Wahikuli-Honokōwai Watershed Management Plan

Volume 1: Watershed Characterization

A component of the West Maui Ridge to Reef Initiative

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NOAA CORAL REEF CONSERVATION PROGRAM

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Production Note: The Wahikuli-Honokōwai Watershed Management Plan has been developed as a two volume document: *Volume 1: Watershed Characterization* (this document), and *Volume 2: Strategies and Implementation*. The complete plan characterizes the project watersheds (Volume 1); recommends pollution control strategies, outlines implementation strategies, provides evaluation and monitoring protocols, and describes education and outreach approaches (Volume 2).

Executive Summary

Healthy coral reefs are vital to our culture, way of life, and economy. Long-term coral reef monitoring has shown that coral reefs in northern Kāʻanapali have declined by as much as 50%. The West Maui region is currently targeted by Federal, State, and private entities for watershed planning efforts with the goals of reducing stressors to and improving the overall health of coral reefs, nearshore waters, and watersheds. The Honolulu District of the U.S. Army Corps of Engineers (USACE) and Hawaiʻi Department of Land and Natural Resources Division of Aquatic Resources (DLNR-DAR) are the lead government agencies for the West Maui Ridge to Reef (R2R) Initiative, covering five watersheds from Wahikuli to Honolua.

Over the past century, land use in this region has resulted in export of land-based pollutants that have impaired the water quality of nearshore ocean waters and adversely impacted the marine ecosystem. Land-based pollutants generated across large areas and from diffuse sources are commonly referred to as non-point source (NPS) pollutants. Pollutants are transported off the watersheds in both surface water and groundwater and delivered into the ocean at various rates and total loads. Two of the most problematic land-based pollutants identified by scientists are nutrients (Nitrogen and Phosphorus) and sediment.

To address the issue, the National Oceanic and Atmospheric Administration (NOAA) Coral Program has sponsored a Watershed Management Plan (WMP) for two watersheds, Wahikuli and Honokōwai, as part of the West Maui R2R Initiative. The *Wahikuli-Honokōwai Watershed Management Plan* (WHWMP) is composed of two volumes: *Volume 1: Watershed Characterization*, and *Volume 2: Strategies and Implementation*. The WHWMP will provide a template for WMPs to be developed for other West Maui watersheds. It adheres to the Environmental Protection Agency (EPA) Clean Water Act (CWA) Section 319 guidelines for watershed plan development. These guidelines require use of a holistic, watershed based approach to identify sources and sinks of NPS pollutants, and the remedial actions necessary to reduce their loads to receiving waters. The complete WHWMP characterizes the project watersheds (Volume 1); and recommends pollution control strategies, outlines implementation strategies, provides evaluation and monitoring protocols, and describes education and outreach approaches (Volume 2).

Volume 1 of the WHWMP summarizes the current and proposed future environmental conditions of Wahikuli and Honokōwai Watersheds, with an emphasis on identifying pollutant sources and types. It was developed using existing data and information, field investigations, interviews with people with historic and current knowledge of land uses and activities, and geospatial data analysis using geographic information system (GIS) software. In general, surface water and groundwater flow and quality data are limited spatially and temporally in the watersheds. As a result, calibration and validation of hydrologic models to estimate NPS pollutant concentrations in runoff and groundwater is challenging. However, sufficient qualitative information exists for making informed inferences about where and what types of pollutants are generated, and the flow paths that carry them into ocean receiving waters. General estimates of NPS pollutant loadings from major sources within the watershed have been made where possible based on available data and assumptions as noted. This information is important for targeting management recommendations.

Land in the two watersheds falls within three Land Use Districts as defined by the State of Hawaiʻi and progressing from mountain to sea: Conservation, Agricultural, and Urban. The Conservation

District encompasses the upper most sections of the watersheds extending up to their divides at the crest of the mountains. Conservation District lands function as a reservoir, capturing high rainfall, and slowly releasing rain that soaks into its surfaces to sustain stream flows and recharge underground aquifers. The lands within the steep mountainous terrain host pristine native flora and fauna communities that are being threatened in various areas by alien plant species, illegal dirt bike use, and disturbance of ground cover by feral ungulates. This compromises the ecohydrologic services the forest provides. Management efforts to prevent damage to and restore parcels within the forested areas are carried out by the West Maui Mountains Watershed Partnership. Conservation District lands are minimally discussed in the WHWMP.

The Agricultural District occupies the middle section of the watersheds, with lands primarily used for agricultural activities. For nearly a century sugarcane and pineapple fields covered almost 40 percent of the watersheds (4,570 acres). By 2008 these crops were phased out. From 1999 until mid-2012, seed corn was actively cultivated on a portion of former sugarcane lands (approximately 300 acres planted at any given time). Today, fallow sugarcane and pineapple fields are mostly covered with a mixture of non-native grasses and shrubs. Fallow seed corn fields are becoming covered with grasses and other plants since cessation of cultivation during the summer of 2012. Coffee is currently cultivated on approximately 311 acres, in areas once used to grow sugarcane. Additional tracts of agricultural lands in the Wahikuli Watershed are currently being developed as small scale single owner coffee farms. The plant types on the fallow fields and arid landscape create conditions that make wildfires a constant threat to the area. The main NPS pollutants associated with the Agricultural District are sediment and nutrients.

Dirt roads dissecting the Agricultural District are a significant source of sediments and a primary transport route of these sediments and those derived from adjacent lands. During field observations, the dirt roads were found to be in variable condition. Some roads exhibit generally acceptable surface and structural condition, and include management practices to direct surface water runoff off the road surface. However, many road sections are highly eroded, and many management practices in disrepair, generating a disproportionate amount of sediment. Runoff generated within the Agricultural District flows along road surfaces during storm events, dislodging surface soil particles, rutting the roads, and creating channels for runoff to travel rapidly downslope into natural drainage ways. The degree to which this occurs in individual locations is a function of many factors, including road slope, contributing drainage area, and presence/operating condition of management practices. Several roads are unstable where they cross streams and gulches, with slopes actively eroding into the drainage channels and no measures in place in some areas to prevent downstream transport of sediment.

Wahikuli Watershed is estimated to contribute more sediment from its agricultural fields than Honokōwai Watershed. The Honokōwai Watershed agricultural lands are primarily covered by vegetated fallow pineapple fields, and to a lesser extent, vegetated fallow sugarcane fields. Conversely, active and fallow fields in Wahikuli Watershed have less vegetative cover compared to Honokōwai, which is the primary reason for higher erosion rates. The fallow seed corn fields are found primarily in Wahikuli Watershed. During the cultivation era, a portion of the rotated acres used to cultivate seed corn were left bare and therefore highly vulnerable to erosion, soil loss, and sediment export. Fugitive dust was generated off of the bare plots, and has been identified as a nuisance in the past by residents located downwind.

Annual soil loss was estimated using the Revised Universal Soil Loss Equation (RUSLE2) model for active and fallow fields. Representative fields were chosen for each of the types, and calculated soil loss rates were compared to tolerable losses.[1] The results showed that seed corn fields under cultivation generate soil losses at a rate that exceeds tolerable levels by 190-480%; while pineapple, sugarcane, and coffee fields all have soil losses falling within tolerable limits. Given that general surface conditions for seed corn fields have not changed substantially since cultivation ceased, it is reasonable to assume these levels are still accurate.

The total amount of fertilizers applied per year to all the active fields is far less compared to amounts under the historic pineapple and sugarcane era. Under cultivation, seed corn fields received the lowest application of Nitrogen, Phosphorus, and Potassium of any crop, former or active. The total acreage of coffee fields in production at one time is roughly equal to the area that was planted in seed corn. However, the amount of Nitrogen is 600% higher and Phosphorus is 140% higher per year compared to seed corn. Sugarcane had the highest Nitrogen and Potassium application of all fields, and depending on the fertilizer mix used, pineapple was highest in Phosphorus applied.

During the sugarcane and pineapple era a portion of the chemicals used to increase plant growth and prevent disease on the crops was most likely transported via surface water and groundwaters into the ocean. These legacy chemicals may still be moving off the watershed via ground and surface waters. Export of chemicals off actively cultivated coffee lands is likely less than during the sugarcane and pineapple era, due to the substantial decrease in cultivated crop area. Future hydrologic studies are recommended to determine the magnitude and timing of Nitrogen, Phosphorus, and other nutrients being exported as a result of historic and active farming practices.

Two county-maintained dams are located in Honokōwai Watershed, on Honokōwai and Māhinahina Streams. The need for these water works was in part due to the acknowledgement by government, land owners, and the public that sediment and nutrients generated off the Conservation and Agricultural lands and delivered to the ocean via these streams was having an adverse impact on the coral reefs. The dams have desilting basins intended to function as sediment traps. The dams are effective in trapping coarse sediments and plant material generated off lands in the Conservation and Agricultural Districts, but their efficiency at capturing fine suspended particulates varies due to their outlet designs. With modifications to their outlets, the existing basins could be more effective in trapping fine particulates over a larger range of discharges. The majority of fallow seed corn fields, active coffee fields, and dirt access roads are in Wahikuli Watershed, which does not drain into either Honokōwai or Māhinahina Streams. In the northern half of Wahikuli Watershed most of the surface water runoff generated from the agricultural fields and roads is routed to a series of sediment detention basins that function to capture both coarse and fine sediments. The southern section of the watershed has only few sediment basins, and runoff from the agricultural areas and roads flows freely into Wahikuli Gulch and other natural drainages. There are no large dams or detention basins within Wahikuli Watershed.

[1] Subsequent to using the RUSLE2 model to estimate sediment losses from seed corn fields, cultivation of this crop ceased. As of December 2012 the fields used for seed corn are fallow and becoming covered with vegetation. The RUSLE2 model was not re-run.

The Urban District encompasses the coastal lands primarily located between the ocean and Honoapiʻilani Highway. The area is known for its beautiful beaches, abundant sunshine, and numerous resort hotels and condominiums. Land uses that potentially generate NPS pollutants include chemicals applied to golf courses and landscaped areas, and runoff generated off impervious surfaces (e.g. roads and parking lots) that cover nearly 50 percent of developed land. Surface water runoff is the primary carrier of NPS pollutants that are by-products of land use and activities (e.g. oil drips) that fall out onto the impervious surfaces. In addition, groundwater is also suspected to be transporting pollutants to the ocean beneath the Urban District

The Maui County owned and operated Lahaina Wastewater Reclamation Facility (WWRF) treats raw sewage collected from the project area's Urban District and areas north to Kapalua and south to Lahaina. The WWRF is subject to Underground Injection Control (UIC) permits administered under the Safe Drinking Water Act (SDWA) to dispose of treated effluent waste water via injection wells. Permits are issued by EPA and Hawaiʻi Department of Health Safe Drinking Water Branch (DOH-SDWB), and require compliance and regular renewal. Both permits are currently expired, although they have been administratively extended. Since expiration of the permits the facility has operated and complied with their provisions, which includes monitoring of the treated effluent water quality (e.g. sediments, biochemical oxygen demand, and nutrients). In addition, the WWRF periodically samples treated effluent for bacteria, chemicals, heavy metals, pesticides, and other compounds designated by EPA and DOH.

The objective of the WWRF is to remove the physical, chemical, and biological contaminants and produce fluid and solid waste (sludge) that is environmentally safe for disposal or reuse. The WWRF employs primary, secondary, and tertiary effluent treatment methods to both physically and biologically remediate contaminants contained in the inflow water. The WWRF currently treats an average flow rate of 4.0 MGD (million gallons per day). During the dry season, up to 1.9 MGD of influent wastewater is treated and reclaimed to R-1 water quality standards (highest level of treatment for reclaimed water), for use as irrigation water on the golf courses and resort areas in Kāʻanapali. Four Class V UIC wells are used for final disposal of excess tertiary treated effluent. Flow rates of injected treated effluent typically range from 2.1 MGD in the dry season to 4.0 MGD during the wettest periods of the year when R-1 water is not being used.

Scientific studies have determined that the some of the treated effluent water flows underground to the ocean, where it discharges as submarine groundwater out two springs located just offshore and north of the Kahekili Beach Park. Scientists hypothesize that the effluent water transports nutrients (e.g. Nitrogen and Phosphorus) and other potential polluting substances (e.g. pharmaceuticals, fire retardant, plasticizer compound) that have negatively impacted the coral reef. Loading rates were calculated for several chemicals found in the effluent using WWRF water quality samples collected during wet and dry periods in 2011. These loading rates were compared to determine the variation in pollutant loading rates injected over the course of the year and the effect that R-1 level reclamation for land irrigation has on the rates of pollutant injection into the wells during the driest periods. Predicted future wastewater flows generated from proposed future development projects are estimated at between 1.6 and 2.0 MGD, resulting in a 40% to 50% increase over the current average flow rate of 4.0 MGD.

The disposal of WWRF treated effluent and its connectivity to and impact on near shore ocean water quality has been the subject of several scientific studies, numerous debates, and a recent lawsuit. This report attempts to objectively present the latest available information and data. Studies on this issue and dialogue between Maui County and the regulatory agencies continue.

Many parcels within Wahikuli and Honokōwai Watersheds have been identified for future development, incorporating single-family, multi-family, and timeshare residential developments. Gradual changes in land use from Agricultural to Urban will increase the amount and extent of impervious surfaces across these areas. Urbanization will introduce new NPS pollutants common to those found in developed landscapes and increase the volume of storm water runoff. Low impact development practices built into the designs of future developments can mitigate changes to the hydrologic regime due to increases in impervious areas.

Volume 1: Watershed Characterization provides a comprehensive though not exhaustive inventory of specific areas of concern and hotspots of NPS pollutant sources identified above within the project area by district (Section 6). In *Volume 2: Strategies and Implementation*, strategies for management of the NPS pollutants that adversely impact water quality and the coral reef ecosystem are presented. The *Implementation Strategy* section discusses elements required to implement a watershed management plan, financial considerations, and necessary technical resources. The *Pollution Control Strategies* section identifies projects and management practices recommended to address identified sources and types of NPS pollutants in Wahikuli and Honokōwai Watersheds. Reduction of pollutant loads is a function of both the types and number of management practices installed. The *Evaluation and Monitoring* section provides programmatic evaluation criteria and describes the types of monitoring necessary to track management practices. This qualitative and quantitative information helps determine their effectiveness and apply the findings to other watersheds. The *Education and Outreach* section provides details on current and planned activities to engage the local community in efforts to reduce NPS pollution in the West Maui Watersheds.

This WHWMP provides a framework for addressing NPS pollutant control in Wahikuli and Honokōwai Watersheds. Implementation of the recommendations is expected to reduce generation and transport of land-based pollutants, resulting in improved water quality and coral reef ecosystem health. The WHWMP provides a framework that can be used as a template for other watersheds within West Maui.

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Acronyms

AOC	Area of Concern
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
C-CAP	Coastal Change Analysis Program
CAP	Conservation Action Plan
cfs	Cubic Feet per Second
CRAMP	Coral Reef Assessment and Monitoring Program
CRWG	Coral Reef Working Group
CTAHR	College of Tropical Agriculture and Human Resources
CWA	Clean Water Act
CWB	Clean Water Branch
CZARA	Coastal Zone Act Reauthorization Amendments
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DAR	Division of Aquatic Resources
DBCP	Dibromochloropropane
DBEDT	Department of Business, Economic Development and Tourism
DCIA	Directly Connected Impervious Areas
DHHL	Department of Hawaiian Home Lands
DLNR	Department of Land and Natural Resources
DO	Dissolved Oxygen
DOFAW	Division of Forestry and Wildlife
DOH	Department of Health
DOI	Department of the Interior
DOT	Department of Transportation
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
F	Fahrenheit
FIRM	Flood Insurance Rate Maps
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Hawaiʻi Administrative Rules
HFMA	Herbivore Fisheries Management Area
HRS	Hawaiʻi Revised Statutes
KLMC	Kāʻanapali Land Management Corp.
KOA	Kāʻanapali Operations Association
LAS	Local Action Strategies
LID	Low Impact Development
MG	Million Gallons
MGD	Million Gallons per Day
MHI	Main Hawaiian Islands
ML&P	Maui Land & Pineapple Company, Inc.
MS4	Municipal Separate Storm Sewer System
msl	Mean Sea Level

NAR	Natural Area Reserve
NCCA	National Coastal Condition Assessment
NH_3	Ammonia
NH_4^+	Ammonium
NO_3^- +	Nitrate
NO_2^-	Nitrite
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPK	Nitrogen/Phosphorus/Potassium
NPS	Non-Point Source
NRCS	National Resources Conservation Service
N-SPECT	Nonpoint-Source Pollution and Erosion Comparison Tool
NURP	National Urban Runoff Program
PSA	Pacific Subtropical Anticyclone
R2R	Ridge to Reef
RUSLE2	Revised Universal Soil Loss Equation
S4	Separate Storm Sewer System
SDWA	Safe Drinking Water Act
SDWB	Safe Drinking Water Branch
SMA	Special Management Area
SRGII	Sustainable Resources Group Intn'l, Inc.
TCP	1,2,3 Trichloropropane
TMDL	Total Maximum Daily Load
Total N (TN)	Total Nitrogen
Total P (TP)	Total Phosphorus;
TNC	The Nature Conservancy
TNL	Total Nitrogen Load
TSS	Total Suspended Solids
UH	University of Hawaiʻi
UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
USCRTF	U.S. Coral Reef Task Force
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UV	Ultraviolet
WHWMP	Wahikuli-Honokōwai Watershed Management Plan
WMMWP	West Maui Mountains Watershed Partnership
WMP	Watershed Management Plan
WMSWCD	West Maui Soil and Water Conservation District
WTF	Water Treatment Facility
WWRF	Wastewater Reclamation Facility

1. Introduction

The region of Maui referred to as "Kāʻanapali" is defined by two large beaches and extends from Hanakaʻōʻō Beach Park (Canoe Beach) in the south, north to Kahana Beach Park over a distance of approximately 4.4 miles (7.1 km) (Figure 1). *Puʻu Kekaʻa* (Black Rock), the prominent geologic feature that protrudes into the ocean, divides the two beaches. Nearly the entire shoreline along both beaches is lined with hotels and condominiums, hosting visitors and *kamaʻāina* (locals). Climatic conditions, relatively calm seas, and the numerous strips of sandy beaches result in a near idyllic tropical setting. The meticulously manicured and green landscaped areas of the resorts, golf courses, and residential parcels distributed around the courses and in the north section of the region are in contrast to the arid agricultural lands *mauka* (inland) of Honoapiʻilani Highway. Further *mauka* in the upper mountainous sections, the landscape is verdant green due to an abundance of rainfall, which supports the rainforest habitat.

The Kāʻanapali region is ecologically, culturally, and economically valuable to the island of Maui, the State of Hawaiʻi, the U.S. and the world. The off-shore waters attract many recreational users that take advantage of snorkeling, surfing, and other beach activities. Current and potential future agricultural activities provide cash crops. However, the region suffers from coral reef degradation and water quality problems caused in part by land-based pollutants carried in surface water and groundwater into the bay.

1.1 Project Background /Drivers

The larger West Maui region is currently targeted by Federal, State, and private efforts for watershed planning efforts with the goals of reducing stressors to and improving the overall health of coral reefs, nearshore waters, and watersheds. The Honolulu District USACE and Hawaiʻi DLNR-DAR are the lead government agencies for the West Maui R2R Initiative, covering five watersheds from Wahikuli to Honolua (Section 1.2; Figure 2).[2] Land use in this area over the past century has resulted in export of land-based pollutants, which have impaired the water quality of nearshore ocean waters and resulted in adverse impacts to the marine ecosystem. Two of the most problematic land-based pollutants identified by scientists are nutrients (e.g. Nitrogen and Phosphorus) and sediment.[3] Detailed information on the occurrence and impacts of toxic chemicals in the West Maui marine environment is currently lacking.

Two watersheds in the West Maui R2R Initiative, Wahikuli and Honokōwai, located in the Kāʻanapali region of West Maui, are the subject of this *Wahikuli-Honokōwai Watershed Management Plan*.[4] At the Federal level coral reef conservation is primarily addressed by NOAA and the U.S. Coral Reef Task Force (USCRTF) (Appendix C.1). The NOAA Coral Program provided funding for this project, as the USCRTF watershed initiative is a key driver of this project. Wahikuli and Honokōwai Watersheds were selected by the *Hawaiʻi Coral Reef Strategy for 2010-2020* (State of Hawaii 2010), which identified the Kāʻanapali region as one of two priority sites to receive Hawaiʻi Coral Reef Program funding and technical support in the initial three to five years. The priority objective is to

[2] http://www.hawaiicoralreefstrategy.com/index.php/prioritysites/westmaui

[3] Unless otherwise stated, the use of the word sediment pertains to soil or rock particles that are transported in suspension in runoff water. Total sediment load includes both suspended sediments, and particles and rocks that are transported as bed load (bounced along and pushed).

[4] Throughout this document, the term "project area" is used to refer to the Wahikuli and Honokōwai Watersheds.

reduce key anthropogenic threats to near shore reef areas by 2015. The WHWMP will provide a template for WMPs to be developed for the other West Maui watersheds.

1.2 Key Stakeholders and Related Efforts

The WHWMP is one part of a larger watershed-based management planning effort in West Maui. People and organizations that have a stake in the outcome of a watershed management plan are called stakeholders. They make and implement decisions, are affected by decisions made, and have the ability to assist or impede implementation of actions selected to address impaired water quality. Funding partners are those entities that have in the past, or will in the future, provide funds to support their own or other's watershed management planning or implementation efforts. Participating partners are those entities that play a direct or indirect role in watershed management planning or implementation efforts. Many of the key stakeholders in the West Maui region are listed in Table 1, however the list is not exhaustive and does not fully reflect efforts being conducted concurrent to the development of this plan to engage more members of the local community.

Table 1. Key Stakeholders in West Maui Watershed Management Efforts

Funding Partners
NOAA Coral Program. Fiscal sponsor of this watershed plan; implementing a stormwater demonstration project; funding watershed coordinator position for West Maui region.
NOAA Office of Ocean and Coastal Resource Management. Fiscal sponsor of this watershed plan.
US Army Corps of Engineers. Funded feasibility study. Facilitating development of West Maui Watershed Management Plan.
US Environmental Protection Agency. Funding for implementation projects to improve water quality. Technical expertise. Water quality monitoring and permitting to assess and potentially regulate pollution levels.
Hawai'i Department of Land and Natural Resources. Plays a project management role, leading development and implementation of specific components of West Maui Watershed Plan depending on agency mandate and expertise.
DLNR Division of Aquatic Resources. Primary agency responsible for coordinating Hawai'i's reef management efforts in the main Hawaiian Islands. Uses the Hawai'i Coral Reef Strategy to guide activities. The DLNR-DAR coral program supports critical program support, planning efforts, community action, awareness-raising activities, and scientific research with direct management applications. Key outcomes of this work include greater capacity to enforce coral reef protections, increased understanding of the key threats to reef ecosystems at priority sites, and substantial progress towards implementing objectives of the Hawai'i Coral Reef Strategy including the LAS's.
DLNR Division of Forestry and Wildlife. Agency responsible for managing State lands in the Conservation District.
DLNR Commission on Water Resource Management. Agency responsible for setting policies and approving water allocations for all water users and administering a statewide in-stream use protection program.
Hawai'i Department of Health. Oversees State water quality monitoring and beach closures. Issues permits for point source discharges and construction sites > 1 acre. Funding for implementing management practices through CWA Section 319 funding.
National Fish and Wildlife Foundation. Funding and administration for implementing management practices.
USDA National Resources Conservation Service. Funding for cost-share implementation of conservation practices on eligible private lands.
Participating Partners
US Coral Reef Task Force. Provides guidance and priority setting for protecting Nation's coral reefs.
US Geological Survey Pacific Islands Water Science Center. Clearing house for water resource information, including surface water and groundwater.

USGS Pacific Coastal & Marine Science Center. Conducts scientific research on source and content of groundwater discharge.
NOAA Hawaiian Humpback Whale National Marine Sanctuary. Coordinates education, research and resource protection activities, to protect humpback whales and their habitat in Hawaiʻi.
West Maui Soil and Water Conservation District. Provides conservation planning and technical assistance with management practices to facilitate soil and water conservation. Reviews and approves conservation plans on agricultural lands.
Hawai'i Coastal Zone Management Program. Provides guiding perspective for the design and implementation of allowable land and water uses and activities throughout the state.
Maui County. Various departments (Table C1)
West Maui Mountains Watershed Partnership. A State-sponsored effort, watershed partnerships are voluntary alliances of public and private landowners committed to the common value of protecting large areas of forested watersheds for water recharge and conservation values. The WMMWP was formed in November 1998 covering 50,000 acres (20,234 ha) of the West Maui Mountains. Management priorities include: feral animal control; weed control; human activities management; public education and awareness; water and watershed monitoring; and management coordination improvements.
The Nature Conservancy. Manages Kapunakea Preserve in Conservation District. Conducting Conservation Action Plan (CAP) process to strengthen conservation planning efforts in the Kahekili region.
Community stakeholders. Concerned citizens, home and condo owners associations, resort operators, commercial entities, volunteer groups, and citizen environmental groups. Many community stakeholders are landowners. Integral role in planning, and supporting implementation of management practices to reduce generation and transport of NPS pollutants.

The WHWMP will be both complimentary and consistent with a series of research and planning efforts that are being conducted in the region including:

Related Efforts
Hawaiʻi Coral Reef Strategy, with specific regard to priority site M-7 (Kāʻanapali-Kahekili). The region is one of two priority sites that will receive program funding and technical assistance support from the Hawaiʻi Coral Management Grant during the initial 3–5 years (2011-2015).
Hawaiʻi Coral Reef Initiative Research Program. Established in 1998 as a partnership between the University of Hawaiʻi (UH) and DAR. The program looks at the link between human activities and damage to the coral reef ecosystem in order to provide managers information to effectively prevent and possibly reverse coral reef degradation. The Pacific Science Association, Bishop Museum and The Nature Conservancy assist in collaboration. This program is funded through NOAA's Center for Sponsored Coastal Ocean Research and the Coral Program.
West Maui Ridge to Reef Initiative. The project goal is to increase West Maui ecosystem resiliency by improving the habitat of coral reefs and nearshore waters through reduction of land-based pollution threats from the summit of Puʻu Kukui to the outer reef. It is jointly sponsored by USACE and DLNR with funding support from NOAA. Other partners include DOH, NOAA, EPA, NRCS, WMMWP, National Fish and Wildlife Foundation, and many others (Figure 2). The West Maui R2R Initiative study area covers approximately 24,000 acres (9,712 ha), includes five watersheds (Wahikuli, Honokōwai, Kahana, Honokahua, and Honolua), and extensive coral reef habitat. USACE chose to prioritize this section of West Maui due to funding constraints. The West Maui R2R Initiative will expand on breadth and detail of the WHWMP to meet other requirements. The West Maui Watershed Plan is planned for completion by 2015. This project is being driven by stakeholder participation and will: identify critical threats to reefs and watershed health; evaluate solutions to these threats from ridge to reef; prioritize actions; and implement restoration or remedial actions. Other benefits include enhanced management and collaboration through greater interagency communication, improved data sharing, education of scientists and government officials, and building local technical capacity.

Related Efforts
West Maui Mountains Watershed Management Plan, managed by WMMWP outlines the cost and contents of a comprehensive plan for the 50,000 acres (20,234 ha) of forest and watershed vegetation occupying the summit and slopes of the West Maui Mountains. Focus areas of management priority include: 1) Feral animal control, 2), Weed control, 3) Human activities management, 4) Public education & awareness, 5) Water and watershed monitoring, and 6) Management coordination improvements. The version of the plan from 1999 is being revised in 2012.
ML&P (Puʻu Kukui Watershed Preserve), established in 1988 to protect watershed forest and associated native plants and animals. At over 8,600 acres, the Puʻu Kukui Watershed Preserve is one of the largest privately-owned nature preserves in the state. Watershed monitoring, conservation, research and protection efforts have continued over the two decades and works closely as an active management partner in the WMMWP. ML&P's conservation team actively manages the preserve.
Kahekili Conservation Action Plan, managed by The Nature Conservancy. The Kahekili CAP was completed in early 2012. The goal of the CAP was to develop priority strategies for implementation to address existing and future threats facing coral reef ecosystems in these regions.
USDA-NRCS West Maui Coral Reef Initiative. This NRCS landscape initiative is targeting $1.2 million in priority funding through September 2014 towards the implementation of conservation practices benefitting coral reef habitat surrounding West Maui. The initiative offers cost-share incentives to eligible applicants to participate in volunteer land conservation programs such as the Environmental Quality Incentives Program and Wetlands Reserve Program. Additionally, the initiative is providing specialized technical assistance for conservation plan development and design, and it will evaluate the water quality improvement effectiveness of installed practices.
Maui Coastal Use Mapping Project, conducted as a partnership of DAR, NOAA Pacific Islands Regional Office, NOAA Pacific Services Center, and the NOAA Coral Program. The project is mapping significant human uses (including range and intensity) of the nearshore area in the Honolua-Wahikuli region to inform ocean resource management.
Kahekili Herbivore Fishery Management Area. The problem of coral to algal phase shifts is a concern for many Hawaiʻi reef areas, particularly around heavily populated parts of the state. To address this threat DAR implemented the Kahekili Herbivore Fishery Management Area (HFMA) in the Northern Kāʻanapali area in July 2009. This management effort aims to decrease the growing threat of invasive algae by maintaining the population of algae-eating fish and sea urchins that help to control overgrowth and degradation of coral reefs. State guidelines prohibit the harvest of surgeonfish, parrotfish, chubs, and sea urchins. These management activities are being assessed through a series of agency and community projects. Fish and habitat assessments are conducted within the Kahekili HFMA. Volunteer community projects include herbivore grazing studies, community-based *makai* watch programs, and a community run fishing survey program. These projects aim to involve local fishers and other community members with the end goal of increasing opportunities for community members to work directly with resource managers to conduct monitoring, outreach and voluntary compliance activities and to help the coral reefs flourish in West Maui.
Lahaina WWRF Ground Water Tracer Study.[5] Research is being conducted to evaluate the suspected discharge of pollutants from the WWRF to the coastal waters along the Kāʻanapali coast (Appendix D.2). The tracer study will help pinpoint wastewater movement from the Lahaina injection wells and evaluate the potential impact of the facility's discharge on the coastal waters. UH scientists have injected a tracer dye into the facility's underground injection wells and are monitoring areas where fresh water seeps into the ocean for signs of the dye. Measurements are being taken on how long it takes for wastewater from the WWRF to flow to the near-shore ocean water. Basic water quality will be sampled at identified groundwater discharge points monthly, while certain toxic pollutants will be sampled quarterly.
CORAL (Coral Reef Alliance). CORAL is an international nonprofit organization that works to unite communities to protect our planet's coral reefs. In West Maui CORAL is working with hotels to change their practices and conceptions about wastewater aimed at increasing use of R-1 water.

