the Wai'ula'ula watershed management project, the MKSWCD seeks to be proactive in the management of this important watershed, focusing both on addressing existing sources of polluted runoff and threats to watershed health and preventing further degradation of the watershed resources as projected land use changes occur.

The overall goal of the Wai'ula'ula watershed management plan is to maintain healthy stream and riparian environments, both in terms of water quality and habitat integrity, that sustain a healthy *mauka-makai* connection and promote community-based environmental stewardship.

## **1.1 Document Overview**

This watershed management plan addresses both EPA's 9 key elements for watershed-based plans and the applicable management measures for Hawai'i's coastal nonpoint pollution control program (CNPCP). Chapter 2 describes the natural and socio-cultural resources of the watershed. Chapter 3 provides water quality and biological data for the watershed, as well as estimations of pollutant loads. Chapter 4 describes the threats to the water quality of the watershed, and Chapter 5 describes management measures that can be implemented to achieve watershed restoration and protection goals and address the existing impairments and threats. Chapter 6 outlines the monitoring plan to measure effectiveness of implementation efforts.

## **1.2 Watershed Management Plan Purpose and Process Used**

The Mauna Kea Soil and Water Conservation District (MKSWCD or District) took the leading role in developing the Wai'ula'ula Watershed Management Plan (WWMP), with significant stakeholder involvement and community input. MKSWCD is a quasi-state agency established in 1955 under Chapter 180, Hawai'i Revised Statutes (HRS). Five volunteer directors administer the MKSWCD programs. The MKSWCD takes available technical, financial and educational resources and focuses them to meet the needs of the local land users for the conservation of soil, water and other related environmental resources. MKSWCD has a proven track record in developing and implementing watershed management plans. Prior to initiating the Wai'ula'ula watershed planning effort, the MKSWCD was responsible for the Pelekane Bay watershed management effort. In 2005, the MKSWCD received a contract from the Hawai'i Department of Health (DOH) supported with Section 319(h) funding to develop the WWMP and, in 2010, received additional funding through the Hawai'i Department of Land and Natural Resources (DLNR) to update the plan.

The MKSWCD directors have been responsible for overseeing the project. The directors who have been involved since the beginning of this effort include: Jim Frazier; David Fuertes; Pete Hendricks; Robby Hind; Ken Kaneshiro; Brad Lau; Chris Robb; and Jim Thain. Carolyn Stewart was hired as the watershed coordinator. She has 20 years of experience in watershed planning and polluted runoff control. Consultants Mike Donoho, Jene Michaud, and Orlando Smith assisted with the development of the watershed management plan. Margaret Fowler, MKSWCD office manager, also contributed significantly to the project. Two University of Hawai'i graduate students – Katie Gaut and James Tait – conducted their thesis work in the Wai'ula'ula watershed, providing information beneficial to the watershed planning effort.

This watershed planning process has been a multi-year effort to develop relationships, educate residents of the watershed on water quality issues, and seek land users and community help to identify contributing pollution sources in the watershed and recommend specific actions needed to effectively control sources of pollution. While a watershed advisory group was initially formed in December 2005 to provide input into the watershed management planning efforts, the MKSWCD found that attendance was generally low. There are many community organizations and committees already in existence, and people were not interested in attending yet another meeting. Instead, the MKSWCD decided to meet with existing organizations and committees and seek input that way.

Presentations were made at the following community meetings:

April 18, 2006	REEFTALK public presentation at Thelma Parker Library
December 20, 2006	Waimea Community Development Plan (CDP) Committee
March 1, 2007	Waimea Community Association
June 1, 2009	Watershed Public Event at Kahilu Theatre

A community stream cleanup was held on April 12, 2008, and watershed personnel helped Parker School teachers and students with several additional stream cleanups. Presentations were made at the local schools about the watershed, and the MKSWCD regularly participated in local community events, such as festivals and fairs.

In addition, there were numerous one-on-one meetings and site visits with land owners, land users, government personnel, school teachers, individuals, and other stakeholders to seek background information, to identify threats and sources of pollution, and to identify and discuss potential implementation projects. This regular dialogue with land owners, agency personnel, and other stakeholders helped shape the goals, objectives, and specific projects described in the WWMP. In particular, the District wanted to be sure there was “buy-in” from land users and responsible parties for the proposed projects.

Stakeholders – defined as people or groups who have a stake, or an interest, in the outcome of a project – that contributed to the planning process fall into several categories:

**Land Owners/ Leasees:**

- Department of Land and Natural Resources
- Hawai‘i County Department of Water Supply
- Parker Ranch
- KTA Shopping Center
- Parker School
- Hawai‘i Preparatory Academy
- FR Cattle Co.
- Queen Emma Land Co.
- Mauna Kea Properties
- County of Hawai‘i
- State of Hawai‘i Department of Transportation
- Various other private landowners adjacent to streams

**Government Agencies:**

- US Environmental Protection Agency
- National Oceanic and Atmospheric Administration
- US Geological Survey
- US Army
- Hawai‘i Department of Health
- Hawai‘i Department of Land and Natural Resources
- Commission on Water Resources Management
- Hawai‘i Land Based Sources of Pollution LAS
- Hawai‘i County Department of Public Works
- Hawai‘i County Department of Water Supply

**Community Groups, Organizations and Businesses:**

- Hawai'i Wildfire Management Organization
- Waimea Community Association
- Waimea Outdoor Circle
- Waimea Trails and Greenways
- Starbucks

**Educational Institutions:**

- University of Hawai'i at Hilo
- Cornell University
- Massachusetts Institute of Technology

There were a number of documents that helped guide the development of this management plan. The first is EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA 2005). While the document did not provide information to address specific issues that arise out of Hawai'i's unique environment (e.g., models, load reduction estimations, absence of data), it did provide a detailed process for building partnerships, gathering data, setting goals, and identifying management strategies. Its worksheets were particularly helpful in terms of asking the right questions of stakeholders and organizing information.

The *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 1993) and the *Updated Management Measures for Hawai'i's Coastal Nonpoint Pollution Control Program* (Stewart 2009) were used to provide direction on potential sources of polluted runoff in the watershed and on the range of management strategies available to addresses those sources. Throughout the watershed planning process, MKSWCD made every effort to incorporate relevant Coastal Nonpoint Pollution Control Program<sup>1</sup> (CNPCP) management measures into the WWMP.

In the context of the CNPCP, management measures are defined as "economically achievable measures for the control of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, and other alternatives" (EPA 1993, p. 1-5). More simply stated, each management measure can be thought of as a goal towards which the State, county, local communities, and landowners can strive in order to improve water quality.

As part of the planning process, the relevant management measures provided a starting point to help with development of goals and objectives for the Wai'ula'ula watershed, and recommended actions ("best management practices" or BMPs) to achieve those goals and

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<sup>1</sup> In 1990, the US Congress required coastal states to develop and implement coastal nonpoint pollution control programs (CNPCP) to be approved by the National Oceanic and Atmospheric Administration (NOAA) and the US Environmental Protection Agency (EPA). The CNPCP, jointly administered by Hawai'i's Coastal Zone Management (CZM) Program and the Department of Health (DOH) is designed to protect coastal waters from polluted runoff and restore impaired coastal water quality.

objectives. They were used as a checklist of sorts to ensure that all existing and potential sources of water pollution in the watershed were addressed comprehensively. Some identified threats in the watershed are not directly related to water pollution (*e.g.*, climate change, unexploded ordnance). However, they have a direct impact of overall watershed health and habitat integrity that sustains a health *mauka* to *makai* connection and ultimately contributes to nearshore water quality.

Using best professional judgment, management actions were assessed and prioritized based on a number of criterion, including load reduction potential, size of watershed effected, landowner buy-in, cost, ease of implementation, and community exposure (to facilitate education and outreach). This process, described in more detail in Chapter 5, resulted in projects being placed in high, medium, and low priority levels for implementation. These priority levels translated into an implementation schedule spanning 15 years. An adaptive management approach is recommended for plan implementation, so that as we learn from actions taken, future management strategies can be altered as necessary in response. While MKSWCD will lead the overall implementation of the management actions, a specific project lead is identified for each project described in Chapter 5 and Appendix A.

# Chapter 2: Watershed Description

## 2.1 Physical and Natural Features

### 2.1.1 Watershed Boundaries

A watershed is the land area that drains water to a stream, river, lake or ocean. These drainage areas are normally confined by topographic divides, such as ridgelines. Hawai'i's watersheds tend to be small, in comparison to Mainland systems, short in length, and steep. On the geologically-young island of Hawai'i, watersheds also tend to display simple stream networks with few tributaries and have shallow, often poorly-defined channels.

The Wai'ula'ula watershed is located in South Kohala, on the northwest coast of Hawai'i Island. According to the watershed layer in the Hawai'i State Geographic Information System (GIS), this watershed stretches from the tops of Kohala Mountain and Mauna Kea, flowing down into inner Kawaihae Bay near the Mauna Kea Beach Resort, a distance of less than 15 miles. As delineated using the island's 10-meter Digital Elevation Model (DEM), this watershed encompasses an area of about 32,000 acres or 50 square miles (Figure 1).

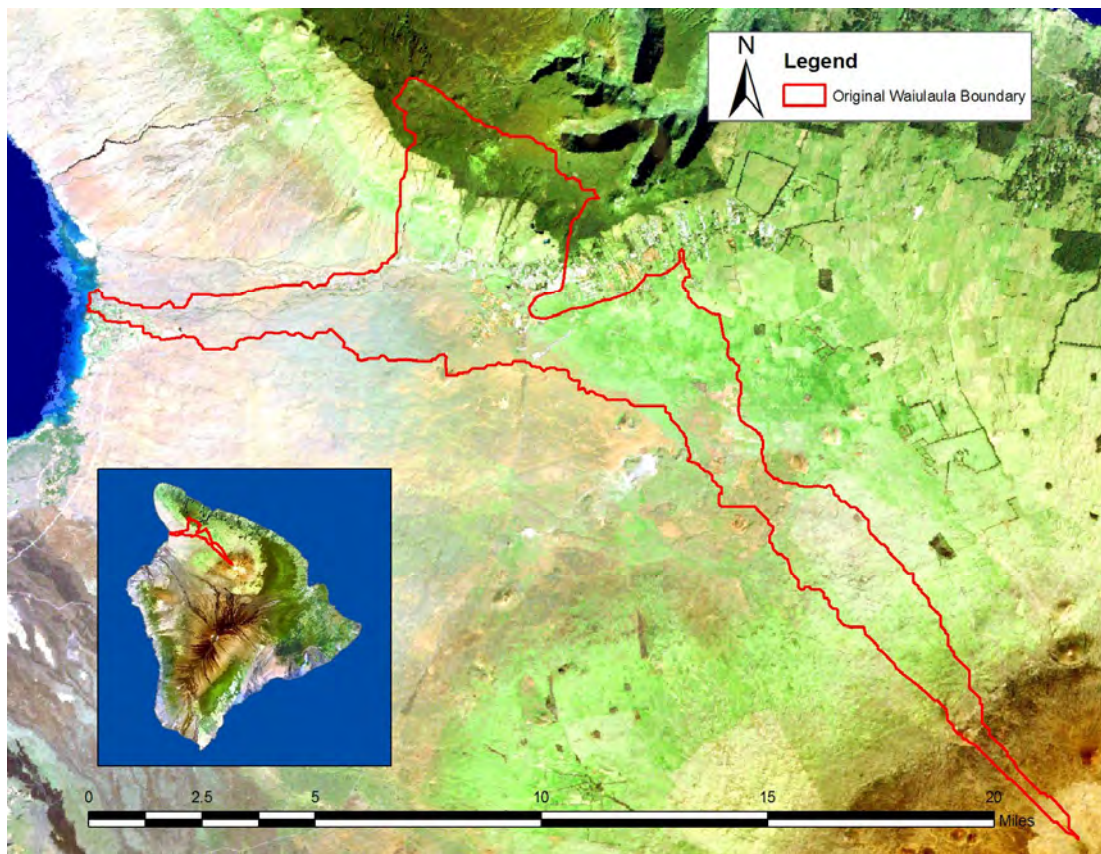
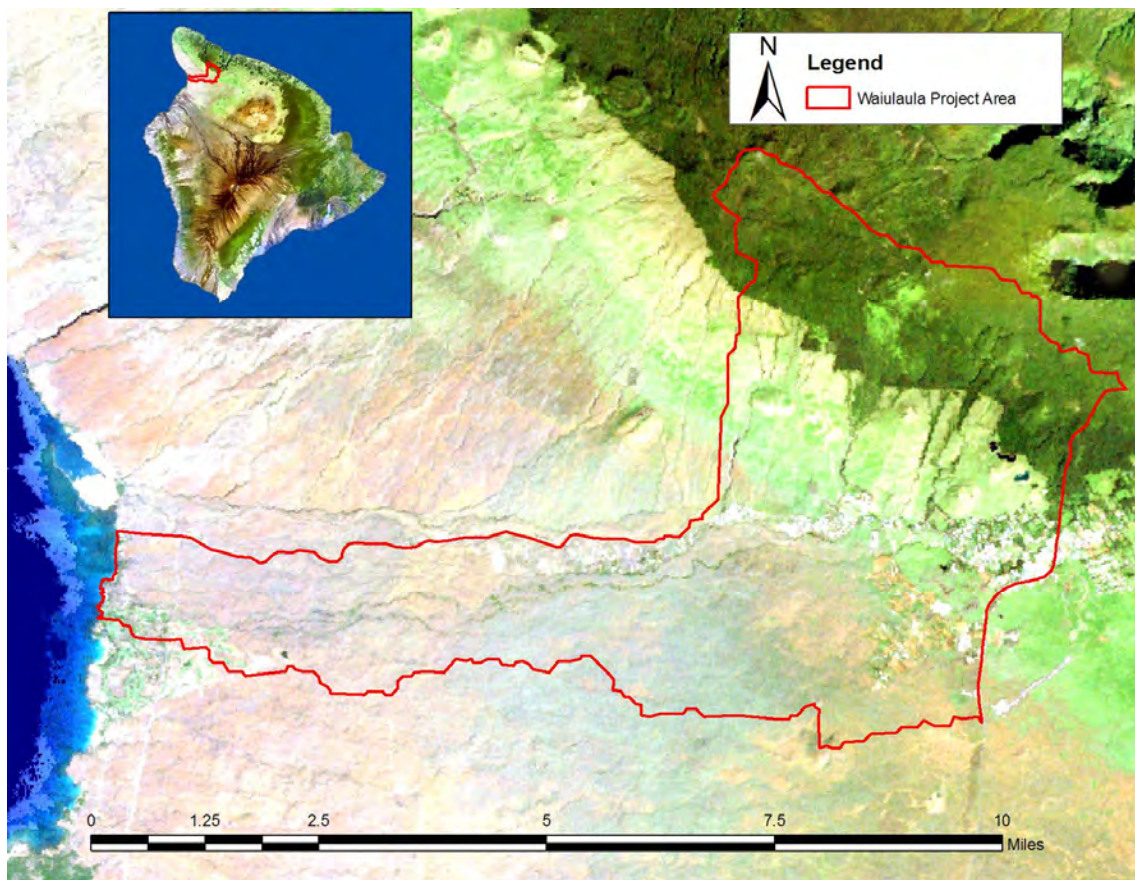


Figure 1: Original Watershed Boundary



As the Mauna Kea Soil and Water Conservation District (MKSWCD) began examining the watershed more closely, there were questions raised about the fate of runoff from the Mauna Kea “leg” of the watershed. It appears that runoff from this section of the watershed does not get into the stream systems of the watershed that outlet into Kawaihae Bay, but rather collects in the broad, flat plain of the Mauna Kea – Kohala saddle. Because the watershed boundary data would be used in the N-SPECT model to help determine pollutant loading and estimate load reductions, it was important to ensure that the MKSWCD was using appropriate watershed boundaries.

Because the MKSWCD was concerned that using the existing watershed boundary would skew modeling results, render the N-SPECT outputs meaningless, and lead the MKSWCD to focus its resources to implement management measures in an area in which it would be unable to demonstrate significant pollutant load reductions, the MKSWCD revised the watershed boundaries for the purposes of this watershed management project. For the purposes of this WWMP and project, the upper Mauna Kea boundary follows Mamalahoa Highway, thereby eliminating the Mauna Kea “leg.” The revised watershed boundary encompasses an area of 18,370 acres or 28.7 square miles (Figure 2).



**Figure 2: Revised Watershed Boundary**

### **2.1.2 Hydrology**

The hydrology of the Wai'ula'ula watershed is very complex. "Overall, the base-flow characteristics of streams are controlled by the distribution of ground water, which, in turn, is controlled by the local geologic setting and climatic conditions. Dike-impounded and perched ground-water bodies are typical sources of perennial discharge that sustain streamflow at higher elevations" (Tribble 2008 p. 13). In the Wai'ula'ula watershed, a low-permeability layer not far below the ground surface is likely causing a perched waterbody that forms the bog at the top of Kohala Mountain that provides the water for the streams. The watershed's hydrology is further complicated by high permeability geologic formations that cause base-flow to disappear from some places within streams, only to reappear further downstream. Withdrawals of water from the upper reaches of several primary streams for domestic and agricultural uses also reduce the natural flow of water downstream. At this time, because of the upstream withdrawals, the streams are generally perennial in their upper reaches but only flow in the lower reaches during storm events.

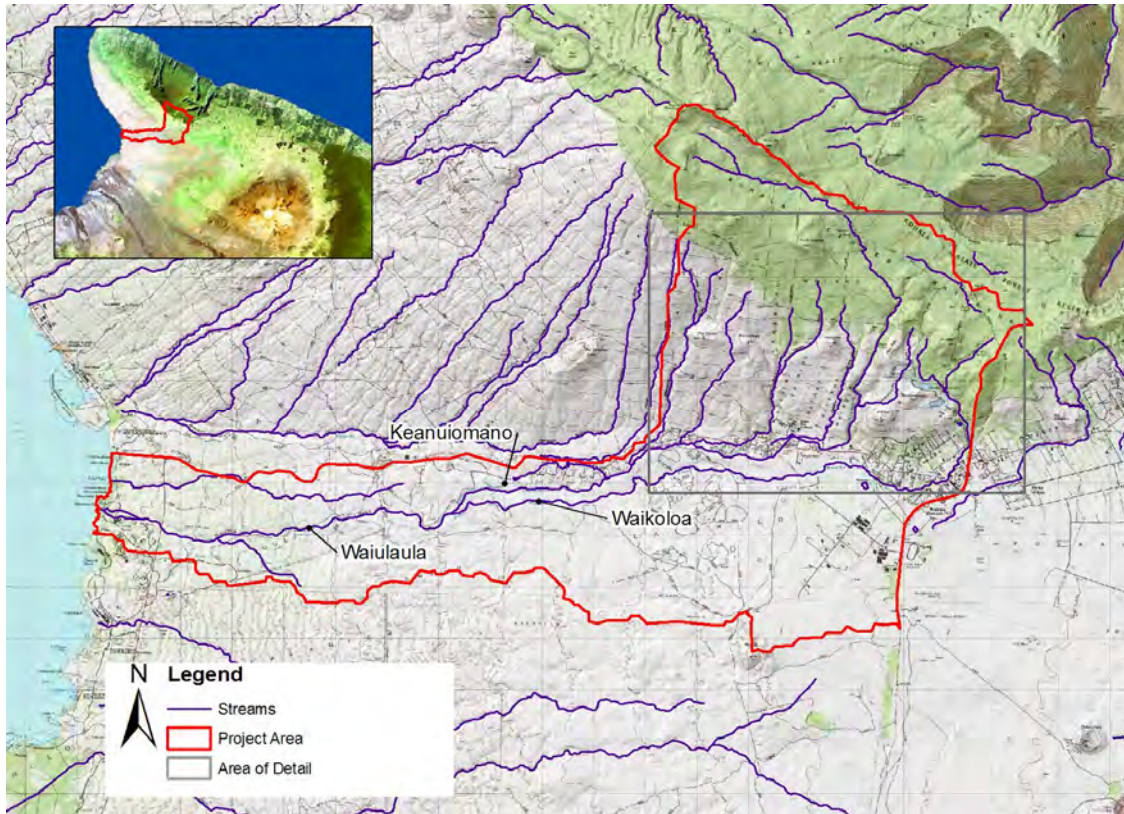
#### **2.1.2.1 Surface Water Resources**

The natural surface water resources in the watershed are limited to streams and the upland montane bogs that feed them. The upper elevations of the Wai'ula'ula watershed comprise 'ohi'a mixed shrub and 'ohi'a/'ōlapa montane wet forest types. These bogs form in areas where low permeability soil hinders drainage, causing standing water to accumulate. Hawai'i Island bogs are characterized primarily by sedges, sphagnum moss, and low-stature 'ohi'a of varying density (Cuddihy and Stone 1990). These wet forests are unique plant communities (described under Section 2.1.9) that serve as natural sponges that store water for slow release into Kohala Mountain's various stream systems.

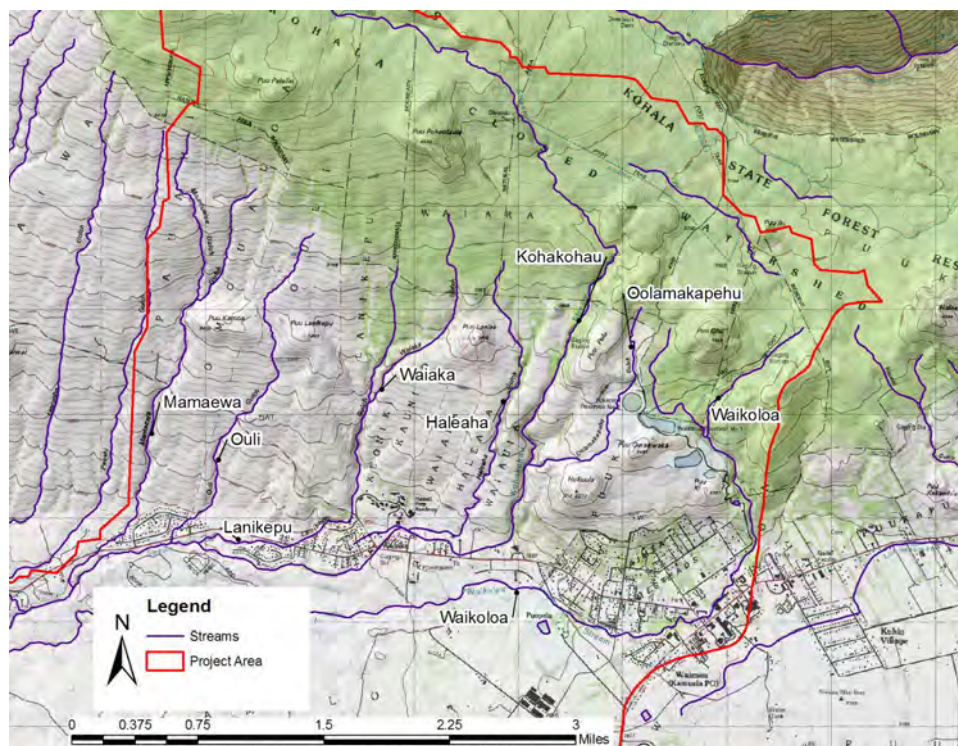
The primary tributaries of the Wai'ula'ula watershed are Waikoloa and Keanu'i'omanō streams, both of which originate at over 4,000-ft. elevation on Kohala Mountain and flow relatively parallel to one another until they join in a series of braided channels at about the 1,440-ft. elevation to form Wai'ula'ula, which terminates in the ocean in Kawaihae Bay (Figure 3). Keanu'i'omanō originates from two smaller intermittent tributaries, Wai'aka (which becomes Lanikepu Stream) and Hale'aha, as well as Kohākōhau Stream, which is considered perennial. It is called Keanu'i'omanō stream below the 2,200-ft. elevation. Two additional intermittent streams join Keanu'i'omanō just below this elevation -- 'Ōuli and Mamaewa (which includes Momoualua upslope). A small intermittent tributary of Kohākōhau stream is 'O'olāmakapehu. (See Figure 4.)

Waikoloa Stream has no tributaries. While, historically, Waikoloa Stream has been considered perennial, "it is unclear whether [it] is now intermittent, with perhaps some occasional permanent pools downstream of Waimea, because of ... numerous diversions and reservoirs" upstream (Englund *et al.* 2002). The *Hawai'i Stream Assessment* (CWRM 1990) classifies Waikoloa Stream as intermittent with year-round flow in the upper reaches and intermittent flow in the lower sections.





**Figure 3: Overview of Streams in the Watershed**



**Figure 4: Upper Tributaries of Watershed**

Wai'ula'ula Stream is considered a "losing" or influent stream, because it loses water as it flows downstream. Losing streams are common in arid landscapes. Much of the loss of its flow probably occurs in the middle to lower reaches as stream flow disappears into the alluvium. This is substantiated by the small stream channel and estuary at the ocean.

The average or "mean" annual daily flow at Waikoloa and Kohākōhau, the only streams that are currently gauged, is 9.12 cubic feet per second (cfs) (5.89 million gallons per day (mgd)) and 9.82 cfs (6.35 mgd), respectively<sup>2</sup>. However, this mean flow likely occurs only 20-30% of the time (Rick Fontaine, pers. comm.). It is probably more revealing to look at the median flow on the flow duration curves for these streams. The median daily discharge for Waikoloa stream is 4.3 cfs (2.78 mgd) and for Kohākōhau stream 2.2 cfs (1.42 mgd) (Oki 2007). Even this level of flow requires it to have rained recently (Rick Fontaine, pers. comm.). On a more typical day, streamflow in Hawaiian streams is within the 70-75% range (meaning the percentage of time discharge equaled or exceeded this amount), or between 2.5-2.8 cfs (1.62-1.81 mgd) for Waikoloa and 0.76-0.95 cfs (0.49-0.61 mgd) for Kohākōhau. The gauges on Waikoloa Stream near the Marine Dam (USGS gauge number 16758000) and Kohākōhau Stream (USGS gauge number 16756100) provide real time data accessible via the Internet.



**Waikoloa Stream near headwaters**

Maximum instantaneous flow recorded at Waikoloa Stream was 3,410 cfs in November 1979. Data available for Kohākōhau Stream since 1998 indicate a maximum instantaneous flow of 1,860 cfs recorded in March 2004. During storm events, the stream level and flow can increase

<sup>2</sup> Average ("mean") annual discharge for Waikoloa (data from 1948-2009) ranges from 3.87 cfs (1962) to 15.3 cfs (1998). Average annual discharge for Kohākōhau (data from 1999-2009) ranges from 4.51 cfs (2008) to 14.0 cfs (1999).



rapidly, demonstrating the flashiness of Hawaiian streams. There is a significant lag time between peak flow at the upper stream gauges (3,460-ft. and 3,470-ft. elevations) and the monitoring site at the mouth of Wai'ula'ula, a distance, following the stream channels, of less than 12 miles. The time it takes for water to flow this distance is on the order of 1-3 hours.

There are permanent stream pools in the streams below Waimea that are apparently receiving some groundwater input. Englund (2010) noted this, as suggested by the difference between surface and sub-surface water temperatures in the pools. He noted that these permanent groundwater-fed pools are important “stepping stones” for native aquatic fish species as they travel upstream to access the upper reaches of the watershed. During recent site visits to some of these pools, it was observed that water-loving plants, such as ferns, were growing in cracks on the rocky faces surrounding the pools, despite long-term drought conditions. Englund (2010) also noted that the presence of a large, native great bulrush 'aka'akai (*Schoenoplectus juncoide*), the roots of which provide habitat for native dragonfly larvae such as *Anax junius* and *Pantala flavescens*, appears to be “a good indicator of permanent spring-fed pool areas within the lower watershed area” (p. 7).



**Evidence of Groundwater Seepage  
Within Stream Channel**

In 2005, the Hawai'i Commission on Water Resource Management (CWRM) adopted surface water hydrologic units and a coding system for Hawai'i's watersheds, after a review of the *Hawai'i Stream Assessment* (CWRM 1990), *State Delineation of Watersheds* (GDSI 1994), and *Refinement of Hawai'i Watershed Delineations* (GDSI 1999). The majority of hydrologic unit

boundaries closely match drainage basin boundaries (CWRM 2005). The surface water hydrologic unit code is a unique combination of four digits (CWRM 2005). The first digit identifies the island and the following three digits the specific hydrologic unit. A Hawaiian geographic name or local geographic term is also used. The Wai'ula'ula watershed is identified as Waikoloa 8161. According to CWRM's *Water Resource Protection Plan* (2008), the Waikoloa surface water hydrologic unit encompasses 51.96 square miles (less with our revised boundaries), 11 diversions, 4 gauges, and 2 active gauges.

The State is in the process of establishing instream flow standards for the perennial streams, in order to balance maintenance of fish and wildlife habitat, estuarine, wetland and stream ecosystems, and water quality with use of the water (CWRM 2005). Section 13-169-46 of the Hawai'i Administrative Rules (HAR), adopted in 1988, establishes interim instream flow standards (IFS) for Hawai'i. These were generally defined as the amount of water flowing in each stream on the effective date of the standard. Standards for some individual streams have subsequently been amended as a result of petitions to amend the IFS and describe the amount of water that can be withdrawn from the stream. Specific instream flow standards have not been established for any streams within the Wai'ula'ula watershed.

#### 2.1.2.2 Groundwater Resources

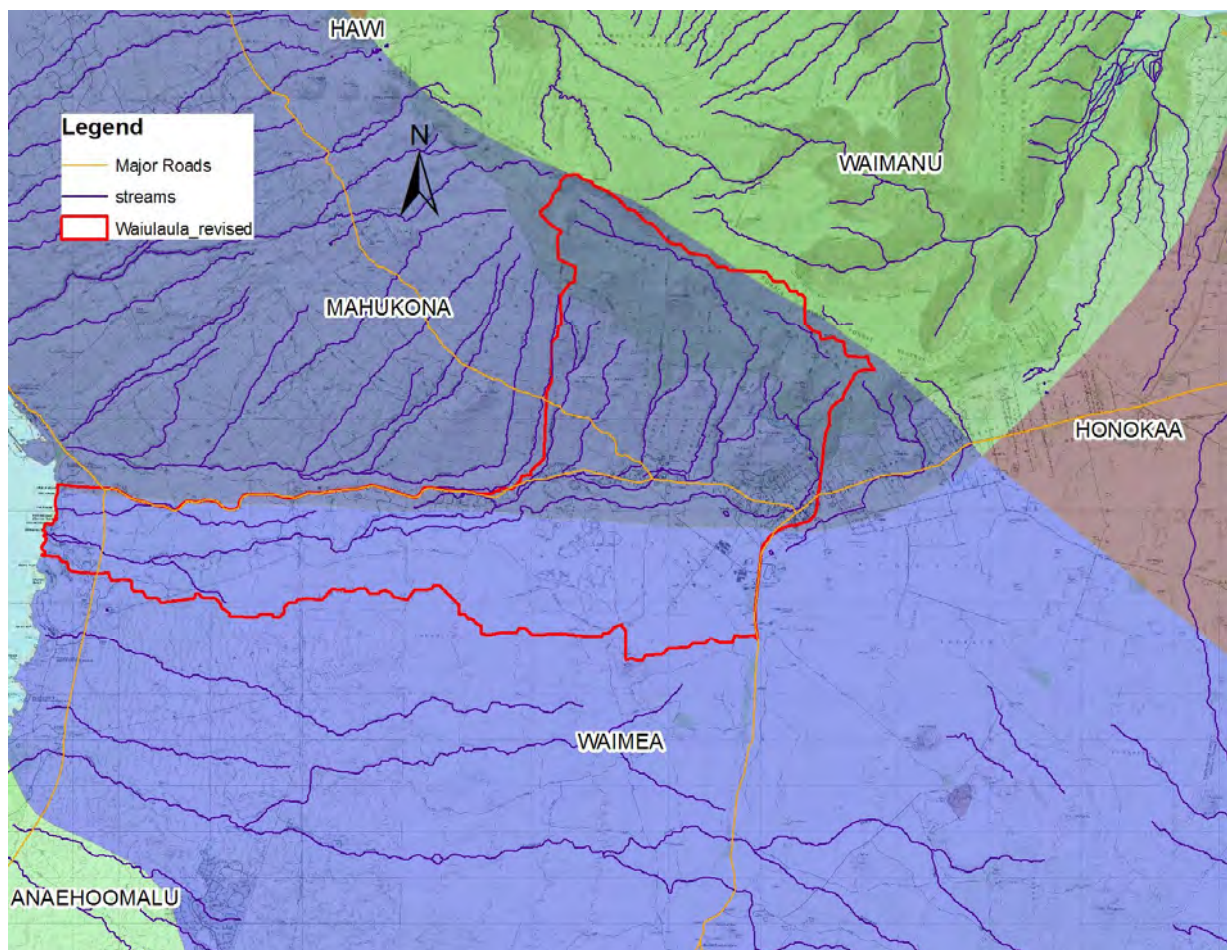
Groundwater on Hawai'i Island occurs as both a freshwater basal lens floating on denser underlying seawater near the coast and as high-level aquifers further inland impounded by lower permeability rocks. Generally, the source of freshwater in the higher elevations is groundwater recharge from infiltration of rainfall and fog drip, as well as irrigation water. The island's subsurface geology controls the movement and occurrence of groundwater (Bauer 2003). Unfortunately, this has not been as well studied as the superficial geology. In the Wai'ula'ula watershed, it is likely that lava flows from Mauna Kea overlay earlier flows from Kohala Mountain, affecting the local presence and movement of groundwater. (See Section 2.1.8 "Geology.")

As a rule, groundwater normally moves from higher elevations to lower elevations and from locations of higher pressure to locations of lower pressure. The flow rate is proportional to the slope of the water table (top surface of groundwater). This slope is known as the hydraulic gradient, which is generally expressed in feet per mile. In most cases, the direction of groundwater flow is controlled by the hydraulic gradient, but is also influenced by the direction that lava layers are dipping. Bauer (2003) reports that "[n]ormal ground-water gradients range from less than one foot per mile to greater than 3 ft. per mile in South Kohala in the Lālāmilo/'Ōuli area. Generally, steeper ground-water gradients either reflect higher rainfall and recharge or lower hydraulic conductivity" (p. 21). The hydraulic conductivity is a measure of how easily water can flow through rocks. Bauer goes on to say:

The steep ground-water gradient between 'Ōuli 1 and 2 wells... may be attributed to the lower hydraulic conductivity associated with denser and typically thicker Hawaiite lavas (and possibly mugearite, if indeed, the bottom of these wells penetrates into Kohala lavas). Because of the arid conditions of South Kohala, the steep gradient ... may be the

result of low hydraulic conductivity of the lavas rather than from direct recharge by rainfall. However, an influx of high-level ground-water from the Waimea-Kamuela region could be enough to increase the ground-water gradient (p. 21-22).

The Kohala Aquifer Sector Area (ASEA) includes the Hawi (80101), Waimanu (80102) and Māhukona (80103) aquifer system areas (see Figure 5), with an estimated total sustainable yield of 154 million gallons per day (mgd) (DWS 2006). A portion of the Wai'ula'ula watershed, including the headwaters of all its streams, falls within the Māhukona aquifer system area. The southern portion of the Wai'ula'ula watershed falls within the Waimea aquifer system (80301) in the West Mauna Kea ASEA. In addition, water from the Waimanu aquifer system area is transmitted via the Upper Hāmākua Ditch and pipelines to Waimea to provide agricultural water for the Lālāmilo farmers.



**Figure 5: Groundwater Aquifers**

In response to competition for water resources in the early 1990s and the lack of basic water level data, CWRM initiated a groundwater monitoring program in 1991. Since then, CWRM has taken groundwater elevation measurements from 40 public and private wells and test holes

throughout the North and South Kona and South Kohala districts, including from two within the Wai'ula'ula watershed ('Ōuli 1 and 2). An analysis of these data found that water levels in the basal lens vary with rainfall (Bauer 2003). The direction of groundwater flow within the basal lens was also found to vary over time. This could affect the path taken by pollutants introduced into groundwater. The data also documented declining water levels in some compartments of the high-level groundwater occurring south of Hualalai's NW rift zone. The data analysis did not examine high-level groundwater occurring in or near the Wai'ula'ula watershed, however. In addition to the wells analyzed in the Bauer report, there is one additional well that has been monitored. The Kawaihae W-3 well (6147-01; USGS 200132155471101) is at the edge of the Wai'ula'ula watershed at the 982-ft. elevation along Kawaihae Road. The USGS has measured its water levels regularly since 1975.

### **2.1.3 Climate and Precipitation**

Because of the steepness of Hawai'i's watersheds, their climates vary considerably by elevation. The upper elevations of the Wai'ula'ula watershed are typically wet and cool, while the coastline is hot and arid. The watershed is typically affected by a regular pattern of orographic cloud formation and precipitation. During typical trade wind weather, the wind blows from the northeast direction and rising moist air cools, forming clouds over the top of Kohala Mountain. The cooled clouds drop moisture in the form of rain and fog drip, keeping these upper, forested elevations wet. Fog drip is the direct interception of water from clouds or fog by vegetation. "Fog drip is likely an important contribution to the hydrologic budget in Hawai'i's forested areas frequently enveloped in clouds. This is especially true when there is little or no precipitation occurring" (CWRM 2008).



**Bog on Kohala Mountain**

The clouds formed by the typical trade wind weather rarely make it to the leeward and *makai* reaches of the watershed. These areas are typically dry and receive most of their moisture during Kona storms and localized convection events during the winter months (November to March). Drought conditions in the watershed in recent years have exacerbated the dry



conditions in the lower watershed. According to DLNR's Commission on Water Resources Management, severe drought conditions affected North Hawai'i or Kohala in 1996, 1998-1999, 2002-2003, 2007-2008, and 2010. The most severe droughts of the past 15 years are associated with El Nino events.

The *Rainfall Atlas of Hawai'i* (Giambelluca *et al.* 1986) contains monthly and annual rainfall maps for each island, which generally serve as the standard isohyet maps for use in estimating precipitation across a watershed (Figure 6). Annual rainfall in the watershed varies from about 120 inches in the upper elevations to 7 inches at the coast. In Waimea, the rainfall is highly variable, ranging between 20 and 60 inches per year.

There are two rain gauges in the watershed that are part of the National Weather Service Hydronet: KUUH1 Kamuela Upper; and KMUH1 Kamuela 1. With recent technological improvements, there are more and more weather stations being established within the watershed by individuals. Many of these can be found on Weather Underground ([www.wunderground.com](http://www.wunderground.com)). However, as a more recent phenomenon, these stations provide current and very recent weather data, but not historical.

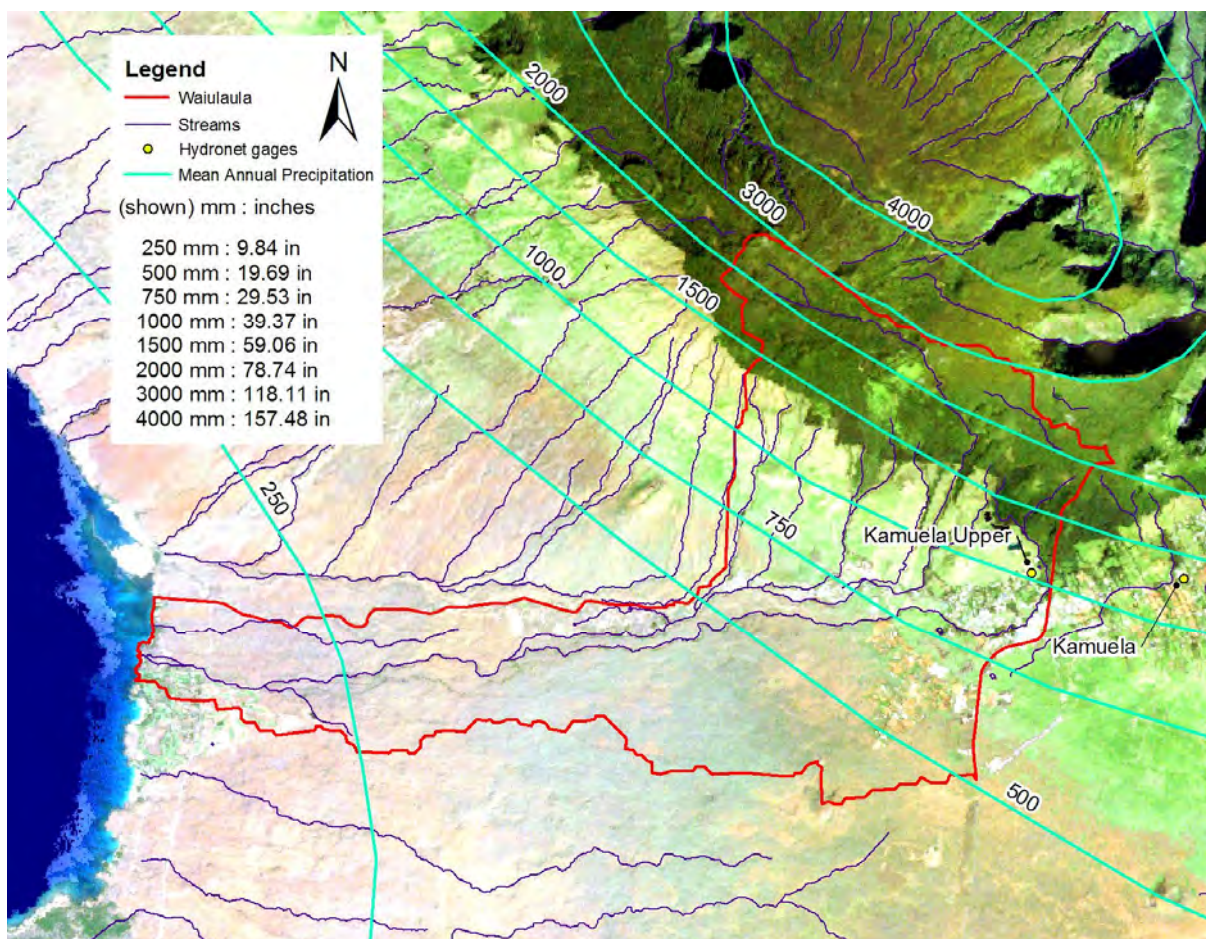


Figure 6: Annual Precipitation

As noted above, trade winds dominate the watershed area. It is during winter months that the major storms occur and the heaviest rains fall. The storms may blow in from any direction but are typically from the south, southwest, or southeast (Kona storms). *Mumuku*, fierce gusts of wind from the northeast, also blow in the watershed.

Temperatures in the watershed are also highly variable and dependent on elevation, weather and time of year. Temperatures at higher elevations are typically cooler, while the coast enjoys year-round averages of 70 to 87°F. In the Waimea area, average temperatures range from 55°F to 75°F. According to DHHL (2002), “the extreme minimum temperature recorded at Waimea is 34 °F, while the extreme maximum temperature is 90 °F” (p. 4-1).

#### **2.1.4 Flood Plains**

FEMA has developed Flood Insurance Rate Maps or FIRMs for Hawai'i Island. Figure 7 shows the flood hazard rating map for the Wai'ula'ula watershed. Zone A is the flood insurance rate zone that corresponds to the 1% annual chance floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods of analysis. This translates into the 100-year floodplain. Zone X500 corresponds to the 500-year floodplain. There is one small area within Waimea town that falls into Zone X500.

Flooding has been identified as a problem in the Wai'ula'ula watershed. Flooding of downtown Waimea and of roads crossing streams has been a particular concern. While flooding has been a reality for decades in Waimea, it has become an even greater problem as more and more development occurs within or adjacent to flood prone areas. As more impervious surfaces are created through increased urban and suburban development, these hardened surfaces prevent infiltration and generate greater volumes of stormwater runoff.



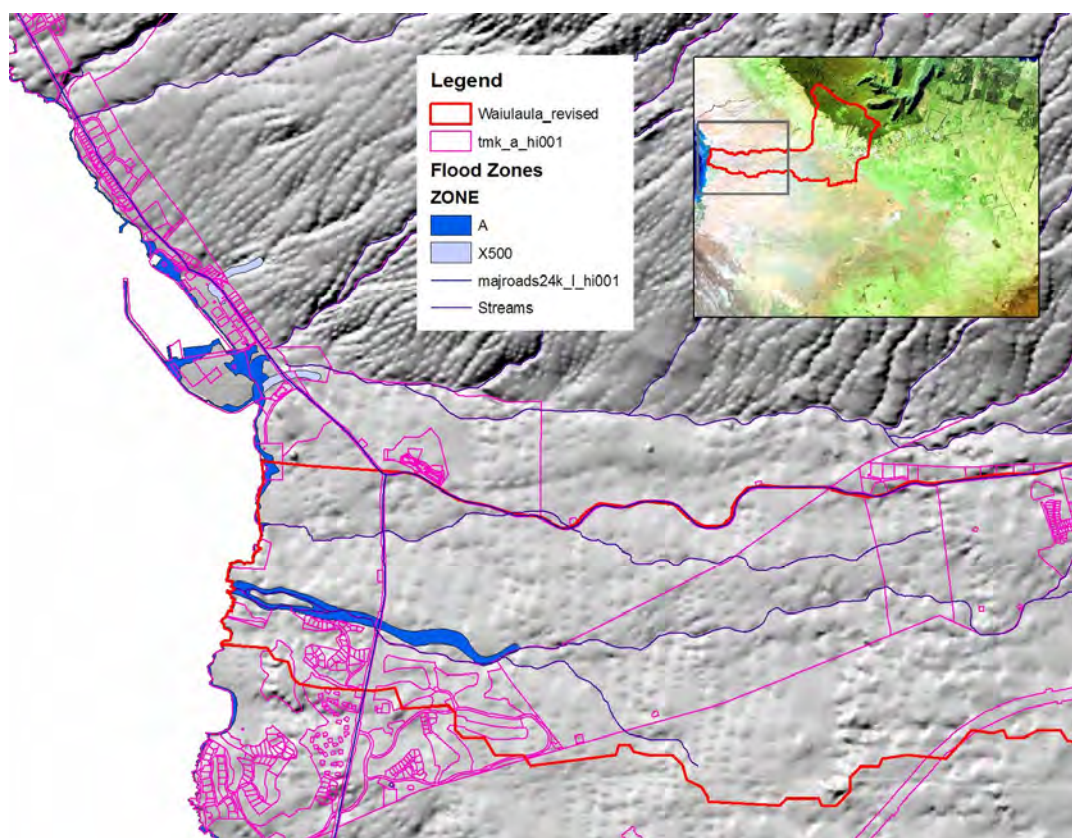
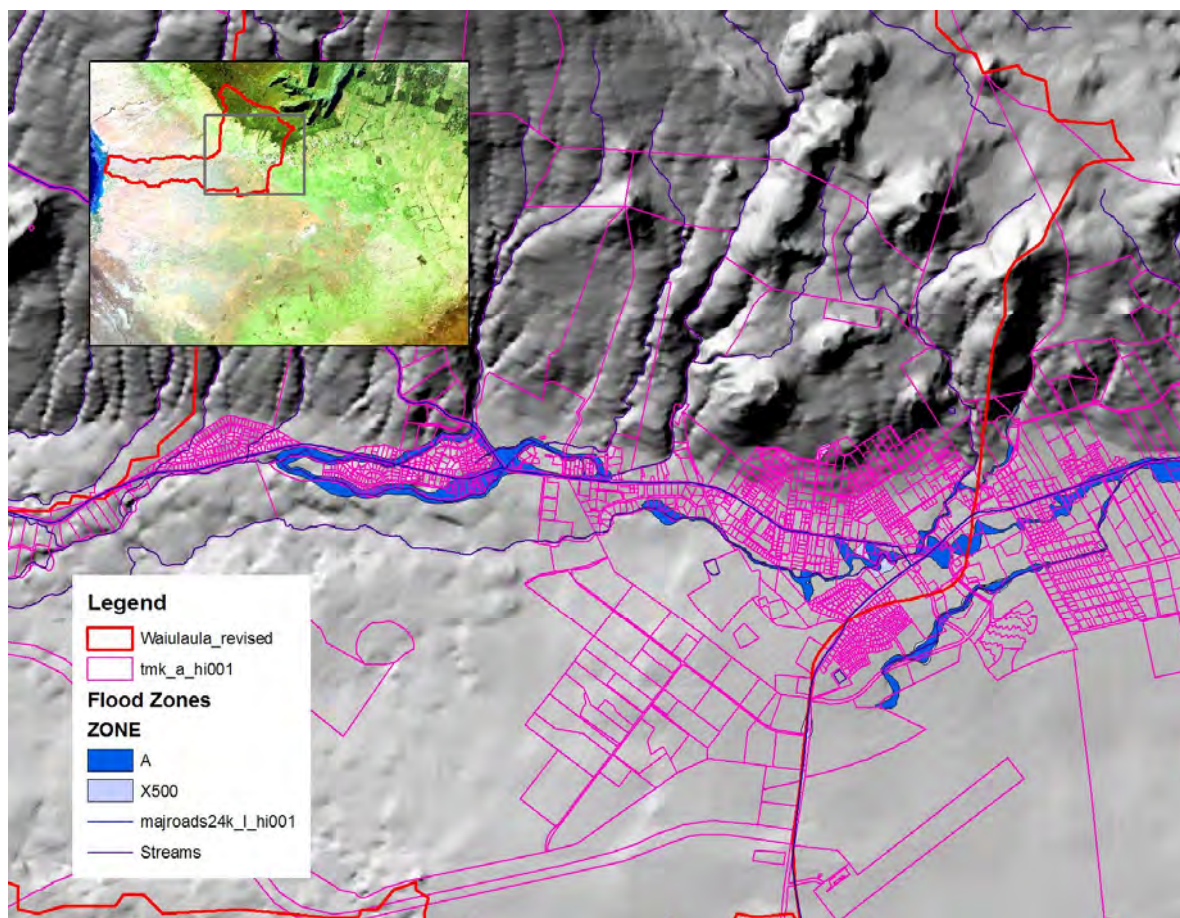


Figure 7: Flood Insurance Rate Maps for Waimea and the Coast

### **2.1.5 Riparian Areas**

Most of the streams within the Wai‘ula‘ula watershed do not have adequate vegetated buffers to intercept runoff. While fully vegetated, connected riparian corridors exist in the upper reaches of many of the streams, extensive riparian vegetation generally disappears outside of the conservation district, where land conversion to agriculture and urban/suburban development has taken place. The pockets of vegetation that exist at lower elevations often comprise invasive species, such as Christmas berry (*Schinus terebinthifolius*), that tend to grow in the stream channel itself, impeding stream flow and altering aquatic habitat.

### **2.1.6 Dams and Diversions**

There are five structures considered dams in the Wai‘ula‘ula watershed. Three of the Department of Water Supply (DWS) reservoirs above Waimea are considered dams because of the heights of the reservoir walls impounding water. There are two dams impounding water in streams, described below. Based on inventoried storage (<1000 acre-feet) and height data (<40 ft.), these dams are considered small. DWS is permitted by the State’s Water Commission to take 1.427 million gallons per day (mgd) total from its diversions at the Marine Dam and Kohākōhau Dam, which is approximately 33% of the median daily discharge of Waikoloa and Kohākōhau streams combined. The specific amount of water taken from each stream varies daily and is not measured as it is withdrawn. However, the streams in the lower watershed have become intermittent because of the numerous diversions in the upper watershed (Englund 2010).

#### **2.1.6.1 Marine Dam**

The Marine Dam is a diversion dam in Waikoloa Stream at 3,460 ft. elevation, built during World War II by the United States Engineering Department to supply water for a new military encampment of several thousand Marines that was being established in Waimea. Built in 1943, the 5-ft. high Marine Dam captured stream water into a 12-inch lightweight steel clamp-on pipeline. In 1966, the steel pipeline was replaced by a more durable 18-inch ductile iron pipe. A still basin and a cleanout were also added. The Marine Dam still serves its original function today and is a major source of drinking water for the South Kohala Water System, which provides potable water to Waimea and environs.

In 1997, the Marine Dam was officially designated an “American Water Landmark” by the American Water Works Association Water Landmark Award Committee. To receive the Landmark status, the facility must be at least 50 years old and of significant value to the community. The community has always called it the “Marine Dam” in reference to those who were originally served by this facility. This is the first neighbor island facility to receive this designation.





**Marine Dam (left) and Kohākōhau Dam (right)**

#### 2.1.6.2 Kohākōhau Dam

Planning for the development of Kohākōhau Dam started in the mid-1960s, and, by 1975, it was supplying water to Waimea and the surrounding area. This diversion dam is located on Kohākōhau Stream at the 3,470-ft. elevation. The dam is approximately 5-ft. high at the sides and 10-ft. high in the middle and about 45-ft. long. With development pressures along the Kohala and Waikoloa coasts, there was a major push to expand Kohākōhau Dam to increase its capacity. This would have required inundation of additional lands in the Kohala watershed. While strong community opposition slowed progress on the Kohākōhau Dam expansion project, the 1970s discovery and development of potable groundwater in the Lālāmilo area eased pressure to expand Kohākōhau Dam to create a larger impoundment area.

#### 2.1.6.3 Diversions

In addition to DWS's permitted diversions, there are many other legal, as well as illegal, diversions within the Wai'ula'ula watershed, withdrawing stream water from Waikoloa, Kohākōhau, and Keanu'i'omanō streams for private use. The total amount being withdrawn on an annual basis from both legal and illegal diversions is currently unknown. It is significant, however, and likely contributes to the fact that the once-perennial streams are no longer perennial in the lower reaches.

Parker Ranch is permitted by the Water Commission to withdraw 420,000 gallons per day total from three intakes on Waikoloa Stream (above the Marine Dam), Kohākōhau Stream (above Kohākōhau Stream), and Alakahi Stream (which is not in the Wai'ula'ula watershed). Most of these intakes were developed in the early 20<sup>th</sup> century and were grandfathered in when Section 13-169-46, HAR, was adopted in 1988. The Commission on Water Resources Management has also permitted diversions on Kohākōhau Stream to Perry-Fiske (operated by the State) and the State Department of Agriculture. There are seven permitted diversions on Keanu'i'omanō

Stream<sup>3</sup>, including one which diverts water from Keanu‘i‘omanō Stream via ‘Ōuli ‘auwai for use by members of the Kanehoa ‘Auwai Compact for irrigation of landscape and windbreak on eleven properties totaling 59.4 acres.

Regular site visits along Keanu‘i‘omanō Stream reveal numerous unpermitted withdrawals from the stream by residents of the Kanehoa and Anekona neighborhoods. These diversions normally consist of pipes or pumps inserted into the stream to withdraw water for storage in water tanks for use for landscape irrigation. There are at least a dozen unpermitted diversions within the watershed.



**Diversion intake in Keanu‘i‘omanō Stream**

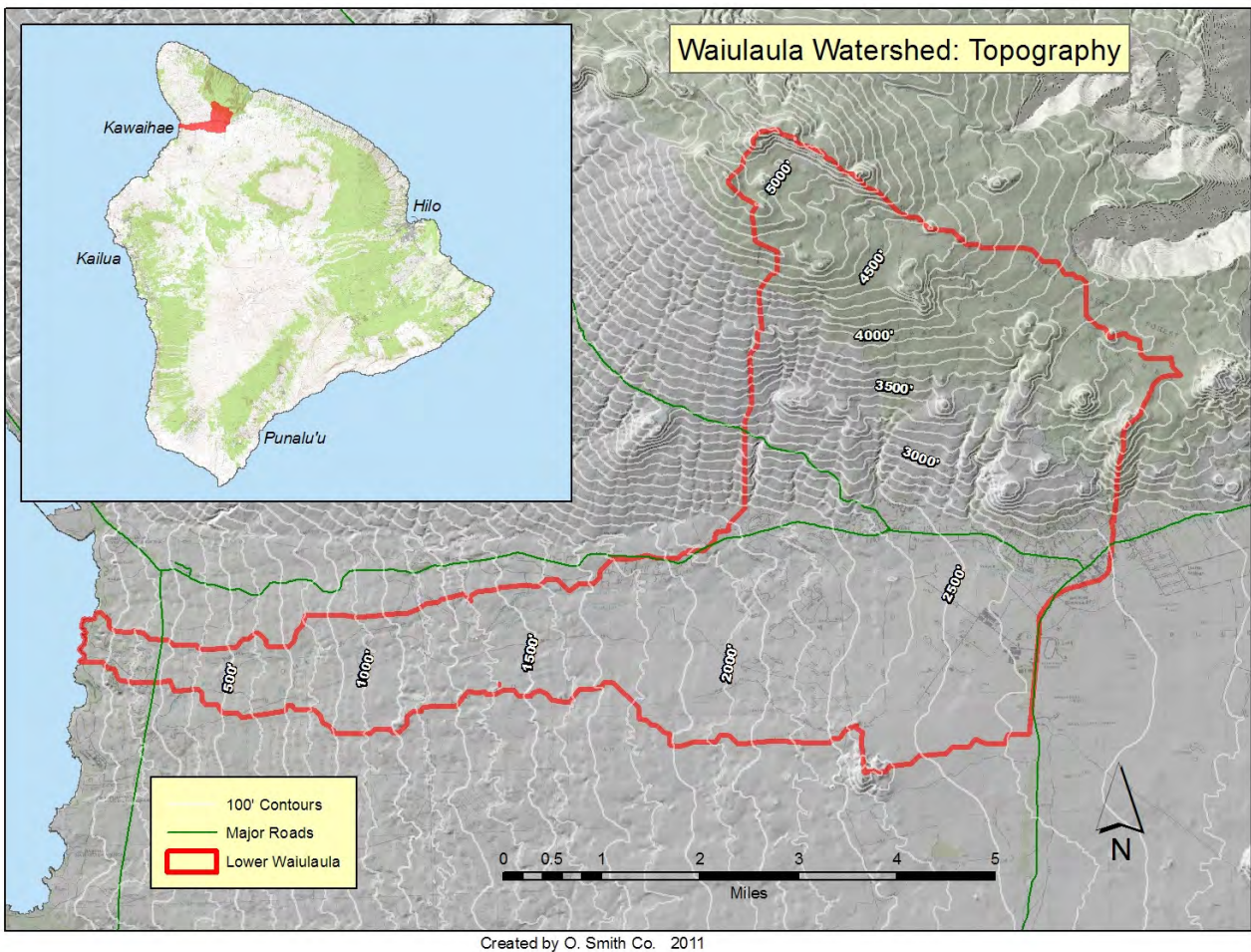
### **2.1.7 Topography and Elevation**

The Wai‘ula‘ula watershed extends from the 5,260-ft. elevation on Kohala Mountain to sea level over a distance of 8.5 miles, if measured as a straight line from headwater to estuary. The upper elevations are generally steeply sloped and bisected by deep gulches. From about 2,500-ft. in elevation, the terrain is rugged but more gently sloped. (See Figure 8.)

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<sup>3</sup> Baldwin, Jardine, Perry-Fiske, Schulze, Wallach, Giacometti, and Wasowski.





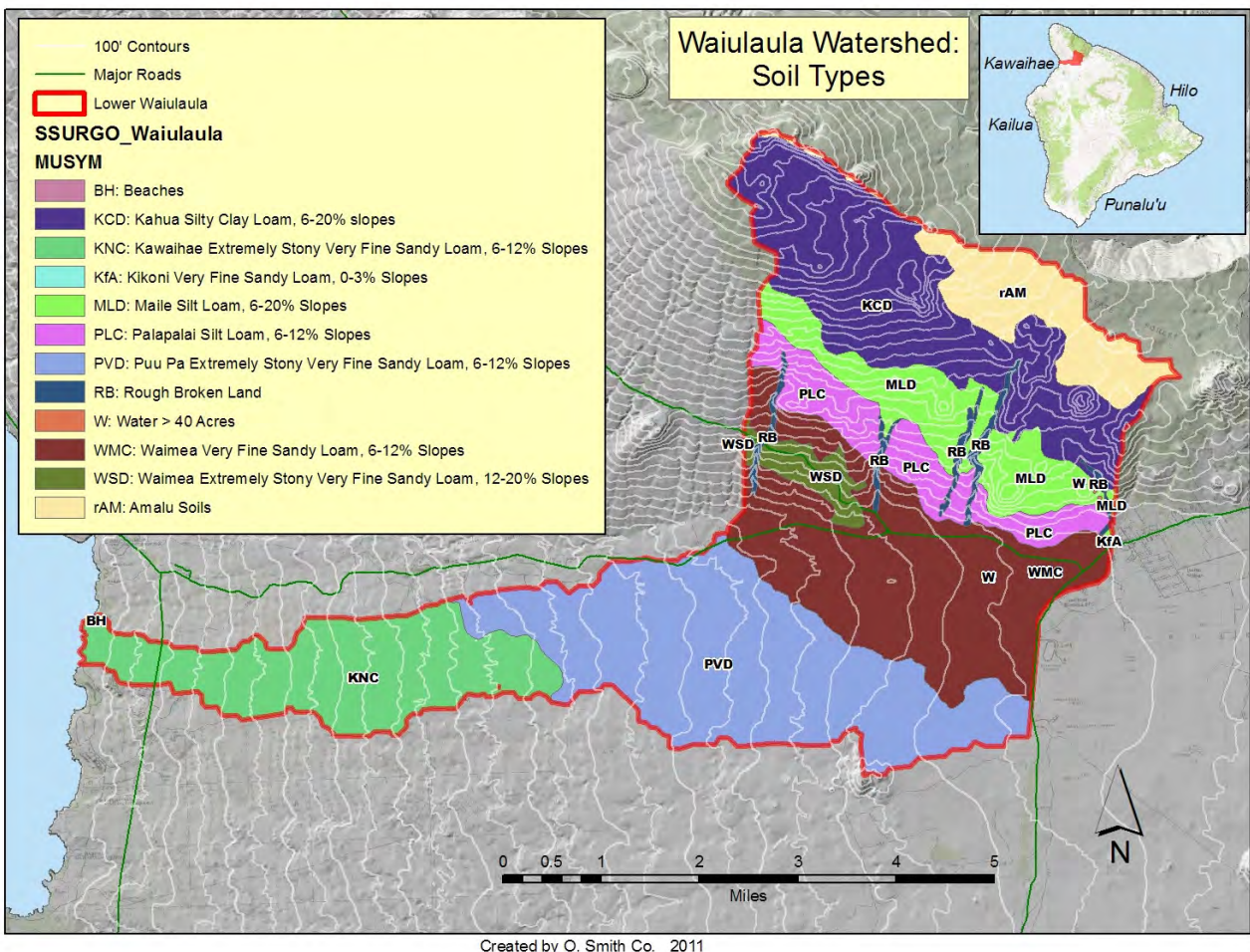
**Figure 8: Topography of the Watershed**

### **2.1.8 Geology and Soils**

The Wai‘ula‘ula watershed is located in the saddle between Kohala Mountain and Mauna Kea, where the Mauna Kea lavas ponded against the older Kohala dome (Clark 1986). As a result, the lands of the watershed comprise the geological substrates of both mountains.

Kohala is the oldest of the five volcanoes on Hawai‘i Island, emerging above sea level more than 500,000 years ago. It last erupted about 120,000 years ago in the late Pleistocene era (USGS HVO website: <http://hvo.wr.usgs.gov/volcanoes/kohala/>). “The last eruptions were moderately explosive and formed a series of large cinder cones that stud the Kohala Mountain surface above Waimea” (Macdonald *et al.* 1983: p. 353). Kohala Mountain is now considered extinct and in a transition between post-shield and erosional stages of its life cycle. In contrast to the highly eroded valleys of the windward side of Kohala Mountain, erosion has made little headway on the leeward side (Macdonald *et al.* 1983).

Mauna Kea, the tallest mountain on Hawai'i Island, is in the post-shield phase and considered dormant. It last erupted about 4,500 years ago. The oldest exposed lava flows on the mountain are about 250,000 years old. Mauna Kea's last eruptions were more explosive than those of the shield-building phase, with viscous magma containing more gas, and produced widespread ash deposits downwind of the mountain. The fertile soils in Waimea are a result of these ash deposits.



**Figure 9: Soil Types in the Watershed**

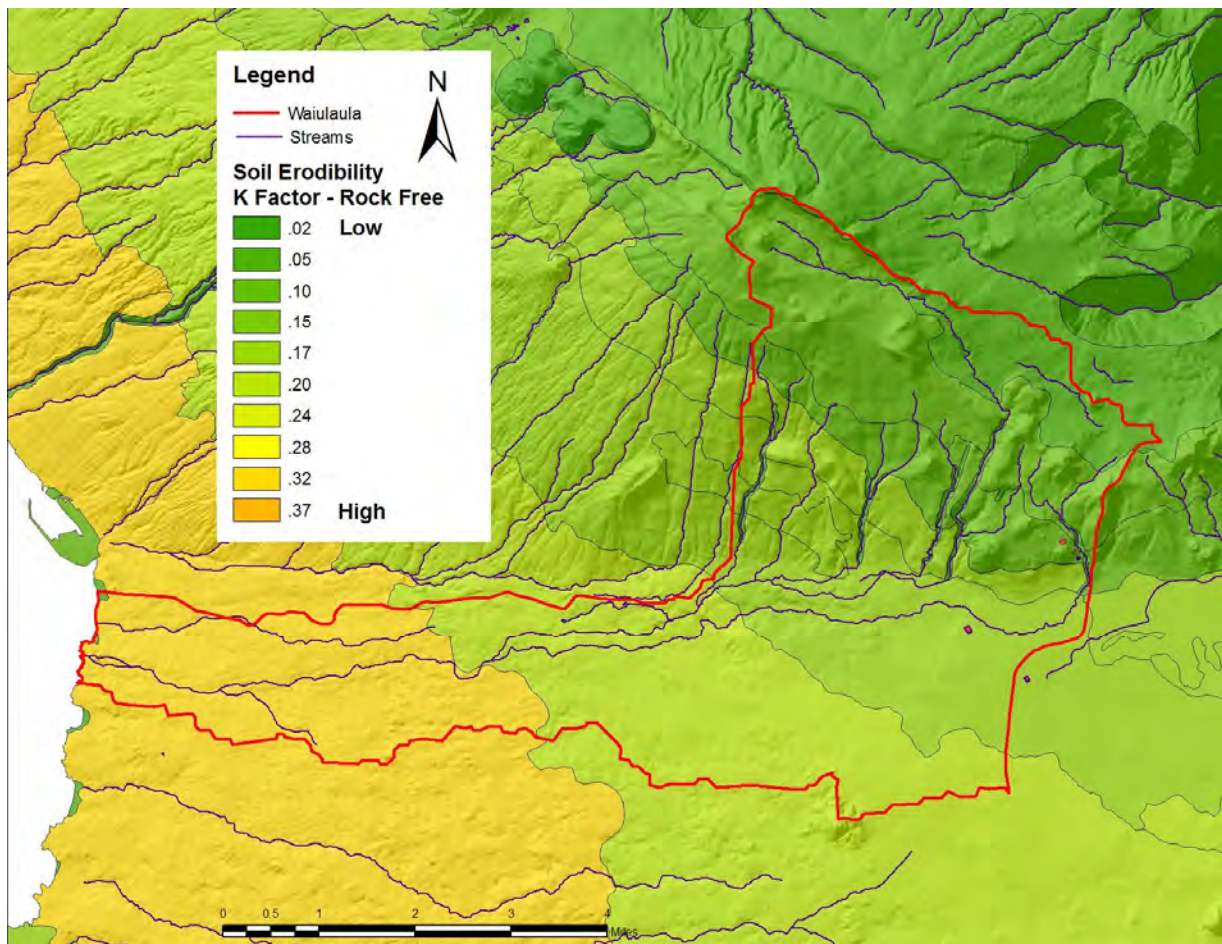
The watershed's geology has implications for both soil types and hydrology, as noted above. The geological substrate consists of lava flows of several volcanic series. The predominate soil types in the watershed are listed below and shown in Figure 9.

- Amalu (rAM) – poorly drained; 3-35% slopes; meets hydric criteria;
- Kahua (KCD) – silty clay loam, somewhat poorly drained; 6-20% slopes;
- Maile (MLD) – well drained silt loams that formed in volcanic ash; 6-20% slopes; moderately rapid permeability, slow runoff, slight erosion hazard;



- Palapalai (PLC) – well drained silt loams that formed in volcanic ash; 6-12% slopes; moderately rapid permeability, slow runoff, slight erosion hazard;
- Waimea (WMC) – well drained very fine sandy loam that formed in volcanic ash; 6-12% slopes; moderately rapid permeability, slow runoff, slight erosion hazard;
- Waimea (WSD) – well drained extremely stony very fine sandy loam that formed in volcanic ash; 12-20% slopes; moderately rapid permeability, medium runoff, moderate erosion hazard;
- Puu Pa (PVD) – well drained extremely stony very fine sandy loam that formed in volcanic ash; 6-20% slopes; moderately rapid permeability, medium runoff, moderate erosion hazard; and
- Kawaihae (KNC) – somewhat excessively drained extremely stony very fine sandy loam; 6-12% slopes; moderate permeability, medium runoff, moderate erosion hazard.

Figure 10 shows the soil erodibility. Soil erodibility is an estimate of the soil's ability to resist erosion, based on the physical characteristics of the soil. The watershed's soil erodibility is the highest in the dry, sparsely-vegetated and fire-prone lower watershed, greatly increasing the risk of erosion from this area.



**Figure 10: Soil Erodibility**

### **2.1.9 Vegetation**

The Wai'ula'ula watershed comprises several broad types of vegetation: forest, grassland, scrub/shrub and cultivated land. With the exception of the forested headwaters, much of the watershed's vegetation has been altered over time. In fact, McEldowney (1983) found that nearly 75% of the vegetation in the area surveyed was composed of introduced grass species.

The forested section of the watershed primarily encompasses wet, predominantly-native 'ohi'a rainforest, more specifically an 'ohi'a/'ōlapa Montane Wet Forest. 'Ohi'a (*Metrosideros polymorpha*) and 'ōlapa (*Cheirodendron* spp.) comprise the upper canopy, reaching 15 to 30 ft. in height. According to McEldowney (1983), this upper canopy is usually "accompanied by native subcanopy trees (3 to 6 m tall), native shrubs (1 to 3 m tall), a herbaceous layer composed of saplings, native and introduced herbs, grasses, sedges, rushes, and ferns (<1 m tall) and numerous epiphytic ferns and bryophytes" (p. 410). Plant surveys of the Pu'u o 'Umi Natural Area Reserve found that the

[c]ommon associated species in the canopy of the 'ohi'a/'ōlapa forest included kawa'u (*Ilex anomala*), kolea (*Myrsine sandwicensis* and *M. lessertiana*), alani (*Pelea clusiifolia* and other species) and hāpu'u (*Cibotium glaucum* and *C. chamissoi*).... Uluhe ferns were often codominant. Shrub species included alani, pūkiawe, pū'ahanui, na'ena'e, 'ōhāwai (*Clermontia* spp.), manono (*Hedyotis terminalis* and *H. hillebrandii*), and pilo (*Coprosma pubens* and *C. ochracea*). Native ferns included hō'i'o (*Athyrium sandwichianum*), 'ākōlea (*Athyrium microphyllum*), *Dryopteris* spp., *Asplenium* spp., 'ae (*Polypodium pellucidum*), 'ama'u (*Sadleria pallid* and *S. souleyetiana*), and pala'ā (*Odontosoria chinensis*). The ground cover was moss-dominated by *Sphagnum* sp., especially in poorly drained areas, but ground cover also included 'ala'alawainui, and *Cyrtandra paludosa*. Maile (*Alyxia oliviformis*) was sometimes abundant (DLNR 1989; p. 7-8).

Bog-like communities are also found in the forested watershed, primarily containing dwarfed forms of trees and shrub species found in the neighboring forests and moss hummocks mixed with grasses, sedges and rushes. According to KWP (2007), "[i]t is believed that bogs develop on poorly drained areas where clay soil formation impedes drainage, causing accumulation of perched water on top of the clay, thereby drowning out root systems of woody plants" (p. 25).

Alien plant species have also become established in the native rainforest on Kohala Mountain. Once established, these weedy plants can compete with native species for nutrients and water, and have the potential to alter the native ecosystem. Known invasive plants in the forested section of the watershed include broomsedge (*Andropogon virginicus*), kahili ginger (*Hedychium gardnerianum*), yellow ginger (*Hedychium flavescens*), *Melastoma candidum*, banana poka (*Passiflora tarminiana*), fountain grass (*Pennisetum setaceum*), blackberry (*Rubus argutus*), palm grass (*Setaria palmifolia*), fireweed (*Senecio madagascarensis*), *Tibouchina herbacea*, *Clidemia hirta*, and *T. urvelliana* (KWP 2007).

McEldowney (1983) describes the eight major plant communities that currently dominate the unforested sections of the region (Figure 11), most of them open grass or grass and shrub communities used for cattle grazing.

Zones I through III occur below the 1,500-ft. elevation. This landscape is dominated by grasses (primarily introduced buffel grass (*Cenchrus ciliaris*), fountain grass (*Pennisetum setaceum*), and native pili grass (*Heteropogon contortus*)) and thickets of kiawe trees (*Prosopis pallida*). There is also a significant proportion of bare land. This area is generally used as open range, its use dependent entirely on forage growth following seasonal or episodic rainfall. It is extremely susceptible to wildfires, which burn through this area with increasing frequency. The primary grass species are all well-adapted to fire.

The kiawe tree (*Prosopis pallida*) is an introduced species. It can desiccate an area, using all available water by tapping groundwater with its deep root system. This species is generally killed by intense fires, although a small proportion of the trees will survive if the bases are partially protected.

Zones IV through VI fall between 1,500 and 3,600-ft. in elevation. According to McEldowney (1983), these intermediate vegetation types are “basically unimproved pastures receiving little or no management” (p. 410). These zones comprise mixed grass and shrub communities containing naturalized introduced species – buffel grass (*Cenchrus ciliaris*), fountain grass (*Pennisetum setaceum*), guinea grass (*Panicum maximum*), Bermuda grass (*Cynodon dactylon*), and Natal redtop grass (*Melinis repens*) – and some scattered native shrubs (e.g., ‘ilima (*Sida* sp.), ‘ākia (*Wikstroemia pulcherrima*)). “The higher percentage of bare ground is ephemerally covered by numerous annual herbs following both seasonal and intermittent concentrations of rainfall” (McEldowney 1983, p. 410).

Fountain grass is beginning to dominate the intermediate corridor. “Usually avoided by cattle [and even feral goats], this stiff-bladed bunch grass increases in dominance following periodic fires” (McEldowney 1983, p. 409). It has the ability to form monotypic stands which increase the fire fuel load of dry lowland regions and, when dry, are highly flammable. The plant is extremely fire-resilient, benefiting from fire at the expense of more palatable, non-fire-hardy grasses. DLNR has designated fountain grass as one of Hawai‘i’s most invasive horticultural plants, and Hawai‘i Department of Agriculture has designated it a noxious weed.

Zones VII and VIII are wetter zones above the 3,600-ft. elevation, dominated by kikuyu grass (*Pennisetum clandestinum*). Kikuyu grows as a dense mat; therefore, it provides better protection against soil erosion. There are scattered pockets of native tree species, primarily in inaccessible gulch areas. Because this part of the watershed normally receives greater amounts of annual rainfall, it is less susceptible to fire. These zones are best suited for grazing and have been subjected to agricultural management practices.

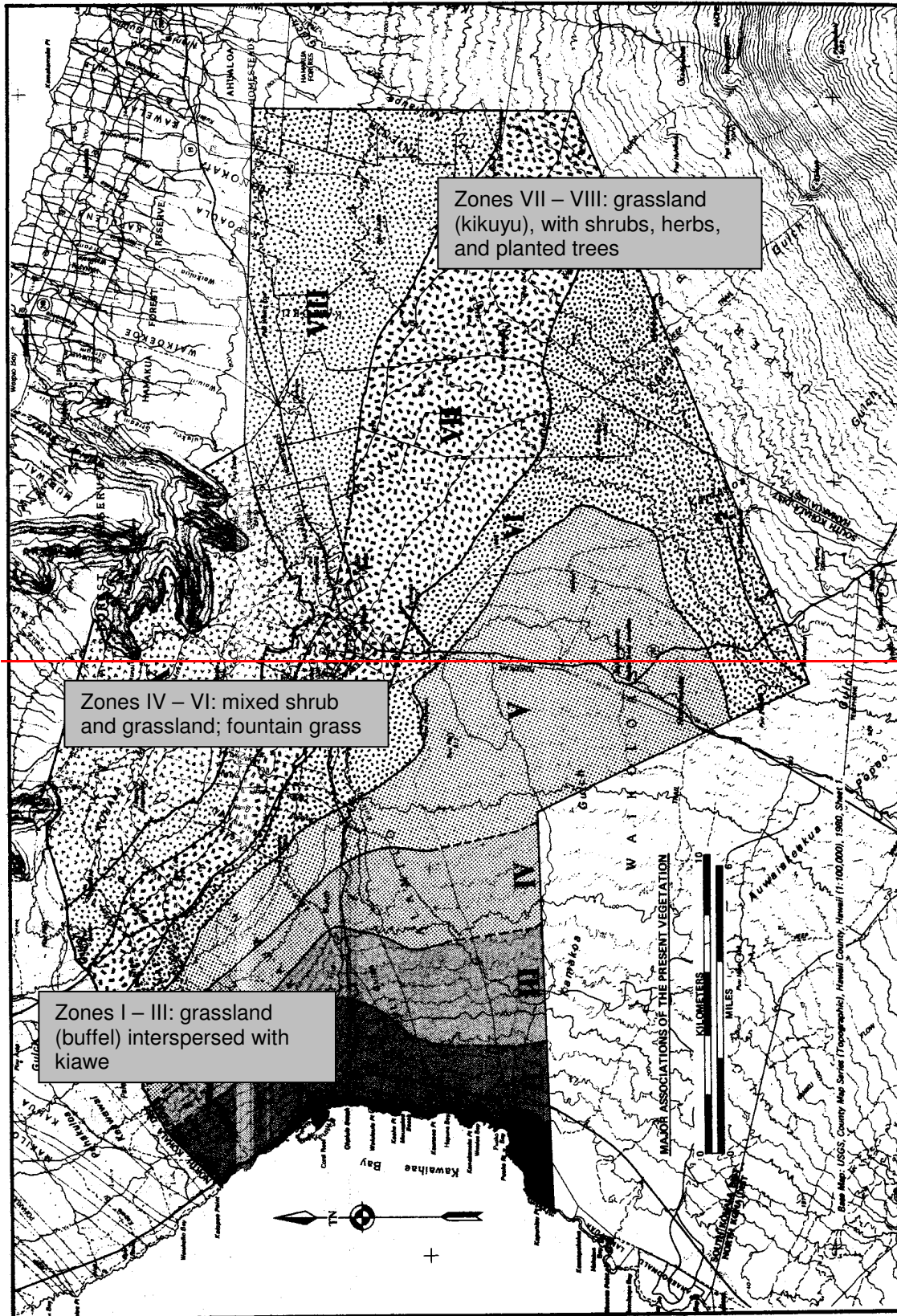


Figure 11: Zones of Major Communities of Present Vegetation (McEldowney 1983)



Fireweed (or Madagascar ragwort, *Senecio madagascariensis*) was discovered in the early 1980s in pastures on Kohala Mountain. It invades pastures, disturbed areas, and roadsides, and is toxic to livestock when eaten. It is commonly found in the pastures in the upper portion of the Wai'ula'ula watershed. It is spread by wind, shoes, vehicles and animals. It is considered very invasive and is on the Hawai'i State Noxious Weed List.

Along the fringe of many of the watershed's streams, there is greater occurrence of vegetation, supported by the relatively steady source of water. In the upper elevations of pasture land (above 3,600-ft. elevation), this riparian vegetation comprises a greater proportion of native species, mostly due to its inaccessibility to grazing because of its location in gulches. In some locations in the central elevations, the vegetation often grows within the stream channel itself (comprising mostly of Christmas berry (*Schinus terebinthifolius*) and other non-natives), making access to the stream difficult and causing debris to get caught on the vegetation during storm events, increasing the potential for flooding. Kiawe trees fringe some reaches of the stream in the lower elevations.

Char (2002) noted plants that prefer a wetter habitat in shallow water and small mudflats in the riparian zone of the DHHL's proposed Lālāmilo Residential Homestead Lots (about 2,500-ft. elevation). "These include several members of the sedge family (Cyperaceae) such as 'aka'akai or great bulrush (*Schoenoplectus lacustris*), kyllinga (*Kyllinga brevifolia*) *Caarex longii*, *Fimbristylis dichotoma*, and *Cyperus haspan*; also found here are scattered clumps of bog rush (*Juncus ensifolius*). Other plants found along the water's edge include honohono (*Commelina diffusa*), marsh purslane (*Ludwigia palustris*), knotweed (*Persicaria glabra*), elephant grass (*Pennisetum purpureum*), and jungle rice (*Echinochloa colona*). All nine fern species found during this study are associated with moist shaded stream banks" (p. 6). Similar plants are likely found in areas of standing water and mud in other parts of the watershed, though a comprehensive assessment of riparian vegetation has not been undertaken for the watershed.

Obviously, it is difficult to know exactly how human pressures altered the distribution and composition of the native plant communities. But, generally, historical accounts document a series of human impacts on the environment of the watershed. The early Hawaiians altered the lands by developing large, irrigated agricultural systems. The sandalwood (*Santalum paniculatum* or 'iliahi) trade of the early 19<sup>th</sup> century drastically altered the landscape as the slopes were denuded of sandalwood trees. With the arrival of European settlers and whaling ships, the cattle industry was born, and cattle grazed down shrub and tree species, and the land was fenced for livestock. Trees were also harvested for firewood.

Fire has been a major threat to maintaining a healthy ecosystem in the watershed, and the changing composition of vegetation in the watershed has contributed to an increased fire hazard. Fire contributes to the erosion problem by stripping the land of vegetation. Without vegetation to hold the soil in place, it is subject to both wind and water erosion. Fire also can render to soil hydrophobic, which increases water repellency, surface runoff, and erosion.

### **2.1.10 Native Wildlife**

The Wai'ula'ula watershed is home to a number of native wildlife, occupying aerial, terrestrial, and aquatic environments. These species play a vital role in the ecological processes within the watershed, as well as hold cultural significance to the Hawaiian people.

Of the avian species, the watershed houses a handful of native birds. A wildlife survey done as part of the Environmental Impact Statement (EIS) for DHHL's Lālāmilo Residential Project (DHHL 2002) revealed nine species of birds. Of the nine, only one species, the Pacific Golden Plover or kōlea (*Pluvialis fulva*), was native. *P. fulva* is migratory and makes its home in Hawai'i during the months of August to April, where they feed on insects. Although not observed in this survey, it is expected that the native Short-Eared Owl or Pueo (*Anas wyvilliana*) resides in the region. The pueo is widespread on Hawai'i Island and often hunts during the day in pastures on the leeward side of the island.

Beyond the mid-regions of the watershed, which the Lālāmilo survey covered, lay the upper reaches of the watershed atop Kohala Mountain. While no formal surveys have been made specifically within the Wai'ula'ula watershed, mountain-wide surveys have encountered many other native avian species that could potentially reside within the upper watershed. The endangered and endemic Hawaiian Goose Nēnē (*Branta sandvicensis*) has been spotted on Kohala mountain. Other native avian species that have been known to reside on Kohala Mountain are the forest birds 'elepaio (*Chasiempis sandwichensis*), 'amakihi (*Hemignathus virens*), 'apapane (*Himatione sanguinea*), and 'i'iwi (*Vestiaria coccinea*). These birds inhabit the closed canopy 'ohi'a and 'ōlapa forests on top of Kohala Mountain above an elevation of 4,000 feet, where they are free of diseases transmitted by mosquitoes (KWP 2007). Also established on Kohala mountain is the endangered Hawaiian duck (*Anas wyvilliana*) (USFWS 1999). The endangered Hawaiian Hawk or 'io (*Buteo solitarius*) can also be found nesting in 'ohi'a forests. All these birds perform a number of important roles within the ecosystem, such as seed dispersal and pollination of native plants by the nectarivorous 'amakihi, 'apapane, and 'i'iwi, pest control of insects by the insectivorous kōlea and 'elepaio, and rodent control by the pueo and 'io.

The Hawaiian hoary bat or 'ōpe'ape'a (*Lasiurus cinereus semotus*) is the only native land mammal of the Hawaiian Islands. This endemic species is federally-protected under the endangered species list. The insectivorous bats have been spotted near Kawaihae and Honoka'a, with some reported sightings in Waimea.

Aquatic species play extremely important ecological roles within the watershed. Their presence or absence is often used as an indicator of stream and watershed health. In the Wai'ula'ula watershed, surveys of Waikoloa and Keanu'i'omanō streams conducted in 1992 by DLNR's Division of Aquatic Resources (DAR), in 2002 by Bishop Museum's Hawai'i Biological Survey (HBS), and in 2010 by R.A. Englund revealed a wide array of native endemic and indigenous aquatic fish and macro-invertebrates.

Englund (2010) observed 4 of the 5 native stream fish species in various locations throughout the watershed. *Lentipes concolor* ('o'opu alamo'o) was detected in Keanu'i'omanō Stream at the 2,700-ft. elevation. Englund notes that "[t]his indicates that native fish traverse long stretches of intermittent stream channels during periods of flowing water, using the ephemeral stream habitat as an access corridor to the headwater regions of upper Keanu'i'omanō Stream" (p. 11). *Awaous guamensis* ('o'opu nākea) was also common in the lower Wai'ula'ula Stream. *Eleotris sandwicensis* ('o'opu 'akupa) and *Stenogobius Hawaiiensis* ('o'opu naniha) were found in the Wai'ula'ula estuary. While *Sicyopterus stimpsoni* ('o'opu nōpili) was not found during Englund's recent survey, it was observed in previous studies (1992 DAR survey). None of the native fish species have been Federally-listed, though the 'o'opu alamo'o is considered a potential candidate (Loope 1998).

The 'o'opu have amphidromous life cycles in which adults reside in freshwater pools, migrate utilizing the intermittent stream flows, and mate in the headwaters. Eggs are deposited on rocks, hatch into larvae, and the larvae travel down the stream to the sea. Post-larval 'o'opu migrate back up a stream in response to freshets, restarting the lifecycle. In addition to the cultural significance of the once-plentiful 'o'opu as a traditional food source, the 'o'opu are important members of the trophic community. The indigenous 'o'opu nākea is omnivorous and feeds on filamentous algae as well as invertebrate species. And, the endemic 'o'opu alamo'o and nōpili feed primarily on algae on the surface of rocks. These fish help control the overabundance of algae and invertebrate species.

"Englund et al. (2007) found that endemic Hawaiian aquatic insects are better bio-indicators for Hawaiian stream health as compared to the native stream macrofauna (fish, crustaceans, mollusks) because aquatic insects have more specific stream habitat requirements" (Englund 2010, p. 11). DLNR's Division of Aquatic Resources (DAR) conducts periodic surveys of the biota in Hawai'i's streams. Its Freshwater Database contains survey data from the State's perennial and intermittent streams, compiled from a variety of sources. The database identifies native and exotic species of fish, crustaceans, mollusks, insects, and algae, and notes the elevation at which the data were collected. The data date back to the 1960s. Data for the streams in the Wai'ula'ula watershed were collected in 1968, 1990, 1992, 1994, 1999-2001. This database identifies 15 total aquatic insect species that have found in the Wai'ula'ula watershed during all previous studies. Englund (2010) collected a total of 23 species of aquatic insects, of which 65% were native and 35% were introduced species. According to Englund (2010), "[t]he relatively high 65% overall native aquatic insect biodiversity found within the entire Wai'ula'ula watershed is comparable to other high quality streams" (p. 12). In the upper reaches of Keanu'i'omanō, Waikoloa, and Kohākōhau streams, native species are even more dominant, maintaining an exceptionally high diversity "equaling any high quality stream found in the Hawaiian archipelago" (Englund 2010, p. 12).

The aquatic insects surveyed have important trophic roles as collectors, grazers, and predators. Collector-gatherer invertebrate species are filter feeders that consume passing particulate organic matter, effectively absorbing nutrients in the water. Native collector species found in the HBS and DAR surveys include the endemic prawn 'ōpae'oeha'a (*Macrobrachium*

*grandimanus*) and the endemic true flies under the order Diptera, *Forcipomyia hardyi*, *Chironomus sp.*, and *Orthocladius grimshawi*. Invertebrate grazers feed on benthic algae and are responsible for maintaining healthy levels of algae. Grazers identified in this survey include the endemic true flies of the Ephydriidae family, *Scatella bryani* and *Scatella clavipes*. The survey also found many native predacious invertebrates that prevent the overabundance of other invertebrates in the ecosystem. These predatory organisms were primarily the dragonflies such as the endemic *Pinao* (*Anax strenuous*) and the indigenous Common Green Darner (*Anax junius*) and Wandering Glider (*Pantala flavescens*). More information about the stream surveys is contained in Section 3.10.

#### **2.1.11 Exotic and Invasive Species**

Alien and invasive species of plants and animals are tremendous problems in Hawai'i, both from environmental and economic standpoints. Every year, new non-native species are introduced into the islands. The majority of the plants in the Wai'ula'ula watershed are considered exotic and/or invasive species. These are described above in Section 2.1.9.

Much of the animal life in the watershed is also introduced. The problems caused by introduced species are well-documented: KWP (2007), SPREP (2000), Atkinson (1977), Giffen (1977), Smith (1985), DLNR (1989), Cuddihy and Stone (1990), Staples and Cowie (2001), and Stone (1985). Introduced cattle, goats, and pigs can be very destructive to their habitats. Feral pigs (*Sus scrofa*), found primarily in the upper reaches of the watershed, destroy areas of native forest, introduce weed species, and serve as vectors for disease. Feral goats (*Capra hircus*) browse on woody plants, herbs, and grasses, in both dry and wet ecosystems. They have proliferated in the lower watershed, damaging the environment through over-grazing. Improper management of domesticated cattle (*Bos taurus*) can also lead to over-grazing, while cattle accessing streams for water can have a negative effect on riparian vegetation and streambanks. Small mammals, such as rats (*Rattus rattus* and *Rattus exulans*), mice (*Mus musculus*) and mongoose (*Herpestes javanicus*), prey on native birds and feed on fruit, seeds, flowers, stems and roots of native plants. Introduced bird and insect species, of which there are many, compete with native ones for food sources and introduce new diseases.

Numerous species of alien aquatic species are established in Hawai'i's streams. Some were introduced intentionally as food fish, ornamentals, or for mosquito and weed control. Others were dumped into streams with no thought about the consequences. Exotic fishes, mollusks, crustaceans, invertebrates, and amphibians can compete with the native stream fauna for food and habitat, introduce parasites, and feed on native species. Invasive aquatic species can also cause economic impacts to agricultural users of water, resulting in crop damage, infrastructure damage, or contamination. While DLNR aquatic surveys of Wai'ula'ula's streams reveal the presence of a majority of Hawai'i's native aquatic species, they also indicate the existence of exotic species, particularly guppies, crayfish, Tahitian prawns, green swordtails, toads and frogs, and midges.



Leptospirosis and Cryptosporidiosis are potentially fatal illnesses caused by water-borne micro-organisms spread by pigs, dogs, mongooses, rats, and even frogs. A few people become ill each year from wading in ponds or drinking water from affected springs and streams. Leptospirosis is from a bacterium, transmitted from animals to humans where people contact the bacteria through water or mud that has been contaminated by animal urine or droppings.

## **2.2 Socio-Cultural Resources**

### **2.2.1 Land Use Zones (State and County)**

#### **2.2.1.1 State Land Use Districts**

The Hawai'i Land Use Law, Chapter 205, Hawai'i Revised Statutes (HRS), places all lands in the State into four districts: Urban, Agricultural, Rural and Conservation. Lands in the Conservation District are managed by the State, and the jurisdiction over Rural and Agricultural Districts is shared by the State Land Use Commission (LUC) and counties. The responsibility for zoning within the Urban District is delegated to the counties. Changes to the boundaries can be made by ordinance of the County Council for areas of 15 acres or less. Otherwise, the LUC must approve changes by a 6-3 vote. Only the LUC can take land out of the Conservation District.

In the past, large-scale, urban-style developments have occurred in the Agricultural District, usually designed as a residential development and often surrounding a golf course. However, this use of agricultural lands has virtually halted as a result of the legal decision regarding the Hokulia development in South Kona.<sup>4</sup> As a result, landowners contemplating this type of development in the future will likely request LUC approval for a district boundary amendment to reclassify lands from Agricultural to Rural.

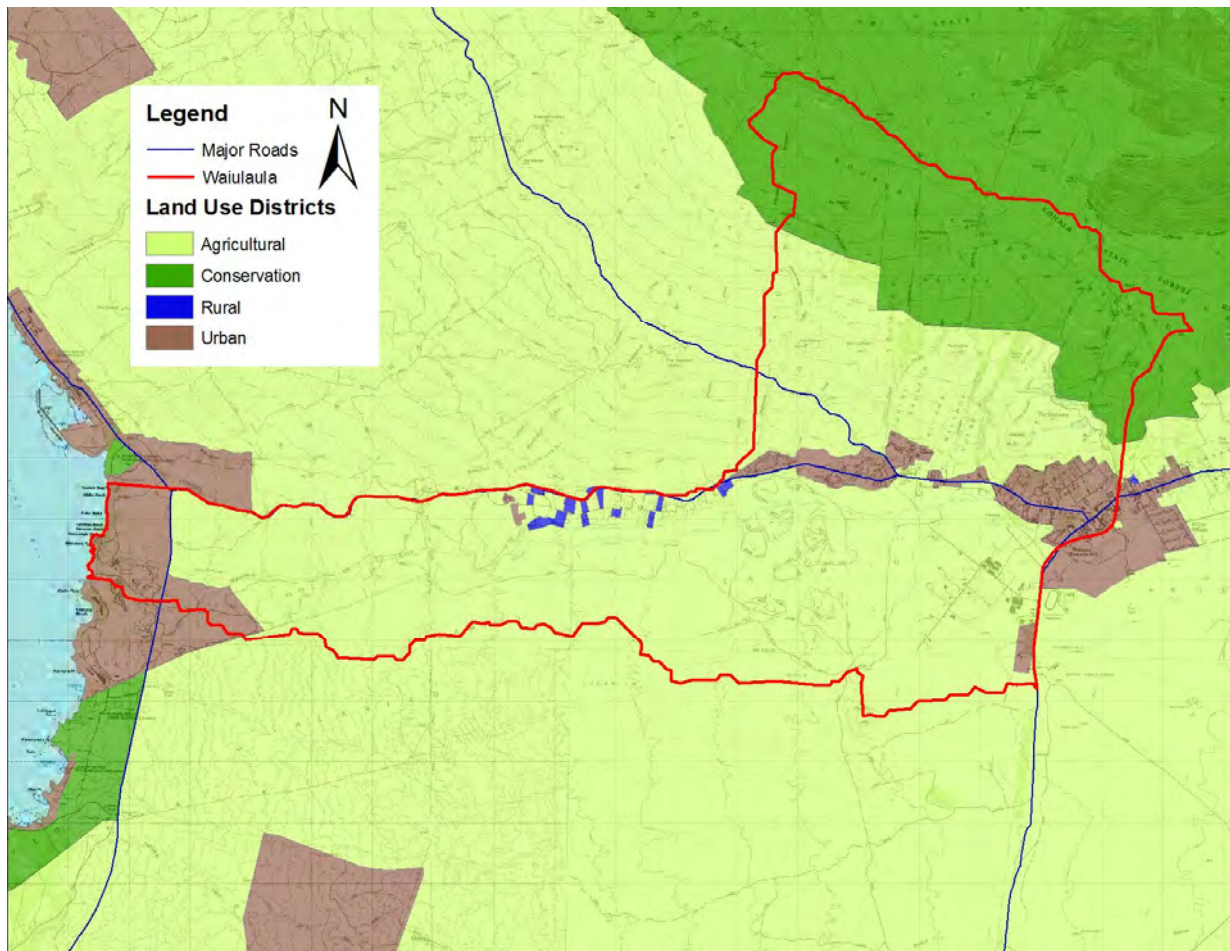
In the Wai'ula'ula watershed, 69.4% of the lands are designated Agriculture, 21.2% Conservation, 0.5% Rural (small farms and low-density residential lots), and 8.9% Urban (Figure 12).

#### **2.2.1.2 Conservation District**

Lands in the Conservation District are managed by the Department of Land and Natural Resources (DLNR) pursuant to Chapter 183C, HRS, and Chapter 13-5, Hawai'i Administrative Rules (HAR). Generally, land use is regulated in the conservation district for the purpose of conserving, protecting, and preserving the important natural resources of the State through appropriate management and use to promote their long-term sustainability and public health, safety, and welfare. Lands within the Conservation District are further subdivided into

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<sup>4</sup> Circuit Court Judge Ibarra ruled in 2003 that Hokulia was an urban project being built illegally on agriculturally-designated lands. He based this conclusion on his findings that the State Land Use Law (Chapter 205, HRS) requires that housing on agricultural lands be related to agricultural use and such agriculture must be economically viable.



**Figure 12: State Land Use Districts**

subzones for which Chapter 13-5, HAR, defines specific objectives and types of activities allowed. The conservation lands within the Wai‘ula‘ula watershed fall within the Protective Subzone, which has the following objective: protect valuable resources in designated areas such as restricted watersheds, marine, plant, and wildlife sanctuaries, significant historic, archaeological, geological, and volcanological features and sites, and other designated unique areas (§13-5-11). Prior to any use of land in the Conservation District, a Conservation District Use Application (CDUA) must be submitted to and approved by the Board of Land and Natural Resources.

The southeastern portion of the conservation lands within the Wai‘ula‘ula watershed is designated as part of the Kohala Watershed Forest Reserve. DLNR’s Division of Forestry and Wildlife (DOFAW) regulates activities in the forest reserves under Chapter 13-104, Hawai‘i Administrative Rules (HAR). These rules prohibit taking of any plant or animal life, except by permit; disturbing of any natural or historic feature; introduction of plants and animals; dumping and littering; and fires. The rules also disallow driving motorized vehicles in any area or trail not designated for that purpose, and prohibit unlicensed vehicles. Camping is allowed in designated areas (of which there are none in the Wai‘ula‘ula watershed) or sites with a permit

from DLNR. Hunting is allowed only as provided for in Chapters 122 (Game bird hunting) and 123 (Game mammal hunting), HAR.

DLNR-DOFAW also regulates activities within restricted watersheds, including the Kohala Restricted Watershed, under Chapter 13-105, HAR. The rules provide for scientific research; hunting, as permitted by hunting rules; hiking and other recreational pursuits; and collecting of fruits, greenery and other plant parts for personal use with a permit for DLNR. These activities are regulated by Chapter 13-104, HAR, rules regulating activities within forest reserves.

The remaining conservation lands within the Wai'ula'ula watershed are part of the Pu'u o 'Umi Natural Area Reserve (NAR). Under Chapter 13-209, HAR, DLNR is responsible for the management of the State's NARs to ensure preservation of specific land and water areas which support communities of natural flora and fauna, including wetland areas. The rules and prohibitions are similar to those within forest reserves, with a few exceptions. Camping is prohibited in the NARs, and any hiking groups larger than ten individuals are required to have a special use permit from DLNR.

#### 2.2.1.3 Agricultural and Rural Lands

Chapter 205, HRS, delegates the responsibility for zoning within the agricultural and rural districts to the counties. For agricultural lands, however, Chapter 205, HRS, outlines permitted uses of the lands classified as "A" or "B" by the Land Study Bureau's land productivity rating system.<sup>5</sup> In Hawai'i County, Chapter 25, Hawai'i County Code (HCC), regulates zoning and identifies permitted uses and other regulations. Under this ordinance, the State Agricultural District is further subdivided into subzones (agriculture, family agriculture, intensive agriculture, etc.), which the County also refers to as "districts."

Chapter 205, HRS, states that only the following uses shall be permitted within Rural Districts: low density residential uses (minimum lot size is one-half acre); agricultural uses; golf courses, golf driving ranges and golf-related facilities; and public, quasi-public, and public utility facilities.

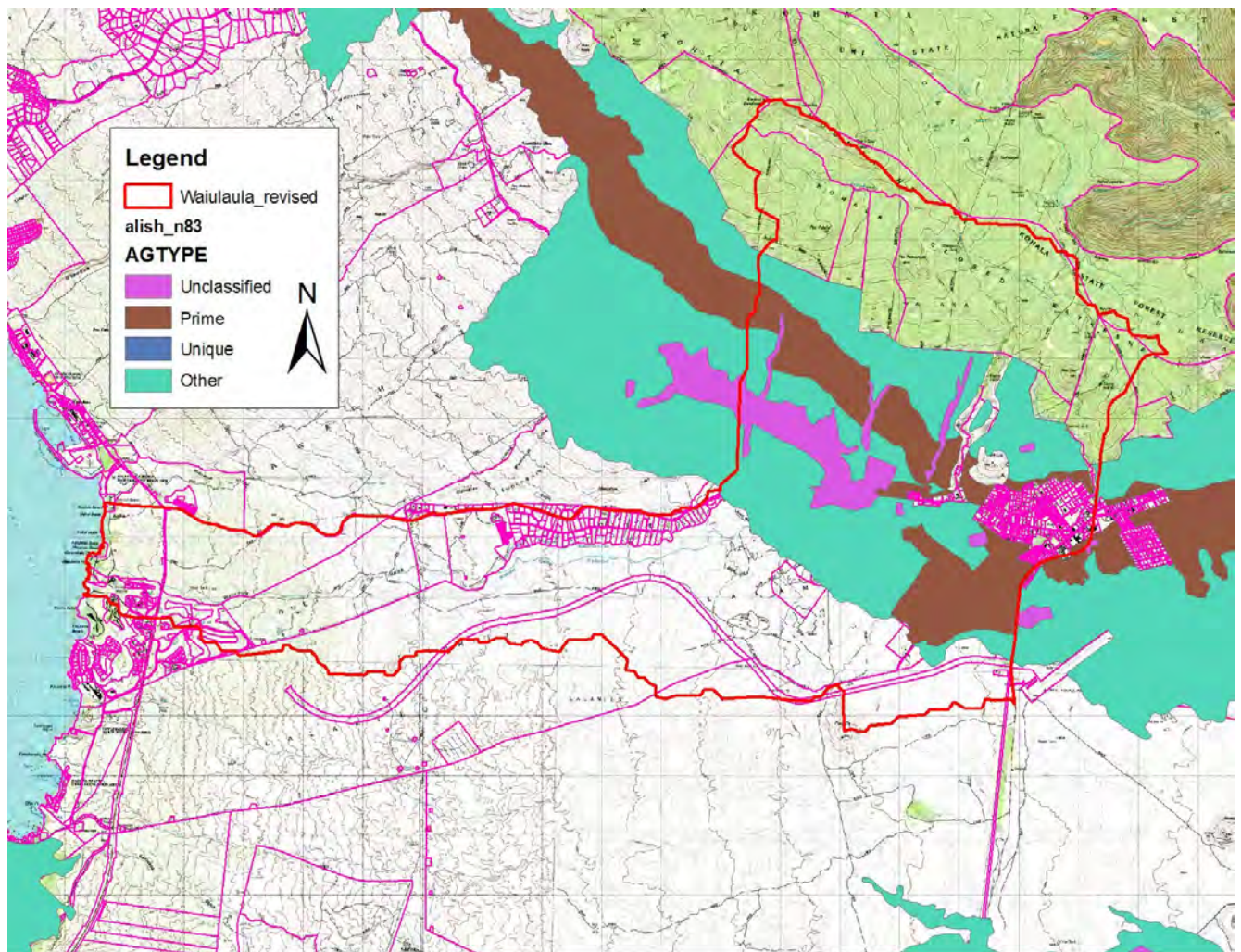
Chapter 205, HRS, also requires that State and county agricultural policies, tax policies, land use plans, ordinances and rules promote the long-term viability of agricultural use of important agricultural lands. One criterion for designating land as important agricultural lands is lands identified under agricultural productivity rating systems, such as ALISH.

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<sup>5</sup> *The University of Hawai'i's Land Study Bureau (LSB) prepared an inventory and evaluation of the State's land resources during the 1960s and 1970s. The LSB rated lands, except those in the urban district, in terms of agricultural productivity based on soil properties and productive capabilities (texture, structure, depth, drainage, parent material, stoniness, topography, climate, and rain). A five-class productivity rating system was developed using the letters A, B, C, D, and E, with "A" representing the class of highest productivity and "E" the lowest. There are no class A lands on the island of Hawai'i.*



*Agricultural Lands of Importance to the State of Hawai‘i (ALISH)*: As part of a national effort to inventory important farmlands, the Hawai‘i Department of Agriculture assessed lands through a rating system for agricultural suitability to produce the Agricultural Lands of Importance to the State of Hawai‘i (ALISH). This was adopted by the Board of Agriculture in 1977. Three classes of important agricultural lands were identified: (1) Prime – soils with best physical, chemical and climatic properties for mechanized field crops; (2) Unique – lands other than prime for unique high-value crops (coffee, taro, watercress, etc.); and (3) Other – lands needing irrigation or possessing characteristics like seasonal wetness, or erodibility that require further management for commercial production. Areas of Prime agricultural lands in the Wai‘ula‘ula watershed include the Lālāmilo farm lots and a band of grazing land *mauka* of Kohala Mountain road (Figure 13).



**Figure 13: ALISH Agricultural Suitability**

*General Plan Important Agricultural Lands*: Chapter 205, HRS, also mandates counties to identify and map potential important agricultural lands within their jurisdictions. One of the goals of Hawai‘i County's *General Plan* (2005) is to identify, protect and maintain important

agricultural lands on the island of Hawai‘i. The general plan defines “important agricultural lands” as “those with better potential for sustained high agricultural yields because of soil type, climate, topography, or other factors” (Hawai‘i County 2005; p. 14-8). In making these determinations, the county included, among other things, data from the 1989 General Plan Land Use Pattern Allocation Guide (LUPAG) maps, the ALISH classification system, and the Land Study Bureau’s (LSB) Soil Survey Report. General Plan Important Agricultural Lands included in the Wai‘ula‘ula watershed are the Lālāmilo farm lots and some grazing lands *mauka* and *makai* of Kohala Mountain Rd (see Figure 16).

#### 2.2.1.4 Urban District

The urban district is entirely under county jurisdiction, and uses are controlled only by county zoning. All areas on the island, except for federal lands like the national parks and some areas in the conservation district, are zoned (Figures 14 and 15). The Zoning Code, Chapter 25, HCC, lists the permitted uses within each zone, and also the required setbacks, height limits, parking areas for commercial developments, and other controls. Within the Wai‘ula‘ula watershed, 4% of the land is zoned residential, 0.7% commercial, 1.2% roads, and 1.2% open, while the remaining lands parallel State designations with 71.5% zoned agricultural and 21.2% forest reserve (conservation).

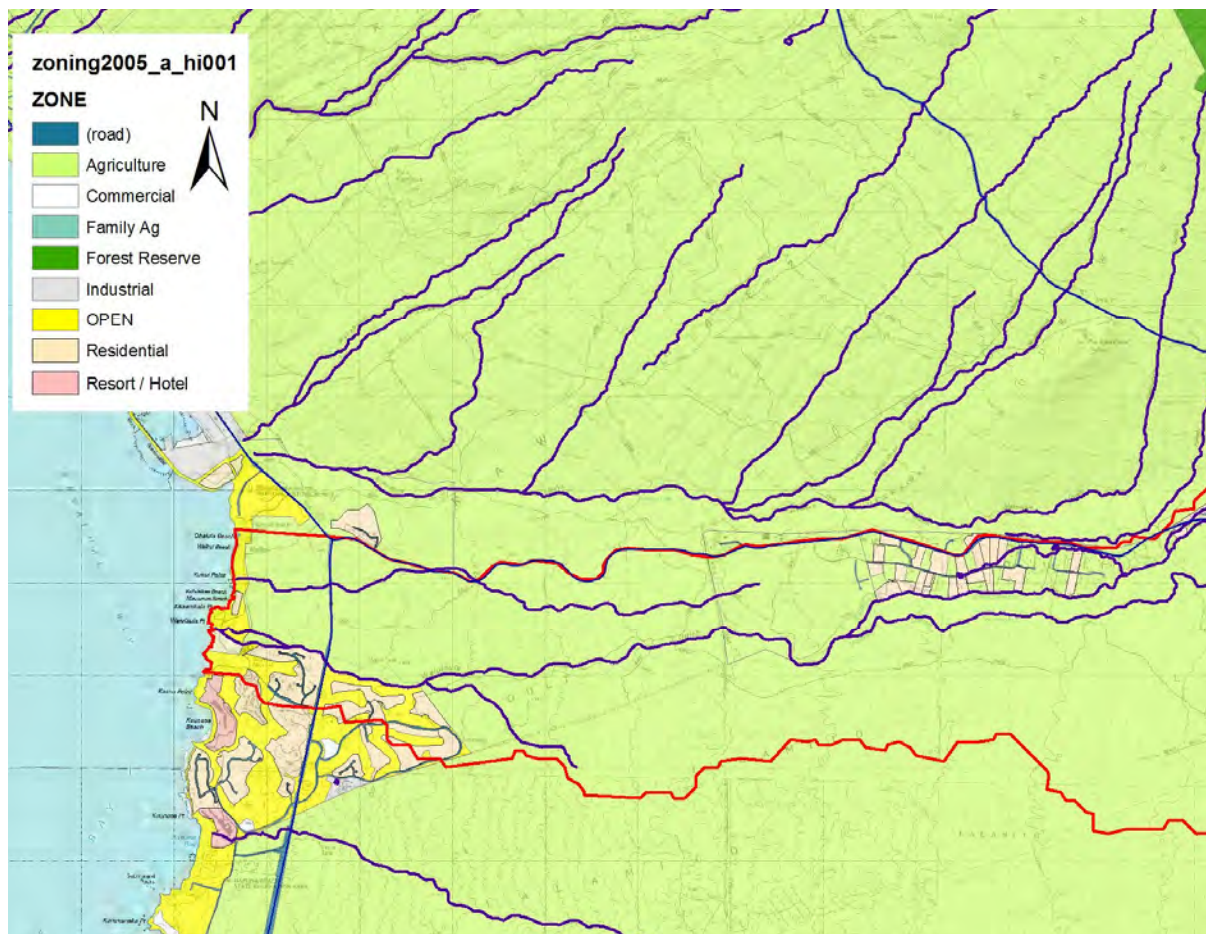
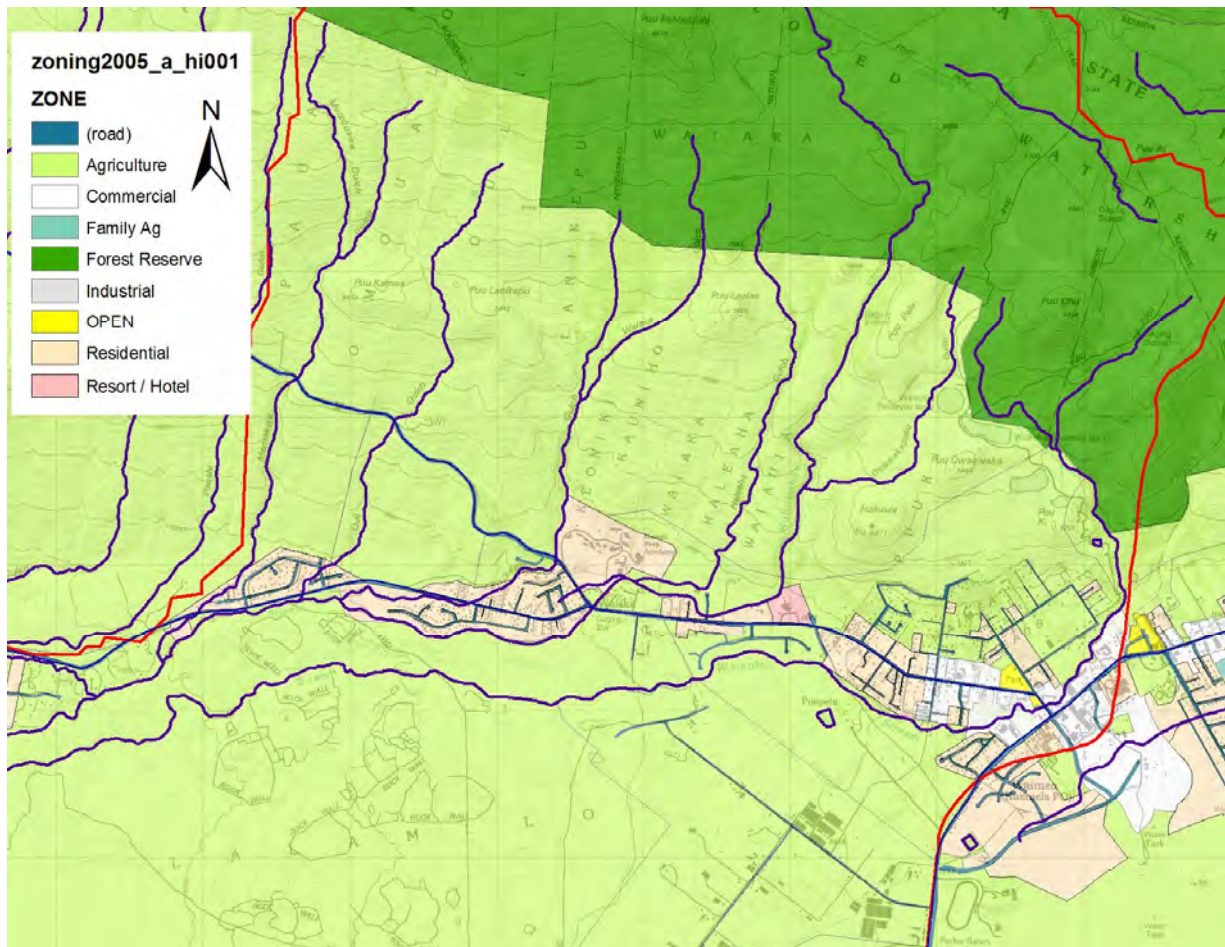


Figure 14: County Zoning - Lower Watershed





**Figure 15: County Zoning - Upper Watershed**

While, currently, there is little urban or suburban development within the watershed, the County's LUPAG map (see Figure 16) shows substantial areas designated for urban and suburban expansion. These areas will likely require a change in land use district classification, shifting management jurisdiction for these lands completely to the County.

#### 2.2.1.5 Hawai'i County General Plan

Generally, all development within the County must conform to the policies outlined in its General Plan (Hawai'i County 2005) and specific community development plans. The county general plan provides a coordinated set of guidelines for decision-making regarding future growth and development and protection of natural and cultural resources. The general plan also guides revisions and updates to the county code. The plan is given the effect of law through adoption by the County Council. Generally, the general plan has policies related to protecting the county's natural resources and minimizing adverse effects resulting from the inappropriate location, use, or design of sites and structures; protecting wetlands and riparian areas; and designing drainage systems to minimize polluted runoff, retain streambank vegetation, and maintain habitat and aesthetic values.

The General Plan provides the direction for the future growth of the County. As a policy document, it provides the legal basis for all subdivision, zoning, and related ordinances and will guide revisions to the county code. The General Plan also includes Land Use Pattern Allocation Guide (LUPAG) maps by district that show conservation, agricultural, rural, resort and urban areas, urban expansion areas, and open areas (Figure 16). These serve to guide the location, type, and intensity of different land uses. The LUPAG identifies significant areas of urban expansion within the Wai'ula'ula watershed, particularly in the lower watershed and within Waimea.

The County general plan is implemented through the specific community development plans; budgeting and capital improvement programs guided by the goals, objectives and policies of the general plan and community development plans; county laws amended to be consistent with the intent of the general plan components; and approval or disapproval of developments seeking zoning and other development approvals based on how they support the visions expressed in the general plan. The county planning department prepares an annual report to monitor progress towards achieving general plan goals, objectives and policies. The annual report is submitted to the Mayor and County Council for review. The General plan is subject to periodic review and amendment, as specified by county procedures, with significant opportunities for input by the public.

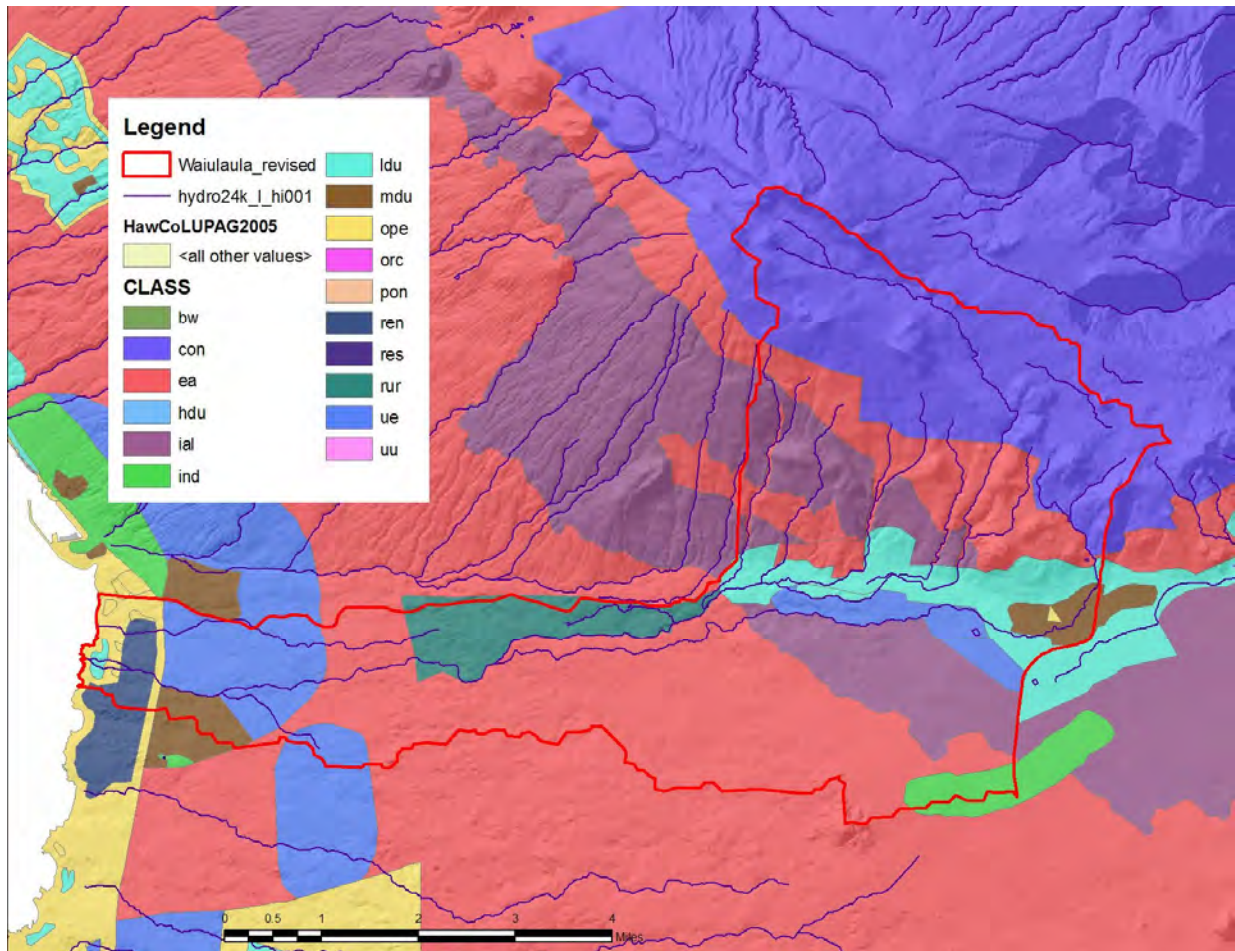
The 2005 General Plan calls for the development of community development plans, which are to be adopted by the County Council. The South Kohala Community Development Plan (CDP) was developed with significant community input and adopted by the Council on November 20, 2008. It provides a long-term plan with a planning horizon to year 2020, consistent with the General Plan. The South Kohala CDP identifies District-wide policies that address the following priority land use issues: preserve culture/sense of place; traffic and transportation; affordable housing; emergency preparedness; and environmental stewardship and sustainability. It specifically identifies a sub-policy for the District that directs the County to develop or collaborate with other agencies and organizations to develop watershed management programs for the district, as well as water quality monitoring (Hawai'i County 2008; p. 52).

The South Kohala CDP includes a Waimea Town Plan, providing general guidelines for the long-range future of Waimea Town. Among the recommendations that are relevant to the Wai'ula'ula watershed management plan are the following:

- Strategy 1.1 Protect the pu'u of Waimea.
- Strategy 1.5 Expand the Lālāmilo Farm lots.
- Strategy 2.1 The County should carefully evaluate and condition, as appropriate, any rezoning that would negatively impact important agricultural lands or culturally, visually and environmentally important open space or resources in Waimea.
- Strategy 2.2 Work with Parker Ranch to phase the "Parker 2020" Development.
- Strategy 2.3 Revise the County subdivision regulations and Planning Department policies and enforcement procedures to ensure that agricultural

subdivisions are created for agricultural purposes and are not used for rural residential purposes without rezoning.

- Strategy 2.4 Amend the County of Hawai'i's General Plan "LUPAG" map by reducing the acreage of "Low Density Urban" land in Waimea Town.
- Strategy 3.1 Protect Important Agricultural Lands.
- Strategy 5.7 Design and construct the Lālāmilo connector road.
- Strategy 5.8 Work with the State Department of Transportation to resolve the best alignment for the proposed Waimea/Kawaihae Road bypass highway.