[5] Funded by EPA, USACE, and DOH; conducted by UH.

1.3 WHWMP Planning Process

1.3.1 Watershed Management Planning

The Federal CWA regulates surface waters of the United States and Section 303(d) requires all States to identify waterbodies that exceed certain water quality parameters. Streams and coastal areas in the region have been identified as "impaired" for various pollutants as not meeting State water quality standards (Section 5.3). The watershed approach, which has been adopted and is supported by the EPA's National Water Program, is a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow.[6] The WHWMP supports the region-wide efforts to protect and restore water quality (Section 1.1) and is in accordance with the EPA's Nine Key Components for Watershed-Based Plans (Box C1). The management practices to improve water quality recommended in this plan will be eligible for Federal funding under CWA Section 319.

A *Watershed Characterization* (this document) is a first step in developing a WMP. It summarizes the general condition of two watersheds in West Maui (Wahikuli and Honokōwai), with an emphasis on the sources, transmission, and fate of land based pollutants. A watershed is a unit of land that drains runoff to a common outlet. The characterization forms the basis for identifying management practices to remediate pollutants. Characterizing a watershed from ridge to reef (including lands *mauka* to *makai* (ocean)) involves gathering and processing existing data and information to document existing watershed conditions. The characterization provides a mechanism to evaluate watershed processes and determine if land uses and activities are generating NPS pollutants, altering the hydrologic regime and ecological processes, and causing adverse impacts to the watershed's ecosystem. Analyzing existing data and information to characterize the watershed and pollutant sources provides the basis for developing effective management strategies to meet watershed goals (EPA 2008). The watershed characterization includes conducting field work to assess and inventory watershed conditions to identify sources and sinks of land based pollutants; and interviewing and soliciting *mana'o* (wisdom) from community members and others with knowledge of the area. This information is used to describe the watershed condition, the uses and activities that take place in the watersheds, and how these uses and activities may or may not impact the generation and transport of NPS pollutants from the land to streams, rivers, and ultimately the ocean.

A complete watershed characterization utilizes a multi-disciplinary scientific approach to assess and make inferences on the ecosystem processes, resource conditions, and historical changes due to cumulative effects of management practices. A series of concepts and categories, as presented in EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters*, have been used to document the watersheds of the Kāʻanapali region: population and land use; physical and natural features; waterbody condition and monitoring data; and pollutant sources (EPA 2008).[7] Gaps in data and knowledge bases are identified and suggestions included for additional information needs and future priorities (Section 6.8).

[6] Details can be found at http://water.epa.gov/resource_performance/planning/.

[7] See http://www.epa.gov/nps/watershed_handbook/.

1.3.2 Data Compilation

Data collection was performed using a combination of information review of published and grey literature in digital and hard copy formats, GIS data from various sources, and infield ground observations and assessments of existing conditions. High resolution satellite images were used to locate and visually identify geographic elements in preparation for field work and throughout the development of the watershed characterization. Data and information collected during the field work phase were recorded into GPS data loggers, on hard copy site maps, and in field books.

1.3.2.1 GIS

When describing the physiographic characteristics of watersheds, GIS is a useful tool for analyzing and showing spatial relationships between various features of a watershed. GIS helps to graphically present spatial data to depict distances and discern relationships such as those between various land uses and land cover types, possible pollutant sources, and water quality measurements. Non-geographic data (e.g. research findings) can be associated with GIS data to qualify and further explain these relationships and interactions. The resulting maps give a visual overview of watershed characteristics.

Sustainable Resources Group Intn'l, Inc. (SRGII) compiled a large geodatabase of GIS data for the project area. Data layers were obtained from various available public sites and project partners including NOAA, DOH, Hawai'i Department of Business, Economic Development and Tourism (DBEDT), and Maui County. SRGII used watershed boundaries defined in a data layer obtained from the DBEDT website. Other GIS layers and maps were then clipped to the project watersheds' area for further analysis. The high resolution satellite imagery was used as the visible background for analysis and figures depicting features on the watersheds. GIS was used to further analyze spatial relationships and create maps showing land uses, land cover, soils, landowners, water quality sampling areas and other relevant features of the project watersheds. This data was also used to compute areas/sizes of various features for the watershed characterization.

For all layers used, datum is North American Datum of 1983 and projection is Universal Transmercator Zone 4 North (NAD83 UTM4N). Unless specified all calculations are based on GIS data available from the Hawai'i GIS Data Repository, hosted by the Office of Planning.[8]

1.3.3 Field Work

Prior to conducting field work extensive efforts to collect background information via telephone and email communications to stakeholders were undertaken. This allowed SRGII to familiarize stakeholders with the project, obtain permission to access land parcels, schedule meetings, and arrange tours of numerous parcels. A primary objective of the field work was to ground truth locations within the watersheds that appear on the satellite imagery and GIS layers. Locations observed on the ground were entered into a GPS data logger and/or on hard copies of the satellite imagery, and subsequently brought into GIS. Informal interviews with and information solicitation from stakeholders during field work assisted in preparing a comprehensive characterization of the watershed general conditions, land uses, and pollutant inputs. Integral to the collection of field work data was the historic and current information regarding land use, land practices, and specific

[8] http://www.state.hi.us/dbedt/gis/

points of interest within the watershed provided by various stakeholders. Photos collected during field work illustrating various lands uses and conditions are presented in Appendix B.

1.3.3.1 Reconnaissance Phase

During the reconnaissance field work phase, general observations were made to identify the location and condition of major drainage networks and land uses within the project area. In addition, initial visual observations helped to preliminarily identify pollutant sources and areas of concern within the Agricultural and Urban Districts. The reconnaissance efforts and subsequent field work benefited significantly from background and logistical information acquired during an in-person meeting with Wes Nohara and two employees of Kāʻanapali Land Management Corp. (KLMC) that took place prior to the field reconnaissance.

1.3.3.2 Inventory Phase

The inventory phase of field work built upon initial observations made during the reconnaissance phase and stakeholder meetings. Eight days were spent conducting inventory and assessments: five days within the Agricultural District, and three days within the Urban District. An inspection of specific pollutant inputs, hotspot areas, drainage courses, and assessment of land conditions within the Agricultural and Urban Districts was conducted using GPS, marked up satellite images, and logging photos of areas of interest.

To characterize the Conservation District lands, meetings with Chris Brosius and Sarah McLane of West Maui Mountains Watershed Partnership (WMMWP) aided in the identification of activities causing active generation of nonpoint source pollutants. Extensive tours of the Agricultural District with Wes Nohara (West Maui Soil and Water Conservation District (WMSWCD)) and Pomakaʻi Kaniaupio-Crozier (Maui Land & Pineapple Company, Inc. (ML&P) and WMSWCD) were integral in creating an overall picture of the historic and current land use, practices, dams and desilting basins, and areas of pollutant input. Interviews with WWRF personnel on facility operations; informal interviews with resort and business personnel; observations of irrigation practices; storm sewer mapping; and inspection of resort land use practices created a comprehensive Urban District characterization.

Although SRGII was unable to conduct tours of all parcels with landowners in the project area, the consistency in land use of properties within the Districts enabled generation of a characterization that reflects the overall project area.

1.3.4 Stakeholder Participation

The National Fish and Wildlife Foundation, with the support of NOAA and DLNR-DAR, hired a West Maui Watershed and Coastal Coordinator in March 2012. The Coordinator is tasked with assisting in comprehensive planning for the West Maui Project Area with a focus on building community networks and educating stakeholders. The Coordinator plays a main role in gathering public input and communicating the findings of the WHWMP. Public engagement in this process is key to success as implementation of recommendations will, to the degree possible, be accomplished through community projects. The Coordinator helps to facilitate this process by providing technical assistance in developing partnerships and projects that align with needs identified in the WHWMP.

Development of the Watershed Characterization (this document) involved interviews, field visits, data exchange, and meetings with project partners and stakeholders (Section 1.2 and Appendix G). Subsequent to developing a working draft, meetings were held with major landowners and managers to provide background on the WHWMP, confirm information being presented (e.g. operational procedures, land use, and activities), and obtain information on management practices. The Watershed Characterization was updated based on the input provided in these meetings to insure accurate descriptions. Key findings were presented to the community to provide a comprehensive picture of the pollutant sources in the project watersheds, confirm information, and solicit input for management practices to address pollution issues. A draft report was made available for public review, and comments were incorporated into the final version.

As a means to ensure regular, timely stakeholder input into this plan and follow-on implementation, the Coordinator has formed a working group of people who are actively engaged in the project area and represent the diversity of uses and interests in the Kāʻanapali region. This working group includes representation from recreational users, land owners, agricultural operations, cultural representatives, environmental groups, natural resource conservationists, visitor industry, and government agencies. The working group is chaired by DLNR and is intended to provide feedback, propose and champion implementation projects, as well as assist in the dissemination of information back to the respective interest groups.

In addition to regular meetings with the Working Group, the Coordinator is engaging with groups or individuals throughout the plan development and implementation process. This may take the form of one-on-one consultations, or attending meetings, functions, trainings or events involving interested/relevant stakeholders. A website (www.kaanapaliwmp.com) has been established to inform stakeholders about the project, key findings, and meetings, and to provide a way of receiving input.

2. Watershed Planning: Setting the Context

2.1 Overview of WHWMP Project Area

This section provides an overview of the WHWMP project area, and discusses the geographic scope, general characteristics, and issues of concern that exist within the two watersheds in respect to pollutant generation.

2.1.1 Geographic Scope

The Kāʻanapali region is located on the west side of the island of Maui. Wahikuli Watershed covers 6,420 acres (2,598 ha), has 3.9 miles (6.3 km) of shoreline, and has a maximum elevation of 5,120 ft (1,561 m). Honokōwai Watershed covers 5,631 acres (2,279 ha), has 1.7 miles (2.7 km) of shoreline, and has a maximum elevation of 5,720 ft (1,744 m) (Photo WH1, WH2) (Figure 1).

Land use in the Wahikuli and Honokōwai Watersheds falls into three general land use types that correspond to three State Land Use Districts: Conservation, Agricultural, and Urban (Section 3.3.1; Figure 3). Although all three Districts are described in detail in this watershed characterization. management practices are only recommended for the Agricultural and Urban Districts. Specific management practices to control NPS pollutants within the Conservation District are being developed separately by the WMMWP (Section 1.2). In total, the project area covers 8,256 acres (3,341 ha) of the 12,051 acre (4,877 ha) watersheds, including the full 5.6 miles (9.0 km) of watershed shoreline. The remaining upper 3,795 acres (1,536 ha) are under WMMWP management.

2.1.2 Watershed Characteristics

The overall condition and land use of Wahikuli and Honokōwai Watersheds varies spatially within the project area. The majority of the Conservation District is moderately to steeply sloped forested lands that have not been impacted directly by development, but are subject to ongoing impacts from humans and non-native (introduced) animals. Non-native plants and animals, especially ungulates, have altered the naturally occurring vegetation communities, reducing their distribution and density. Changes in vegetative cover and damage induced by non-native ungulates have been widely reported by scientists studying Hawaiian ecosystems. These changes cause adverse impacts to ecological functions and hydrology of many watersheds.

Large tracts of land in the Agricultural District consist of fallow sugarcane and pineapple fields covered with a mixture of non-native vegetation; as well as large tracts of fallow seed corn plots that are largely bare of vegetation. Active coffee fields are vegetated and cover a portion of the former sugarcane fields. Wahikuli Watershed is a combination of fallow seed corn and sugarcane, active and fallow coffee, and grazing areas. Honokōwai Watershed consists primarily of fallow pineapple fields, with fallow sugarcane, a small section of coffee fields, and grazing areas south of Honokōwai Stream. Past agriculture practices, and to a lesser degree the current ones, significantly altered the landscape and impacted the hydrology of surface water and groundwaters.

The Urban District contains resort complexes, residential housing, commercial properties, golf courses, the WWRF, and the Kapalua-West Maui Airport. Small patches of natural open spaces (e.g. shrubs, wetlands, and parks) are found throughout the project area. Impacts to the watershed in this area include covering large areas with impervious surfaces, generation of a variety of NPS pollutants as part of land uses, and hardening of the shoreline. Maintenance of landscaped areas around resorts, residential properties, and golf courses are suspected sources of nutrients. Stevenson (1997) reported high Nitrogen and Phosphorus in urban runoff in West Maui, noting that Phosphorus consisted almost entirely of orthophosphate, a highly soluble form readily available for terrestrial plant and marine algae uptake. The primary source of dissolved Phosphorus was determined to be fertilizer application. While seemingly benign, the pollutants and alterations to the runoff regime from the urban areas, combined with impacts from the agriculture and conservation areas, have cumulatively resulted in degradation of the ocean waters fronting the two watersheds. Further detail on landowners and land uses in the two watersheds is found in Section 3.3.2.

2.1.3 Issues of Concern

Coral reefs and nearshore waters along the two watersheds have been and continue to be impaired and degraded by land-based pollutants. Land-based pollutants are carried into the nearshore waters via surface water and groundwaters, and disrupt the biogeochemical processes of the ocean waters, resulting in stress to corals and proliferation of invasive algae. Land-based pollutants of primary concern include sediment and nutrients (Nitrogen and Phosphorus). These pollutants are generated across all areas of the watersheds both from natural processes (background) and human uses (accelerated). Movement of sediments sourced from agricultural runoff has been ongoing for decades and continues presently even though most of the historically active fields are now fallow. Rates of erosion and sediment delivery from the agricultural lands are most probably occurring at rates and with loads less than during active plantation era farming. Stevenson (1997) observed generally low total suspended sediment and Phosphorus contributions from the forest reserve lands; and low Ammonium-Nitrogen levels as compared to agricultural sites. Transport of sediment into the ocean is associated with surface water runoff generated by moderate to heavy rainfall. Streams within the two watersheds are dry during most of the year, with flashy flows occurring during storm events.

Sediments are the product of soil erosion off land surfaces and along streams and gulches draining the watersheds. Single intense storms can carry the majority of sediment load over a year and temporarily inundate the coastal waters with nutrients and sediment (Soicher and Peterson 1996). The amount of sediment generated is a function of rainfall, ground cover, and slope. When plantations dominated the West Maui landscape, agricultural lands contributed the majority of the sediment and nutrient load in Honokōwai Stream (Soicher and Peterson 1996). Accelerated erosion rates on lands altered by feral ungulates and human uses occur across large areas in the Agricultural and Conservation districts but the relative sediment loads of the current land uses has not been determined.

Nutrients are moved in both surface water and groundwater, occurring in runoff along with sediments and more chronically in groundwater discharged along the coast in submarine seeps and springs. Soicher and Peterson (1996) reported on an annual basis that groundwater sources of Nitrogen and Phosphorus appear to exceed those from stream flow. Accelerated nutrient inputs result from fertilizers applied to agriculture fields and landscaped areas, and from disposal of treated wastewater effluent into the ground. The soils and aquifer of West Maui may also contain a legacy load of Nitrogen and agro-chemicals from the ~100 years of agricultural use.

Other NPS pollutants that are generated on the watersheds and carried in surface waters and groundwaters include: pathogenic and non pathogenic strains of bacteria; viruses; metals; and organics and other chemicals used in pesticide, herbicide, and petroleum products. These other pollutants can adversely impact water quality, induce stress to aquatic organisms, reduce recreational opportunities, and transmit disease to both humans and animals. While these pollutants are detrimental to the health of the ecosystem, the main pollutants of concern, due to historic and current inputs, are sediment and nutrients. Additionally, though not a pollutant itself, excess water generated off impervious surfaces during rainstorms can be problematic in that it carries pollutants that accumulate on the ground surface. The water can also increase erosion rates and sediment generation.

2.2 Regulatory Environment

Understanding the regulatory environment is essential for establishing a clear picture of water quality issues and ultimately solutions (Appendix C). There are numerous Federal, State and county agencies that have responsibility related to implementing activities related to controlling polluted runoff and maintaining water quality. Some of these entities have a role in promoting both regulatory and voluntary approaches. Implementation of management measures is most effectively done through economic incentives or by regulatory drivers. Regulatory approaches work best when adequate mechanisms are in place to provide oversight and enforcement. Appendix C summarizes the key agencies and regulations that address point source and NPS pollutants.

2.3 Summary of Previous Reports and Information

Watershed and stream resources in West Maui have been studied by a range of public and private entities including University of Hawaiʻi researchers, Federal and State agencies (e.g. U.S. Department of the Interior (DOI), U.S. Fish and Wildlife Service (USFWS), USACE, U.S. Geological Survey (USGS), and DLNR-DAR) and other organizations (e.g. The Nature Conservancy (TNC), WMMWP, ML&P (Puʻu Kukui Watershed Preserve)). Available information ranges from previous plans developed for management of the West Maui watersheds to the amount and type of anthropogenic inputs found in the waters of Maui.

Several key reports characterize overall health of the project area watersheds and provide guidance with respect to water quality and watershed degradation. These efforts are largely concentrated in the agricultural and urban areas. Most of the research studies have focused on wastewater pollutant contributions from the WWRF to the coastal waters of the project area. The presence of disposed effluent from the injection wells at the WWRF has now been confirmed in coastal waters by multiple researchers, most recently through the use of algal bioassays and dye injection. Summaries of key reports are provided in Appendix D.

3. Population and Land Use Characteristics

This section characterizes population and land use within the watersheds. It begins with a discussion of the general historic anthropogenic impacts to the West Maui region, followed by current socio-economic statistics.[9] A summary discussion of the major land owners and land managers within the watersheds follows. Future development projects acknowledged by the County of Maui's Long Range Planning Division are also included. Describing these past, present, and future population and land use characteristics assists in identification and quantification of land-based pollutants from the region that enter the off-shore waters.

3.1 Anthropogenic Impacts

During the formation of Maui, and for many millions of years following, the hydrologic cycle (Box 3) was unaffected by human impacts. During this time fluvial processes eroded the landscape carving streams and creating steep ridgelines that define the watershed boundaries we see today. Early residents of the Kāʻanapali region engaged in fishing, gathering and subsistence agriculture. The first anthropogenic impacts to the region likely resulted from Polynesian settlers who diverted a portion of water out of the streams and into taro and fish *loʻi* (patch). Extraction of resources (i.e. plants and animals) occurred from the upland forests, low-lying coastal areas, and the ocean. Impacts to the hydrologic cycle by Polynesian settlers were likely minimal. A second wave of human contact to the island, beginning in the 1800s, was by peoples of European and Asian ancestry. These groups brought animals and resource extraction techniques that significantly altered vegetation communities in the coastal zones and inland forest. They also brought diseases that decimated the Hawaiian population. By the early 1900s large tracts of land within the larger west Maui region were actively used for sugarcane and pineapple production. The nearby ocean waters were frequented by whalers who hunted and used landings to resupply their boats.

Although commercial agriculture was well established in the Kāʻanapali region by the first half of the 20th century, development to support a growing residential population and commercial tourism interests accelerated during the second half. The urban environment near the shoreline and associated uplands has been built up to support the residential and commercial needs. Major hotels in Kāʻanapali were built between 1962 and 1982. In addition to residential housing, hotels, and condominiums, the Kāʻanapali region has two golf courses (Royal Kāʻanapali Golf Course and Kāʻanapali Kai Golf Course), Kapalua-West Maui Airport, and various associated services (e.g. restaurants, gas stations).

According to the 2010 US census there are approximately 155,000 people living on Maui, with over 8,000 people living in the West Maui area between Kāʻanapali and Nāpili. In addition to residents, the area attracts thousands of visitors each year due to the available recreational opportunities and commercial facilities. Both the historical land use, and the current agricultural and residential/commercial land uses, contribute to the land-based pollution that is impacting the quality of stream and ocean waters and coral reef health.

[9] Anthropogenic impacts are those caused by human activity.

3.2 Socio-Economics

The 2010 census determined that the median household income for Maui from 2006 to 2010 was $63,989. The per capita income for 2010 was $29,180. Over the past two decades agriculture and tourism have been the primary economic activities in the Kāʻanapali area. The majority of agriculture, historically pineapple and sugarcane, has ceased. Although coffee is still cultivated in this region, agriculture does not provide the number of jobs and monies to the local economy as it once did. A portion of the former agricultural lands in the Kāʻanapali region are either proposed or committed for future development (Section 4.3.3).

The visitor industry generates more than 80% of Maui County's economic activity and provides 75% of all private sector jobs (County of Maui 2009). DBEDT reports that there were 2,186,279 visitor arrivals to the island of Maui in 2010, with each visitor spending an average of $173 per day. Tourism accounted for a total of nearly $3 billion spent on Maui in 2010. West Maui has beautiful beaches, reefs for snorkeling and diving, and mountainous scenery. Although many people stay in the resort, hotel and condominium facilities in West Maui region, many tourists staying at other parts of the island travel to West Maui to enjoy these scenic amenities. The tourism industry employs an estimated 3,000 people in the Kāʻanapali region. The lack of affordable housing in this area means that workers must commute to Kāʻanapali from other parts of Maui.

3.3 Land Use

Land use within the watersheds is characterized by three State-designated Land Use Districts, and can be divided further within each District by land owners and/or managers. Future land use projects for the project area are also included, to show how planned developments within the various Districts may affect the types of land-based pollutants generated.

3.3.1 Land Use Districts

All lands in Hawaiʻi are assigned to one of four Land Use Districts as defined by the Hawaiʻi Land Use Law, Chapter 205 Hawaiʻi Revised Statutes (HRS): Conservation, Agricultural, Urban, and Rural. Land within the Wahikuli and Honokōwai Watersheds falls into three of these district types: Conservation, Agricultural, and Urban (Table 2; Figure 3). Generally speaking, the current land uses occurring within each of the Land Use Districts match the type of District (e.g. agricultural use in the Agricultural District, urban use in the Urban District) although in terms of actual development it is not always an exact match.

A series of plans, the *Countywide Policy Plan*, the *Maui Island Plan* and the *West Maui Community Plan*, were developed to provide general guidance on how growth will be accommodated in Maui County (Appendix C.5.3). The *Maui County Code* provides ordinances with more specific details on land use planning and zoning in terms of development (Appendix C.5.3.4). The County has multiple zoning provisions that are regulated by Title 19 of the *Maui County Code*. These provisions govern zoning issues within multiple districts on a case by case basis. Each district has regulations on the types of structures, land uses, and subdivisions that can occur.

3.3.1.1 Conservation District

Lands in the Conservation District are administered by DLNR's Office of Conservation and Coastal Lands. Lands designated Conservation District are located in the middle to upper elevations of the two watersheds with the exception of a small coastal parcel of conservation land at the southern end of the Wahikuli Watershed (Figure 3). Within the project area, the upper third of Honokōwai Watershed is classified as protective, or most environmentally sensitive; while the remaining Conservation District area is zoned as resource, the third-highest environmental sensitivity (Appendix C.5.3.5).

Most of the Conservation District lands are contained within one of three parcels: the 695 acre (281 ha) West Maui Forest Reserve, the 803 acre (325 ha) Honokōwai Section of the West Maui Natural Area Reserve (NAR), and the 1,339 acre (542 ha) Kapunakea Preserve. In both watersheds, the Conservation District boundary generally runs parallel to the slope contours and varies between elevation 1,100 ft (335 m) and 2,100 ft (640 m) mean sea level (msl). Land within the Conservation District accounts for 31% of the total land area within Wahikuli and Honokōwai Watersheds (Table 2). WMMWP manages the lands in the upland Conservation District (Section 3.3.2).

Human uses in the Conservation District are primarily recreational (e.g. hiking). There are no known commercial activities that take place, nor are there any dwellings except for a cabin used by personnel conducting forest restoration activities. Potential proposed activities or construction of structures, of which none are known, would be required to secure a Conservation District Use Permit.

3.3.1.2 Agricultural District

Jurisdiction of the Agricultural District is shared by the State Land Use Commission and County of Maui (Appendix C.5.3.6). The County of Maui is responsible for zoning within the Agricultural District, as is also the case for the other counties of Hawaiʻi. Within the Agricultural District, the WMSWCD works with land owners and land managers to provide conservation planning.[10] In the past, WMSWCD has worked with KLMC to produce a draft conservation plan, and is currently working with them on a management and cultural practices plan.

The Agricultural District extends from the WMMWP management boundary downslope to the Honoapiʻilani Highway, and the lower limits vary in elevation from 50 ft (15 m) to 300 ft (91 m) msl (Figure 3). Land within the Agricultural District accounts for the majority (54%) of the total land area within Wahikuli and Honokōwai Watersheds (Table 2).

Table 2. Land Use Districts[11]

Land Use District	Wahikuli (acres)	Wahikuli (%)	Honokōwai (acres)	Honokōwai (%)	Total Area (acres)	Total Area (%)
Conservation	1,464	23	2,302	41	3,766	31
Agricultural	3,393	53	3,088	55	6,481	54
Urban	1,563	24	241	4	1,804	15
Watershed Total	**6,420**	**100**	**5,631**	**100**	**12,051**	**100**

[10] Conservation Plans are developed in coordination with NRCS to help land owners better manage the natural resources on farms. They help to address the soil, water, air, plant, and animal resources and offer conservation practices for implementation to address these resources.

[11] Data derived from the Office of Planning, State of Hawaiʻi DBEDT GIS Program, 'State Land Use Districts'.

3.3.1.3 Urban District

The State Land Use Commission and the County of Maui share jurisdiction of the Urban District (Appendix C.5.3.7). The Urban District extends from the coastline to both the *mauka* and *makai* sides of the highway. The upper limits of the urban area vary between elevation 50 ft (15 m) and 350 ft (107 m) msl in terms of actual development, although parcels classified as Urban by the State Land Use Districts occur as high as 400-600 ft (122-183 m) msl elevation (Figure 3). Land within the Urban District accounts for 15% of the total land area within Wahikuli and Honokōwai Watersheds.

3.3.2 Major Land Owners, Managers, and Uses

Table 3 lists the major landowners within the Conservation, Agricultural, and Urban Districts.[12] As illustrated, WMMWP is responsible for management of nearly all Conservation District parcels within the project area. Of the total acreage under WMMWP management, KLMC is the largest landowner. Within the Agricultural District, KLMC is the largest landowner in Wahikuli Watershed and ML&P owns the largest acreage of land in Honokōwai Watershed. The Urban District is comprised of smaller parcels with a multitude of individual owners. As shown, several land owners (e.g. KLMC and ML&P) have holdings in multiple districts (Figure 4 and Figure 5).

Table 3. Major Land Owners and Land Managers[13]

Land Owners and/or Land Managers	Wahikuli (acres)	Honokōwai (acres)
Conservation District	**1,464**	**2,302[14]**
West Maui Mountains Watershed Partnership (WMMWP)[15]	1,459	2,302
Kāʻanapali Land Management Corp. (KLMC)	332	1,007
Government: State: Forest Reserves	486	317
Government: State: Natural Area Reserves	N/A	695
Government: State: Other	N/A	133
Maui Land & Pineapple Company, Inc. (ML&P)	N/A	141
General Finance Corporation	635	N/A
Other (Private or unidentified parcels less than 10 acres)	11[16]	9[17]
Total identified landowner acreage	**1,453**	**2,293**

[12] Due to variations in average lot size within each of the districts, the following minimum areas were used to define a major land owner: Conservation District - 30 acres (12 ha); Agricultural District - 30 acres (12 ha); Urban District - 10 acres (4 ha).

[13] Data derived from the Office of Planning, State of Hawaiʻi DBEDT GIS Program, 'TMK', 'State Land Use Districts', 'Reserves'; KLMC-provided map of their lands; and Maui County Parcel ID website: http://agis10g.co.maui.hi.us:8080/agis/map/viewer.jsp.