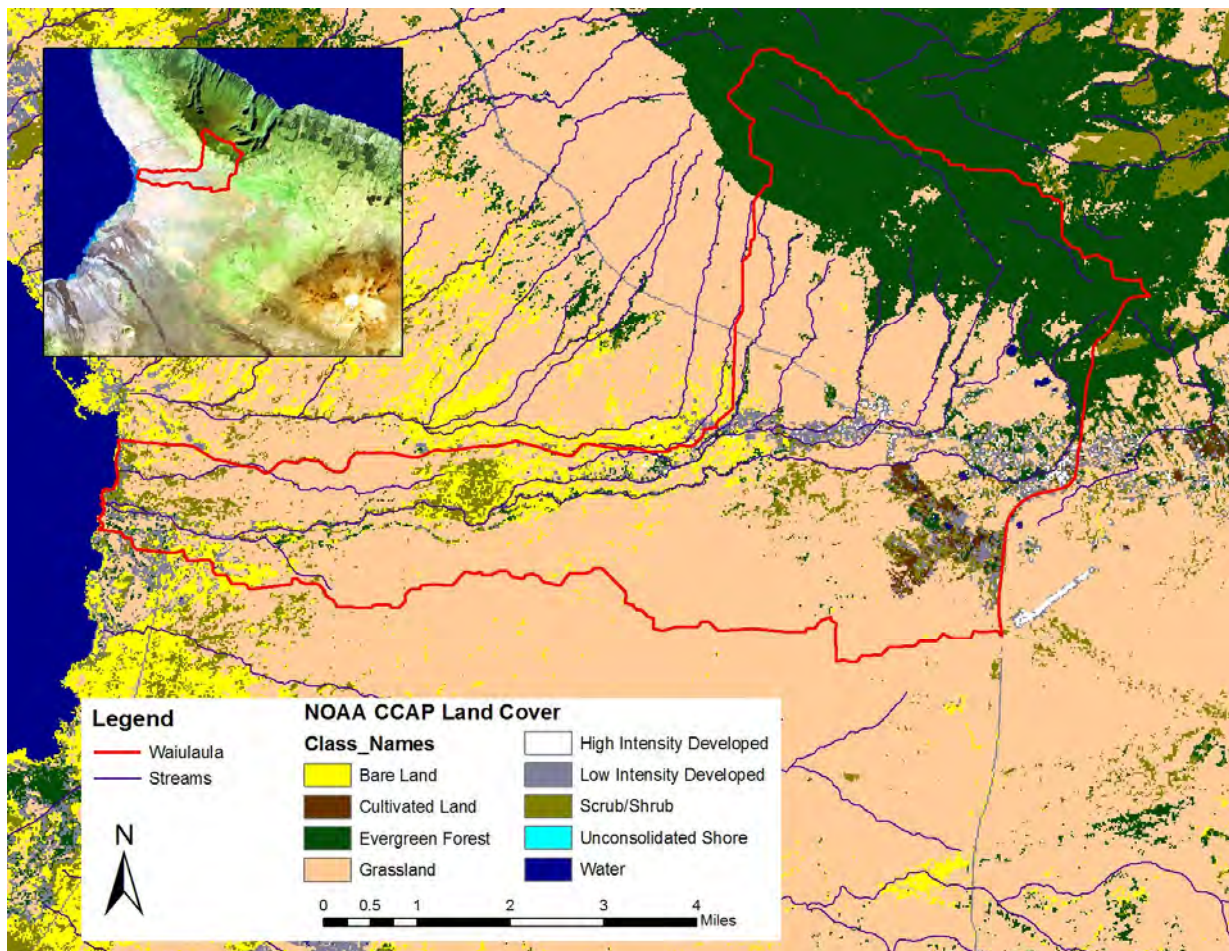
**Figure 16: County LUPAG Map**

bw	(breakwater)	mdu	Medium Density Urban
con	Conservation	ope	Open Area
ea	Extensive Agriculture	pon	(ponds)
hdu	High Density Urban	ren	Resort Node
ial	Important Ag. Lands	rur	Rural
ind	Industrial	ue	Urban Expansion
ldu	Low Density Urban		



### **2.2.2 Land Cover**

Land cover is based on NOAA's Coastal Change Analysis Program (C-CAP) land cover classes (Figure 17). The majority of the watershed (58%) is in grassland, dominated by grammanoid or herbaceous vegetation and not subject to intensive management such as tilling. Evergreen forest, with trees generally greater than 5 meters tall and greater than 20% of total vegetation, accounts for 26% of the land cover. This land cover type is primarily found within the protected Conservation District. Of the remaining land cover, scrub/shrub and low-intensity developed each account for 5%, bare land 4%, and cultivated land and high intensity developed each 1%.



**Figure 17: C-CAP Land Cover**

### **2.2.3 Population and Local Communities (Demographics)**

Waimea is the main population center within the Wai'ula'ula watershed. Waimea is a rural community that developed around the historic Parker Ranch. Residential subdivisions extend down Kawaihae Road, located primarily between Kawaihae Road and Keanu'i'omanō stream to the south. Mauna Kea Beach Resort is a destination resort located near the mouth of the watershed, with a large-scale, high end hotel, restaurants, golf courses, and residential

developments. Most of the commercial development in the watershed is concentrated in and around Waimea town center.

The South Kohala District, in which the Wai'ula'ula watershed is located, was the fastest growing district on Hawai'i Island from 1980 to 1990 and the second fastest growing district from 1990 to 2000 (Hawai'i County 2008). While census data does not provide population information on a watershed basis, it is estimated that Waimea's population in 2000 was over 7,000 people. The South Kohala Community Development Plan estimates (based on building permits issued) that, since 2000, the population of Waimea alone could have increased by about 1,500 people (Hawai'i County 2008). There are currently around 2,900 housing units in Waimea. This does not include additional units along Kawaihae Road and at the Mauna Kea Beach Resort.

Many people are employed by the tourism sector. Agricultural operations, both truck crop farms and cattle ranching also employ people within the watershed. Waimea is the home to the headquarters of Canada-France-Hawai'i Telescope and W.M. Keck Observatory, numerous public and private schools (Waimea Elementary School, Waimea Middle Public Conversion Charter School, Kanu o Ka 'Āina Public Charter School, Hawai'i Preparatory Academy, and Parker School), and the North Hawai'i Community Hospital. Waimea's per capita income is \$20,773, based on 2000 census data. Median income is \$51,150 for households, \$55,822 for families, and \$29,750 for non-family households.

#### **2.2.4 Land Uses – Historic and Current**

In the Cultural Impact Assessment for the DHHL Lālāmilo Residential Development Project, authors McGuire and Haun (2002) describe historic land uses in the area: "From ancient times, Waimea has been associated with royalty and chiefly lineages. Waimea was one of the lands which was highly valued by the *ali'i* (chiefs) and traditional stories indicate they maintained a dominant presence there" (p. 6). Waimea was also a training ground for young chiefly warriors. McGuire and Haun (2002, p. 8) describe the story of Kekuhaopio, a trainer during the time of Kamehameha, which lists many famous battles either fought in Waimea or fought by Waimea warriors, including a battle between Kamalalawalu of Maui and Lonoikamahakihi from Hawai'i in the late 16<sup>th</sup> to early 17<sup>th</sup> century that took place in the Waimea area: the battle of Pu'oa'oaka (Pu'u'owā'owaka Hil). McGuire and Haun also report that a battle occurred at Hōkū'ula.

With so many chiefs and warriors coming from Waimea and being trained in Waimea, an extensive agricultural field system was developed that is still evident today. Clark (1981) notes that this Waimea agricultural system can be subdivided into four field complexes, three of which are contained within the current day Wai'ula'ula watershed:

Field Complex 1 is located on the Kohala slopes, principally between Lanikepu and Hale'aha Gulches on the west and east, respectively. It lies south of Pu'ula'ela'e, and north of Keanu'i'omanō and Kohākōhau Streams, once they run off the slope and turn to an east-west

flow direction. This area is one of comparatively steep slope, and is characterized by a series of terraces and/or terraced field ridges. These features range from 0.5 to 1.5 m. in height and appear to be primarily soil with little or no stone in the retaining faces. The upper portion of the complex is dominated by mildly terraced field ridges, usually comparatively low. These seem most likely to be more of a linchet-type development than intentionally constructed ridges. The lower portion of the complex is characterized by the presence of larger terraces with broader and noticeably flatter surfaces behind the soil embankments. The method of construction of these latter features is probably cut-and-fill.

In association with the agricultural fields are a series of water flow channels and at least one set of 'auwai. The water flow channels are found over the entire complex, running down the slope. With one possible exception, they do not appear to divert from a stream flow but, rather, simply begin as small depressions at the upper margins of the fields. The angle of slope would necessitate a very rapid flow, and some of the channels are in comparatively low-lying areas; both conditions would make diversions into fields somewhat difficult. Consequently, it seems most likely that these channels served more a drainage function, diverting water off of rather than onto the fields. Also present, however, is a clearly identifiable 'auwai set, the main channel of which is diverted from the Kohākōhau Stream at approximately 3,000 ft elevation, that feeds a series of fields in the Waiaula land division before emptying into the Hale'aha Gulch. A historic period irrigation ditch (with a diversion wall of concrete and boulders) is taken off of the east side of the Kohākōhau Stream, but its route was not determined.

A few fields may be present immediately east of Kohākōhau Stream Gulch, but there are no signs of agricultural activity much beyond it. On the other side, an occasional low terrace, residential structure, or wall can be found beyond the first few hundred meters west of Lanikepu Gulch, but for the most part the field complex proper ends at that point....

Field Complex 2 is situated between Keanu'i'omanō and Kohākōhau Streams on the north, and Waikoloa Stream on the south. It is characterized by a set of agricultural fields demarcated by terrace retaining faces, or low ridges of soil and/or stone. The fields average ca. 25 m in width with the long axis oriented northwest by southeast, or perpendicular to the prevailing winds. Associated with the fields is a set of 'auwai, which diverge from the Kohākōhau Stream and angle to the southeast across the complex, draining into the Waikoloa Stream....

Field Complex 3 lies south of Waikoloa Stream and north of Pu'u Pā. The existing Lālāmilo Farm Lots have destroyed much of the eastern end of this complex. The precise western extent has not yet been determined but it appears to incorporate most, if not all, of the Lālāmilo Kuleana and Ranch District.... (Clark 1981: 17-19)

The upper Lālāmilo fields of the Waimea agricultural complex differ from the Kohala field system "due to the fact that they received supplemental water by means of an extensive and complex irrigation system. Indeed, it is this difference that makes the Waimea agricultural system unique" (Clark 1981: 50).

In 1793, Captain George Vancouver brought Longhorn cattle along with some sheep, and gave them to King Kamehameha as a gift. Kamehameha put a ten-year *kapu* on the cattle, prohibiting anyone from touching or hunting them. From these cattle, large herds eventually

multiplied, causing significant damage to the forest on Kohala Mountain. McGuire and Haun (2002) suggest that along with cattle, “other early western visitors introduced goats, horses, a new pig breed, and new vegetable, fruit and plant varieties. Kawaihae and its port became the impetus for the development of trade and commerce. Waimea provided much of the produce, and later on salted beef, to refurbish supplies for foreign ships” (p.18). To harvest the cattle, which all belonged to the Crown, the King hired bullock hunters, like John Palmer Parker. The meat would be salted and brought to Kawaihae. Hides were tanned and tallow was produced from the cattle. All these products were sold to the ships that resupplied in Kawaihae. In 1832, Spanish-Mexican vaquero were brought from California to teach Hawaiians how to manage the wild cattle (Bergin 2004).

Waimea had a reputation for producing fine and durable leather. However, the enterprise of tanning the hides had a noticeable effect on the forest of the area. Haun and McGuire (2002) write:

ecologically, the tanning business had a negative impact to the landscape. The bark from native trees was used to tan hides. Lyons reports that the “Konohikis demanded high prices for bark gathering permits; and koa and ‘ohi’a were used more than scarcer trees that made handsomer leather...” Kukui was richest in tannin” (Doyle 1945: 50). Lyons’ comment implies there had already been loss of the native forest besides sandalwood. The tanneries no doubt contributed to more loss of the native forest. There were several tanneries in operation during the 1840s and 1850s. One tan works was “under the direction of Chinamen”; one owned by James Fay; and two others were at Waiemi and Pukalani, owned and run by William Burke (Olmsted 1841: 233; Barrera & Kelly 1974: 45; Native Testimony, Waimea Water Rights Case 1914 – 1915). (p. 22)

McGuire and Haun (2002) describe that the sandalwood trade started in the early 1800s. By 1811, King Kamehameha had signed an exclusive agreement with three American entrepreneurs for access to Hawai‘i’s sandalwood resource. In return, Kamehameha received one-fourth of the net profits. As a monopoly of the ali‘i, the sandalwood trade grew unabated. Sandalwood was harvested from the slopes of Kohala Mountain and brought down to Kawaihae for shipment, until the supply of trees declined by the early 1840s. The sandalwood harvest had significant environmental impacts on the watershed resources, denuding the forest of sandalwood and causing a major change in the forest ecosystem species composition.

Other agricultural products grown in the Waimea area in the first half of the 19<sup>th</sup> century included sugar and potatoes. McGuire and Haun (2002) describe that sugar was an industry in Waimea from the mid-1830s until at least 1843. Before this time, sugar cane was grown by Hawaiians for their own consumption at locations around Waimea. The first sugar mill is described as having been established by a Chinese man named Lauki, who had come to Hawai‘i with Captain Joseph Carter, grandfather of A.W. Carter. The mill was powered by a water wheel using water from Waikoloa Stream. Because of the demand for Irish potatoes and sweet potatoes by those in California involved with the Gold Rush, Waimea farmers began to increase their production and shipping of potatoes to California, along with other agricultural products like vegetables, sugar, molasses and coffee (Kuykendall 1965: 313-314, 321-322). Haun and

McGuire (2002) note that this export market lasted only three short years, when the Irish potato market collapsed.

By 1840, there was concern that the great herds of cattle would be diminished because of consistent hunting pressure. So, another *kapu* was placed on the cattle. In 1844, a man named William Beckley was named as konohiki of Waimea, “in addition to his role as manager of the king’s and government’s cattle (Lyons 1846 in McEldowney 1983: 432). Under his management, more lands were converted to pasturage and holding pens. McEldowney (1983) states that Lyons wrote that Waimea had turned into a “cattle pen.” He wrote that “[b]y another unfavorable arrangement 2/3 of Waimea have been converted to a pasture for government herds of cattle, sheep, horses, etc.” (Lyons 1846 in McEldowney 1983: 432).

Through the 1840s and 1850s, the government of Hawai‘i passed new laws that initiated a process called the Mahele in which the land tenure system changed from a feudal system with all land controlled by the king and his chiefs, to a system of private land ownership. With the changes brought about by the Mahele, and in land ownership in Waimea, cattle ranching went through a major transition. Former cattlemen and others began to establish ranching operations. John Palmer Parker purchased the first acres of land that would become Parker Ranch in 1847. Bergin (2004) describes the history of Parker Ranch and its role in the development of Waimea town.

During both World War I and World War II, Parker Ranch supplied the Armed Forces in Hawai‘i with beef. During World War II, over 20,000 men in the Army and Marines were living at a major encampment located at Puopelu in Waimea. They also used a large area of land between Waimea and Waikoloa as a firing range. Unexploded ordnance from this era remains a problem to this day.

During the war, the farmers in the Waimea area prospered, growing fresh produce for the servicemen living in Waimea. McGuire and Haun (2002) describe that,

Each farmer leased twenty acres of lands combined between Ranch and Waimea homesteaders. The farmers learned to grow new kinds of vegetables they had never grown before – lettuce, asparagus, celery, and broccoli were especially requested by the servicemen (Nakano 1992: 101). The war helped the Waimea farmers make the shift from tenant farmers to commercial farmers. (p. 44)

Laurance S. Rockefeller constructed the Mauna Kea Beach Hotel in the early 1960s, paving the way for future resorts and hotels to be developed in the region (Hawai‘i County 2008). In 1975, the Queen Ka‘ahumanu Highway was completed, connecting the coastal towns in West Hawai‘i and enabling further development of the coastline.

During the 1980s, Parker Ranch, under the direction of the last remaining heir, Richard Smart, developed the *Parker Ranch 2020 Plan* to guide the future development of Waimea. Smart hoped the plan would allow Waimea to expand without losing its village character. In 1992,



approval of the plan was granted by the County through the adoption of Ordinance 92-65, which rezoned over 580 acres of land in the Waimea area for commercial, industrial, and residential activities, as well as for community facilities. When Richard Smart died in 1992, he left most of the Ranch assets to the Parker Ranch Trust Foundation. This foundation supports five beneficiaries: North Hawai'i Community Hospital, Lucy Henriques Medical Center, Parker School Trust Corporation, Hawai'i Preparatory Academy, and the Richard Smart Fund of the Hawai'i Community Foundation.

In 1994, Parker Ranch began to revise its plan in response to community concerns and in light of the fiduciary responsibilities of the Parker Ranch Foundation trustees to the beneficiaries. As the cattle industry has become less profitable, the trustees have needed to explore diversification alternatives to generate more stable income for distribution to the beneficiaries. This diversification has included selling Parker Ranch Center and Parker Square, selling land to a developer for the development of condominium homes at HoloHoloKu, and a joint venture with Schuler Homes to develop single-family homes at Luala'i. Figure 18 shows the Waimea Town Center Land Use Map from the *Parker Ranch 2020 Plan*.

Today, Waimea town is the commercial center of the Wai'ula'ula watershed. There is residential development within Waimea town and along Kawaihae Road. Mauna Kea Beach Resort at the coast comprises hotel and residential developments, and golf courses. There are over 500 acres in cultivated agriculture within the Lālāmilo Farm Lots. Much of the remaining watershed is grazed or in a wildland state.

### **2.2.5 Water Uses – Historic and Current**

For years, the presence of an extensive 'auwai (irrigation channel system) has given rise to the possibility that large portions of the Waimea plains were irrigated and cultivated in ancient times. In fact, an important legal case on the water rights of Parker Ranch in the early 1900s led to the production of a detailed map of the 'auwai system on the *kula lands* of Waikoloa Nui, Waikoloa Iki, Lālāmilo and Pu'ukapu (Kanakanui *et al.*, 1914; Reg. Map No. 2576), which depicts flow of water to and through many of the fee simple land interests awarded to native tenants in the region (Maly and Maly 2004).

Hawai'i County Department of Water Supply (DWS) relies on the streams of Kohala Mountain for its primary source of water in the Waimea area. The DWS system draws its water from diversions on Waikoloa and Kohākōhau streams. According to DWS (2006), the stream diversions currently provide 1.427 mgd of water. "The 2006 DWS 20-Year Water Master Plan indicates the estimated capacity of the surface water sources used by the water system to be 1.45 mgd" (DWS 2006, p. 801-15). The diversion on Waikoloa Stream was first developed in 1925, and the one on Kohākōhau Stream was completed in 1971. Raw water from the streams is stored in 4 reservoirs (2 of which were damaged in the 2006 earthquake and are currently undergoing repairs) with a total capacity of over 150 million gallons (MG). The water is treated in the DWS filtration plant.

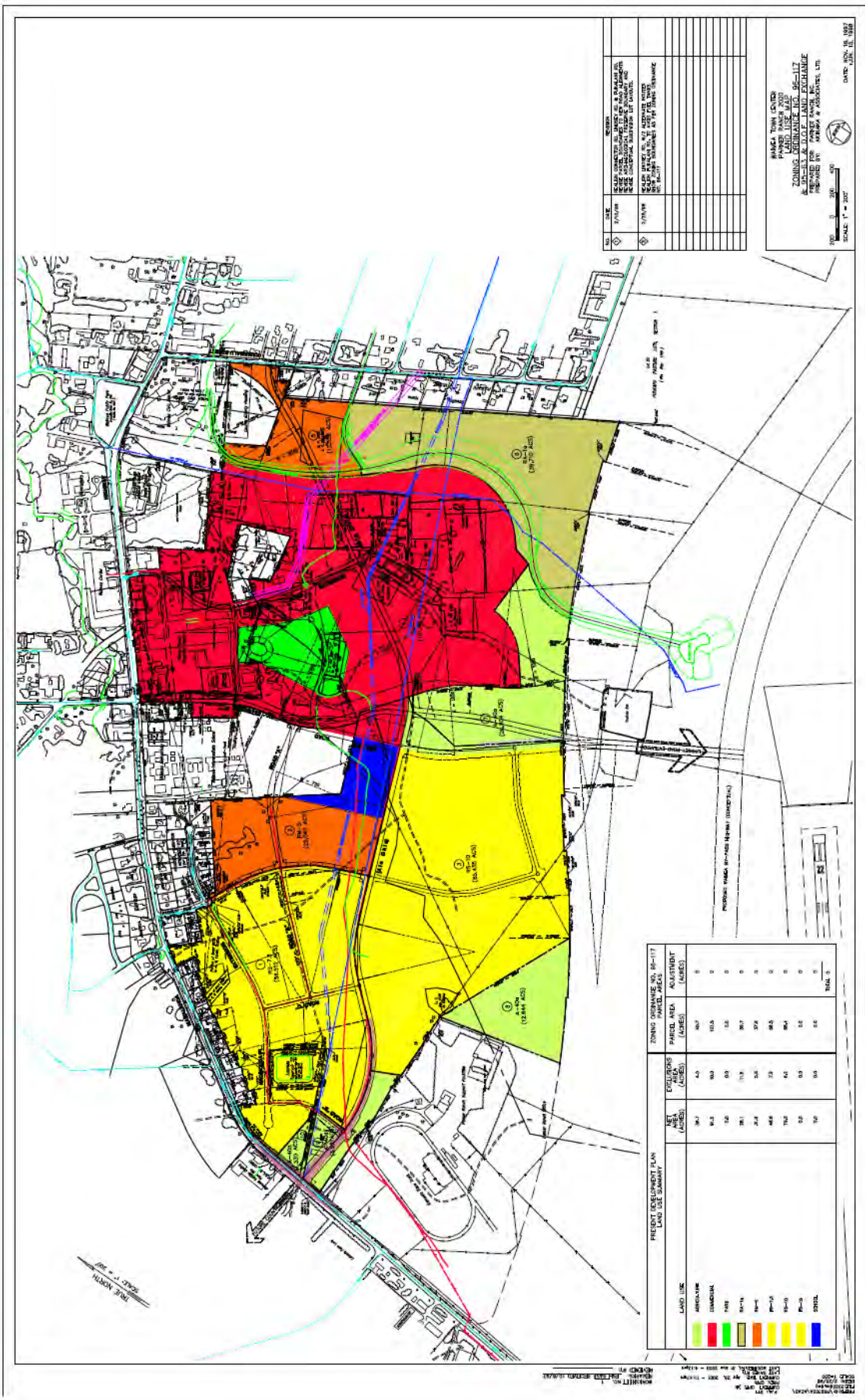


Figure 18: Waimea Town Center Land Use Map - Parker Ranch 2020 Plan

Use of surface water to supply potable water requires strict adherence to DOH regulations related to treatment and monitoring. The surface water is treated by conventional filtration for odor and color control, and for corrosion control and disinfection, and blended with groundwater before distribution (DWS 2006).

During periods of prolonged dry weather or high water usage, the treatment plant cannot process enough surface water sources to meet demand; as a result, DWS has developed a deep well in Waimea, which taps a high-level groundwater source, to supplement surface water sources. The Waimea water system provides about 2.0 mgd to users in Waimea and as far east as Paʻauilo and west to the Waiemi subdivision on Kawaihae Road.

DWS is currently updating its water use and development plan. A draft of the Hawaiʻi County Water Use and Development Plan Update was completed in December 2006. With the existing DWS filtration plant at capacity, stricter Environmental Protection Agency (EPA) standards for surface water used for domestic consumption, and rapid growth within the North and South Kohala regions taxing water supplies, the county will likely develop more groundwater resources in the very near future to meet the growing demand. Groundwater is also more reliable during periods of drought.

Surface water from outside the Waiʻulaʻula watershed is transported into the watershed for use by farmers in the Lālāmilo Farm Lots. The Hawaiʻi Department of Agriculture's (DOA) Waimea Irrigation Water System provides irrigation water to farmers in both Puʻukapu and Lālāmilo (Figure 19). Puʻukapu farm lots are located on DHHL land east of Waimea town and south of Māmalohoa Highway. The Lālāmilo farm lots are situated west of Māmalohoa Highway south of Waimea town, within the Waiʻulaʻula watershed at the terminus of the Waimea Irrigation System. Surface water from windward Kohala streams is diverted into the Upper Hāmākua Ditch to the system's 60 MG Waimea and 100 MG Puʻu Pulehu reservoirs (DOA 2004). Puʻu Pulehu Reservoir water can be transferred to the Waimea Reservoir via a booster pump and connecting pipeline (DOA 2004). The system then distributes water from the Waimea Reservoir to 566 acres of farm land in Puʻukapu and Lālāmilo. According to the DOA website ([www.Hawaii.gov/hdoa/arm/arm\\_irrigation](http://www.Hawaii.gov/hdoa/arm/arm_irrigation)), the system currently transports 307.2 MG per year (0.842 mgd). During the 2006 earthquake, this 15-mile long system suffered considerable damage to the water intake structures, and conveyance ditches and tunnels.

Other diversions in the watershed are described in Section 2.1.6.



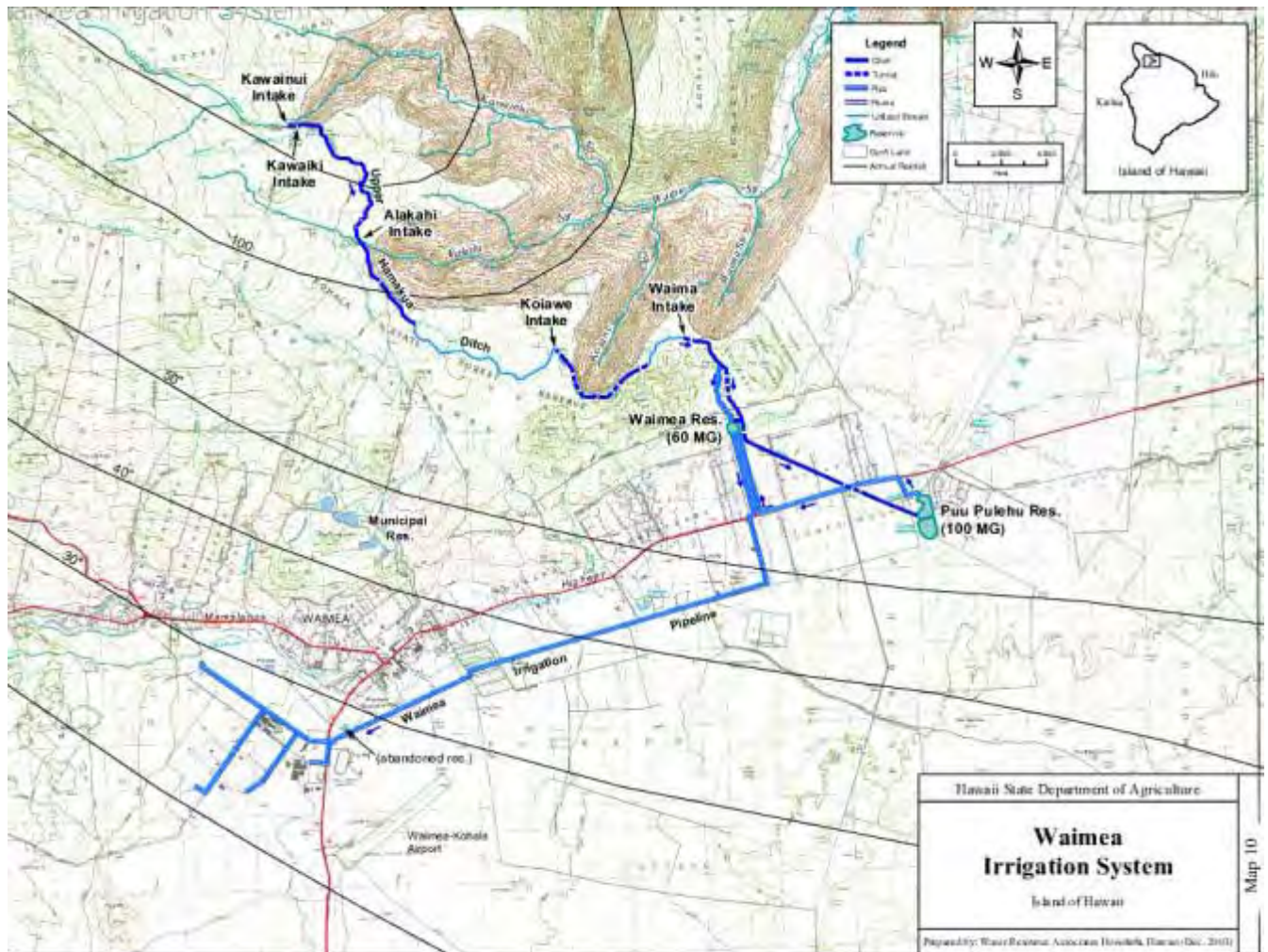


Figure 19: Waimea Irrigation System (taken from DOA 2003)

### 2.2.6 Flooding and Flood Control

Flooding has been a chronic problem in the Waimea area. Flooding of downtown Waimea and of roads crossing streams has been a particular concern. As Waimea has grown over the years, there are greater numbers of structures potentially in harm's way. In 2004, a 25-year storm event led to flooding of downtown Waimea when Waikoloa Stream jumped its banks, and to the closure of Wai'aka bridge, Kawaihae Road, and Queen Kaahumanu Highway because of high water. In addition, the pipelines transmitting water from the water treatment plant to Waimea were badly damaged, leaving Waimea without potable water for several days.

While flooding has been a reality for decades in Waimea, it has become an even greater problem as more and more development occurs within or adjacent to flood prone areas. As more impervious surfaces are created through increased urban and suburban development, these hardened surfaces prevent infiltration and generate greater volumes of stormwater runoff.



Photo by Carolyn Wong



photo by Rosemary Alles

### 2004 Waimea Flood

In 1973, the State proposed channelizing a 1,600-ft. length of Waikoloa Stream as a way to reduce the frequency of flooding in Waimea (DLNR 1973). At the time of the EIS preparation, flooding had occurred at least eight times during the previous 12 years (DLNR 1973). The EIS identified one area prone to flooding as the stream section above Lindsey Road, where flood waters flowed through Waimea Park and sections of the old Hawai'i Preparatory Academy (now St. James' Episcopal Church Circle). The State proposed building a concrete-lined channel beginning below the Lindsey Road bridge and ending downstream at a State of Hawai'i owned property (Waimea Nature Park), bypassing the meanders of the natural stream and following a straight alignment (Figure 20). The draft EIS stated that "the flood control channel will alleviate the flooding in the area for the 50 year flood event, and may be capable of a 100 year flood capacity" (DLNR 1973; p. 16). It is hoped that through the Wai'ula'ula watershed management project and innovative stormwater management techniques, Waikoloa Stream will never have to be channelized.

In 1997, construction was completed on a grassed drainage channel on Parker Ranch land to divert Kamuela and Lanimaumau streams away from Waimea Town Center and toward open pasture land. While this flood control channel protects parts of Waimea from flooding, it falls outside the Wai'ula'ula watershed.

Tom Nance Water Resource Engineering prepared a drainage analysis for the DHHL Lālānilo Residential Project EIS "to establish the probable limits of flood inundation and provide greater accuracy for Keanu'i'omanō and Lanikepu Streams (than shown on the FEMA FIRM maps), and to provide an initial flood delineation for Waikoloa Stream" (Nance 2002). To prepare the drainage analysis, an aerial topographic survey with 2-ft. contour intervals was undertaken; the 100-year peak discharge rates for Waikoloa, Keanu'i'omanō, and Lanikepu streams were determined; and the areas subject to flooding by the 100-year storm peaks were computed and mapped.

The 100-year peak discharge rates used for the flood delineations on the FIRM panels for Hawai'i Island are based on regression equations developed in 1977. These have not been updated, despite the availability of more streamflow data. To check the validity of the



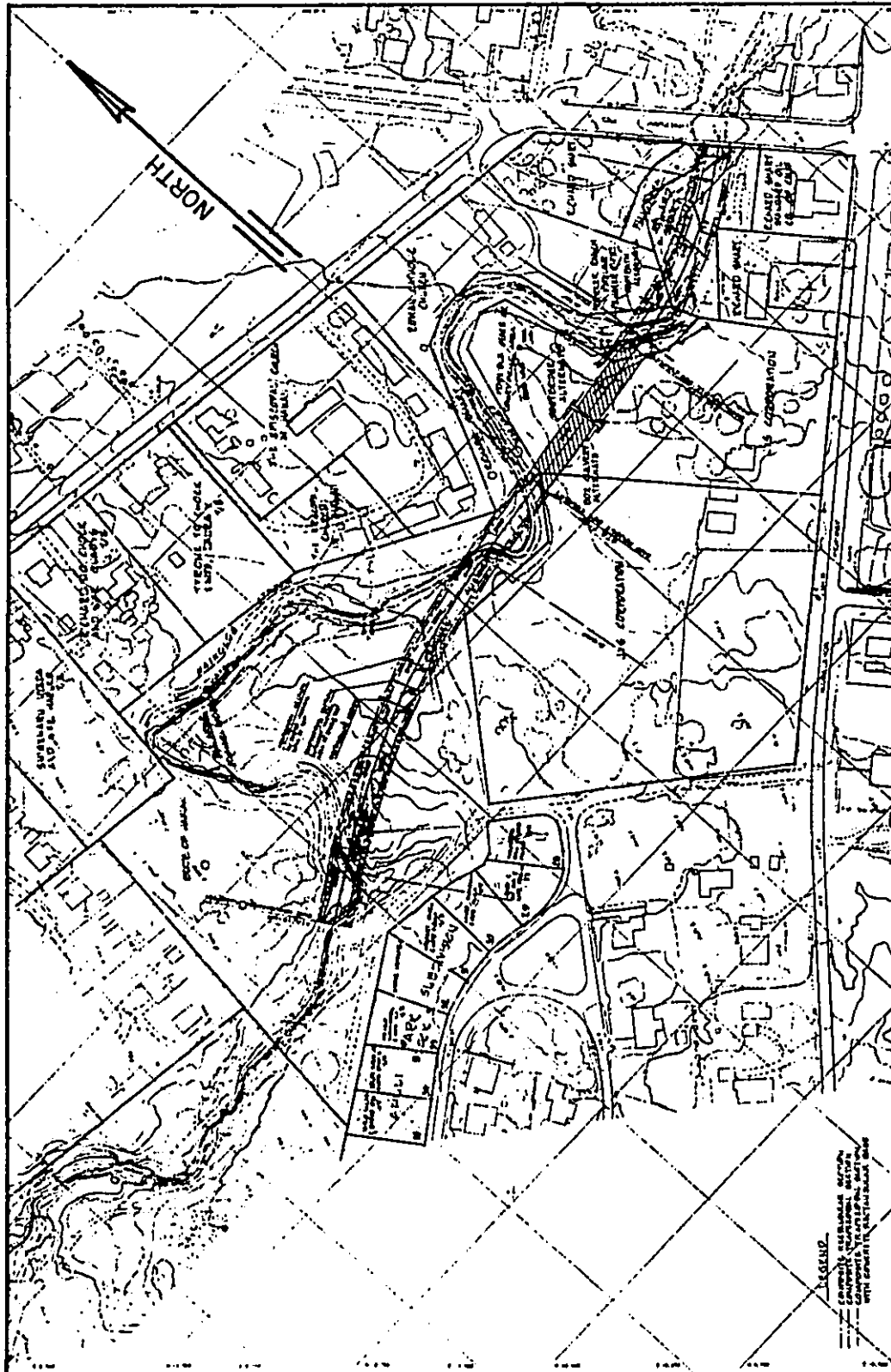


Figure 20: Proposed Pu'ukapu Flood Control Project (Figure 3 from DLNR 1973)

regression equation for leeward streams in light of the data now available, Nance (2002) compared data for four USGS gaging stations in the general vicinity of the project site. Table 1 is taken from DHHL (2002) and compares the 100-year flood peak based on a Log Pearson Type III analysis of the annual flood peaks with the 100-year flood peak computed with the 1977 regression equation.

**Table 1: Comparison of Computed 100-Year Peak Discharge Rates (Table 11 in DHHL 2002)**

	<b>Keanu‘i‘omanō Stream</b>	<b>Luahine Gulch</b>	<b>Waikoloa Stream</b>	<b>Kohākōhau Stream</b>
USGS Gage No.	7565	7558	7580	7560
Elevation of Gaging Station (Feet MSL)	2410	3160	3460	3273
Years of Record	31	33	53	37
Log Pearson Type III Analysis of Annual Flood Peaks:				
M (Log Units)	3.0092	1.9475	2.6779	3.0102
S (Log Units)	0.2936	0.2835	0.3457	0.3057
$k_{100}$ (at skew = -0.05)	2.2895	2.2895	2.2895	2.2895
$Q_{100}$ (CFS)	4801	395	2947	5130
Application of the 1977 Regression Equation:				
DA (Square Miles)	4.30	0.32	1.18	2.51
$P_{24-2}$ (Inches)	6.00	4.40	6.20	6.20
$Q_{100}$ (CFS)	6050	406	2407	4304

The analysis concluded the following:

The regression equation provides a conservative (i.e., safe) estimate for the Keanu‘i‘omanō Stream gage. Since this gage is located immediately above the mauka end of DHHL’s project site, the regression equation result can be used for this stream.

The regression equation also provides a conservative estimate for Luahine Gulch. This gulch has the same orientation relative to rainfall patterns as Lanikepu Stream and both waterways are normally dry. For this reason, it appears reasonable to use the regression equation for Lanikepu Stream.

The regression equation significantly underestimates peak runoff for the gaging station site on Waikoloa and Kohākōhau Streams. However, both these gaging stations are at high elevations in the watershed where the stream channels are relatively deeply dissected. The channel of Waikoloa Stream makai of Waimea Town has less topographic definition. This means that there would be a significant amount of overbank flow during the 100-year flood event, resulting in significant attenuation of the peak discharge rate. In other words, the regression equation is

considered to be a reasonable predictor of peak flowrates in the reach of Waikoloa Stream that passes along the south boundary of the project site.

Areas subject to inundation by a 100-year flood were determined for Waikoloa, Keanu'i'omanō, and Lanikepu Streams. For Lanikepu and Keanu'i'omanō Streams, the areas subject to inundation by the 100-year flood are considerably narrower than shown on FEMA Panel 155166 0164D. Waikoloa Stream's inundated area, with the single exception where the flow splits into two channels, is also relatively narrow. The drainage analysis determined that the capacities of the stream channels are generally sufficient to contain most of the flood waters." (DHHL 2002, pp. 4-10 to 4-13)

In 2004, NRCS developed an *Engineering Report for the Waimea Nature Park* (Ulu La'au) that describes alternatives for enhancing stream channel and bank stability, reducing flood-related damage to the Park and improving wildlife and aquatic habitat. It provides detailed hydrologic and hydraulic analyses of the stream reach. The hydraulic analysis determines the peak flood discharge rates at identified stream locations for various storm intensities, associated with recurrence intervals. The peak flood discharges for Waikoloa Stream through the Park were estimated using the existing FEMA analysis. Based on this information, NRCS (2004) estimated that the peak discharge for a 100-year storm at the Park would be 2,600 cfs. NRCS also conducted a hydraulic analysis to determine the characteristics of stream flow in the natural channel and with proposed modifications.

## **2.2.7 Stormwater Management**

In Hawai'i County, all new urban developments (with very few exceptions) have been mandated to maintain pre-development runoff conditions (Chapter 27, HCC, "Floodplain Management"). Pre- and post- development runoffs are calculated using the County "Storm Drainage Standard." The minimum criteria used for runoff calculations are a 1-hour, 10-year storm event. This requirement inhibits conveyance of development runoff into natural drainage systems. It specifies that stormwater shall be disposed into drywells, infiltration basins or other approved infiltration methods. Chapter 23, HCC, "Subdivision" and Chapter 25, HCC, "Zoning" contain these same requirements.

Hawai'i County has historically relied on deep (+20 feet) 5-ft diameter drainage injection wells (or "dry wells") as the primary means of capturing and disposing of urban stormwater runoff from roads and parking lots because Hawai'i Island's geology allows for good lateral and downward percolation. The county allows a maximum disposal rate of 6 cfs of water per dry well (Kuba 2005). While Izuka *et al.* (2010) examined the potential effects of dry wells on county roads on the water quality of receiving waters at the coast and in drinking water wells, they did not consider effects to surface waters. Figure 21 identifies the location of many of Waimea's dry wells.

There is one large pipe discharging urban stormwater runoff directly into Waikoloa Stream. This concrete pipe is located behind the Waimea Community Education building on Māmalohoa Highway and discharges untreated runoff from storm drains along Māmalohoa Highway. PVC

pipes discharge roof runoff from the KTA shopping center directly into Waikoloa stream. Within DHHL's Lālāmilo development, it appears that runoff from the subdivision's yards is being channeled down steep, rock lined slopes into Lanikepu and Keanu'i'omanō streams.



Figure 21: Dry Wells In and Around Waimea

### **2.2.8 Cultural Resources**

The Wai'ula'ula watershed is located in an area that has a very rich cultural history. Table 2.9 of the South Kohala Community Development Plan (Hawai'i County 2008) summarizes information on historical and cultural sites within the Waimea area, many of which are in the Wai'ula'ula watershed.

### Historical and Cultural Sites in Waimea: Native Hawaiian Sites (Hawai'i County 2008)

No.	Site	Structure	Description	Wai'ula'ula watershed
1	Haleino "Women's Heiau"	Heiau	Historical accounts attribute the founding of the heiau to high chiefess Hoapilihae. It is said that young virgins performed ceremonies at the heiau and learned about the science and practices of healing.	✓
2	Heiau built by Makuakua	Heiau	The akua Makuakua observed a rainbow and found the goddess Wao. The two lived at Hōkū'ula. Wao returned to the Waimea hillsides to bear children. Thus the hillsides were sacred. A kapu was proclaimed in her honor on the hillsides. The boundary of the kapu area was delineated by rolling stones down the hill. The place where the stones stopped delineated the boundary of the area.	✓
3	Lālāmilo Field System		Identified in 1976 as a veritable treasure of 400+ acres of pastoral lands, house sites, hearths and stone enclosures. The field system was developed by Native Hawaiians prior to contact with western civilization.	✓
4	Various agricultural, habitation, religious, and burial sites		Several of these sites are known to exist in the vicinity of various streams, pasture lands, and hillsides of Waimea. Although most have not been surveyed, they have been identified especially in areas that have not been altered by farming or urban development.	✓

### Historical and Cultural Sites in Waimea: Paniolo Sites (Hawai'i County 2008)

No.	Site	Structure	Description	Wai'ula'ula watershed
5	Parker Ranch Race Track	Track built in 1901; Horse Barn (1915); Attendant House and Stallion Barn (1930)		
6	Additional Parker Ranch Structures	Mana Complex (1847); Spencer Home (1875); Manager's House (1885); Kahilu Hall (1918)		✓
7	Parker Ranch Slaughter House		Stone wall enclosure that formed Minuke Ole pen. Built in the early 1940s.	✓
8	Pukalani Complex	This complex of buildings consists of: Pu'u Hihale Complex, Breaking Pen Stables, Carriage Barn (Surgery Barn), Black Smith Stable, Pukalani Stables	These buildings were essential to Parker Ranch's ranching operations. Possibility of incorporating this complex into a heritage community with a heritage center/museum. Built in the late 1800s.	
9	Breaking Pen		Coffee shack and stone wall enclosure. Built in 1905.	



No.	Site	Structure	Description	Wai'ula'ula watershed
10	Pu'u Hihale Complex	Viewing lanai (1900); Cowboy Gang Stables (1930, remodeled 1985); Bucking and Grooming Chute (1944)	Stone wall corral with walls 8' high by 6' wide. Cattle branding viewing lanai. Chute built for the Marine Rodeo. Referred to as the "Paniolo Heiau" and is considered the most significant Paniolo historic site in Waimea. Built in the late 1800s.	
11	Waimea Stables	Stone wall that pre-existed the stables by 50-100 years.	Converted to a working corral in 1985. Originally constructed in 1960.	
12	Kemole Corral		Rebuilt often. Originally built in 1930.	
13	Pu'u Kikoni Corral		Rebuilt often. Originally built in 1930.	
14	Pu'u Kikoni Dairy Site		Called New Dairy. Built in 1920.	
15	Anna Ranch		Anna Lindsey Perry-Fiske, the last of five generations of Lindseys to run the ranch, died at age 95 in 1995 and left the ranch as her legacy to the people of Waimea.	v
16	Pali Ho'oukapapa Dairy Site	Creamery (late 1800s); Corn Silo (1914); Corral (1920+)	Later became a working corral. Originally built in the late 1800s.	
17	Mana House Complex			
18	Makahalau Complex	Corn Crib and Silo (1914); Cowboy Camp House (1920); Makahalau Stables and Corral (1920); Purebred Bull Barns (1935)	Was once a village like Mana.	
19	Hanaipoe Line Cabin		Became the home for section chief Seichi Morifuji and was kept as a recreational cabin for ranch employees. Built in the 1930s.	
20	Waikii Complex	Corn Silos (1914); Cooking ovens (1915); Large Barn, Corn Crib and Cowboy Stable Barn (1920); Attendant Corral, Homes and Quonset Huts (various dates)	Ovens of both Russian and Portuguese origin.	

### Historical and Cultural Sites in Waimea: Homes (Hawai'i County 2008)

No.	Site	Structure	Description	Wai'ula'ula watershed
23	Frank Spencer House		Combined styles and the use of Koa wood. Home of Judge Bickerton and served as an early court house and hotel. Associated with several of Waimea's prominent families. Built in 1850.	√
24	Antony Smart House		Original location in Waiemi. Built during the 1830s.	√
25	Purdy House		Built by Harry W.W. Purdy who was one of Waimea's earliest foreign adventurers and a contemporary of John Palmer Parker. Built in 1840.	
26	Old Lindsey House			√
27	Hale Kea (Jacaranda Inn)		Home of A.W. Carter. The oldest part of Hale Kea was built around 1885 and was first used as an Episcopal Church.	√

### Historical and Cultural Sites in Waimea: Stores (Hawai'i County 2008)

No.	Site	Structure	Description	Wai'ula'ula watershed
28	Kamuela Liquor		Formerly this location was the Wakayama Theater, a gathering place for early Japanese settlers in Waimea.	
29	Chock In		One of the last surviving stores that was built near the turn of the century. Built in 1908.	√

### **2.2.9 Relevant Authorities/Policies**

There are numerous authorities at the county, state and federal levels that affect the management of natural resources and regulate potential sources of polluted runoff (Stewart 2009). Those relevant to land and water use activities within the Wai'ula'ula watershed are summarized below.

#### **2.2.9.1 Agricultural Lands**

The local Mauna Kea Soil and Water Conservation District (MKSWCD) is a major player in the management of agricultural lands because it develops and approves conservation plans which allow agricultural operations to receive an exemption from the county grading ordinances (Chapter 180, HRS). Without an approved conservation plan, agricultural operators are required under Chapter 10, HCC, to get a permit from the Hawai'i County Department of Public Works (DPW) for any earthwork.

Significant amounts of land in agriculture are State lands leased to agricultural operators. The Department of Land and Natural Resources (DLNR) Land Division is responsible for leasing these lands under Chapter 171, HRS. One of the lease conditions is that the operator works with the local soil and water conservation district to develop and implement a conservation plan. Pursuant to Act 90, SLH 2003, beginning on January 1, 2010, the authority to manage, administer, and exercise control over any public lands that are designated important agricultural lands pursuant to Section 205-44.5, HRS, will be transferred from DLNR to the State Department of Agriculture (DOA) (Section 171-3(b), HRS).

U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) usually helps in developing conservation plans to treat existing and potential resource problems and has funding available to assist with the installation of best management practices. NRCS primarily develops plans for operators seeking funding under Federal Farm Bill programs. NRCS's *Hawai'i Field Office Technical Guide* (eFOTG) outlines conservation practice standards and specifications.

Chapter 11-21, HAR, "Cross-Connection and Back-Flow Control," administered by DOH, requires that a reduced pressure principal back-flow preventer or air gap separation be installed as part of any piping network in which fertilizers, pesticides and other chemicals or toxic contaminants are injected or siphoned into the irrigation system (§11-21-7(a)(4), HAR).

#### 2.2.9.2 Pesticides

Under the authority of Chapter 149A, HRS, DOA, Pesticides Branch, is the lead agency for implementing those measures that relate to regulating pesticides. Chapter 4-66, HAR, administered by DOA, relates to the registration, licensing, certification, record-keeping, usage, and other activities related to the safe and effective use of pesticides. It requires that those who apply or directly supervise others who apply restricted use pesticides be certified. Certification requires some understanding of the environmental concerns of using pesticides. This requirement is implemented under the CES/DOA Pesticide Applicator Program. Certification is not required for those using pesticides that are not classified as "restricted use."

#### 2.2.9.3 Wastewater Disposal

Chapter 11-62, HAR, administered by DOH, outlines the requirements for locating, building and operating wastewater treatment systems and individual wastewater systems. Section 11-62-03, HAR, defines an "individual wastewater system" as "a facility which is used and designed to receive and dispose of no more than 1,000 gallons per day of domestic wastewater" and "treatment works" as "any treatment unit and its associated collection system and disposal system, excluding individual wastewater systems." The chapter provides specific requirements for both types of wastewater systems. An engineer must evaluate the site for suitability for an on-site disposal system (OSDS), including depth of permeable soil over seasonal high groundwater, bedrock, or other limiting layer, soil factors, land slope, flooding hazard, and amount of suitable area available. No OSDS can be located within 50 feet of a stream, the

ocean at the vegetation line, pond, lake, or other surface water body; or within 1,000 feet of a potable water source serving public water systems. Chapter 11-62, HAR, also requires that no wastewater system (including OSDs) be operated in such a way that it creates or contributes to: wastewater spill, overflow, or discharge onto the ground or surface waters; or contamination, pollution or endangerment of drinking water.

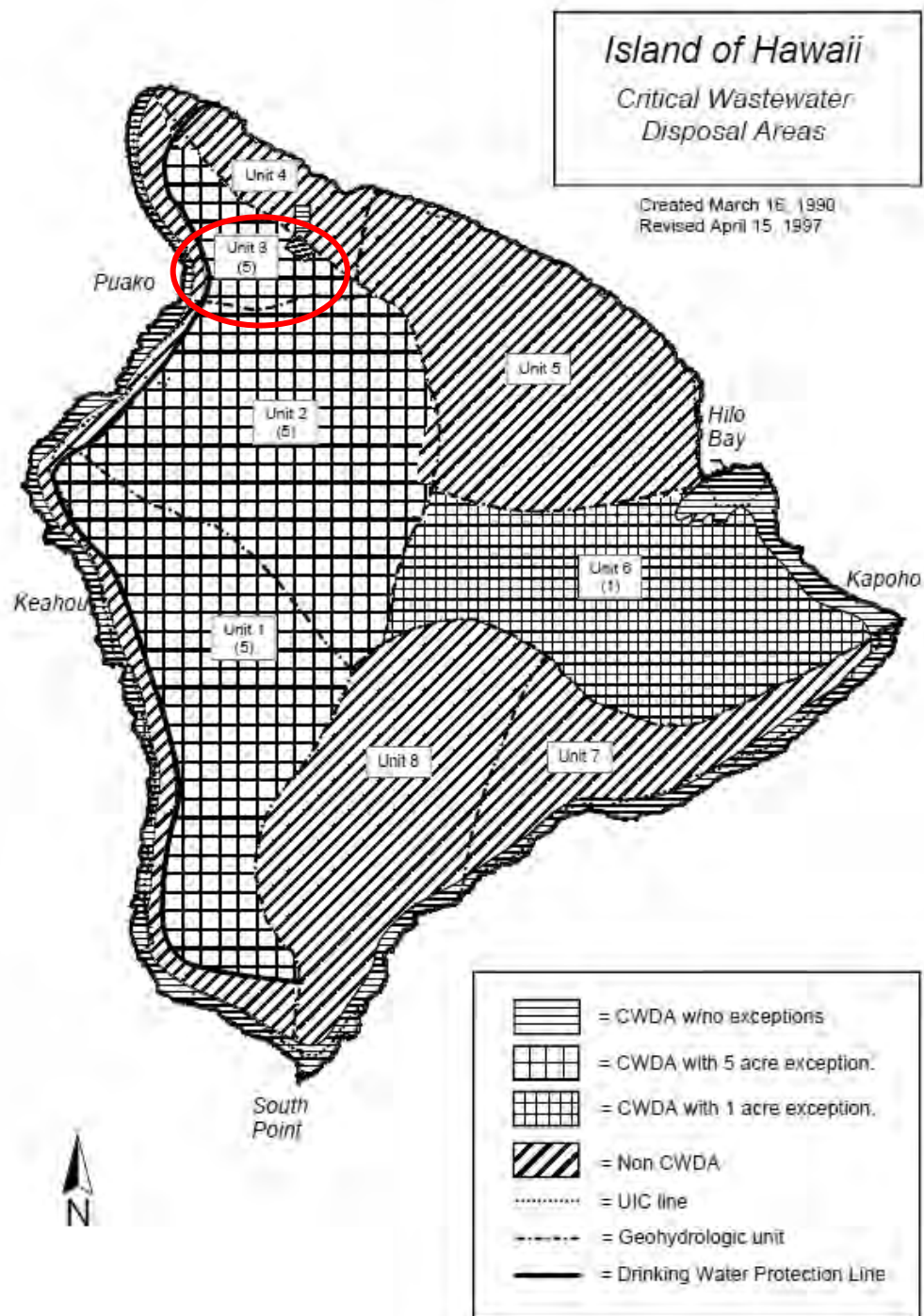
Chapter 11-62, HAR, also provides for the establishment of Critical Wastewater Disposal Areas (CWDAs), where the disposal of wastewater has or may cause adverse effects on human health or the environment due to existing hydrogeological conditions. CWDAs are established based on one or more of the following concerns: high water table; impermeable soil or rock formation; steep terrain; flood zone; protection of coastal waters and inland surface waters; high rate of cesspool failures; and protection of groundwater resources. CWDAs were designated for each county in 1990 and updated in 1997 (see Figure 22). Within CWDAs, DOH may impose more stringent requirements for wastewater systems, and cesspools are severely restricted or prohibited.

Chapter 11-23, HAR, also administered by DOH, establishes a state underground injection control (UIC) program in order to protect the quality of the State's underground sources of drinking water from pollution by subsurface disposal of fluids. It classifies exempted aquifers and underground sources of drinking water. Unless expressly exempted, all aquifers are considered underground sources of drinking water. UIC maps indicate the boundary line of exempted aquifers. While individual wastewater systems serving single family residential households are excluded from the chapter, no large municipal or community serving systems can use injection wells above the UIC line. Certain activities are also prohibited interior of the line.

The U.S. Environmental Protection Agency (EPA) promulgated Underground Injection Control (UIC) regulations on December 7, 1999, which prohibit the construction of new large capacity cesspools nationwide, effective April 5, 2000. A large capacity cesspool (LCC) is a cesspool serving multiple (two or more) dwellings, a community or regional development, or any non-single family residential building/business that generates sanitary wastes, containing human excreta from 20 or more persons per day. Existing LCCs were required to be replaced by an alternative wastewater system and closed by April 5, 2005.

Efforts to ban the use of new cesspools statewide have been made through revision to Chapter 11-62, HAR. The rule either bans or severely restricts the use of cesspools throughout the state. New cesspools are completely banned on the islands of Oahu and Kauai. On the islands of Maui, Molokai, and Hawai'i, new cesspools for individual homes only are allowed in certain areas. These areas are designated in Critical Wastewater Disposal Area (CWDA) maps. The CWDA maps also delineate areas where cesspools are completely banned. In the Wai'ula'ula watershed, the coastal area and specific areas of Waimea are designated CWDA with no exceptions, meaning that cesspools are not allowed. While there is one small band in the lower watershed delineated as non-CWDA, the majority of the watershed is designated CWDA with 5-acre exception, in which cesspools are allowed for individual houses on parcels greater than 5

acres. The maps are based upon development density, groundwater development, potential contamination of coastal waters, and the use of OSDS.



**Figure 22: Critical Wastewater Disposal Areas for Hawai'i Island**

Although the current rule still allows some new cesspools in limited areas, there are a number of items that either prohibit new cesspools or require that existing cesspools be upgraded. They include:



- Not allowing a new dwelling to be connected to an existing cesspool serving an existing dwelling;
- Requiring an existing cesspool system to meet current wastewater rules if there is a change in building usage or characteristics of the wastewater. For example, an existing cesspool must be upgraded if a non-dwelling using a cesspool is converted to a dwelling or a commercial building (*e.g.*, office space) is converted to a food establishment;
- Current rules do not allow two new dwellings (including *‘ohana* units) to be served by a cesspool; such a cesspool would be considered a large capacity cesspool (LCC), which is banned; and
- Current rules do not allow non-dwellings generating non-domestic-like wastewater to discharge wastewater into a new cesspool.

The South Kohala Community Development Plan (Hawai‘i County 2008) includes as a District-wide sub-policy “ensure the quality of South Kohala's groundwater resources and marine resources.” It goes on to recommend: “County should consider adding the following requirement to HCC 23-85(b) for residential projects: No cesspools or seepage pits shall be installed in South Kohala after the effective date of this plan. The effluent from any septic tank installed in South Kohala after the effective date of this plan shall be discharged into an absorption system that meets the design standards of the State Department of Health” (p. 51).

Chapter 17-47, HCC, administered by the County of Hawai‘i DPW, modifies the Uniform Plumbing Code to require the use of low flow plumbing fixtures. Chapter 27, HCC, states that on-site cesspools and septic systems shall be located to avoid impairment to them or contamination from them during flooding.

#### 2.2.9.4 Use of Recycled Wastewater

Chapter 11-62, HAR, administered by DOH, allows for the use of recycled water for irrigation with written approval by the director, provided the owner of the recycled water system submits an engineering report for approval which clearly identifies all BMPs to be implemented, an irrigation use plan, overflow control plan, management plan, public information and access plan, labeling plan, employee training plan, vector control plan, and groundwater monitoring plan. For golf courses, the director is guided by DOH’s *Guidelines for the Treatment and Use of Recycled Water* (May 2002). R-2 and R-1 waters may be used for golf course irrigation.

#### 2.2.9.5 Rubbish and Pet Waste

Chapter 342H, HRS, “Solid Waste Management,” administered by DOH, prohibits disposal of solid waste anywhere other than a permitted solid waste management system. It encourages the recycling of solid wastes, including animal wastes and selected non-hazardous industrial wastes, and the composting of animal manures and by-products for agricultural and horticultural purposes. It also encourages the use of treated sludge effluent for fertilizer and other agricultural purposes.

Chapter 20, HCC, administered by the Hawai'i County DPW, prohibits littering on any highway, street, road, alley, sidewalk, beach, public park, or other public place in the county. Litter is broadly defined to include, among other things, dirt, paper, wrappings, cigarettes, yard clippings, leaves, wood, scrap metal, and any other waste materials.

The county also administers the ordinance addressing pet waste. Chapter 4, HCC, prohibits pet owners from allowing their pets to defecate on public streets, including sidewalks, passageways, or bypasses, or on any play areas, parks, or places where people congregate or walk, or on any public property, or on any private property without the permission of the owner of the property, unless the pet owner immediately picks up and properly disposes of the feces.

#### 2.2.9.6 Hazardous Materials Disposal and Storage

Chapter 342I, HRS, "Special Waste Recycling," administered by DOH, prohibits disposal of used lead acid battery, except by delivery to a lead acid battery retailer or wholesaler, a collection or recycling facility, or a secondary lead smelter, and specifically prohibits disposal of electrolyte from any used lead acid battery onto the ground or into sewers, drainage systems, surface or ground waters, or ocean waters.

Chapter 342J, HRS, "Hazardous Waste," also administered by DOH, prohibits discharge of new, used or recycled oil into sewers, drainage systems, surface or ground waters, watercourse, marine waters, or onto the ground. The prohibition does not apply to inadvertent, normal discharges from vehicles and equipment, or maintenance and repair activities, provided that appropriate measures are taken to minimize releases.

Chapter 11-281, HAR, administered by DOH, regulates underground storage tanks (UST). Each UST must be properly designed, constructed, and installed, and any portion underground that routinely contains product must be protected from corrosion. UST are used to store petroleum products at gas stations in the watershed, two of which are located adjacent to Waikoloa Stream.

#### 2.2.9.7 Urban Development

In urban areas, the county has the lead in the control of erosion during site development and ensuring proper site planning and stormwater management to protect sensitive natural features, through its ordinances and rules related to zoning, subdivisions, drainage, and erosion and sediment control.

Chapter 10, HCC, "Soil Erosion and Sediment Control," administered by the Hawai'i County Department of Public Works (DPW), requires a permit for grading and grubbing of land, and stockpiling of material in excess of 500 cubic yards. All grading, grubbing, and stockpiling

permits and operations must conform to erosion and sedimentation control standards and guidelines. Hawai'i County is currently in the process of revising this ordinance.

In Hawai'i County, all urban developments (with very few exceptions) have been mandated to maintain pre-development runoff conditions (Chapter 27, HCC, "Floodplain Management"). Pre- and post- development runoffs are calculated using the County "Storm Drainage Standard." The minimum criteria used for runoff calculations are a 1-hour, 10-year storm event. This requirement inhibits conveyance of development runoff into natural drainage systems. It specifies that stormwater shall be disposed into drywells, infiltration basins or other approved infiltration methods. Chapter 23, HCC, "Subdivision," and Chapter 25, HCC, "Zoning," contain these same requirements.

In Hawai'i County, Chapter 25, HCC, "Zoning," provides for Cluster Plan Development, in which exceptions are made to the density requirements of the single-family residential (RS) district on lands greater than two acres so that permitted density of dwelling units contemplated by the minimum building site requirements is maintained on an overall basis, and desirable open space, tree cover, recreational areas, and scenic vistas are preserved. It also provides for Project Districts, which are intended to provide for a flexible and creative planning approach rather than specific land use designations for quality developments on lands greater than 50 acres, establishing a continuity in land uses and designs while providing for a comprehensive network of infrastructural facilities and systems.

If development activity will disturb one acre or more of total land area, then a National Pollutant Discharge Elimination System (NPDES) permit is required from the Hawai'i Department of Health (DOH). This permit process is described in Chapter 11-55, HAR, "Water Pollution Control" (<http://gen.doh.hawaii.gov/sites/har/AdmRules1/11-55.pdf>). A County grading permit is required for any grading and grubbing work before a NPDES permit can be issued. The grading permit allows the grading, while the NPDES permit regulates stormwater runoff from the construction site.

Typically, large development proposals must undergo numerous permit processes, with their associated environmental assessments and extensive public review. Development in the Conservation District triggers a Conservation District Use Permit (CDUP) from DLNR; development within the county's Special Management Area (SMA) requires an SMA permit from the County planning department. Chapter 343, HRS, and Chapter 11-200, HAR, both about Environmental Impact Statements, require the preparation of an environmental assessment (EA) and/or environmental impact statement (EIS) for proposed activities that trigger the environmental review process. Some of the trigger conditions include: (1) use of State or county lands or funds; (2) use within the conservation district; (3) use within a shoreline setback area; (4) use within an historic site; (5) reclassification of conservation lands; and (6) certain amendments to a county general plan.

The county administers the Special Management Area (SMA) permit process. SMAs are a subset of the State's coastal zone and include all lands and waters beginning at the shoreline

and extending inland or *mauka* at least 100 yards. The SMA permit process, administered by the Hawai'i County Planning Department, ensures that developments in these more-sensitive coastal areas are consistent with Hawai'i's coastal zone management (CZM) program objectives and policies. Although each county has its own procedures for administering SMA permits, the requirements and review processes for SMA applications are based on Chapter 205A-26, HRS ("Special management area guidelines"). The county requires a permit applicant to describe the proposed development in terms of the CZM objectives and policies.

#### 2.2.9.8 Roads, Highways and Bridges

In Hawai'i, roads, highways and bridges are usually developed by the State or county government, with State, county and/or Federal funds, or by private entities as part of a subdivision or other large development. Privately-constructed roads and highways usually must meet standards set by the State and/or county because they are transferred over to the State or county as public roadways upon completion of construction. Privately-constructed roads that remain private must still comply with county requirements for erosion and sediment control, stormwater management, drainage, zoning and subdivisions. A 1999 State Attorney General's opinion clarified that all public highways are County highways unless declared by Chapter 264, HRS, to be under State jurisdiction.

Construction of public roads, highways and bridges will normally trigger the Chapter 343, HRS, process because of the use of State or county funds and/or lands. In determining whether an action may have a significant effect on the environment, the approving State or county agency must consider every phase of a proposed action, the expected consequences, both primary and secondary, and the cumulative as well as the short-term and long-term effects of the action. In most instances, an action will be determined to have a significant effect on the environment if it detrimentally affects water quality or affects an environmentally sensitive area such as a flood plain, beach, erosion-prone area, estuary, fresh water, or coastal waters. Mitigation measures must be identified to address these detrimental effects.

Hawai'i Department of Transportation (DOT) has jurisdiction over State roadways. According to Section 264-8, HRS, specifications, standards and procedures prescribed by DOT are to be followed in the installation and construction of connections for streets, roads and driveways, concrete curbs and sidewalks, structures, drainage systems, landscaping or grading within the highway rights-of-way, excavation and backfilling of trenches or other openings in state highways, and in the restoration, replacement, or repair of the base course, pavement surfaces, highway structures, and other highway improvements.

DOT Standard Specifications are used for highway design and construction for Hawai'i's transportation infrastructure. The current specifications in use are dated 1994, though many sections (technical provisions) have been revised since then. The updated 2005 *Standard Specifications for Road and Bridge Construction* requires written, site-specific BMPs describing activities to minimize water pollution and soil erosion into State waters, drainage or sewer systems, and a plan indicating location of the BMPs, areas of soil disturbance, areas where

vegetative practices are to be implemented, and drainage patterns. DOT's *Storm Water Permanent Best Management Practices (BMP) Manual* (February 2007) applies to projects statewide within the DOT right-of-way.

Chapter 23, HCC, provides requirements for street design in subdivisions in Hawai'i County. It requires the location, width, and grade of a street to conform to the County general plan and to be considered in its relation to existing and planned streets, to topographical conditions, to public convenience and safety, and to the proposed use of land to be served by the street. When an existing street adjacent to or within a tract is not of the width required by this chapter, additional rights-of-way shall be provided at the time of subdivision. Preliminary and final plats must show the location of lots, streets, water mains, and storm drainage systems, and are subject to technical review by the county director of public works, State DOH, and district engineer for DOT when the subdivision involves State highways. The ordinance also provides requirements for dedicable streets and standards for non-dedicable streets. Subdivisions, including roads, must maintain pre-development runoff conditions. Pre- and post-development runoffs are calculated using the County "Storm Drainage Standard." The minimum criteria used for runoff calculations are a 1-hour, 10-year storm event. This requirement inhibits conveyance of development runoff into natural drainage systems. Chapter 22, HCC, "County Streets," defines and regulates construction within a county street. It states that no driveway approach shall interfere with the proper runoff of waters into or passage of waters through existing drainage culverts, swales, ditches, watercourses, defiles, or depressions.

Chapter 19-127.1, HAR, administered by DOT, addresses the design, construction and maintenance of public streets and highways. It applies to all persons and agencies who design, construct, and maintain facilities which are, or are intended to become, public streets and highways in the State. The chapter establishes design, construction and maintenance guidelines that should be followed in the construction, reconstruction, and maintenance of all highways, streets, or roads undertaken either by State or county authorities or by individuals intending to dedicate the facilities to governmental authorities.

#### 2.2.9.9 Hydromodifications

The State Water Code (Chapter 174C, HRS), adopted by the Hawai'i Legislature in 1987 and amended in 2004, provides the regulatory framework to protect streams, wetlands and other areas critical to water quality. The State, in its stewardship capacity, has management responsibility for all water resources of the State through the Commission on Water Resource Management (CWRM) – also known as the Water Commission. The Water Commission sets policies and approves water allocations for all water users.

CWRM issues permits to regulate the use of surface and ground water in the State. Existing uses established prior to 1987 are grandfathered in, provided the existing use is reasonable and beneficial. A stream channel alteration permit (SCAP) is required prior to undertaking a stream channel alteration in order to protect fishery, wildlife, recreational, aesthetic, scenic, and other



beneficial instream uses. Routine streambed and drainageway maintenance activities are exempted from obtaining a permit.

The Water Code also requires CWRM to establish and administer a statewide in-stream use protection program, including flow standards on a stream-by-stream basis whenever necessary to protect the public interest. Instream flow standards describe the flow necessary to adequately protect fishery, wildlife, aesthetic, scenic, or other beneficial instream uses. Instream uses include: maintenance of fish and wildlife habitats, outdoor recreational activities, maintenance of ecosystems such as estuaries, wetlands, and stream vegetation, aesthetic values such as waterfalls and scenic waterways, navigation, instream hydropower generation, maintenance of water quality, conveyance of irrigation and domestic water supplies to downstream points of diversion, and the protection of traditional and customary Hawaiian rights.

The State is in the process of establishing instream flow standards for perennial streams, in order to balance maintenance of fish and wildlife habitat, estuarine, wetland and stream ecosystems, and water quality with use of the water (CWRM 2005). Section 13-169-46, HAR, adopted in 1988, establishes interim instream flow standards (IFS) for Hawai'i. These were generally defined as the amount of water flowing in each stream on the effective date of the standard. The standards for some individual streams have subsequently been amended as a result of petitions to amend the IFS and describe the amount of water that can be withdrawn from the stream. Specific instream flow standards have not been established for any streams within the Wai'ula'ula watershed.

Under Chapter 46-11.5, HRS, the counties are responsible for the maintenance of channels, streambeds, streambanks, and drainageways, whether natural or artificial, including their exits into the ocean, in suitable condition to carry off stormwaters. For lands comprising the channels, streams, streambanks, and drainageways that are privately owned or owned by the State, the respective owner is responsible for maintenance.

The U.S. Army Corps of Engineers (USACOE) has the authority to protect the waters of the United States, including wetlands and some streams, by regulating certain activities within those waters. Section 404 of the Clean Water Act requires that anyone interested in placing dredged or fill material into waters of the United States must first obtain a permit from the Corps. Section 10 of the Rivers and Harbors Act of 1899 requires approval prior to the accomplishment of any work in or over navigable waters of the United States, or which affects the course, location, condition, or capacity of such waters. The law applies to any dredging or disposal of dredged materials, excavation, filling, rechannelization, or any other modification of a navigable water of the United States, and applies to all structures large or small. The initiation of a Section 404 permit process triggers a Section 401 water quality certification from DOH.

Chapter 13-190, HAR, "Dams and Reservoirs", is administered by DLNR. These rules govern the design, construction, operation, maintenance, enlargement, alteration, repair and removal of

dams in the State. Written approval from DLNR of the construction plans is required for any construction, enlargement, repair or alteration project. Owners are required to provide for adequate and timely maintenance, operation, and inspection of their dams and reservoirs to insure public safety. DLNR is required to inspect all dams and reservoirs at least every five years.

#### 2.2.9.10 Water Quality Protection

Chapter 342D, HRS, “Water Pollution,” prohibits discharge of any pollutant into State waters. It allows DOH to institute a civil action for injunctive relief to prevent violation of State water quality standards. Under the statute, DOH may also request the court to order nonpoint source polluters to implement required management measures.

DOH establishes and enforces the State water quality standards contained in Chapter 11-54, HAR. All inland fresh waters are classified based on their ecological characteristics and other natural criteria as flowing waters (*e.g.*, streams), standing waters (*e.g.*, lakes and reservoirs), and wetlands. These waters are further classified for the purposes of applying water quality standards and selecting appropriate quality parameters and uses to be protected in these waters.

Three stream classifications can be found in the Wai’ula’ula watershed. Streams within the Pu’u o ‘Umi Natural Area Reserve are Class 1(a). Streams within the Conservation District but outside of Pu’u o ‘Umi NAR are Class 1(b). All other areas of the watershed are Class 2. Note that a single stream can have different classifications in different reaches.

Class 1 inland waters are to remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. Waste discharge into these waters is prohibited. The uses to be protected in class 1(a) waters are 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. The additional uses to be protected in class 1(b) waters are domestic water supplies and food processing. Class 2 inland waters are to be protected for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping and navigation. Class 2 waters shall not act as receiving waters for any discharge that has not received the best degree of treatment or control.

Hawai’i also has water quality standards for marine waters. The receiving marine waters immediately offshore of the Wai’ula’ula watershed are classified as AA (south of Wai’ula’ula Point) and A (north of Wai’ula’ula Point). The outlet of Wai’ula’ula Stream is immediately south of Wai’ula’ula Point, so the receiving waters at the stream outlet are classified class AA. The objective of “class AA, marine waters” is that these waters 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. To the extent practical, the wilderness character of class AA waters shall be protected. The objective of “class A, marine waters” is that their use for

recreational purposes and aesthetic enjoyment be protected. Any other use shall be permitted as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class.

#### 2.2.9.11 Hunting in the Conservation District

Bird and mammal hunting is permitted by persons with valid Hawai'i hunting licenses under Chapter 183D, HRS, in designated public hunting areas following guidelines set forth in Chapter 122, HAR, Exhibits 1 and 2, and Chapter 123, HAR, Exhibits 11 and 12. Public hunting areas within the Wai'ula'ula watershed include Units K (Pu'u o 'Umi Natural Area Reserve) and D (Kohala Watershed Forest Reserve). Hunting for wild pigs, wild sheep and wild goats in Unit K is permitted year-round on a daily basis, while hunting in Unit D is limited to weekends and State holidays. Bird hunting is permitted on public lands during designated hunting seasons.

#### 2.2.9.12 Conservation Lands and Nearshore Waters

DLNR manages and regulates all lands set apart as forest reserves under Chapter 13-104, HAR. Under Chapter 13-209, HAR, it is also responsible for the management of the State's Natural Area Reserve System (NARS) to ensure preservation of specific land and water areas which support communities of natural flora and fauna. Chapter 195, HRS, establishes a Natural Area Partnership program to provide state funds to help match private funds for the management of private lands that are dedicated to conservation. Chapter 173A, HRS, enables the State to acquire lands of exceptional value due to the presence of habitats for threatened or endangered species of flora, fauna, or aquatic resources. Chapter 195D, HRS, authorizes DLNR to acquire habitat for endangered species restoration. Chapter 198, HRS, authorizes DLNR to acquire conservation easements to preserve natural lands and waters.

Chapter 205A, HRS, defines the shoreline as "the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of the vegetation growth, or the upper limit of debris left by the wash of the waves." The area seaward or *makai* of the shoreline is part of the Conservation District and is under State jurisdiction. The coastal area landward or *mauka* of the shoreline is managed by the counties as part of the Shoreline Management Area (SMA) established under Chapter 205A, HRS and described above.

DLNR manages the area seaward of the shoreline. Pursuant to Chapter 183, HRS, DLNR is responsible for establishing the procedures and certifying where the shoreline is located, and for promulgating and administering the Conservation District use regulations. All activities proposed within the Conservation District, whether *mauka* or *makai*, require a CDUP, for which there is an application and review process. The Board of Land and Natural Resources can approve, deny, or approve with conditions proposed uses of the Conservation District.

#### 2.2.9.13 Boat Operation

Rules regulating the operation of vessels in ocean waters and navigable streams, administered by DLNR's Division of Boating and Ocean Recreation (DOBOR) restrict vessel speeds in Ocean Recreation Management Areas, along shorelines, and near other vessels, docks, and swimmers/divers. Chapter 13-244, HAR, specifically states that "no person shall operate a vessel at a rate of speed greater than is reasonable having regard to conditions and circumstances."

Chapter 13-232, HAR, "Sanitation and Fire Safety," administered by DOBOR, prohibits dumping, discharging, or pumping of oil, spirits, gasoline, distillate, any petroleum product, or any other flammable material into the waters of a small boat harbor or designated offshore mooring area.

Chapter 13-235, HAR, "Offshore Mooring Rules and Areas," states that no person shall anchor, moor or stay aboard a vessel except those equipped with an approved marine sanitation device (MSD) in proper working condition, or those vessels exempt from MSD requirements in accordance with USCG regulations.

#### 2.2.10 Future Land Use Considerations

The Hawai'i County's General Plan Land Use Pattern Allocation Guide (LUPAG) maps include significant urban expansion areas on both the coast and in Waimea town (see Figure 16). Proposed urban expansion areas allow for a mix of high density, medium density, low density, industrial, industrial-commercial and/or open designation in areas where new settlements may be desirable, but where the specific settlement pattern and mix of uses have not yet been determined. In the South Kohala District, this includes 12,264 acres or 42% of the designated urban expansion area for the entire island. Of this, there are several hundred acres of urban expansion land on the south side of Kawaihae Road just west of Waimea Town along Waikoloa Stream. There are also several hundred acres of rural land shown along the south side of Kawaihae Road, which would encourage low density residential development there.

Parker Ranch also has considerable development slated as part of its Parker Ranch 2020 Plan (see Figure 18). The plan calls for 750 new homes. It proposes to rezone 37.66 acres to multiple-family residential. In addition, commercial lands within Waimea Town were increased by about 104 acres in 1992 as part of the implementation of the Parker 2020 Master Plan. Luala'i at Parker Ranch, for which Phase 1 was completed in 2002, will eventually have 322 residential units, parks and open space on 75 acres.

DHHL's Lālāmilo Residential project proposes 442 houses on 160 acres adjacent to both Waikoloa and Keanu'i'omanō streams (Figure 23). The development will also include a community center, parks, general agriculture, preservation area (19.1 acres), and open space areas (44.5 acres). Phase 1, currently under development, includes 34 in-fill house lots. The remaining planned house lots will be built in subsequent phases.

Mauna Kea Resort is tentatively planning to develop a golf course and 135 large acreage residential lots with associated infrastructure and commercial use on its 'Ōuli 2 property near the bottom of the watershed. Waimea Parkside is a 40-lot subdivision on 9.18 acres in Waimea town across Lindsey Road from the park. This development is currently under construction.

Finally, the South Kohala Community Development Plan recommends expanding the Lālāmilo Farm lots by over 100 acres and constructing several connector roads around Waimea.

All these projects could have implications for polluted runoff in the watershed. The proliferation of impervious surfaces and the greater number of people living in close proximity to the watershed's streams will likely increase the generation of urban pollutants. With much of this additional growth occurring adjacent to the streams, there is a greater likelihood of the urban pollutants reaching the surface waters.



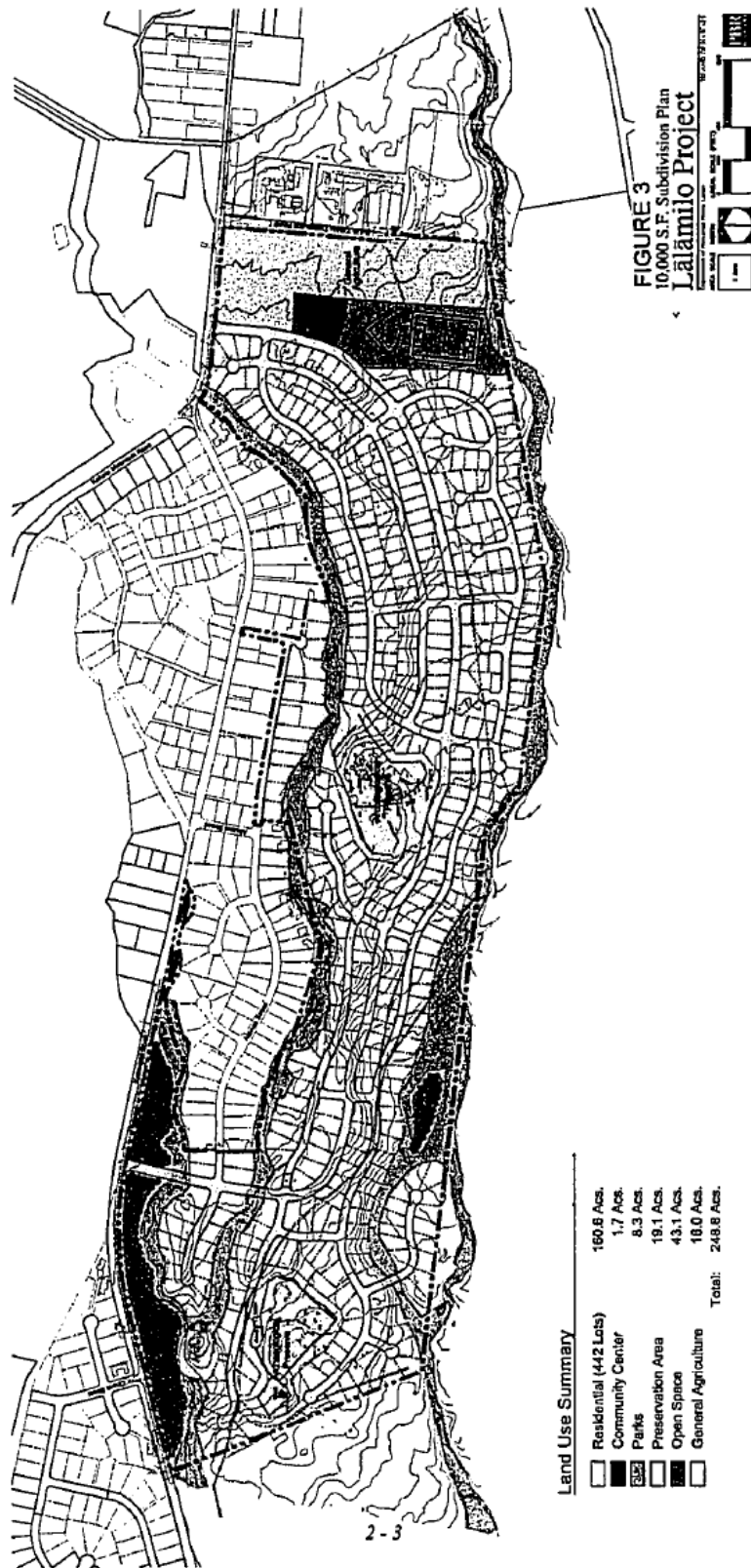


Figure 23: DHHL Lālāmilo Residential Project

# Chapter 3: Water Quality Conditions

## **3.1 Explanation and Meaning of Water Quality Parameters**

Measurements of stream water quality has focused on concentrations of nitrate ( $\text{NO}_3$ ) ammonia ( $\text{NH}_4$ ), total dissolved nitrogen (TDN), total nitrogen (TN, includes all forms of nitrogen, including dissolved and solid components), phosphate ( $\text{PO}_4$ ), total phosphorus (TP, includes all forms of phosphorus, including both dissolved and solid components), and suspended sediment (Total Suspended Solids or TSS). Nitrate measurements are actually measurements of the sum of nitrate plus nitrite ( $\text{NO}_3 + \text{NO}_2$ ); however, the amount of nitrite is negligible. In reporting the concentrations (weight of pollutant per liter of water), the notation  $\text{NH}_4$  as N or  $\text{NH}_4\text{-N}$  means that only the weight of nitrogen (N) is included; the weight of other atoms such as hydrogen or oxygen is not included.

Water quality monitoring in the Wai'ula'ula watershed has focused on nitrogen (which comes in many forms) and phosphorus (which comes in several forms) because they encourage growth of algae. Too much algae makes the water cloudy and will eventually cause oxygen levels to decline. High levels of oxygen are needed for a health ecosystem.

In addition to the above, marine water quality measurements include dissolved silica and chlorophyll-a. The silica is not a pollutant. It is found in groundwater, so higher levels indicate greater groundwater influence. High levels of chlorophyll-a indicate that excessive levels of algae are growing in the water.

## **3.2 Availability of Data**

The following data are available:

- 1) Older water quality data (1971-1989) collected by the U.S. Geological Survey (USGS) in the headwaters of Waikoloa Stream (Marine Dam gaging station 16758000).
- 2) Recent stream water quality data (2007-2009) collected by the MKSWCD at four locations with autosamplers. Grab sample data are available for several additional locations.
- 3) Water quality data for runoff from parking lots and roads.
- 4) Discharge data at most locations where stream water quality data were collected. Discharge data were used to calculate discharge-weighted average concentrations and to calculate nutrient loads.
- 5) Marine water quality data (2006-2008) collected by the Hawai'i Department of Health (DOH).

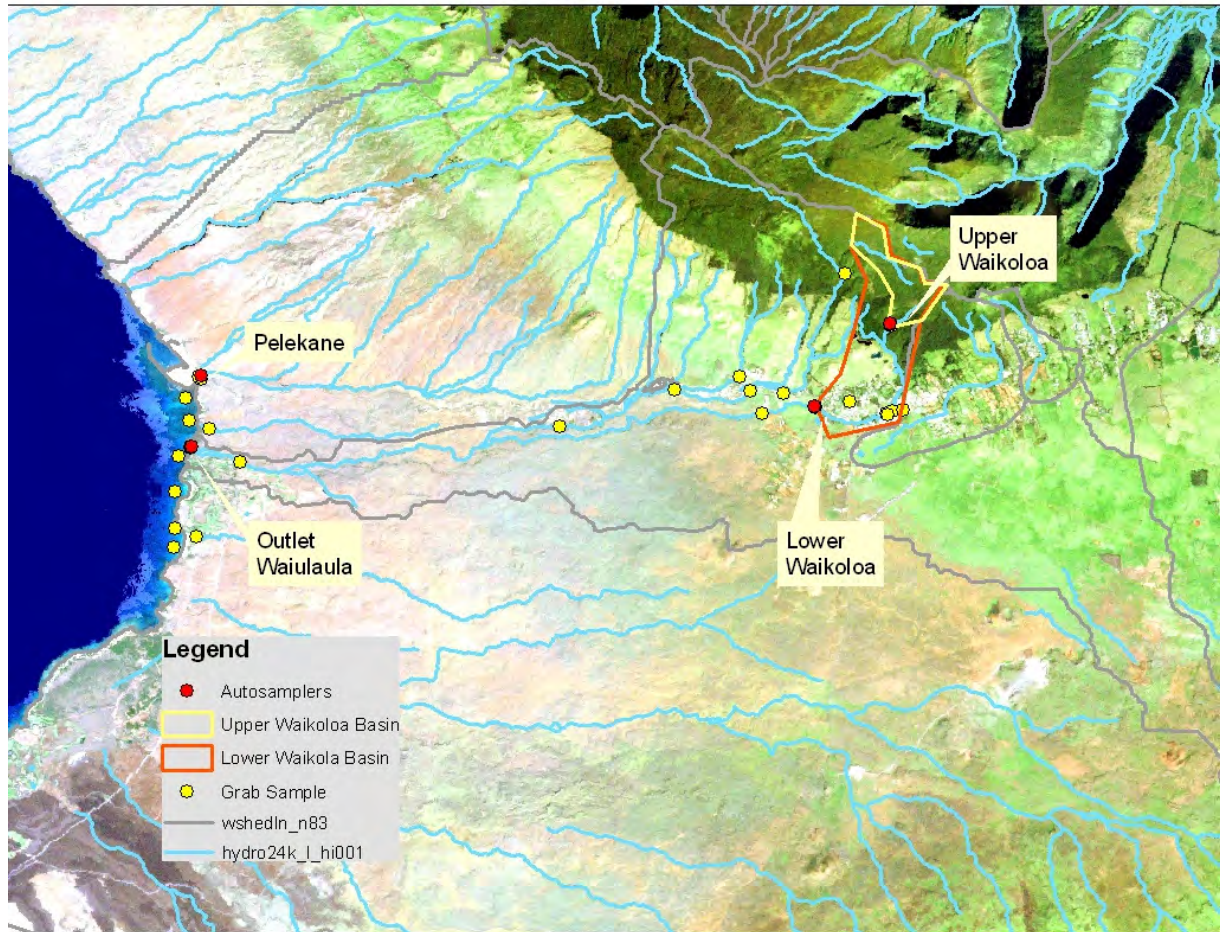
- 6) Biological surveys.
- 7) Trace metals in stream and roadside sediment.

Older water quality data: Water quality data were collected at the Marine Dam gage station (16758000) between 1971 and 1989. These data were collected by the USGS Water Resources Branch. Along with physical parameters like temperature and discharge, nutrients and trace element concentrations were measured on fourteen occasions. Nutrient concentrations were all very low (near detection limits) except for orthophosphate which showed two elevated readings.

New water quality data: Autosamplers were used to collect stormwater runoff that was analyzed for nutrient and suspended sediment concentrations. The autosamplers were located on Waikoloa stream at the Marine Dam (“upper” site), Waikoloa stream downstream of Waimea town (“middle” or “Sandalwood” site), and Wai’ula’ula stream just upstream of the ocean entry (“lowest” or “ocean entry” site) (Figure 24). Data represent eleven storm events that occurred between November 2007 and February 2009. For one of these storms, autosampler data was also collected from Makeāhua stream just upstream at of its entry into Pelekane Bay (“Pelekane” site). The Makeāhua/Pelekane watershed is similar to the middle and lower sections of the Wai’ula’ula watershed, but it is denuded by overgrazing and fire. It represents the worst case scenario that we are trying to prevent in the Wai’ula’ula watershed. Grab samples of urban storm water runoff were collected on four occasions from sites in Waimea town.

The USGS makes routine measurements of streamflow (discharge) at the Marine Dam site. At the other autosampler sites, approximate estimates of stream discharge have been made on the basis of water level measurements. Measuring flow data at the same time that nutrient concentrations are measured permits us to calculate nutrient fluxes. Flux can be viewed as the amount of substance passing a point on the stream in a given period of time. Multiplying our concentrations (mass / volume) by flow rate (in volume / time) gives flux (mass / time).

Drainage basins contributing flow to the four sampling sites are very different. The forested Marine Dam basin (865 ac.) is comprised almost exclusively of protected headwater bog. The Sandalwood basin (2,037 ac.) drains much of Waimea Town and includes the Marine Dam basin. As discussed elsewhere in this report, the Waikoloa stream is affected by diversions. Wai’ula’ula and Pelekane basins (associated with the two autosamplers near sea-level) cover the entire watersheds and contain a variety of land covers and land uses. Both basins include a large amount of ranch lands. Table 2 shows percent land cover of each of the four drainage basins. Land cover was derived from 2001 NOAA Coastal Change Analysis Program (C-CAP) data.



**Figure 24: Sample Locations**

**Table 2: Land Cover in Four Drainage Basins**

	Waiulaula above Marine Dam	Waiulaula above Sandalwood	Waiulaula at Ocean	Pelekane
High intensity development		5%	1%	0%
Low intensity development		10%	5%	1%
Cultivated		1%	1%	0%
Grass	2%	42%	58%	72%
Evergreen Forest	98%	36%	26%	5%
Scrub/Shrub	trace	5%	5%	6%
Bare		0%	4%	16%
Water		1%	trace	0%
SUM	100%	100%	100%	100%

### **3.3 Water Quality Standards**

In the state of Hawai'i, minimum water quality standards (Chapter 11-54, HAR) are established by the Department of Health under the provisions of the Clean Water Act. These standards are intended to protect designated uses of streams and marine waters. (See Section 2.2.9.10 in the previous chapter for a discussion of classification and designated uses of waters within the Wai'ula'ula watershed and immediately offshore.)

Nutrient and sediment standards applicable to all Wai'ula'ula watershed streams are listed in Table 3. There are several additional standards:

- pH should not exceed 8.0, be lower than 5.5, or deviate more than 0.5 units from ambient conditions.
- Dissolved oxygen concentrations should not be less than 80% of saturation.
- Specific conductance should not be more than 300 umho/cm. [Note: umho/cm is a unit of electrical resistance. Very pure water does not conduct electricity as well as salty water.]
- Temperature should not vary more than 1 degree C from ambient conditions.

Most of the standards are based on the geometric mean of all samples taken within a relatively recent period (say five years). If there are  $n$  measurements on a given stream, the geometric mean is equal to the  $n^{\text{th}}$  root of all the measurements multiplied together. For example, if there are three measurements with values of 2, 3, and 20, then the geometric mean is equal to  $(2*3*20)^{1/3}$ . Compared to an arithmetic average, the geometric mean is less influenced by occasional very large values. There are certain protocols that are used to officially determine if a water body meets standards. These procedures include having a sufficiently large number of recent samples, more than one sampling site on a stream, and using strict quality assurance protocols including a certified laboratory. The water quality measurements undertaken as part of this watershed assessment were not intended to be used for official determination of whether water bodies of interest meet regulatory standards. Thus, although measurements are compared to standards, this does not constitute official evaluation of whether the water bodies are impaired.



**Table 3: Water Quality Criteria for Streams**

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to exceed the given value more than two percent of the time
Total Nitrogen (mg /L)	0.250* 0.180**	0.520* 0.380**	0.800* 0.600**
Nitrate + Nitrite (mg/L-N)	0.070* 0.030**	0.180* 0.090**	0.300* 0.170**
Total Phosphorous (mg/L-P)	0.050* 0.030**	0.100* 0.060**	0.150* 0.080**
Total Suspended Solids (mg/L)	20.0* 10.0**	50.0* 30.0**	80.0* 55.0**
Turbidity (N.T.U.)	5.0* 2.0**	15.0* 5.5**	25.0* 10.0**

\*standard applicable during rainy (wet) season of November 1 through April 30

\*\*standard applicable during dry season of May 1 through October 31

Table 4 lists nutrient and sediment standards applicable to the marine waters immediately offshore of the watershed (both A and AA waters). There are several additional standards:

- pH should not deviate more than 0.5 units from 8.1, unless affected by freshwater discharges, in which case pH must not be lower than 7.0.
- Dissolved oxygen concentrations should not be less than 75% of saturation.
- Salinity should not vary more than 10% from what is expected for oceanographic conditions, seasonal variations, or hydrologic inputs.
- Temperature should not vary more than 1 degree C from ambient conditions.

**Table 4: Open Coastal Waters Water Quality Criteria**

Parameter	Geometric mean not to exceed this value
Total Dissolved Nitrogen*	0.10 mg/L
Ammonia Nitrogen (NH <sub>4</sub> )	0.0025 mg/L-N
Nitrate + Nitrite Nitrogen*	0.0045 mg/L-N
Total Dissolved Phosphorous*	0.0125 mg/L
Phosphate*	0.005 mg/L
Chlorophyll a	0.30 µg/L
Turbidity	0.10 N.T.U.

If salinity is less than or equal to 32 parts per thousand, this parameter shall be related to salinity using a regression equation specified in HAR 11-54-6, pages 47-48.

Chapter 11-54, HAR also provides freshwater and marine standards relating to toxic substances (pesticides, heavy metals, organic solvents) and bottom sediments. These are not believed to be a problem for the Wai'ula'ula watershed. It is unlikely that bottom sediments in Pelekane Bay meet standards, but that is outside the scope of this report.

## **3.4 Stream Data (nutrient and sediment concentrations)**

### **3.4.1 Observed Concentrations**

Autosamplers were set to collect water samples whenever the water level in the stream rose rapidly and then every 30-60 minutes thereafter. For each storm events, 24 one-liter samples were collected over a 12 to 20 hour period. To reduce costs, only 8-10 of these bottles were sent to the laboratory for analysis. Typically, bottles were selected based on turbidity and with a view towards being able to characterize changes over time. For example, early in the storm, when turbidity changed rapidly, every bottle would be selected. Late in the storm, when turbidity changed slowly, every third bottle might be selected. Discharge-weighted average concentrations were then calculated for each runoff event and autosampler location. Discharge-weighted averages are also known as the "event mean concentration" or EMC.<sup>6</sup> For

<sup>6</sup> The following procedure was used to obtain the EMC average. For each sample, the concentration (weight of pollutant per unit volume) was multiplied by the streamflow rate (volume of water per unit time) times the length of time represented by that sample (typically the time between successive samples). The resulting number was summed across samples, and then divided by the total volume of flow for that event.

each runoff event, the EMC is the total load of pollutant (amount measured as a weight) divided by the flow volume. Streamflow data are needed to make EMC calculations. Streamflow data for the Marine Dam were obtained from the USGS. Flow data at the other autosampler sites were obtained from measurements of water depth (which is recorded continuously by the autosampler) and the Manning equation. Streamflow data from the Sandalwood, Wai'ula'ula, and Pelekane sites should be considered approximate.

TSS and TP increase when stream discharge increases (correlation coefficient of 0.81 for TSS and 0.78 for TP).

There are several factors that should be taken into consideration when comparing nutrient concentrations and fluxes at the upper site (above town) and the Sandalwood site (below town). First, water is diverted from Waikoloa stream immediately downstream of the upper site. Normally, the stream is completely impounded by the dam and all water is diverted into the Department of Water Supply intake. During a storm event, the water will rise and eventually overtop the dam. Only after the dam is overtopped will water flow down the channel towards Waimea. Second, it is likely that Waikoloa is a losing stream between the upper autosampler and Waimea Town. This means that the streambed leaks and some of the streamwater (along with whatever is dissolved in it) filters into the ground and does not make it to the Sandalwood autosampler site. The exact amount that is lost is unknown. It is noteworthy, however, that for the three events with data (12/6/07, 12/16/07 and 1/26/08), the stormflow volume at the Sandalwood site is only 3% more than the streamflow volume at the upper gage. Even taking into account the fact that the streamflow data at the Sandalwood site are not very accurate, it is clear that much of the runoff from the upper forested part of Waikoloa stream is not making it down to Waimea Town. This issue is revisited in the Monitoring chapter (Chapter 6).

### **3.4.2 Are Streams Polluted?**

Measured sediment and nutrient concentrations were compared to water quality standards in order to evaluate whether or not streams are polluted (Tables 5 and 6).

At Marine Dam (where Waikoloa stream exits the high-elevation forest), the stream has relatively low concentrations of nitrate, ammonia, and orthophosphate ( $\text{PO}_4$ ). The geometric mean of measured nitrate concentration was only 23% of the water quality standard, and mean  $\text{PO}_4$  was only 9% of the standard. There is no standard for ammonia. The geometric mean of total nitrogen concentration (sum of particulate and dissolved forms) was 17% higher than the standard. The geometric mean of total phosphorus (TP) concentration was 30% lower than the standard. Mean suspended solids (sediment concentration) were only 50% of the standard.

Further down on the same stream, concentrations were measured at the Sandalwood site, which is at the downstream edge of Waimea Town. In comparison to the Marine Dam site, ammonia concentrations doubled, total phosphorus concentrations (TP) more than doubled, and nitrate concentrations quadrupled. The average nitrate concentration just barely exceeded

the water quality standard. The TP concentration was nearly twice the allowable amount. Sediment concentrations at Sandalwood were higher than at the Marine Dam. The Sandalwood sediment concentrations were below the standard, although just barely.

Much further downstream, an autosampler was installed on the Wai'ula'ula Stream a short distance above where it enters the ocean. At this location, sediment, ammonia, nitrate, and total phosphorus concentrations were low and within acceptable limits. Nitrate was less than half of what is allowed; sediment and total phosphorus were about 30% lower than what is allowed. Total nitrogen was high, however, with measured concentrations nearly twice what is allowed.

Only one runoff event was captured by the Pelekane autosampler, which is located several hundred yards above where the stream enters the ocean. Sediment and nutrient concentrations were incredibly high. The sediment concentration was 150 times greater than what is allowed, and the total nitrogen concentration was 240 times greater than what is allowed. The corresponding figures for nitrate and total phosphorus are 11 times and 40 times greater, respectively.

At all sites, the majority of phosphorus (>86%) was present as particulate matter, with only a small amount ( $\leq 14\%$ ) present in dissolved form. This is not surprising, as streams on Hawai'i Island (and elsewhere) have a majority of phosphorus present in particulate form (Michaud and Weigner 2011). No analyses were conducted to determine whether N or P is the limiting nutrient. A study conducted that examined four Oahu streams (Larned and Santos 2000) found that they were P limited. There is no guarantee, however, the Wai'ula'ula is also P limited.

Dissolved nitrogen can be present in three different forms: organic (DON), nitrate, nitrite, and ammonia. Of these, nitrite is rarely present under conditions experienced in the watershed. While dissolved organic nitrogen is abundant, it is not immediately available to algae, whereas nitrate and ammonia are utilized directly by algae. Ammonia is toxic to fish and aquatic invertebrates.

The three sites on the Wai'ula'ula/Waikoloa stream differ in the proportions of the various forms of dissolved nitrogen. The Sandalwood site just below Waimea Town has the lowest proportion of DON (54% of dissolved nitrogen is organic) and the highest proportion of nitrate (31% of dissolved nitrogen is nitrate).

Most particulate nitrogen is present as living OR partially decomposed dead organisms (including plankton and partially decomposed vegetation).

**SIDEBAR: Understanding Nitrogen**

**Table 5: Nutrient and Sediment Concentrations in Samples Collected by Autosamplers. Values are discharge-weighted (EMC).**

SITE	Date	TSS mg/l	TDN mg/l - N	TN mg/l - N	NO <sub>3</sub> +NO <sub>2</sub> mg/l - N	NH <sub>4</sub> mg/l-N	PO <sub>4</sub> mg/l-P	TP mg/l-P	Runoff m <sup>3</sup>
Marine Dam (forest)	1-Nov-07	9	0.233	<i>0.343</i>	0.020	0.019	0.005	0.047	25,000
Marine Dam (forest)	6-Nov-07	17	0.223	<i>0.399</i>	0.010	< 0.014	0.007	0.056	25,000
Marine Dam (forest)	14-Nov-07	5	0.077	<i>0.140</i>	0.015	0.0113	0.005	0.019	18,000
Marine Dam (forest)	3-Dec-07	8	0.191	<i>0.300</i>	0.015	0.0169	0.004	0.025	42,000
Marine Dam (forest)	5-Dec-07	24	0.230	<i>0.373</i>	<i>0.012</i>	0.011	0.0026	0.063	140,000
Marine Dam (forest)	16-Dec-07	32	0.148	<i>0.372</i>	0.016	0.023	0.004	0.120	210,000
Marine Dam (forest)	26-Jan-08	2	0.187	<i>0.229</i>	0.025	0.021	0.004	0.007	23,000
<b>geometric mean</b>		<b>10</b>	<b>0.174</b>	<b>0.292</b>	<b>0.016</b>	<b>0.014</b>	<b>0.0043</b>	<b>0.035</b>	
Sandalwood	22-Nov-07	49	0.251	<i>0.652</i>	0.121	0.017	0.015	0.164	100,000
Sandalwood *	4-Dec-07	8	0.348	<i>0.505</i>	0.110	0.152	0.026	0.067	n/a
Sandalwood	6-Dec-07	37	0.303	<i>0.576</i>	0.080	0.017	0.012	0.141	167,000
Sandalwood	16-Dec-07	42	0.188	<i>0.487</i>	0.033	0.014	0.007	0.194	203,000
Sandalwood	26-Jan-08	3	0.215	<i>0.275</i>	0.064	0.033	0.010	0.019	15,000
<b>geometric mean</b>		<b>18</b>	<b>0.255</b>	<b>0.480</b>	<b>0.074</b>	<b>0.029</b>	<b>0.013</b>	<b>0.089</b>	
Coastal Outlet	17-Jan-09	21	0.442	0.826	0.191	0.025	< 0.003	0.046	48,000
Coastal Outlet**	24-Jan-09	8	0.225	0.339	0.005	< 0.014	< 0.003	0.035	40,000
Coastal Outlet	3-Feb-09	12	0.244	0.415	0.024	0.029	0.004	0.027	132,000
<b>geometric mean</b>		<b>13</b>	<b>0.290</b>	<b>0.488</b>	<b>0.028</b>	<b>0.017</b>	<b>0.002</b>	<b>0.035</b>	
Pelekane	6-Dec-07	<b>3045</b>	<b>1.93</b>	<b>59.6</b>	<b>0.77</b>	<b>0.22</b>	<b>0.046</b>	<b>1.98</b>	69,000
Water quality standard***		<b>20</b>	<b>n/a</b>	<b>.250</b>	<b>.070</b>	<b>n/a</b>	<b>n/a</b>	<b>.050</b>	<b>n/a</b>

\* arithmetic average of 2 grab samples    \*\* arithmetic average of 6 autosamples    \*\*\* Wet season geometric mean should not exceed.

TN values in italics are estimated based on TSS and TDN concentrations.



Table 6 summarizes whether or not sediment and nutrient concentrations are high enough to impair water quality. This interpretation is based on comparing the measured value (geometric mean of measurements from several runoff events) to the water quality standards. There were 7 runoff events measured at Marine Dam, 5 events at Sandalwood, 3 events at the watershed outlet, and 1 event at Pelekane. In this table “impairment” is meant in a general sense, and not in the sense of a formal assessment by the Hawai‘i Department of Health.

**Table 6: Summary of Stream Impairments for Nutrient and Sediment Based on Monitoring Data**

<b>Site</b>	<b>TSS (sediment)</b>	<b>Total Nitrogen</b>	<b>Nitrate</b>	<b>Total Phosphorus</b>
<b>Marine Dam (above Waimea)</b>	Not impaired  (measured value below the standard)	Could be impaired  (measured value near the standard)	Not impaired  (measured value well below standard)	Probably not impaired  (measured value below standard, but not by much)
<b>Sandalwood (below Waimea)</b>	Could be impaired  (measured value near the standard)	Impaired  (measured value almost double the standard)	Could be impaired  (measured values near the standard)	Impaired  (measured value almost double the standard)
<b>Watershed outlet</b>	Not impaired  (measured value below the standard)	Impaired  (measured value almost double the standard)	Not impaired  (measured values below standard)	Probably not impaired  (measured value below standard, but not by much)
<b>Pelekane</b>	Very polluted  (Exceeds standard by 2 orders of magnitude)	Very polluted  (Exceeds standard by 2 orders of magnitude)	Very polluted  (Exceeds standard by 1 order of magnitude)	Very polluted  (Exceeds standard by 2 orders of magnitude)

## **3.5 Urban Runoff (nutrient and sediment concentrations)**

### **3.5.1 Observed Concentrations**

Nine samples of urban storm runoff were collected by taking grab samples of flowing water in parking lots, storm water running off of roads, or from pipes that collect parking lot/road runoff (Table 7). All sites were located in Waimea, and samples were collected between November 2008 and April 2009.

### **3.5.2 How Polluted is Waimea's Urban Runoff?**

Based on a limited amount of data, it appears likely that runoff from high-use paved areas exceeds water quality criteria for sediment (by a factor of five), total phosphorus (by a factor of four), total nitrogen (by a factor of three) and nitrate (measured values are only slightly greater than the standard). These results are not surprising as urban storm runoff is usually high in sediment and nutrients. The urban runoff concentrations can also be compared to concentrations measured in Waikoloa Stream immediately downstream of Waimea (at the middle or Sandalwood autosampler). Compared to the stream, the urban runoff was more enriched in sediment (by a factor of six), orthophosphate (by a factor of 5), total phosphorus (by a factor of 2.3), ammonium (by a factor of 1.7), and total nitrogen (by a factor of 1.7). The urban and stream samples were taken on different days, so results could very well be different if stream and urban samples were taken on the same day, or if more urban samples were collected at more times in more locations. These limitations notwithstanding, the data that are available show that runoff from paved urban areas has high concentrations of sediment and nutrients, particularly particulate nutrients. Further, it appears that the runoff from high-use paved areas is more polluted than the water in the stream.

Studies on Oahu and on the mainland have shown that urban runoff often contains heavy metals and occasionally pesticides, but similar measurements of Waimea's stormwater have not been made. Measurements have been made in Waimea's roadside sediment, however. These data are discussed in section 3.8.

### **3.5.3 First Flush**

"First flush" occurs when the initial runoff washes pollutants off roads and fields, delivering a majority of pollutants in the early part of a runoff event (when water levels are still rising). To see if this was occurring in the Waikoloa Stream, autosampler data from the Marine Dam watershed (forested higher-elevation area) and Sandalwood watershed (includes Waimea urban core) were analyzed using the dimensionless mass-volume (MV) method. The first flush

**Table 7: Grab Samples of Urban Storm Runoff Collected from Waimea Parking Lots and Roads**

<b>Location</b>	<b>Date</b>	<b>TSS mg/L</b>	<b>TDN mg/L- N</b>	<b>TN* mg/L-N</b>	<b>NO<sub>3</sub> + NO<sub>2</sub> mg/L-N</b>	<b>NH<sub>4</sub> mg/L-N</b>	<b>PO<sub>4</sub> mg/L-P</b>	<b>TP . mg/L-P</b>
KTA parking lot white pipe	11/18/08	32	0.14	<i>0.30</i>	0.008	<.0014	0.007	0.061
Comm Ed Ctr	11/18/08	378	1.03	<i>5.56</i>	0.502	0.165	0.127	1.008
KTA backlot (parking)	11/18/08	550	1.07	<i>8.33</i>	0.149	0.081	0.817	0.908
Paniolo Parking Lot	11/18/08	44	0.55	<i>0.83</i>	0.055	0.036	0.091	0.242
Community. Ed Big Pipe	1/11/09	35	0.22	0.56	0.068	0.096	0.040	n/a
Community Ed Big Pipe	12/11/08	368	0.47	3.35	0.148	0.062	0.037	0.834
Community Ed Big Pipe	4/15/09	97	1.87	2.95	0.557	0.164	0.031	0.359
Mamalahoa Hwy KTA side	11/18/08	139	0.59	<i>1.76</i>	0.084	0.091	0.089	0.482
Mamalahoa Highway site #2	11/18/08	49	0.39	<i>0.69</i>	0.048	0.059	0.044	0.152
<b>geometric mean</b>		<b>111</b>	<b>0.54</b>	<b>0.83</b>	<b>0.10</b>	<b>0.05</b>	<b>0.05</b>	<b>0.21</b>
<i>compare to</i>								
geometric mean of stream at Sandalwood autosampler		18	0.26	0.48	0.07	0.03	0.01	0.09
wet season geometric mean should not exceed		20	n/a	0.25	0.07	n/a	n/a	0.05

\* Values in italics are based on measured TDN values and estimated PN values.

phenomenon was not seen in the majority of storms. However, a first flush of total suspended solids (TSS) and ammonia occurred during the 11/22/07 storm and a first flush of  $\text{NH}_4$  occurred during the 11/14/07 storm. In these cases, 25% to 50% of the pollutants were seen in the first 20% of stream flow.

Some storm events have data for both the Marine Dam and Sandalwood sites. For these storms, nitrogen pollutants were delivered earlier (relative to the onset of flooding) at the Sandalwood site compared to the upper site in the forest. This could indicate that in Waimea there is nitrogen on the surface of the ground (for example, fertilizer or animal feces) that is quickly washed off at the beginning of the storm. This interpretation is uncertain, however, because results were mixed for TP and TSS.

#### **3.5.4 Variations in the form of nitrogen**

Nitrogen can occur in several different forms. The three basic categories are dissolved organic nitrogen, dissolved inorganic nitrogen, and particulate nitrogen. Dissolved inorganic nitrogen can be present as nitrate (most stable form), nitrite (rarely present), ammonia (unstable form found in sewage and fertilizer). Dissolved organic nitrogen consists of carbon-rich compounds of biological origin. Pound for pound, the common forms of inorganic nitrogen (nitrate and ammonia) have a greater influence on ecosystems than an equivalent amount of organic nitrogen. There is more organic nitrogen than inorganic nitrogen, however. Nitrogen readily changes from one form to another and can be transformed to a gas through a process called denitrification. Denitrification typically occurs when there is little oxygen present and results in loss of nitrogen to the atmosphere. High concentrations of ammonia are stressful to aquatic life. Notably, ammonia concentrations in Kawaihae Bay at Wai'ula'ula exceed marine water quality standards. (There are no ammonia limits for streams.) In the Bay, there is more ammonia than nitrate, whereas in the stream there is more nitrate than ammonia. When oxygen is present, ammonia tends to be converted to nitrate. The higher proportion of ammonia in Kawaihae Bay at Wai'ula'ula suggests that an ammonia source could be nearby.

In the stream, different sites have different concentrations of the various types of nitrogen (Table 8). Compared to the other sites, the forest site has the lowest concentration of nitrate and ammonia. The watershed outlet has the highest concentration of dissolved organic nitrogen. There are also differences in the *proportions* of the three kinds of dissolved nitrogen. In comparison to the other sites, the urban site has the greatest proportion of nitrate and ammonia (as a percentage of total dissolved nitrogen).

**Table 8: Concentrations of Various Forms of Dissolved Nitrogen**

Values are concentrations (geometric mean of all days with measurements) in units of mg/l as N. The value in parentheses is the percentage of that station's total dissolved nitrogen.

	Ocean (Wai'ula'ula Bay)	Stream at watershed outlet	Urban runoff	Sandalwood (below Waimea)	Marine Dam (edge of forest)
<b>Nitrate</b>	<b>0.005</b> (5%)	<b>0.028</b> (10%)	<b>0.10</b> (19%)	<b>0.074</b> (29%)	<b>0.016</b> (9%)
<b>Ammonia</b>	<b>0.007</b> (7%)	<b>0.017</b> (6%)	<b>0.05</b> (9%)	<b>0.029</b> (11%)	<b>0.014</b> (8%)
<b>Organic</b>	<b>0.088</b> (88%)	<b>0.245</b> (84%)	<b>0.39</b> (72%)	<b>0.152</b> (60%)	<b>0.144</b> (83%)

## **3.6 Marine Data (nutrient, sediment, and algae concentrations)**

### **3.6.1 Observed Concentrations**

During the period July 2006 – April 2008, DOH made frequent measurements of water quality at a number of coastal sites. Measurements in the nearshore waters of Kawaihae Bay at Wai'ula'ula were taken on thirty-three separate days. Average values (geometric mean) are shown in Table 9; a similar table showing variability over time is found in the appendix.

The water quality measurements included suspended sediment, several types of nutrients, dissolved silica, and chlorophyll-a. The silica is not a pollutant. It is found in groundwater, so higher levels indicate greater groundwater influence. Nutrients are substances that encourage the growth of algae. Measurements were made of two types of dissolved nutrients (ammonia and the combination of nitrate+nitrite). Total nitrogen (or total phosphorus) is a measurement of all possible forms of dissolved and solid nitrogen (or phosphorus). High levels of chlorophyll-a indicate that excessive levels of algae are growing in the water. Too much algae makes the water cloudy, blocking sunlight needed by coral. Very high levels of algae result in too little oxygen in the water.

Marine algal growth could either be phosphorus-limited or nitrogen-limited. Studies that would shed light on this issue have not been conducted at Wai'ula'ula, but a study conducted on Oahu (Larned 1998) found that marine macroalgae in Kaneohe Bay were N limited. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus can shed light on nitrogen and phosphorus dynamics. No measurements of dissolved inorganic phosphorus have been made at Wai'ula'ula, however, presumably because there are no regulatory standards for it. The observed TN:TP ratio is 15:8, which is a typical value for coastal waters. It would be

more informative to examine the ratio of dissolved N to dissolved P, but the necessary data are not available.

**Table 9: Geometric Mean of Ocean Water Quality Measurements Made Near the Mouth of the Wai'ula'ula River and at Several Comparison Sites**

The water quality standards listed in the table are the ones that should not be exceeded if the salinity is > 32 parts per thousand. The TP and TN standards are for filtered samples, and it is presumed that TP and TN data are for filtered samples.

	<b>TSS (mg/L)</b>	<b>Ammonia (mg/L-N)</b>	<b>Nitrate + Nitrite (mg/L-N)</b>	<b>TN (mg/L -N)</b>	<b>TP (mg/L -P)</b>	<b>Filtered Silica (mg/L)</b>	<b>Chlorophyll 'a' (ug/L)</b>
<b>Kawaihae Bay at Wai'ula'ula</b> (Leeward Hawai'i)	9.26	0.007	0.005	0.10	0.014	0.26	0.62
<b>Wai'ula'ula water quality standard</b>	none	0.0025	0.0045	0.1	0.0125	none	0.3
<b>Pelekane Bay</b> (Leeward Hawai'i)	44.28	0.038	0.050	0.26	0.050	1.60	3.28
<b>Hapuna Beach</b> (Leeward Hawai'i)	9.59	0.004	0.060	0.15	0.019	1.45	0.36
<b>Hilo Bay</b> (Lighthouse) (Windward Hawai'i)	13.01	0.010	0.025	0.16	0.021	1.99	1.77
<b>Kihei (South)</b> (Leeward Maui)	16.93	0.013	0.036	0.36	0.029	0.97	1.05
<b>Moana Beach, Waikiki</b> (Leeward Oahu)	13.42	0.004	0.016	0.14	0.017	0.12	0.41

### **3.6.2 Is the Ocean Polluted near the Mouth of the Wai'ula'ula Stream?**

There are two important questions about water quality in Kawaihae Bay at Wai'ula'ula:

- (1) Is the water polluted with nutrients, sediment, and algae?
- (2) How does water quality in Kawaihae Bay at Wai'ula'ula compare to water quality in other Hawaiian shorelines?

Comparison of measurement against the water quality standards (Table 9) shows that the Bay has too much ammonia (concentrations are 2.8 more than what is allowed) and too much



chlorophyll (concentrations are double what is allowed). The high chlorophyll levels indicate that there is too much algae. It is likely the high ammonia levels are contributing to high excess algae. Because ammonia is rapidly converted to nitrate in the presence of oxygen, it is likely that the source of the ammonia is nearby. The measured nitrate and total nitrogen concentrations are near the standard. Total phosphorus concentrations are slightly above the standard.

Water quality in Kawaihae Bay at Wai'ula'ula is considerably better than in nearby Pelekane Bay (Table 9). The water quality in Pelekane Bay is poor: there are high levels of sediment, ammonia, nitrate, and chlorophyll. If Pelekane is excluded, then the water quality in Kawaihae Bay at Wai'ula'ula is roughly the same or better than the comparison beaches shown in Table 9. Compared to the other beaches, Wai'ula'ula has lower concentrations of total phosphorus and nitrate. Wai'ula'ula's chlorophyll and ammonia concentrations are lower than some beaches and higher than others. For suspended sediment, Wai'ula'ula's concentration is the same or better than that found at comparison beaches.

In summary, the waters of Kawaihae Bay at Wai'ula'ula are impaired by excessive levels of ammonia and algae. Levels of other nutrients are near the standard or slightly above. The levels of nutrients and algae are comparable to—if not slightly better than—many other Hawaiian beaches. Notably, Pelekane Bay, which receives runoff from the watershed immediately north of the Wai'ula'ula watershed, is strongly impaired by high levels of nutrients, sediment, and algae. It is important to prevent conditions in Wai'ula'ula watershed from deteriorating to the level found in Pelekane watershed.

Marine water quality can deteriorate after watershed runoff events and after high surf events. To see if the runoff events were a factor at Kawaihae Bay (Wai'ula'ula outlet), Kawaihae data (33 measurements made over 22 months) were compared with stream discharge in the watershed headwaters (Marine Dam) and with open ocean wave height (NOAA buoy 51003 at 19.087N, 160.66W). When streamflow increases at Marine dam, ocean TN and silica increase two days later. (Silica comes from the land, not the ocean). This suggests that watershed runoff is contributing nitrogen to the bay. Marine algae concentrations are *lower* when there is high surf or higher than usual streamflow. This could indicate that coastal waters are being diluted with either open ocean seawater or stream floodwaters.

### **3.7 Watershed Loads (total amount of pollutants)**

“Loads” are the total amount of a pollutant that is exported from a watershed. Loads are usually measured in pounds (of Nitrogen, Phosphorus, or Sediment) per year. We want to know what the loads are now, what they will be in the future, and whether there is anything that can be done to reduce loads. Existing loads can be measured, although obtaining data is very expensive. Modeling can be used to estimate loads for locations where measurements are

not available. Modeling is also used to estimate future loads or reductions in loads resulting from remediation efforts.

Measuring loads requires simultaneous measurements of stream discharge and sediment/nutrient concentration. Discharge and concentration are multiplied together to obtain loads or fluxes. (Fluxes and loads are synonyms.) The MKSWCD measured fluxes for several runoff events, but did not make the year-long measurements necessary to obtain the total load for an entire year. Annual loads were, therefore, estimated using NOAA's N-SPECT model.

### **3.7.1 Load Measurements**

Each autosampler collected discharge and water quality data for several runoff events. By multiplying discharge and sediment/nutrient concentration together, it is possible to calculate the load (pounds of sediment, nitrogen, phosphorus) carried by the stream for a particular runoff event (Table 10). The values in Table 10 represent all the pollutants carried by the stream (at each location) for a particular runoff event. Not all storms were sampled, so we do not have annual loads (total for an entire year). The discharge at the upper sampler was measured very accurately, but the discharge measurements at the other locations are approximate. As a result, the load measurements are approximate for all but the upper site (Marine Dam). Data from the Marine Dam site are reasonably representative of loads produced in the high-elevation forests. Data from the Sandalwood site and the watershed outlet, however, represent a mix of land uses.

The load measurements, while valuable, are limited because they cover only some locations and some storms. Because weather varies from one year to the next, several years of data would be needed to obtain a reliable estimate of the average annual load. Because such data do not exist for the Wai'ula'ula watershed, a model was used to estimate average annual loads and examine spatial variations over the watershed. Collection of even one complete year of data would be very expensive and currently there are no immediately plans to do so.

### **3.7.2 Using the N-SPECT Model to Estimate Loads and Spatial Variability in Pollutants**

The Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT model) estimates average annual pollutant loads as a function of climate, soil characteristics, topography, and landcover class. (Landcover classes describe both vegetation and land use.) One advantage of using a model is that it will provide explicit estimates of the contributions of each landcover class. N-SPECT can also identify areas that are particularly susceptible to erosion or predict the change in loads resulting from land use changes. The success of this approach depends on the model's assumptions about how runoff coefficients and nutrient concentrations vary among landcover classes. The key issue is whether the relative differences between landcover classes reflect the relative differences in the actual watershed.

**Table 10: Measured Loads**

Measurements of the amount of nutrients and sediment carried by the stream during a particular runoff event. Values represent how much was carried past each autosampler. The Marine Dam site is above Waimea Town near the lower edge of the forest. The Sandalwood site is immediately below Waimea Town. TN values in italics were estimated from sediment and TDN data.