[14] Totals for each district are the sum of the 'Other' and 'Total identified landowner acreage' rows.

[15] WMMWP is not a landowner. The entire upland Conservation District of the Wahikuli and Honokōwai Watersheds is managed by WMMWP. This area consists mainly of: West Maui Forest Reserve; the Honokōwai section of the West Maui NAR; and the Kapunakea Preserve (Figure **6**). The acreages shown are the area in the Conservation District under WMMWP management. These acreages are not part of the total. In addition, there are 34 acres in Honokōwai Watershed's Agricultural District managed by WMMWP.

[16] This is the Wahikuli Wayside Beach Park, located along the shoreline (5 ac.), Kahoma Land Co. LLC (4 ac.), and Kamehameha Schools (3 ac.).

[17] This is unidentified parcels less than 10 acres (5 ac.), and Kamehameha Schools (4 ac.).

Land Owners and/or Land Managers	Wahikuli (acres)	Honokōwai (acres)
Agricultural District	**3,393**	**3,088**
Kāʻanapali Land Management Corp. (KLMC)	2,174	294
Maui Land & Pineapple Company, Inc. (ML&P)	N/A	1,445
Government: State	860	1,173
General Finance Corporation	312	N/A
Other (Unidentified parcels less than 10 acres)	47	176
Total identified landowner acreage	**3,346**	**2,903**
Urban District	**1,563**	**241**
Royal Kāʻanapali Holdings, LLC	279	N/A
Kāʻanapali Land Management Corp. (KLMC)	230	N/A
Honua Kai Resort and Spa	40	N/A
SVO Pacific Inc. (Westin)	27	N/A
The Westin Kāʻanapali Ocean Resort Villas	14	N/A
The Westin Kāʻanapali Ocean Resort Villas North	12	N/A
Hale Kāʻanapali Condominiums	11	N/A
The Maui Ocean Club (Marriott)	17	N/A
Campbell Hawaii Investor LLC (The Westin Maui Resort and Spa)	12	N/A
The Vintage at Kāʻanapali	17	N/A
Papakea Resort (Aston)	N/A	12
Lanikeha Owners Association	17	N/A
HMC Maui LP	30	N/A
Kāʻanapali Operations Association	19	N/A
KBHL LLC	11	N/A
Kyo-ya Co Ltd	23	N/A
Villas at Royal Lahaina	11	N/A
Government: State	176	47
Other Private Residential/Commercial (Parcels are less than 10 acres (4.1 ha): Residential/Commercial/Condos)	617	182
Total identified landowner acreage	**946**	**59**
Watershed Total	**6,420**	**5,631**

West Maui Mountains Watershed Partnership

The Conservation District in the upper part of both watersheds contains protected forest reserve land that is managed and maintained by the WMMWP (Figure 6). The WMMWP is part of the Watershed Partnerships Program, which is funded by the NAR Special Fund, established by HRS §195-9. The WMMWP was formed in November 1998 covering 50,000 acres (20,234 ha) of the West Maui Mountains.[18] The purpose of the WMMWP is to collaboratively manage these lands for the protection of the West Maui Watershed and to prevent further degradation. ML&P (Puʻu Kukui

[18] The original WMMWP Memorandum of Understanding was signed November 20, 1998, by and between C Brewer and Company, Limited; Kamehameha Schools Bishop Estate, ML&P, Amfac/JMB Hawaii LLC, Maui County Board of Water Supply, DLNR and TNC as major land owners, and the County of Maui.

Watershed Preserve) is an active partner in the WMMWP and also supports its own conservation team to manage the upper watershed from the summit of Puʻu Kukui to the lower boundary of the preserve.

Kāʻanapali Land Management Corp.

KLMC is a local land holding company with parcels in both watersheds, primarily in the Conservation and Agricultural Districts, and a small portion in the Urban District. KLMC is a partner in the WMMWP and supports WMMWP's efforts by granting a conservation easement of its *mauka* lands to TNC. This, in turn, supports the management of the watershed and the protection of its rare species. It is in KLMC's best interest to retain and maintain the soil within their lands, as it, along with the water, are necessary and valuable resources (J. Rebugio, pers. comm.).

Within the Agricultural District, KLMC is committed to preserving agriculture through Kāʻanapali Farm Services, their subsidiary.[19] Kāʻanapali Coffee Farms, a 300 acre (121 ha) private agricultural community (located *mauka* of Kāʻanapali Beach Resort) offers 4 to 7 acre (1.6–2.8 ha) farm lots for purchase. Each lot is part of the working coffee farm, growing Kāʻanapali Estate Coffee. KLMC sells private production lots to buyers and creates a plantation style ownership, with KLMC managing production on 80% of the lot and 20% of the lot available for the owner to use for house lot development or for other agricultural interests (J. Rebugio, pers. comm.). Approximately half of the total area occupied by the coffee fields is within the agriculture subdivision, with the farming of coffee done under lease of the lot to the lot owners' association; with the association contracting a general farmer (J. Rebugio, pers. comm.). Several additional master planned development projects are proposed on KLMC lands (Section 3.3.3).

Until production ceased in mid-2012, 1,288 acres (521 ha) of KLMC agricultural fields were leased for seed corn production. Of this, 600 acres (242 ha) was actively used for crop production and rotated annually so that at any one time 300 acres (121 ha) would have seed corn growing. The other 688 acres (278 ha) was unfarmable lands, roadways, and infrastructure not part of the active fields. There are also fallow sugarcane fields on KLMC lands.

In the Urban District, KLMC owns land on which a proposed 240 acre (97 ha) master planned community, Puʻukoliʻi Village Mauka, would include mixed residential, commercial, community, and open space.

Maui Land & Pineapple Company, Inc.

As a landholding and operating company, ML&P owns approximately 22,000 acres (8,903 ha) of land on the Island of Maui, with nearly half of it dedicated to Conservation and active conservation management, including 141 acres within the project watersheds. Only a small portion [1,588 acres (643 ha)] of ML&P lands are in the Honokōwai Watershed. ML&P is a partner in the WMMWP and has participating lands in the Honokōwai Watershed, including a portion of their 8,824 acre (3,571 ha) Puʻu Kukui Watershed Preserve. ML&P was one of the first large land owners in the State to protect and manage upper forested areas of land, and has been a leader managing upper watersheds for the protection of water resources and native flora and fauna. ML&P also holds lands in the Agricultural District of Honokōwai Watershed. All ML&P fields *makai* of Honokohau Ditch

[19] See www. kaanapaliland.com

were actively cultivated as sugarcane until the 1980's when conversion to pineapple began (W. Nohara, pers. comm.). The lands *mauka* of Honokohau Ditch and north of Honokōwai Stream within Honokōwai Watershed were pineapple already and had been since the 1950's. Conversion of the lower fields to pineapple gradually progressed in a southerly direction toward Honokōwai Stream until 2000, when fields began to be phased out and left abandoned. In 2008, active ML&P pineapple cultivation ceased altogether. ML&P's lands within the Agricultural District are now primarily vegetated fallow pineapple fields. ML&P is dedicated to conservation, agriculture, operation of resorts, and creation and management of holistic communities.[20] ML&P also operates the Kapalua Resort Community along the shore in the Urban District.

State of Hawai'i

The State of Hawai'i holds a significant amount of land within the Wahikuli and Honokōwai Watersheds. These lands are administered by various State departments, with DLNR administering multiple parcels within the Conservation and Agricultural Districts.

In the Conservation District, the State owns land in both Wahikuli and Honokōwai Watersheds. Protected Conservation District areas include: the West Maui Forest Reserve administered by DLNR-Division of Forestry and Wildlife (DOFAW) Forest Reserve System; the Honokōwai Section of the West Maui NAR administered by DLNR-DOFAW Natural Area Reserves System; and the Kapunakea Preserve administered in partnership by DLNR and TNC.

State-owned lands in the Agricultural District of Honokōwai Watershed contain former sugarcane and pineapple fields, whereas land in the Wahikuli Watershed was limited to sugar cane cultivation. A portion of these lands are owned by the Department of Hawaiian Home Lands (DHHL) and are identified on GIS distributed by the State. Other lands under State ownership in the two watersheds do not contain parcel information in GIS as to the department or division that manages them. Although a portion of the DHHL lands within Honokōwai Watershed were recently leased to KLMC for growing of seed corn, since seed corn cultivation has ceased, the DHHL lands remain fallow (J. Rebugio, pers. comm.).

The Kapalua-West Maui Airport, within the Urban District of Honokōwai Watershed, was acquired by the State of Hawai'i in 1993 after previous private ownership. The airport is administered by the Airports Division of the State Department of Transportation (DOT). It is managed by the Maui Airport District, located at Kahului Airport in Kahului. The airport includes a single runway with terminal and support facilities.[21] It is served only by commercial propeller air carriers and commuter/air taxi aircraft, and operations are limited to daylight hours. Access to the airport is via a two lane road at the intersection of Honoapi'ilani Highway.

General Finance Corporation

General Finance Corporation provides storage containers, trailers and other types of accommodation units.[22] It serves various industries such as agriculture, construction and government. General Finance Corporation is technically one of the partners of the WMMWP although they do not have a signed memorandum of understanding at this time. Their WMMWP

[20] See www. mauiland.com
[21] See http://hawaii.gov/jhm/airport-information
[22] See www. generalfinance.com

managed lands in the Conservation District are in the Wahikuli Watershed. Their Agricultural District lands are in the Wahikuli Watershed and consist of fallow sugarcane fields dominated primarily by vegetative cover.

Kahoma Land Company, LLC

Kahoma Land Company, LLC, formed in 2000, is a *hui* (organization or partnership) made up primarily of Maui residents. The *hui* was established to acquire and manage several land tracts and various Land Commission Awards. Kahoma Land Company, LLC is a partner in the WMMWP with lands in the Wahikuli Watershed.

Kamehameha Schools

Bishop Estate is the largest private land holder in the State of Hawaiʻi. Income from the trust of the estate is used to run Kamehameha Schools. Part of Kamehameha School's mission includes protecting the environment and recognizing the significant cultural value of the land, the flora and the fauna. Kamehameha Schools owns approximately 1,000 acres (405 ha) within the WMMWP managed lands. A very small portion of this is in the Honokōwai Watershed.

Royal Kāʻanapali Holdings, LLC (Kāʻanapali Golf Resort)

Royal Kāʻanapali Holdings, LLC owns the Kāʻanapali Golf Resort, located at 2290 Kāʻanapali Parkway. The resort is situated on 1,200 acres (486 ha) of land within the Urban District of the Wahikuli Watershed. The property includes two 18-hole golf courses: the Royal Kāʻanapali and the Kāʻanapali Kai.[23] The Royal Kāʻanapali course is a 6,700 yard, par 71 design that opened in 1962. The recently renovated layout begins at sea level and extends into the West Maui mountain foothills. The Kāʻanapali Kai Course is a 6,400 yard par 70 design that was renovated in 2008.

Major Resort and Condominium Ownership

Major land owners and managers of resorts and condominiums occupying over 10 acres of land within the Urban District are included in Table 3.

3.3.3 Future Land Use

The Maui County Department of Planning's Long Range Division provides information on development projects that have come to their attention. There are several proposed projects in the Wahikuli and Honokōwai Watersheds (Table 4; Figure 7). Projects identified as "Planned/ Committed" have the appropriate conforming Community Plan and zoning entitlements, are approved agricultural subdivisions, are approved 201G/H projects, or are Department of Hawaiian Homelands projects. Projects identified as "Planned/Designated" have urban or rural Community Plan designations but not the conforming zoning entitlements to proceed. Projects identified as "Proposed" are currently lacking urban or rural Community Plan designations. Future land development projects do not necessarily require a change in Land Use District designation for development, as some projects will conform to the existing District requirements (e.g. Kāʻanapali Coffee Farms, an agricultural subdivision located in the Agricultural District). However, any conflict between District requirements and characteristics of a development is required to be approved by the Land Use Commission. Since 1,570 ac. of "Planned/Committed" projects have the appropriate

[23] See www.kaanapaligolfcourses.com

zoning entitlements, 1,621 ac. of future development may or may not have conflicts with zoning (527 ac. of Planned/Designated projects plus 1,094 ac. Proposed projects).

As Table 4 illustrates, there are eight "Planned/Committed" future development projects in the Kāʻanapali region, the largest of which is the Honokōwai – DHHL project, encompassing 781 acres of land, the vast majority of which is located in Honokōwai Watershed. The Kāʻanapali Lower 'North' Honokōwai project is the largest "Planned/Designated" project, 332 acres in size, and is situated entirely on KLMC lands in Wahikuli Watershed. The four projects designated as "Proposed" are relatively similar in size, between 235 and 312 acres. In total, 26% of the land area within Wahikuli and Honokōwai Watersheds has been identified as potential future development projects; half of which have the necessary Community Plan and zoning entitlements.

Table 4. Future Development Projects[24]

Name of Project	Extent (ac)	Percentage of Total Watershed Area[25]	Single Family Units	Multi-Family Units	Time Share and Hotel	Current State Land Use District
Planned/Committed						
Honokōwai – DHHL	781	6.48	1,250	0	0	Agricultural
Hyatt Regency Maui Timeshares	19	0.16	0	0	131	Urban
Kāʻanapali Coffee Farms	337	2,80	67	0	0	Agricultural
Kāʻanapali Residences – Landtech Parcel 10-H	8	0	18	0	0	Urban
Lanikeha Kāʻanapali	109	0.904	132	0	0	Urban
Puʻukoliʻi Villages	300	2	292	648	0	Urban
Villages of Leialiʻi Ph. 1B (Portion)	13	0.11	253	0	0	Urban
West Maui Breakers	3	0	0	90	0	Urban
Total	**1,570**	**13**	**2,012**	**738**	**131**	**N/A**
Planned/Designated						
Kāʻanapali Ocean Resort Villas SVO Pacific (N.B. Lot 3)	16	0.13	0	0	390	Urban
Kāʻanapali Lower 'North' Honokōwai	332	2.76	275	330	0	Agricultural
Leialiʻi HHFDC Community (Portion)	167	1.39	4,000	0	0	Urban
Total	**527**	**4.27**	**4,275**	**330**	**390**	**N/A**
Proposed						
Kāʻanapali Lower 'East' Honokōwai	303	2.51	225	0	0	Agricultural
Kāʻanapali Lower 'South' Honokōwai	235	1.95	410	630	0	Agricultural
Kahoma Lots (Portion)	312	2.59	55	0	0	Agricultural
Pulelehua	244	2.03	533	349	0	Urban
Total	**1,094**	**9.08**	**1,223**	**979**	**0**	**N/A**
Grand Total	**3,191**	**26**	**7,510**	**2,047**	**521**	**N/A**

[24] Data derived from Long Range Planning Division, Department of Planning, County of Maui, map titled *West Maui Development Projects –Northern Extent - Kapalua to Lahaina Town*, February 15, 2011.

[25] Calculated as extent of development (ac.) divided by total watershed area of 12,051 ac. (Honokōwai Watershed: 5,631 ac..; Wahikuli Watershed: 6,420 ac.).

4. Physical and Natural Features

4.1 Watershed Boundaries

A watershed is a geographical area sharing a common location that surface water runoff concentrates or is drained to, e.g. the mouth of a stream. Watershed boundaries are formed by topographic divides, and within any size watershed smaller subwatersheds can be delineated within a larger watershed boundary.[26] Subwatersheds range in size depending on factors including their specific purpose and their land contouring. For example, when determining impervious area contributions to runoff volume, a parking lot could potentially be considered a subwatershed. In urbanized areas, manmade drainage features such as pipes and other drainage structures can convey runoff across natural topographic watershed boundaries and increase or decrease the watershed area artificially. In addition, ditches that divert water from a stream located in one watershed can carry water to a second watershed, adding water to the latter.

4.1.1 Wahikuli Watershed

Wahikuli Watershed covers 6,420 acres (2,598 hectares) and is approximately 6.8 miles (10.9 km) long by 1.4 miles (2.3 km) wide at its midpoint (Figure 1). It is triangular in shape and bounded by Kahoma Watershed on its southern side, Honokōwai Watershed on its northern side, and the coastline on its western side. The Wahikuli/Kahoma boundary runs in an easterly direction from the coastline of Wahikuli Park to a highpoint in the West Maui Mountains at elevation 5,120 ft (1,561 m). The Wahikuli/Honokōwai boundary runs from this point in a northwesterly direction to the coastline of Honokōwai Point. The western coastline boundary runs southerly from Honokōwai Point to Wahikuli Park and is approximately 3.9 miles (6.2 km) long.

There are three main named drainages in the watershed from north to south: Hanakaʻōʻ ō, Hāhākea Gulch, and Wahikuli Gulch. Additionally, Hāhākea Gulch is fed by Kealiʻi Gulch in the Conservation District upper region. Each of the main stream/gulches terminates at the ocean and in their lower section is dry except for periods following moderate to heavy rainfall (Section 4.7.1).

4.1.2 Honokōwai Watershed

Honokōwai Watershed covers 5,631 acres (2,278 hectares) and is approximately 8.0 miles (12.9 km) long by 1.4 miles (2.3 km) wide at its midpoint (Figure 1). It is bounded by Wahikuli Watershed on its southern side, Kahana Watershed on its northern side, the coastline on its western side, Kahoma Watershed on its southwestern side in the upper reaches, and Honokohau Watershed and the West Maui Mountains on its eastern side. The southern boundary of Honokōwai Watershed runs in a southeasterly direction from the coastline of Honokōwai Point to a highpoint at Puʻu Kukui, elevation 5,720 ft (1,744 m). Most of this southern boundary (7.7 miles/12.4 km) is shared with Wahikuli Watershed, but at elevations higher than Wahikuli, it is bordered by Kahoma Watershed for 0.8 miles (1.3 km). The Honokōwai/Honokohau boundary runs from the high point

[26] The most common way to delineate a watershed boundary is to start at the outlet of stream and identify all lands up to the topographic divides. This delineation is primarily done using GIS software and an elevation model of the ground surface. The boundaries of the two watersheds characterized in this report were delineated by Geographic Decision Systems International in 1995 and are available in digital format from DBEDT. These watershed boundaries and the areas reported are commonly used by planners and others conducting watershed analyses and are the same boundaries used by the USACE West Maui R2R Initiative. These watershed boundaries differ from watershed boundaries delineated by DLNR-DAR, and as a result, areas of the DAR watersheds differ from those archived at DBEDT.

in a northerly direction for 1.7 miles (2.8 km) to a point at elevation 4,450 ft (1,356 m). The Honokōwai/Kahana boundary runs from this point in a northwesterly direction for 7.4 miles (11.9 km) to the coastline of Māhinahina Point. The western coastline boundary runs southerly from Māhinahina Point to Honokōwai Point and is approximately 1.7 miles (2.7 km) long.

There are three main drainages in the watershed from north to south: Pōhakukāʻanapali Stream, Māhinahina Stream, and Honokōwai Stream. Additionally, Honokōwai Stream is fed by Amalu and Kapaloa Streams in the upper regions of the Conservation District. Each of the three main streams/gulches terminates at the ocean and is dry in their lower section except for periods following moderate to heavy rainfall (Section 4.7.1).

4.2 Geology

The geology of Maui is similar to other Hawaiian Islands and is primarily the result of repeated volcanic eruptions. Some geologists hypothesize that Maui is a remnant of one large extinct volcano, Maui Nui, which was made up of Maui, Lānaʻi, Molokaʻi and Kahoʻolawe islands (Macdonald et al. 1983). The island of Maui has two major volcanoes, Haleakalā and West Maui, both of which are in a period of eruption quiescence and dormant. The older West Maui, and its younger and larger counterpart Haleakalā, are separated by an isthmus.

Lavas that created West Maui, and in particular the landscape in the Wahikuli and Honokōwai Watersheds, are predominately made up of thin layers of basalts and are part of the Wailuku Volcanic Series (Stearns 1942) (Box 1). The low lying coastal areas in the Wahikuli and Honokōwai Watersheds are comprised of layers of alluvium. Alluvium is a deposition feature comprised of sediments eroded off the watersheds that fall out of water carrying them along flood ways and the mouth of streams and gulches. The beach zones along both watersheds and the low-lying coastal strip of land immediately *mauka* are primarily comprised of calcareous sands. Both the low lying areas and the beach zones are made up of sedimentary rocks as opposed to igneous volcanic basalts.

Concurrent and subsequent to formation of the West Maui volcanic edifice, rainfall and the runoff it generated has physically altered the landscape. The slopes of the watershed are a function of the build-up of lavas near their vents, the downhill flow of lava to the ocean, and to a lesser degree the subsidence of land into the ocean. The process of water concentrating and flowing down these slopes first forming rivulets, or small channels, and with time and weathering eventually creating larger channels, resulted in the present landscape. The drainage network in both watersheds is comprised of channels aligned mostly parallel to each other with smaller channels terminating in larger ones. The windward side of West Maui, where precipitation at all elevations is considerably higher, has an extensive drainage network and large perennial streams, as compared to the arid leeward side, which has a less extensive surface water drainage network and smaller channels.

Box 1. Lavas and Sub-surface Geology

Viscous lavas are laid down during repeated non-explosive eruptions in layers ranging from few feet thick to tens of feet thick. Most lavas across the watersheds are comprised predominately of *a'a* with layers of *pāhoehoe* interspersed between them. These two types of lavas are chemically similar, with the major difference being the amount of air they contain during eruption. The biggest post-eruptive difference is in the surface they create. *A'a* flows have three layers within each flow, with a top layer of rough, jumbled fragments. *Pāhoehoe* is uniform and has surface best described as ropy. *Pāhoehoe* lavas cool differentially, meaning the interior of each individual flow remains hot while the exposed surface starts to cool. As the outer edges cool and harden, lavas continue to flow inside the tube, and in some cases drain out leave a hollow center referred to as a lava tube. This sequence of lava flows is collectively referred to as the 'shield building stage' of Hawai'i volcanoes, and is what occurred on West Maui.

Towards the end of the shield building stage, a short period of eruptions occurred and deposited thin layers of tuff across the landscape. Tuff is basically fused rock fragments that can create thin layers that retard or prevent water from passing through. Some magma inside the core of a volcano does not get ejected as lavas, and cools beneath the exterior surface. Magma that pushes up in near vertical alignment inside a shield edifice creates dikes. Dikes are comprised of dense, very hard rock, ranging from inches to feet in thickness.

One effect of the different layers of rock at and beneath the ground surface is that they transmit water at different rates and have varying water holding capacities. Water flowing vertically beneath the ground surface that encounters a horizontally aligned layer with low permeability (aquitard) may be directed laterally downslope, or perched, both of which can increase the time it takes for the water to reach the aquifer.[27] Similarly, water flowing beneath the surface horizontally may encounter a vertically aligned dike, preventing its passage or slowing it, and resulting in ponding and creation of a localized perched aquifer. Understanding the subsurface stratigraphy and physical properties is important to hydrogeologists in estimating how long it takes for water that seeps into the ground to reach the aquifer and/or flow from springs and seeps. Identification of flow rates and paths are also important so that management of land use can be informed with respect to where pollutants carried in groundwater are moving to and for how long.

4.3 Topography

Topography describes the surface shape and features of the earth including slope, relief, and landforms (Figure 8). Honokōwai Watershed elevations range from 5,720 ft (1,744 m) at Pu'u Kukui, to sea level. Wahikuli Watershed elevations range from 5,120 ft (1,561 m) to sea level. Slopes within the Conservation District of the two watersheds generally range from 36-86%, with the steepest slopes in the uppermost elevations. Slopes within the Agricultural District generally range from 12-36%, with the steepest slopes near the boundary of the Conservation District and along the gulches and streams. Slopes generally range from 0-12% within the Urban District, with steepest slopes bordering the boundary of the Agricultural District. Rainfall and the surface runoff it generates over the watersheds drains at different rates due to the variability in surface slopes, surface cover, and soil types. Generally runoff moves quickly down the steep sections and slowly along the flat coastal areas.

4.4 Soils

Figure 9 illustrates the soil series in Wahikuli and Honokōwai Watersheds as classified by the Natural Resources Conservation Service (NRCS).[28] These series come from four major soil orders: Inceptisols, Oxisols, Mollisols and Ultisols (Appendix F).

Silty clay soils are predominant throughout the watersheds. Clay soils contain very small void spaces, which act to retain moisture for long periods using capillary action and chemical bonds. These small voids are prone to compaction and reduction of pore volume from mechanical actions that exert shear stress on the soil horizons, resulting in reduction of infiltration rates and water holding capacities. The susceptibility of these soils to compaction can often lead to erosion

[27] An aquifer is layer of rock or sediment beneath the ground that contains water in its voids or open spaces.

[28] Detailed information on the soil series can be found at http://soils.usda.gov/technical/classification/scfile/index.html.

problems by reducing infiltration and creating concentrated surface runoff and flow along the compacted surface. Significant compaction was observed within the access roads in the agricultural areas of both watersheds, and the roads appeared hardened in many locations. The steepest sections of access roads, which run in the *mauka/makai* direction, appeared to be the most hardened (Photo WA13, WA14). This is most likely because the roads in these sections have been subject to historic runoff flows that have scoured and dislodged the surface soil particles. This erosive action, in combination with the compaction of road soils from stakeholder vehicle egress during the peak years of field cultivation, has left many roads in a highly compacted and hardened condition.

Clay soils are generally resistant to detachment due to the chemical bond between particles. However because of their planar shape and small size, once detached they are readily transported via wind and water and can remain in suspension in water for long periods. The particles that comprise clay soils are referred to as colloids, and they present a difficult challenge to control once they are detached and become suspended in surface water runoff. These particles can remain in suspension for long periods of time and/or become resuspended under low turbulent conditions such as when small waves break along the shoreline. Figure 10 details the potential erodibility of the soils in the Wahikuli and Honokōwai Watersheds.

Based on field observations in both watersheds, it is apparent that the soils have been affected by land use activities that occurred in the past and present (Section 4.8). The level of effect varies according to the extent of land use and activity within the area. In the Conservation District, areas of compacted soils from human and animal presence have been noted, along with turned up and trampled areas and long trails of exposed soils resulting from dirt bike riding. In the Agricultural District, soils across large tracts of land have been impacted by tillings, earthen roads, grading, and general compaction of soils. In the Urban District hardscaping and grading activities associated with development have significantly compacted soils and reduced infiltration rates, often rendering them virtually impervious to infiltration. Figure 11 illustrates the approximate extent of highly compacted/impervious surfaces within the watersheds, including both exposed soil surfaces (e.g. agricultural access roads) and hardened surfaces (e.g. pavement, buildings).[29]

4.5 Land Cover

Land cover is the description of the physical material, including natural and manmade, on or above the earth surface, e.g. trees or parking lots. Land cover is broadly delineated as either pervious or impervious surfaces.[30] Pervious surfaces are present within all three Districts of the two watersheds, with examples including forested zones, fallow and active agricultural lands, and urban landscaped areas. Examples of impervious surfaces within the watersheds include naturally occurring sections of exposed rock, paved and concrete surfaces, buildings, highly compacted and eroded field access roads, and other man made features (Box 2; Figure 11 (man-made features only)). The percentage of impervious area within Wahikuli and Honokōwai Watersheds is shown in Table 5.

[29] Generally speaking, the amount of impervious lands increases over time and as a result Figure **11** may not depict all the current impervious surfaces in the watersheds.

[30] Pervious surfaces allow rainwater to pass through them and soak into the ground. Impervious surfaces prevent rainfall from infiltrating into the ground.

4.5.1 Land Cover Percentages Within Watersheds

The predominant cover of Wahikuli Watershed is grassland (30%), scrub/shrub land (25%), evergreen forest (25%), and cultivated land (12%). This makes up 92% of the total watershed area. The remaining 8% is comprised of developed and open spaces and impervious surfaces. The predominant cover of Honokōwai Watershed in its entirety is evergreen forest (37%), cultivated land (36%), and scrub/shrub land (19%). This makes up 92% of the total watershed area.[31] The remaining 8% is comprised of developed areas with open spaces and impervious surfaces. Land cover is illustrated in Figure 12.

4.5.2 Land Cover Within State Land Use Districts

4.5.2.1 Conservation District

The predominant cover in the Conservation District of the Wahikuli Watershed is evergreen forest, which covers 78% (1,140 acres, 461 ha). The other two dominant types of cover are scrub/shrub, which occupies 14% (198 acres, 80 ha), and palustrine forested wetland, which occupies 7% (105 acres, 42 ha). Impervious surfaces occupy less than 1% (1 acre, 0.4 ha). A small parcel (5.4 acres, 2.2 ha) of the Conservation District, Wahikuli State Wayside Park, is located on the southern end of Wahikuli Watershed along the coast. The park is dominated by grassland and herbaceous herb cover, but includes bare ground and impervious surfaces.

The predominant cover in the Conservation District of the Honokōwai Watershed is evergreen forest, which covers 69% (1,563 acres, 633 ha) of the upper watershed. The other two dominant types of cover are scrub/shrub, which occupies 17% (383 acres, 155 ha), and wetlands (palustrine forested, scrub/shrub and emergent), which occupies 14% (328 acres, 133 ha). Impervious surfaces occupy less than 1% (4 acres, 1.6 ha). The native plant communities of the Honokōwai Section of the West Maui NAR include two kinds of rare bogs, wet forests, shrublands and a montane lake.[32]

The Kapunakea Preserve is located in both the Wahikuli and Honokōwai Watersheds, and the Puʻu Kukui Watershed Preserve is located in the Honokōwai Watershed. They contain native-dominated plant communities including the rare Ōʻhiʻa Mixed Montane Bog, as well as lowland mesic forest dominated by koa/ʻōhiʻa and lama/ʻōhiʼa, montane forests, scrub/shrub lands and bogs.