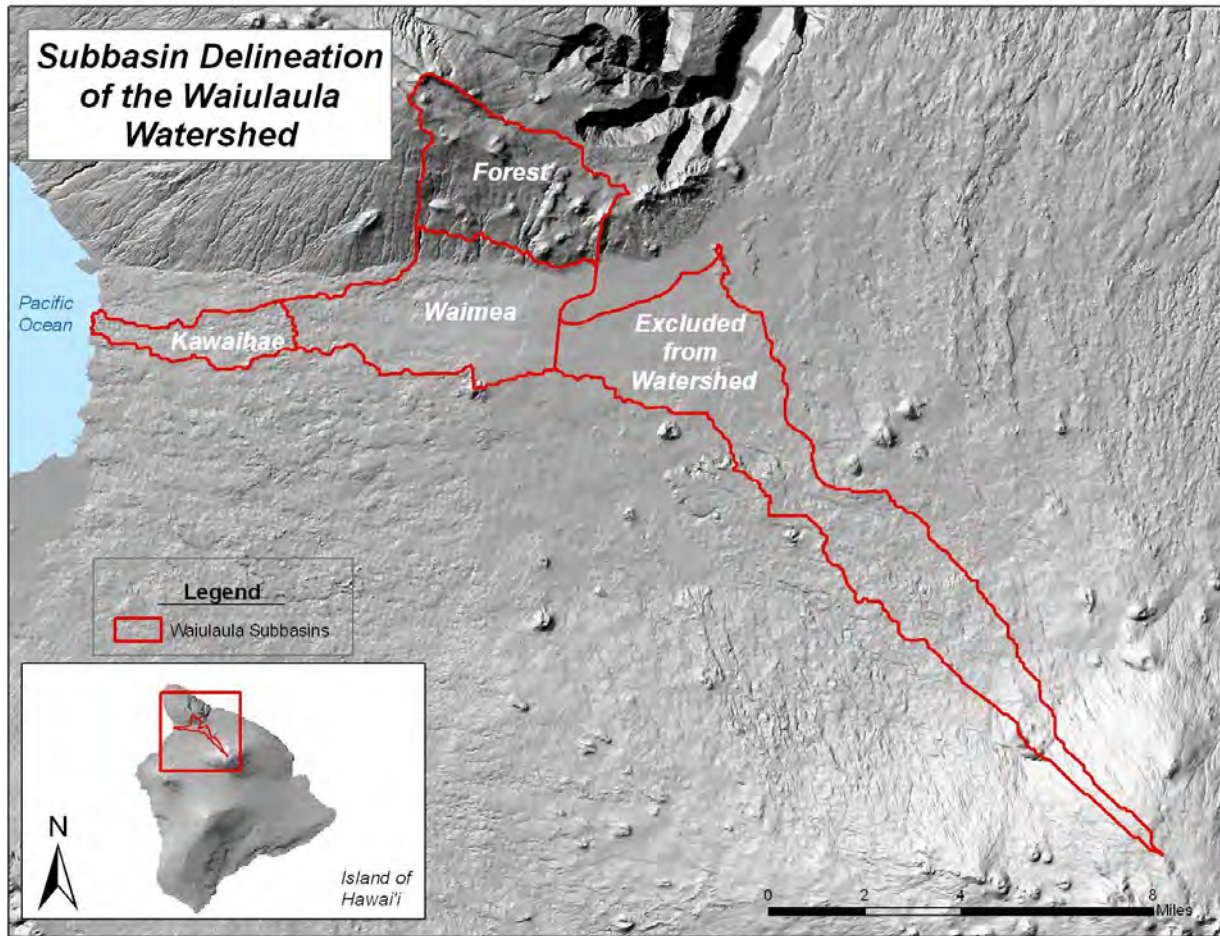
SITE	Runoff event	Sediment Tons	TDN lbs as N	TN lbs as N	NO <sub>3</sub> +NO <sub>2</sub> lbs as N	NH <sub>4</sub> lbs as N	PO <sub>4</sub> lbs as P	TP lbs as P	Runoff acre- feet*
Marine Dam	11/1/07	0.2	12.9	19.0	1.1	1.0	0.3	2.6	20
Marine Dam	11/6/07	0.5	12.3	22.5	0.6	0.8	0.3	3.2	20
Marine Dam	11/14/07	0.1	3.0	5.4	0.6	0.4	0.2	0.7	15
Marine Dam	12/3/07	0.4	17.6	27.7	1.4	1.6	0.4	2.3	34
Marine Dam	12/5/07	3.7	71.4	115.3	3.6	3.5	0.8	19.4	113
Marine Dam	12/16/07	7.5	68.6	172.6	7.4	10.5	2.0	55.6	169
Marine Dam	1/26/08	0.1	9.3	11.5	1.2	1.1	0.2	0.4	19
<b>geometric mean</b>		<b>0.5</b>	<b>16.8</b>	<b>28.3</b>	<b>1.5</b>	<b>0.4</b>	<b>0.4</b>	<b>3.4</b>	<b>36</b>
Sandalwood	11/22/07	5.4	55.3	143.5	26.6	3.6	3.2	36.2	81
Sandalwood	12/6/07	6.8	102.1	199.3	26.6	5.4	4.3	51.1	135
Sandalwood	12/16/07	9.2	72.6	200.6	13.2	3.9	3.0	84.2	164
Sandalwood	1/26/08	0.1	7.3	9.3	2.2	1.1	0.3	0.6	12
<b>geometric mean</b>		<b>2.1</b>	<b>41.6</b>	<b>85.5</b>	<b>11.9</b>	<b>3.1</b>	<b>1.9</b>	<b>17.7</b>	<b>68</b>
Coastal outlet	1/17/09	1.1	47.0	87.9	20.4	2.7	0.4	4.9	39
Coastal outlet	2/3/09	1.7	71.2	121.0	7.1	8.5	1.3	7.9	106
<b>geometric mean</b>		<b>1.4</b>	<b>57.9</b>	<b>103.1</b>	<b>12.0</b>	<b>0.5</b>	<b>0.0</b>	<b>6.2</b>	<b>64</b>
34									
Pelekane	12/6/07	<b>157</b>	<b>157</b>	<b>199</b>	<b>6147</b>	<b>79</b>	<b>22</b>	<b>5</b>	<b>204</b>

\* An acre-foot is a volume equal to one acre of land flooded to a depth of one foot.

N-SPECT, which was developed by NOAA, is a GIS-based watershed model. It uses the SCS Curve Number method to estimate runoff and the RUSLE method to estimate erosion export of sediment from the watershed. The watershed's export of total nitrogen and total phosphorus are estimated by multiplying predicted runoff by the average concentration of nitrogen and phosphorus in streamwater. At the time the modeling was done, the field measurements in the Wai'ula'ula watershed had not been collected. (Even if they were available, most of the data represent a mix of landcover classes, whereas we needed distinct values for each different landcover class.) Default pollutant coefficients (NT and TP concentrations in mg/L), which had been developed from a national database, were therefore used (Table 11). The Wai'ula'ula watershed was divided into 4 sub-basins, based on elevation and precipitation gradients, to allow for distribution of the raining days factor in the model (Figure 25). The Mauna Kea "leg" was excluded, for reasons described in Section 2.1.1. The modeling work was conducted by Ms. Katie Gaut as part of her Master's thesis (Gaut 2009).

**Table 11: Pollutant Coefficients (average concentrations in runoff)**

	<b>Total Phosphorus (mg/L)</b>	<b>Total Nitrogen (mg/L)</b>	<b>comment</b>
<u>Model's Default Values for various CCAP categories</u>			
High Intensity Development	0.47	2.22	
Low Intensity Development	0.18	1.77	
Cultivated Land	0.42	2.68	
Grassland	0.48	2.48	
Evergreen Forest	0.05	1.25	
Scrub/ Shrub	0.05	1.25	
Bare Land	0.12	0.97	
<u>Measurements (provided for comparison)</u>			
Waimea urban runoff	0.51	2.67	arithmetic average of all measurements
Marine Dam (Forest)	0.08	0.35	volume-weighted average of 7 events
Sandalwood (below Waimea)	0.16	0.52	volume-weighted average of 4 events
Watershed outlet	0.03	0.49	volume-weighted average of 3 events



**Figure 25: Sub-basin Delineation of the Waiulaula Watershed for N-SPECT (from Gaut 2009)**

Gaut (2009) notes that the limited hydrologic and water quality data for the watershed “means that it is not possible to validate the model by statistically rigorous comparison with historic observations. She goes on to add “Nevertheless, model simulations that are based on reasonable assumptions, expert advice of local resource managers, and default parameter values may give results that are of sufficient quality for the purposes of section 319-related watershed management” (p.14).

Modeled runoff was similar to stream gage measurements in the watershed, as well as other watersheds within Hawai‘i (Table 12). The best results were obtained when the model’s “raining days” parameter was set to 0.50 inches. In the model, the forest sub-basin accounts for the majority of runoff.

**Table 12: Model Prediction of Pollutant Concentrations**

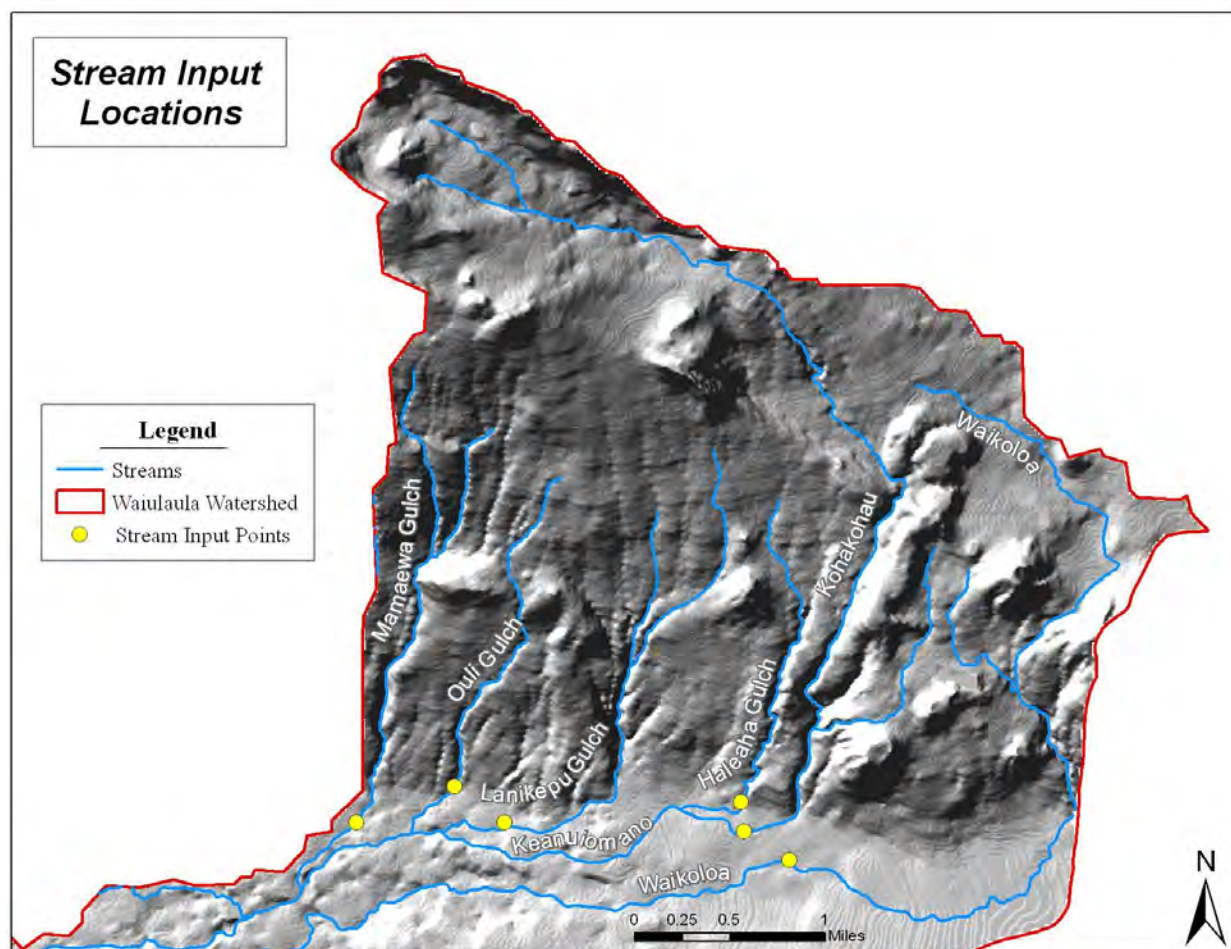
Measured values are volume-weighted averages from the autosampler sites. Modeled and measured values are not directly comparable because the former represents the annual average, whereas measurements reflect only four (Sandalwood), seven (Marine Dam), or three (outlet) storms.

	Total Phosphorus concentration mg/L	Total Nitrogen concentration mg/L	TSS concentration mg/L
Marine Dam Measured Values	0.08	0.35	23
Marine Dam Modeled Values	0.06	1.27	12
Sandalwood Measured Values	0.16	0.52	40
Sandalwood Modeled Values	0.34	2.01	42
Watershed outlet measured values	0.03	0.49	13
Watershed outlet Modeled values	0.16	1.56	14

Gaut (2009) calculated the relative contributions of major tributaries for total suspended solids, nitrogen, and phosphorus (See Figure 26 and Table 13). This information can help direct future monitoring efforts in the watershed so that ground-truthing can help confirm these results. She found:

The largest contributors of runoff were Kohākōhau and Waikoloa streams. As these are the only two perennial streams in the watershed, the results are reasonable and expected. These two tributaries also are the primary contributors of nitrogen and total suspended solids to the watershed, with a combined input of 57% and 47%, respectively. Kohākōhau and Lanikepu Gulch were the primary and secondary tributary contributors of phosphorus, respectively. Lanikepu Gulch was found to deliver the majority of sediment. Mamaewe Gulch and Kohākōhau were the secondary tributaries for sediment delivery. (67%)





**Figure 26: Tributaries in the Wai'ula'ula Watershed Assessed for Runoff, Nutrient, and Sediment Contributions in Table 11 (Figure 19 in Gaut 2009)**

The model's estimate of sediment concentration (TSS) was about 20% higher than the measured concentration at the Marine Dam autosampler and more than double the measured concentration at the Sandalwood autosampler. Also, the model produced higher sediment loads than has been observed in other watersheds in Hawai'i. It is possible that NSPECT underestimated the amount of sediment that is re-deposited a short distance from where it was eroded. Or, it is possible that some of the RUSLE/MUSLE coefficients are not appropriate to Hawai'i. On an average annual basis, the model predicts that the accumulated nitrogen load from the watershed is approximately 23,000 kg or 1.4 kg/acre/year, while the predicted accumulated phosphorus is 2,176 kg or 0.129 kg/acre/year (Gaut 2009). When compared to other watersheds in Hawai'i, N-SPECT produced reasonable estimates of nitrogen and phosphorus loads; however, the limited water quality data collected by autosamplers within the Wai'ula'ula watershed suggest these estimates may be high (Gaut 2009).

**Table 13: Relative contributions of major tributaries for pollutants displayed.**

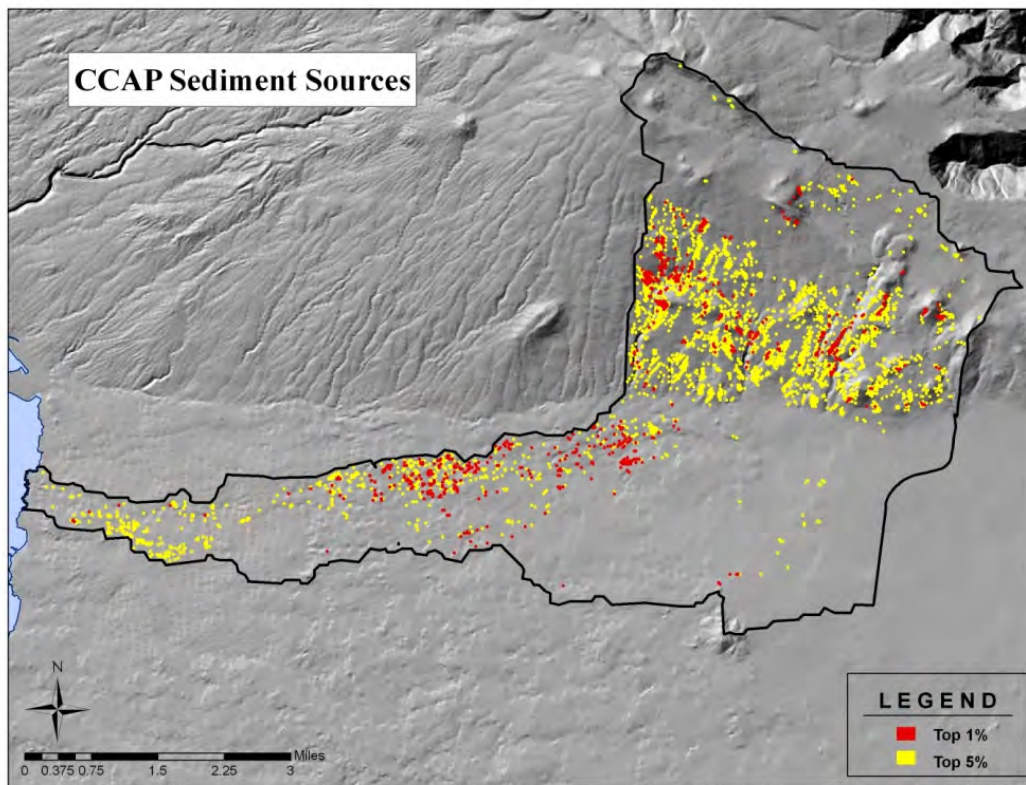
Underlined and bold values represent the first and second largest contributor tributaries for that particular pollutant, respectively. (From Gaut 2009: Table 28)

	1	2	3	4	5	6
	<b>Mamaewa Gulch</b>	<b>Ouli Gulch</b>	<b>Lanikepu Gulch</b>	<b>Haleaha Gulch</b>	<b>Kohakohau</b>	<b>Waikoloa</b>
Accumulated Sediment	<b>25%</b>	8%	<u>26%</u>	10%	24%	7%
Accumulated Runoff	11%	4%	15%	7%	<u>39%</u>	<b>24%</b>
Accumulated Nitrogen	13%	5%	17%	7%	<u>36%</u>	<b>21%</b>
Accumulated Phosphorus	19%	8%	<b>21%</b>	10%	<u>28%</u>	14%
Accumulated TSS	13%	5%	17%	7%	<u>36%</u>	<b>21%</b>

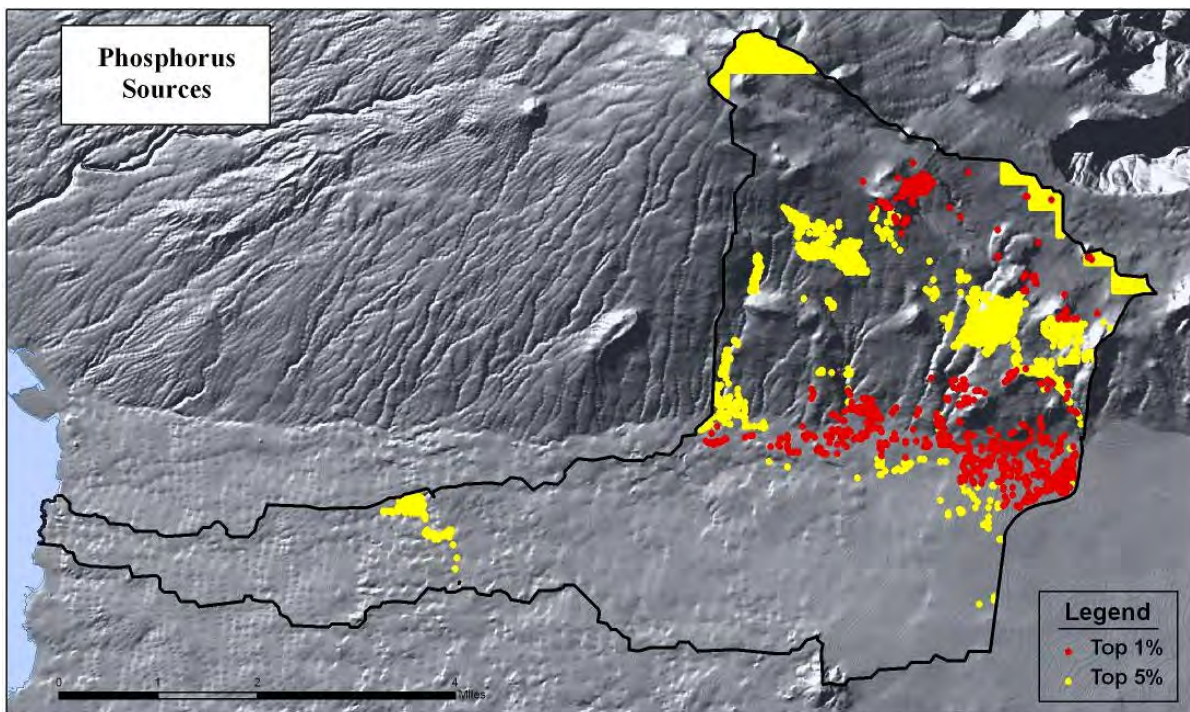
The model was also used to identify “critical” areas that produced disproportionately large amounts of sediment and nutrients (Figures 27, 28, and 29). The model predicts high sediment sources in the mid-west region of the forest sub-basin, as well as the lower reaches of the Waimea sub-basin. Gaut (2009) notes that “the top 1% of source areas are on steep grassy slopes. In the middle region of the watershed, however, the high sediment source areas appear to be associated with bare lands....” (p. 70). The model predicts that the lower watershed produces little sediment and nutrients. The reason for this is probably that there is little rainfall in the lower watershed.

If critical areas are identified, then selected BMPs can be evaluated with N-SPECT to assist in estimating potential load reductions from the implementation of these BMPs. Gaut (2009) examined several BMPs. She found that restoration of riparian areas did result in significant reductions in accumulated sediment and phosphorus (11% and 8%). Replanting of 50% of the bare land resulted in a 15% reduction of accumulated sediment. The modeling effort found little to no change in polluted runoff with the implementation of BMPs on agricultural (cultivated) lands. However, it may be that, given the small proportion of cultivated agricultural land in the watershed, the N-SPECT model operates at too large a scale (30x30 meter pixels) to accurately model these BMPs (Gaut 2009).

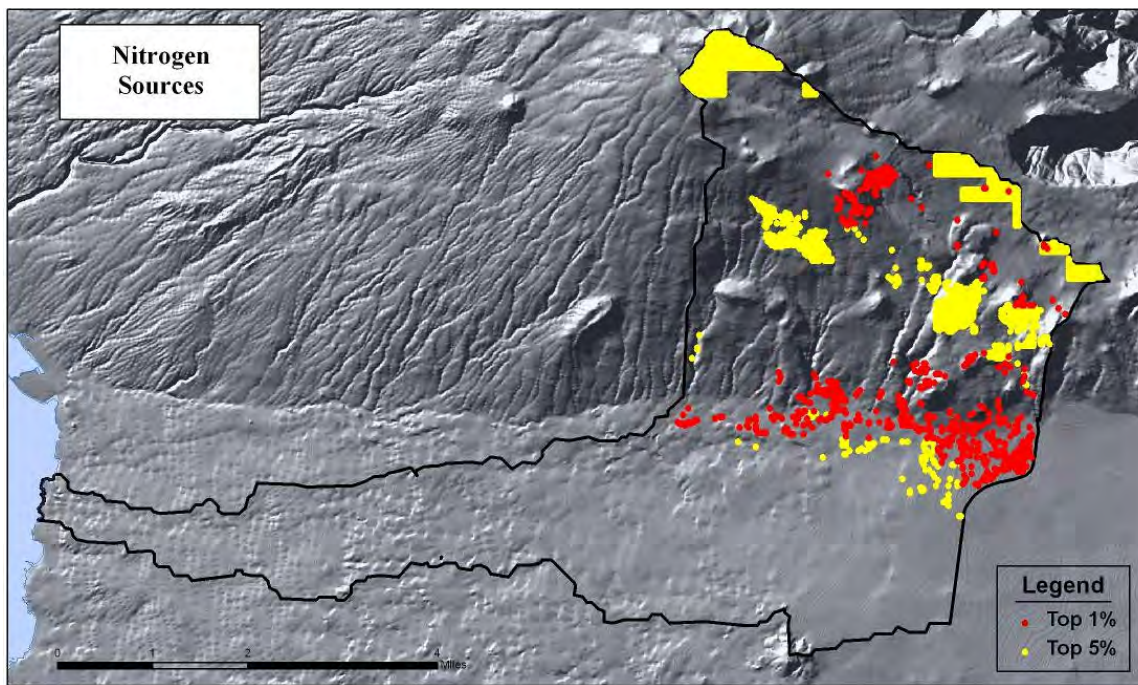




**Figure 27: Modeled Sediment Sources**



**Figure 28: Modeled Phosphorus Sources**



**Figure 29: Modeled Nitrogen Sources**

### **3.7.3 Using the N-SPECT Model to Estimate Future Loads**

Gaut (2009) also ran a simulation of future conditions, using land use changes projected in Hawai'i County's General Plan LUPAG (Table 14). She found:

Percent changes for the future scenario predict further increases in runoff, nitrogen and phosphorus. The phosphorus amounts are predicted to increase by over 20%. In addition, a large proportion of the increase in the amount of phosphorus is expected to occur at a close proximity to the coast. Much of the watershed that is currently classified as bare land is planned to be converted to urban expansion zones, which will cause the predicted overall accumulated sediment to decrease. (p. 79)

While the absolute quantitative output values may not be accurate, “they are indicative of the overall magnitude and patterns of sediment and nutrient delivery in the watershed” (Gaut 2009: 79).

**Table 14: Current and Future Load Estimates from the N-SPECT Model (based on Gaut 2009: Table 33)**

Exports are at the watershed mouth (where the stream enters the ocean).

	<b>Current Scenario</b>	<b>Future Scenario</b>	<b>% Change from Current</b>
Total Watershed Runoff (m <sup>3</sup> /yr)	15,290,900	16,692,500	9%
Total Sediment Export (tons/yr)	233,637	212,551	-9%
Total Nitrogen Export (kg/yr)	23,860	26,824	12%
Total Phosphorus Export (kg/yr)	2,473	3,003	21%



### **3.8 Toxics**

University of Hawai'i graduate student James Tait conducted a study to see if trace elements in stream sediment reflect land use in the upstream watershed (Tait 2008). Four main classes of land use were evaluated as potential sources of pollution: Urban, Cultivated, Pasture / Rangeland, and Forest. The study looked at lead (Pb), zinc (Zn), copper (Cu), arsenic (As) and Vanadium (V).

Tait concluded:

Both anthropogenic and natural factors were found to influence the composition of soils and streambed sediment. The composition of non-point pollutants often showed significant variability but some consistent trends were identified:

- Lead and zinc were enriched in surface soils that are near roadways.
- Larger urban areas were associated with more lead and zinc in streambed sediment (downstream of the urban area). This was also true to a lesser extent for Copper.

The Tait study also looked at whether the isotopic composition of nitrate in stream waters could be used to identify the source of nitrate. These results were inconclusive, however.

### **3.9 Biological Data**

Assessment of ecosystem health can be based either on water quality or on biological populations. A healthy ecosystem is diverse and contains native species.

DLNR's *Atlas of Hawaiian Watersheds and Their Aquatic Resources* (2008) compiles information from many years of surveys and publications on Hawaiian stream animals. The following data, taken from DLNR (2008), comes from biotic samples collected in 1968, 1990, 1992, 1994, 1999, 2000, and 2001 (Table 15). It includes data most recently collected by Bishop Museum's Hawai'i Biological Survey for DHHL's Lālāmilo Residential Project EIS. In addition, information from the recent stream survey undertaken by Englund (2010) is also included.

**Table 15: Distribution of Biotic Sampling**

The number of survey locations that were sampled in the various reach types.

Survey type	Estuary	Lower	Middle	Upper	Headwaters
Damselfly Surveys	0	0	1	0	1
DAR Point Quadrat	0	26	41	129	0
HDFG	0	0	0	0	1
Microhabitat Survey	0	0	0	24	0
Published Reports	1	1	1	2	1

Table 16 compiles the list of species found in different stream reaches within the Wai‘ula‘ula watershed. The letter “P” indicates the presence of that species in that reach of stream. Data from DLNR (2008) is in regular font; data from Englund (2010) is in bold font. The reach classification system was developed by Parham and Lapp (2006). The reach types are based on elevation and the presence of different sized barriers (waterfalls) in the stream:

- Estuary: all stream segments between the coastline and 1 m. elevation.
- Lower Reach: stream segments between 1 and 20 m. elevation and below any barrier of approximately 10 m. high.
- Middle Reach: stream segments greater than 20 m. elevation or above the first 10 m. barrier and less than 200 m. elevation or below the first 20 m. high barrier.
- Upper Reach: stream segments greater than 200 m. elevation or above the first 20 m. barrier and less than 750 m. elevation.
- Headwaters: stream segments greater than 750 m. elevation.



**Table 16: Presence (P) of Species in Different Stream Reaches**

Scientific Name (Common Name)	Status	Estuary	Lower	Middle	Upper	Head-waters
<b>Fish</b>						
<i>Lentipes concolor</i> ('o'opu hi'ukole)	Endemic				P	P
<i>Sicyopterus stimpsoni</i> ('o'opu nōpili)	Endemic		P	P	P	
<i>Stenogobius Hawai'iensis</i> ('o'opu naniha)	Endemic	P				
<i>Eleotris sandwincensis</i> ('o'opu 'akupa)	Endemic	P				
<i>Awaous guamensis</i> ('o'opu nākea)	Indigenous	P	P	P/P	P	
<i>Mugil cephalus</i> (striped mullet)		P				
<i>Gambusia affinis</i> (mosquito fish)	Introduced		P	P	P/P	
<i>Poecilia reticulate</i> (guppy)	Introduced		P/P	P	P/P	
<i>Misgurnus anguillicaudatus</i> (dojo loach)	Introduced			P/P	P/P	
<i>Poeciliidae</i> sp.	Introduced		P	P	P	
<b>Crustaceans</b>						
<i>Macrobrachium grandimanus</i> ('Ōpae 'oeha'a)	Indigenous		P	P		
<i>Macrobrachium lar</i> (Tahitian prawn)	Introduced		P	P/P	P/P	
<i>Procambarus clarki</i> (crayfish)	Introduced				P	
<i>Hyalalea azteca</i>					P	
<i>Metopograpsus</i> sp. (Purple climber crabs)	Indigenous	P				
<b>Mollusks</b>						
<i>Physa</i> sp.	Introduced		P	P	P	
<i>Lymnaea</i> sp.	Indigenous					P
<b>Amphibians</b>						
<i>Bufo marinus</i> (Cane toad)	Introduced		P/P	P/P	P	
<i>Rana catesbeiana</i> (American bullfrog)	Introduced				P/P	P
<i>Rana rugosa</i> (wrinkled frog)	Introduced		P	P	P	
<i>Ranidae</i> sp. (bullfrog)	Introduced		P			
<b>Aquatic Insects</b>						
<i>Anax junius</i> (common green darner)	Indigenous	P	P	P	P/P	
<i>Anax strenuous</i> (giant Hawai'ian dragonfly)	Endemic				P/P	P

Scientific Name (Common Name)	Status	Estuary	Lower	Middle	Upper	Head-waters
<i>Crocothemis servilia</i> (scarlet skimmer)	Introduced			P	P/P	
<i>Orthemis ferruginea</i> (roseate skimmer)	Introduced			P	P/P	
<i>Pantala flavescens</i> (wandering glider)	Indigenous		P	P	P/P	
<i>Tramea lacerate</i> (black saddlebags)				P	P	
<i>Megalagrion caliphya</i>	Endemic					P
<i>Enallagma civile</i> (familiar bluet damselfly)	Introduced			P	P/P	
<i>Ischnura ramburii</i> (Rambur's forktail)	Introduced	P	P	P/P	P	
<i>Chironomus Hawai'iensis</i> (Hawaiian midge)	Endemic				P	
<i>Megalagrion sp.</i> (dragonfly)	Endemic			P	P	
<i>Orthocladus grimshawi</i>	Endemic				P	
<i>Ischnura posita</i>	Introduced					P/P
<i>Rhantus gutticollis</i>	Introduced				P	
<b>Diptera (Flies, gnats)</b>						
<i>Chironomus sp.</i>	Endemic			P		P
<i>Procanace sp.</i>	Endemic					P
<i>Forcipomyia hardyi</i>	Endemic					P
<i>Cricotopus bicinctus</i>	Introduced				P	P
<i>Dolichopus exsul</i>	Introduced					P
<i>Dolichopodidae sp. 1</i>	Endemic					P
<i>Scatella sp.</i>	Endemic				P	P
<i>Scatella clavipes</i>	Endemic				P	
<b>Heteroptera</b>						
<i>Saldula exulans</i>	Endemic					P
<i>Microvelia vagans</i>	Endemic					P
<b>Trichoptera</b>						
<i>Cheumatopsyche analis</i>	Introduced					P
<i>Oxyethira maya</i>	Introduced				P	P
<b>Bryozoans</b>						
<i>Plumatella repens</i>	Introduced			P		

As noted in Section 2.1.10, the biodiversity of native species found in the Wai'ula'ula watershed is high. This indicates that, from a biological resources standpoint, the stream quality is very high, particularly in the upper reaches.

## **3.10 Summary**

### **3.10.1 Pollutants of greatest concern and their spatial variability**

Water quality data were collected for the purpose of determining which nonpoint pollutants are of the greatest concern in the watershed and in the marine receiving waters. Marine waters just offshore of the watershed have excessive levels of algae and ammonia. Ammonia is a form of nitrogen that is especially harmful to marine life. For streams, the parameter of greatest concern is total nitrogen (TN), followed by total phosphorus (TP). Suspended sediment and nitrate are parameters of possible concern. Stream water quality was measured in three locations. The highest levels of nutrients and sediment were found at the downstream edge of Waimea Town, and the lowest levels were found where Waikoloa stream exits the forest. Intermediate levels were found at the watershed outlet (where the stream enters the ocean).

There are high levels of pollutants in runoff from high-use paved areas in urban Waimea. This urban runoff has particularly high values of TSS, TN, and TP. The headwaters of the watershed contain pristine forests. Runoff originating in the forest contains sediment and nutrients, but, for the most part, the concentrations are not particularly high. The forest runoff does, however, have slightly elevated TN concentrations, and, occasionally, TP concentrations are elevated.

### **3.10.2 Information Gaps**

A few of the following data gaps are addressed in the monitoring plan (Chapter 6).

- Monitoring has been conducted on only one of the two major tributaries of the Wai'ula'ula Stream. We do not have data for Keanu'i'omanō stream, so it is unknown if different sections of the high elevation forest generates runoff with different chemical characteristics. It is possible that there are differences based on vegetation type (nitrogen fixing or not) or distribution of oxygen-poor bogs.
- The middle reaches of the stream are intermittent, and there are periods when these reaches contain stagnant isolated pools. Although these pools are small, they are quite important to aquatic species. It is likely that the water quality in these pools is poor, but we do not have any measurements of water quality. Nor do we know the extent to which these pools are adversely affected by upstream diversions (both legal and illegal).
- Interpretation of the nitrogen data is complicated by the fact that we know little about the nitrogen transformations (one type changing into another) (cycling) occurring in Wai'ula'ula Bay.

- We do not know if the stream water is N-limited or P-limited. Nor do we know if Wai'ula'ula Bay is N-limited or P-limited.
- We are unsure if the lower Wai'ula'ula watershed is capable of occasionally generating the kind of sediment-rich runoff that has been observed in the Pelekane Bay watershed immediately to the north. Based on one event measured at the outlet of Pelekane watershed, the concentration of sediment in Pelekane storm runoff is 150 times greater than what is allowed. The total nitrogen concentration was 240 times greater than what is allowed. The lower elevation regions of the Pelekane and Wai'ula'ula watersheds are similar in climate and land use, so it is difficult to dismiss the possibility that, given the right storm, the lower portion of the Wai'ula'ula watershed is capable of generating runoff with very high concentrations of sediment and nitrogen. On the other hand, the lower Pelekane watershed is steeper than the lower Wai'ula'ula watershed and has older soils. Moreover, the comparison between the two watersheds is based on only one event for Pelekane and three events for Wai'ula'ula. The Pelekane samples were collected on a day that we did not collect data at the outlet of the Wai'ula'ula watershed.
- Sections of the Wai'ula'ula Stream and its tributaries are losing streams, meaning that water leaks through the streambed. Infiltrating water likely goes into groundwater, although it is possible that some of it is taken up by streamside vegetation. Thus, the water that leaks through the streambed could eventually flow to the ocean. Notably, most of the lower reaches are losing. Also, it is likely that the stream is a losing one (at least some of the time) between the Sandalwood autosampler and the Marine Dam autosampler. This raises the question as to how much of the nonpoint pollutants generated in the upper and middle reaches of the watershed are delivered to the ocean. We do not have data on the amount of losses, however, nor on which reaches are gaining reaches.
- The modeling results suggest that large amounts of sediment are being eroded from certain sections of the middle watershed that have an unfavorable combination of intense rain and erodible soil. Ground-truthing is recommended to verify this result.

# Chapter 4: Threats to the Water Quality of the Watershed

This section describes the threats to the water quality of Wai'ula'ula watershed. It responds to element (a) of EPA's 9 key elements for watershed-based plans that are critical for achieving improvements in water quality (see Appendix B). At this time, there are insufficient data to conclusively prioritize threats by load contribution or impacts to resources.

The focus of this management plan is on preventing further degradation of water quality. Possible pollutant sources and threats to the watershed are described below. Based on these threats, the management plan establishes goals and objectives for maintaining and restoring water quality.

## **4.1 Nonpoint Sources of Pollution**

Nonpoint source pollution (or polluted runoff) is pollution that cannot be traced to a single source but, rather, comes from many diffuse sources. It generally results from precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification or atmospheric deposition. As runoff from rainfall moves across the landscape, it picks up pollutants from human activities, ultimately depositing them in surface waters. Pollutants can also seep into the ground and affect groundwater, as well as surface water with connections to groundwater.

### **4.1.1 Agriculture**

Agricultural activities, if not properly managed, can contribute polluted runoff in the forms of sediment, nutrients, pesticides and animal waste. Agricultural activities can also directly impact the habitat of aquatic species through physical disturbances caused by livestock or equipment. Agriculture is a significant land use in the Wai'ula'ula watershed, with over 8,000 acres dedicated to crops and livestock grazing.

Good soil is essential to conventional farming. Farmers are generally motivated to prevent soil runoff and keep the soil on the land where it benefits food production. However, without proper management, there is always the potential for soil erosion into streams during storm events or from excessive irrigation after fields have been tilled and before there is sufficient vegetative cover to prevent runoff.

Sediment is a result of soil erosion. Soil erosion can be characterized as the transport of particles that are detached by rainfall, flowing water or wind. Eroded soil is either redeposited

on the same field or transported from the field in runoff. The types of erosion associated with agriculture are typically sheet and rill erosion, and gully erosion. Sediments transported from the field into waterbodies often have other pollutants attached to the soil particles, such as nutrients and chemicals (herbicides, pesticides, etc.). Suspended sediments in stream and coastal waters reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, smother coral reefs, adversely affect the filtering capacity of filter feeders, and clog and harm the gills of fish.

Nitrogen (N) and phosphorus (P) are the two major nutrients from agricultural activities that can degrade water quality. Nutrients are applied to agricultural lands in several different forms and come from a variety of sources, including commercial fertilizers, manure, and irrigation water. While all plants require nutrients for growth, excessive nutrient application can cause runoff into streams and the ocean, disrupting ecosystems by causing blooms of aquatic and marine plants such as algae. In addition, over-application of nutrients costs the farmer unnecessary expense.

When excessive nutrients are introduced into a stream or ocean, aquatic plant growth may increase dramatically, a process called eutrophication. This adds more organic material to the system, which eventually dies and decays. The decaying organic matter can produce odors and deplete the oxygen supply required by aquatic organisms. Eutrophication also increases turbidity and is harmful to coral reefs.

The term pesticide includes any substance or mixture of substances used to prevent, destroy, repel, or mitigate any pest or intended for use as a plant regulator, defoliant, or desiccant. Pesticides are generally applied to crops to kill insects, molds, mildew, fungus, and weedy plants that are detrimental to the successful growth of the food crop. Pesticides can harm the environment by eliminating or reducing populations of desirable organisms and riparian or aquatic plants. Some chemicals resist degradation and can persist in soils and aquatic environments. Pesticides are normally transported into surface water either through direct application or attached to sediment in runoff.

Animal waste from agricultural activities in the Wai'ula'ula watershed is comprised mostly of the fecal and urinary wastes of cattle. Not only is manure high in nutrients that can lead to eutrophication, but it can also contain bacteria, viruses, and pathogens. Cattle are currently allowed to graze adjacent to streams and access the streams for water. This facilitates the introduction of pollutants into the waterbodies of the watershed. Livestock grazing near and in the streams can also destabilize streambanks and reduce streambank vegetation.

The Mauna Kea Soil and Water Conservation District (MKSWCD) normally works with individual agricultural landowners to develop conservation plans for approval by the district. A conservation plan is a customized document that outlines the use of conservation practices to maintain or improve the natural resources that support productive and profitable agricultural operations. An approved conservation plan enables the landowner to be exempted from the county grading ordinances for any earthmoving activities. NRCS usually assists in developing



conservation plans to treat existing and potential resource problems and has funding available for eligible participants to assist with the installation of best management practices, under the Federal Farm Bill. Every farm or ranch has its own unique resource problems or concerns. Conservation planning is a voluntary way for operators to meet land management goals, with planning assistance from NRCS and the local conservation district to help identify options that provide the greatest conservation benefit while meeting production goals.

Of the 640 acres currently used for farming, only 94 acres (or 15%) are farmed under conservation plans developed by NRCS and approved by the MKSWCD. While those farms with conservation plans are probably implementing appropriate best management practices to control erosion, properly manage nutrient and pesticide applications, and apply irrigation water, there are many others who may not be. This objective addresses the CNPCP management measures for agricultural erosion and sediment control, nutrient management, pesticide management, and irrigation water management.

As noted earlier, a high percentage of land in the watershed - both prime kikuyu land and marginal land - is used for grazing (about 8,000 acres). While the primary grazers, Parker Ranch and FR Cattle Co., have conservation plans with the Mauna Kea Soil and Water Conservation District, improvements can still be made. Infrastructure is limited, with more fencing to reduce paddock size and watering facilities needed. In some areas, cattle are accessing streams for water because there are no other sources of water available, causing streambank erosion, and adding nutrients and pathogens to the stream system.

A considerable amount of land currently being grazed in the watershed is considered marginal lands. With sufficient rainfall, these lands support cattle production. During the drought conditions experienced during most of the past decade, grazing in these areas has been seasonal at best. However, the grazing of these lands can be considered a public benefit, protecting the numerous residential communities adjacent to these marginal lands. Without periodic grazing, the resulting tall, dry grasses would present a significant fire hazard.

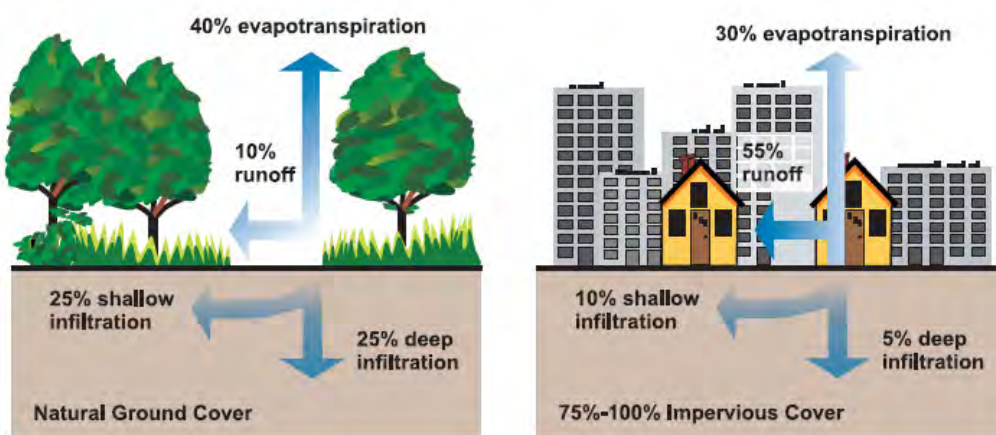
The Conservation Reserve Enhancement Program (CREP) is a joint federal-state program that was recently started in Hawai'i to help restore degraded agricultural lands and reduce polluted runoff from these lands. It provides incentives to farmers and ranchers to remove degraded cropland and marginal pastureland from agricultural production and convert the land to native grasses, trees, and other vegetation.

#### **4.1.2 Urban/Suburban Runoff**

Urban development can have a negative impact on the hydrology and water quality of a watershed. Impervious surface area is often associated with polluted runoff. The "hardening" of the landscape that comes with urbanization increases runoff volumes and pollutant loadings. Impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, decrease the infiltration capacity of the ground and result in greater runoff volumes that can exacerbate

flooding problems. Urban development also causes an increase in pollutants, such as sediments, nutrients, pathogens, hydrocarbons, heavy metals, and toxins.

Scientists use percent imperviousness to describe how much of a given area is covered by hard surfaces. As the amount of impervious cover increases, the amount of runoff generated also increases, making it difficult for the water to seep into the soil because it is flowing so quickly. This visual, developed by EPA, shows the relationship between impervious cover and surface runoff. As little as 10% impervious cover in a watershed can result in stream degradation (EPA 2003).



According to NOAA's C-CAP Land Cover map, the high-intensity and low-intensity developed (urban) areas within the watershed are concentrated along the streams. While urban areas occupy relatively small areas of the Wai'ula'ula watershed (2%), their pollutant contributions can be significant. Measured water quality below Waimea town is significantly worse than upstream. Comparing water quality below Waimea to water quality above town, ammonia concentrations doubled, total phosphorus concentrations (TP) more than doubled, and nitrate concentrations quadrupled. Urban development within the watershed increased significantly over the past 30 years and is projected to continue to increase. The lower watershed is slated for urban expansion (Hawai'i County 2005), and additional urban growth is projected in Waimea town and along Waikoloa and Keanu'i'omanō streams.

Stormwater picks up nutrients, sediment, and chemical contaminants as it flows across yards, parking lots, construction sites, and parks. Roofs and driveways generate additional stormwater runoff that must be managed. Development activities like clearing vegetation, grading, removing or compacting soil, and adding impervious surfaces also increase stormwater and polluted runoff.

Fifty-five to seventy percent of impervious surfaces in an urban area are transportation associated (Chesapeake Bay Program 2008). Runoff from roadways and parking lots can have a particularly adverse effect on water quality if no measures are taken to remove contaminants

before the runoff reaches the receiving water. Oil and grease are leaked onto road surfaces from car and truck engines, spilled at fueling stations, and discarded directly into storm drains instead of being taken to recycling stations. Heavy metals come from car and truck exhaust, worn tires and engine parts, brake linings, weathered paint, and rust. Rain water picks up these pollutants and carries them to roadsides or into storm drains.

In urban areas of the Wai'ula'ula watershed, Hawai'i County has the lead in the control of erosion during site development, and ensuring proper site planning and stormwater management to protect sensitive natural features, through its ordinances and rules related to zoning, subdivisions, drainage, and erosion and sediment control. The State Department of Health also regulates stormwater runoff through its NPDES permit process. The Hawai'i Department of Transportation requires best management practices during construction of State roads, highways, and bridges. The Hawai'i CZM Program funded the production of a Low Impact Development (LID) manual for Hawai'i (Horsley Witten Group 2006), which describes stormwater and wastewater management techniques for urban and suburban areas that reduces impacts on sensitive water resources.

Many roads within the Wai'ula'ula watershed are fitted with curb and gutter catch basins to convey stormwater away from roads. This stormwater is then discharged into dry wells or directly into streams, affecting either groundwater or surface water. On other roads, stormwater is conveyed to grassy shoulders on either side of the road, where it ponds until it is either absorbed or runs off. All the bridges in the watershed have scuppers that discharge stormwater directly into the streams below.

Hawai'i County has historically relied on deep (+20 feet) 5-foot diameter drainage injection wells (or "dry wells") as the primary means of capturing and disposing of urban stormwater runoff, because Hawai'i Island's geology allows for good lateral and downward percolation. The county allows a maximum disposal rate of 6 cubic-feet per second (cfs) of water per dry well (Kuba 2005). Many new and existing developments within the Waimea area employ dry wells to trap runoff from roadways and parking areas, notably the Parker Ranch shopping center, Sandalwood residential area, Parker Ranch's Luala'i development, and DHHL's new Lālāmilo housing development.

The U.S. Geological Survey in cooperation with Hawai'i County Department of Public Works assessed the potential for roadside dry wells to affect water quality (Izuka *et al.* 2010). Using the presence or absence of urbanization in the drainage area, distance between the bottom of the dry well and the water table, and the proximity to receiving waters, USGS identified wells that have the greatest potential to affect the water quality of receiving waters at the coast and in drinking-water wells. Effects to surface water were not considered. Water quality sampling of water entering the dry wells has not been undertaken on a large scale. Sampling of runoff into dry wells in Waimea show significant pollutant loads. Based on a limited amount of data, it appears likely that runoff from high-use paved areas exceeds water quality criteria for sediment (by a factor of five), total phosphorus (by a factor of four), total nitrogen (by a factor of three) and nitrate (measured values are only slightly greater than the standard).

According to Kuba (2005), all dry wells operate functionally “as both a sediment trap and a storm water disposal system.” The County Department of Public Works has a dry well cleaning program for its transportation-related dry wells to removed accumulated sediment in its more than 1,000 permitted dry wells island-wide, in order to maintain the capacity of these dry wells. It is less clear how frequently private dry wells are maintained.



**Pipe Discharging into Waikoloa Stream**

There is one large pipe discharging urban stormwater runoff directly into Waikoloa Stream. This concrete pipe is located behind the Waimea Community Education building on Māmalohoa Highway and discharges untreated runoff from storm drains along Māmalohoa Highway. PVC pipes discharge roof runoff from the KTA shopping center directly into Waikoloa stream. Within DHHL’s Lālāmilo development, it appears that runoff from the subdivision’s yards is being channeled down steep, rock lined slopes into Lanikepu and Keanu’i’omanō streams.

#### **4.1.3 Wastewater Disposal Systems**

Sewage contains pathogens, high levels of nutrients and oxygen-consuming organic matter. Standard sewage treatment (primary plus secondary) kills pathogens, removes solids, and removes some of the nutrients from the wastewater. Typically, a significant amount of nutrients (more than half of what was originally in the sewage) is not removed. Septic systems tanks are somewhat more effective than secondary treatment at removing nitrogen, but cesspools are less effective.

Sewer systems within the Wai’ula’ula watershed are limited to sections of Waimea town and the Mauna Kea Beach Resort properties. Everyone else is using an onsite disposal system (OSDS), either a cesspool or septic system, which are effective over the long-term only if properly operated and maintained. When system failure occurs, untreated wastewater and sewage can be introduced into groundwater or nearby streams and waterbodies, introducing pathogens and causing eutrophication.

Hawaii has made progress in eliminating new individual cesspools<sup>7</sup>. Efforts to ban the use of new cesspools statewide have been made through revision to Chapter 11-62, HAR. The rule either bans or severely restricts the use of cesspools throughout the state. On Hawai'i Island, new cesspools for individual homes only are allowed in certain areas. These areas are designated in Critical Wastewater Disposal Area maps. The maps are based upon development density, groundwater development, potential contamination of coastal waters and the use of OSDS. In the Wai'ula'ula watershed, cesspools are allowed in most areas on parcels of greater than 5 acres in size.

Although the current rule still allows some new cesspools in limited areas, there are a number of items that either prohibit new cesspools or require that existing cesspools be upgraded. These are described in Section 2.2.9.3.

Houses in the Waimea area built before 1991 will likely have cesspools, unless they were required to convert to a septic system because of problems with the existing cesspool or if significant changes were made to the structure. Houses built more recently, especially if part of a subdivision, will likely have septic systems. The type of wastewater system by TMK has not yet been mapped for the watershed, because at this time these data are not available in an electronic format. This information would help identify potential sources of nutrients within the watershed, and, then, more detailed water quality assessments can be undertaken to determine whether these systems, particularly the older cesspools, in neighborhoods adjacent to the streams are having a detrimental effect on surface water quality.



**Pumping Septic Tank**

<sup>7</sup> The U.S. Environmental Protection Agency (EPA) promulgated Underground Injection Control (UIC) regulations on December 7, 1999, which prohibited the construction of new large capacity cesspools (LCCs) nationwide, effective April 5, 2000. Existing large capacity cesspools were required to be replaced by an alternative wastewater system and closed by April 5, 2005. Numerous large capacity or “gang” cesspools in Waimea were converted to alternative systems as a result.

Parker Ranch owns and operates the Waimea Treatment Company, the only wastewater treatment plant in the Waimea area. The current treatment capacity is 0.1 MGD (100,000 gallons per day). Currently inflow is 65% of its capacity. Wastewater is treated to R-3 quality, which, according to DOH, is undisinfected water that has received primary and secondary treatment. Treated effluent is disbursed through a 40-acre sprinkler system that is located approximately 300 yards from the treatment plant on Parker Ranch land. The treatment plant currently handles sewage from areas of downtown Waimea, including the KTA shopping center, Parker Ranch shopping center, Ace hardware store, North Hawai'i Community Hospital, Kamuela senior housing project, Kahilu Theatre, HoloHolo Ku residential development, and Luala'i subdivision.

Mauna Kea Beach Resort also operates a wastewater treatment plant which serves all the resort-associated developments in the coastal part of the watershed, including Kumulani, Moani, Apa Apa'a, Wai'ula'ula, Kaunaoa, High Bluffs, Bluffs, and Hapuna and Mauna Kea Beach resorts. The plant's maximum capacity is 600,000 gallons per day (gpd), though current inflow ranges between 130,000 and 300,000 gpd. The wastewater is treated to R-1 standards, which is the highest level of treatment in Hawai'i. This means the wastewater goes through secondary treatment (activated sludge), tertiary treatment (filtration), and ultraviolet disinfection. The treated wastewater is then blended with brackish well water and used to irrigate the golf course.

#### **4.1.4 Streambank Erosion**

Hawai'i's streams are subject to wide fluctuations in both flow depth and velocity because of their flashy nature. As flow depths and velocities increase, the force of water flowing against the streambank removes particles from the banks. Over time, the erosion can cause the streambank to slump and fall into the stream channel. Runoff from adjacent land that enters a stream by flowing over the streambanks can also erode soil from streambanks, particularly if the banks are already unstable because of an absence of vegetation or roots holding soil in place. Streambanks can also be destabilized by hoof action, when cattle access the streams for water. Fallen trees or other debris in the stream channel can contribute to streambank erosion, as the flowing water finds other ways around the impediments in the stream channel.

Riparian buffers can help stabilize eroding streambanks. They can also help improve the quality of water resources by removing or ameliorating the effects of pollutants in runoff. A riparian buffer is defined as:

an area of trees and other vegetation located in areas adjoining and upgradient from surface water bodies and designed to intercept surface runoff, wastewater, subsurface flow, and deeper groundwater flows from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and groundwater recharge areas. (Welsch 2007)



There are a number of streambanks within the Wai'ula'ula that are experiencing erosion. The most significant are along Waikoloa stream within Waimea town and along Keanu'i'omanō stream from Wai'aka bridge to Kamuela Plantations. A detailed survey of all streambanks is needed to discover the extent of the problem.



**Streambank erosion on Waikoloa Stream**

In 2004, NRCS prepared an *Engineering Report for the Waimea Nature (Ulu La`au) Park* (NRCS 2004), in which it conducted hydrologic and hydraulic analyses and developed alternatives for enhancing stream channel and bank stability and reducing flood-related damage to the park. The document outlines potential streambank treatments for several specific problem areas within the park.

Just upstream and downstream from the Waimea Nature Park, several areas have been identified where streambank stabilization is needed in association with the proposed Waimea Trails and Greenways path. In addition, the county has identified two stream crossings for the trail that will require streambank stabilization at the ends of the headwalls and culverts.

The streambanks behind and downstream of KTA shopping center are also experiencing erosion. This is the area where the stream jumped its banks during the 2004 flood event. A riparian buffer along this stream segment would help stabilize the streambank in a highly visible location in the middle of Waimea town.

#### **4.1.5 Feral Ungulates**

Wild pigs and goats can contribute to polluted runoff in the Wai'ula'ula watershed. Feral pigs (*Sus scrofa*) create soil disturbances, accelerating degradation, erosion, landslides, and sedimentation. They destroy native habitat, spread seeds of weedy plants and eat native plants. They also serve as carriers and vectors of parasites and diseases, such as Leptospirosis, found in stream waters on Kohala Mountain. Feral pigs reduce and change the understory vegetation, affecting the watershed hydrology. The management of feral pigs in the forest reserve and NAR is addressed in KWP (2007) and will not be addressed under this plan.

The population of wild goats (*Ovis aries*) in West Hawai'i has increased dramatically over the past decade. Goats are extremely destructive herbivores that will eat nearly any type of available vegetation. These browsing ungulates are having a significant impact on the groundcover in the lower watershed. There is currently no management of these animals, and they roam freely in the watershed, moving in response to available vegetation and water sources. Goat-proof fencing will be critical to the success of any revegetation or groundcover management project proposed in the watershed.

#### **4.1.6 Invasive Plants**

There are numerous invasive plants that are well-established in the Wai'ula'ula watershed. These plants in the forested upper watershed can out-compete native plants for nutrients or water and quickly alter a native ecosystem by changing the vegetation. The diversity of plants and physical structure of the forest is lost when invasive plants form homogenized plant communities. According to KWP (2007), "Many invasive plant root structures do not hold the soil well when the plants form monotypic stands, which can accelerate geologic processes like erosion.... This in turn accelerates geologic erosion and decreases water quality, resulting in reef sedimentation" (p. 54).

In the lower, more arid parts of the watershed, fountain grass (*Pennisetum setaceum*) has become a problematic plant. It poses a major fire threat and has been designated one of Hawai'i's most invasive horticultural plants by DLNR. Fountain grass is considered fire-promoting, because dry fountain grass is an excellent fuel for brush fires. It is also considered fire-adapted because it can survive wildfires, where native plants often cannot. Wildfires strip the land of vegetation and render the thin soil susceptible to erosion through runoff, leading to sedimentation of streams and nearshore waters.

#### **4.1.7 Atmospheric Sources of Nitrogen**

Nitrogen is present in the atmosphere as N<sub>2</sub> gas (comprising about 80% of the atmosphere), other types of nitrogen-containing gases that occur in trace amounts, tiny liquid droplets containing dissolved nitrogen, and in the form of dust that includes nitrogen compounds. Rain contains nitrogen in the form of nitrate. Part of a watershed's nitrogen input is from rain, or from so-called "dry deposition" of nitrogen-containing dust. A variety of natural (lightning) and

man-made (combustion) processes contribute to atmospheric deposition of nitrogen. The extreme temperatures on the surface of a lava flow facilitate chemical processes that change N<sub>2</sub> gas to nitrate-rich cloud droplets (Huebert *et al.* 1999). The volcanic nitrate has been shown to be biologically-significant at certain locations near Kilauea Volcano, but the significance in the Wai'ula'ula watershed is unknown. A new eruption of Mauna Loa could increase the delivery of atmospheric nitrogen to the watershed.

Another way that nitrogen can be transferred to watersheds is when plants (actually the bacteria on their roots) “fix” atmospheric nitrogen (turn it from a gas to forms that plants can use). The distribution of nitrogen-fixing plants, particularly crops, is therefore important. In some watersheds, it is not uncommon for atmospheric deposition to account for one-third of the nitrogen inputs and biological fixation to account for another one-third. The density and distribution of nitrogen-fixing plants within the watershed is therefore significant. Elsewhere on Hawai'i Island, the spread of the nitrogen-fixing Albizia tree is affecting watershed nitrogen budgets (Atwood *et al.* 2010).

It is estimated that human activities have doubled the amount of atmospheric nitrogen that is delivered to tropical watersheds (relative to background).

## **4.2 Wildfire**

Wildfire is a significant threat in the Wai'ula'ula watershed. In the last decade, some part of the watershed has burned every couple of years on average, due to the recurring fire cycle and unmanaged grass fuels. Wildfires strip the land of vegetation and render the thin soil susceptible to erosion through runoff, leading to sedimentation of streams and nearshore waters. It was estimated, using the modeling tool called the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT), that if 1,350 acres in the lower watershed burned, it could increase the load of total suspended sediments to the streams and coastal waters by 290%.

The changing composition of vegetation in the watershed has contributed to an increased fire hazard. Alien grasses, such as fountain grass (*Pennisetum setaceum*), now dominate much of the lower watershed and are often more fire-adapted than native species and will not only carry fire well but quickly exploit suitable habitat after a fire. The area's strong, gusty winds and naturally hot and dry weather produce a climate conducive to wildfire occurrence and contribute to the rapid spread of fire. Wildfires typically start at the end of a dry cycle, and the exposed soils are most vulnerable at the onset of the wet season.

There have been numerous fires within the watershed over the past five years, many of a suspicious nature (Figure 30). In September 2004, a 1,500-acre fire started south of Kawaihae Road near the egg farm and burned down to Queen Ka'ahumanu Highway, causing the evacuation of 40 homes within the 'Ōuli Ekahi subdivision and 16 homes in the Mauna Kea Uplands subdivision. In May and June of 2005, fires blackened 400 acres at Pu'u Pā on Parker

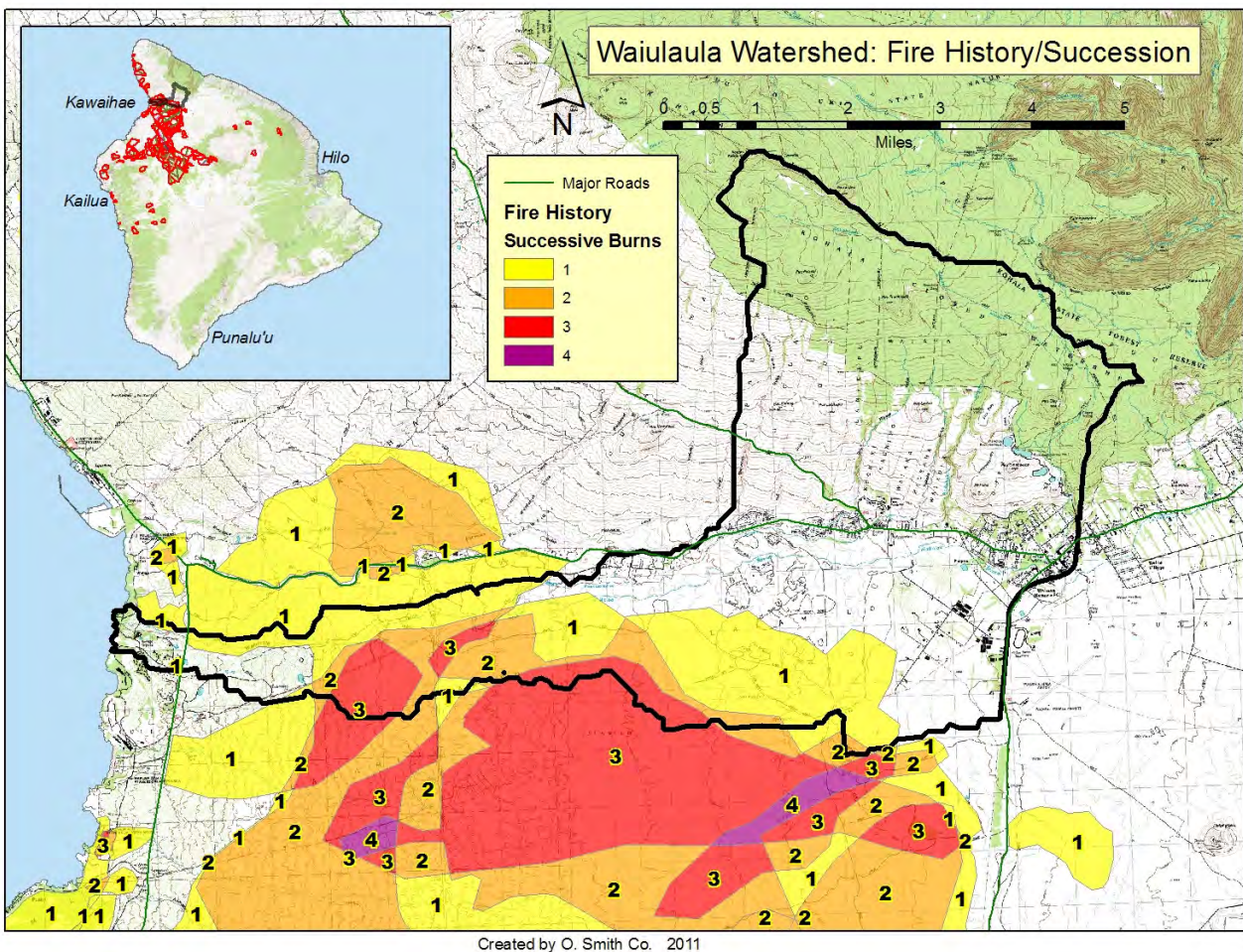
Ranch lands near the Waimea Airport and 100 acres *makai* of Queen Ka‘ahumanu Highway just south of Kawaihae Road. In August 2005, a fire that began near the Lālāmilo Farm lots burned 15,000 acres and led to the evacuation of 4,000 residents of Waikoloa Village. The fire also burned north towards Waikoloa Stream. However, the reduced fuel load from cattle grazing in the area slowed the fire considerably and kept the neighborhoods along Kawaihae Road safe. The August 2005 fire lasted days and required the collective efforts of the Hawai‘i County Fire Department, volunteer units, U.S. Army, and Hawai‘i DLNR. In late August 2005, another fire started near the Lālāmilo Farm lots, but because of favorable weather conditions and cattle grazing, it was slower-moving and more-easily contained.

In July 2007, brushfires burned about 10 acres *makai* of Kawaihae Road near the Pu‘ukoholā Heiau National Historic Site, forcing the evacuation of residents of the Kawaihae transitional housing, and 600 acres *makai* of Māmalohoa Highway near the Waimea Airport. In August 2007, a wind-driven brush fire burned down the slopes above Kamuela View Estates, burning approximately 170 acres. The fire, likely caused by a downed power line, came within a quarter of a mile of homes, until a fire break was cut between the flames and homes. In October 2007, a wildfire burned 550 acres near Spencer Beach Park and Mau‘umae. In July 2008, a fire burned 2-1/2 acres on the south side of Kawaihae Road near mile-marker 66. Another fire burned about 35 acres near the subdivisions of Anekona and ‘Ōuli Ekahi in September 2008, causing the evacuation of some homes. While no houses were damaged, the fire came extremely close to 10 homes. In March 2010, roadside mowing operations along Kawaihae Road sparked a fire that burned 630 acres in the lower watershed. A November 2010 fire burned 130 acres within the Kanehoa subdivision, destroying an agricultural out-building, damaging a house, and resulting in the evacuation of the subdivision residents.



Sediment in the Stream Channel Following the March 2010 Wildfire





**Figure 30: Wai'ula'ula Watershed Wildfire History Map (1973-2009)**

Managed grazing is a tool to mitigate the risk of wildfire. Effective fine fuels management via cattle grazing has been demonstrated to slow the spread of wildfire and, therefore, reduce the surface area that is susceptible to sediment runoff. About 90% of fire starts occur along the highways bordering the watershed and away from the stream corridor. With effective grazing management, fire starts can be contained more rapidly, preventing the spread of fire to the sensitive stream corridor. This will protect water quality within Wai'ula'ula stream as well as coastal areas.

While a significant portion of the watershed is used for cattle grazing, parts of the watershed have historically remained ungrazed because they have not been fenced and there has been no water available for cattle. In particular, the lower watershed between 1,200-ft elevation and sea level is currently unfenced. These wildland areas, classified as Agricultural District, are the most fire-prone part of the watershed. These areas have burned several times in the past five years, leaving bare land susceptible to significant erosion. Queen Ka'ahumanu Highway bisects

these marginal lands and Kawaihae Road follows the northern boundary, providing access for intentional and accidental fire starts.

Fire-fighting within the Wai'ula'ula watershed is challenging. Access is difficult and, because of the concern about unexploded ordnance from WWII-era firing exercises in the area, it is normally not considered safe for firefighters to fight the fire on the ground. Rather, they are stationed around the perimeter of the fire, and the Fire Department uses helicopters to drop water on the hot spots. Bulldozers are brought in to cut fire breaks to help contain the fire and protect neighborhoods from its encroachment.

Not only does fire itself damage the natural environment, but the process of fighting the fire also affects the resources of the watershed. Construction of access roads and fire breaks during a fire can create channels for future erosion. Therefore, it is critical that post-fire assessments be performed and restoration activities undertaken, preferably before available heavy equipment is released from the site following a fire.

The Hawai'i Wildfire Management Organization (HWMO) is a 501(c)(3) non-profit organization established in 2002 to protect, conserve and enhance resource values in West Hawai'i by reducing wildfire frequency and size. The organization's goals are to develop and implement fuels management activities, to provide educational opportunities about wildfire, to conduct fuels management research, to promote the protection of native ecosystems from the effects of wildfire, and to support and facilitate a multi-faceted approach to wildfire prevention and management. Participating agencies and organizations include DLNR, Hawai'i County Fire Department, NRCS, U.S. Fish and Wildlife Service (USFWS), U.S. Army, U.S. Forest Service, University of Hawai'i Cooperative Extension Service (CES), MKSWCD, and affected landowners and communities.

## **4.3 Unexploded Ordnance**

Between 1943 and 1953, the U.S. military used 130,000 acres of land in West Hawai'i for training purposes (Figure 31). At least 40% of the area was used for training with live military munitions (Hawai'i County 2008), including significant portions of the Wai'ula'ula watershed. Following the deactivation of Camp Tarawa and the Waikoloa Maneuver Area, the Department of Defense performed cleanup activities, consistent with the standards and technologies of that time. However, within the last decade, unexploded ordnance (UXO) has been found at several sites within Waimea and in and around Waikoloa Village. At least six people have been killed or injured by old artillery rounds since the 1940s (USACOE 2005).

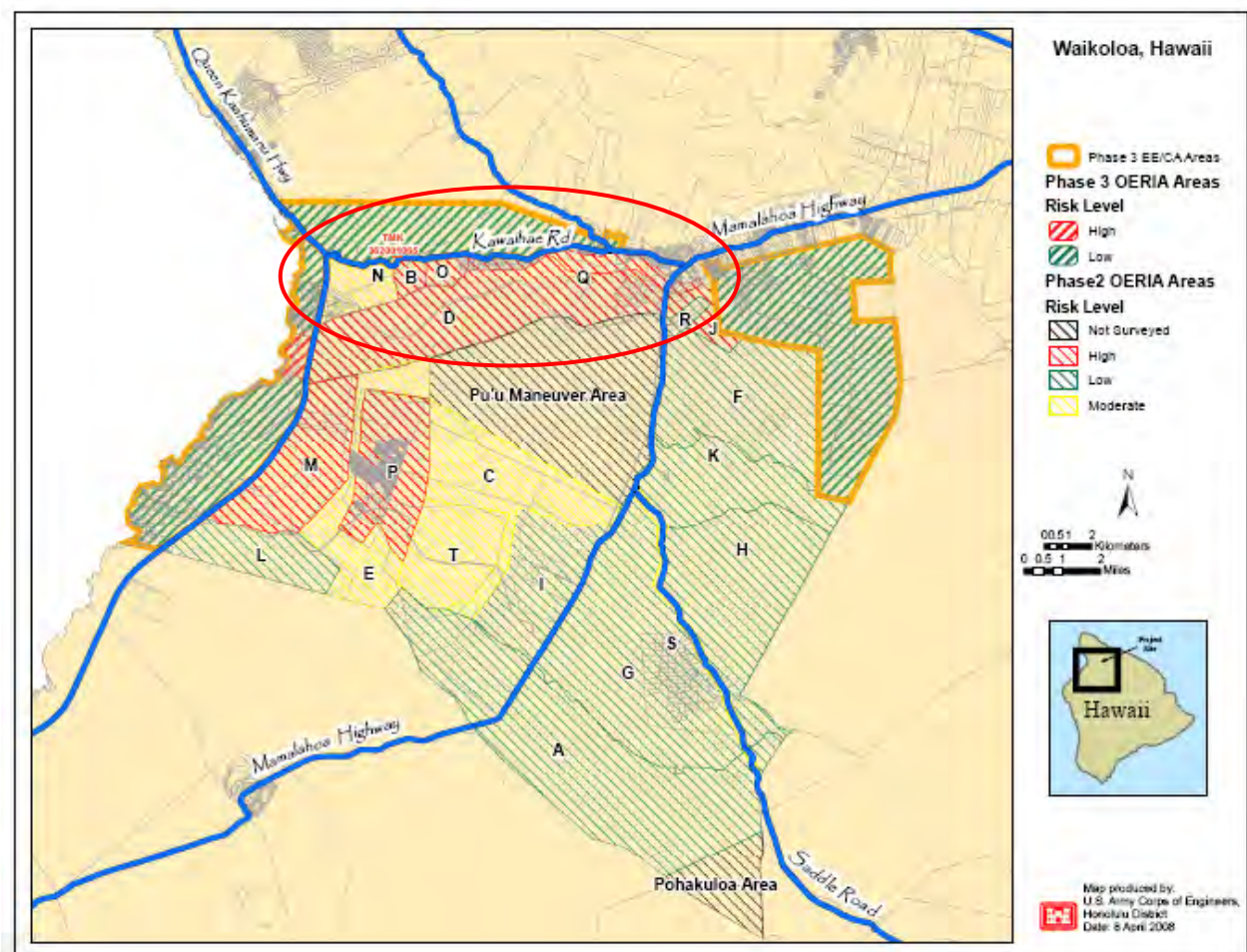
The Formerly Used Defense Sites (FUDS) program, administered by the U.S. Army Corps of Engineers, addresses potential risks on lands formerly owned or controlled by the Department of Defense prior to 1986 (Hawai'i County 2008). The Waikoloa FUDS area covers 137,000 acres, of which 50,000 are considered "high risk." Most of these high risk lands are in or adjacent to



the Wai'ula'ula watershed. "To date the Army Corps has cleared about 8,000 acres of land and removed approximately 1,800 pieces of live munitions" (Hawai'i County 2008: p. 36). Live ordnance found in the area includes grenades, bazooka rounds, artillery and mortar rounds, land mines, and hedgehog missiles.

As more and more of the region is undergoing development, "the Corps' FUDS team has taken an aggressive approach to reaching current and future homeowners and developers" (Hawai'i County 2008: p. 36). Private land owners who have property in high- or moderate-risk areas that have not yet been cleared are encouraged to contact the USACOE for help in surveying the land for UXO prior to construction.

Because of the risk of unexploded ordnance, the policy of the Hawai'i County Fire Department is to not allow firefighters to access those high risk areas on-the-ground to fight wildfires. Rather, they use helicopter water drop operations, fuel breaks, and perimeter defense as a way to control wildfires in these areas.



**Figure 31: Formerly Used Defense Sites (FUDS) in South Kohala (from Hawai'i County 2008)**

Addressing UXO removal is beyond the scope of this watershed management project. However, implementing projects to facilitate fire-fighting without on-the-ground response that could endangered fire-fighter lives is part of the scope of this plan.

## **4.4 Solid and Hazardous Waste**

The old Waimea landfill is located immediately adjacent to Waikoloa Stream, downstream of Sandalwood and adjacent to the transfer station. This unlined, 30-40-ft. deep landfill was closed in 1987 and replaced with the solid waste transfer station. It was covered with approximately two feet of soil and planted with grass. Inspections of the old landfill by DOH in 2001 and 2002 confirmed the presence of an active underground fire (DHHL 2002). As material buried in the landfill decomposes, cracks and sinkholes have also developed in the landfill surface. The landfill is under the jurisdiction of the Hawai'i County Department of Environmental Management. According to DHHL (2002), the County applies layers of dirt on a regular basis to suppress the smoke and particulate emissions, and fill cracks and fissures. No information is currently available on the effects of the landfill on stream water quality, though it is likely there is seepage of pollutants from the landfill into the adjacent stream. Water sampling above and below the old landfill would be necessary to determine its effects on water quality. However, addressing any effects of the landfill on water quality is beyond the scope of this watershed management plan.

The County Solid Waste Division Waimea Baseyard and County Solid Waste Transfer Station are also located adjacent to Waikoloa Stream. Trash is deposited at the transfer station into enclosed containers. The containers are removed from the site when they are full, and the waste is transferred to the Pu'uana'hulu landfill. Because the transfer station is exposed to the strong trade winds, trash – usually plastic waste – often blows out of the containers downwind, where it gets caught in fences or trees and shrubs along Waikoloa Stream. This trash often ends up in Waikoloa Stream, where it is carried downstream during storm events.

There are several areas within the watershed that are used as dumping grounds. There are unfenced areas in the lower watershed that are accessed by people to abandon vehicles, which are often smashed up and left to rust, spilling fluids on the ground. There are also sections of Waikoloa stream, particularly in Waimea town, where people litter regularly. Because the stream bed is usually dry, people seem to treat it as more of a “back alley” than as a natural asset to be protected. A District-sponsored stream cleanup in April 2008 netted 25 bags of trash, a foam mattress, and several large pieces of rusty metal within a ¼ mile section of stream in town. Parker School classes regularly pick up trash within the stream along the school grounds.

## **4.5 Flooding**

Flooding is not normally a threat, unless development has occurred in the floodplain. That being said, flooding has been a problem in the Waimea area for decades, as described in Section 2.2.6. During times of unusually heavy rainfall, the town of Waimea has suffered disruptive flooding. As Waimea has grown over the years, there are greater numbers of structures potentially in harm's way.

Flood control structures have been built (Parker Ranch's grassed drainage channel) and contemplated (proposed concrete channelization of Waikoloa Stream in Waimea town center). Stormwater runoff is currently managed primarily through regulation and by dry wells as a means to reduce flooding potential. As more impervious surfaces are created through increased urban and suburban development, the hardened areas prevent infiltration and generate greater volumes of stormwater runoff. While the runoff may carry relatively smaller pollutant loads, it consists of a greater volume of water, which can lead to more frequent and severe flooding. Low Impact Development (LID) techniques, a relatively new and under-utilized concept in stormwater management, can create less impervious area, generate less surface runoff, and require smaller infrastructure for drainage.

## **4.6 Stream Diversions**

There are numerous permitted and unpermitted diversions within the Wai'ula'ula watershed. So much water is being diverted, in fact, that the watershed's streams are no longer perennial in the lower reaches. The specific amount of water taken from each stream varies daily, and total annual withdrawal amounts are not documented.

There are segments of the Wai'ula'ula Stream system that are sometimes dry or sometimes have water only in stagnant pools. This creates stress for aquatic life (insects, crustaceans, fish, etc.), which is particularly important given the presence of native species in the stream. Legal and illegal streamflow diversions contribute to this situation. Increases in the amount of diversions have the potential to threaten the freshwater aquatic ecosystem in certain reaches. The timing of diversions is important. Diversions during periods of low streamflow are less significant than diversions during periods of high streamflow, which native fish species are actively migrating upstream. Because of the importance of water resources, this is a potentially sensitive issue.

## **4.7 Climate Change**

There is a considerable body of evidence that the global climate has undergone change in the last 50-100 years, and the scientific consensus is that continued change is very likely. In addition to warming, the hydrological cycle is expected to intensify, with more evaporation, more precipitation, and more runoff in certain regions (Huntington 2006). Indeed, these changes have already been detected at the global scale. It is more difficult, however, to predict changes in regional hydrology (some regions could become wetter and some drier) than to predict global averages. One study of possible changes in Hawai'i concluded that within a hundred years, rainy season rainfall could decrease and dry season rainfall could increase slightly (Timm and Diaz 2009). Another report predicts increasing temperatures, decreasing net precipitation during the winter (with concurrent decline in streamflow), in addition to increasing sea level (exacerbating high wave inundation), ocean temperatures (leading to coral bleaching), and ocean acidification (negative effects on coral, disruption of marine food web) (HCA 2009).

The specific impact to the Wai'ula'ula watershed is unknown. Climate change has the potential to exacerbate other threats to watershed health. The possibility of altered streamflow regimes cannot be ruled out. This would have negative impacts on freshwater availability for domestic and agricultural uses, and survival of native aquatic species. Further, temperature shifts could alter biogeochemical nutrient cycles, thereby altering stream nutrient concentrations and fluxes. Shifts in vegetation communities are possible, which could affect erosion and runoff. Given the obvious trends but the uncertainty about specific regional effects, it is important to protect ecosystems from non-climate stressors in order to promote ecosystem resilience and adaptation (HCA 2009).

# Chapter 5: Recommended Management Measures

The purpose of this chapter is to describe management actions that can be implemented to achieve watershed restoration and protection goals and address the existing impairments and threats described in Chapters 3 and 4. Management actions are typically groups of management practices – both structural and non-structural – that have the greatest likelihood of achieving watershed goals, treating sources of pollutants in the watershed and types of impairments found, and achieving the amount of load reduction needed.

This plan focuses efforts primarily in the riparian corridor and on the land immediately adjacent to the riparian zone because these areas most directly impact the quality of the stream and nearshore waters and habitats. Riparian corridors are considered critical areas within a watershed because they serve as buffer strips, trapping and filtering pollutants, stabilizing streambanks, and attenuating effects of high flows and volumes. Riparian corridors also provide habitat for wildlife and can provide various economic, recreational and aesthetic opportunities for landowners. A well-functioning corridor consists of a variety of plant species and vegetative covers. The goals, objectives, and recommended actions contained in this chapter support the plan’s overall goal to maintain healthy stream and riparian environments, both in terms of water quality and habitat integrity, that sustain a healthy *mauka-makai* connection and promote community-based environmental stewardship.

Polluted runoff comes from a large number of sources that vary in size and impact on water quality. Degradation of a waterbody results from the cumulative effect of pollutants from these sources. This watershed management plan describes a coordinated program of effective actions to be implemented to prevent and abate polluted runoff within the watershed, as well as address other threats that have a direct impact of overall watershed health and habitat integrity. As noted in Section 1.2, management strategies were developed using the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (EPA 1993) and the *Updated Management Measures for Hawai‘i’s Coastal Nonpoint Pollution Control Program* (CNPCP) (Stewart 2009). See Appendix B for a list of relevant management measures.

As part of the planning process, the relevant management measures provided a starting point to help with development of goals and objectives for the Wai‘ula‘ula watershed and recommended actions (“best management practices” or BMPs) to achieve those goals and objectives. While there are 50 management measures within Hawai‘i’s CNPCP, only 24 apply to the land uses in the Wai‘ula‘ula watershed: 5 for agriculture; 12 for urban areas; 4 for hydromodifications<sup>8</sup>; and 3 for wetlands and riparian areas. Table 17 lists these management measures and notes the implementing projects that relate to each.

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<sup>8</sup> Hydromodification means an “alteration of the hydrologic characteristic of coastal and non-coastal waters, which in turn could cause degradation of water resources” (EPA 1993; p. 6-90).

**Table 17: Management Measures Applicable to the Waiulaula Watershed**

<b>Management Measures</b>	<b>Applicable to Watershed?</b>	<b>Implementing Projects</b>
<b>AGRICULTURE</b>		
Erosion and Sediment Control	Yes	NUTR-1, 2; SED-1, 2, 3; FIRE-1, 2, STREAM-1
Wastewater & Runoff from Confined Animal Facilities	No	
Nutrient Management	Yes	NUTR-1, 2; SED-2, STREAM-1
Pesticide Management	Yes	NUTR-1, SED-1
Grazing Management	Yes	NUTR-2, SED-2, 3; FIRE-1, 2; STREAM-1
Irrigation Water Management	Yes	NUTR-1, SED-1, 2
<b>FORESTRY</b>		
(10 management measures)	No	
<b>URBAN</b>		
New Development	Yes	STORM-4, 5, 6; STREAM-4
Watershed Protection	Yes	NUTR-3, 4; SED-4, FIRE-3, 4, 5; STORM-1 through 6; STREAM-2,3,4
Site Development	Yes	STORM-1, 2, 3, 4, 6; STREAM-2, 4
Existing Development	Yes	NUTR-3, 4; FIRE-3, 5; STORM-2, 4, 6; STREAM 4
New On-Site Disposal Systems (OSDS)	Yes	STORM 6
Operating OSDS	Yes	NUTR-3, 4
Pollution Prevention	Yes	NUTR-3, 4; FIRE-5; STORM-1 through 6; STREAM 2, 3, 4;
Golf Course Management	Yes	STREAM 3, 4; MONIT-1
Planning, Siting, & Developing Roads and Highways	Yes	STORM-5, 6
Bridges	Yes	STORM-4, 5, 6
Operation & Maint. of Roads, Highways, Bridges	Yes	STORM-5, 6
Road, Highway, and Bridge Runoff Systems	Yes	STORM-4, 5, 6
<b>MARINAS and RECREATIONAL BOATING</b>		
(15 management measures)	No	
<b>HYDROMODIFICATIONS</b>		
<u>Channelization and Channel Modification</u>		
Physical & Chem. Characteristics of Surface Waters	Yes	STORM 2, 4; STREAM-3, 4; AQU-1, 3; MONIT-1
Instream and Riparian Habitat Restoration	Yes	STREAM-1, 3, 4; AQU-1, 3
<u>Dams</u>		
Protection of Surface Water Quality and Instream and Riparian Habitat	Yes	STREAM-3, 4; AQU-1, 3



<b>Management Measures</b>	<b>Applicable to Watershed?</b>	<b>Implementing Projects</b>
<u>Streambank and Shoreline Erosion</u>		
Eroding Streambanks and Shorelines	Yes	STREAM-1, 3, 4; AQU-1
<b>WETLANDS, RIPARIAN AREAS, and VEGETATED TREATMENT SYSTEMS</b>		
Protection of Wetlands and Riparian Areas	Yes	STREAM-1, 3, 4; AQU-1
Restoration of Wetlands and Riparian Areas	Yes	STREAM-1, 3, 4; AQU-1
Vegetated Treatment Systems	Yes	STREAM-1, 3, 4; AQU-1

The watershed management plan also addresses EPA's 9 key elements for watershed-based plans that EPA believes are critical for achieving improvements in water quality. All projects that apply for Section 319(h) funding under the Clean Water Act and administered by the Hawai'i Department of Health must include nine key elements in their watershed-based plans. Appendix C lists these 9 required elements and indicates where each is addressed in the Wai'ula'ula watershed management plan.

This chapter lays out watershed restoration and protection goals and objectives, as well as recommended projects and tasks to address the goals and objectives. This chapter identified implementing measures that will have the greatest likelihood of achieving the stated watershed goals. Under each goal, there is a brief description of the problem to be addressed, estimated pollutant load reductions expected, and a table listing criteria by which to measure success in achieving that particular goal, followed by one or more measurable objectives. Under each objective there are one or more projects to implement the objective. Under each project there is a list of tasks, which are interim measurable milestones to gauge progress toward project implementation. Table 19 summarizes these projects. Worksheets for each project are provided in Appendix A, summarizing project tasks, implementation timeframe and schedule, pollutant load reduction estimates (if applicable), responsible entity and project partners, and an estimation of costs and technical assistance. Table 20 outlines the timelines for project implementation. Project timeframes and schedules assume a start date of 2012 for plan implementation.

The projects proposed in the Wai'ula'ula Watershed Management Plan were prioritized based on relative scores generated against a set of criteria. These criteria were developed by the planning team from information gathered by stakeholders and input from agency representatives. Criteria used to evaluate and prioritize projects include 1) total load reduction; 2) significance as a pollution source; 3) ease of implementation; 4) feasibility of project costs; 5) level of stakeholder buy-in; 6) severity of the threat addressed by the project; 7) the area of impact from the project; and 8) its relevance to management measures and plan objectives. Each of the proposed projects was evaluated against the eight criterion and assigned a value between one and three, for a total possible score of 24. A value of "3" given for project cost feasibility, for instance, would mean that the project cost totals less than \$25,000; "2" would represent a project cost between \$25,000 and \$100,000, and a "1" would be given to a project

costing over \$100,000. For total load reduction, a "3" represents a direct relationship or a significant load reduction, a "2" would be indirectly related or an assumption that loads would be somewhat reduced, and a "1" would be given to a project with no relevance to load reduction or would not result in load reduction.

The results of this prioritization process placed the projects in high, medium, or low priority levels for implementation (Table 18), and their respective implementation schedules are based on their cumulative scores for each criterion. Some projects were moved up in priority as their implementation is prerequisite to projects in other priority levels. While these are the priority levels as proposed at the finalization of this management plan, projects assigned a lower priority may be implemented sooner if project funding or grant opportunities become available, or new information elevates a project's urgency. The implementation schedule for priority level 1 is from 0 to 5 years, priority level 2 from 6 to 10 years, and priority level 3 between 11 and 15 years. Monitoring the overall implementation of the Wai'ula'ula watershed management plan on an ongoing basis will determine if the proposed priority levels are relevant over the planning horizon of 15 years, and, if they are not, they shall be adjusted accordingly.

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**Table 18: Priority Levels for Projects in the Wai'ula'ula Watershed Management Plan**

<b>Priority Level 1 Projects (1-5 years)</b>	<b>Priority Level 2 Projects (6 to 10 years)</b>	<b>Priority Level 3 Projects (11-15 years)</b>
<p><b>NUTR-2:</b> Fence riparian areas to exclude cattle</p> <p><b>NUTR-3:</b> OSDS education and outreach</p> <p><b>SED-2:</b> Extend Waimea Irrigation System to lower watershed</p> <p><b>SED-3:</b> Divide large paddocks in grazing areas</p> <p><b>SED-4:</b> Assess streambank erosion</p> <p><b>SED-5:</b> Remove goats between rock wall and Queen K</p> <p><b>FIRE-1:</b> Fence large grass-dominated area above Queen K to manage fine fuels with cattle grazing</p> <p><b>FIRE-3:</b> Update fire resources maps</p> <p><b>FIRE-4:</b> Develop agreements for access and water use</p> <p><b>FIRE-6:</b> Develop post-fire restoration manual</p> <p><b>STORM-1:</b> Survey and line catch basins within the watershed</p> <p><b>STORM-3:</b> Stormwater educ and outreach program</p> <p><b>STORM-6:</b> Develop &amp; implement LID outreach program</p> <p><b>STREAM-2:</b> Educational events/ projects to educate about riparian buffers</p> <p><b>AQU-4:</b> Invasive aquatic species control</p> <p><b>EDU-1:</b> Develop/ adapt educational materials</p> <p><b>EDU-2:</b> Provide on-the-ground svc learning opportunities</p> <p><b>ADMIN-1:</b> Wai'ula'ula Watershed Coordinator</p> <p><b>MONIT-1:</b> Implement monitoring program</p>	<p><b>NUTR-1, SED-1:</b> Assist Farmers in Lālāmilo Farm Lots with Conservation Plans</p> <p><b>NUTR-4:</b> Incorporate point-of-sale inspections of OSDS</p> <p><b>SED-6:</b> Remove goats below Queen K</p> <p><b>FIRE-2:</b> Fence large grass-dominated area below Queen K to manage fine fuels</p> <p><b>FIRE-5:</b> Construct and maintain fuel breaks</p> <p><b>STORM-2:</b> Dry well insert installation and maintenance program</p> <p><b>STREAM-1:</b> Convert marginal grazing lands into native vegetation via CREP</p> <p><b>STREAM-3:</b> Restore riparian areas within the watershed</p> <p><b>STREAM-4:</b> Policy language for overlay district that protects wetlands and riparian areas</p> <p><b>AQU-1:</b> Remove illegal diversions</p> <p><b>AQU-2:</b> Evaluate need for specific instream flow standards</p> <p><b>AQU-3:</b> Determine the effects of dams on 'o'opu habitat</p> <p><b>AQU-5:</b> Protect priority instream perennial pools</p> <p><b>EDU-1:</b> Develop/ adapt educational materials</p> <p><b>EDU-2:</b> Provide on-the-ground service learning opportunities</p> <p><b>ADMIN-1:</b> Wai'ula'ula Watershed Coordinator</p> <p><b>MONIT-1:</b> Implement monitoring program</p>	<p><b>SED-7:</b> Identify and revegetate bare land in watershed</p> <p><b>STORM-4:</b> Upgrade existing runoff control structures</p> <p><b>STORM-5:</b> Develop operation and maintenance guidelines for County roads</p> <p><b>EDU-1:</b> Develop/ adapt educational materials</p> <p><b>EDU-2:</b> Provide on-the-ground service learning opportunities</p> <p><b>ADMIN-1:</b> Wai'ula'ula Watershed Coordinator</p> <p><b>MONIT-1:</b> Implement monitoring program</p>

**Goal 1: Reduce nutrient loads in the Wai‘ula‘ula watershed.**

In the limited water quality monitoring undertaken for this management plan, results indicated water quality impairment with respect to nutrient loads. Nitrate concentrations in Waikoloa Stream below Waimea town slightly exceeded state water quality standards, while the TP concentration was nearly twice the allowable amount. Further downstream just above the mouth of the Wai‘ula‘ula watershed, TN concentrations were double the allowable amount. In the nearshore waters, ammonia concentrations were 2.8 times the water quality standard and chlorophyll-a concentrations were double. All other nutrients measured at the various stations were within allowable limits.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Total Phosphorus (TP)	By 2025, the geometric mean of measurements for all water quality indicators shall be less than water quality standards for the dry season in any year and at any sampling site.
Total Nitrogen (TN)	
Ammonia – mouth of watershed only	By 2025, the difference between upstream values and downstream values for all water quality indicators in any year and for every upstream/ downstream sampling pair shall be indistinguishable from zero according to a paired t-test.
Dissolved Oxygen (DO)	
Nitrate	
Chlorophyll-a	
Linear feet of riparian corridor excluded from cattle	By 2025, fence 58,000-ft. of riparian corridor in the grazing area between 1,200-ft. and 2,600-ft. elevation along Keanu‘i‘omanō and Waikoloa streams.

**Objective 1a: Reduce nutrient loads in agricultural runoff from Lālāmilo Farm Lots by 20% by 2019.**

The Lālāmilo Farm Lots are located adjacent to and upslope of Waikoloa Stream. While conservation planning is an effective tool for ensuring that agricultural operations do not have a negative impact on a watershed’s natural resources, only 94 acres (or 15%) of the Wai‘ula‘ula watershed’s farmlands are currently covered by a plan. These lands are a mix of crop agriculture, with regular tilling of the fields, and greenhouses, buildings, and other areas that could still benefit from conservation plans to address stormwater runoff. Farmers may not know that MKSWCD and NRCS can provide technical expertise free-of-charge to assist them in identifying immediate or potential resource problems and developing a conservation plan to address those problems. Recognizing that conservation planning is a voluntary action taken by agricultural operators, outreach into the agricultural community is important first step.

Through outreach, the benefits of conservation planning to the land and to the productivity, sustainability and profitability of farm operations can be explained.

Current nutrient loads from the Lālāmilo Farm Lots estimated through N-SPECT analysis are 290 kg/yr for nitrogen and 40 kg/yr for phosphorus.

***Project NUTR-1. Assist farmers in Lālāmilo Farm Lots with the development and implementation of Conservation Plans to reduce polluted runoff. This project also addresses objectives for sediment control and stormwater management.***

*Project Tasks:*

- *Identify all active and inactive agricultural producers by TMK in the Lālāmilo Farm Lots.*
- *Conduct outreach to active producers about developing a conservation plan for their operations or expanding upon existing plans, targeting producers closest to the stream or with obvious resource concerns.*
- *Execute cooperator agreements with at least three additional producers or covering at least 200 additional acres.*
- *Assist cooperators in identifying possible cost-share opportunities for best management practice implementation.*
- *Follow-up with cooperators to track implementation of BMPs.*

**Objective 1b: Fence 58,000-ft. of riparian corridors on Keanu'i'omanō Stream to exclude livestock from streams by 2023 (relates to Project STREAM-1).**

At this time, there are two primary grazers of the watershed's rangelands: Parker Ranch in the mauka area and FR Cattle Co. in the marginal lands. Much of the grazing land is owned by the State of Hawai'i (DLNR and DHHL) and leased to the ranchers. While these lands are being grazed under existing conservation plans, improvements can still be made. Infrastructure is limited, with more fencing to reduce paddock size and watering facilities needed. In some areas, cattle are accessing streams for water because there are no other sources of water available, causing streambank erosion and adding nutrients and pathogens to the stream system.

***Project NUTR-2. Work with Parker Ranch and FR Cattle Co. to fence critical riparian areas that cattle are currently using to access water. This project will also address pathogens and sediment loads from eroding streambanks caused by cattle trampling.***

*Project Tasks:*

- *Identify stream segments used by cattle for watering and prioritize based on critical resources, environmental impact, availability of alternative water sources, and continuity among stream segments.*

- *Work with land users to develop alternative water sources (troughs) for cattle away from stream (see Project SED-2).*
- *Once alternative water sources are developed, limit livestock access by installing fence.*

**Objective 1c: Increase inspections and maintenance (pumping) of onsite wastewater disposal systems (OSDS) within the watershed by 20% by 2019.**

The majority of homes and businesses in the Wai‘ula‘ula watershed are using onsite wastewater disposal systems (OSDS), either a cesspool or septic system, which are effective over the long-term only if they are properly sited, designed, operated and maintained. According to Ogata (2009), “many of these systems are at or past their designed lifetimes and are operated by owners with little knowledge of the basic workings/ maintenance requirements of their system” (p. 1). At this time, there is no map or electronic document that identifies type of wastewater treatment system by TMK within the watershed. Therefore, it is currently not possible to assess the effects of OSDS on water quality.

***Project NUTR-3. By 2016, educate home owners about proper operation and maintenance of OSDS and the effects of failing OSDS on water quality, public health, and environmental conditions.***

**Project Tasks:**

- *Inventory and map type of wastewater system by TMK and year installed, focusing first on areas adjacent to the streams within the watershed.*
- *Conduct risk assessment to highlight potential critical areas based on density on OSDS, average age of systems, proximity to stream or floodplain.*
- *Compile information required by Section 11-62-62, HAR, and received by DOH from wastewater pumpers in the watershed, including number of systems pumped, location by TMK, type of OSDS, date, and volume.*
- *During baseflow periods, monitor above and below potential problem areas on a quarterly basis for two years to look for onsite waste signals. Parameters to be monitored include TN, TP, and c. perfringens.*
- *Develop or adapt outreach materials about OSDS and potential effects on water quality and environmental and public health.*
- *Distribute information to homeowners with OSDS about the operation, maintenance, and self-inspection of cesspools and septic systems as a way to extend their operating lives and prevent failures.*



***Project NUTR-4. Work with local realtors and lenders to establish voluntary point-of-sale inspections of OSDS in critical areas of the watershed by 2017.***

**Project Tasks:**

- *Meet with local realtors and lenders to discuss the importance of OSDS inspections to protect both buyer and seller from conflicts arising from failing OSDS, and to gauge interest and level of cooperation.*
- *Develop process for third party inspection of OSDS at time of sale.*
- *Develop or adapt form to disclose, at time of property sale, type of OSDS, location, when it was last pumped, known operational defects, date of last inspection and inspector name, system design and plumbing information, and any special monitoring or maintenance needs.*

**Goal 2: Prevent an increase in sediment loads in the Wai'ula'ula watershed.**

As measured through limited water quality monitoring, sediment loads throughout the watershed meet State water quality standards, though sediment concentrations below Waimea are just slightly below the threshold level. Sediment pulses into the ocean are likely to be episodic in nature, following fire or other land disturbances that precede a major storm event. In contrast to the adjacent Pelekane watershed -- which generates sediment concentrations in runoff that exceed the water quality standard by two orders of magnitude because it has been denuded by an unfortunate combination of fire, overgrazing, and drought -- the Wai'ula'ula watershed has generally maintained decent ground cover. A goal of this plan is to prevent wildfire, overgrazing and other land disturbances that would strip the land of vegetation and render the thin soil susceptible to erosion.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Turbidity	By 2025, the geometric mean of measurements for all water quality indicators shall be less than water quality standards for the dry season in any year and at any sampling site.  By 2025, the difference between upstream values and downstream values for all water quality indicators in any year and for every upstream/ downstream sampling pair shall be indistinguishable from zero according to a paired t-test.
Total Suspended Sediment (TSS)	
Erosion Rate	Statistically-significant reduction in erosion rates over 67% of erosion pins
Number of goats	Reduce goats in fenced areas of watershed by 80%

**Objective 2a: Reduce sediment loads in agricultural runoff from Lālāmilo Farm Lots by 20% by 2019.**

Current sediment loads from the Lālāmilo Farm Lots estimated through N-SPECT analysis are 10,900 kg/yr.

***Project SED-1. Assist farmers in Lālāmilo Farm Lots with the development and implementation of Conservation Plans to reduce polluted runoff. (Implement concurrently with Project NUTR-1 above.)***

**Objective 2b: By 2020, improve grazing efficiency<sup>9</sup> as a way to prevent overgrazing and limit wildfire size to an average of 100 acres burned per year in the fire prone area between 1,200-ft. and 2,600-ft. elevation.**

A high percentage of land in the watershed - both prime kikuyu land and marginal land - is used for grazing (about 8,000 acres). A significant amount of this grazing land is considered marginal. With sufficient rainfall, these marginal lands can support cattle production. During dry conditions, grazing in these areas is seasonal at best, with cattle grazing for a short time when the grass is green following a rain event. However, it is important to graze these marginal lands; otherwise, without periodic grazing, the resulting tall, dry grasses would present a significant fire hazard to the numerous adjacent residential communities.

While the primary grazers, Parker Ranch and FR Cattle Co., have conservation plans with the Mauna Kea Soil and Water Conservation District, improvements can still be made to encourage cattle to graze the land more evenly, rather than concentrate on specific locations or grass species. In addition, infrastructure is limited or non-existent in some areas, with more fencing to reduce paddock size and watering facilities needed.

N-SPECT modeling suggests that if the grazed area between 1,200-ft. and 2,600-ft. elevation were to burn (5,550 acres), sediment loads would increase sevenfold (3,613 to 26,867 kg/yr.). Phosphorus loads would more than double (189 to 417 kg/yr.) and Nitrogen loads would more than triple (1,085 to 3,373 kg/yr.).

***Project SED-2. By 2013, extend the Waimea Irrigation Water System from Lālāmilo Farm Lots to the rock wall at the 1,200-ft. elevation.***

Surface water from outside the Wai‘ula‘ula watershed is transported into the watershed for use by farmers in the Lālāmilo Farm Lots. Surface water from windward Kohala streams is diverted into the Upper Hāmākua Ditch to the Hawai‘i Department of Agriculture’s Waimea Irrigation Water System’s 60 MG Waimea and 100 MG Pu‘u Pulehu reservoirs. This system provides

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<sup>9</sup> Grazing efficiency is the percentage of forage produced that animals actually consume (versus trample, soil and reject).

irrigation water to farmers in both Pu'ukapu and Lālāmilo. While crop agriculture receives priority for use of the water, grazers may also use this agricultural water.

*Project Tasks:*

- *Develop an agreement between the Hawai'i Department of Agriculture Waimea Irrigation Water System and MKSWCD to extend irrigation water pipeline from the Lālāmilo Farm Lots to the rock wall at the 1,200-ft. elevation, a distance of six miles. (This land is all zoned for agricultural use.)*
- *Design a water conveyance system that meets NRCS standards and specifications.*
- *Install pipeline and water tanks, as needed, to store water for cattle use during dry times.*
- *Water users of the pipeline will pay the agricultural water rate through individual metering.*
- *Use of water from the pipeline will be limited to the agricultural and revegetation projects proposed in the watershed management plan (Projects NUTR-2, SED-3, SED-7, FIRE-1, STREAM-1, STREAM-3).*

***Project SED-3. Sub-divide large paddocks in the wildfire prone area between Lālāmilo and the rock wall at 1,200-ft. elevation into smaller paddocks by 2016 to improve grazing efficiency of fine fuels.***

*Project Tasks:*

- *Work with land user to design an improved rotational grazing system that meets NRCS standards and specifications as part of the land user's conservation plan.*
- *Install approximately 5 miles of additional fence to sub-divide existing paddocks in order to achieve even grazing throughout paddocks.*
- *Use water storage and conveyance system developed under Project SED-2 to convey water into the new paddocks. Assist land user in securing a permit to withdraw water from Keanu'i'omanō Stream as a back-up supply in the event of low flows from the Waimea Irrigation Water System.*
- *Conduct bi-weekly stubble height monitoring when cattle are present as a management tool to determine when cattle should be rotated out of paddocks, based on the minimum heights established under NRCS's standards and specifications.*
- *Monitor long-term changes in erosion rates from these lands, using erosion pin monitoring described under Chapter 6 "Monitoring".*

**Objective 2c: By 2016, assess 100% of the watershed’s riparian corridors to identify eroding or unstable streambanks and monitor at least 10 sites over 3 years to determine annual erosion rates.**

While site visits and anecdotal information suggest there are eroding streambanks within the watershed, no comprehensive survey has been conducted to document the location, extent, cause, and sediment-load contribution of such erosion. Fixing streambank erosion problems will be a long-term undertaking. In the near-term, MKSWCD will identify potential problem areas and monitor actual erosion rates from representative streambanks. With this additional information in hand, MKSWCD will be able to develop actions to address eroding streambanks that are contributing to the sediment load in the watershed.

***Project SED-4. Identify eroding and unstable streambanks and install erosion pins in representative sites to monitor annual erosion rates.***

*Project Tasks:*

- *Conduct stream corridor assessment by 2013 to identify and map locations of a variety of environmental problems including streambank erosion and instability (see Chapter 6 “Monitoring”). (This assessment tool will need to be developed/ adapted for Hawai’i’s stream systems first.)*
- *For representative eroding streambanks at various elevations within the watershed, install erosion pins (see Chapter 6 “Monitoring”) to measure annual rate of erosion. A minimum of 10 sites will be selected and monitored over a 3-year period.*
- *Given the findings of stream corridor assessment and erosion pin monitoring, a prioritized list of needed management actions for streambank stabilization and restoration will be developed.*
- *Stabilize and restore high priority streambanks that are severely eroding using dormant plantings, vegetative materials, stone structures and other low-cost techniques. (project costs and timeframes TBD)*

**Objective 2d: Following fencing projects (FIRE-1 and FIRE-2), remove all feral goats from the lower watershed (rock wall down to the coast) by 2020.**

The population of wild goats (*Capra hircus*) in West Hawai’i has increased dramatically over the past decade. Goats are extremely destructive herbivores that will eat nearly any type of available vegetation. These browsing ungulates are having a significant impact on the groundcover in the lower watershed, stripping certain areas of vegetation and rendering these areas susceptible to erosion. There is currently no management of these animals, and they roam freely in the watershed, moving in response to available vegetation and water sources.

***Project SED-5. Remove feral goats from the lower watershed between Queen Kaʻahumanu Highway and the rock wall at the 1,200-ft. elevation by 2014.***

***Project Tasks:***

- *In coordination with Project FIRE-1, ensure fence constructed in lower watershed between Queen Kaʻahumanu Highway and the rock wall is “goat proof” (extra strands of barbed wire at top, mesh covering gates, no large gaps at ground).*
- *Work with land owners to develop and implement feral ungulate removal program.*

***Project SED-6. Remove goats from lower watershed below Queen Kaʻahumanu Highway by 2020. This project would only occur following the fencing of this area under Project FIRE-2.***

***Project Tasks:***

- *In coordination with Project FIRE-2, ensure fence in lower watershed between the coast and Queen Kaʻahumanu Highway is “goat proof”.*
- *Work with land owners to develop and implement a feral ungulate removal program.*

**Objective 2e: By 2022, restore 25% of bare land in the watershed contributing to erosion, using techniques described in the post-fire restoration manual (Project FIRE-6).**

There are several areas within the watershed that have been rendered bare land for a variety of reasons, including recent fire, intentional land clearing, demolition, change in land use and other causes. These areas are particularly susceptible to erosion and sedimentation of streams and nearshore waters.

***Project SED-7. Identify and re-vegetate 25% of priority bare land contributing to sediment load in the watershed by 2022.***

***Project Tasks:***

- *Survey and map all significant bare areas within the watershed, noting proximity to a stream and whether they are hydrologically-connected to a stream, cause of de-vegetation (fire, overgrazing, land disturbance, etc.), and infiltration rate of soil (will determine what size storm event will cause runoff from area).*
- *Select priority areas for restoration based on above information and develop implementation plan and schedule.*
- *Install erosion pins (see Chapter 6 “Monitoring”) in priority areas to measure annual rate of erosion before and after restoration activities. At least one erosion pin grid will be installed per area and monitoring for at*

*least one year before restoration and for at least five years following restoration.*

- *Using practices described in the post-fire restoration manual (Project FIRE-6), restore priority bare land contributing to sediment load in the watershed (project costs and timeframes TBD).*

**Goal 3: Reduce wildfire occurrences and associated impacts to water quality and ecosystem health.**

Wildfire is a significant threat in the Wai'ula'ula watershed. In the past decade, some part of the watershed has burned every couple of years on average, due to the recurring fire cycle and unmanaged grass fuels. The accumulation of unmanaged fine fuels (grasses) is a recurring threat for devastating wildfires that strip the land of vegetation and render the thin soil susceptible to erosion through runoff, leading to sedimentation of streams and nearshore waters.

The changing composition of vegetation in the watershed has contributed to an increased fire hazard. The alien grasses that now dominate much of the lower watershed are more fire-adapted than native species and will not only carry fire well but quickly exploit suitable habitat after a fire. The area's strong, gusty winds and naturally hot and dry weather produce a climate conducive to wildfire occurrence and contribute to the rapid spread of fire. Wildfires typically start at the end of a dry cycle, and the exposed soils are most vulnerable at the onset of the wet season.

There are a number of fuels mitigation techniques used in Hawai'i and on the continental United States to reduce or modify the size, arrangement, and kind of vegetative fuels. These techniques include: mechanical removal (fuel break treatment), prescribed burn (landscape-scale), herbicide (fuel break treatment), and grazing (landscape-scale).

Cattle grazing is arguably one of the most valuable and cost-effective techniques. Effective fine fuels management via cattle grazing has been demonstrated to slow the spread of wildfire and therefore reduce the surface area that is susceptible to sediment runoff. About 90% of fire starts occur along the highways bordering and bisecting the watershed. With effective grazing management, fire starts can be contained more rapidly, preventing the spread of fire to the sensitive stream corridor. This will protect water quality within Wailulaula stream as well as coastal areas.



The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Fuel loads / stubble height	Fuel loads of 1,500 lbs/acre for buffel grass (key forage species) and 3" stubble height
Annual acreage burned	Less than an average of 100-acres burned per year throughout the watershed.

**Objective 3a: Reduce size of wildfires to an average of 100 acres burned per year by 2015 in the fire prone area between Queen Ka‘ahumanu Highway and 1,200-ft. elevation by using grazing to manage fine fuel loads.**

***Project FIRE-1. Fence lower watershed between Queen Ka‘ahumanu Highway and the rock wall at 1,200-ft. by 2013 to manage fine fuel loads with cattle grazing.***

The lower watershed between Queen Ka‘ahumanu Highway and the rock wall (1,200-ft. elevation) is neither fenced nor grazed. Consequently, this area and its immediate vicinity have burned repeatedly over the past few decades, including a 630-acre fire within the project area in March 2010. This 1,350-acre project area represents about 8% of the roughly 18,000-acre watershed. N-SPECT modeling suggests that if this ungrazed area were to burn, sediment loads would increase sevenfold (3,702 to 26,755 kg/yr.). Phosphorus loads would more than double (33 to 77 kg/yr.) and Nitrogen loads would more than triple (194 to 627 kg/yr.).

*Project Tasks:*

- *Develop agreement between landowners, land user (grazer) and MKSWCD regarding the implementation and maintenance of the project.*
- *Work with land user to amend his conservation plan to include the project area and develop a grazing system that meets NRCS standards and specifications.*
- *Survey and map intended fence alignment and location of gates for approval of landowners.*
- *Install approximately 6.8 miles of new cattle fence in conformance with NRCS standards and specifications, including perimeter fence along Kawaihae Road, Queen Ka‘ahumanu Highway, the rock wall, the north side of Wai‘ula‘ula stream and cross-fencing at 600-ft. elevation.*
- *Install water pipeline and infrastructure in conformance with NRCS standards and specifications to convey water to troughs strategically-placed in the paddocks to ensure even grazing and sufficient reduction of fuel loads along highways, and to keep cattle away from stream.*
- *When the cattle fence has been installed and the pipelines and troughs are operational, permanent monitoring points will be established to assess fuel loads at the onset of grazing activities. Initial monitoring of the grass loads*

*will take place as soon as the fence is complete and prior to the introduction of cattle to the project area.*

- *Land user will graze approximately 400 head of cattle within the project area for about 60 days per year, during the wet season that instigates rapid growth of the dominant buffel grass cover.*
- *Conduct bi-weekly stubble height monitoring when cattle are present as a management tool to determine when cattle should be rotated out of paddocks, based on the minimum heights established under NRCS's standards and specifications.*

***Project FIRE-2. By 2018, develop a project to reduce the fuel load in the unfenced, ungrazed area below Queen Ka'ahumanu Highway (to sea level) in consultation with land owners, Hawai'i Wildfire Management Organization, NRCS, UH Cooperative Extension Service, and possible grazers.***

While equally important, managing the fuel load in the 80-acre fire-prone area below Queen Ka'ahumanu Highway is a much more difficult undertaking. Unlike the area above Queen Ka'ahumanu Highway, it does not adjoin an area currently grazed, and the question of how to move cattle (or another type of ungulate such as sheep) has been the subject of many discussions. Water is also not readily available. For these reasons, MKSWCD sees this as a longer-term project, so that options can be explored, a willing grazer found, and issues of public access to Mau'umae Beach and along the Ala Kahakai National Historic Trail addressed. In this plan, we propose continuing the discussions and identifying possible solutions that will be presented separately for implementation funding.

**Project Tasks:**

- *Assembled a committee to explore the issues, including representatives of the land owners, MKSWCD, NRCS, UH Cooperative Extension Service, HWMO, and possible grazers.*
- *Conduct site visit(s) and meet to discuss and agree upon the most cost-effective and practical way to manage the fuel load.*
- *Submit proposal for implementation funding (project costs and timeframes TBD).*

**Objective 3b: By 2020, install measures within the watershed to facilitate rapid response by fire suppression agencies in the event of a fire start, to include reducing fuel loads in a 150-ft. to 300-ft. buffer zone around neighborhoods and along roadways by 80%.**

Because of the history of wildfire in the Wai'ula'ula watershed, it is important to implement additional on-the-ground mitigation measures and pre-suppression planning to reduce the number and/or severity of fires and facilitate fire-fighting in the event of a fire. Managing fuel loads and providing on-the-ground resources that will assist fire fighters will be especially important in the future, with climate change likely causing conditions (changes to vegetation, rainfall patterns, wind speed and/or direction) that will exacerbate the fire-grass cycle.

Effective pre-suppression planning enables firefighters and land managers to more easily and effectively control a fire. Knowing the location in the watershed of sensitive resources (natural and cultural) that are a priority for protection, water resources, access points, roads, and the types of equipment available from land users for fire suppression will enable a quick and effective initial attack against fire outbreaks.

Availability of water is critical to the suppression of fire. Water use agreements and strategically-placed water sources within the watershed, such as pipelines and water tanks (Project SED-2, Project FIRE-1), allow first responders to more-quickly respond to a fire in the first hour, which can be the difference between a 100 acre or several thousand acre fire.

Fuel breaks, areas where vegetation that easily carries fire has been reduced, keep firestarts from spreading quickly, provide access for fire-fighting, and divide fire-prone areas into smaller areas that provide easier fire control. These can be strategically-located and established through grazing, mowing, weed-whacking, bull-dozing, and strategic use of herbicides. Cattle grazing along the southern boundaries of the neighborhoods of Kanehoa, Anekona, 'Ōuli Ekahi already provide a fuel break of sorts to attenuate the fire risk to these communities. More fuel breaks are needed, especially along Kawaihae Road, Queen Ka'ahumanu Highway, and Kohala Mountain Road.

***Project FIRE-3. Update fire resource maps that cover the Wai'ula'ula watershed by 2012.***

*Project Tasks:*

- *Meet with HWMO personnel and large land owners in the Wai'ula'ula watershed to verify and update information for the fire resource maps, including primary responders by location, location of sensitive cultural and natural resources, water resources, roads, access points and access codes/keys, available equipment for fire suppression, and contact information for land owner representatives.*
- *Work with HWMO to update the maps and provide copies (paper and electronic) to State and county fire response agencies.*

***Project FIRE-4. Facilitate development and/or update of water use and access agreements between private land owners in the Wai'ula'ula watershed and fire response agencies by 2012.***

*Project Tasks:*

- *Help execute agreements between private land owners in the watershed (Parker Ranch, Queen Emma Land Co., Mauna Kea Properties, Mauna Kea Resort, Hapuna Prince Hotel, etc.) and fire response agencies to facilitate rapid access to water sources on private property in the event of a wildfire.*

***Project FIRE-5. Construct and/or maintain at least 6 miles of fuel breaks by 2017 to protect residential communities in fire-prone areas from wildfire and to slow spread of fire starts along roadways in the watershed.***

**Project Tasks:**

- *Survey and map existing fuel breaks and note current condition of those breaks.*
- *Evaluate current grazing adjacent to Kamuela Plantations, Lālāmilo (DHHL), Kanehoa, Anekona, 'Ōuli Ekahi for its effectiveness in protecting these communities from wildfire.*
- *Work with HWMO to identify and map priority residential areas and roadsides in need of protective fuel breaks. Calculate current fuel loads in a 150-ft. to 300-ft. wide buffer zone around priority residential areas and along priority roadways.*
- *Determine most appropriate type of fuelbreak for each area. An emphasis will be on the use of existing cattle grazing to reduce fuel loads in priority areas.*
- *For fuel breaks around residential areas, present proposed fuel break projects to each relevant neighborhood association for comments and concerns.*
- *Create approximately 6 miles of fuel breaks. Fuel breaks will be a minimum of 150-ft. wide. Develop a maintenance plan to ensure regular maintenance of fuel breaks, especially preceding the dry season.*
- *Measure changes in fuel loads at representative sites within fuel breaks on a semi-annual basis.*

**Objective 3c: In cooperation with HWMO, develop a post-fire restoration manual of effective practices by 2015.**

Sometimes, areas that have been overgrazed, experienced fires, or suffered severe erosion remain bare for long periods of time, exacerbating their erosion potential. This can occur for a number of reasons: absence of seeds in the soil, poor or depleted soil quality, capping of the soil making seed penetration difficult, and lack of rainfall or other forms of irrigation. Opportunistic species of grasses and plants introduced into an area are sometimes less effective for erosion control and create a greater fire hazard (e.g., fountain grass). Frequently, the riparian corridor, which normally would provide a buffer to polluted runoff entering the streams, is completely denuded during a fire, because of its tremendous fuel load in the form of trees and shrubs. In these situations, there may be a need for human assistance in restoring or revegetating areas severely impacted by wildfires or other causes, particularly in the riparian zone. There is currently little data available on successful revegetation of burned areas in Hawai'i.

**Project FIRE-6. In cooperation with HWMO, develop a post-fire restoration manual of effective practices by 2015.**

Project Tasks:

- *In coordination with HWMO, develop a post-fire restoration manual of effective practices to restore burned areas following fires. The manual will also be applicable to other denuded lands, whatever the cause. The manual will address large- and small-scale restoration of grasslands and riparian corridors, using grasses, fire-resistant species, and native species. Development of the manual will involve research on post-fire revegetation techniques used in dry environments around the world, small-scale test plots to determine effectiveness of practices in Hawai'i's leeward environments, and consultation with local and Mainland experts.*
- *Organize and host a workshop to present information to land and resource managers and others.*
- *Implement techniques developed to remediate burned areas (project costs and timeframes TBD).*

**Goal 4: Reduce the volume and increase the quality of stormwater runoff in the urban and suburban areas of the Wai'ula'ula watershed.**

Urban development can have a negative impact on the hydrology and water quality of a watershed. Impervious surface area is often associated with polluted runoff. The "hardening" of the landscape that comes with urbanization increases runoff volumes and pollutant loadings. Impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, decrease the infiltration capacity of the ground and result in greater runoff volumes that can exacerbate flooding problems. Urban development also causes an increase in pollutants, such as excessive nutrients, pathogens, hydrocarbons, heavy metals, and toxins.

Based on a limited amount of data, it appears that urban runoff in parts of the Wai'ula'ula watershed exceeds State water quality criteria for sediment (by a factor of five), TP (by a factor of four), TN (by a factor of three), and nitrate (slightly greater than the standard). These problems can be addressed during the implementation timeframe of this management plan.

N-SPECT was used to model future pollutant loads, given the land use changes (mostly urban and suburban expansion) projected in Hawai'i County's General Plan LUPAG. With future development scenarios, sediment loads will decrease but stormwater runoff volume and nutrient loads will increase.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Total Suspended Sediment (TSS)	By 2020, reduce pollutants loads in stormwater runoff conveyed directly into streams or into dry wells in close proximity to stream channels by 50%.
Total Nitrogen (TN)	
Total Phosphorus (TP)	
Runoff Volume	A percentage increase in runoff volume less than 5% from new developments in the watershed, and a decrease of runoff volume of at least 5% from existing development.

**Objective 4a: By 2020, treat 70% of urban stormwater runoff that is conveyed directly into streams and 30% of stormwater conveyed to dry wells in close proximity to stream channels.**

Many roads within the Wai‘ula‘ula watershed are fitted with curb and gutter catch basins to convey stormwater away from roads. This nutrient- and sediment-laden stormwater is then discharged into dry wells or directly into streams, affecting either groundwater or surface water. While Izuka *et al.* (2010) examined the potential effects of dry wells on county roads on the water quality of receiving waters at the coast and in drinking water wells, they did not consider effects to surface waters. On other roads, stormwater is conveyed to grassy shoulders on either side of the road, where it ponds until it is either absorbed or runs off. All existing bridges in the watershed have scuppers that discharge stormwater directly into the streams below.

There are several new residential development projects, highway projects, road realignments, bypasses, and new bridges proposed for the watershed. These provide opportunities for the District to work with the responsible State and county agencies to ensure the projects protect sensitive aquatic ecosystems, consider types and locations of permanent erosion and sediment controls, and manage stormwater through a combination of structural and non-structural practices.