4.5.2.2 Agricultural District

Throughout much of the 20th century, sugarcane was grown in the majority of the Agricultural District and some of the coastal sections of Urban District in Wahikuli and Honokōwai Watersheds. Sugarcane cultivation in this area ceased in 1999 (W. Nohara, pers. comm.). In the 1950's cultivation of pineapple began in northeast areas Honokōwai Watershed *mauka* of Honokohau Ditch. Later in the 1980's ML&P ceased sugar production and started to expand pineapple

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[31] The land cover percentages were derived using remotely sensed data derived from satellite imagery. The images were collected in 2005, and do not reflect subsequent changes in cover. In addition, the cover classification is general and does not describe the variety of specific cover types that comprise the cover classes. Data derived from NOAA Coastal Services Center C-CAP data at: http://www.csc.noaa.gov/digitalcoast/data/ccapregional/.

[32] Native means naturally occurring in a given area. When used in reference to plants and animals in Hawaiʻi, the term native means species that were not brought to the islands by mankind.

production onto fields south of Honokōwai Stream and *makai* of Honokohau Ditch. Cultivation of pineapple began to be phased out beginning in 2000 with the last crop harvested in 2012.

Field cover within the Agricultural District includes both active coffee fields and unmanaged fallow fields. Most of the former pineapple and sugarcane fields across the watersheds are not actively cultivated or maintained, and all are fallow, although there are still some pineapple fields with naturally occurring pineapple plants. An extensive network of dirt roads provides access between the fields, connecting to paved roadways within the agricultural areas and lower urban areas. These dirt roads are considered impervious surfaces due to their compaction from years of use.

Seed corn crops began in the West Maui area in 1999, became a major crop within Wahikuli Watershed in 2001, and ceased operation in mid-2012.[33] Seed corn growers leased 1,288 acres (521 ha). Seed corn was cultivated on a rotational basis over 600 acres (242 ha) of active fields, and at any one time there were 300 acres (121 ha) of fields planted. Coffee production began during the late 1980's and continues today. Coffee growers lease 622 acres (251 ha), half of which (311 acres (125 ha)) are planted. The total land area leased to the seed corn and coffee growers, located primarily in Wahikuli Watershed, was approximately 42% of the 4,570 acres (1,840 ha) that was historically used for pineapple and sugarcane production in the two watersheds. The area of seed corn and coffee fields that was actively cultivated (911 acres) represented only 20% of the historically cultivated pineapple and sugarcane lands. Cropping practices vary among the historically cultivated farm fields, as does density of the ground cover and plant types dispersed between the cultivated crops.

Fallow fields, with the exception of seed corn (which lies bare with minimal vegetative cover), are predominately covered in non-native grasses, shrubs, and trees. The density and vigor of the plants growing on the fallow fields varies, with lower density and less plant vigor in the lower elevations as compared to the middle and upper fields. This is likely the result of rainfall gradient across the two watersheds. Other fallow sections of agricultural land are identified on State agriculture maps as pasture. The pasture lands are located upslope and adjacent to fallow sugar fields in Wahikuli Watershed. It is unknown if grazing by domestic animals is occurring in either watershed. No domestic animals were observed during site visits. The lands classified as pasture are overgrown with shrubs, small trees, and non-native grasses.

Field Cover within Wahikuli Watershed

Agricultural fields within Wahikuli Watershed consist of fallow seed corn fields and coffee orchards *makai* of Honokohau Ditch, and unmanaged fallow coffee orchards and sugarcane fields *mauka* of the ditch (Photo WA1) (Figure 13). The active coffee orchards are primarily located *mauka of the* seed corn fields.

Active Fields

Approximately 622 acres (252 ha) of KLMC lands are allocated to coffee production consisting of commercial growing orchards and private production lots. Of the total area, approximately 50 percent is under production. The commercial orchards include rows of coffee trees with a grass cover crop between them. During the winter months the vegetative cover is mowed periodically to

[33] In June 2012, it was learned that Monsanto Corporation would no longer be using KLMC lands for seed corn cultivation. It is unknown if new growers will move onto the fields, or what the land will be used for in the immediate future.

prevent weeds from crowding the coffee trees. During the summer months, weed management takes place on a routine schedule and mechanical and chemical treatments are employed. Plant residue is left on the ground after pruning the coffee trees and mulched in place to provide organic matter for the soil and crop.

Fallow Fields

Seed corn production involved cultivation of corn to be used as a seed source. Seed corn fields are currently bare with minimal plant residue since recent cultivation ceased. Approximately 600 acres (242 ha) of KLMC lands were used to produce seed corn during active operation, with half planted at any time (Figure 14). Active fields ranged in size from several acres up to 30 acres (9 ha). During production, the actively cultivated corn fields were surrounded by bare, fallow fields in order to prevent cross pollination. Space between crop rows was left bare. Prior to production terminating, the bare fields were observed to be void of any plant cover, leaving their surfaces completely exposed and extremely vulnerable to wind and water erosion. The fields showed active signs of extensive tilling, resulting in exposure of fine grain soil. The ratio of actively cultivated fields to fallow bare fields was approximately 20:1 during field operation.

Fallow coffee orchards consist of rows of coffee trees with a mixture of grass and shrubs as cover between them. A 20 acre (8 ha) area of land within these fallow fields is also designated for commercial coffee production (Figure 14) (J. Astilla, pers. comm.). The fallow cane fields are primarily covered with grass of varying density, which adequately protected most of the fields from erosion. A concern with the grass-covered, fallow cane fields is that the grass could be quickly consumed by a wildland fire, resulting in a bare and exposed landscape that would be vulnerable to erosion.

Field Cover within Honokōwai Watershed

Agricultural fields within Honokōwai Watershed consist of fallow pineapple and sugarcane (Figure 13). Most of the agricultural land *mauka* and *makai* of Honokohau Ditch was used to grow pineapple in the recent past. There are no actively managed crop fields within Honokōwai Watershed (W. Nohara, pers. comm.). The majority of pineapple fields are covered with either remnant pineapple plants that still produce some fruit, or a combination of sour grass, low lying shrubs, and vegetative residue from former pineapple production. Pineapple residue distributed across the fields provides some ground cover and organic matter for the soil ecology. The combination of crop residue and plants growing in the fields appears to provide low to moderate ground cover and some protection of soils from erosion.

Field observations indicated that a high percentage of the fallow sugarcane fields were covered with a moderate density of tall non-native grasses that appear to provide moderate to high ground cover and protection from erosion. In the sugarcane fields the most common plant species observed were guinea grass (*Panicum maximum*), alexandergrass (*Brachiaria planteginea*), and swollen fingergrass (*Chloris inflata*).

4.5.2.3 Urban District

Infrastructure

The Urban District of the two watersheds have a total of 382 acres (154 ha) of impervious surfaces covering 3 percent of the total 12,051 acres (4876 ha) of combined watershed areas (Table 5, Figure 11).[34] Honokōwai Watershed contains 109 acres (44 ha) of impervious surfaces and Wahikuli Watershed contains 273 acres (110 ha) of impervious surfaces. The percentage in Wahikuli Watershed is skewed low since much of the Urban lands are *mauka* of Honoapiʻilani Highway in an area that contains large lots with only a portion covered by impervious surfaces. The resorts, hotels, and condominiums fronting the ocean and located between the highway and the ocean contain nearly 40 percent impervious surfaces when looked at as subset of the Wahikuli Urban District. Nearly all impervious surfaces within Wahikuli and Honokōwai Watersheds are manmade features (Box 2).

Table 5. Impervious Surfaces

	Urban District		Other Districts		Total (acres)
	(acres)	% of district	(acres)	% of district	
Wahikuli Watershed	273	17%	112	2%	385
Honokōwai Watershed	109	45%	115	2%	224
Total	382		227		609

Managed landscaped surfaces are present within the urban district at golf courses, resorts, and residential and commercial properties. Non-native and ornamental plants are the primary vegetation except along beach front resort properties north of the *Puʻu Kekaʻa* (Black Rock) area where native plants dominate the vegetation communities, most likely due to development permit requirements. Landscaped surfaces are considered permeable surfaces that allow a percentage of rainfall and irrigation water into the ground.

Box 2. Impervious Surfaces

Buildings, rooftops, parking lots, roads, and other impervious surfaces generate surface runoff under all rainfall events, except for those generating negligible rainfall. Impervious surfaces affect storm water runoff quantity and quality in two primary ways: (1) Impervious surfaces do not allow rainfall to infiltrate into the ground, preventing water from recharging soil and the aquifer and slow release to streams and the ocean; and (2) Rain falling on impervious surfaces begins to pond almost immediately at the onset of rains, generating rapid runoff with higher volumes than compared to a pervious surface. This rapid transport of runoff reduces detention time of water on the watershed and the amount of rainfall that infiltrates into the ground. This, in turn, diminishes the capture and remediation of pollutants by microbes in the soils and plant roots and results in the direct delivery of contaminants to the ocean.

Wahikuli Watershed

The Urban District in Wahikuli Watershed encompasses four parcels on land located between the watershed's north and south boundaries at roughly Kāʻanapali Beach Club Condominiums, and the north end of Wahikuli Wayside Park respectively (Figure 16). The north boundary of the largest parcel extends from the ocean to Honoapiʻilani Highway. At the *mauka* side of the highway it turns

[34] The estimate of impervious areas in the two watersheds was made in 2005 by NOAA based on satellite images collected in the same year. Subsequent to 2005, several large hotels and associated infrastructures have been constructed. As a result the area and percentages of impervious surfaces provided herein are not current and underestimate the actual and relative amounts.

to the south running along the *mauka* side of the highway until Puʻukolkiʻi Road, where it turns upslope in an east direction to approximately 400 ft (123 m) elevation. From this point the boundary heads south along to Wahikuli Gulch, turning west and following a sinuous path where it ends at the ocean near the park. There are four other Urban parcels non-contiguous to the parcel delineated above. One parcel houses Maui County's Lahaina WWRF and other light industrial use, and is located *mauka* of the highway between Honokōwai Stream and Halawai Drive on a 16 acre (6 ha) parcel. The other three parcels are located *mauka* of the Royal Kāʻanapali Golf Course between elevation 400-550 ft (123-168 m). These parcels (sized: 61 acres (25 ha), 165 acres (67 ha), and 240 acres (98 ha)) are not under active Urban use and are either fallow farm fields or actively cultivated with coffee.

The Urban lands in Wahikuli Watershed contain Kāʻanapali and Kahekili Beaches, along with most of the large resort complexes that line the coast in this part of Maui. The lands can be roughly divided into the Kahekili and the Kāʻanapali sections. Kahekili extends from the watershed's north boundary along the coast to *Puʻu Kekaʻa* (Black Rock) and houses Kahekili/Airport Beach Park, and the lagoon at *Puʻu Kekaʻa*. Several large lot single family homes and individual condominiums are located between Kahekili Beach and the Royal Lahaina Resort. The larger area has two 18 hole golf courses, including the Royal Kāʻanapali Kai Golf Course that is located between the highway and ocean in the Kahekili section and Kāʻanapali Parkway and Nohea Roads in the Kāʻanapali section. The total number of condominiums and resort hotel properties are less than the number in Honokōwai Watershed, however the average lot size fronting the ocean is much larger in Wahikuli Watershed. Residential houses are located in the urban stretch between Puʻukoliʻi Road and Wahikuli/Hāhākea Gulch. Single family houses are located in several residential neighborhoods located on the north and east boundaries of the Royal Kāʻanapali Golf Course.

Honokōwai Watershed

The Urban District encompasses land located between Honokōwai Watershed's north and south boundaries at roughly Kahana Beach Condominiums, and the Kāʻanapali Shores Resort respectively, and the east and west boundaries along Honoapiʻilani Highway and the ocean (Figure 15). The Kapalua-West Maui Airport, also designated Urban, is located outside of the above boundaries *mauka* of Honoapiʻilani Highway just north of Māhinahina Gulch. The average linear distance between the highway and the ocean in this section is approximately 1,400 ft (426 m). A subsection of this stretch bounded by the highway and Lower Honoapiʻilani Road (between the north and south watershed boundaries) is parcels containing residential and light commercial properties. The commercial properties, comprised of retail shops, grocery stores, a gas station, and other light mixed business, are concentrated mostly at south end of this stretch. A second subsection between the ocean and Lower Honoapiʻilani Road hosts condominiums and resorts fronting the ocean.

4.6 Climate

4.6.1 Precipitation

Ancient Hawaiians distinguished the annual precipitation cycle into two six month seasons: *kau* (May to October) and *hoʻoilo* (November to April) (Lau and Mink 2006). Modern analysis now divides the annual cycle in Hawaiʻi into a summer season of five months (May to September) and a winter season of seven months (October to April) (Blumenstock and Price 1967). The climate of the Hawaiian Islands is controlled in large part by the presence of the Pacific Subtropical Anticyclone

(PSA), a high-pressure ridge located north and east of the islands. The PSA generates winds that blow from its base and travel from a northeasterly direction toward the island chain. These winds are referred to as 'trade winds'. During the summer season, when trade winds are most persistent, areas of maximum rainfall are generally located on windward slopes where orographic effects are most pronounced (Chu and Chen 2005).[35] During the winter season, the trade winds are often interrupted by mid-latitude frontal systems, upper-level troughs, and cutoff lows in the upper-level subtropical westerlies, locally known as *kona* storms (Chu and Chen 2005). These three mechanisms generate widespread rainfall and are major sources of winter season rainfall. This weather pattern is representative of what occurs over Wahikuli and Honokōwai Watersheds.

Rainfall in Hawaiʻi is characterized by steep spatial gradients (Giambelluca et al. 1986). Rainfall totals for gages representing the highest elevation in the two watersheds and near sea level are provided in Table 6 (Giambelluca et al. 2011). Rainfall is highly variable with elevation on the watersheds and temporally variable throughout the year (Figure 17). The five summer months, May-September, are the driest for both stations with 37 percent and 8 percent of the total annual rainfall occurring in this period at the Kukui and Field D-4 stations respectively. April is the wettest month at Kukui with an average rainfall 38 inches (97 cm), whereas January is the wettest at Field D-4 with an average of 3.5 inches (8.9 cm). Analysis of the raw rainfall data for the Field D-4 site finds that on average five storms occur during the winter months with average rainfall totals of 2.2 inches (5.6 cm). Depending on the duration of an individual storm event, and its rainfall intensity, the average storm can produced localized flooding and high volumes of fresh water discharge to the ocean.

Table 6. Average Annual Rainfall

Station	Elevation (ft msl)	Average Annual Rainfall (in)	Comment
Kukui	5,770	365	Top of Honokōwai Watershed
Field D-4	40	19	Station in Honokōwai by Airport

Evaporation in Hawaiʻi is affected by the three primary controls that govern rainfall: the marine position of the Main Hawaiian islands (MHI) as a land mass surrounded by water in the subtropical latitudes; the PSA; and the high mountains (Lau and Mink 2006). Trade winds and temperature inversion are two principal features of the PSA and their interaction with the high mountains accounts for the spatial variation of the evaporation climate. As trade winds move onshore in windward areas, the orographic cloud reduces radiation and evaporation beneath the cloud becomes nearly constant throughout the year. Evaporation off Wahikuli and Honokōwai Watersheds increases from the mountains down to the ocean where it is highest.

The Conservation District is located in the portion of both watersheds that receives the highest amount of rainfall. The condition of this section of the watersheds is ecologically important in that it hosts native and endemic plants and animals and is the source of water for all areas of the

[35] *Orographic*. Of or pertaining to the effects of mountains on weather.

watersheds.[36] Protection of the vegetation and maintenance of ecosystem functions is critical to ensure that rainfall is captured, stored, and transmitted via surface water and groundwater flows.

The sparse rainfall in the mid to lower elevations, coupled with the relatively high amounts of evaporation, results in an arid climate. Estimates of evaporation made during plantation era operations range from 66 inches per year (106 cm) at 800 feet elevation (244 m) to 82 inches per year (168 cm) at sea level. The high loss of water from evaporation and plant's transpiration regulates vegetation growth and favors drought tolerant plants. Much of the vegetation across the fallow fields is non-native. During summer months, this vegetation becomes stressed or desiccated and a portion dies off. These areas of the watersheds are most vulnerable to erosion at the onset of the winter rainy season due in part to the climatically induced reduction of vegetative cover that exposes more of the ground surface to rain drops and subsequent overland flow.

4.6.2 Temperature

Temperatures in West Maui are mild and generally range from a daily mean minimum of 65° Fahrenheit (F) to a maximum of 89° F, the warmest temperatures occurring in August and September (WMO 2009).

4.6.3 Natural Hazards

The Hawaii Coastal Hazards Atlas describes hazards inherent to the region. "The Overall Hazard Assessment for the Nāpili coast is moderate to high (5) and is largely influenced by high tsunami, stream flooding, and erosion hazards and moderately high storm, sea-level rise, and seismicity threats on this Maui coastline" (Fletcher et al. 2002).

The coast's high tsunami hazard rating is supported by a 1946 event during which a 15 ft tsunami made landfall (Fletcher et al. 2002). The exception to which is *Puʻu Kekaʻa* (Black Rock), rated as moderately high. Otherwise, Kāʻanapali records show few historic tsunami events. The region's high stream flooding hazard rating is supported by a 1968 event during which heavy rains and flash floods resulted from 24 inches of rainfall in 48 hours, the exception to which again is *Puʻu Kekaʻa* (Black Rock), rated as moderately low. High wave threats are ranked moderately low along the coast, with storm and sea-level rise hazards moderately high, once again with the exception of the *Puʻu Kekaʻa* (Black Rock) headland, rated as moderately low.

The coast's high erosion hazard rating has seen an expansion of seawalls and revetments to counteract the effects and preserve coastal properties, however this has caused continued beach losses in the area (Fletcher et al. 2002). The exception within the project area is the rocky headlands of *Puʻu Kekaʻa* (Black Rock), rated as moderately low. The coast's moderately high volcanic/seismic hazard is supported by its location within seismic hazard zone 2. At *Puʻu Kekaʻa* (Black Rock) the Overall Hazard Assessment is reduced to moderate to low (3), and from Hanakaʻōʻō Point southward the rating is increased to moderate (4) to reflect the lower coastal slope hazards inherent to that area.

[36] Endemic refers to those species that are native and restricted to a particular geographical region. Highly endemic species are those with very restricted natural ranges; they are especially vulnerable to extinction if their natural habitat is eliminated or significantly disturbed.

4.6.4 Climate Change

While uncertainty remains as to future rates of sea level rise because of uncertainty about future carbon emission rates and the oceans' response, it is reasonably certain that three feet of sea level rise from the 1990 level will occur by the end of the 21st century (Vermeer and Rahmstorf 2009; Fletcher 2009). Sea level rise is expected to alter the location of the shoreline and impact infrastructure layout (i.e. buildings, roads). It will also impact the water table of aquifers currently in contact with the ocean, and in some locations may increase the salinity level of the groundwater, reducing availability for fresh water uses. Low lying areas presently at or just above sea level may become ponded and unusable. Changes to the flood regime, including its frequency and the extent of land impacted under future climatic conditions are unknown. However, with sea level rise it is logical to assume drainage channels at their outlets would be backed up proportional to changes in sea level elevations. This may reduce channel conveyance and increase duration and areal extent of runoff water in the channels.

Global warming is likely to impact the Hawaiian trade wind regime and may have negative impacts on Hawaiian rainfall. A decrease in atmospheric circulation in the tropical Pacific Ocean has already been observed and attributed to global warming (Vecchi et al. 2006). Timm and Diaz (2009) noted that significant changes in the wind fields around Hawaiʻi are forecast to occur by the late twenty-first century under one of several climate change scenarios described by the Intergovernmental Panel on Climate Change (IPCC 2007). However, the predicted impact on rainfall is not clear and Timm and Diaz (2009) concluded that the most likely scenario for Hawaiʻi is a 5 to 10% reduction of wet-season rainfall and a 5% increase of dry-season rainfall as a result of changes in the wind field.

4.7 Hydrology

Hydrology refers to the movement and fate of water across the watershed, its quality, and the man-made and natural drainage networks (Box 3).

Box 3. Hydrologic Cycle

The hydrologic cycle is the most fundamental principle of hydrology. Water evaporates off the ocean and land surfaces and is carried over the earth in atmospheric circulation as water vapor, it precipitates out as rain or snow and is intercepted by trees and vegetation, provides runoff over the land surface, infiltrates in the soils, recharges groundwater, discharges into streams and all ultimately flows out to the oceans from which it eventually will evaporate once again. The hydrologic cycle is fueled by solar energy, driven by gravity, and proceeds endlessly in the presence or absence of human activity. However, human activity can significantly alter the hydrologic cycle, especially the processes that occur on land.

A key component of the hydrologic cycle is what happens to rainfall that reaches the earth's surface. Raindrops can be intercepted by plants, where they collect on leaves, branches and twigs and then either evaporate, drip off to the ground surface beneath the canopy (through flow), or flow down the trunk or stem of a plant to the ground (stemflow). Rainfall may directly hit the ground surface and some of this infiltrates into the soil, filling pores, and used by plants. A portion of the infiltrated water percolates beneath the soil layer flowing into aquifers or along subsurface flow paths and emerging down slope as springs or seepage into waterbodies (e.g. streams, ocean). Groundwater that flows into streams is referred to as baseflow. A portion of the total rainfall reaching the ground becomes surface runoff. Surface runoff occurs either when the rainfall rate exceeds a soil's infiltration rate (Hortonian overland flow) or when the soil is saturated and cannot absorb any additional water (saturated overland flow). The fate of water running over a watershed is of particular importance and plays a significant role in the transport of pollutants and formation of the landscape. Alterations to a watershed by people, plants, and animals can affect all of the pathways, and in many cases the alterations results in adverse impacts to the ecosystem.

4.7.1 Major Streams

4.7.1.1 Overview of Major Stream Systems

The larger, more developed streams[37] in the region have headwaters originating in the Conservation District where high rainfall amounts generate surface flow and recharge the aquifers that leak into the streams during dry periods. These large streams continue down slope through the Agricultural and Urban Districts before terminating at the coastline. The streams that dissect the watersheds from the upper elevation to the coast are referred to as the mainstem channel, and often are fed by smaller channels that drain subwatershed areas and terminate into the mainstem channel. Within Wahikuli Watershed, the major streams include Hanaka‘ō‘ ō Gulch, which drains the north section of the watershed, and Wahikuli/Hāhākea Gulch in the south end of the watershed, which are fed by Keali‘i Gulch. The land area in the middle of Wahikuli Watershed has several small natural surface channels. These channels are not as deeply incised compared to the other two channel networks due in part to the low rainfall over the area, the smaller watershed size, and resultant low frequency of overland flow. Most of these channels are no longer discernible *makai* of Honoapi‘ilai Highway due to urbanization and agriculture development. Within Honokōwai Watershed, there are two major stream systems, Māhinahina and Honokōwai. Honokōwai Stream forms below the confluence of Amalu and Kapaloa Streams, both of which start in the upper elevations of the watershed. Māhinahina Stream drains lands in the middle to north section of the watershed. A third smaller channel, Pōhakukā‘anapali Gulch, drains the northern lands of Honokōwai Watershed. This gulch was likely cut off by the construction of the Kapalua-West Maui Airport, and probably extended further upslope (*mauka*) in the geological past (Figure 18).

4.7.1.2 Riparian Vegetation

The streams are lined with riparian vegetation that varies longitudinally along the channels.[38] In the steep, deeply incised sections of the streams, such as the upper reaches in the Conservation District, the riparian vegetation strip may be narrow due to the small width of the valley bottoms. In sections where the stream valleys are wider, the riparian zones are wider.

The density and type of plants in the riparian zones are primarily a function of water availability. In general, in the lower reaches of the streams, near the mid to low elevations, the riparian zone is dominated by plants that are more adapted to arid conditions due to less frequent surface water in the channels and lower water tables. In sections where the water table is near the stream bed and/or surface water is frequently in the channels, plants are primarily comprised of more water demanding species.

The density and diversity of plants is one of several variables that control the rate of erosion and deposition along the stream channel. In general, the riparian vegetation density and diversity are greater in the wetter sections of the stream channel. Sections with high plant density are likely to

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[37] A channel is an actual physical feature on the landscape and can either be manmade or formed under natural fluvial process. Channels vary in dimension (i.e. width length, and depth) and have varying bottom slopes and bed and bank materials. ‘Stream’ is a descriptor usually given to a naturally formed channel that flows year round (perennial) or did historically. ‘Gulch’ is a descriptor given to channel that flows for short periods of time (ephemeral) following rainfall events. An ‘intermittent stream’ contains threads of water or pools perennially. A stream may be perennial in some sections such as the upper elevations and intermittent and/or ephemeral in other sections.

[38] Riparian vegetation is plants along the streams with roots that have access to either or both surface or ground water.

erode at lower rates than sections where density and diversity of plants are lower if all other variables are constant.

A riparian zone inventory and assessment was not conducted as part of this project. However, observations were made during field work in order to make recommendations for future investigations and strategies to address potential riparian corridor issues.

4.7.1.3 Māhinahina Stream System

Māhinahina Stream is a moderately well formed channel located north of Honokōwai Stream that drains a portion of the northern lands of Honokōwai Watershed. It drains approximately 25 percent of the total land area in the Honokōwai Watershed. Māhinahina Stream is 23,340 ft (7,114 m) in length from its headwaters, which form at approximately elevation 2,400 ft (732 m), to its mouth at the ocean between Lokelani and Hale Ono Loa condominiums. Māhinahina Dam and its desilting basin are located on the channel immediately *mauka* of Honoapiʻilani Highway. The channel is in a natural condition from the headwaters to the dam. From the *makai* face of the dam to its mouth the channel has been fitted with a concrete box culvert. A series of outfalls that are part of the Separate Storm Sewer System (S4) owned by Maui County are connected to the concrete section at seven locations. Māhinahina Stream is intermittent in its headwater section down to about 1,500 ft (458 m) where it becomes ephemeral (A. Hood, personal observation).

4.7.1.4 Honokōwai Stream System

Honokōwai Stream drains approximately 70 percent of the total area of the Honokōwai Watershed. The channel is perennial from its headwaters down to an elevation of approximately 1,300 ft (398 m), where it becomes ephemeral to its mouth. Honokōwai Stream is formed at the confluence of Amalu Stream and Kapaloa Stream, which are both formed by the confluence of smaller headwater streams. An unnamed stream (headwaters at elevation 4,400 ft (1,341 m); segment length = 4,373 ft (1,333 m)) flows to a point of convergence with Amalu Stream (headwaters at elevation 4,600 ft (1,402 m); segment length = 6,565 ft (2,001 m)), at elevation 3,200 ft (975 m). Amalu Stream flows from this point 8,720 ft (2,658 m) to a point of convergence with Kapaloa Stream (headwaters at elevation 5,600 ft (1,707 m), segment length = 20,479 ft (6,242 m)) at elevation 1,300 ft (396 m) to form Honokōwai Stream. Honokōwai Stream flows from this point 21,768 ft (6,635 m) to a point of convergence with an unnamed stream (headwaters at elevation 2,900 ft (884 m), segment length = 23,048 ft (7,025 m)), at elevation 150 ft (46 m), upstream of the Honokōwai Dam and desilting basin. Honokōwai Dam and its debris basin are located on the main channel 750 ft (229 m) *mauka* of Honoapiʻilani Highway. Maui County owns the dam and the debris basin and the County Department of Public Works maintains the structures. From the headwaters to the dam the channel is in a natural condition. From the *makai* face of the dam to its mouth the channel has been fitted with a concrete box culvert over a distance of 2,949 ft (899 m) (Photo HA1). The stream mouth is located between Aston at Papakea Resort and Kāʻanapali Shore Resort. A series of outfalls on the S4 system discharge storm water runoff into the concrete section of the stream at several locations.

Both Māhinahina and Honokōwai Streams have perennial pools between the sand berms that block their channel at the ocean. The blockage is the result of sand deposited by wave run-up. The length of channel impounded varies due to the amount of runoff that is carried in the channel and to a lesser degree the tide levels. Based on visual assessment, the water in both channels was stagnant and degraded.

Both of the primary tributaries that flow together and form Honokōwai Stream are diverted and used to supply Honokōwai Ditch. The diversions reportedly divert all of the stream water during base flow periods. During moderate to high flows the amount of water in the tributaries is greater than the capacity of the diversions and Honokōwai Stream carries water in its downstream reaches. The USGS is currently studying the hydrology of the Honokōwai Watershed and other watersheds in West Maui in order to quantify the relationship between rainfall, diversions, and stream flow in the region.

Box 4. Watershed Hydrology

Hawaiʻi streams tend to be naturally flashy, meaning they rise and fall quickly during and following rainfall due to their small steep watersheds and intense rainfall rates. Urbanization and development of land for agricultural use alters the ground surface and further enhances the natural flashiness of stream runoff. Stream flow occurs when either or both surface flows of sufficient volume are delivered to a stream or a steady baseflow is intercepted by the stream.[39] Under either situation, when the volume of water delivered to the stream is sufficient to maintain conditions of continuous water in the channel, the stream is classified as perennial. When the water delivery is intermittent the stream is classified as intermittent, and when the channel flows only following rain it is classified as ephemeral.

Along their longitudinal profile streams have sections where groundwater drains into the stream increasing surface flow volume in the channel, and other sections where the channel loses water through its bed and banks. During rainy years the stream likely flows for longer periods when compared to low rainfall years. Under natural or pre-urbanized conditions only a small percentage of the rainfall that reaches the ground results in runoff. This is due to infiltration of water into the soil, detention of water on surfaces such as plants, and retention of water in small depressions common in natural landscapes. A portion of water infiltrates into the soil and recharges groundwater, some of which makes its way slowly though subsurface flow paths into the streams as base flow. Under natural conditions the volume of runoff is attenuated and the contaminants contained in it remediated along the flow path or sequestered on the watershed. Groundwater recharge rates and subsequently stream base flow have likely decreased across the urban area of the watershed due to extensive covering of the land with impervious surfaces.

4.7.1.5 Wahikuli Gulch System

Wahikuli Gulch drains approximately 40 percent of the total area of the Honokōwai Watershed. Wahikuli Gulch is perennial from its headwaters down to an elevation of approximately 1,800 ft (549 m), where it becomes ephemeral to its mouth. Kealiʻi Gulch (headwaters at elevation 3,200 ft (975 m); segment length = 10,597 ft (3,230m)) flows to a point of convergence with Hāhākea Gulch (headwaters at elevation 4,600 ft (1,402 m); segment length = 18,753 ft (5,716 m)), at elevation 1,400 ft (427 m). Hāhākea Gulch flows from this point 11,591 ft (3,533 m) to a point of convergence with Wahikuli Gulch (headwaters at elevation 4,400 ft (1,341 m); segment length = 29,238 ft (8,912 m)). Wahikuli Gulch flows from this point 4,111 ft (1,253 m) downslope and under the highway through a concrete box culvert and earthen channel before discharging into the ocean at Hanakaʻōʻō Beach Park. The stream mouth is located between the Hanakaʻōʻō Cemetery and southern parking lot of the Hyatt Regency.

Wahikuli and Hāhākea Gulches are intersected by Honokōwai Ditch at elevation 900 ft (274 m), Honokohau Ditch at elevation 700 ft (213 m), a ditch at elevation 400 ft (122 m). Hāhākea Gulch has an additional ditch intersection at elevation 1,300 ft (396 m) and an intersection with Reservoir Ditch at elevation 500 ft (152 m).

4.7.2 Groundwater Resources

Groundwater is water found in underground layers of rock or sediment, referred to as an aquifer. An aquifer is roughly defined as an area in which the spaces (voids) are filled with water. The water

[39] *Baseflow* is commonly referred to as the volume of flow in river or stream that is derived from ground water.

table is the upper elevation of the water in an aquifer. Similar to surface water, water in an aquifer flows under the force of gravity. The flow rate of water through an aquifer is a function of the elevation head (or slope) of the water table, the hydraulic conductivity of the substrate it encounters, the cross section of the area it flows through, and the viscosity of the water. In general flow rates through dense material are slower compared to flow through loosely packed materials if all other variables are the same. Water in aquifers can either be fresh, salt, or brackish.

All aquifers in Hawaiʻi are classified using a system developed and reported by Mink and Lau (1990). The classification is based on an eight digit code using the following parameters:

- Island code
- Sector: Areas with similar hydrogeological properties
- System: Sub area of a sector with hydrogeological continuity
- Type: Sub area of system with uniform hydrologic and geologic features

The aquifers beneath the Wahikuli and Honokōwai Watersheds are in the same Sector (02, Lahaina) and System (03, Honokōwai), and are separated into three types: High Level (2), Unconfined (1), Dike (2); Basal (1), Unconfined (1), Flank (1); and Basal (1), Unconfined (1), Sedimentary (6) (Figure 19).[40]

In addition to the aquifer code, the State has a groundwater Status Code that is assigned to each aquifer type. The five digit Status Code describes the aquifers with respect to: development stage, utility, salinity, uniqueness, and vulnerability to contamination. The code categories are based on EPA directives and were developed so that groundwater resources would receive protection from adverse impacts. The dike and flank aquifers in the watersheds are classified (11111): Currently Developed, Drinking, Fresh, Irreplaceable, and High. The sedimentary aquifer is coded (33421): No potential use, No utility, High salinity (5,000-15,000 mg/l Cl^-), Replaceable, and High.

4.7.2.1 High Level, Unconfined, Dike Aquifer

The High Level (2), Unconfined (1), Dike (2) Aquifer is located beneath the land surface from the top of the watersheds down to approximately 2,800 ft (853 m) elevation. High level means the water is fresh and does not contact seawater. Unconfined means the top of the water table in the aquifer is the upper surface. Dike means that the water is held in dike compartments. A more detailed description of related geological features is presented in Section 4.2. Dike compartments are similar to boxes that are filled with water. The sides of the compartments are dense rock aligned in a mostly vertical pattern. Dikes fill up as water percolates down into the box, and drain out when the box fills, or through leaks in the sides or bottom. The high level aquifers in Wahikuli and Honokōwai Watersheds occur in moderate to high rainfall zones, and function as mountain reservoirs. The outflow and leakage of water from the dikes during periods free of rainfall sustain the flow of water in the upper reaches of the streams, and are a significant hydrogeologic feature of the watersheds.

[40] The numbers in parenthesis refer to the Aquifer Type, either Hydrology or Geology, as defined in the Aquifer Classification for Hawaiʻi (Mink and Lau 1990).

4.7.2.2 Basal, Unconfined, Flank Aquifer

The Basal (1), Unconfined (1), Flank (1) Aquifers is located beneath the watersheds from the contact line with the dike aquifers to the land surface at approximately 100 ft (300 m) elevation. Basal water is a fresh water layer that is in contact with seawater. The fresh water in the aquifer is buoyed above the deeper saltwater layer because fresh water is less dense than saltwater. A brackish water zone of varying thickness is usually located between the fresh and salt water layers. In basal aquifers the water table can vary spatially, as can the flow rate of water through the aquifer. Unconfined means that water percolating through soils can recharge the aquifer. However, this water can also carry pollutants that can contaminate and degrade the water quality of the aquifer. Due to the slow rate of water movement through basal aquifers, once a contaminant has been introduced it can reside in and impair aquifer water quality for a significant amount of time.

The geological descriptor 'flank' refers to lavas that are horizontally aligned. In an idealized setting the lavas comprising the flank would be tilted in the same direction with the same slope as the ground surface. Water percolating into the ground may flow vertically for some distance and encounter a less porous lava layer, causing the water to change direction and flow along the top of the layer. Understanding and quantifying groundwater quality and the magnitude and direction of its flow is challenging. The fact that the flow can vary in three spatial dimensions, and is subjected to complex biogeochemical processes that alter it quality are the primary reasons for this complexity.

4.7.2.3 Basal, Unconfined, Sedimentary Aquifer

The Basal (1), Unconfined (1), Sedimentary (6) Aquifer is located beneath the watersheds from the land surface at approximately 100 ft (300 m) elevation to the shoreline. The water in this aquifer differs from the other two primarily in that the groundwater is contained in sediments. The aquifer is comprised of terrestrial sediments, carried by surface water running over the landscape and deposited along the flat coastal zone, and calcareous sediments, sourced from coral reefs and deposited by ocean waves. The water table in this aquifer varies as well, however its depth below the ground surface is small due the low elevation of the ground surface in this area of the watersheds. Similar to the flank aquifer, the issue of contamination carried in percolating water is of concern, in part due to the aquifer's close proximity to the shoreline.

4.7.2.4 Groundwater Supply

The Hawaiʻi Water Service Company is a water utility that provides potable water to hotels, resorts, and private entities within the two watersheds. This company has a series of wells and reservoirs located in the middle elevations of the project area. The Public Utilities Commission of the State of Hawaiʻi Department of Budget and Finance regulates water rates and oversees all regulations pertaining to the sale and acquisition of the company. High quality groundwater distributed is used for both domestic and irrigation purposes. The quantities of water pumped and used, and details on well hydraulics were not available.

The volume of water discharging along the coast in seeps and springs and off-shore as submarine groundwater has not been quantified. However, it is generally thought that annual groundwater fluxes from the beneath the two watersheds to the ocean are small when compared to volumes of water delivered via surface water flows (Soicher and Peterson 1996). Groundwater is discharged more consistently and uniformly along the coast. The changes to the groundwater tables of the region and groundwater fluxes have not been quantified since cessation of sugar cane and pineapple cultivation. Groundwater is generally associated with transporting ammonium and nitrate forms of nitrogen (Soicher and Peterson 1997).

4.7.3 Floodway Issues

Areas subject to coastal flooding or tsunami inundation are identified on Flood Insurance Rate Maps (FIRM) prepared by the Federal Emergency Management Agency, Federal Insurance Administration. In the Kāʻanapali region the flood prone areas extend slightly inland along the coast and farther inland in the flood plains of each stream. The flood hazard zone around Māhinahina Stream extends about 1,180 ft (360 m) inland across Honoapiʻilani Highway. At Honokōwai Stream, the flood zone extends about 2,690 ft (820 m) inland across the highway. At Wahikuli Gulch, the flood zone extends about 3,280 ft (1 km) inland across the highway. Flood hazard areas, which include tsunami inundation areas, are categorized by the probability of hazard, based upon USACE surveys. According to the FIRM, approximately 162 acres (66 ha), or 9% of the 1,804 acre Urban District, are located with the 100-year floodway. These areas are designated by FIRM as Zone A. Zone X500, which is the 500-year floodway, encompasses approximately 46 acres (19 ha), or 2.5 % of the Urban District.[41] Figure 20 and Figure 21 depict the region's FIRM map flood zone classifications and Box 5 provides definitions.

Box 5. FIRM Flood Zone Designations[42]

Zone A: Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Since detailed analyses are not performed for such areas; no depths or base flood elevations are shown in these zones.

Zone AE: Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. In most cases, base flood elevations derived from detailed analyses are shown at selected intervals within these zones.

Zone B, X: Areas outside the 1% annual chance floodplain, areas of 1% annual chance sheet flow flooding where average depths are less than 1 foot, areas of 1% annual chance stream flooding where the contributing drainage area is less than 1 square mile, or areas protected from the 1% annual chance flood by levees. No Base Flood Elevations or depths are shown within this zone. Insurance purchase is not required in these zones.

Zone D: Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

4.8 Impacts of Land Use on Watershed Hydrology

4.8.1 Impacts of Changes to Conservation Areas on Watershed Hydrology

Most of the land in the Conservation District occurs in high elevation zones where rainfall is high. Protecting these areas is important for maintaining and restoring native ecosystems and sustaining water resources that are a source of water for developed lands. Although the upland conservation areas in Wahikuli and Honokōwai Watersheds have not been urbanized, they have been adversely impacted in some areas by human and animal activities. Dirt bike riding, illegal trespassing, feral ungulate activity, and other activities have all contributed to removal of vegetation, exposure and erosion of soils, and reduction of infiltration rates (Section 6.3). This has resulted in alteration of the runoff regime, including increased runoff volume and increased volume of sediment in runoff when compared to pre-disturbed, vegetated conditions. Non-native vegetation is less effective than

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[41] The flood insurance rate zone that corresponds to the 100-year floodplain is determined in the Flood Insurance Study by detailed methods. Mandatory flood insurance is required for land owners in this zone.

[42] FEMA website: http://msc.fema.gov/webapp/wcs/stores/servlet/info?storeId=10001&catalogId=10001&langId=-1&content=floodZones&title=FEMA%20Flood%20Zone%20Designations.

native vegetation in controlling erosion rates, capturing rainfall, and maintaining recharge to high level aquifers (Appendix E.3.2).

Feral ungulates, especially pigs, have and continue to degrade forested areas in both Wahikuli and Honokōwai Watersheds. Pigs uproot plants, trample soil, and create trails, all of which result in adverse impacts to ground cover and soil physical condition, reducing infiltration rates and increasing erosion rates. Axis deer, a non native species originally from Asia, are migrating from the woodlands of East Maui into areas of West Maui. Although deer are not commonly seen in the forested areas of the Wahikuli and Honokōwai Watersheds, there has been an increase in the number of deer observed in watersheds to the south. Similar to pigs, deer alter ecology and generally degrade native vegetation communities. They can adversely impact agricultural operations by feeding on crops. Efforts are underway to prevent deer from establishing population in West Maui. The extent of logging and extraction of trees from Wahikuli and Honokōwai Watersheds for wood products is unknown. It is assumed that some harvest of trees has occurred.

4.8.2 Impacts of Agriculture on Watershed Hydrology

Agriculture modified the hydrology of watersheds on their most basic level with the introduction of ditch systems. Ditches convey flow from a water source to another location within the watershed, and often convey water between multiple watersheds through the use of siphons, tunnels, pipes, and concrete lined channels. Ditch systems were historically an integral part of field production within the Agricultural District, supporting the differing irrigation needs of pineapple and sugarcane. The fields used for cultivating pineapple and sugarcane were cleared of vegetation and roads and other infrastructure (e.g. ditch networks) created.

4.8.2.1 Honokōwai and Honokohau Agricultural Ditch Networks

Wahikuli and Honokōwai Watersheds contain numerous manmade water works constructed during the plantation era, and to a much lesser extent modern times. Plantation era works include ditches of varying size, flumes, open surface reservoirs, and other features used to distribute water diverted from and imported into the two watersheds (Figure 18).

There are two primary ditch systems that are the source of nearly all the surface water that was distributed in the plantation era irrigation system and that currently supply water for irrigation and potable uses. The Honokōwai Ditch and Honokohau Ditch, both aligned perpendicular to the slope of the land, carry water under the force of gravity. Their mainstems have numerous lateral smaller ditches that were used to supply water to fields. The diversion of stream water within and outside the natural watershed boundaries via this ditching network makes both past and present land uses possible in the two watersheds.

Honokōwai Ditch

The Honokōwai Ditch is supplied by streams in the Honokōwai Watershed, The Honokōwai Ditch diverts water from Amalu and Kapaloa Streams *mauka* of their confluence at elevation 1,575 ft (480 m). The diverted water is carried in a tunnel in a southwesterly direction and into Wahikuli Watershed where it supplies flow to its ditch and for filling Pu‘ukoli‘i and Horner Reservoirs.

Honokohau Ditch

Honokohau Ditch is the primary source of surface water used for potable water by Maui County Board of Water Supply and agriculture irrigation in the two watersheds (Photo WA2). The primary source of water for the ditch is Honokohau Stream located approximately 7 miles to the north, with additional inputs from Kaluanui and Honolua Streams. Water is conveyed into the project area running in a southerly direction at elevation 700 ft (213 m). Honokohau Ditch and was built between 1902 and 1904 to convey water through the West Maui agricultural region and provide irrigation to the crop fields (W. Nohara, pers. comm.). A portion of it was renamed Honolua Ditch 1912 when it was concrete lined and enclosed in tunnels and pipes. This is the portion that carries water from Honokohau Stream and other nearby stream diversions and crosses over Māhinahina Stream. Māhinahina Stream flow is intermittent and maps do not show that a diversion of its stream flow occurs to supplement water into Honokohau Ditch. At this point, it transitions to an open, concrete lined ditch and retains its original name, Honokohau Ditch, through the remainder of its length. The County of Maui Board of Water Supply withdraws water from Honolua Ditch at the transition point of ditches. The County is allocated 2.5 million gallons a day, though their rate of withdrawal varies, and on some days they withdraw less than the allocation, and others more. The two primary tributaries of Honokōwai Stream are also diverted to supply Honokōwai Ditch, which adds a relatively small volume of water compared to Honokohau in the regional ditch network. The percentage of the stream flows diverted by the various ditches is unknown.

The irrigation ditches that carry water into and across the two watersheds were not systematically inspected as part of this project, however some observations of general conditions were made. Earthen berms line various sections of ditches, and during rainfall events some of the earthen materials likely wash into the ditches. Several stretches of ditches had limited adjacent vegetative cover, meaning that overland flow and material carried with it can flow unimpeded into the ditches. Though not quantified, the amount of sediment generated along the ditch systems appeared to vary. However, the ditch system is not considered a major source of fine sediments when compared to other surfaces in the watersheds.

The amount of water lost from ditches due to evaporation and seepage was not measured. In general due to the high potential evaporation in the Kāʻanapali region, it is expected that surface water bodies such as open reservoirs lose approximately 50 in (1,270 mm) per year.[43]

The imported water made the cultivation of sugarcane and pineapple possible for nearly 80 years in the two watersheds. The import of water sourced from Honokohau Stream continues to this day, however only a small fraction is used for irrigating crops compared to historic plantation era use (W. Nohara, pers. comm.). Water in this system is currently used as a potable supply within Wahikuli and Honokōwai Watersheds by Maui County.

4.8.2.2 Former Field Irrigation Practices

Historic pineapple and sugarcane field irrigation practices likely resulted in the elevated recharge of aquifers beneath the various fields. Construction of fields and ditch systems also changed the timing, rates, and quantity of runoff from the agricultural areas, as well as sediment runoff

[43] Losses attributed to evaporation are derived from PAN measurements made during the sugar cane era. Total volume lost for a water body is the product of evaporation loss and the surface area.

according to the characteristics of the various crop types. The major West Maui streams likely had perennial flow before construction of the diversion and ditch systems but now only flow intermittently in response to rain events.

Pineapple Fields

Pineapple terraces, diversions, and plastic mulch were designed to shed surface water runoff generated by rainfall quickly off the pineapple fields to prevent water infiltration into the soil, which led to root rot of the plants (W. Nohara, pers. comm.), From an erosion perspective, this practice likely had an adverse impact since the runoff accumulated on impervious plastic mulch and was routed quickly off the fields and most probably resulted in accelerated erosion and deposition of eroded sediments into the natural water ways (e.g. gulches and streams that drain to the ocean).

The terraces were aligned roughly perpendicular to the slope of the fields and their outlets placed along the edge of the fields. Dirt roads used by farmers were fitted with small earthen berms angled across the roads that were used to divert runoff water to the gulches and swales along roads to prevent the roads from eroding and washing out. It is unknown when this practice was initiated. This earthen berm design is locally referred to as a 'water bar', however the geometry and installation of the design is more similar to a broad based dip.

The cross block planting and terrace layout formerly used to control surface water is still present today. A majority of the unmaintained terraces have filled with sediment generated from within the fields and from erosion of the adjacent dirt roads.

Sugarcane Fields

The former agricultural practices and features used in sugarcane fields are not as evident as the terraces on the pineapple fields. The sugarcane terraces were fewer and spaced further apart. A major difference in the cultivation and practices between the two crops is that pineapple fields were designed to shed surface water runoff rapidly while the goal on the cane fields was to retain water to irrigate the sugarcane crop (W. Nohara, pers. comm.).

4.8.2.3 Honokōwai Watershed Dams and Basins

In response to algal blooms that occurred in ocean waters in the late 1980s and early 1990s, and observations that large pulses of sediment were discharged from streams draining the West Maui watersheds, WMSWCD, government agencies, and land owners (primarily ML&P) constructed dams and desilting basins. Most of these dams and basins are located on the *mauka* side of Honoapiʻilani Highway within the channel of the streams and gulches they are located on. Three structures were constructed in Honokōwai Watershed: Honokōwai Structure #8, Māhinahina Dam, and Pōhakukāʻanapali (Table 7).

The dams and their basins were primarily designed to capture sediments carried in runoff and not for flood control. However, the structures do capture and store a portion of runoff during flow events, providing for some flood control. A hydrologic analysis conducted by Woodward-Clyde (1996) found that the dams and their basins were effective at attenuating peak flows generated from up to the two year return 24 hour duration rainfall events.

Table 7. Desilting Basin Elevation and Capacity Data

Basin Name	Top of Dam (ft msl)	Spillway Crest Elevation (ft msl)	Height of Dam (ft)	Storage Capacity at Spillway (MG)	Storm Event Capacity
Pōhakukā'anapali	68	66	8	1	<1 yr, 24 hr
Māhinahina	47.5	47.5	9.5	10	<1 yr, 24 hr
Honokōwai	79.4	57.2	50	26	<1 yr, 24 hr

In addition to dams and desilting basins, Honokōwai Stream and Māhinahina Gulch were fitted with concrete lined channels from the dams to their outlets at the ocean, which provide protection to properties *makai* of Honoapi'ilani Highway from flood waters estimated to occur under 100-year flood conditions.

Honokōwai Structure #8[44]

Honokōwai Structure #8 is a State-regulated dam located within Honokōwai Stream, *mauka* of the WWRF, with a drainage area of six square miles. It is 41 feet high with an earthen dam and a maximum storage capacity of 281 ac-ft (Photo HA2). It was designed by NRCS as part of the Honolua Watershed Project and construction was completed in 1995 (M. Hayama, pers. comm.). It is commonly known as Honokōwai Flood Control (Maui County, pers. comm.). The dam was built for debris control and flood control and to act as a debris and desilting basin for capturing large rocks and other large debris from the contributing drainage area (M. Hayama, pers. comm.). It is owned and operated by the County of Maui Public Works, which sponsored the project and took over maintenance after construction was completed. The basin outlet consists of a concrete structure with ports for trapping coarse debris cast incrementally in height along one side of the structure and larger overflow ports at the top of the structure that discharge into the principal outlet channel. An emergency spillway south of the dam conveys water at high flow storm events to prevent overtopping of the earthen dam structure.

SRGII made several observations of Honokōwai Structure #8 during field inspections. Graduations indicating height above ground level are printed on the side of the concrete outlet structure. According to the graduations, there are two sets of three rectangular debris ports estimated to measure 1 ft high by 2 ft long, cast in the stream side face of the concrete outlet structure at elevations 6 ft, 9 ft, and 12 ft. The coarse debris within the channel leading to the outlet structure was at approximate elevation 4 ft, meaning there was 2 ft of vertical distance between the lowest two debris ports and the visible debris level (Photo HA3). Overflow ports at the top of the structure were observed at elevation 25 ft and the principal spillway was estimated to be approximately at an elevation equal to one-half the height of the dam face (elevation 20 ft +/-). Based on these observations, the logical assumption is that water will only impound to a height of roughly one-half of the dam height, making it under-utilized in terms of flood control capacity. Likewise, the basin is effective at retaining sediment during low flow storm events when the water level does not rise above the elevation of the principal spillway or the overflow ports on top of the structure. However, events at which water rises to the height of the overflow ports or spillway most likely discharge sediments stored downstream, moving them through the system rather than retaining them.

[44] http://www.hidlnr.org/eng/dam/pdf/factSheets/maui/MA-0130-Honokōwai8.pdf

The County of Maui mows the basin and berm area on an as needed basis, with more mowing necessary during the winter months (Maui County, pers. comm.). Debris is removed from the concrete outlet structure an average of three times per year depending on the frequency of debris deposition from large storm events. Debris has been observed as mostly large, woody, and vegetative, as opposed to fine or coarse sediment. The water level has not been observed overtopping the dam, and approximately six times in the last 20 years debris has been observed on top of the concrete outlet structure.

Māhinahina Dam

Māhinahina Dam is located within Māhinahina Stream, *mauka* of the highway and southwest of the Kapalua-West Maui Airport (Photo HA4). It is not on the State list of regulated dams through the DLNR Dam Safety Program. The dam was built for flood control and captures debris and sediments from the contributing drainage area within the basin (W. Nohara, pers. comm.). It is operated by the County of Maui Public Works and was designed by the NRCS with Public Law 83-566 funding on land donated by ML&P.[45] The Māhinahina basin is effective at trapping fine sediments due to a long retention time and the orifice sizing of the outlet, and is meant to overtop at large storm events as evidenced by the reinforced concrete dam face on the downstream side of the structure.

The County of Maui mows the basin approximately once or twice per month (E .Kukahiko, pers. comm.). Sediment typically accumulates within the basin in the area of the concrete embankment and is removed with a backhoe and loader approximately two or three times per year. The sediment level typically ranges between 1.5 to two feet at time of removal, but does not exceed three feet due to regular maintenance. An estimated 250–500 cy of sediment is removed annually (this is roughly equivalent to a 6 inch deep layer of sediment covering between 13,500 – 27,000 sq ft of land area). Within the last two years a riprap wall was constructed around the horizontal perforated drainage pipe that protrudes from the concrete embankment in order to provide permanent pipe exposure. This action was taken to alleviate the berm erosion and subsequent sediment deposition that had been occurring upon the pipe.

Pōhakukā'anapali Sediment Basin

Pōhakukāʻanapali Gulch, which empties into the ocean near the S-turns surf break, is fitted with an earthen dam similar in design to the Māhinahina Dam. This impoundment is maintained by Maui County and is not listed on the DLNR Dam Safety Program.

4.8.3 Impacts of Urbanization on Watershed Hydrology

Approximately 21% of the land surface within the Urban District of the Wahikuli and Honokōwai Watersheds is covered by impervious surfaces (e.g., paved roads, parking lots, and roofs) (Table 5). Impervious surfaces prevent rainfall from infiltrating into the ground reducing infiltration rates, increasing surface runoff volume, and degrading runoff quality. Surface runoff flowing over impervious areas has a higher velocity then when flowing over surfaces covered in vegetation because impervious surfaces are smoother. The net effect of impervious surfaces is that they generate larger volumes of runoff and higher peak flows, and decrease the time it takes for runoff to

[45] PL-83-566, along with PL 78-534, is the USDA's nationwide Small Watershed Program, which "assists local organization in conducting watershed surveys and investigations, and in planning and installing structural and land treatment measures for watershed protection and flood prevention". http://www.nd.nrcs.usda.gov/technical/Watershed_Approach/Small_Watershed_Program_PL556.html.

reach the ocean. The end result is that peak flow rates increase and the transport of contaminants off the watershed accelerates, ultimately resulting in adverse impacts to the receiving waters.

The historic and recent urbanization of the two watersheds has had an impact on the hydrologic cycle. Prior to urbanization, and for most of the 20th century, the moderately sloped to near level coastal lowlands were covered with coastal vegetation, wetlands, sand dunes, and agriculture lands and served as flood plain filtering and attenuating storm flows. Now, most of the coastal zone is urbanized and its surface is nearly 50% impervious. The amount of surface water runoff generated under storm events has increased when compared to historic land cover. Impervious surfaces generate runoff more frequently and in larger volumes when compared to the pervious land under agriculture. The fresh water runoff can be considered a pollutant since it can dilute ocean water salinity locally along the shoreline, which can stress coral and other aquatic organisms that do not tolerate low salinity levels (D. Minton, pers. comm.). However, stream flow volumes were greatly reduced compared with historic levels by stream diversions in the early 1900's and in last 30 years by declining rainfall.

Box 6. Impacts of Urbanization on Hydrology

Hydrologic studies conducted in both temperate and tropical watersheds show that the largest changes in runoff from urbanization are seen in the frequently occurring storms such as the two-year storms.[46] The changes in runoff volume were found to be smallest for the 100-year storms. These studies suggest that small to medium rainfall events in urbanized areas generate higher runoff volume carrying more pollutants than for a rainfall event of similar magnitude prior to urbanization. This is mainly due to the directly connected impervious areas (DCIA) in urbanized areas. DCIA are impermeable areas that drain directly to an improved drainage component such as a street, gutter, ditch, or pipe that is part of the S4. An example is a roof that drains into a gutter draining into a downspout, which discharges onto a driveway discharging water onto a street, which runs down a curb into an inlet into a pipe and into Honokōwai Stream. The smooth surfaces of these man-made features increase the velocity that water travels at from its point of concentration to its outlet. Contaminants on DCIA surfaces come from both human activity and natural sources. Most of the contaminants are by-products of daily human activities and are not considered as pollutants or potential pollutants by many people.

An example is the conversion of one acre of land near the shoreline from a surface covered in grass to an impervious parking lot. This changes the time it takes for water to run off and the volume generated. A one hour duration rainfall event with one inch of rain generates 0.1 cubic feet per second (cfs) (0.75 gallons per second) of peak runoff in 40 minutes off the grassed area compared to 1.0 cfs in eight minutes (7.5 gallons in eight minutes) from the parking lot. For the entire impervious surfaces of approximately 200 acres (89 ha) in both watersheds, the difference between the grass and impervious parking lots for peak and total runoff volume are 240 cfs and 35,400 ft^3 (1,000 m^3 or 265,000 gallons).

Ground based inventory and assessment of the storm water system of the Wahikuli and Honokōwai Watersheds confirmed the existence of directly connected impervious areas (DCIA) across many of the neighborhoods, resorts complexes, and condominiums (Box 6). Several of the newer resort complexes have less DCIA when compared to the older condominiums located along the coast in the Honokōwai Watershed. The amount of DCIA in Wahikuli Watershed is less when compared to Honokōwai Watershed. Further discussions about observations of individual properties are presented in Section 6.5.