***Project STORM-1. Install storm drain and curbside catch basin filter inserts by 2016 on priority drains/ basins that discharge directly into streams.***

*Project Tasks:*

- *Survey and map all storm drains and curbside catch basins in Waimea, quantify impervious surface areas, and determine which flow into dry wells and which flow directly into streams.*
- *Model volume of runoff from 2 year-24 hour storm event generated in the catchment areas of storm drain systems that discharge directly into streams.*



- *Prioritize storm drains and curbside catch basins for treatment upgrade based on discharge into stream systems.*
- *In cooperation with the County Division of Public Works (DPW), research available catch basin insert products and select product based on design features, pollutants captured, effectiveness, cost, and ease of installation and maintenance.*
- *In cooperation with the County DPW, install catch basin filter inserts on priority storm drains/ curbside catch basins.*
- *Work with County to establish a maintenance plan and establish a tracking system to gage effectiveness of catch basin insert program.*
- *Monitor water quality from end of storm pipe(s) discharging into stream before and for every storm event for one year after installation of filter inserts. Parameters to be monitored include TSS, TP, TN.*

***Project STORM-2. By 2018, install catch basin filter inserts on priority dry wells that are in close proximity to streams, where stormwater carrying pollutants may rapidly seep into stream channels.***

*Project Tasks:*

- *Based on survey, mapping, and modeling conducted under Project STORM-1, prioritize dry wells for treatment upgrade based on proximity to streams.*
- *In cooperation with the dry well owners (private or public), install catch basin filter inserts on priority dry wells.*
- *Work with dry well owners to establish maintenance plan and tracking system to gage effectiveness of catch basin insert program.*
- *On a representative dry well, monitor water quality entering storm drain and water quality below the filter insert. Parameters to be monitored include TSS, TP, TN.*

**Objective 4b: Conduct semi-annual educational events to engage residential property owners in managing stormwater onsite for three years before 2016.**

***Project STORM-3. Develop and implement a public education and outreach program for residential stormwater management.***

*Project Tasks:*

- *Develop or adapt outreach materials about innovative residential stormwater management, including fact sheets about best management practices, including stormwater harvesting (rain barrels, cisterns), rain gardens, and pervious pavement.*
- *Distribute information through MKSWCD website and at community outreach events.*

- *Conduct two educational events per year for three years, including hands-on events and demonstration projects.*

**Objective 4c: Decrease volumes flowing offsite and increase treatment of stormwater from existing commercial and residential developments by 15% by 2023.**

In response to flood hazards caused by development in the early 1980s, all new urban developments (with very few exceptions) have been mandated by Hawai'i County to maintain pre-development runoff conditions (Kuba 2005). Developers island-wide are now routinely required to dispose of all development-generated runoff onsite. These requirements have been codified in Chapter 23, HCC, "Subdivisions," Chapter 25, HCC, "Zoning," and Chapter 27, HCC, "Flood Control." Hawai'i County relies on deep (+20 feet) 5-foot diameter drainage injection wells (or "dry wells") as the primary means of capturing and disposing of stormwater runoff.

Older developments that pre-date the changes in regulations often convey stormwater runoff directly offsite into streams and storm drainage systems, which can contribute to flooding during large storm events. While not required by State or county directives, upgrading existing stormwater control structures to meet new requirements would help reduce both volume and pollutant loads in stormwater runoff.

***Project STORM-4. Upgrade existing urban runoff control structures on a priority basis.***

**Project Tasks:**

- *Survey existing urban runoff control structures in commercial and residential developments and identify and prioritize needed upgrades/improvements to reduce runoff pollutant concentrations and volumes or retain conveyance of polluted runoff onsite.*
- *Work with landowners to identify cost-share opportunities to retrofit/upgrade existing urban runoff control structures.*
- *Survey stream corridor rehabilitation opportunities that would help attenuate effects of runoff from existing development by improving retention and treatment capabilities of riparian corridors.*
- *Implement improvements to priority urban runoff control structures in coordination with land owners (project costs and timeframes TBD).*

**Objective 4d: Develop written pollution prevention procedures for the operation and maintenance of existing County roads, highways, and bridges by 2019 to reduce pollutant loadings to surface waters.**

New publicly-constructed roads, highways and bridges, and privately-constructed roads, highways and bridges that are transferred over to the State or county as public roadways upon completion of construction must comply with State and county standards. New privately-constructed roads, highways, and bridges that remain private must comply with counties

requirements for erosion and sediment control, stormwater management, drainage, zoning and subdivisions.

The State and county are responsible for maintenance of their respective roads, highways, and bridges. Chapter 19-127.1, HAR, administered by DOT, establishes design, construction and maintenance guidelines that should be followed in the construction, reconstruction, and maintenance of all highways, streets, or roads undertaken either by State or county authorities or by individuals intending to dedicate the facilities to governmental authorities. Hawai'i County, however, does not have separate written operation and maintenance guidelines for its roads, highways and bridges.

***Project STORM-5. Work with the County to formalize operations and maintenance practices for County roads, highways, and bridges by developing written guidelines.***

*Project Tasks:*

- *Using the "Pollution Prevention and Good Housekeeping" chapter of Hawai'i DOT's Oahu Storm Water Management Program Plan (DOT 2007) as a model, draft maintenance guidelines for debris control, chemical application, erosion control, maintenance facilities (baseyards, etc.), and flood control facilities related to County roads, highways and bridges.*

**Objective 4e: By promoting use of Low Impact Development techniques, reduce the volume of stormwater runoff conveyed offsite from new large developments by 2025 so that total runoff volumes calculated by N-SPECT modeling of land use changes do not increase as urban and suburban expansion occurs.**

As noted above, urban development generally increases stormwater runoff volumes. Low Impact Development (LID) is a relatively new concept in stormwater management. "It incorporates a suite of landscaping and design techniques known as "Better Site Design" that attempt to maintain the natural, pre-development hydrology of a site and the surrounding watershed" (Horsley Witten Group 2006, p. 1-2). The goal of LID is to minimize the environmental footprint of a development, while retaining the owner's purpose for the site. According to Horsley Witten (2006), more concentrated (cluster) design creates less impervious area, generates less surface runoff, and requires smaller infrastructure for drainage and other utilities. EPA has found that implementing LID practices saves money for developers, property owners and communities while protecting and restoring water quality (EPA 2007).

Urban developments (with very few exceptions) have been mandated by Hawai'i County to maintain pre-development runoff conditions (Kuba 2005). Developers island-wide are now routinely required to dispose of all development-generated runoff onsite. These requirements have been codified in Chapter 23, HCC, "Subdivisions," Chapter 25, HCC, "Zoning," and Chapter 27, HCC, "Flood Control." In addition, Hawai'i County's Zoning ordinance provides for cluster development and flexible design standards, though it is not well-publicized. It may also allow for innovative stormwater management techniques, reduced street and sidewalk widths, and

other management measures to attenuate runoff from developments. While it does not explicitly promote the minimizing of impervious surfaces, the County may permit the use of pervious pavements and other management measures that are not currently allowed under regular zoning and subdivision provisions. Cluster development can result in a cost savings with respect to infrastructure.

Workshops on LID techniques for Hawai'i have been held on other islands, and informational resources have been developed for Hawai'i (see Horsley Witten 2006). However, large landowners and developers on Hawai'i Island may not be familiar with these resources. Therefore, there is a need develop outreach programs to landowners, businesses, and land management agencies in order to encourage use of LID techniques in new urban developments. Key large landowners to target in the short term for the Wai'ula'ula watershed include Department of Hawaiian Homelands, Parker Ranch, and Mauna Kea Properties.

***Project STORM-6. Develop and implement a LID outreach program for large landowners, developers, State and county land managers and permitting agencies, and engineering and land use planning firms by 2015.***

*Project Tasks:*

- *Organize and host a workshop on LID techniques and applicable regulations, with site visit(s), for large landowners, developers, State and county land managers and permitting agencies, and engineering and land use planning firms.*
- *Make documents on LID available for download on the MKSWCD website.*
- *Meet with individual land owners to discuss the possibility of implementing small-scale LID projects to demonstrate the effectiveness of these techniques.*
- *Submit proposal for implementation funding for small-scale LID project (project costs and timeframes TBD).*

**Goal 5: Restore and enhance riparian buffers that serve as protective filters for streams in the Wai'ula'ula watershed.**

A riparian buffer is land next to a stream that is vegetated, usually with trees and shrubs, which serves as a protective filter for streams. It protects water quality against pollutants and helps stabilize eroding streambanks. Establishing riparian buffer zones and protecting existing riparian zones help in trapping sediment and particulates, in slowing flows, and in increasing water percolation. Riparian buffers can vary in width, depending on the stream, soil type, vegetation, slope, surrounding land use, and desired level of protection.

In Hawai'i, riparian buffers are afforded the greatest protection within the Conservation District. DLNR manages lands in the Conservation District in order to conserve, protect, and preserve the important natural resources of the State through appropriate management and

use to promote their long-term sustainability. The headwaters of the streams in the Wai'ula'ula watershed originate in the conservation district. The southeastern portion of the conservation lands within the Wai'ula'ula watershed are designated as part of the Kohala Watershed Forest Reserve. Another portion is designated the Kohala Restricted Watershed. The remaining conservation lands within the Wai'ula'ula watershed are part of the Pu'u o 'Umi Natural Area Reserve. The conservation lands of the Wai'ula'ula watershed are also part of the Kohala Watershed Partnership.

Outside of the conservation district, the State does not have a specific process by which to protect wetlands and riparian areas. These areas are afforded marginal protection under regulations addressing flood plains, stormwater, and zoning. However, these regulations are aimed primarily at protecting homeowners from flooding rather than protecting the functions of riparian buffers. Many of the riparian corridors in the Wai'ula'ula watershed pass through grazing lands, where, historically, cattle have been provided access to streams for water. Many of these grazing lands, particular below 2,600-ft. elevation are marginal agricultural lands because of dry conditions and invasive grass species (*i.e.*, fountaingrass).

N-SPECT modeling has shown that for every 100-ft. of stream corridor converted to evergreen cover<sup>10</sup>, an average of 900 kg/yr. of sediment, 86 kg/yr. of phosphorus, and 293 kg/yr of nitrogen are reduced. These numbers vary by elevation of the restored riparian buffer and pollutant type.

A first step to restoring riparian buffers is the development of a mechanism by which to identify environmental problems present within a stream system and along its riparian corridor and to provide sufficient information on each problem so that both the severity and correctability can be determined and restoration efforts can be prioritized. Maryland has developed survey protocols for a Stream Corridor Assessment to rapidly measure the general physical condition of a stream system and identify the locations of a variety of environmental problems within its stream corridors (Yetman 2001). These problems could include erosion sites, inadequate stream buffers, fish migration blockages, exposed or discharging pipes, channelized stream sections, trash dumping sites, in or near-stream construction, streambank instability, areas prone to flooding, and any unusual conditions. Project MONIT-1 will develop such a survey tool to help determine specific areas in which to focus limited resources.

Bishop Museum has developed an interactive plant key designed to assist in selecting native plants appropriate for their outplanting sites. This plant key *Riparian Plant Restoration: A Management Tool for Habitat Restoration in Hawai'i* can be found at [http://hawaiiconservation.org/resources/publications/pacific\\_island\\_plant\\_restration\\_database](http://hawaiiconservation.org/resources/publications/pacific_island_plant_restration_database).

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<sup>10</sup> from scrub/shrub below 2,600-ft. elevation and from grassland above 2,600-ft. elevation.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Total Suspended Sediment (TSS)	By 2020, a 10% reduction in modeled loads, using N-SPECT.
Total Phosphorus (TP)	
Total Nitrogen (TN)	
Linear feet of riparian corridor fenced and restored	25,000-ft. total by 2025
New legislation protecting wetlands and riparian buffers	Established by 2018
Number of people accessed by public education and outreach	8,500 people by 2025

**Objective 5a:** By 2025, restore 25,000-ft. of stream riparian corridor to provide an adequate buffer for managing stormwater, reducing pollutant loads by 10% from current levels, protecting from property loss due to flooding and erosion, and creating healthy habitat for native aquatic species.

***Project STREAM-1. By 2017, convert marginal agricultural lands within a 15,000-ft. length of the stream corridor into native vegetation under the Hawai'i Conservation Resource Enhancement Program.***

Through the Hawai'i Conservation Resource Enhancement Program (CREP), program participants receive financial incentives to voluntarily enroll and remove marginal pastureland from agricultural production and convert the land to natives grasses, trees and other vegetation. Hawaii CREP will provide for restoration of previously forested, degraded agricultural land. This project will improve water quality and quantity by reducing soil runoff, increasing potential ground absorption, and reducing stream sedimentation and nutrient loading to near-shore environments.

***Project Tasks:***

- *Using results of the stream corridor assessment conducted under Project MONIT-1), prioritize stream corridor segments in need of restoration by 2013 based on severity of problem and correctability. Identify stream corridor segments by elevation, land use, threat and/or problem.*
- *Identify riparian corridor areas experiencing streambank erosion/instability, being used by cattle for water (relates to Project NUTR-2), and/or located within degraded or marginal pastureland.*
- *Identify interested land users for participation in CREP. Determine eligibility and extent of area that will be included in CREP.*
- *Assist land user(s) in enrolling in CREP, through NRCS.*



- *Develop or amend conservation plans for the areas, in consultation with MKSWCD and NRCS.*
- *Fence and restore at least 15,000-ft. of riparian corridor within marginal agricultural lands (specific site TBD). Buffer width can be between 30-ft. and 1,320-ft. depending on circumstances specific to each site.*

***Project STREAM-2. Conduct semi-annual educational events, including hands-on events and demonstration projects, for three years before 2016 to educate the public about the importance of riparian buffers.***

*Project Tasks:*

- *By 2013, develop or adapt informational materials for streamside property owners about the importance of riparian buffers for managing stormwater, protecting from property loss due to flooding and erosion, and creating healthy habitat for native aquatic species. Include information about appropriate riparian plants based on elevation and proper planting techniques.*
- *Distribute information through MKSWCD website and at community outreach events.*
- *Conduct two educational events per year for three years, including hands-on events and demonstration projects.*
- *In cooperation with the land owner (Parker School), re-establish a riparian buffer along Waikoloa Stream from upstream of the KTA Shopping Center to behind the Waimea Community Education building by 2015 as part of providing hands-on educational events to community members. This highly-visible 1.5-acre site in the middle of Waimea town is a perfect teaching site and will help inspire and promote other riparian restoration efforts.*

***Project STREAM-3. Prioritize riparian buffers for restoration, and work with land owner(s) to implement restoration project(s) on at least 10,000-ft. of priority stream corridors.***

*Project Tasks:*

- *Using results of the stream corridor assessment conducted under Project MONIT-1), prioritize stream corridor segments in need of restoration by 2013 based on severity of problem and correctability. Identify stream corridor segments by elevation, land use, threat and/or problem.*
- *Develop a Comprehensive Riparian Management Plan by 2017 that identifies describes restoration activities for each priority stream corridor segment, including fencing, weed removal, planting, streambank stabilization, ongoing maintenance, and Adopt-a-Stream suitability and other community involvement opportunities.*

- *Fence and restore a minimum of 10,000-ft. of priority stream corridors within the Wai‘ula‘ula watershed by 2021 (specific sites TBD).*

**Objective 5b:** By 2018, establish a county regulatory mechanism that specifically protects wetlands and riparian areas of perennial streams on Hawai‘i Island.

There are mechanisms that could be used to strengthen protection of riparian areas. Mechanisms such as overlay districts or zones have been used in recent years around the U.S. to provide a framework for conservation of special geographical areas. An overlay district is an additional zoning requirement that is placed on a geographical area but does not change the underlying zoning.

**Project STREAM-4.** *Help draft policy language to enact an overlay district that explicitly protects wetlands and riparian areas.*

**Project Tasks:**

- *Work with Hawai‘i County Council members to draft legislation creating an overlay district that enhances protection of wetlands and riparian areas of perennial streams. An overlay zone focused on conserving natural features, such as wetlands, riparian areas, aquifers, or other sensitive resource areas, would typically impose greater restrictions on the development of the land, but only on those parcels whose development, as permitted under the zoning, may threaten the viability of these features. In the context of protecting wetlands and riparian areas, an overlay district could be adopted that contains setback provisions, requires a portion of the existing vegetation to be maintained as a buffer, limits the amount of tree and shrub clearing, limits impervious surfaces in the stream buffer unless approved by special permit, or requires the use of additional BMPs.*
- *Use informational materials developed under STREAM-2 to educate lawmakers and the public about the importance of riparian buffers for managing stormwater, protecting from property loss due to flooding and erosion, and creating healthy habitat for native aquatic species.*
- *Develop informational materials about the benefits of an overlay district to help protect riparian areas.*

**Goal 6: Protect aquatic habitat and manage instream flows.**

Freshwater streams have many values. They provide irreplaceable habitats for aquatic fauna and flora. Streams link the mountains with the ocean. They are essential to the productivity and quality of Hawai‘i’s nearshore waters. Stream health is both integral to the survival of the unique stream organisms and indicative of the overall quality of our island environment.

The Wai'ula'ula watershed is exceptional, from a native aquatic species standpoint. According to Englund (2010), "[t]he relatively high 65% overall native aquatic insect biodiversity found within the entire Wai'ula'ula watershed is comparable to other high quality streams (p. 12)." In the upper reaches of Keanu'i'omanō, Waikoloa, and Kohākōhau streams, native species are even more dominant, maintaining an exceptionally high diversity "equaling any high quality stream found in the Hawaiian archipelago" (Englund 2010; p. 12). Stream surveys have noted all five native stream fish species in various locations throughout the watershed, from the Wai'ula'ula estuary to about the 2,700-ft. elevation. These species require streamflow for their survival. Their presence at various elevations in the Wai'ula'ula watershed "indicates that native fish traverse long stretches of intermittent stream channels during periods of flowing water, using the ephemeral stream habitat as an access corridor to the headwater regions..." (Englund 2010; p. 11).

The Water Commission, as provided for under the State Water Code (Chapter 174C, HRS), sets policies and approves water allocations for all water users. Existing uses established prior to 1987 are grandfathered in, provided the existing use is reasonable and beneficial. The Water Commission also establishes instream flow standards for perennial streams, in order to balance maintenance of fish and wildlife habitat, estuarine, wetland and stream ecosystems, and water quality with use of the water. Section 13-169-46, HAR, establishes interim instream flow standards (IFS) for Hawai'i. These were generally defined as the amount of water flowing in each stream on the effective date of the standard (1988). The standards for some individual streams have subsequently been amended as a result of petitions to amend the IFS and describe the amount of water that can be withdrawn from the stream. Specific instream flow standards have not been established for any streams within the Wai'ula'ula watershed.

At the same time, there are legal and illegal diversions of water that reduce otherwise normal streamflow volume. It is vital to the survival of these endemic species that adequate streamflow is ensured through a careful analysis of all diversions of water from streams in the watershed, and that unneeded or unauthorized diversions are removed to enhance stream ecosystems.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Dissolved Oxygen (instream perennial pools only)	Every measurement shall be 80% saturation or greater; additionally, absolute values shall never fall below 6.25 mg/l (80% saturation of water at 86°F (30°C)).
Total Phosphorus (TP)	By 2025, the geometric mean of measurements for all indicators shall be less than water quality standards for the dry season in any year and at any sampling site.
Total Nitrogen (TN)	

Indicators	Targeted load, level or value
Temperature (instream perennial pools only)	Between noon and 3 p.m., the surface water temperature shall be not more than 10°F greater than air temperature in the shade.
Diversity of native aquatic insects within the watershed	At a minimum, maintain 65% overall native aquatic insect biodiversity within the entire watershed
Number of unpermitted diversion and instream structures	90% reduction
Total volume of water withdrawn annually from all diversions	Annual diversions should not exceed half the combined flow at the Marine Dam and Kohākōhau stream gages.

**Objective 6a:** By 2021, ensure that instream flows for the streams within the Wai‘ula‘ula watershed balance permitted sustainable water use and protection of the biological, chemical, and physical integrity of these waters, and that annual diversions do not exceed half the combined flows at the Marine Dam and Kohākōhau stream gages.

**Project AQU-1. Work with landowners and the Water Commission to permit or remove 100% of illegal diversions by 2018.**

Project Tasks:

- Using results of the stream corridor assessment conducted under Project MONIT-1), identify all diversions within the Wai‘ula‘ula watershed.
- Work with Water Commission staff to identify permitted and unpermitted diversions.
- Develop or adapt an outreach program about Hawai‘i’s native aquatic species and the importance of maintaining instream flows. Develop a fact sheet about Water Commission permits and procedures.
- Distribute information through MKSWCD website and at community outreach events.
- Attend neighborhood association meetings in subdivisions with unpermitted withdrawals of stream water to present information and answer questions.
- Support the Water Commission in taking action against illegal withdrawals if public outreach does not succeed in permit requests or remedial actions by land owners.

***Project AQU-2. Evaluate need for specific instream flow standards for streams within the Wai'ula'ula watershed by 2019.***

***Project Tasks:***

- *Measure actual water withdrawals from diversions in the watershed to determine a total average annual withdrawal amount for each stream in the watershed.*
- *Work with the Water Commission to evaluate current and anticipated water withdrawals from the streams within the watershed to determine if specific instream flow standards are required.*

***Objective 6b: Maintain or improve the current native species diversity of fish and invertebrate communities in the Wai'ula'ula watershed by 2025.***

***Project AQU-3. Consult with experts by 2016 to determine if existing dams and other instream structures are having a negative effect on 'o'opu instream migration.***

***Project Tasks:***

- *Using results of the stream corridor assessment conducted under Project MONIT-1), identify all dams and other instream structures within the Wai'ula'ula watershed.*
- *Work with Water Commission staff to identify permitted and unpermitted in-stream structures. Support the Water Commission in taking action against illegal in-stream structures.*
- *Consult 'o'opu experts about the effects of existing, permitted dams on 'o'opu migration and seek advice on possible remedial actions.*
- *Depending on expert advice, submit proposal for implementation funding for "effective removal"<sup>11</sup> of barriers to 'o'opu passage (project costs and timeframes TBD).*

***Project AQU-4. Prevent further introduction of invasive aquatic species into the streams and identify how to remove existing invasive species that threaten native species by 2020.***

***Project Tasks:***

- *Develop or adapt outreach materials about the damage invasive aquatic species can have on the native Hawaiian aquatic ecosystem as a way to reduce new introductions. Distribute materials to streamside homeowners and schools.*
- *Monitor for potentially-harmful invasive species when a threat to native fauna is likely.*

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<sup>11</sup> "Effective removal" can mean physical removal, breaching of a barrier, installation of fish passage structures, or implementation of other fish passage strategies to result in effective fish passage around or through a barrier.

- *Consult with aquatic ecosystem experts on how best to remove invasive aquatic species from the watershed without harming native species. Submit research proposals to evaluate impacts and possible control measures, if necessary.*

***Project AQU-5. By 2015, protect priority instream perennial pools that provide important habitat for native aquatic species.***

*Project Tasks:*

- *Using results of the stream corridor assessment conducted under Project MONIT-1), identify and map all significant instream perennial pools within the Wai'ula'ula watershed.*
- *Monitor water quality in instream perennial pools (DO, TP, TN, chlorophyll-a, temperature at surface and bottom) at various elevations and on different streams within the watershed on a quarterly basis. Note presence of both native and invasive aquatic species, along with other qualitative measures of ecosystem health (e.g., stagnant water, algae, etc.)*
- *In consultation with aquatic ecosystem experts, prioritize pools based on size, depth, habitat quality, presence of native aquatic species, elevation, and distance between pools.*
- *Conduct biological surveys of aquatic species every four years, with an emphasis on sites previously monitored.*
- *Consult with aquatic ecosystem experts about how best to protect these deep pools because of their importance to the life cycle of Hawai'i's native aquatic species.*
- *Depending on expert advice, implement measures to protect priority instream perennial ponds.*

**Goal 7: Increase public education, understanding, and participation regarding watershed issues.**

Educating the public about the Wai'ula'ula watershed, its resources and values, threats to these resources and values, and management activities is vital to all watershed restoration and protection goals and objectives. Conservation education and watershed awareness will help reduce unwanted human impacts on the landscape. Greater awareness about the watershed should also translate into greater support for management efforts, in the form of a greater community voice for conservation measures and increased volunteerism.

Public education and outreach are also helpful in recruiting a cadre of volunteers to assist in certain management activities, especially in labor-intensive efforts such as ecosystem restoration. Volunteers tend to be extremely enthusiastic, but often require an organized volunteer program to help keep motivation levels high. Hands-on opportunities both increase

awareness of watershed conditions and enable community members to participate in improving those conditions with a heightened sense of connection to the natural resources.

Many of the projects described above have a strong educational component. Initially, watershed education and outreach will be conducted by the watershed coordinator, MKSWCD personnel and contractors. However, as the program expands and more community members volunteer on projects, an education coordinator will be hired.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Number of volunteers	100 participants per year
Stakeholder awareness as measured by community survey	Increase awareness by 20% by 2020
Number of Facebook friends for Wai'ula'ula page	500 friends by 2020

**Objective 7a: Increase stakeholder awareness and involvement by 15% by implementing an integrated watershed management information and education campaign by 2016.**

***Project EDUC-1: Develop/ adapt and distribute educational materials related to watershed issues to community members. The majority of these educational materials relate to projects described above.***

**Project Tasks:**

- *Develop or adapt outreach materials about OSDS and potential effects on water quality and environmental and public health. Distribute information to homeowners with OSDS about the operation, maintenance, and self-inspection of cesspools and septic systems as a way to extend their operating lives and prevent failures. (Project NUTR-3)*
- *Work with HWMO to distribute educational information about mitigating wildfire risk and implementing Firewise techniques to protect homes in fire-prone areas. (Relates to Goal 3.)*
- *Develop or adapt outreach materials about innovative residential stormwater management, including fact sheets about best management practices, including stormwater harvesting (rain barrels, cisterns), rain gardens, and pervious pavement. (Project STORM-3)*
- *Develop or adapt informational materials for streamside property owners about the importance of riparian buffers for managing stormwater, protecting from property loss due to flooding and erosion, and creating healthy habitat for native aquatic species. Include information about appropriate riparian plants based on elevation and proper planting techniques. (Project STREAM-2)*



- *Develop or adapt an outreach program about Hawai'i's native aquatic species and the importance of maintaining instream flows. Develop a fact sheet about Water Commission permits and procedures. (Project AQU-1)*
- *Develop or adapt outreach materials about the damage invasive aquatic species can have on the native Hawaiian aquatic ecosystem as a way to reduce new introductions. Distribute materials to streamside homeowners and schools. (Project AQU-4)*
- *Develop or adapt targeted outreach activities and materials related to polluted runoff control, including lawn care practices, household hazardous waste disposal, low impact development techniques, graywater reuse, etc.*
- *Distribute information through MKSWCD website and at community outreach events.*
- *Use social media (i.e., Facebook) and direct emailing to distribute information about the watershed effort and educational materials, and post calendar events. Encourage people to become "friends" of the Wai'ula'ula Facebook site.*
- *Use social media to conduct baseline and periodic surveys of community awareness about watershed issues.*

**Objective 7b: Recruit and engage volunteers to assist in at least two large community-based projects in the watershed every year beginning in 2013.**

***Project EDUC-2: Provide on-the-ground service learning opportunities for school children and community members.***

- *Foster partnerships with landowners, agencies, local schools, stakeholders and the community at large.*
- *Coordinate and supervise volunteer efforts by community members and students. These citizen engagement efforts will include stream cleanups, trash pickups, invasive species removal, riparian plantings, and water quality monitoring.*
- *Develop and coordinate an "Adopt-a-Stream" program.*
- *Attend festivals and events to provide information at gatherings attended by the community.*
- *Hire an outreach coordinator when the educational and volunteers programs have expanded to the point that dedicated outreach personnel is needed to build on established momentum and sustain and grow efforts throughout the watershed.*

**Goal 8: Provide effective project administration and management to ensure long-term success.**

Implementation of the Wai'ula'ula watershed management plan is a long-term commitment that requires sufficient personnel and financial resources. The management plan represents more work than can be accomplished by existing personnel under the Mauna Kea Soil and Water Conservation District or its partners. Effective, coordinated implementation is required for overall success and achievement of the goals and objectives described herein. Regular monitoring of the effectiveness of the Plan as a whole is required to ensure that the recommended actions are resulting in progress toward the desired outcomes, and to take corrective actions, if necessary. As such, a Watershed Coordinator is needed to oversee partners and personnel, contractors, vendors, and stakeholders in the watershed.

The following table provides criteria to measure success in achieving this watershed and ecosystem health goal.

Indicators	Targeted load, level or value
Percentage of Wai'ula'ula watershed management plan implemented during the planning timeframe between 2011 and 2025	25% by 2015 55% by 2020 85% by 2025
Sustained monitoring as outlined in Chapter 6	Type and frequency of monitoring described in Chapter 6
Sustained funding	Sufficient funding to implement projects outlined in the Wai'ula'ula watershed management plan

**Objective 8a: Establish appropriate administrative framework by 2012 to allow for effective and timely implementation of the Wai'ula'ula watershed plan.**

***Project ADMIN-1: Hire Wai'ula'ula watershed coordinator.***

*Project Tasks:*

- Hire watershed coordinator with a wide range of skills and abilities to implement, administer, and evaluate the full spectrum of projects contained in the watershed management plan.*
- Maintain communication among project partners to facilitate information sharing and project implementation.*
- Revise and update watershed management plan as management needs change, management techniques evolve, and new data become available.*

**Objective 8b:** Implement monitoring program described in Chapter 6, following the timeframes established.

***Project: MONIT-1: When management plan implementation begins, initiate monitoring components described in Chapter 6.***

*Project Tasks:*

- *By 2013, develop a stream corridor assessment mechanism by which to rapidly identify environmental problems present within a stream system and along its riparian corridor and to provide sufficient information on each problem so that both the severity and correctability can be determined and restoration efforts can be prioritized. These problems could include erosion sites, inadequate stream buffers, fish migration blockages, exposed or discharging pipes, channelized stream sections, trash dumping sites, in or near-stream construction, streambank instability, areas prone to flooding, areas of invasive plant species, and any unusual conditions.*
- *Undertake monitoring described under above projects (with details provided in Chapter 6).*
- *Monitor project implementation and measure success towards achieving project goals and objectives.*
- *Track installation of management practices and gage effectiveness of these practices in preventing or reducing pollutant loads.*
- *Institute long-term water quality monitoring described in Chapter 6.*
- *Implement monitoring of watershed conditions as described in Chapter 6.*

Table 19: Summary of Implementation Projects

#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
NUTR-1	Assist Lālanilo Farmers with Conservation Plans	1: Reduce nutrient loads in Wai'ula W5	1a: Reduce nutrient loads in agricultural runoff by 20% by 2019.	Nonpoint source pollution-ag	MKSWCD	Farmers	2	\$2,563.20	Outreach to all farmers
NUTR-2	Fence riparian areas to exclude cattle and goats	1: Reduce nutrient loads in Wai'ula W5	1b: Fence 58,000 feet of riparian corridors on Keanu 'i'omanō and Waikoloa Streams by 2023.	Nonpoint source pollution-ag	MKSWCD	Ranchers	1	\$452,400 (\$7.80/l.f.)	Outreach to all farmers
NUTR-3	Onsite disposal systems (OSDS) outreach and education	1: Reduce nutrient loads in Wai'ula W5	1c: Increase inspections and maintenance of OSDS by 20% by 2019	Non-point source pollution-wastewater disposal systems	MKSWCD	DOH, County, Realtor Assn.	1	\$15,000-\$25,000	Presentations; general outreach materials, door to door
NUTR-4	Incorporate point of sale inspections of OSDS	1: Reduce nutrient loads in Wai'ula W5	1c: Increase inspections and maintenance of OSDS by 20% by 2019	Non-point source pollution-wastewater disposal systems	MKSWCD	DOH, County, Realtor Assn.	2	\$5,000-\$10,000	Presentations; general outreach materials
SED-1	Assist farmers in Lālanilo with Conservation Plans	2: Prevent an increase in sediment loads in Wai'ula W5	2a: Reduce sediment loads in ag runoff from Lālanilo by 20% by 2019.	Nonpoint source pollution-ag	MKSWCD	Farmers	2	\$2,563.20	Outreach to all farmers
SED-2	Extend Waimea Irrigation System to rock wall	1: Reduce nutrient loads 2: Prevent increase sediment loads 3: Reduce wildfire 5: Restore riparian buffers 6: Protect aquatic habitat	2b: Improve grazing efficiency, prevent overgrazing, limit wildfire between 1,200' and 2,600' elevation. 3b: Facilitate rapid wildfire response. 5a: Restore riparian corridor. 6a: Ensure instream flows	Nonpoint source pollution-agriculture, streambank erosion; wildfire.	MKSWCD	State Dept. of Ag; USDA-NRCS; HWMO;	1	\$170,438	Public relations via brochure, presentations

#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
SED-3	Subdivide paddocks between Lalāmilo and rock wall	2: Prevent an increase in sediment loads in Wai'ula WS	2b: Improve grazing efficiency, prevent overgrazing, limit wildfire between 1,200' and 2,600' elevation.	Non-point source pollution-ag, streambank erosion, invasive plants; Wildfire	MKSWCD	Ranchers, HWMO	1	\$92,664	Presentations, tours; general outreach materials
SED-4	ID eroding streambanks and monitor annual erosion rates	2: Prevent an increase in sediment loads in Wai'ula WS	2c: Assess riparian corridors and monitor erosion rates by 2016. 8a: Implement monitoring program	Non-point source pollution streambank erosion	MKSWCD	CWRM, land-owners, DOH	1	\$80,000-\$100,000	Presentations, tours; general outreach materials
SED-5	Remove goats from grazing areas between Queen Ka'ahumanu Hwy. and rock wall	2: Prevent an increase in sediment loads in Wai'ula WS	2d: Following fencing projects, remove all feral goats from 1,200' elev. to coast	Non-point source pollution feral ungulates	MKSWCD	DOFAW, Ranchers	1	\$5,000-\$10,000	Presentations, general outreach materials
SED-6	Remove goats from watershed below Queen Ka'ahumanu Highway	2: Prevent an increase in sediment loads in Wai'ula WS	2d: Following fencing projects, remove all feral goats from 1,200' elev. to coast	Non-point source pollution feral ungulates	MKSWCD	DOFAW, Land-owners	2	\$2,000-\$5,000	Presentations, general outreach materials
SED-7	Identify and re-vegetate all areas of bare land in the watershed	2: Prevent an increase in sediment loads in Wai'ula WS	2e: Restore bare land contributing to erosion in the watershed	Non-point source pollution	MKSWCD	Land-owners, schools, community groups	3	\$791.24/acre	Service learning, volunteers, presentations, general outreach mats.

#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
FIRE-1	<i>Fence and graze area between rock wall and Queen Ka'ahumanu Highway</i>	3: Reduce wildfire occurrences and impacts	3a: Use grazing to manage fine fuels and reduce wildfire size	Wildfire	MKSWCD, HWMO	State DOH, ranchers, land-owners, HWMO	1	\$271,151	Presentations, tours; general outreach materials
FIRE-2	<i>Reduce fuel loads below Queen Ka'ahumanu Highway</i>	3: Reduce wildfire occurrences and impacts	3a: Use grazing to manage fine fuels and reduce wildfire size	Wildfire	MKSWCD	State DOH, ranchers, land-owners, HWMO	2	\$67,410 (\$842.63/acre)	Presentations, tours; general outreach materials
FIRE-3	<i>Develop fire resource maps</i>	3: Reduce wildfire occurrences and impacts	3b: Facilitate rapid response to wildfires	Wildfire	HWMO	DLNR, HFD, Landowner	1	\$15,000-\$20,000	Presentations; general outreach
FIRE-4	<i>Develop agreements for water use</i>	3: Reduce wildfire occurrences and impacts	3b: Facilitate rapid response to wildfires	Wildfire	MKSWCD	HWMO, land-owners	1	\$5,000-\$7,000 per agreement	Presentations; general outreach
FIRE-5	<i>Construct and maintain fuel breaks</i>	3: Reduce wildfire occurrences and impacts	3b: Facilitate rapid response to wildfires	Wildfire	HWMO	MKSWCD, land-owners	2	\$17,500; \$9,626 maint. Yrly.	Presentations, tours; general outreach materials
FIRE-6	<i>Develop post-fire restoration manual</i>	3: Reduce wildfire occurrences and impacts	3c: Develop post fire restoration practices	Wildfire	MKSWCD	HWMO, land-owners	1	\$15,000-\$20,000	Presentations; general outreach
STORM-1	<i>Install catch basin filter inserts discharging directly into streams</i>	4: Reduce volume/increase quality of stormwater runoff	4a: Treat urban stormwater runoff into streams and dry wells in the watershed	Non-point source pollution-urban/suburban runoff	MKSWCD	DOT/County DPW	1	TBD	Presentations; general outreach materials

#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
STORM-2	<i>Install catch basin filter inserts on priority dry wells near streams</i>	4: Reduce volume/increase quality of stormwater runoff	4a: Treat urban stormwater runoff into streams and dry wells in the watershed	Non-point source pollution-urban/suburban runoff	MKSWCD	Land-owners	2	TBD	Presentations; general outreach materials
STORM-3	<i>Stormwater education and outreach program</i>	4: Reduce volume/increase quality of stormwater runoff	4b: Conduct stormwater management outreach for residential property owners	Non-point source pollution-urban/suburban runoff	MKSWCD	DOH, DOE, EPA, County	1	\$10,000-\$15,000	Presentations; general outreach materials, events, workshops
STORM-4	<i>Upgrade existing urban runoff control structures</i>	4: Reduce volume/increase quality of stormwater runoff	4c: Decrease volume and increase treatment of commercial and residential stormwater	Non-point source pollution-urban/suburban runoff	MKSWCD	County/land-owners	3	TBD	Presentations; general outreach materials
STORM-5	<i>Develop written guidelines for operations and maintenance of county roadways</i>	4: Reduce volume/increase quality of stormwater runoff	4d: Develop written pollution prevention procedures for the operation and maintenance of county roads, highways and bridges	Non-point source pollution-urban/suburban runoff	DOT/County DPW	MKSWCD	3	\$10,000-\$15,000	Public meetings, presentations, general outreach mats.
STORM-6	<i>Develop and implement LID outreach program</i>	4: Reduce volume/increase quality of stormwater runoff	4e: Reduce volume of stormwater runoff from new developments by incorporating LID techniques	Non-point source pollution-urban/suburban runoff	MKSWCD	Office of State Planning/County	1	\$10,000-\$15,000	Presentations; general outreach materials
STREAM-1	<i>Convert 15,000' of riparian corridor in marginal grazing lands into native vegetation via CREP</i>	5: Restore and enhance riparian buffers in the watershed	5a: Restore riparian corridors in the watershed	NPS pollution – ag, streambank erosion, invasive plants; Flooding	MKSWCD	USDA-FSA; ranchers; volunteers	2	\$55,000	Service learning/ volunteer planting



#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
STREAM-2	<i>Events/projects to educate about riparian buffers</i>	5: Restore and enhance riparian buffers in the watershed	5a: Restore riparian corridors in the watershed	NPS pollution - ag, streambank erosion, invasive plants; Flooding	MKSWCD		1		Service learning, volunteers, presentations, general outreach mats.
	<i>Restore riparian areas within the watershed</i>	5: Restore and enhance riparian buffers in the watershed	5a: Restore riparian corridors in the watershed	NPS pollution - ag, streambank erosion, invasive plants; Flooding	MKSWCD	Land-owners, schools, community groups	1	TBD	Service learning, volunteers, presentations, general outreach
STREAM-3	<i>Draft policy language to enact an overlay district protecting wetlands and riparian areas</i>	5: Restore and enhance riparian buffers in the watershed	5b: Establish county regulatory mechanism to protect wetlands and riparian areas on Hawaii Island	NPS pollution - ag, streambank erosion, invasive plants; Flooding	MKSWCD	Hawaii County Council	2	\$10,000	Testimony, presentations, general outreach materials
	<i>Remove illegal diversions</i>	6: protect aquatic habitat and manage instream flows	6a: Balance sustainable water use and protection of water quality	Stream diversions	MKSWCD	CWRM	2	\$20,000-\$25,000 per structure, diversion	Presentations; general outreach materials; door-to-door
AQU-1	<i>Evaluate the need for specific instream flow standards</i>	6: protect aquatic habitat and manage instream flows	6a: Balance sustainable water use and protection of water quality	Stream diversions	MKSWCD	DOH, EPA, CWRM	2	TBD	Presentations; general outreach materials
	<i>Determine the effect of dams on 'o'opu habitat</i>	6: protect aquatic habitat and manage instream flows	6b: Maintain diversity of native aquatic species in the watershed	Stream diversions	MKSWCD	DLNR/UH	2	\$2,500	Presentations; general outreach materials

#	Project	WWMP Goal	WWMP Objectives	Threats Addressed	Project Lead	Project Partners	Priority Level	Estimated Cost	Educational Component
AQU-4	<i>Invasive aquatic species control</i>	6: protect aquatic habitat and manage instream flows	6b: Maintain diversity of native aquatic species in the watershed	Invasive species	MKSWCD	DLNR-DAR	1	\$10,000-\$15,000	Presentations; general outreach materials
AQU-5	<i>Protect priority instream perennial pools</i>	6: protect aquatic habitat and manage instream flows	6b: Maintain diversity of native aquatic species in the watershed	Stream diversions	MKSWCD	DLNR-DAR, land-owners	2	TBD	Service learning, volunteers, presentations, general outreach
EDU-1	<i>Develop and distribute educational materials about watershed issues to the community</i>	7: Increase education, understanding and participation of watershed issues	7a: Increase stakeholder awareness and involvement through an integrated watershed education campaign	All threats	MKSWCD	DOH, EPA, CWRM	?	\$10,000-\$15,000	Events, volunteers, presentations, general outreach
EDU-2	<i>Provide on-the-ground service learning opportunities</i>	7: Increase education, understanding and participation of watershed issues	7b: Provide on-the-ground service learning opportunities for school groups and other members of the community	All threats	MKSWCD	Schools, community groups	?	\$15,000-\$20,000	Service learning, volunteers, presentations, general outreach
ADMIN-1	<i>Hire a Wai'ula'ula Watershed Coordinator</i>	8: Provide effective project administration and management to ensure long-term success	8a: Establish administrative framework to implement the Wai'ula'ula Watershed Management Plan	All threats	MKSWCD	Land-owners/ Stakeholders/ Partner Agencies	?	\$90,000 per annum, salary and materials	Service learning, volunteers, presentations, general outreach mats.
MONIT-1	<i>Establish a Wai'ula'ula Watershed Management Plan monitoring program</i>	WWMP Goals 1-8	8b: Implement monitoring program described in Chapter 6 according to established timeframes	All threats	MKSWCD	Land-owners/ Stakeholders/ Partner Agencies	?	TBD	Presentations, general outreach materials

**Table 20: Project Timelines**

	12	13	14	15	16	17	18	19	20	21	22	23
NUTR-1 – Assist Lālāmilo farmers with Conservations Plans												
NUTR-2 – Fence riparian areas to exclude cattle												
NUTR-3 – OSDS education and outreach												
NUTR-4 – Incorporate point-of-sale inspections of OSDS												
SED-1 -- Assist Lālāmilo farmers with Conservations Plans												
SED-2 – Extend Waimea Irrigation System to rock wall												
SED-3 – Subdivide paddocks between Lālāmilo and rock wall												
SED-4 – Assess streambank erosion												
SED-5 – goat removal from rock wall to Queen Ka’ahumanu												
SED-6 – goat removal below Queen Ka’ahumanu												
SED-7 – Identify and revegetate bare land in watershed												
FIRE 1 – Fence and graze area between rock wall and Queen K												
FIRE-2 – Fence area below Queen K to manage fine fuels												
FIRE-3 – Update fire resources maps (3 periodic updates)												
FIRE-4 – Develop agreements for access and water use												
FIRE-5 – Construct and/or maintain 6 miles of fuel breaks												
FIRE-6 – Develop post-fire restoration manual												
STORM-1 – survey and line catch basins within watershed												
STORM-2 – dry well insert installation and maintenance program												
STORM-3 – stormwater education and outreach program												
STORM-4 – upgrade existing urban runoff control structures												
STORM-5 – develop operation and maintenance guidelines for roads												
STORM-6 – develop and implement LID outreach program												
STREAM-1 – convert marginal grazing lands via CREP												
STREAM-2 –events/projects to educate about riparian buffers												
STREAM-3 – restore riparian areas within the watershed												
STREAM-4 – policy language for County overlay district												
AQU-1 – remove illegal diversions												

	12	13	14	15	16	17	18	19	20	21	22	23
AQU-2 – evaluate need for specific instream flow standards												
AQU-3 – determine effects of dams on ‘o’opu habitat												
AQU-4 – invasive aquatic species control												
AQU-5 – protect priority instream perennial pools												
EDU-1 – develop/ adapt educational materials												
EDU-2 – provide on-the-ground service learning opportunities												
ADMIN-1 – Wai‘ula‘ula watershed coordinator												
MONIT-1 – implement monitoring program												

# Chapter 6: Monitoring

Monitoring is an essential part of watershed planning. Monitoring can identify emerging problems or document response to changes in land use or climate. Equally important, monitoring is needed to evaluate the effectiveness of implemented BMPs.

This chapter addresses EPA's key element (i).

Monitoring activities will be conducted by MKSWCD personnel, contractors, and trained citizen volunteers.

## **6.1 Implementation Monitoring**

Implementation monitoring determines whether the management strategies outlined in the work plan are being implemented as written. Data gathered from this monitoring will help the District determine how well it is doing in implementing the work plan, as well as help the District modify the management strategies as needed to better protect water quality.

Implementation monitoring involves:

- documenting types, amounts and locations of management activities on a quarterly basis;
- comparing results with interim milestones included in an implementation plan;
- providing feedback to stakeholders; and
- determining need for modifications.

Agendas, minutes, activity and project status reports, and other records should be maintained so that important issues and decisions are well-documented.

## **6.2 Land Use Monitoring**

Changes in land use have the potential to result in changes to water quality or integrity of riparian habitats. Such changes should be tracked and correlated with changes in baseline water quality (see section 6.3). Each year, the watershed coordinator will compile a list of land use changes occurring in the watershed, noting

- 1) Planned developments that generate draft or final EIS;
- 2) Rezoning;
- 3) Actual construction of new developments, noting the proximity to stream channels or the ocean, and noting arrangements for wastewater;

- 4) Changes to permitted diversions;
- 5) If available, the actual amounts of water diverted by major users (*e.g.*, DWS, Parker Ranch) should be documented and broken down by stream; and
- 6) Other changed deemed worthy of note.

## **6.3 Long-Term Routine Monitoring of Water Quality**

Long-term monitoring of water quality is needed to:

- 1) Identify whether new disturbances or management activities (sections 6.1 and 6.2) are having a negative or positive impact on water quality.
- 2) Measure whether there are progressive changes in water quality, either for better or for worse.
- 3) Evaluate, when fires occur, whether there are downstream impacts.
- 4) Evaluate year-to-year variability in order to more realistically evaluate pre- and post-monitoring of BMPs.

There is no substitute for long-term monitoring, yet the cost of water quality monitoring is a significant barrier to its occurrence. A reasonably-priced baseflow monitoring program is, therefore, proposed as a realistic approach for routine monitoring. Also, to minimize costs, the parameters to be measured are restricted to those that are currently causing water quality impairments or do not have analytical lab costs (turbidity and oxygen).

Several lessons were learned from the monitoring conducted during the development of this plan. For example, in order to isolate the effect of the Waimea urban area on the Wai'ula'ula stream, measurements must be taken both below and above town. The Sandalwood site was satisfactory for the site below town, but the Marine Dam site may be too far upstream from Waimea. It is, therefore, recommended to monitor only a short distance upstream from Waimea. Another lesson was that reliable source characterization requires *simultaneous* measurements at multiple sites.

### **6.3.1 Recommendations for Long-term Baseflow Monitoring**

#### *What will be monitored (fresh water):*

- Turbidity (streamside measurement)
- TP (vial filled at streamside and frozen pending shipment to lab)
- TN (filtered at streamside; vial and filters frozen pending shipment to lab)
- Ammonia (mouth of watershed only; needed to see if marine ammonia impairment is from the stream or from submarine groundwater discharge.)
- When safe, measurements will be depth- and cross-sectionally integrated.

- DO (instream perennial pools only) (DO is expected to be impaired in the pool but not in the stream.)

Note: Ideally, chlorophyll-a would be measured in the instream perennial pools, but there is no convenient, local facility for measurement, nor an inexpensive in-situ probe. TP and TN can be analyzed at the University of Hawai'i at Hilo analytical laboratory.

Where monitoring will be conducted (fresh water):

- Waikoloa stream immediately above Waimea (near DWS gate)\*\*
- Waikoloa stream immediately below Waimea (Sandalwood autosampler site) (Compare with data from site listed above to see urban influence)\*
- Waikoloa stream below Lālāmilo Farm Lots (compare with data from Sandalwood site to see influence of farms and landfill.)\*\*\*
- Keanu'i'omanō stream below confluence with Lanikepu\*\*\*
- Immediately upstream of mouth of Wai'ula'ula stream (autosampler site)\*
- Several miles upstream of mouth of Wai'ula'ula stream (at Queen Ka'ahumanu Highway) (Compare to data from autosampler site at mouth of Wai'ula'ula stream to see influence of oceanside urban/resort zone.)\*\*\*
- Instream perennial pools at various elevations within watershed\*

Note: Because funding levels are uncertain, sites are prioritized: \* is highest priority, \*\* is medium priority, and \*\*\* is lower priority.

Frequency (fresh water):

- Following dry periods, sampling will be conducted within one week of when stream begins to flow.
- A subsequent sample will occur two weeks later (if stream is still flowing), and then 4 weeks after that (if stream is still flowing).
- The instream perennial pool samples shall be taken at least quarterly, even if the streams are not flowing.
- Samples shall be taken on the same day when feasible. (Simultaneous measurements at multiple sites.)

Criteria for success (fresh water):

- In any year, and at any sampling site, the geometric mean of measurements shall be less than water quality standards for the dry season.



- In any year, and for every upstream/downstream sampling pair, the difference between upstream values and downstream values shall be indistinguishable from zero according to a paired t-test.

Estimated costs are as follows:

- First year cost of \$1,600 for turbidimeter and oxygen meter.
- Subsequent years' annual cost of \$600 for turbidimeter standards, replacement oxygen membranes/fluids, and replacement filter holders.
- \$35-40 per sample for field supplies and analytical costs. Depending on the number of sampling dates and sites, this cost will range from \$600/yr to \$1,500 yr.
- Volunteer labor or commitments by MKSWCD personnel is assumed.
- The recommended monitoring is for feedback into the watershed planning process. It is not intended to provide a basis for regulatory determination of compliance with water quality standards. Costs would rise substantially if additional measures (*e.g.* certified laboratory) were added so that data meet protocols at the regulatory level.

### **6.3.2 Recommended Long-term Marine Monitoring**

Maintenance of water quality in the marine receiving waters is an important part of the rationale for managing nonpoint pollutants in the watershed. Recent measurements of the receiving waters indicate impairments of ammonia and algae. These parameters should be monitored in the future.

#### **What will be monitored (nearshore marine waters):**

- Ammonia
- Chlorophyll-a

Note: measurement protocols shall be consistent with DOH procedures for its routine monitoring of nearshore marine waters. Ammonia can be analyzed by the UH-Hilo analytical laboratory, but chlorophyll-a may need to be analyzed at a DOH facility.

#### **Where monitoring will be conducted (nearshore marine waters):**

- Kawaihae Bay at the same location(s) where DOH has previously taken measurements.

Frequency (nearshore marine waters):

- Ideally, on the same day that the streams are sampled, but in no case less than quarterly.

Criteria for success (nearshore marine waters):

- In any year, the geometric mean shall be less than water quality standards for the dry season.

### **6.3.3 Recommendations for Stormflow Monitoring**

Characterization of annual loads in the watershed is incomplete. Water quality and nutrient loads vary with the weather, so a longer monitoring period means that a wider variety of conditions are sampled. While some load data have been collected, they do not span an entire year, nor do they fully represent the various sub-watersheds. If the goal is to use measurements to characterize pollutant sources, it is important to take *simultaneous* measurements at several locations (upper Waikoloa stream, Waikoloa stream below Waimea, watershed outlet, Keanu'i'omanō stream) in order to evaluate the effects of anthropogenic and natural conditions on water quality.

Unfortunately, annual load measurements require the installation of autosamplers. Costs are very high. For example, contracts with the USGS to provide data meeting regulatory protocols are on the order of \$50,000 per year per site. The District owns one autosampler and in the past has borrowed three others from DOH. Using these autosamplers and having samples analyzed locally (and not necessarily at a certified lab) will help keep costs down.

In the event that funding becomes available, there is no substitute for autosampler-based stormflow measurements of sediment and nutrient loads. In this case, the following measurement program is recommended.

What will be monitored:

- TN, TP, nitrate, TSS
- Ammonia (at watershed mouth only)

Where monitoring will be conducted: (these may need to be prioritized, given number of autosamplers available)

- Waikoloa stream immediately above Waimea (near DWS gate)
- Waikoloa stream immediately below Waimea (Sandalwood autosampler site)  
(Compare with data from the above site to see urban influence)
- Keanu'i'omanō stream below confluence with Lanikepu

- Immediately upstream of mouth of Wai'ula'ula stream (reoccupy the previously-used site)
- Several miles upstream of mouth of Wai'ula'ula stream (at Queen Ka'ahumanu Highway) (Compare to data from autosampler site at mouth of Wai'ula'ula stream to see influence of oceanside urban/resort zone.)
- Immediately upstream of Pelekane Bay (at highway; former autosampler site).

*Frequency:*

- Every storm for at least one year.

## **6.4 Monitoring of Watershed Condition**

The purpose of the watershed condition monitoring is to assess the status and trend of watershed attributes to help determine if Wai'ula'ula watershed management efforts are achieving goals of maintaining and restoring a healthy watershed. Recommended types of monitoring are described below.

### **6.4.1. Vegetation Monitoring**

#### *6.4.1.1. Stubble Height Monitoring*

In 2001, the Natural Resources Conservation Service (NRCS) established general guidelines for judging proper grazing use on grass pasture as part of its Standards and Specifications for Prescribed Grazing (528A). Regular stubble height monitoring can be used as a management tool to determine when cattle should be rotated out of paddocks, based on the minimum heights established under NRCS's standards and specifications, and as a monitoring tool to ensure that grasslands are being sufficiently grazed to reduce the fuel load but are not being over-grazed.

*What will be monitored:*

- Key forage grass species (*e.g.*, kikuyu, buffel)

*Where monitoring will be conducted:*

- Sampling sites will be established in all paddocks used for cattle grazing within the watershed. Sampling sites will also be established in grasslands that are currently ungrazed, for comparative purposes.

Frequency:

- Semi-annually in each paddock.
- For projects involving introduction of cattle to previously ungrazed areas, before introduction of cattle for baseline data, bi-weekly while cattle are present to document grazing efficiency and estimate removal date, regularly after cattle removal to track grass growth and estimate fuel loading.

6.4.1.2. Fuel Loads

Fine fuels created by non-native grasses are a land management problem in leeward Hawai'i. These fuels facilitate the ignition of wildfires and promote their spread. By measuring representative fuel loads before and after fuels management projects are implemented, the amount of fuel loading reduced by each project can be calculated as a measure of success in mitigating wildfire risk.

Transects will be established within areas of grass fuels at different elevations within the marginal, fire-prone watershed lands below the 2,500-ft. elevation. Permanent, 100 m transect lines will be established and marked with rebar or metal stakes at both ends, which will be GPSed for ease of finding the sites again. Plots will be established every 10 m along each transect with the first plot at 0 m and the last at 90 m. A total of 10 samples will be collected from each transect line. Daubenmire frames (20cm x 50cm) will be used to delineate each plot.

All standing grass (biomass) at each plot will be clipped as close to the ground as possible and placed in zip-lock plastic bags labeled with the transect and plot numbers. Samples will be weighed within 12 hours from collection to obtain the wet weights. The clippings from each plot will then be transferred into paper bags for drying in a convection oven at 100° C. The samples will be checked for completeness of drying and will be considered totally dry if the dry weight of the samples does not change over two consecutive weighing sessions.

Fuel loads will be extrapolated to a hectare. Fuel loads from sites where fuels management practices have been implemented will be compared with baseline or ungrazed loads to determine the amount of fuel biomass that has been eliminated from the area, thereby reducing wildfire risk.

Assessing fuel loads is a relatively low-cost undertaking, with negligible material and equipment costs. The costs associated with this monitoring are for field and laboratory personnel.

What will be monitored:

- Fuel biomass within ten 20cm x 50cm quadrats (or plots) along each 100m transect line
- There will be two 100m transect lines at each sampling site for a total of 20 sampled plots per site

Where monitoring will be conducted:

- 1-3 transects will be established in grassy areas that have not been grazed (*i.e.*, adjacent to streams where cattle are currently excluded) to determine a representative worse-case fuel loading (or baseline without grazing and fire).
- Transects will be established in currently ungrazed and marginally-grazed areas where grazing will be established, grazing infrastructure improved, or other fuels management techniques implemented.

Frequency:

- Before the implementation of any fuels management project
- Annually, at the end of the wet season and before the beginning of the dry season

Criteria for Success:

- Fuel loads averaging 1,500 lbs per acre for buffel grass.

6.4.1.3. Vegetation Transects

The purpose of vegetative cover monitoring is to determine percent and composition of groundcover in the watershed, as an indicator of watershed health. This is a common method to evaluate land degradation and recovery, and the success of restoration projects. While there are various methodologies to quantify vegetation cover and composition, a line-point intercept sampling method will be used in the Wai'ula'ula watershed. Monitoring will focus on vegetation cover.

Using the sampling method described in Godinez-Alvarez *et al.* (2009), four parallel 70 m transects, separated by at least 10 m, will be established in a representative area of each monitoring site. End-points of transect lines will be marked with rebar or metal stakes, which will be GPSed for ease of finding the sites again. A 1-mm diameter pole will be dropped at every meter along each transect, for a total of 70 points per transect and 280 points per site. At each point, the simple presence or absence of vegetation will be noted. Vegetation cover will be estimated by dividing the total number of plant intercepts by the total number of points per transect. On occasion, the plant species contacted by the pole will also be recorded, in order to provide a general record of species composition.

Assessing vegetation cover is a relatively low-cost undertaking, with negligible material and equipment costs. The costs associated with this monitoring are for field personnel.

What will be monitored:

- Presence or absence of vegetation at one-meter intervals along four 70m transects

- On occasion, plants species will also be noted

Where monitoring will be conducted:

- Transects will be established at representative elevations within the marginal, fire-prone watershed lands below the 2,500-ft. elevation
- Vegetation transects will be established in conjunction with erosion pin monitoring. We anticipate that, as vegetative cover at a project site increases, erosion rates will decrease.

Frequency:

- Before the implementation of any fuels management project
- Annually, at the end of the wet season and before the beginning of the dry season

Criteria for Success:

- On bare land, a statistically-significant increase in vegetation cover
- For vegetation transects associated with revegetation projects, a statistically-significant increase in vegetative cover and a statistically-significant reduction in erosion rates (see Section 6.4.3.2.)

## **6.4.2. Stream Condition Assessment**

A first step to restoring riparian buffers is the development of a mechanism by which to identify environmental problems present within a stream system and along its riparian corridor and to provide sufficient information on each problem so that both the severity and correctability can be determined and restoration efforts can be prioritized. Maryland has developed survey protocols for a Stream Corridor Assessment to rapidly measure the general physical condition of a stream system and identify the locations of a variety of environmental problems within its stream corridors (Yetman 2001). These problems could include erosion sites, inadequate stream buffers, fish migration blockages, exposed or discharging pipes, channelized stream sections, trash dumping sites, in or near-stream construction, streambank instability, areas prone to flooding, areas of invasive plant species, and any unusual conditions. Such a survey tool will be developed for the watershed (and applicable to all of Hawai'i) to help determine specific areas in which to focus limited resources. Upon the completion of the survey tool, monitoring will be conducted.

What will be monitored:

- All stream corridors throughout the watershed

Where monitoring will be conducted:

- The length of all stream corridors will be walked, with the exception of segments that cannot be accessed safely. Inaccessible reaches in the upper watershed will also be excluded.

Frequency:

- Bi-annually

### **6.4.3. Erosion Monitoring**

#### **6.4.3.1. Infiltration Rates**

A tension disc infiltrometer test conducted in the lower watershed in 2010 indicated a preliminary saturated hydraulic conductivity of 10 mm/hr. for silt-sized material. This means that once the surface becomes saturated, rainfall in excess of 10 mm/hr is likely to generate surface runoff, resulting in erosion of bare soil by rainsplash, sheetwash, and rill/channel incision.

Determining infiltration rates throughout the watershed will help us to understand what intensity of rainfall will lead to surface runoff and associated erosion, and how this varies in different parts of the watershed. We can expect infiltration rates to increase with elevation (based on soil type, weathering, etc.) and with vegetative cover.

What will be monitored:

- Representative bare lands

Where monitoring will be conducted:

- At different elevations within the watershed
- In conjunction with erosion pin monitoring and revegetation/ restoration projects

Frequency:

- Every four years
- Annually, in association with revegetation/ restoration projects



#### 6.4.3.2. Erosion Rates

The least-expensive method to begin estimating erosion rates is called erosion pin monitoring. A network or array of long nails whose heads are driven flush with the ground will be installed in representative locations within the watershed and in association with specific projects. Data from a USGS project on Molokai demonstrated that erosion pin values closely approximate the value from other far more expensive techniques such as repeat ground-based LiDAR and suspended sediment yields (Stock 2010). In the Wai'ula'ula watershed, a network of pins will be installed on representative hillslopes suspected of providing fines to stream channels, on representative legacy fill terraces in stream channels, and on suspected eroding streambanks.

Each erosion pin monitoring site on hillslopes and legacy fill terraces will consist of 50 pins installed in similar topography to provide representative values. Streambank monitoring sites will consist of 20 pins. Each line of pins should be parallel or normal to the local slope, with rebar or large stakes marking each end. The nails should be spaced at even increments so far as groundcover permits (e.g., every 0.5 m, every 1.0 m, etc.). The rebar or stakes should be GPSed to facilitate finding the monitoring site.

At least once a year, trained volunteers or MKSWCD personnel will measure the amount of sediment lowering at each pin (in mm).

Tipping bucket rain gages will be installed at representative elevations as part of this monitoring effort. One rain gage was installed in the lower watershed in 2011. Three to four additional rain gages will be installed at a range of elevations, at a cost of \$500 per rain gage, plus \$260 for a download shuttle. Rainfall data will be collected electronically on an hourly basis and downloaded every two months.