4.8.3.1 Water Treatment Facilities[47]

The County of Maui Department of Water Supply operates the Māhinahina Water Treatment Facility (WTF) located within Honokōwai Watershed, southeast of Kapalua-West Maui Airport. Its water source is the Honokohau Ditch, and it draws raw surface water from three primary sources

[46] A two year storm is a storm with a 50 percent chance of occurring on any given day in any year.
[47] Information from http://www.co.maui.hi.us/index.aspx?nid=571

outside of the project area: Honokohau, Honolua, and Kaluanui Stream. The WTF's average daily production is 2.4 MGD. The Māhinahina WTF service area includes Lahaina, Nāpili, Wahikuli, Kahana, and ʻAlaeloa. The Māhinahina WTF utilizes pre-sedimentation to treat raw surface water. Techniques including rapid mix, flocculation, and direct filtration with a mixed media filter are used. Chlorine is then added for disinfection.

The Hawaiʻi Water Service Company also operates WTFs in the Wahikuli and Honokōwai Watersheds. This private company uses groundwater mined from several wells distributed across the watersheds.

4.8.3.2 Surface Water Drainage Network

The Urban District is serviced by a S4 fitted with curbs, gutters, inlets, and drainage pipes with outfalls that discharge storm water runoff either directly into the ocean or inland into streams that discharge into the ocean. The primary objective of the S4 is to collect and rapidly move storm water off the watershed and into the receiving waters. A result of the impervious areas and the S4 is an increase in magnitude and frequency of storm water runoff and pollutants carried in it. There are a few management practices (e.g. vegetated swales) on the S4 in the two watersheds to reduce or treat pollutants it transports in storm water runoff, but most of the area is free of management practices.[48]

The S4 is designed to be hydraulically efficient, meaning it will collect and carry runoff rapidly from the area it is located in. S4 systems without management practices installed and integrated into their network do not treat, remove, or improve the water quality.

The S4 extends throughout the watersheds collecting surface runoff from the residential and resorts zones (Photo WU1). The amount of DCIA in Wahikuli Watershed is less when compared to Honokōwai Watershed. The newer resorts (e.g. Westin, Honua Kai), utilize vegetated, landscaped areas within their properties to dispose of some of the storm water collected off impervious surfaces, and vegetated strips between building, parking lots, and retail areas to break up the impervious surfaces. However, parking lots, driveways, and access roads are connected, and part of the S4 conveys runoff to storm water inlets and pipes for disposal.

The urban areas in the watersheds, including the residential and resort properties, are mostly well maintained and free of litter, resulting in a well kept appearance. There are exceptions to this general observation including parking lots with dirt piles, accumulations of particulate matter, signs of liquid spills, and excessive irrigation watering and fertilizers use. Visual inspection of numerous properties was conducted to identify areas of NPS issues, however the inspection did not occur on all parcels and was not exhaustive.

Wahikuli Watershed

There are four surface water channels that drain Wahikuli Watershed and discharge directly into the ocean. They are, from north to south: Hanakaʻōʻō Gulch; an unnamed grass swale that empties into the lagoon located on the north side of *Puʻu Kekaʻa* (Black Rock) at the site of the historic Kakaʻa Landing Pier; Wahikuli/Hāhākea Gulch; and a unnamed gulch that terminates at the

[48] Management practice refers to treatments or preventative actions, which are either structural or non structural, used to reduce generation of, trap, or remediate non-point source pollutants, thereby reducing their loading of receiving waters.

watershed's southern boundary at Wahikuli Wayside Park. A fifth outlet draining the watershed is a pipe that caries water from the ponds located within the Royal Kāʻanapali Kai Golf Course to the ocean. The underground pipe terminates in the ocean near the Cove Bar at the Hyatt Resort.

In the northern end of Wahikuli Watershed, the three resorts located *makai* of Kai Malina Parkway (Kāʻanapali Beach Club, Maikai 301, and Makaha Hotel) dispose of storm water into pipes that connect to Honokōwai Stream along Lower Honoapiʻilani Road. Having been built over a decade ago, these properties were likely required to connect to the S4.

On the north side of the Westin Villa Two is a 3 acre (1.2 ha) open space parcel set aside for infiltration, to maintain flood storage capacity in the area and prevent stormwater discharge to the ocean. This parcel, and the 7 acre (2.8 ha) open space parcel it abuts to the north, were the site of the old Kāʻanapali Airport runway, along with the Honua Kai and the undeveloped Westin property to the north. The channel in the 3 acre (1.2 ha) parcel is lined with grass, has a very gentle slope, and is slightly blocked by an earthen grass berm elevated just *makai* of the ocean. The berm, which is part of a coastal trail network, impounds water, promotes infiltration, and captures pollutants carried in storm water. Runoff generated on the properties and Honoapiʻilani Highway from the Westin Villa 2 south to Maui Kāʻanapali Villas is collected and routed into the S4 fitted with outfalls and then into vegetated swales behind the beach. The swales extend from Hanakaʻōʻ ō Gulch to Maui Kāʻanapali Villas and are aligned parallel to the shore immediately *mauka* of a walkway trail. The vegetated swales slow runoff, filter pollutants, and are an aesthetically appeasing vegetated buffer between the shoreline and the resorts. The swales were mandated in the Special Management Area (SMA) permit as a measure to preserve the flood storage capacity of area and prevent discharge to the ocean.

Runoff generated off a portion of Honoapiʻilani Highway, and the urban area *mauka* of the highway, is captured via the S4 and discharged at an outfall connect to a grass lined swale located on northern most fairway of the Royal Kāʻanapali Kai Golf Course. This swale terminates at the ocean at what is locally referred to as the Lagoon at Black Rock (*Puʻu Kekaʻa*). It is unknown if there are outfalls between the highway and the ocean from the S4 into the swale, though none were observed during field work.

Storm water runoff from all other sections of the Wahikuli Watersheds' urban area to the south, and including the sections *mauka* of the highway, is transported via the S4 to ponds located on Royal Kāʻanapali Kai Golf Course to between Nohea Kai Drive and the highway. The flow direction of the ponds is to the south, where it is eventually carried underground in a pipe terminating in the ocean near the Cove Bar at the Hyatt Resort.

Storm water runoff generated off the highway surface between the southern end of the watershed at its boundary north for approximately 4,000 ft (1,220 m) discharges either into Wahikuli/Hāhākea Gulch, or the unnamed gulch located near the Wahikuli Wayside Park.

Honokōwai Watershed

With the exception of a few, all parcels route most of the runoff generated off their impervious surfaces to underground S4 pipes located on the *mauka* and *makai* edges of Lower Honoapiʻilani Road. Many of the parcels have DCIA across their entire properties, and in some sections there very few spaces where runoff encounters pervious surfaces. The pipes that collect the runoff run parallel to the road and have outfalls that deposit runoff waters to one of four surface water channels that drain subwatershed areas of the Honokōwai Watershed and discharge into the ocean. The four channel from north to south are: Pōhakukā'anapali Gulch located on south edge of Pōhaku Park, Māhinahina Gulch, an unnamed earthen channel at Honokōwai Beach Park, and Honokōwai Stream. The distance between the outfalls at the channels and the ocean ranges between 125 ft (38 m) at Pōhakukā'anapali Gulch to 550 ft (167 m) at Honokōwai Stream. The unnamed channel does not extend *mauka* of Lower Honoapi'ilani Road, and though it is earthen, may have been excavated during urbanization of the watershed, or was a natural channel that was altered and filled above the road.

Storm water runoff generated off the tarmac, runway, parking lot, and terminal building at the Kapalua-West Maui Airport is routed to inlets located along the *makai* edge of the parking lot. The inlets are fitted to a buried pipe aligned along the airport access road connected to Honoapi'ilani Highway, which is turn fitted to a pipe aligned parallel to the highway that outfalls into either Māhinahina or Pōhakukā'anpali Gulch. An unknown amount of the runway is sloped toward the grass/shrublands around its perimeter, and runoff from this area does not go into the S4 directly.

4.9 Biotic Environment

The entire West Maui mountains area is known to contain numerous native plants and animals including at least: 56 endangered species; one threatened species; 21 candidate species; 91 species of concern; and six rare natural plant communities (WMMWP 2011). A portion of these protected species occur in the project watersheds.[49] Habitat destruction and the introduction of invasive species have been the prominent causes of the loss of biodiversity in Hawai'i for over a century (El-Kadi et al. 2008). Invasive plant and feral animals in the upper Conservation District of Wahikuli and Honokōwai Watersheds pose a threat to the watershed and its water resources.

4.9.1 Plant Species and Communities

4.9.1.1 Native Plants

In the entire area that WMMWP manages, there are over 33,000 acres (13,355 ha) of native plant communities including 23,213 acres (9,394 ha) of critical habitat for endangered plants (WMMWP 2011). Portions of this critical habitat occur in both the Wahikuli and Honokōwai Watersheds. The Honokōwai Section of the West Maui NAR contains many rare plants, such as *'Eke* silversword (*Argyroxiphium caliginis*).[50] The Kapunakea Preserve contains at least 24 species of rare plants, including the endangered *mahoe* (*Alectryon macrococcus var. macrococcus*), Hawai'i lady's night cap (*Bonamia menziesii*), *kauila* (*Colubrina oppositifolia*), Pacific lacefern (*pauoa*, *Ctenitis squamigera*), Hawai'i bog orchid (*Platanthera holochila*), and sandalwood (*'iliahi*, *Santalum freycinetianum var. lanaiense*) (TNC 2003). Pu'u Kukui Watershed Preserve contains 15 terrestrial native communities, one of these considered rare as it occurs in fewer than 20 sites worldwide; *'ohi'a* mixed montane bog, 36 species of rare plants (eight endangered), three native forest birds, several tree snails and invertebrates, and Hawai'i's only endemic land mammal, the hoary bat.

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[49] Although biotic information pertaining specifically to the project watersheds is limited, available general information about the West Maui mountains presented in this section is pertinent and presented for the reader's information. Management efforts by the WMMWP address biota in the Conservation District including rare species protection and invasive species control.

[50] Rare is defined by the Hawai'i Natural Heritage Program as species that exist in fewer than 20 populations worldwide.

4.9.1.2 Non-native (Introduced) Plants

Non-native invasive plants can impact native plant communities by altering the environment (e.g., changing the fire regime, inhibiting native plant growth, attracting or supporting increased populations of herbivores). Each of these conditions can negatively affect water quality, mainly through increased potential for erosion.

Over 200 non-native weed species have been recorded in the Conservation District lands under WMMWP management, including strawberry guava (*Psidium cattleianum*), apple guava (*Psidium guajava*), soapbush (*Clidemia hirta)*, Pampas Grass (*Cortaderia jubata*), *Tibouchina spp*., Ironwood (*Casuarinas spp.)*, and java plum (*Syzygium cumini*). WMMWP works to monitor and control established and new occurrences of non-native and invasive plant populations in the intact native communities, as well as restore areas that are a mixture of native and invasive species. Strawberry guava is a well established species and a focus of the majority of control efforts.

Non-native plants dominate the Agricultural and Urban Districts of Wahikuli and Honokōwai Watersheds. In the Agricultural District, both productive and fallow fields harbor non-native plants. Cultivated land provides open space where non-native plants readily colonize and reproduce, providing a seed bank that allows non-natives to persist even after herbicides (both pre-emergent and post emergent) have been applied. Although in-depth surveys for non-native and invasive plant species have not been conducted in the Wahikuli and Honokōwai Watersheds specifically, some of the common non-native and invasive species found throughout Maui and in the MHI are likely present.

4.9.2 Fauna

4.9.2.1 Aquatic Fauna

DLNR-DAR has conducted aquatic surveys of streams in Hawai'i with the objective of quantifying the distribution and abundance of organisms, both native and non-native, to provide critical information for monitoring, assessing, managing, and protecting freshwater resources (Section 5.2). This statewide database has attempted to collect historical biota information and methodically assign labels and rankings to features within Hawai'i's watersheds.[51] Wahikuli Watershed streams have not been sampled.

Honokōwai Watershed streams contain at least eight species of endemic insects, one species of endemic crustacean (*'opae-kaka'ole*, *Atyoida bisulcata*) and one species of endemic sponge (*Heteromeyenia baileyi*). All of these species are found in the higher elevations of the watershed in the headwaters and upper stream reaches. Non-native species of fish and crustaceans are also present in Honokōwai Watershed streams in the upper, middle and lower stream reaches.

4.9.2.2 Marine Biota

Coral species present at two Coral Reef Assessment and Monitoring Program (CRAMP) survey sites located in this area, Kahekili and Māhinahina, have been recorded regularly since 1999 and 2004, respectively. Species that have been consistently observed include: *Montipora capitata*, *Montipora patula*, *Pavona varians, Pocillopora meandrina*, *Porities compressa*, *Porities evermanni*, and *Porities lobata*. Several other species which have been observed sporadically and in low densities include:

[51] Details can be found at: http://www.hawaiiwatershedatlas.com/key3.html.

Leptastrea purpurea, *Montipora flabellate*, *Pavona duerdeni, Pavona maldivensis, Pavona varians*, *Pocillopora damicornis*, *Porities brighami*, and *Porities lichen*. NOAA National Marine Fisheries Service is currently reviewing the status of 82 coral species for potential listing under the U.S. Endangered Species Act. Nine of these species are found in Hawaiʻi waters. Two of these species, *Montipora patula* and *Montipora flabellate*, have been observed during the CRAMP surveys

Both native and non-native fish species utilize the reefs off of Wahikuli and Honokōwai Watersheds. At the Kahekili CRAMP survey site, at least 44 fish species have been observed. The most abundant species were the Brown surgeonfish (*Acanthurus nigrofuscus*) at the 3m reef site, and the Palenose parrotfish (*Scarus psittacus*) at the 7m reef site. The species with the highest biomass were the Brown surgeonfish (*Acanthurus nigrofuscus*) at the 3m reef site, and the Orangespine unicornfish (*Naso lituratus*) at the 7m reef site. Certain species of herbivorous reef fish are protected in the Kahekili HFMA (Section 5.5.4). The protected area extends from Kakaʻa Point to Honokōwai Park.

Green sea turtles (*honu*, *Chelonia mydas*) are a federally listed species (threatened in Hawaiʻi) that are commonly seen in the nearshore waters of West Maui as well as basking on the beaches. Although green sea turtles nest in the Northwestern Hawaiian Islands, they spend much of the year in the MHI feeding on seagrass and algae. Bottlenose dolphins (*Tursiops truncatus*) and pilot whales (*Globicephala macrorhynus*) are two other large marine species that are seen frequently off of West Maui, although they do not forage in the nearshore waters (R. Rankin, pers. comm.).

Other species that move through the waters off of West Maui but are likely not foraging in the area are spinner dolphins (*Stenella longirostris*), humpback whales (*Megaptera novaeangliae*), false killer whales (*Pseudorca crassidens*), and melon-headed whales (*Peponocephala electra*).

Large episodic blooms of oceanic algae species have been a problem in West Maui for over two decades (Photo WO1, HO1) (Section 5.5.2). Non-native species that have been increasingly recorded are *Acanthophora spicifera* and *Hypnea musciformis*. Two algae species thought to be native, *Ulva* spp. and *Cladaphora* spp., can also be invasive. Research indicates that land-based sources of nutrients, including those from agriculture and wastewater are providing support for the continued algal blooms (Dailer 2010, Smith 2005, Morand and Merceron 2005).

4.9.2.3 Snails

Four species of rare endemic land snails, three *Partulina* species and *Perdicella kuhnsi* are found in the area. These species are threatened by rats, non native snails, and habitat degradation.

4.9.2.4 Avian Species

At least four native forest birds have been recorded in the Conservation District: *ʻapapane* (*Himatione sanguinea*), *iʻiwi* (*Vestiaria coccinea*), *ʻamakihi* (*Hemignathus virens*), and *pueo* (*Asio flammeus sandwichensis*). *ʻUaʻu* (*Pterodroma sandwichensis*) have been heard. *ʻApapane* are reliant on native forests for feeding and nesting, specifically *ʻōhiʻa* (*Metrosideros polymorpha*), and are important pollinators of *ʻōhiʻa* flowers. *Iʻiwi,* which is currently being reviewed for listing as a threatened and endangered species by the USFWS, serves an important role as a pollinator of native plant species including *ʻōhiʻa*. *ʻAmakihi*, like *ʻapapane* and *ʻiʻiwi*, is a Hawaiian honeycreeper that serves as a pollinator of native plants, but also forages on select non-natives. The endangered *Pueo* is a subspecies of short-eared owl that inhabits both grasslands and forests, and is endemic to Hawaiʻi. It has been confirmed in the Conservation District but is likely also utilizing resources in the agricultural lands. Hawaiian petrel or *'ua'u*, is an endangered species that has been heard in the area but sightings are difficult to confirm. Petrels likely utilize the Conservation District for nesting.

Non-native birds are also present in the project watersheds. They are thought to play an important role in the dispersal of non-native invasive plant species in Hawai'i (Stone 1985, Woodward et al. 1990). Non-native birds can hinder population growth of native birds through competition for resources and by enhancing the feral cat and rat population by providing a food source.

4.9.2.5 Non-native (Introduced) Fauna

Currently forest degradation caused by wild ungulates is damaging forests in the upper areas of the West Maui watersheds. Wild ungulates damage vegetation and threaten water quality by destroying native plants, accelerating erosion, spreading weeds and depositing feces. Monitoring for ungulates is conducted frequently in the Conservation District of both watersheds. Observations of deer within the WMMWP management area occurred for the first time in 2010 (except for a historic sighting and capture about 10 years ago), although not in the Wahikuli and Honokōwai Watersheds (WMMWP 2011). Pigs have been present for many years within the Conservation District of these two watersheds. Although the WMMWP reported in 2010 that pig captures had significantly decreased since the previous year in the overall WMMWP management area, pigs are the most prevalent ungulate (WMMWP 2011). Wahikuli/Hāhākea Gulches are considered pig "hotspots" and several sightings and captures have occurred there in recent years. Although the effects of feral pigs on native ecosystems are wide ranging, there is emerging evidence that their presence alone may be linked to increases in runoff and soil loss (Browning 2008). Management efforts to control damage from wild ungulates include fencing and animal control at "hotspots" of activity. Currently over 21,000 acres (8,498 ha) in the WMMWP managed areas are fenced. Higher fences are being installed in some areas to reduce the potential of deer entering. In the Honokōwai Watershed portions of the boundary between the Conservation District and the Agricultural District are fenced. In the Wahikuli Watershed the entire boundary between the Conservation District and the Agricultural District is currently fenced. There are also several places throughout the Conservation District of both watersheds that have been fenced to exclude ungulates. All of the fences are maintained by WMMWP.

Mongoose, feral cats and dogs, rodents are known to be present throughout the project area. The presence of these small mammals can negatively impact waterbodies in a watershed by: disturbing native plant populations by trampling, rooting, and eating seeds; dispersing seeds of non-native plants on fur and in feces; and depositing feces. Cats and rodents also prey on native birds contributing to the overall degradation of the ecosystem.

5. Watershed Condition

This section describes the current watershed conditions in terms of classification, ratings, priority/listing status, monitoring data, and coral reef ecosystem condition.

5.1 Surface Water Classifications

There are various designations and classifications for surface waters in the Kāʻanapali region under various statutes and non statutory systems. Some of these offer protections to water resources while others rank the area to support needed action. The Wahikuli and Honokōwai Watersheds have been designated as a priority site by DLNR-DAR's Coral Program to address key threats to coral reefs (Section C.1). The streams of the Wahikuli and Honokōwai Watersheds drain to offshore waters within the boundaries of the Hawaiian Islands Humpback Whale National Marine Sanctuary co-managed as a Federal-State partnership by DLNR, NOAA's National Ocean Service, and the Office of National Marine Sanctuaries. The Kahekili HFMA was established by DLNR-DAR in July 2009 in the reef region adjoining Kahekili Beach Park (Section 5.5.4).

The marine waters around West Maui are designated as Class A by the State of Hawaiʻi (DOH 2006). The objective of Class A 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 the recreation in and on these waters" (DOH 2004). Wastewater discharge into Class A marine waters is controlled and must be treated to a level compatible with the criteria established for this class.

Inland waters throughout Wahikuli and Honokōwai Watersheds are mainly designated as Class 2, with a small number of Class 1 waters in the upper most part of both the watersheds that border the NARs. Class 1 waters are afforded the State's highest level of protection. The objective of Class 2 waters is "to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping and navigation. The uses to be protected in this class of waters are all uses compatible with the propagation of fish, shellfish, and wildlife, and with recreation in and on these waters" (Hawaiʻi Administrative Rules (HAR) §11-54-3).

5.2 Watershed Rating

An assessment by DAR scored watersheds and streams with a standardized rating system that ranges from zero to ten (Parham et al. 2008). The 'Total Watershed Rating', 'Total Biological Rating' and 'Overall Rating' as well as the 'Rating Strength' for each watershed are shown in Table 8.[52]

Table 8. Watershed Ratings[53]

Watershed	Total Watershed Rating	Total Biological Rating	Overall Rating	Rating Strength
Wahikuli	4	NR	NR	0
Honokōwai	5	4	5	6

[52] Total Watershed Rating is based on the combination of criteria that includes land cover, shallow water, stewardship, size, wetness, and reach diversity. Total Biological Rating is based on the combination of criteria that includes native species, introduced genera, and all species. The Overall Rating is a combination of the Total Watershed Rating and the Total Biological Rating. Rating Strength represents an estimate of the overall study effort in the stream.

[53] All ratings have been standardized to a 0-10 range based on the results for all watersheds statewide. Zero is the lowest and 10 is the highest rating based on the quality of specific criteria. Watersheds without survey efforts are unranked (NR).

5.3 Listed Waterbodies

Water quality standards are composed of three elements: designated uses, numeric and narrative criteria, and anti-degradation policies and procedures. Water quality standards set the goals, pollution limits, and protection requirements for each waterbody. The existing Water Quality Management Plan for the State of Hawaiʻi (HAR §11-54) defines State standards for particular parameters for Hawaiʻi waters by both narrative and numerical criteria (Appendix E.2).[54] Standards for inland fresh water systems and marine waters follow the regulations listed in the plan. According to these regulations, elevated levels above numeric toxic pollutant standards would be cause for listing. Intermittent and perennial streams as well as marine waters are considered for the following specific water quality criteria: basic criteria (narrative 'free of' and numeric standards for pollutants (HAR §11-54-4); inland recreational waters (HAR §11-54-8.a); water column for streams (HAR §11-54-5.2.b); and marine waters (HAR §11-54-6) (DOH 2012).

Table 9. Waterbodies in the Integrated 303(d) List/305(b) Report[55]

Geographic Scope of Listing	Impaired for Pollutants on 303(d) List[56]	Exceed Criteria for Pollutants, but not on 303(d) List[57]
Stream Waters		
Honokōwai Stream	Turbidity	TSS (unknown)
Marine Waters		
Hanakaʻōʻō: Hanakaʻōʻō Beach Park	*Enterococci*[58], Turbidity, Nitrate + Nitrite ($NO_3^- + NO_2^-$)	
Hanakaʻōʻō: Hanakaʻōʻō Station	Turbidity, Nitrate + Nitrite ($NO_3^- + NO_2^-$)	
Honokōwai Pt. to Kāʻanapali	Turbidity, Nitrate + Nitrite ($NO_3^- + NO_2^-$), Total Nitrogen, Total Phosphorus	Chlorophyll a, Ammonium (NH_4^+)
Kahekili Beach Park	*Enterococci*, Turbidity	
West Maui Coast: Sheraton Kāʻanapali Shoreline Station	Turbidity	Chlorophyll a
West Maui Coast: Hale Onoloa Condominium Shore Station	Turbidity, Total Phosphorus	Chlorophyll a
West Maui Coast: Māhinahina Condo Shoreline Station	Turbidity, Total Phosphorus	Chlorophyll a
West Maui Coast - Nearshore Waters to 60' from Honolua to Lahaina	Turbidity, Nitrate + Nitrite ($NO_3^- + NO_2^-$), Total Nitrogen, Total Phosphorus, Total Suspended Solids (TSS)	

Under CWA Section 303(d), EPA requires that each state develop a list of waters that fail to meet established water quality standards. To address the point and NPS pollutants creating these water quality problems, Total Maximum Daily Loads (TMDLs) are developed for waterbodies listed on the

[54] Details can be found at http://gen.doh.hawaii.gov/sites/har/AdmRules1/11-54.pdf.

[55] Impaired constituents on the 2008/2010 Integrated 303(d) List/305(b) Report for Hawaii are available from DOH: http://hawaii.gov/health/environmental/water/cleanwater/integrated/2010_Integrated_Report/ChapterIII.pdf

[56] NO_3^- + NO_2^- = Nitrite + Nitrate Nitrogen; Total P = Total Phosphorus; Total N = Total Nitrogen; NH_4^+ = Ammonium Nitrogen

[57] Although water quality data confirms that water bodies are at risk for these pollutants, there is not adequate data to support listing as impaired due to them.

[58] Assessment results for *enterococci* microbiological sampling in embayments and open coastal waters are only applicable within the 1,000 ft (300 m) boundary from the shoreline (HRS 11-54-8(b)).

303(d) list. A TMDL is a calculation of a pollutant budget that generates the maximum load of a pollutant that a waterbody can receive per day and still safely meet water quality standards. Waters within the Wahikuli and Honokōwai Watersheds that are listed in the 2008/2010 Integrated 303(d) List/305(b) Report for Hawaii are shown in Table 9 (DOH 2012). Each of these waterbodies is listed as medium priority (on a scale of low, medium, high) for initiating TMDL development based on prioritization criteria and resource availability. However, TMDLs have not yet been initiated. Studies or projects aimed at addressing sources and reducing NPS pollutants qualify for Federal funding under CWA Section 319, provided these recommendations are part of a watershed plan or comprehensive implementation that addresses EPA's nine elements (Box C1).

5.4 Available Data

Monitoring data, including water quality, flow and geometry are critical to characterizing the watershed and evaluating the condition of the waterbodies (EPA 2008). Data used for this characterization were collected from 2008 through 2011. Data indicate standards for certain parameters were exceeded during this time period. Although the data discussed provides only a snapshot of water quality in the area, this region has had a history of poor water quality for over two decades. Water quality that has consistently exceeded standards for certain parameters, as well as historical nuisance algal blooms and recent coral decline together, is what triggered current studies and this WMP.

5.4.1 Groundwater Well Elevation Data

Numerous historical groundwater observation sites exist within the Wahikuli and Honokōwai Watersheds. Limited online data for well and hole depths, year(s) measured, and water levels was available from the USGS National Water Information System Web Interface[59] for five of these sites, including four wells and one shaft, with no applicable data available for the remainder of the sites. Table 10 summarizes the available data that was extracted. Figure 22 shows the locations of these wells within the watershed, with the majority located within the Agricultural District in close proximity to streams.

Table 10. Groundwater Well Elevation Data

Vertical reference datum: HILOCAL (Local Hawaiian Datum)

Well or Shaft ID	Well Depth (ft below land surface)	Hole Depth (ft below land surface)	Year Measured	Water Level (ft below land surface)	Water Level (ft above vertical datum)
Kā'anapali P-4 (well)	922	922	2008 1981	N/A 862.00	3.63 N/A
Honokōwai B (well)	842	895	2009	N/A	5.43
Puukolii (well)	472	N/A	N/A	N/A	N/A
Hāhākea 2 (well)	524	N/A	N/A	N/A	N/A
Kā'anapali Shaft (S3)	28	N/A	N/A	N/A	N/A

[59] http://nwis.waterdata.usgs.gov/hi/nwis/qwdata

5.4.2 Water Quality Data

Water quality is assessed based on measurements of physical, chemical and biological parameters (Appendix E.1).

5.4.2.1 Data Sources

Sources of data include DOH Clean Water Branch (CWB), USGS, EPA, and scientific research studies.

Water Quality Data from DOH-CWB

As part of the Beach Monitoring Program, DOH-CWB collects and analyzes water samples throughout the year at many different sites Statewide. Water is evaluated for both physical and chemical properties including: *Enterococci*; *Clostridium perffingens*; Total Suspended Solids (TSS); Ammonium (NH_4^+); Nitrate + Nitrite (NO_3^- + NO_2^-); Total Nitrogen; Total Phosphorus; and Chlorophyll a. The water quality data from these collections is posted on the DOH-CWB website. There are two coastal sites within the Wahikuli and Honokōwai Watersheds where samples have been collected over a period of time on a regular basis: Hanakaʻōʻō Beach Park and Airport/Kahekili Beach. Analysis of data from these sites is presented in Section 5.4.2.3.

In 2010 and 2011, DOH-CWB collected and analyzed water samples from 50 sites offshore of the Kahana, Honokōwai, and Wahikuli Watersheds. The intent of the monitoring was to characterize the water quality condition of the entire area based on a set of samples collected throughout the area at randomly selected locations. The effort was charged to DOH by EPA and was funded by Section 106 Monitoring Initiative Grant monies that come to the State via the monitoring section of DOH-CWB. For this monitoring, DOH-CWB used the same protocols followed for the National Coastal Condition Assessment (NCCA). The results of the effort for the Wahikuli and Honokōwai Watersheds are presented in Section 5.4.2.3.[60]

Water Quality Data from Scientific Research Studies

Research conducted in the West Maui area by several agencies and professionals provides some insight as to the water quality and which pollutants as most prevalent. There are also some studies that have conducted modeling based on newly gathered and/or existing water quality data.

5.4.2.2 Physical Water Quality

Physical water quality parameters include pH, dissolved oxygen (DO); biochemical oxygen demand (BOD), temperature, TSS and turbidity (Appendix E.1). Turbidity is one of the impairments for the locations from the Wahikuli and Honokōwai Watersheds that are on the 303(d) List. Table 11 depicts the available data (TSS) for the two sites regularly monitored by DOH-CWB as well as the 2010 and 2011 effort by DOH based on NCCA protocols.

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[60] Only data from sample sites located offshore of the Wahikuli and Honokōwai Watersheds are used in this WMP. This was 31 of the 50 sites in 2010 and 2011.

Table 11. Monitoring Data: Total Suspended Solids (mg/L)[61]

Site	Dates Sample Collection	Number of Samples Collected	Geometric mean	Min	Max
Hanakaʻōʻō Beach Park	3/8/2010 - 12/8/2010	25	28.08	8.00	122.00
Airport/Kahekili Beach	3/8/2010 - 11/30/2011	40	17.79	5.00	87.00
DOH 2010 Sampling	8/16/2010 - 9/15/2010	31	14.83	11.00	24.00
DOH 2011 Sampling	8/30/2011 - 9/1/2011	62	17.78	6.00	41.00

5.4.2.3 Chemical Water Quality

A number of water quality studies have been conducted in the larger West Maui area, including sampling locations within Wahikuli and Honokōwai Watersheds. The studies included analysis of water samples collected from groundwater wells, inland surface water bodies, and the ocean. Several of these efforts were undertaken to quantify levels of land based pollutants generated from land use activities on the watershed, including agriculture and residential and resort landscaping.

The sampling efforts are disparate, in that sample locations included in each study vary, with only a few of the locations sampled repeatedly. The studies did not report standardized forms of Nitrogen, making direct comparison of the reported results a challenge. In addition, none of the sampling efforts are comprised of a large data set, meaning that the data and its statistical summary are based on limited samples for each location. There is no study or effort to collect and analyze water quality on a continuous and consistent sampling schedule. As a result, the samples in each report represent a snap shot for the time period they were collected.

Groundwater Water Quality Data

Soicher's (1996) research shows historic data available for Nitrogen concentrations that was sampled from wells (Table 12). Limited online data on Nitrogen concentrations in wells was available through the USGS National Water Information System Web Interface. Hunt and Rosa (2009) provided data points at Puukolii well and Black Point lagoon. Figure 22 shows the locations of wells and the lagoon by study.

Six shallow groundwater wells were monitored over a 10-year period from 2001 to 2010 on parcels located along the north end of Kahekili Beach (referred to locally as North Beach) by Brock (2011) (Figure 22). These six wells are distributed in pairs, with *makai* sites adjacent to the beach and *mauka* sites no more 1500 ft (500 m) from the ocean. These wells were initially monitored as part of the conditions of a 1998 SMA permit for development that required monitoring until 18 months after completion of construction on the property. The property owners, which include both the Honua Kai and the Westin, have reportedly funded sampling and analysis of the data past the required 18 months. The results from this study are included in Appendix D.2.

[61] There is no State water quality standard for TSS. Although turbidity and TSS are related, a direct comparison of the values is not possible (E.1.3).

Table 12. Groundwater Well and Water Column Water Quality Data

[USGS[62], Soicher (1996) and Hunt and Rosa (2009)]

Source	Sample Date	Nitrate (NO_3^-) (mg/L)	Dissolved Inorganic Nitrogen (DIN) (mg/L)	Nitrate + Nitrite (NO_3^- + NO_2^-)(mg/L)	Ammonium (NH4+) (mg/L)	Dissolved Organic Nitrogen (DON) (mg/L)	Total Dissolved Nitrogen (TDN) (mg/L)	Ammonia (NH_3) water, fltrd, mg/L as N	Nitrate + Nitrite (NO_3^- + NO_2^-) unfltrd mg/L as Nitrogen
5638-03: Honokōwai-B									
Soicher	6/1/93	0.30	-	-	0.001	-	-	-	-
Soicher	10/21/93	0.26	-	-	0	0.06	0.33	-	-
Soicher	4/14/94	0.28	-	-	0.001	0.07	0.36	-	-
Soicher	12/2/94	0.29	-	-	0.01	0.10	0.40	-	-
Soicher	10/20/95	0.29	-	-	0.003	0.06	0.35	-	-
5739-01: Kāʻanapali-P4									
USGS	2/8/82	-	-	1.60	-	-	-	-	-
Soicher	4/14/94	1.85	-	-	0.001	0.03	1.88	-	-
Soicher	12/2/94	1.69	-	-	0.007	0.09	1.79	-	-
5540-01: Puukolii = Upland Well L11 (Hunt and Rosa)									
USGS	2/28/80	-	-	-	-	-	-	-	2.60
Soicher	6/1/93	2.2	-	-	0.001	-	-	-	-
Soicher	10/21/93	2.39	-	-	0	0.04	2.43	-	-
Soicher	4/14/94	2.35	-	-	0.001	0.02	2.37	-	-
Soicher	12/2/94	2.04	-	-	0.007	0.08	2.12	-	-
Soicher	10/20/95	2.35	-	-	0.004	0.06	2.41	-	-
USGS	5/22/08	-	-	3.55	-	-	-	E0.010	-
Hunt and Rosa	5/21/08	-	3.56	3.55	E0.010	-	-	-	-
5540-03: Hāhākea-2									
USGS	2/28/80	-	-	-	-	-	-	-	2.50
Soicher	6/1/93	2.30	-	-	0.001	-	-	-	-
Soicher	10/21/93	2.49	-	-	0	0.04	2.53	-	-
Soicher	4/14/94	2.52	-	-	0.001	0.09	2.61	-	-
Soicher	12/2/94	2.12	-	-	0.006	0.07	2.19	-	-
Soicher	10/20/95	2.35	-	-	0.003	0.01	2.26	-	-
5541-01 (USGS) = Kāʻanapali G (Soicher)									
Soicher	6/1/93	3.40	-	-	0.005	-	-	-	-
Soicher	10/21/93	3.69	-	-	0	0.07	3.76	-	-
Soicher	12/2/94	3.14	-	-	0.006	0.08	3.23	-	-
5640-01: Honokōwai Shaft (USGS) = Honokōwai-R (Soicher)									
Soicher	1974	1.9	-	-	-	-	-	-	-
USGS	12/04/74	-	-	1.80	-	-	-	-	-

62 http://nwis.waterdata.usgs.gov/hi/nwis/qwdata

Source	Sample Date	Nitrate (NO_3^-) (mg/L)	Dissolved Inorganic Nitrogen (DIN) (mg/L)	Nitrate + Nitrite (NO_3^- + NO_2^-)(mg/L)	Ammonium (NH4+) (mg/L)	Dissolved Organic Nitrogen (DON) (mg/L)	Total Dissolved Nitrogen (TDN) (mg/L)	Ammonia (NH_3) water, fltrd, mg/L as N	Nitrate + Nitrite (NO_3^- + NO_2^-) unfltrd mg/L as Nitrogen
Soicher	6/1/93	2.10	-	-	0.008	-	-	-	-
Soicher	10/21/93	2.34	-	-	0	0.02	2.36	-	-
Soicher	10/20/95	1.73	-	-	0.004	0.04	1.76	-	-
5641-01: Kāʻanapali Shaft (S3) (USGS) = Kāʻanapali-D (Soicher)									
Soicher	2/80	4.4	-	-	-	-	-	-	-
USGS	2/28/80	-	-	4.40	-	-	-	-	4.60
Soicher	6/1/93	1.8	-	-	0.005	-	-	-	-
L10: Lagoon Water Column									
Hunt and Rosa	5/21/08	-	3.31	3.31	<0.200	-	-	-	-

Water Quality Data from DOH CWB[63]

In support of the Polluted Runoff Control Program DOH-CWB collects shoreline marine water quality samples for nutrient analysis. Table 13 depicts recent data from the chemical water quality analysis for two regularly monitored shoreline sites in the Wahikuli and Honokōwai Watersheds. Data was analyzed against the Hawaiʻi State standard "geometric mean not to exceed the given value".[64] [65] The analysis shows that at both sites not only did the samples in aggregate exceed State water quality standards for Nitrate + Nitrite (NO_3^- + NO_2^-) for both "dry season" and "wet season" criteria, but nearly all the individual sample values were considerably higher than State standards. The values for Nitrate + Nitrite (NO_3^- + NO_2^-) of individual samples were higher at Hanakaʻōʻ ō Beach Park than at Airport/Kahekili Beach Park. At Hanakaʻōʻō Beach Park, all of the other pollutants, except Total Nitrogen, exceeded State standards when using the "dry season" criteria, whereas at Airport/Kahekili Beach Park, none of the pollutants other than Nitrate + Nitrite (NO_3^- + NO_2^-) exceeded State standards. However, at least some portion of the individual samples from Airport/Kahekili Beach Park exceeded State standards for each of the pollutants monitored.

[63] In accordance with HAR §11-54-6 criteria for "dry season" or "wet season" exceedance is based on the amount of freshwater discharge per shoreline mile. Since this parameter is not known, data presented in this section was compared to criteria for both "dry season" and "wet season". However, it is likely that due to the general climate of the area that a comparison with the "dry season" criteria provides a more accurate portrayal of which parameters may or may not exceed the State standards (S. Roser, pers. comm.).

[64] The geometric mean indicates the central tendency or typical value of a set of numbers (Appendix E.1.1).

[65] The data were not compared to the not to exceed the given value more that 10% and 2% of the time due to the small sample size (Appendix E.1.1).

Table 13. Standard Exceedance for Selected Chemical Water Quality Parameters: DOH-CWB Beach Monitoring Program

	Dissolved Ammonia (NH_3) (mg N/L)	Nitrate + Nitrite (NO_3^- + NO_2^-) (mg N/L)	Total Nitrogen (mg N/L)	Total Phosphorus (mg P/L)	Chlorophyll A (µg/L)
State Water Quality Standard	**0.002**	**0.0035**	**0.11**	**0.016**	**0.15**
Hanakaʻōʻō Beach Park (3/8/2010 - 12/8/2010: 25 Sample Days)					
Geometric mean	0.0025	0.029	0.074	0.017	0.420
Min	0.002	0.002	0.033	0.009	0.070
Max	0.018	0.232	0.375	0.037	3.370
"Dry Season" Criteria					
Geometric mean of samples exceeded geometric mean standards	Yes	Yes	No	Yes	Yes
% of samples that exceeded geometric mean standards	16%	96%	24%	52%	80%
"Wet Season" Criteria					
Geometric mean of samples exceeded geometric mean standards	No	Yes	No	No	Yes
% of samples that exceeded geometric mean standards	8%	92%	8%	32%	68%
Airport / Kahekili Beach (3/8/2010 - 11/30/2011: 41 Sample Days)					
Geometric mean	0.0022	0.014	0.071	0.015	0.134
Min	0.002	0.003	0.030	0.005	0.030
Max	0.011	0.046	0.590	0.035	0.490
"Dry Season" Criteria					
Geometric mean of samples exceeded geometric mean standards	No	Yes	No	No	No
% of samples that exceeded geometric mean standards	12%	95%	22%	39%	51%
"Wet Season" Criteria					
Geometric mean of samples exceeded geometric mean standards	No	Yes	No	No	No
% of samples that exceeded geometric mean standards	7%	93%	10%	20%	12%

For a more complete picture of the water quality in the area, data from the DOH-CWB collection offshore of the Wahikuli and Honokōwai Watersheds in 2010-2011 is presented (Table 14). For each year the data represents 31 sites, with different locations for each year. The sites were selected at random with a minimum number of sites at each of three depths, less than 10 meters, 10-20 meters and 20-30 meters. In 2010 sampling occurred on five days (August 16 through August 18, and September 14 and 15). Conditions were optimal for collection during this time (e.g. calm seas, sunny weather). In 2011 sampling occurred on four days (August 29 through September 1). Conditions were less than optimal with rough seas and stormy weather (W. Okubo, pers. comm.). The 2010 and 2011 results are presented separately because each represents a snapshot of water quality for this area under different conditions.

Table 14. Standard Exceedance for Selected Chemical Water Quality Parameters: 2010 and 2011 DOH-CWB Sampling Using NCCA Protocols

	Water Quality Parameter					
	Dissolved Ammonia (NH_3) (mg N/L)	Nitrate + Nitrite (NO_3^- + NO_2^-) (mg N/L)	Total Nitrogen (mg N/L)	Total Phosphorus (mg P/L)	Dissolved Silica (mg SiO2/L)	Chlorophyll A (µg/L)
State Water Quality Standard	**0.002**	**0.0035**	**0.11**	**0.016**	**N/A**	**0.15**
2010 Data (31 Sample Sites)						
Geometric mean	0.002	0.0038	0.057	0.013	0.136	0.076
Min	0.002	0.001	0.025	0.010	0.050	0.040
Max	0.003	0.021	0.105	0.019	0.673	0.180
2010 Samples "Dry Season" Criteria						
Geometric mean of all sites in aggregate exceeded geometric mean standards	No	Yes	No	No	N/A	No
# of sites that exceeded geometric mean standards	1	18	0	3	N/A	3
% of sites that exceeded geometric mean standards	3%	58%	0%	10%	N/A	10%
2010 Samples "Wet Season" Criteria						
Geometric mean of all sites in aggregate exceeded geometric mean standards	No	Yes	No	No	N/A	No
# of sites that exceeded geometric mean standards	0	11	0	0	N/A	0
% of sites that exceeded geometric mean standards	0%	35%	0%	0%	N/A	0%
2011 Data (31 Sample Sites)						
Geometric mean	0.003	0.0057	0.060	0.011	0.124	0.330
Min	0.006	0.001	0.029	0.007	0.100	0.060
Max	0.002	0.119	0.416	0.058	0.748	3.200
2011 Samples "Dry Season" Criteria						
Geometric mean of all sites in aggregate exceeded geometric mean standards	No	Yes	No	No	N/A	Yes
# of sites that exceeded geometric mean standards	21	25	10	7	N/A	27
% of sites that exceeded geometric mean standards	68%	81%	38%	23%	N/A	87%
2011 Samples "Wet Season" Criteria						
Geometric mean of all sites in aggregate exceeded geometric mean standards	No	Yes	No	No	N/A	Yes
# of sites that exceeded geometric mean standards	14	14	3	2	N/A	19
% of sites that exceeded geometric mean standards	45%	45%	12%	1%	N/A	61%

† For 2011 sample, Total N was only collected at 26 of the 31 sites.

To assess chemical water quality the levels of the following pollutants were evaluated: TSS, Dissolved Ammonia (NH_3), Nitrate + Nitrite (NO_3^- + NO_2^-), Total Nitrogen, Total Phosphorus, Dissolved Silica and Chlorophyll a (Table 14). In order to gain a sense of the water quality of the coastal waters, samples were compared to the "geometric mean not to exceed" as an aggregate set as well as individually.[66] Comparing the samples for each year in aggregate illustrates which pollutants did or did not exceed acceptable levels during 2010 and 2011 for the general area. While individual samples do not represent a "mean", comparison to the "geometric mean not to exceed" (the only available standard) provides a more in-depth picture of the area's water quality and may provide an indication of where additional monitoring might be pursued. Figure 23 - Figure 27 depict the exceedances of the "dry season" criteria for certain pollutants for the 2010 and 2011 samplings.

When looking at the aggregate data, the geometric mean value for Nitrate + Nitrite (NO_3^- + NO_2^-) and Chlorophyll a (2011 sampling effort only) exceed the geometric mean State standards for both the "dry season" and "wet season" criteria, while those for Dissolved Ammonia (NH_3), Total Nitrogen, and Total Phosphorus, do not. Although the criteria for Dissolved Ammonia (NH_3) was not exceeded when assessed in aggregate, when samples were assessed individually, over half of the samples from 2011 exceeded "dry season" criteria (Table 14).

Water Quality Data from Other Sources

Several scientific researchers have collected and analyzed water samples from the Kāʻanapali region as part of their studies.

In a recently published study, Hunt and Rosa (2009) detail results from samples collected just south of Kāʻanapali in Lahaina. They determined that the presence of wastewater constituents within the marine water column at Lahaina has been confirmed and includes tribromomethane, two musk fragrances, a fire retardant, and a plasticizer compound. These same constituents were detected in sampled effluent at the WWRF. The most diagnostic pharmaceutical was carbamazepine, also detected in multiple marine water-column samples and within the WWRF effluent.

Another recent study by Smith (2005) quantified the nutrient environment through samples of the water column and sediment porewater. While nutrient concentrations in the water column were found to be low, sediment porewater sampled 0.82 ft (0.25 m) into the substrate had high concentrations of Ammonium (NH_4^+), Nitrate (NO_3^-), and Silicate, and low salinity relative to overlying ambient water. Smith concluded that this suggests groundwater intrusion was occurring into the sediment interstices and that the elevated nutrients in the groundwater were from land-based anthropogenic activities.

Stevenson (1997) studied samples of sites from the forest reserve, agricultural, and urban lands of the watersheds. The forest reserve was found to have notably low Nitrogen, Phosphorus, and Total Suspended Solids contributions; while sugarcane fields active at the time had extremely high sediment loads. Urban samples contained Total Phosphorus levels that fell outside National Urban Runoff Program (NURP) event mean concentrations (EMCs), and were composed almost entirely of orthophosphate, a soluble form readily available for uptake by plants and algae.[67] The geometric

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[66] The data were not compared to the not to exceed the given value more that 10% and 2% of the time due to the small sample size (Appendix E.1.1).

[67] Event mean concentration is a method for characterizing pollutant concentrations in a receiving water from a runoff event. The value is determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis.

mean of Dissolved Phosphorus exceeded NURP ranges and was suspected to be sourced primarily from fertilizer application.

There are a number of other older research studies that involved the collection and analysis of water samples from these watersheds including Laws (2001) "Coastal Water Quality in West Maui-Lahaina and Kīhei" (16 dates at Honokōwai Stream outlet, Māhinahina Stream outlet, and Pōhakukāʻanapali S-turns); Dollar (2001) "Response of Nearshore Marine Water Chemistry to Termination of Sugarcane Agriculture; West Maui, Hawaii" (two dates at Honokōwai Stream outlet and Wahikuli); Soicher and Peterson (1996) "Assessing Terrestrial Nutrient and Sediment Discharge to the Coastal Waters of West Maui, Hawaii" (groundwater wells and Honokōwai Stream samples); De Carlo and Dollar (1997) "Assessment of Suspended Solids and Particulate Nutrient Loading to Surface Runoff and the Coastal Ocean in the Honokōwai Drainage Basin, Lahaina District, Maui" (four dates at Honokōwai Stream outlet); Dollar and Andrews (1997) "Algal Blooms Off West Maui: Assessing Causal Linkages Between Land and Coastal Ocean" (42 dates at Māhinahina Stream outlet, two dates at Wahikuli); and Dollar, Atkinson, and Atkinson (1999) "Investigations of the Relation Between Cesspool Nutrients and Abundance of *Hypnea Musciformis*, West Maui, Hawaii" (one date at *Puʻu Kekaʻa* (Black Rock)). Each of these studies concluded from the results of water quality analysis that nutrients at levels above normal background were present in the water due to anthropogenic activities.

Legacy pollutants associated with pineapple production have appeared in wells many years after their introduction into the watershed. These include pesticides containing dibromochloropropane (DBCP), which were legally applied to kill nematodes during production of pineapple fields before being banned in 1985; Ametryn, a herbicide; and the chemical 1,2,3 trichloropropane (TCP), a chemical compound commonly used as an industrial solvent. DBCP was detected in three groundwater wells in the West Maui region in 2005 and one in 1993; Ametryn was detected in one well within the project area in 2003; and TCP was detected in five wells in the West Maui region in 2005, one of which was in the project area.[68] The exceedance of drinking water standards for DBCP and TCP in multiple wells, as well as Ametryn in one well in the Kāʻanapali region, confirms that West Maui's groundwater wells are vulnerable to chemical contamination.

5.4.2.4 Biological Water Quality

Sources of microbes in the Wahikuli and Honokōwai Watersheds include humans, feral pigs, rats, birds, and naturally occurring strains. Human sources are tied to waste water systems such as effluent from waste water disposal. Animal inputs can be diffuse or concentrated depending on the number of animals and their spatial distribution.

The water quality measurements performed to ascertain whether there is a human health risk are not based on actual pathogens of concern, but rather on levels of fecal indicator bacteria. The bacteria indicator species used in the United States and Hawaiʻi is *Enterococcus* (Appendix E.1.5.1). The EPA has allowed Hawaiʻi to use *Clostridium perfringens,* in conjunction with *enterococci*, as a tracer to help confirm the presence of human fecal bacteria. Table 15 shows the results of water analysis for *enterococci* and *Clostridium perfringens* at the sites regularly monitored by DOH-CWB.

[68] http://www.hi5deposit.com/health/environmental/environmental/water/sdwb/conmaps/pdf/conmaps05.pdf.

Table 15. Proportion of Samples Exceeding State Standards for *Enterococci* and *Clostridium perfringens*: DOH-CWB Beach Monitoring Program

	2011		2010		2009		2008	
	Sample Days (#)	Exceedance (# days/%)	Sample Days (#)	Exceedance (# days/%)	Sample Days (#)	Exceedance (# days/%)	Sample Days (#)	Exceedance (# days/%)
Hanakaʻōʻō Beach Park	41	2 / 5%	91	7 / 8%	85	15 / 18%	103	4 / 4%
Airport/Kahekili Beach	19	0 / 0%	29	1 / 3%	5	1 / 20%	2	0 / 0%

5.4.3 Surface Water and Groundwater Monitoring

There are no permanent stream flow monitoring stations in the area to assess stream discharge on a regular basis. The streams that drain the watershed all are ephemeral in their lower reaches and do not carry water except for periods following moderate to high rainfall events. There are no wells in the watershed that continually monitor water surface levels. Data on water quantities diverted from the tributaries of Honokōwai Stream is not publically available and thus it was not possible to determine the volume carried in the ditch system.

5.5 Coral Reef Ecosystem Status

Several factors threaten the health and abundance of coral reefs in Hawaiʻi including land-based sources of pollutants, such as sediment, nutrients, and other pollutants (Appendix E.5). Land-based pollutants are generated from eroding land surfaces, and as the by-products of day-to-day activities occurring on the watershed. These pollutants are transported to the ocean in surface water runoff and in groundwater. They are delivered in varying amounts ranging from large loads carried in storm water runoff from intense rainfall events to smaller chronic loads from submarine groundwater discharge. Land-based pollution is responsible for eutrophication, increased sedimentation, toxins, and introduction of pathogens on coral reef systems.

5.5.1 Coral Reef Cover Decline

The majority of reef development along the West Maui coastline has been shown to take place in the shallower depths, between 7-67 ft (2-20 m) (Brown 2008). Fringing reefs increase in abundance along the coastline moving south from Kapalua to Kāʻanapali, with Honokōwai and Kahekili exhibiting some of the best reefs in this area.

Coral reefs at Kahekili have been monitored yearly since 1994 (DAR 2006).[69] Based on an assessment of a series of studies that have examined coral community structure along the West Maui coastline, including monitoring efforts, Brown (2008) estimated change in coral cover. He found that between 1994 and 2006, coral cover at Kahekili declined from 52% to 38% (27% relative decrease) at the shallow site and from 58% to 31% (47% relative decrease) at the deeper site. The most dramatic change occurred between 1999 and 2001 (Brown 2008). See Table 16 for coral reef coverage data by year surveyed for both of the Kahekili sites. Although the reef is still intact, and still looks much like a normal reef, about half of the living coral that was on the bottom

[69] The Pacific Whale Foundation began monitoring in 1994. DLNR-DAR in partnership with the CRAMP began annual surveys in 1999.

of the reef has disappeared. Given the strong possibility that the sites were already somewhat degraded when monitoring began, recent trends almost certainly underestimate declines over longer timeframes (DAR 2006). Several West Maui sites besides Kahekili have experienced decrease in coral cover as well, with human impact a likely contributor.

Table 16. Coral Reef Cover at Kahekili Sites (%) 1994-2006[70]

Site	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Shallow	52	42	51	42	49	44	-	29	33	32	35	29	38
Deep	58	45	50	56	51	30	-	22	21	25	29	24	31

5.5.2 Invasive Algae Growth

Overgrowth of Hawai‘i’s reefs by invasive algae, particularly *Acanthophora spicifera*, *Hypnea musciformis*, *Cladophora spp.,* and *Ulva* spp., is a significant and growing concern. *A. spicifera* has become much more abundant in recent years on the reefs at Honokōwai/Kahekili. Honokōwai was found to have super abundant (greater than 30%) algal cover in multiple reef zones, while Kahekili has abundant (10-30%) algal cover on extensive portions of the reef (DAR 2006).

Episodic algal blooms in the region are also problematic. Blooms generally occur when one or more limiting resources becomes available, leading to rapid algal growth that may grow from shore to depths greater than 100 ft (30 m). The alga smothers coral-dominated areas, and may contribute to a decline in coral cover over time. In addition, beaches are covered with rotting biomass. Algal blooms end once the limiting resource has been exhausted or light levels are sufficiently reduced (Smith et al 2005).

The first publicly recorded occurrence of *Hypnea musciformis* on Maui was in 1985, at a public meeting held to discuss protection measures for *Hypnea musciformis* beds and *moi* (a Hawaiian fish cultivated in fishponds along the coastline) (Woodward-Clyde 1996). DLNR received the first complaints of accumulations in 1987 in Māhinahina, near the Hoyocki Nikko condominiums, and in that same year it was reported to be a problem in several areas including Honokōwai.

Episodic blooms of the green alga *Cladophora sericea* have occurred on the coral reefs of West Maui since the mid-1980’s (Smith et al. 2005). Between blooms, *Cladophora* has been reported growing off of West Maui. Cladophora blooms were first reported to DLNR in 1989, and in 1990 a bloom was found between Honokōwai Point and Māhinahina Stream. *Hypnea musciformis* was found in piles of greater abundance along the shoreline than *Cladophora* at this time. In 1991, a bloom of *Cladophora* was reported between depths of 40-100 ft (12-30 m) near Kā‘anapali (West Maui Watershed Management Advisory Committee 1997). The bloom spread to between Hawea Point and Lahaina Roadsteads at depths of 20 to 60 feet. In the summer of 2001 a bloom of *Cladophora* occurred from shore to about 110 ft (34 m), most abundant at 30 ft (9 m) (Smith et al. 2005). The bloom extended along several miles of the coastline from Kahana in the north to Lahaina in the south.

[70] Friedlander et al. 2008

5.5.3 Herbivorious Fish Decline

Herbivorous fish are the primary grazers in reef ecosystems. They control marine algae growth, enabling new coral recruits to effectively compete for space. Absent healthy populations of herbivorous fish, algae can grow unchecked and limit coral colonization and growth. The presence of healthy populations of herbivorous fish in their native environment can contribute to the recovery of degraded, algae-dominated reefs. DLNR-DAR surveys in December 2006 showed that herbivorous fish biomass at Kahekili was comparable to that of fish communities at other West Maui reefs that are open to fishing. These open fishing locations average around 40% of the total fish biomass observed in the Honolua Bay Marine Life Conservation District, which is the nearest reef closed to fishing (Smith 2009).

5.5.4 Kahekili Herbivore Fisheries Management Area

The Kahekili HFMA was established in July 2009 in the reef region adjoining Kahekili Beach Park (Figure 28). The basis for the designation was data showing a decline in coral cover and an increase in algae, especially invasive *Acanthophora spicifera*. The goal of the HFMA is to increase the reef's capacity to resist a phase shift from coral to macroalgal domination by prohibiting the take of herbivorous fish and sea-urchins that eat the algae. Specifically, the Kahekili HFMA will protect three families of fish (in each family there may be several different species): surgeon fish family (*Acanthuridae*); parrot fish family (*Scaridae*); chubs or *nenue* (*Kyphosidae*); and all sea urchins of the *Echinoidea* class. The management effort is targeted at increasing these grazing populations, which in turn will decrease algae coverage and allow for recovery of coral reef health. In Hawai'i, reefs with abundant populations of herbivorous fishes have little or no invasive algae (DAR 2006).

6. Pollutant Source Assessment

Pollutants generated and transported in and off the Wahikuli and Honokōwai Watersheds are categorized as non-point source. The term 'non-point source' refers to sources of water pollution that are not characterized under the legal definition of 'point source'.[71] NPS pollutants are derived from diffuse origins (e.g. landscaped areas, forests, agriculture lands) and transported via surface water and groundwater. The diffuse nature of NPS pollutant origins and the flow paths over which they are conveyed make it a challenge to reduce their generation and transport. Practically, S4 outlets can be considered point discharges even though the sources of most of the pollutants contained within the runoff are from diffuse sources and classified as NPS.[72] Pollutants from both point and non-point sources degrade water quality, place stressors on biotic organisms, and may render the water non-usable or unsafe to humans. Identification of point sources and storm water runoff and erosion hot spots throughout a watershed assists in identifying locations for treatment or management prescriptions to correct or mitigate the generation and/or transport of pollutants. Effectively targeting NPS pollutants is a complex undertaking as a wide variety of underlying conditions may exist.