Data from the erosion pins coupled with rainfall data will enable us to determine erosion rates for specific areas. In order to normalize erosion rates to account for the infrequent but high-intensity rainfall that defines this leeward landscape, the average annual amount of lowering measures at each network on pins (in mm) will be divided by the amount of time (in hours) that rainfall, as measured by the nearest rain gage, exceeds the infiltration capacity of 10 mm/hr. (or infiltration rate determined for that specific location).

#### What will be monitored:

- Representative hillslopes, hydrologically-connected to a stream and suspected of providing fines to stream channels
- Representative legacy fill terraces in stream channels
- Suspected eroding streambanks at representative elevations

#### Where monitoring will be conducted:

- At different elevations within the watershed

- In conjunction with erosion pin monitoring and revegetation/ restoration projects

**Frequency:**

- Annually

**Criteria for Success:**

- Statistically-significant reduction in erosion rates over 67% of pins
- For erosion monitoring associated with revegetation projects, a statistically-significant increase in vegetative cover (see Section 6.4.1.3.) and a statistically-significant reduction in erosion rates

#### **6.4.4. Biological Surveys of Aquatic Species**

Assessment of ecosystem health can be based either on water quality or on biological populations. A healthy ecosystem is diverse and contains native species. A number of biological surveys have been conducted in the Wai'ula'ula watershed since 1968. Survey data have been compiled by DLNR and indicate high biodiversity of native species found in the watershed. Regular stream surveys will be conducted to monitor changes in biological communities.

**What will be monitored:**

- Emphasis will be on native aquatic species
- Other species will be noted, along with qualitative measures of ecosystem health (e.g., stagnant water, algae, etc.)

**Where monitoring will be conducted:**

- Freshwater streams, with an emphasis on sites previously monitored
- Instream perennial pools, with an emphasis on sites previously monitored
- Nearshore waters at the mouth of the watershed

**Frequency:**

- Once every four years

## **6.5 Monitoring Plan Implementation**

### **6.5.1. Sampling and Analysis Plan (SAP)**

A detailed sampling and analysis plan that outlines parameters to be monitored, sampling location and frequency, roles and responsibilities, documentation and records, quality control requirements, and chain of custody will be developed prior to implementation of management projects.

### **6.5.2. Data Management**

The watershed coordinator will maintain the SAP and be the point person for communications concerning any updates or changes to the SAP.

Information and records to be included in the final data report package include:

1. Field notes (photocopies).
2. Laboratory results in ASCII or Excel format.
3. Hard copy and Excel files of water quality and field data.
4. Detection levels of analytical methods.
5. Map and GPS coordinates showing location of sample sites.
6. Photographs of field sites, especially for vegetation monitoring projects.
7. Documentation of field procedures, sample collection, lab methods, and any special conditions or circumstances.
8. Chain of custody forms.

All original data, including field notes and laboratory analyses, will be archived by the Mauna Kea Soil and Water Conservation District.

### **6.5.3. Adaptive Management Approach**

The monitoring component of the Wai'ula'ula watershed management plan is a working document. It is expected that the implementation process will reveal new information, emerging technologies, and practical operational realities that can be used to improve or revise the monitoring strategies. An adaptive management approach is recommended, so that, as we learn from actions taken, future monitoring techniques and procedures can be altered as necessary in response.

## Chapter 7: Bibliography

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# Appendices

# Appendix A: Project Worksheets

(still to come)

# Appendix B: Relevant CNPCP Management Measures

## Agriculture

### **A. Erosion and Sediment Control Management Measure**

Apply any combination of conservation structural and management practices based on U.S. Department of Agriculture – Natural Resources Conservation Service standards and specifications to minimize the delivery of sediment from agricultural lands to surface waters, or

Design and install a combination of management and structural practices to settle the settleable solids and associated pollutants in runoff delivered from the contributing area for storms of up to and including a 10-year, 24-hour frequency.

### **C. Nutrient Management Measure**

Develop, implement, and periodically update a nutrient management plan to: (1) apply nutrients at rates necessary to achieve realistic crop yields, (2) improve the timing of nutrient application, and (3) use agronomic crop production technology to increase nutrient use efficiency. When the source of the nutrients is other than commercial fertilizer, determine the nutrient value. Determine and credit the nitrogen contribution of any legume crop. Soil and/or plant tissue testing should be used at a suitable interval. Nutrient management plans contain the following core components:

1. Farm and field maps showing acreage, crops, soils, and waterbodies.
2. Realistic yield expectations for the crop(s) to be grown, based on achievable yields for the crop. Individual producer constraints and other producer's yields would be considered in determining achievable yields.
3. A summary of the soil condition and nutrient resources available to the producer, which at a minimum would include:
  - An appropriate mix of soil (pH, P, K) and/or plant tissue testing or historic yield response data for the particular crop;
  - Nutrient analysis of manure, sludge, mortality compost (birds, pigs, etc.), or effluent (if applicable);
  - Nitrogen contribution to the soil from legumes grown in the rotation (if applicable); and
  - Other significant nutrient sources (e.g., irrigation water).
4. An evaluation of field limitations based on environmental hazards or concerns, such as:
  - Lava tubes, shallow soils over fractured bedrock, and soils with high leaching or runoff potential,
  - Distance to surface water,
  - Highly erodible soils, and
  - Shallow aquifers.
5. Best available information is used in developing recommendations for the appropriate mix of nutrient sources and requirements for the crops.
6. Identification of timing and application methods for nutrients to: provide nutrients at rates necessary to achieve realistic crop yields; reduce losses to the environment; and avoid applications as much as possible during periods of leaching or runoff.

7. Methods and practices used to prevent soil erosion or sediment loss.
8. Provisions for the proper calibration and operation of nutrient application equipment.

#### **D. Pesticide Management Measure**

To eliminate the unnecessary release of pesticides into the environment and to reduce contamination of surface water and ground water from pesticides:

1. Use integrated pest management strategies where available that minimize chemical uses for pest control.
2. Manage pesticides efficiently by:
  1. calibrating equipment;
  2. using appropriate pesticides for given situation and environment;
  3. using alternative methods of pest control; and
  4. minimizing the movement of pest control agents from target area.
3. Use anti-backflow devices on hoses used for filling tank mixtures.
4. Enhance degradation or retention by increasing organic matter content in the soil or manipulating soil pH.

#### **E. Grazing Management Measure**

Protect range, pasture and other grazing lands:

1. By implementing one or more of the following to protect sensitive areas (such as streambanks, wetlands, estuaries, ponds, lake shores, near coastal waters/ shorelines, and riparian zones):
  1. Exclude livestock,
  2. Provide stream crossings or hardened watering access for drinking,
  3. Provide alternative drinking water locations,
  4. Locate salt and additional shade, if needed, away from sensitive areas, or
  5. Use improved grazing management (e.g., herding) to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock; *and*
2. By achieving either of the following on all range, pasture, and other grazing lands not addressed under (1):
  1. Implement range and pasture conservation and management practices that apply the progressive planning approach of USDA-NRCS following the standards and specifications contained in the FOTG that achieve an acceptable level of treatment to reduce erosion, and/or
  2. Maintain range, pasture, and other grazing lands in accordance with activity plans established by the Division of Land Management of DLNR, federal agencies managing grazing land, or other designated land management agencies.

#### **F. Irrigation Water Management Measure**

To reduce nonpoint source pollution of surface waters caused by irrigation:

1. Operate the irrigation system so that the timing and amount of irrigation water applied match crop water needs. This will require, as a minimum: (a) the measurement of soil-water depletion volume and the volume of irrigation water applied; (b) uniform application of water; and (c) application rate which does not exceed infiltration rate in the field.
2. When chemigation is used, include backflow preventers for wells, minimize the harmful amounts of chemigated waters that discharge from the edge of the field, and control deep



percolation. In cases where chemigation is performed with furrow irrigation systems, a tailwater management system may be needed.

The following limitations and special conditions apply:

1. In some locations, irrigation return flows are subject to other water rights or are required to maintain stream flow. In these special cases, on-site reuse could be precluded and would not be considered part of the management measure for such locations.
2. By increasing the water use efficiency, the discharge volume from the system will usually be reduced. While the total pollutant load may be reduced somewhat, there is the potential for an increase in the concentration of pollutants in the discharge. In these special cases, where living resources or human health may be adversely affected and where other management measures (nutrients and pesticides) do not reduce concentrations in the discharge, increasing water use efficiency would not be considered part of the management measure.
3. The time interval between the order for and the delivery of irrigation water to the farm may limit the irrigator's ability to achieve the maximum on-farm application efficiencies that are otherwise possible.
4. In some locations, leaching is necessary to control salt in the soil profile. Leaching for salt control should be limited to the leaching requirement for the root zone.
5. Where leakage from delivery systems or return flows supports wetlands or wildlife refuges, it may be preferable to modify the system to achieve a high level of efficiency and then divert the "saved water" to the wetland or wildlife refuge. This will improve the quality of water delivered to wetlands or wildlife refuges by preventing the introduction of pollutants from irrigated lands to such diverted water.
6. In some locations, sprinkler irrigation is used for crop cooling or other benefits (*e.g.*, watercress). In these special cases, applications should be limited to the amount necessary for crop protection, and applied water should not contribute to erosion or pollution.

## **Urban Areas**

### **Urban Runoff**

#### **A. New Development Management Measure**

1. By design or performance:
  1. After construction has been completed and the site is permanently stabilized, reduce the average annual total suspended solid (TSS) loadings by 80%. For the purposes of this measure, an 80% TSS reduction is to be determined on an average annual basis,\* or
  2. Reduce the postdevelopment loadings of TSS so that the average annual TSS loadings are no greater than predevelopment loadings, and
2. To the extent practicable, maintain postdevelopment peak runoff rate and average volume at levels that are similar to predevelopment levels.

Sound watershed management requires that both structural and nonstructural measures be employed to mitigate the adverse impacts of storm water. Nonstructural Management Measures II.B and II.C can be effectively used in conjunction with Management Measure II.A to reduce both the short- and long-term costs of meeting the treatment goals of this management measure.

### **C. Site Development Management Measure**

Plan, design, and develop sites to:

1. Protect areas that provide important water quality benefits and/or are particularly susceptible to erosion and sediment loss;
2. Limit increases of impervious areas, except where necessary;
3. Limit land disturbance activities such as clearing and grading, and cut and fill to reduce erosion and sediment loss; and
4. Limit disturbance of natural drainage features and vegetation.

### Existing Development

#### **A. Existing Development Management Measure**

Develop and implement watershed management programs to reduce runoff pollutant concentrations and volumes from existing development:

1. Identify priority local and/or regional watershed pollutant reduction opportunities, e.g., improvements to existing urban runoff control structures;
2. Contain a schedule for implementing appropriate controls;
3. Limit destruction of natural conveyance systems; and
4. Where appropriate, preserve, enhance, or establish buffers along surface waterbodies and their tributaries.

### Onsite Disposal Systems

#### **A. New Onsite Disposal Systems (OSDS) Management Measure**

1. Ensure that new Onsite Disposal Systems (OSDS) are located, designed, installed, operated, inspected, and maintained to prevent the discharge of pollutants to the surface of the ground and to the extent practicable reduce the discharge of pollutants into ground waters that are closely hydrologically connected to surface waters. Where necessary to meet these objectives: (a) discourage the installation of garbage disposals to reduce hydraulic and nutrient loadings; and (b) where low-volume plumbing fixtures have not been installed in new developments or redevelopments, reduce total hydraulic loadings to the OSDS by 25%. Implement OSDS inspection schedules for preconstruction, construction, and postconstruction;
2. Direct placement of OSDS away from unsuitable areas. Where OSDS placement away from unsuitable areas is not practicable, ensure that the OSDS is designed or sited at a density so as not to adversely affect surface waters or ground water that is closely hydrologically connected to surface water. Unsuitable areas include, but are not limited to, areas with poorly or excessively drained soils; areas with shallow water tables or areas with high seasonal water tables; areas overlaying fractured bedrock that drain directly to ground water; areas within floodplains; or areas where nutrient and/or pathogen concentrations in the effluent cannot be sufficiently treated or reduced before the effluent reaches sensitive waterbodies;
3. Establish protective setbacks from surface waters, wetlands, and floodplains for conventional as well as alternative OSDS. The lateral setbacks should be based on soil type, slope, hydrologic factors, and type of OSDS. Where uniform protective setbacks cannot be achieved, site development with OSDS so as not to adversely affect waterbodies and/or contribute to a public health nuisance;
4. Establish protective separation distances between OSDS system components and groundwater which is closely hydrologically connected to surface waters. The separation distances should be based on soil type, distance to ground water, hydrologic factors, and type of OSDS;

5. Where conditions indicate that nitrogen-limited surface waters may be adversely affected by excess nitrogen loadings from ground water, require the installation of OSDS that reduce total nitrogen loadings by 50% to groundwater that is closely hydrologically connected to surface water.

#### **B. Operating OSDS Management Measure**

1. Establish and implement policies and systems to ensure that existing OSDS are operated and maintained to prevent the discharge of pollutants to the surface of the ground and to the extent practicable reduce the discharge of pollutants into ground waters that are closely hydrologically connected to surface waters. Where necessary to meet these objectives, encourage the reduced use of garbage disposals, encourage the use of low-volume plumbing fixtures, and reduce total phosphorus loadings to the OSDS by 15% (if the use of low-level phosphate detergents has not been required or widely adopted by OSDS users). Establish and implement policies that require an OSDS to be repaired, replaced, or modified where the OSDS fails, or threatens or impairs surface waters;
2. Inspect OSDS at a frequency adequate to ascertain whether OSDS are failing;
3. Consider replacing or upgrading OSDS to treat influent so that total nitrogen loadings in the effluent are reduced by 50%. This provision applies only:
  1. where conditions indicate that nitrogen-limited surface waters may be adversely affected by significant groundwater nitrogen loadings from OSDS, and
  2. where nitrogen loadings from OSDS are delivered to groundwater that is closely hydrologically connected to surface water.

#### Pollution Prevention

##### **A. Pollution Prevention Management Measure**

Implement pollution prevention and education programs to reduce nonpoint source pollutants generated from the following activities, where applicable:

1. The improper storage, use, and disposal of household hazardous chemicals, including automobile fluids, pesticides, paints, solvents, etc.;
2. Lawn and garden activities, including the application and disposal of lawn and garden care products, and the improper disposal of leaves and yard trimmings;
3. Turf management on golf courses, parks, and recreational areas;
4. Improper operation and maintenance of onsite disposal systems;
5. Discharge of pollutants into storm drains including floatables, waste oil, and litter;
6. Commercial activities including parking lots, gas stations, and other entities not under NPDES purview; and
7. Improper disposal of pet excrement.

##### **B. Golf Course Management Measure**

1. Develop and implement grading and site preparation plans to:
  1. Design and install a combination of management and physical practices to settle solids and associated pollutants in runoff from heavy rains and/or from wind;
  2. Prevent erosion and retain sediment, to the extent practicable, onsite during and after construction;
  3. Protect areas that provide important water quality benefits and/or are environmentally-sensitive ecosystems;

4. Avoid construction, to the extent practicable, in areas that are susceptible to erosion and sediment loss;
  5. Protect the natural integrity of waterbodies and natural drainage systems by establishing streamside buffers; and
  6. Follow, to the extent practicable, the amended U.S. Golfing Association (USGA) guidelines for the construction of greens.
2. Develop nutrient management guidelines appropriate to Hawai'i for qualified superintendents to implement so that nutrients are applied at rates necessary to establish and maintain vegetation without causing leaching into ground and surface waters.
  3. Develop and implement an integrated pest management plan. Follow EPA guidelines for the proper storage and disposal of pesticides.
  4. Develop and implement irrigation management practices to match the water needs of the turf.

### Roads, Highways, and Bridges

#### **A. Management Measure for Planning, Siting, and Developing Roads and Highways**

Plan, site, and develop roads and highways to:

1. Protect areas that provide important water quality benefits or are particularly susceptible to erosion or sediment loss;
2. Limit land disturbance such as clearing, grading and cut and fill to reduce erosion and sediment loss; and
3. Limit disturbance of natural drainage features and vegetation.

#### **B. Management Measure for Bridges**

Site, design, and maintain bridge structures so that sensitive and valuable aquatic ecosystems and areas providing important water quality benefits are protected from adverse effects.

#### **E. Management Measure for Operation and Maintenance**

Incorporate pollution prevention procedures into the operation and maintenance of roads, highways, and bridges to reduce pollutant loadings to surface waters.

#### **F. Management Measure for Road, Highway, and Bridge Runoff Systems**

Develop and implement runoff management systems for existing roads, highways, and bridges to reduce runoff pollutant concentrations and volumes entering surface waters.

1. Identify priority and watershed pollutant reduction opportunities (e.g., improvements to existing urban runoff control structures); and
2. Establish schedules for implementing appropriate controls.

### Hydromodifications

#### Channelization and Channel Modification

#### **A. Management Measure for Physical and Chemical Characteristics of Surface Waters**

1. Evaluate the potential effects of proposed channelization and channel modification on the physical and chemical characteristics of surface waters in coastal areas;
2. Plan and design channelization and channel modification to reduce undesirable impacts; and

3. Develop an operation and maintenance program for existing modified channels that includes identification and implementation of opportunities to improve physical and chemical characteristics of surface waters in those channels.

#### **B. Instream and Riparian Habitat Restoration Management Measure**

1. Evaluate the potential effects of proposed channelization and channel modification on instream and riparian habitat in coastal areas;
2. Plan and design channelization and channel modification to reduce undesirable impacts; and
3. Develop an operation and maintenance program with specific timetables for existing modified channels that includes identification of opportunities to restore instream and riparian habitat in those channels.

#### Dams

#### **C. Management Measure for Protection of Surface Water Quality and Instream and Riparian Habitat**

Develop and implement a program to manage the operation of dams in coastal areas that includes an assessment of:

1. Surface water quality and instream and riparian habitat and potential for improvement and
2. Significant nonpoint source pollution problems that result from excessive surface water withdrawals.

#### Streambank and Shoreline Erosion

#### **A. Management Measure for Eroding Streambanks and Shorelines**

1. Where streambank or shoreline erosion is a serious nonpoint source pollution problem, streambanks and shorelines may need to be stabilized. Vegetative methods are strongly preferred. Structural methods may be necessary where vegetative methods cannot work and where they do not interfere with natural beach processes or harm other sensitive ecological areas.
2. Protect streambank and shoreline features with the potential to reduce nonpoint source pollution.
3. Protect streambanks and shorelines from erosion due to uses of either the shorelands or adjacent surface waters.
4. Where artificial fill is eroding into adjacent streams or coastal waters, it should be removed.

#### Wetlands, Riparian Areas, and Vegetated Treatment Systems

#### **A. Management Measure for Protection of Wetlands and Riparian Areas**

Protect from adverse effects wetlands and riparian areas that are serving a significant nonpoint source pollution abatement function and maintain this function while protecting the other existing functions of these wetlands and riparian areas as measured by characteristics such as vegetative composition and cover, hydrology of surface water and ground water, geochemistry of the substrate, and species composition.

#### **B. Management Measure for Restoration of Wetlands and Riparian Areas**

Promote the restoration of the pre-existing functions in damaged and destroyed wetlands and riparian systems in areas where the systems will serve a significant nonpoint source pollution abatement function.

### **C. Management Measure for Vegetated Treatment Systems**

Promote the use of engineered vegetated treatment systems such as constructed wetlands or vegetated filter strips where these systems will serve a significant nonpoint source pollution abatement function.

## Appendix C: EPA's Nine Key Elements

To ensure that Section 319 projects funded with incremental dollars make progress towards restoring waters impaired by nonpoint source pollution, watershed-based plans that are developed or implemented with Section 319 funds to address 303(d)-listed waters must include at least the elements listed below.

a. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan, as discussed in item (b) immediately below. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed.

*This element is addressed in Chapter 4 "Threats to the Water Quality of the Watershed" and, to a lesser extent, Chapters 2 and 3.*

b. An estimate of the load reductions expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

*This element is addressed in Chapter 5 "Recommended Management Measures" and Appendix A of the WWMP.*

c. A description of the NPS management measures that will need to be implemented to achieve the load reductions estimated under paragraph (b) above, and an identification of the critical areas in which those measures will be needed to implement this plan.

*This element is addressed in Chapter 5 "Recommended Management Measures" and Appendix A of the WWMP.*

d. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

*This element is addressed in Chapter 5 "Recommended Management Measures" and Appendix A of the WWMP.*



e. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

*This element is addressed in Chapter 5 “Recommended Management Measures” and Appendix A of the WWMP.*

f. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.

*This element is addressed in Chapter 5 “Recommended Management Measures” and Appendix A of the WWMP.*

g. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented.

*This element is addressed in Chapter 5 “Recommended Management Measures” and Appendix A of the WWMP.*

h. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised.

*This element is addressed in Chapter 5 “Recommended Management Measures” and Chapter 6 “Monitoring” of the WWMP.*

i. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

*This element is addressed in Chapter 6 “Monitoring” of the WWMP.*

**APPENDIX D. ADDENDUM TO THE  
WAIULAULA WATERSHED  
MANAGEMENT PLAN**

**August 2025**

## **Estimating Pollutant Load Reductions Resulting from Control and Removal of Invasive Plant and Animal Species and Establishment of Native Species**

### **Introduction**

This addendum has been developed by the Hawaii Department of Health (HDOH) to address additional considerations and updates relevant to watershed management efforts. This addendum supplements the Waiulaula Watershed Management Plan to include activities and additional guidance related to the removal of invasive plants and animals, as well as the reintroduction of native species. In addition to including these activities in the menu of best management practices (BMPs) that are eligible for 319 funding, this addendum provides an approach for calculating the pollutant reductions associated with these restoration activities. These pollutant reductions can be used by project managers and sub-grantees to develop individual project plans and by HDOH to calculate annual pollutant reductions for the broader NPS program.

### **Pollutant Loading from Invasive Species**

Invasive plants and animals are an increasingly challenging source of pollution in many of Hawaii's watersheds. Invasive plants, such as miconia, have shallow root systems, which are unable to stabilize the soil and are susceptible to erosion and landslides during rainfall events. Invasive animals, such as feral hogs, are destructive grazers, uprooting plant material and exposing additional areas to erosion.

As a result, sediment is the primary pollutant of concern from invasive species, although other pollutants may also be transported during rainfall events (e.g., nutrients and bacteria). Sediment has been identified by HDOH as a pollutant of concern across the state and is a focus of water quality improvement efforts. This watershed-based plan already includes a discussion of pollutants of concern and the load reductions needed to return the impaired waters to attainment. This addendum supplements that discussion; invasive species are one of multiple pollutant sources to be addressed.

### **Pollution Control Practices**

Across Hawaii, many organizations (including federal, state and local government, as well as watershed groups) are working to mitigate these problems. In many cases, this involves removing the invasive species and replacing them with native species. Native plant species<sup>1</sup> are better adapted to the soils and climate and provide improved soil retention, among other benefits. Excluding invasive animals, such as using fencing to block access to an area, allows vegetation to recover and thrive.

Table 1 below includes BMPs that can address pollutant loading caused by invasive species.<sup>2</sup> As shown by the large number of potential BMPs, vegetative plantings are a common element of many BMPs; ensuring that native species are used (and in the necessary quantities for establishment) will help to restore native plant communities. Managing invasive animal species is typically limited to exclusion or removal.

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<sup>1</sup> See, for example, <https://dlnr.hawaii.gov/forestry/plants/> for a discussion of native plant species.

<sup>2</sup> The table shows only a selection of BMPs. Other BMPs may also accomplish the goals of invasive removal and re-establishment of native species. Watershed planners should consult with HDOH when developing project plans to ensure BMP eligibility.

**Table 1: Selection of BMPs to Address Invasive Species**

Management Practice	Description
Bioretention Cell (Rain Garden)	Depression consisting of native plant species and soil mixtures that receives stormwater flow and infiltrates to treat pollutants.
Channel Maintenance and Restoration	Practices used to control sediment and plant pollution into waterways during earthwork such as stream bank stabilization or habitat enhancement. Examples include floating booms and silt curtains extended across river or stream banks downstream of work.
Constructed Wetlands	Creation of an artificial wetland ecosystem to improve the quality of stormwater runoff or other water flows. A constructed wetland provides biological treatment in areas where wetland function can be created or enhanced. Constructed wetlands also can be used to treat runoff from agricultural land uses and stormwater runoff and other contaminated flows from urban areas and other land uses. The practice involves establishment of inlet and outlet control structures for an impoundment designed to accumulate settleable solids, decayed plant matter, and microbial biomass and support propagation of hydrophytic vegetation.
Critical Area Planting	Establishment of permanent vegetation in areas with heavy erosion problems. Particularly useful for areas that need stabilization before/after flood events.
Grassed Waterway	A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet. Used to convey runoff from terraces, diversions, or similar; to prevent gully formation; and to protect or improve water quality.
Herbaceous Weed Treatment/Invasive Species Removal	The removal or control of herbaceous weeds, including invasive, noxious, and prohibited plants.
Sediment Basin	Captures and retains stormwater runoff until sediments settle out; water is released through engineered outlet.
Feral Ungulate Fencing	A structural conservation practice that prevents movement of ungulates across a given boundary. Within areas impacted by feral ungulate presence, fences prevent their movement into the forested lands. Ungulate fencing prevents direct contact of fecal matter with waterways, allows for restoration of vegetation, and reduces bacteria and nitrogen loadings and sediment input into waterways.
Feral Ungulate Removal	Hunting or trapping wild goats, pigs, and other non-native hooved mammals to reduce erosion caused by trampling and vegetation removal, as well as nutrient and bacterial impacts from defecation in and around water bodies.

Through this addendum, these BMPs are now eligible for funding under Section 319 to address water quality concerns caused by invasive species (if the BMPs were not already identified in the original plan). Implementation of these BMPs will lead to a reduction in pollutant loading in the watershed. The original watershed-based plan may include information on specific locations or land use types that may be most appropriate for invasive species BMPs. Additional information can be found in other resources,

such as the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service's *Field Office Technical Guide* for Hawaii.<sup>3</sup>

### **Calculating Pollutant Reductions**

Accounting for the total pollutant reductions is an important step in tracking water quality improvements. HDOH and watershed stakeholders develop watershed-based plans under the state's nonpoint source pollution (NPS) program; these plans include a projected level of pollutant reduction for the proposed project.

There are various models that can be used to calculate the pollutant reductions associated with BMP implementation. HDOH researched the advantages and disadvantages of each model, including the ease of use for watershed project managers and evaluating the model's appropriateness for use in Hawaii. After reviewing several models, HDOH selected the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model.

### **Description of the InVEST Model**

InVEST is a suite of models focused on ecosystems and how they connect to downstream economics. This addendum is focused on the sediment delivery ratio model in the InVEST suite. The InVEST sediment delivery ratio model was chosen by HDOH because it is easy to use and its ability to estimate sediment loading both with current condition and with BMPs implemented. Additionally, the InVEST model can be modified to accommodate the unique geologic conditions in Hawaii.

The InVEST sediment delivery ratio model is focused on sediment loading and erosion. The model outputs a set of maps showing the sediment erosion, including the amount of sediment soil loss per pixel, and the amount of erosion that is prevented by the presence of vegetation per pixel. The effect of BMPs on sediment erosion can be measured by comparing model outputs ran under the current conditions against model outputs ran with BMPs implemented. To calculate the annual soil loss per pixel, the InVEST model uses the Revised Universal Soil Loss Equation (RUSLE; Renard et al., 1997). Along with the factors that are in the RUSLE equation (rainfall erosivity, soil erodibility, slope length gradient, cover management, and support practice), this addendum recommends including an additional terrain factor to accommodate for the geology of Hawaii. The inclusion of the terrain factor prevents the model from overestimating the soil loss in places with geologically new basaltic bedrock which has minimal soil cover (Falinski, 2016). The required data inputs for this model are integrated into the RUSLE equation. To determine the effects of BMPs on sediment load reduction and erosion, the model should be run with altered data inputs.

The required data inputs include GIS data, a table, and five additional values. These five inputs are described in detail in the Step-by-Step Procedure below. To measure the reduction in sediment load and erosion with BMP implementation, these inputs can be changed to integrate the increase in vegetation that would come along with BMP implementation. The Step-by-Step Procedure section of this addendum describes each of these required inputs in further detail along with recommended values and sources for GIS data inputs.

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<sup>3</sup> <https://efotg.sc.egov.usda.gov/#/state/HI/documents>

### **Step-by-Step Procedure**

The step-by-step procedure begins with collecting and creating the proper data inputs for the current conditions in the watershed and running the InVEST model with those data inputs. After the first model run, the next step is to use multiple lines of evidence, including model outputs and other information, to determine the most appropriate areas in the watershed to implement BMPs. Next, the model should be run again with inputs that incorporate the impacts that BMPs would have on the land cover or support practices. The reduction in pollutant loading is the difference between the two model output runs. The steps to compile each data input and descriptions of each required data input are shown in Table 2. All GIS inputs must be the same coordinate reference system. The coordinate reference system must be projected and in linear units of meters.

**Table 2: Required Data Inputs for the Invest Model**

GIS Data Inputs		
Input Name and Description	Data Type	Suggested Sources
<b>Digital Elevation Model:</b> A digital elevation map (DEM) showing elevation in meters. The map should be clipped beyond the watershed boundary.	Raster	The 3D Elevation Program (3DEP) from USGS. <sup>4</sup> The best available resolution for the state is 1/3 arc-second.
		The Hawaii Statewide GIS Program's Digital Terrain Model. <sup>5</sup> Data is only available for portions of the state and as a JPEG or PNG, so it must be converted to a raster format. The resolution is 1 meter, and the elevation values are in meters.
<b>Erosivity:</b> A map of rainfall erosivity in units of MJ • mm/(h • ha • year). The map should illustrate both intensity and duration of rainfall.	Raster	For the island of Hawaii, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703. <sup>6</sup> The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		For the island of Oahu, NOAA's digitized version of the rainfall erosivity map from the Agriculture Handbook No. 703. <sup>7</sup> The units are US customary units, so the units must be converted by multiplying each value by 17.02 (Renard, et al., 1997).
		The rainfall erosivity map on page 57 of the Agriculture Handbook No. 703. This map must be digitized into raster data by a GIS specialist and units must be converted to SI by multiplying each value by 17.02 (Renard, et al., 1997).
		A rainfall erosivity raster can be made using precipitation from the Hawaii Climate Data Portal. <sup>8</sup> Rainfall erosivity can be calculated using the Roose equation (Renard and Freimund, 1994): $R = 0.5 \times P \times 17.02$ , where R is the rainfall erosivity value in the proper SI units and P is the annual rainfall in mm/year.

<sup>4</sup> <https://apps.nationalmap.gov/downloader/>

<sup>5</sup> <https://geoportal.hawaii.gov/datasets/HiStateGIS::hawaii-dtm-elevation/about>

<sup>6</sup> <https://www.fisheries.noaa.gov/inport/item/48225>

<sup>7</sup> <https://www.fisheries.noaa.gov/inport/item/48230>

<sup>8</sup> <https://www.hawaii.edu/climate-data-portal/data-portal/>

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<b>Soil Erodibility:</b> A map showing the soil erodibility in the watershed. Soil erodibility, also called K factor, is the likelihood of soil particles to erode and be transported downstream by precipitation or runoff. The soil erodibility raster must be in units of $t \cdot h \cdot ha / (ha \cdot MJ \cdot mm)$ .	Raster	Soil data, including K factors, is available from the Soil Survey Geographic Database (SSURGO). <sup>9</sup> This database provides raster data of soil type in an area of interest, and a table showing the K factor of each soil type. Raster data of K factors in a projected coordinate system will have to be generated by combining the soil raster data and the K factor table.
<b>Land Use/Land Cover:</b> A map showing the land use and land cover within the watershed. The C-CAP raster described below must also be combined with geology data. Each pixel should be categorized by its land use/land cover and geologic origin from the geology dataset. Every combination of land use/land cover and geologic origin should be assigned a unique LULC code.	Raster	NOAA has C-CAP high resolution land cover raster data available for the entire state of Hawaii from 2021. <sup>10</sup> NOAA's land cover data has a resolution of 1-meter and includes up to 25 classifications including forests and urban development.
		Geology data for the state of Hawaii is available for download from USGS. <sup>11</sup> This data is available as shapefiles, so it must be converted to raster data.
<b>Watersheds:</b> A map of the boundary of the watershed.	Vector (polygon/multipolygon)	The USGS Watershed Boundary Dataset has vector watershed delineation data available at different hydrologic unit levels for the entire state of Hawaii. <sup>12</sup>
		The Hawaii Statewide GIS Program has vector watershed delineation data available that was created by the Division of Aquatic Resources (DAR). <sup>13</sup>
		The InVEST suite includes the DelineateIt tool, used for generating watersheds based on user inputs. This tool outputs a GeoPackage containing a vector with the model's estimated watershed delineations. More information on this tool can be found in the DelineateIt section of the InVEST suite. <sup>14</sup>

<sup>9</sup> <https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo>

<sup>10</sup> <https://coast.noaa.gov/digitalcoast/data/>

<sup>11</sup> <https://pubs.usgs.gov/of/2007/1089/>

<sup>12</sup> <https://www.usgs.gov/national-hydrography/watershed-boundary-dataset>

<sup>13</sup> <https://geoportal.hawaii.gov/datasets/HiStateGIS::watersheds-dar-version/about>

<sup>14</sup> <https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/delineateit.html>



		Watershed delineations can be generated using a USGS StreamStats's tool. <sup>15</sup> Delineations can be downloaded as vectors.
Other Required Data Inputs		
Input Name and Description	Data type	Suggested Input Value
<b>Threshold Flow Accumulation:</b> The minimum number of pixels that flow into another pixel for it to be classified as a stream.	Number of pixels	This value should be determined by the user via trial and error. Users should test different values until the streams on the output maps resemble the streams in the watershed.
<b>Borselli k Parameter:</b> A calibration parameter in the sediment delivery ratio equation.	Number	This value is based on watershed location. Table 3 shows the Borselli k Parameter by location.
<b>Maximum SDR Value:</b> The maximum sediment delivery ratio a pixel is allowed to have.	Number between 0 and 1	For all watersheds in the state of Hawaii, the value should be 0.5 (Falinski, 2016).
<b>Borselli IC<sub>0</sub> Parameter:</b> A calibration parameter in the sediment delivery ratio equation.	Number	For all watersheds in the state of Hawaii, the value should be 0.1 (Falinski, 2016).
<b>Maximum L Value:</b> The maximum allowed slope value in the slope length-gradient factor.	Number	For all watershed in the state of Hawaii, the value should be 122 (Falinski, 2016).
<b>Biophysical Table:</b> A table mapping each LULC code to its cover-management factor (C) and support practice factor (P). One column should be named "lucode" and contain the LULC code from the land cover and land use raster. The other two columns should be named "usle_c" and "usle_p" and contain the associated C factor and P factor, respectively. The C factor indicates how much erosion is likely to occur at this land use/land cover type. The smaller the C factor value, the less erosion is expected to come from that type. To account for the terrain factor in the model run, the C factor in the biophysical table should be modified. The C factor for each LULC code should be the original C factor from Table 4 multiplied by the terrain factor from	.CSV file	Table 4 shows the C factors for land use/land covers in Hawaii, and Table 5 shows the terrain factor by geologic origin.

<sup>15</sup> <https://www.usgs.gov/streamstats>

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Table 5 that is associated with the geologic origin under that LULC code. The P factor indicates whether erosion reduction practices are implemented in that area. A value of 1 means there are no erosion reduction practices implemented in that land cover/land use type and a smaller value indicates best management practices are implemented in that land cover/land use type.		
<b>Workspace:</b> The folder where outputs will be written.	Folder name	--

**Table 3: Borselli k Parameter by Watershed Location (Falinski, 2016)**

Watershed Location	Borselli k Parameter
Windward part of the island of Hawaii	4
Leeward part of the island of Hawaii	2.5
Oahu	2.5
Maui	2
Lanai	2
Molokai	1.25
Kahoolawe	2.4
Kauai	1.6
Niihau	1.5

**Table 4: C Factor Values for Land Use/Land Cover (Falinski, 2016)**

Land Use/Land Cover	C Factor	Land Use/Land Cover	C Factor
Evergreen	0.014 <sup>16</sup>	Developed, Medium Intensity	0.01
Scrub Shrub	0.014 <sup>17</sup>	Impervious Surface	0.001
Bare Land	0.7	Palustrine Scrub Shrub Wetland	0.003
Pasture/Hay	0.05	Palustrine Emergent Wetland	0.003
Grassland	0.05	Unconsolidated Shore	0.003
Open Water	0	Estuarine Forested Wetland	0.003
Cultivated Land	0.24 <sup>18</sup>	Estuarine Scrub Shrub Wetland	0.003
Developed, Low Intensity	0.03	Estuarine Emergent Wetland	0.003
Palustrine Forested Wetland	0.003	Background	0
Open Space Developed	0.05	Palustrine Aquatic Bed	0

**Table 5: Terrain Factor by Geologic Origin (Falinski, 2016)**

Hawaii		Oahu, Kauai and Niihau	
Geologic origin	Terrain factor	Geologic origin	Terrain factor
Hamakua Volcanics	1	Honolulu Volcanics	1
Hawi Volcanics	1	Kolekole Volcanics	1
Hilina Basalt	0.001	Koolau Basalt	1
Hualalai Volcanics	0.001	Waianae Volcanics	1
Kahuku Basalt	0.001	Kiekie Volcanics	1
Kau Basalt	0.001	Koloa Volcanics	1
Laupahoehoe Volcanics	0.1	Paniau Basalt	0.1
Ninole Basalt	1	Waimea Canyon	0.1
Pololu Volcanics	1	--	--
Puna Basalt	0.001	--	--

<sup>16</sup> Evergreen forest: 0.035 for Hamakua and Kohala volcanoes

<sup>17</sup> Scrub/shrub: 0.05 for leeward volcanic units

<sup>18</sup> Cultivated land: 0.4 for pineapple (Lanai) or 0.51 for sugarcane crop (central Maui)

Maui, Molokai, Lanai and Kahoolawe		All Islands	
Geologic Origin	Terrain factor	Geologic origin	Terrain factor
East Molokai Volcanics	1	Open water	1
Hana Volcanics	0.001	Fill	1
Honolua Volcanics	1	Alluvium	1
Honomanu Basalt	1	Landslide Deposits	1
Kalaupapa Volcanics	1	Slope Deposits	0.001
Kanapou Volcanics	1	Tephra Deposits	0.1
Kaupo Mud Flow	1	Beach Deposits	0.1
Kula Volcanics	0.01	Lagoon Deposits	1
Lahaina Volcanics	1	Older Dune Deposits	1
Lanai Basalt	1	Younger Dune Deposits	0.1
Wailuku Volcanics	1	Talus and Colluvium	0.1
West Molokai Volcanics	1	Marine Conglomerate and Breccia	0.1
--	--	Caldera Wall Rocks	0.001

The most relevant output is the “sed\_export.tif”, showing the sediment exported from every pixel. Because of the geology of Hawaii, data on the pixel level from this raster may be inaccurate. The model tends to predict higher sediment export from areas with steeper slopes. In Hawaii, high slopes occur in high elevation areas where the sediment supply may be naturally limited by the unique geology of Hawaii. Therefore, the model overestimates the amount of sediment export in the mountains because it assumes unlimited sediment supply in steep areas with thin or little soil. For this reason, the sediment export raster data should not be used as the sole or main method for determining where BMPs should be implemented within the watershed.

The sediment export raster can be combined with land use/land cover data to determine which land use classes are disproportionately contributing to sediment loading. The amount of sediment mass exported per acre for each land use can be calculated by adding up the value of every pixel in the sediment export raster in each land use and dividing that sum by the number of acres that the land use covers.

It is crucial that multiple lines of evidence are considered when determining where BMPs should be implemented. The normalized difference vegetation index (NDVI)<sup>19</sup> is a satellite-based measurement that could be useful in identifying areas with minimal vegetation which may be susceptible to increased erosion. The NDVI quantifies vegetative health and density. NDVI values closer to positive 1 indicate the presence of abundant and healthy vegetation, and a value closer to 0 indicates there is less vegetation (NASA, 2025). Looking at NDVI data in a raster format would allow a user to visualize areas within the watershed that have little vegetation or unhealthy vegetation, indicating that the area could benefit from BMP implementation. If the resolution of the NDVI data is a lower resolution, it may be difficult to pinpoint areas where BMP implementation would be the most valuable. Therefore, further evidence should be used when selecting areas for BMP implementation. A high resolution and recent satellite image can supplement older land use/land cover data and lower resolution NDVI raster data. A satellite

<sup>19</sup> One potential source of NDVI data is NOAA’s Suomi National Polar-orbiting Partnership (Suomi NPP) [Visible Infrared Imaging Radiometer Suite \(VIIRS\) Vegetation Indices \(VNP13A2\) Version 2](#) data product which can be queried using the ‘[modisfast](#)’ R package.

image can be used to more accurately identify areas with minimal vegetative cover which could benefit most from BMP implementation. Further useful evidence can be collected on-site in the watershed. If possible, a person can walk along streams in the watershed and identify locations in the watershed where BMP implementation would be the most advantageous, such as locations with invasive plant species, minimal vegetation and/or the presence of feral ungulates. Each of the options listed above is important evidence that should be considered when the user is deciding on locations for BMP implementation.

After determining where BMPs will be implemented, the next step is to re-run the model with inputs that account for the BMPs that would be implemented to determine how they would affect sediment loading. The model inputs for the revised run should remain almost entirely the same. A different directory should be entered into the Workspace field or the results from the last model run will be overwritten. Additionally, either the support practice factors in the biophysical table or the land use/cover raster should be edited:

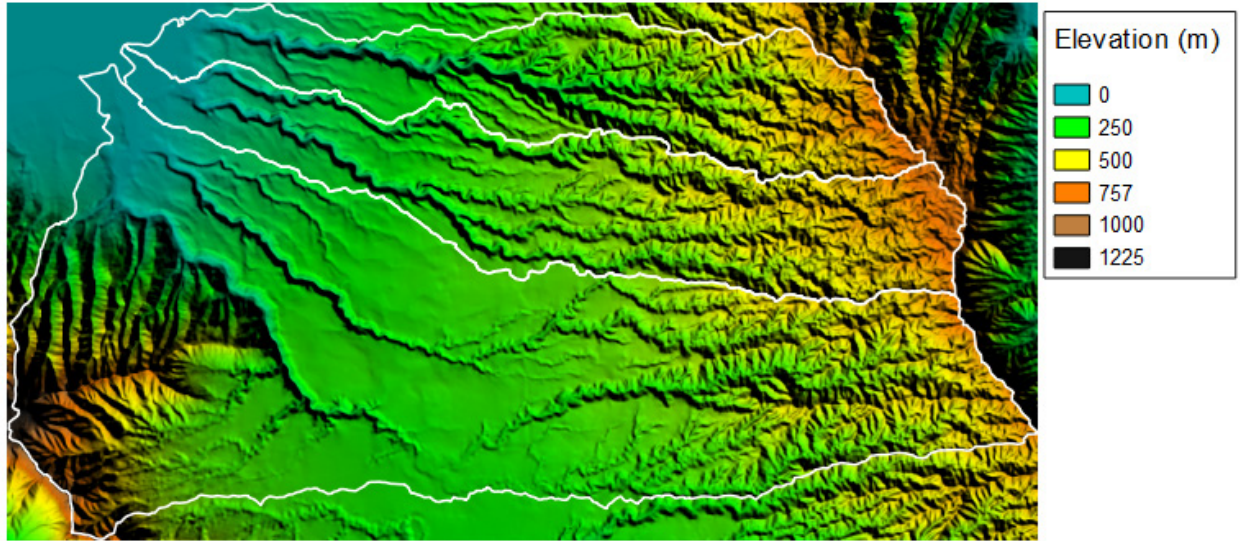
- The P factors in the biophysical table should be decreased for each land use/land cover type where an erosion reduction practice will be implemented.
- Alternatively, the land cover/land use raster should be edited to show how the land use/land cover would change with erosion reduction practices implemented. For example, bare land could be changed to a type of forest cover if a best management practice would be to plant native species on non-vegetated land.

To determine the effect that the implementation of best management practices would have on sediment exports, the outputs from both model runs can be compared. The sum across every pixel in “sed\_export.tif” outputs illustrate how much sediment load reduction would occur with BMP implementation on the watershed level.

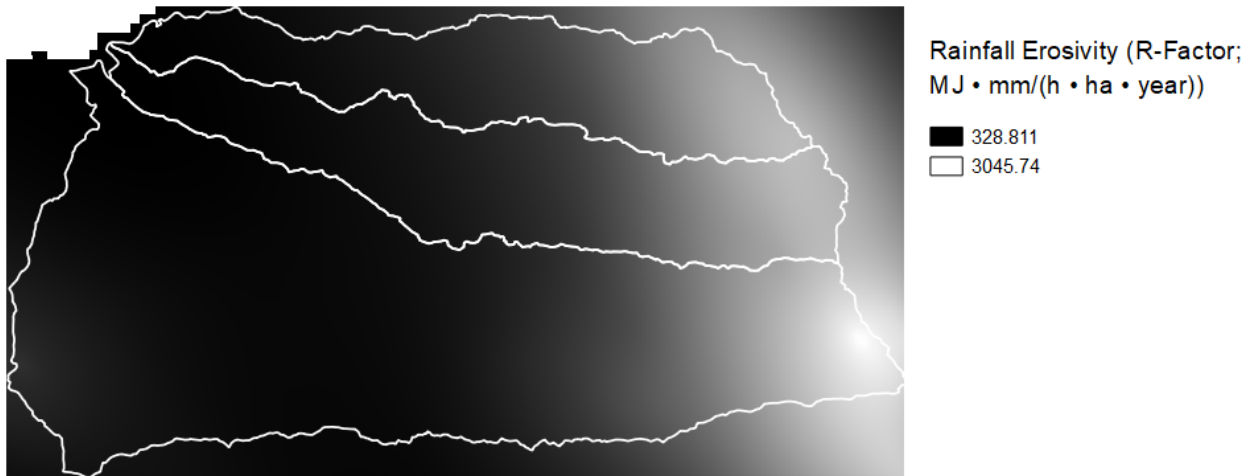
### **Example Use of the Procedure**

To illustrate the Step-by-Step Procedure, this section looks at an example watershed: Kaiaka Bay. The Kaiaka Bay watershed is on the coast of the island of Oahu. The Kaiaka Bay and several streams that drain into the bay are listed as impaired. Both invasive plant species and feral ungulates are thought to cause high levels of erosion in this watershed, making the Kaiaka Bay watershed a good example watershed for the procedure (AECOM et al., 2018). The GIS data inputs for the InVEST model must all be in the same projected coordinate reference system, so every GIS data input is in the NAD83 coordinate reference system. The data inputs used for running the model with current conditions are below:

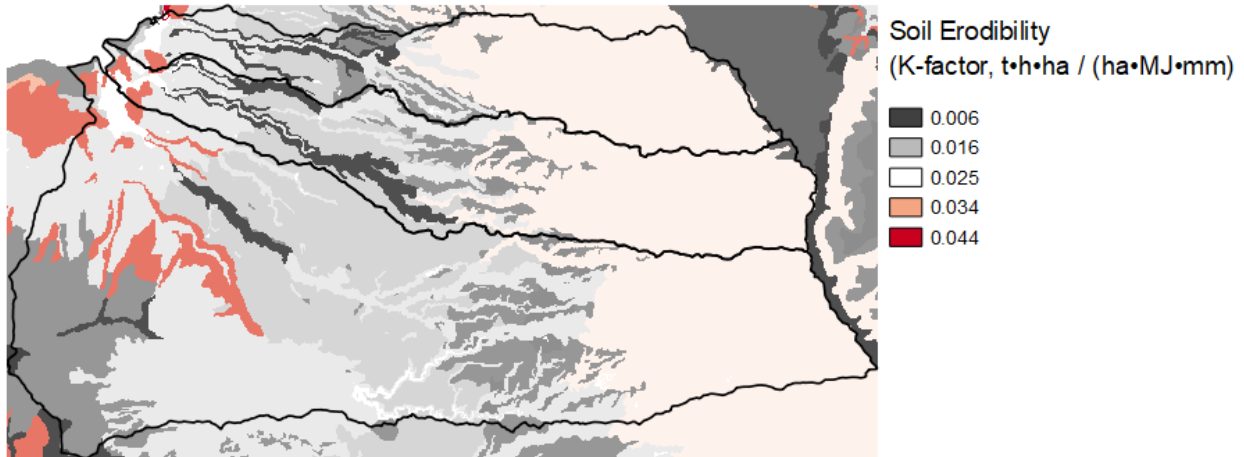
- Elevation Map: A DEM raster showing elevation in meters in the Kaiaka Bay and the surrounding area. This raster is a valid input for the InVEST model because the elevation is in meters and it extends beyond the Kaiaka Bay watershed boundary.



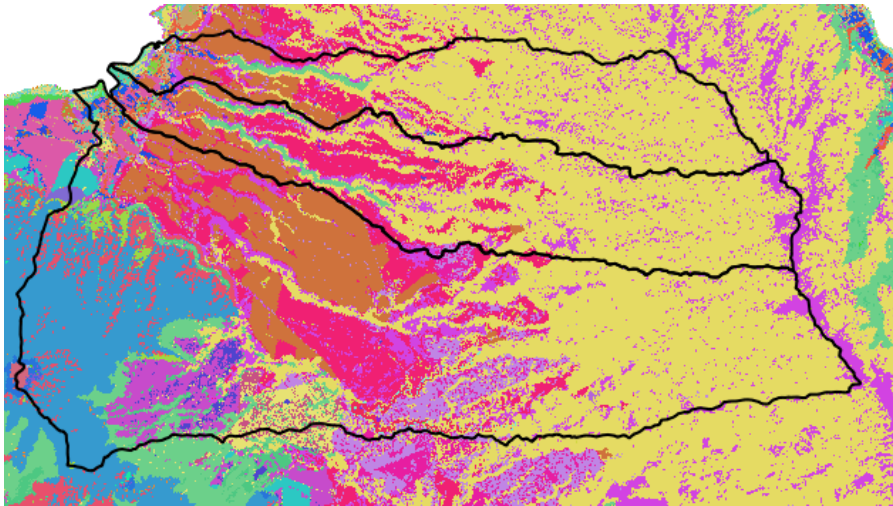
- **Rainfall Erosivity:** A rainfall erosivity map in raster format showing the rainfall erosivity throughout the Kaiaka Bay watershed in  $\text{MJ} \cdot \text{mm}/(\text{h} \cdot \text{ha} \cdot \text{year})$ , the units required by the model.



- **Soil Erodibility:** A map showing soil erodibility, or K factors, within the Kaiaka Bay watershed in raster format. The values in the raster format are in the proper units for the model,  $\text{t} \cdot \text{h} \cdot \text{ha} / (\text{ha} \cdot \text{MJ} \cdot \text{mm})$ .

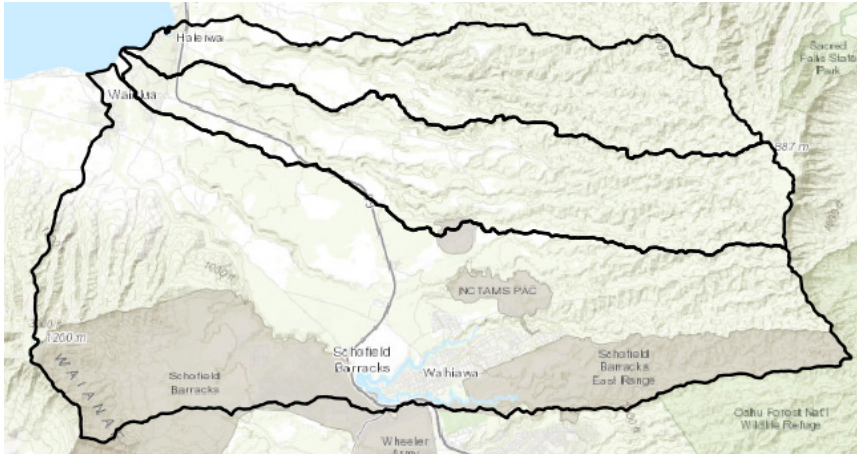


- Land Use & Land Cover and Geologic Formation: A raster categorizing the land in Kaiaka Bay watershed by their land use/land cover and their geologic formation. This raster has over 1000 land cover/geologic formation categories, but not all categories have pixels that belong to them. Each land cover/geologic formation category has a unique LULC code so that this raster can be connected to the biophysical table.



- Watershed boundary: A vector outlining the Kaiaka Bay watershed.

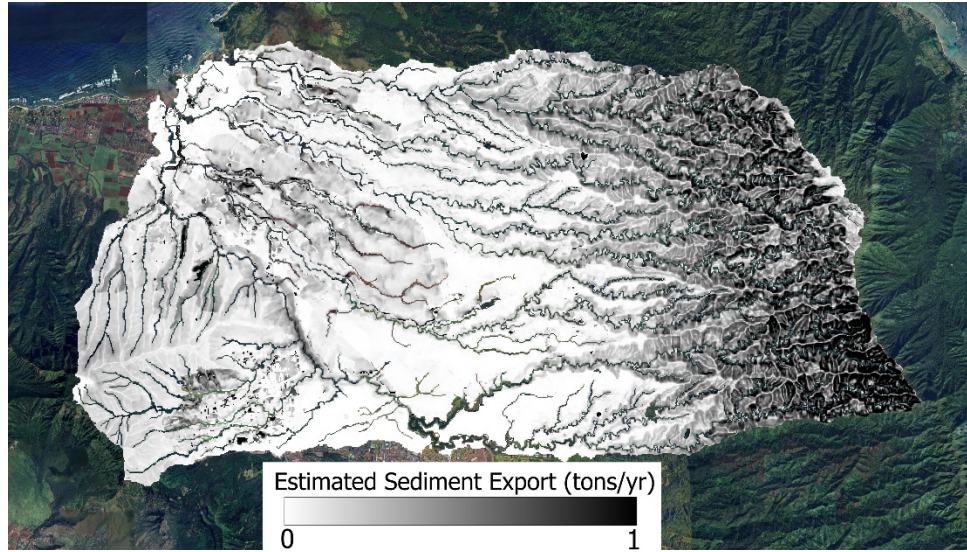




- Threshold Flow Accumulation: 200. Value was derived through trial and error, and was identified when the delineated stream network approximately matched the “real” stream network for the watershed.
- Borselli k Parameter: The Borselli k parameter for this model run is 2.5, the value for all watersheds on Oahu.
- Maximum SDR Value: The maximum SDR value for this model run is 0.5, the value for all watersheds on the state of Hawaii.
- Maximum L Value: The maximum L value for this model run is 122, the value for all watersheds on the state of Hawaii.
- Biophysical Table: The biophysical table for this model run contains a column with each LULC code from the land use and land cover raster. Each LULC code is mapped to a modified C factor that is the original C factor from Table 4 multiplied by the terrain factor from Table 5 or the geologic origin associated with the LULC code. For example, a small piece of land in the Kaiaka Bay watershed is scrub shrub land (C factor = 0.014) with beach deposits as its geologic formation (terrain factor = 0.1), so the modified C factor in the biophysical table is 0.0014. The P factor for every LULC code is 1 because no support practices have been implemented in this watershed.

Once the inputs have been gathered, the baseline scenario is run. The model outputs suggest that a disproportionate amount of sediment export is occurring in the mountainous area of the Kaiaka Bay watershed. The sediment export raster is shown below:





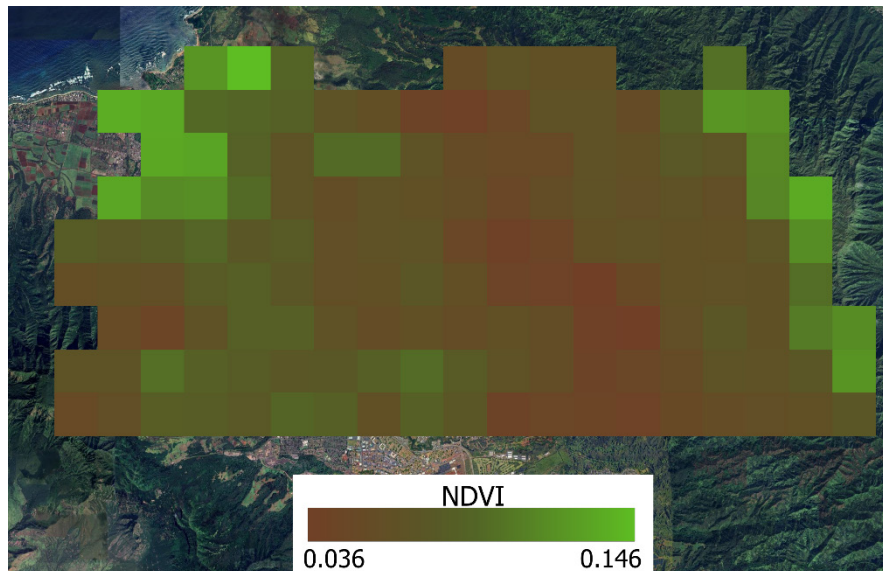
This raster indicates that the model expects the highest amount of sediment export to occur at the higher elevations of the watershed, but as discussed in the Step-by-Step Procedure section, the InVEST model tends to overestimate sediment export in high elevation areas. For this reason, multiple lines of evidence are considered when deciding on the locations for BMP implementation in this example. To determine the land class/land uses that contribute the most to sediment export relative to their area in the watershed, the pounds of sediment exported per acre is important evidence to evaluate as well. This value is calculated by adding the sediment export for every pixel in each land use/land cover and then dividing this sum by the acres each land use covers in the watershed. For example, bare land covers 405 acres of land in the Kaiaka Bay watershed and the model estimates that 1790.5 pounds of sediment are exported from bare land each year, so the pounds of sediment load per acre per year for bare land is 1790.5 divided by 405 which is 4.42. The sediment load per acre for each land use is shown in Table 6.

**Table 6: Pounds of Sediment Load Per Acre Per Year by Land Use**

Class	Edge of Stream Sediment Load (lbs/acre/year)
Developed, High Intensity	0.00
Developed, Med Intensity	0.00
Developed, Low Intensity	0.00
Developed, Open Space	0.11
Cultivated Crops	1.08
Pasture/Hay	0.26
Grassland/Herbaceous	0.44
Evergreen Forest	1.37
Scrub/Shrub	0.90
Palustrine Emergent Wetland	0.01
Palustrine Forested Wetland	0.01
Palustrine Scrub/Shrub Wetland	0.01
Estuarine Forested Wetland	0.03

Class	Edge of Stream Sediment Load (lbs/acre/year)
Estuarine Scrub/Shrub Wetland	0.23
Unconsolidated Shore	0.00
Bare Land	4.42
Open Water	0

This table indicates that bare land areas contribute the most sediment per acre in the Kaiaka Bay watershed, so bare land within the watershed may be a beneficial target for BMP implementation. Planting native plant species could minimize the sediment load coming from areas that are currently bare land by transforming it into vegetative cover (or evergreen forest in terms of land cover classes). Currently, bare land covers 405 acres of the watershed and the sediment export from this land is 1790.5 pounds. To calculate the amount of sediment load from this land after BMP implementation, assuming all the bare land becomes evergreen forest, the acres of bare land should be multiplied by the sediment load per acre for evergreen forest. This returns a value of 554.85 pounds of sediment load per year from this land, a 1235.65 pound decrease. These calculations should be considered when selecting locations for BMP implementation, but additional evidence should be evaluated as well. As discussed in the Step-by-Step Procedure section, NDVI data can be useful evidence as well. The NDVI data in raster format for the Kaiaka Bay is below:



The pixels with a lower NDVI index, which are shown in darker brown, are less vegetated areas. This image indicates that the middle section of the Kaiaka Bay watershed is less vegetated, so BMP implementation could be especially valuable in this area. However, the resolution of this raster data is low, so it is difficult to use it to precisely choose locations for BMP implementation. Therefore, other evidence such as high-resolution satellite images and drone footage can be used to pinpoint areas with minimal or invasive vegetation. As an additional line of evidence, people familiar with the Kaiaka Bay watershed can be interviewed to collect information on areas with minimal vegetation, invasive plants and/or feral ungulates. Furthermore, a person can walk along streams in the Kaiaka Bay watershed and document the most eroded areas. The information gathered from the InVEST model run, the NDVI index

raster, satellite images, drone footage, interviews and documentation from someone on site should all be carefully considered when determining where BMPs should be implemented.

### **Useful Resources and Materials**

To supplement the information included in this addendum, more information on the InVEST model and using this model in the state of Hawaii is linked below:

- More information on the InVEST sediment ratio delivery model including background information, required data inputs, and guidance on interpreting outputs is here: [SDR: Sediment Delivery Ratio — InVEST® documentation](#)
- More information on the InVEST Delineatelt tool discussed in the Step-by-Step Procedure to create watershed boundaries: [Delineatelt — InVEST® documentation](#)
- Further details on the Kaiaka Bay watershed: [Kaiaka Bay Watersheds Characterization](#)
- For more information on running the InVEST model for watersheds in Hawaii, including the rationale for many of the non-GIS inputs see Predicting Sediment Export into Tropical Coastal Ecosystems to Support Ridge to Reef Management [dissertation], available for download here: [\(PDF\) PREDICTING SEDIMENT EXPORT INTO TROPICAL COASTAL ECOSYSTEMS TO SUPPORT RIDGE TO REEF MANAGEMENT](#)

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