The rate at which NPS pollutants are generated and transported to water sources is greatly influenced by anthropogenic behaviors within a watershed. A primary objective of this plan is to identify the types and sources of activities that generate NPS pollution in stormwater runoff. This will facilitate the development of targeted remedial actions aimed at reducing pollutant loads delivered to the ocean.

6.1 Non-Point Source Pollutants

NPS pollutant sources are present in the Conservation, Agricultural, and Urban Districts, generated as part of land use by both humans and animals and land conditions. Natural processes in the environment can also generate NPS pollutants. This section discusses general NPS pollutant sources, resulting impacts, and methods of transport into the environment.

Table 17 provides an overview of major categories of NPS pollutants, including sources and potential impacts. This table is not specific to Wahikuli and Honokōwai Watersheds but rather uses examples of various pollutant types, their sources, and related impacts.

NPS pollutants are transported through the watersheds primarily in surface water and groundwaters. Some NPS pollutants, such as fine sediments, can also be transported via wind. The relative amount of each pollutant type carried in surface water and groundwater varies based on its

[71] 'Point source' pollution is defined in Section 502(14) of the CWA: "The term 'point source' means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture" (http://water.epa.gov/polwaste/nps/whatis.cfm). Point source pollutants are regulated under the CWA, which limits the allowable concentration of pollutants.

[72] There are many storm water conveyance structures within the project area including pipes, channels, ditches, and conduits that discharge water from the urban area. From a hydrologic/engineering perspective the outfalls of these structures are considered point sources. These structures primarily direct runoff collected from diffuse locations distributed over the area they drain during and after rainfall events into stream channels or directly into the ocean. Pipes can be stand-alone structures or interconnected within a system of drop inlets and drain manholes. However, these structures do not meet the legal definition of point source under the CWA.

physical and chemical properties, the agent transporting it, and its position on the watershed (Appendix E.4).

Table 17. Major Categories of Non-point Source Pollutants, Sources and Related Impacts[73]

NPS Pollutant	Major Sources	Related Impacts
Nutrients: Nitrogen, Phosphorus	Urban runoff; failing septic systems; croplands; nurseries; orchards; livestock operations: gardens; lawns; forests; fertilizers; construction soil losses; waste water effluent	Algal growth; reduced clarity; lower dissolved oxygen; release of other pollutants; visual impairment; recreational impacts; water supply impairment
Solids: Sediment (clean and contaminated)	Agriculture (fields & roads);Construction sites; other disturbed and/or non-vegetated lands; urban runoff; mining operations; stream bank and shoreline erosion	Increased turbidity; reduced clarity; lower dissolved oxygen; deposition of sediments; smothering of aquatic habitat including spawning and settling sites; sediment and benthic toxicity
Oxygen-depleting substances	Biodegradable organic material such as plant; fish; animal matter; leaves; lawn clippings; sewage; manure; shellfish processing waste; milk solids; other food processing wastes; antifreeze; other applied chemicals	Suffocation or stress of adult fish, resulting in fish kills; reduction in fish reproduction by suffocation/stress of sensitive eggs and larvae; aquatic larvae kills; increased anaerobic bacteria activity resulting in noxious gases or foul odors often associated with polluted water bodies; release of particulate bound pollutants
Pathogens: Bacteria, Viruses, Protozoans	Domestic and natural animal wastes; urban runoff; failing septic systems; landfills; illegal cross-connections to sanitary sewers; natural generation	Human health risks via drinking water supplies; contaminated shellfish growing areas and swimming beaches; incidental ingestion or contact; swimming
Metals: Lead, Copper, Cadmium, Zinc, Mercury, Chromium, Aluminum, others	Industrial processes; mining operations; normal wear of automobile brake pads and tires; automobile emissions; automobile fluid leaks; metal roofs; gutters; landfills; corrosion; urban runoff; soil erosion; atmospheric deposition; contaminated soils	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain
Hydrocarbons: Oil and Grease, Polyaromatichydrocarbons (PAHs) - e.g., Naphthalenes, Pyrenes	Industrial processes; automobile wear; automobile emissions; automobile fluid leaks; waste oil	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain; lower dissolved oxygen; coating of aquatic organism gills/impact on respiration
Organics: Pesticides, Polychlorinated biphenyls (PCBs), Synthetic chemicals	Applied pesticides (herbicides, insecticides, fungicides, rodenticides, etc.); industrial processes; nurseries; orchards; lawns; gardens; pharmaceuticals, historically	Toxicity of water column and sediment; bioaccumulation in aquatic species and through food chain contaminated soils/wash-off
Inorganic Acids and Salts (sulphuric acid, sodium chloride)	Irrigated lands; mining operations; landfills	Toxicity of water column and sediment

[73] Modified from Field et al. (2004).

6.2 Identification of NPS Pollutant Sources by Land Use Districts

Types and sources of NPS pollutants generated off project area lands are described by district. In addition, available information on specific NPS pollutants, their sources, transport paths, and quantities for Wahikuli and Honokōwai Watersheds is presented (see also Appendix E.4).

Field observations were made throughout the project area and several meetings were conducted by SRGII in January 2012 to aid in identifying general pollutant sources and types within each of the Land Use Districts. NPS pollutant areas of concern (AOC) were compiled based on this work and screening the watershed using high resolution satellite images to determine areas and uses that broadly contribute to sediment, nutrient, and other pollutant loadings. These AOCs were then further divided into specific hotspot areas or sites that were obviously generating or transporting NPS (Figure 29 and Figure 30). AOCs vary considerably within each of the Land Use Districts, due to changes in land use, topography, and other factors. Several of these sources are occur in widespread areas of the watersheds and are denoted as such.

The priority ranking system for addressing NPS pollutant hotspots is dependent upon factors specific to each of the Land Use Districts. Hotspots contain one or more of the factors listed under each of the Land Use District headings. Although a hotspot may appear in only one geographic location, it does not imply that it is less critical than widespread areas. In addition, since field inspections were comprehensive but not exhaustive, there likely are other hotspots in Wahikuli and Honokōwai Watersheds that have not been specifically identified.

6.3 Conservation District: NPS Pollutant Types and Sources

NPS pollutants generated and exported off the Conservation District include nutrients, sediment, and bacteria. Sources including feral ungulate activity and illegal trespassing for recreation cause substantial removal of native vegetation and erosion of soils. Nutrients subsequently migrate into the soils via groundwater infiltration and surface water runoff. During rainfall events, nutrients, sediment, and bacterial pollutants are carried overland into the stream channels, where they are carried in runoff to the ocean.

Within the Conservation District, the highest priority hotspots are those land surfaces with soils that have been exposed by human use, animal use, or natural causes and are subject to erosive action during a rainfall event; or those surfaces that have the potential to be exposed and undergo accelerated erosion as a result of a wildfire.

High priority hotspot characteristics:

- Land characterized by the presence of exposed soil particles on the surface of the earth, as a direct result of human or ungulate activity, with no permanent ground cover to prevent immediate dislodging in event of a rainfall runoff event;
- The underlying soils of stream channel banks and channel bedding, which has been exposed to the environment and is actively eroding due to the natural action of streams.
- Areas that will become susceptible to erosion in the event of wildfire within the region.

Table 18 provides a summary of the pollutant types, pollutant sources, and AOCs within the Conservation District, and Table 19 summarizes the NPS pollution hotspot areas within the AOCs. Hotspots are numbered for reference to *Volume 2, Strategies and Implementation*, where management practices are recommended to address selected hotspots. This section also describes critical areas in further detail based on examination of aerial photography, meetings with various stakeholders, and background research of documented areas of impact within the Conservation District.

Table 18. Pollutant Types, Sources, and AOCs within Conservation District

Pollutant Source	Areas of Concern
Nutrients	
Animal Waste: Feral ungulate and wildlife waste matter.	Wherever species present
Plant Matter: Decay of plant vegetative matter that migrates into natural stream channels.	Recreational bike trails, areas affected by unauthorized access, ungulate activity areas
Sediment from Surface Erosion and Mass Wasting	
Unauthorized recreational dirt bike use	All trails accessed by riders
Feral ungulate trampling and removal of native vegetation	Throughout Conservation District where fencing not effective for control
Non-native and invasive flora and fauna	Select areas not managed by WMMWP
Wildfire Potential	All
Erosion of natural stream channels	Steeper upper sections
Pathogens	
Animal waste	Throughout Conservation District where fencing not effective for control
Natural strains	Research has shown that some bacteria (e.g. *Enterococci* sp.) can reside and propagate in soils
Debris	
Vegetative debris: vegetative matter lost by natural means or due to feral ungulate activity	Wherever species present

Table 19. NPS Pollutant Hotspots within Conservation District

Hotspot Location(s)	Priority
Main dirt bike trail along conservation area; fence cutting locations	High
Locations with populations of feral ungulates, e.g. pigs	High
Eroding stream channels	Moderate
Areas of wildfire potential	High

6.3.1 Descriptions of Pollutant Sources and Hotspot Areas

6.3.1.1 Unauthorized Human Activity

Unauthorized human activity includes the illegal trespassing, and recreational use of trails and reserve areas within the Conservation District, mainly by dirt bike riders. The creation and repeated use of trails by dirt bike recreational users destroys native vegetation and directly exposes soils, resulting in accelerated erosion and sedimentation (Photo CD1, CD2). The trails often become drainage ways carrying runoff and sediment and transporting plant debris and nutrients to the streams (C. Brosius, pers. comm.). Although the WMMWP actively installs fences within the Conservation District to prevent unauthorized trespass, fence cutting to gain access to restricted areas by dirt bike riders and trespassers is an ongoing issue.

Hotspot locations of human activity include entrance to the main trail, heavily traveled dirt bike trails, and where the fencing meets the trail and access is made.

6.3.1.2 Feral Ungulate and Wildlife Activity

Feral ungulate presence in the upper portions of the watershed causes trampling and removal of native vegetation, creates trails, wallows, and generally degrades the landscape (Photo CD3). Ungulates also assist in the dispersal of invasive species, which further degrades the native habitat and often replaces it with a monotypic stand. Ungulate and wildlife waste is also responsible for nutrient and pathogen generation. Feral ungulates and rodents in the watersheds carry leptospirosis, giardia, and cryptosporidium, which can create public health problems in surface waters. Accelerated rates of erosion result from the exposure and sediment transport of the underlying soils during rainfall events, and nutrients and plant debris migrate downstream during storm events. Although fencing operations have been successful in limiting the migration of ungulates within the Conservation District, their presence remains an ongoing problem.

Hotspot areas of ungulate and wildlife activity include all areas where erected fencing has not inhibited migration, as well as fenced areas that have been breached due to vandalism or natural occurrences such as flash floods and downed trees (C. Brosius, pers. comm.).

6.3.1.3 Non-native (Introduced) Flora and Fauna

Dieback of native vegetation and subsequent alteration of the landscape by non-native and invasive flora and fauna has been shown to change rainfall regime and affect runoff volume and infiltration (Appendix E.3.2). This in turn leads to accelerated erosion of soils on affected slopes and subsequent migration of sediment downstream.

The transport of invasive plant species is concurrent with the trespassing of dirt bikers entering the Conservation District, as well as dispersal due to feral ungulates, hikers, wind, and birds (C. Brosius, pers. comm.). Fire, disease, storms, and other disturbance factors can also open up gaps in the forest for weeds to exploit. As seeds of the plants are carried into forest areas, they spread, and in several locations invasive plant species create monotypic stands adversely impacting the hydrologic cycle. Evidence of invasive plant spreading and dominating the landscape is seen in the *makai* end of the WMMWP lands by strawberry guava.

Specific hotspot areas of non-native and invasive flora and fauna are not shown due to the sensitive nature of the topic. These areas are mapped and maintained by WMMWP.

6.3.1.4 Wildfire Potential

The dominance of non-native vegetation across large tracts of both the Agricultural and Conservation Districts is a significant variable in the wildfire regime on the watersheds, although it is not required, as native cover will burn well if the moisture content is low enough. In the more arid portions of the districts where vegetation is comprised mostly of grasses, woody shrubs, and small trees, the potential for wildfire can be high due to the presence of highly combustible fuel loads. Much of the vegetation is classified as ‘one hour fuels’, meaning that in one hour, half the moisture content in a plant can be lost. These areas contain a large fuel source and when ignited, fire can travel at high rates across the landscape and consume a large amount of the total plant matter. The resulting bare and exposed landscape is vulnerable to accelerated erosion (Photo CD4) (Appendix E.3.4).

Drought conditions were a large contributor to a recent 100 acre (40 ha) wildfire in the Kahana-Kahanaiki Watersheds on WMMWP managed lands (C. Brosius, pers. comm.). The fire exposed the landscape to sediment and Nitrogen transport as well as landslide potential. Documented wildfire events within the project area have occurred in the Wahikuli/Hāhākea region at elevations just below the forest reserve boundary, as well as in lower Honokōwai Watershed *mauka* of the WWRF. Conservation District lands remain vulnerable to future wildfires of a similar nature.

KLMC participates with Maui County emergency personnel (including Fire, Police, and Civil Defense personnel), as well as neighboring land owners, in the planning and prevention of wildfires (J. Rebugio, pers. comm.). The resources necessary for farming the land (i.e. equipment, access, irrigation water infrastructure, land base knowledge, green non-fuel) inherently provide for wildfire prevention control.

6.3.1.5 Natural Stream Channels

The streams draining the Conservation District transport sediment and woody debris delivered into their channels via surface overland flow. Additional inputs of sediment and woody debris occur from within the channels. In several reaches the inputs from within the channel are increased over background due to feral ungulates that trample and generally destabilize the channel's bed and banks making them prone to erosion. Mass wasting, or landslides, input sediments and woody debris directly into channels in some locations where steep slopes tower above the stream valley. Mass wasting along steep slopes is similar to surficial erosion in that it can occur at naturally occurring rates or accelerated rates due to land disturbance that destabilizes the slope.

6.4 Agricultural District: NPS Pollutant Types and Sources

Primary NPS pollutants within the agricultural areas include nutrients, animal waste, sediment, pesticides, and salts (Tetra Tech 2010). Surface runoff and leaching of pollutants into groundwater are the two methods of transport of these pollutants into the ocean (Appendix E.4). Fine sediments may also be transported by wind, though in less amounts as compared to water. Fugitive dust and its fallout onto parcels downwind of agriculture fields have been observed by residents in both watersheds. Salts on field surfaces come from irrigating with brackish water or other soil amendments. Salt can be pulled to the surface in water that is evaporated, leaving salt residue. This salt residue can be washed off the surface during runoff events and delivered to the ocean. It is unknown if farming practices to remove salt from fields occurs. Salts at certain levels may be an issue to growing target crops.

Within the Agricultural District, the highest priority hotspots are areas of exposed soil that are actively eroding, or have high erosion potential due to anthropogenic land alteration, activities, and land use. These hotspots are characterized by exposed soil particles on the surface of the earth, with no ground cover to prevent particle dislodging when in contact with rainfall runoff. Soils have a high likelihood for rapid downstream transport into stream channels and the coral reef environment when intermixed in stormwater runoff.

High priority hotspots include one or more of the following characteristics:

- Lack of vegetative ground cover or conservation cover on agricultural field surfaces. Lack of practices to control erosion and runoff from fields, and roads. Exposed and unprotected surfaces are vulnerable to accelerated erosion and sedimentation from both water and wind.
- Have high potential for rapid transport of particles from an exposed soil surface downslope via the access roads (access roads convey stormwater runoff along the surface and behave like a conduit for rapidly transporting runoff into the Urban District under storm conditions).
- Have extensive square footage of exposed soil surface area within the Kāʻanapali region (greater surface area of exposed soils equates to higher generation of sediment loads).
- Located on steep topographical grades within road surfaces, which exposes soils to the greatest kinetic energy for dislodgement of particles due to runoff action.
- Pollutants generated at the hotspot and intermixed with stormwater runoff would be ultimately directed to Wahikuli Gulch or another stream channel that does not have existing basin or dam structures in place. Pollutants would not receive any treatment benefits due to attenuation or settling that may occur as a result of these structures within a stream channel, prior to discharge into the coral reef environment.
- Located at manmade drainage conveyance structures, showing evidence of highly active sediment deposition into or erosion of natural stream and drainage channels.

Medium priority hotspots include one or more of the following characteristics:

- Have cover crops planted on an agricultural field surface, but the surface is still subject to erosive action due to exposed underlying soils. The field lacks grass or conservation cover necessary for soil stabilization.
- Pollutants generated at the hotspot would be ultimately directed to either Māhinahina Stream or Honokōwai Stream when intermixed within stormwater runoff and most likely receive some level of treatment due to attenuation or settling within the existing basin/dam structures (e.g. Māhinahina Dam or Honokōwai Structure #8) present in those streams, prior to discharge into the coral reef environment.
- Located at manmade drainage conveyance structures showing evidence of medium sediment deposition into or erosion of natural stream and drainage channels.
- Located at manmade drainage detention structures with exposed soil surfaces over the majority of their footprint, and in close proximity to natural drainage channels.
- Located at field access roads aligned with contours and showing no substantial erosion.
- Located on exposed soils on steep topographical grades adjacent to, but not within, access roads, and running parallel to ground topography. Medium potential for conveyance along surface of roads and into drainage system.

Low priority hotspots include the following:

- Manmade drainage conveyance structures within fallow fields, showing minimal evidence of sediment deposition into or erosion of natural stream and drainage channels.
- Stream channels subject to natural erosion processes.
- Wild plantings, tall grass, or other vegetative cover that stabilizes an agricultural field surface. The surface is minimally subject to erosive action.

Table 20 provides a summary of the pollutant types, pollutant sources, and AOCs within the Agricultural District. Table 21and Table 22 summarize the NPS pollution hotspot areas within these

AOCs. Based on field observations of the various crop fields, surrounding agricultural road network, associated drainage infrastructure, and meetings with stakeholders in the Agricultural District, hotspot locations were also generated and are shown on Figure 29.

Table 20. Pollutant Types, Sources, and AOCs within Agricultural District

Pollutant Source[74]	Areas of Concern
Nutrients	
Fertilizer: Present applications used for various types of crop production.	Active coffee fields.
Fertilizer: Past applications used for various types of crop production.	Fallow pineapple, sugarcane, seed corn, and coffee fields
Animal Waste: Feral ungulate, wildlife waste matter.	Upper fields closer to Conservation District boundary
Sediment	
Unstabilized manmade channels: streams and stormwater conveyance channels, basin embankments, and basins	Former agricultural ditches, channels and County of Maui maintained stormwater basins
Stream bed and bank erosion	Accelerated erosion of unstable stream and gulch banks generating sediment
Bare fields	Fallow seed corn fields
Unmaintained field access roads	All dirt roads
Eroding shoulders of paved roadways (Puukolii, Kakaalaheo, and Akahele Roads	Primary access roads into Agricultural District and Kapalua Airport
Unauthorized recreational dirt bike use	Upper fields closer to Conservation District boundary: all trails accessed by riders
Organics	
Pesticide: Present applications used for various types of crop production.	Active coffee fields
Pesticide: Past applications used for various types of crop production.	Fallow pineapple, sugarcane, seed corn, and coffee fields
Pathogens	
Feral ungulate and wildlife waste matter	Upper fields closer to Conservation District boundary
Debris/Litter	
Vegetative debris: illicit green waste dumping	Various locations
Illegal dumping of household, commercial, and industrial litter	Along culvert crossings of access roads
Shredded plastic irrigation tubing on fallow fields and nearby access roads	Fallow pineapple fields / nearby access roads

Table 21. NPS Pollutant Hotspots within Agricultural District

Hotspot Location(s)	Priority

[74] See Section 6.4.1 for additional detail on fertilizers and pesticides by crop type.

Hotspot Location(s)	Priority
Agriculture roads (Pineapple fields): Steep upper segments, running perpendicular to contours, showing evidence of heavy erosion	High
Agriculture roads (Seed corn fields): Steep segments, running perpendicular to contours, showing evidence of heavy erosion	High
Pineapple field terraces: Primarily in lower fields north of Honokōwai Stream	Medium
Pineapple field terrace outlets and access road outlets into stream channels: at various locations in along fallow fields	High
Fallow bare seed corn fields (all)	High
Māhinahina and Honokōwai Streams, other natural stream channels	Low
County of Maui maintained earthen dams and desilting basins	Low
Unmaintained field access roads (aligned with contours, showing no moderate erosion, all regions)	Medium
Eroding access road shoulders (steep segments aligned with contour)	Medium
Active and fallow coffee field terraces: Location (all)	Low
Fallow pineapple and sugarcane fields, active and fallow coffee fields (all)	Low
Dirt bike trails along upper elevations of agricultural region	High
Base yards used for chemical and equipment storage	Low

Table 22. Nutrient Source Areas of Concerns within Agricultural Areas

Areas of Concern	Priority
Fallow pineapple fields	Low
Fallow sugarcane fields	Low
Fallow seed corn crop fields	Unknown or Low
Active and fallow coffee fields	Low
Māhinahina and Honokōwai Streams, other natural stream channels	Low
Dam embankments and desilting basins	Low
Unmaintained agriculture roads	Low
Feral ungulates	Low
Ditch erosion	Low
Individual wastewater systems	Low

6.4.1 Descriptions of Select Pollutant Sources and Hotspot Areas

Sources of pollutant input within the project area include elements of both historic and current land practices associated with growing of crops over the past century (Photo WA3). Soil amendments, irrigation practices, current field conditions, field drainage practices, and associated infrastructure are all components of agricultural development and production that generate and contribute pollutant loads to the ocean. Specific practices related to crop management in West Maui for current and former crops are presented in this section.

6.4.1.1 Soil Amendments

Since sugarcane and pineapple production has ceased, the amount of fertilizers and pesticides being applied in the Wahikuli and Honokōwai Watersheds on agriculture lands has decreased.

Dollar (2001) estimated that 50% of the Nitrate Nitrogen present in the groundwater that discharged into the coastal region of West Maui was from fertilizers applied to sugarcane fields. Those chemicals that reside as legacy to the former plantation era farming are most probably degrading and being remediated in-situ in the soils and groundwater. In addition, the amount being exported from beneath the agriculture lands to the ocean via ground and surface water is probably decreasing with time. Although the current crops are irrigated and soil amendments are applied (e.g. fertilizers and pesticides), the amounts and frequency are far less than what was applied during sugarcane and pineapple production due to the difference in acres cultivated. While the fate of some of the amendments, namely pesticides and herbicides, in these watersheds remains unknown, the movement of Nitrogen and Phosphorus from fertilizers into the water and to different parts of the watershed has been well documented (Smith 2005, Dollar and Andrews 1997, Soicher and Peterson 1997, Soicher and Peterson 1996). Dollar (2001) noted that flushing the aquifer of agricultural nutrients is likely to take 2 to 10 years. Soicher and Peterson (1996) noted that in some cases Nitrates may be introduced into the aquifer 15 years after their application on the surface. Previous research found elevated nutrient levels in groundwater down slope of active agriculture fields.

Table 23 shows the general amount of Nitrogen/Phosphorus/Potassium (NPK) applied to specific crops in Hawaiʻi. The NPK value represents the percentage of each nutrient by weight found in the mix.[75] The amount varies and is a function of plant uptake and soil type, and rates should be based on periodic soil testing. Nitrogen may be applied as either urea in liquid form added to irrigation water or in solid form as Ammonium Sulfate.

Table 23. Range of Fertilizer Application Rates to Crops in Hawaiʻi[76]

	Nitrogen (lbs/ac/yr)	Phosphorus (lbs/ac/yr)	Potassium (lbs/ac/yr)
Seed Corn	57	57	57
Coffee	200-300	50-75	200-300
Sugarcane	163	25	357-402
Pineapple	207	0-162	357

As illustrated in Table 23, typical seed corn application rates for Nitrogen, Phosphorus, and Potassium are generally low compared to the other three field types. Nitrogen application rates are highest for coffee and pineapple, while pineapple has the highest upper range of Phosphorus rates. Potassium rates are comparable for coffee, sugarcane, and pineapple.

Within any crop or orchard operation, fertilizer is a high and variable cost. In order to minimize additive fertilizer and only apply necessary amounts, nutrient monitoring was conducted (J. Rebugio, pers. comm.). Fertilizers are applied efficiently and directly via a drip irrigation system. Naturally occurring materials within the farms produce some level of nutrient input as well (J. Rebugio, pers. comm.).

[75] For example, a 10N-5P-20K NPK mix for coffee field application means there is 10% Nitrogen, 5% Phosphorus, and 20% Potassium by weight. Individual nutrient application rates are then calculated by multiplying the percent weight by the fertilizer application rate. For coffee, a lower range value of 1,786 lb/ac/yr x 10% = 179 lb/ac/yr Nitrogen is applied.

[76] See additional details in crop specific information below.

Active and Fallow Coffee Fields

Generally fertilizers and herbicides are the main amendments used for coffee cultivation in Hawaiʻi. Typically coffee production requires large amounts of fertilizer. The addition of fertilizer to coffee depends on what stage of growth and production the trees are in, as well as the local environmental conditions. Current application rates used in West Maui are 200-300 lbs/ac/yr (224-336 kg/ha/yr) of Nitrogen, 50-75 lbs/ac/yr (56-84 kg/ha/yr) of Phosphorus, and 200-300 lbs/yr (224-336 kg/ha/yr) of Potassium (K. Falconer, pers. comm.).[77] Foliar application of micro-nutrients is also performed twice per year at rates less than 5 lbs/ac/yr (6 kg/ha/yr), which includes Copper, Zinc, Calcium, and Boron. Although some weed control is accomplished by mechanical means and using different types of mulches, the use of post-emergence herbicides, usually those containing glyphosate, are the main method of weed control in Hawaiʻi coffee orchards.

Fallow Seed Corn Fields[78]

Fertilizers and herbicides are the main amendments applied to fields and crops for seed corn production (Photo WA4). In Hawaiʻi the recommended application rate for fertilizer is 357 lbs/ac (400 kg/ha) of a 16N-16P-16K mix just before seed is planted and then weekly applications in proportion to Nitrogen uptake.[79] There are approximately 70 chemicals that can be used for weed management for corn crops in Hawaiʻi. These are both post-emergence herbicides including: those containing glyphosate (Roundup), glufosinate, 2,4-D, and paraquat; as well pre-emergence herbicides that fall into the four major classes: thiocarbamate, triazine, acetanilide, and dinitroanalines.

Fallow Sugarcane Fields

Fertilizers and herbicides are the main amendments used for sugarcane cultivation in Hawaiʻi. While some nutrients, such as Phosphorus, are only applied once or twice during the crop cycle, Nitrogen and Potassium are applied monthly in small amounts for the first 10 to 12 months of the 24 month crop cycle. After that, applications of Nitrogen cease in order to induce ripening. Manure or sewage effluent are not used because the Nitrogen may be released too late in the crop cycle, inducing vegetative growth instead of sugar storage. The typical rate of Nitrogen application to sugarcane fields in Hawaiʻi is 268-357 lbs/ac (300-400 kg/ha). Locally, sugar fertilization rates (163 lb N/ac/yr and 25 lb P/ac/yr) were provided by Pioneer Mill for the 1997 West Maui Watershed Owner's Manual and are shown here in Table 23, averaged over the two year growing cycle. Herbicides are particularly important for profitable sugarcane production. The industry depends principally on pre-emergence herbicides, usually from the triazine class but also utilizes post-emergence herbicides such as those containing glyphosate or 2,4-D.

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[77] In general for Hawaiʻi the CTHAR recommended fertilizer rate for coffee is 1,786-2,321 lbs/ac (2,000-2,600 kg/ha) of a 10N-5P-20K mix. This equates to 179-232 lb/ac/yr (200-260 kg/ha/yr) of Nitrogen, 89-116 lb/ac/yr (100-134 kg/ha/yr) of Phosphorus, and 357-464 lb/ac/yr (400-520 kg/ha/yr) of Potassium.

[78] Data for fields specific to West Maui was not available.

[79] This translates to 57 lbs/ac/yr of N, P, and K. Specific values were not available for fields in West Maui.

Fallow Pineapple Fields

Generally fertilizer, herbicides, and fungicides are the main amendments used for pineapple cultivation in Hawaiʻi. Fertilizer in particular is important because high fertility produces the best crop yield. In Hawaiʻi the need for added Nitrogen is visually assessed since soil Nitrogen analysis is quite variable (Bartholomew et al. 2003). Fertilizer is generally applied to pineapple once or twice per month for up to 12 to 14 months depending on need. Pineapple fertilization rates (207 lb N/ac/yr (232 kg/ha/yr) and O-162 lb P/ac/yr (0-181 kg/ha/yr)) were provided by Maui Pineapple Company for the 1997 West Maui Watershed Owner's Manual and are shown here in Table 23, averaged over a five year growing cycle.[80]

Bartholomew et al. (2003) notes that "when growers strive for maximum production, the use of large amounts of fertilizer can result in nutrient losses, especially Nitrate losses, in drainage water". With the amount of fertilizer typically applied to pineapple fields, Nitrogen losses due to leaching, run off, and erosion may be an important problem in tropical islands such as Hawaiʻi (Bartholomew et al. 2003). A study of Nitrate leaching in pineapple showed that the loss of Nitrate below a depth of 12 inches (30 cm) was greatest where large amounts of Nitrogen (more than 268 lbs/ac (300 kg/ha)) were applied to a soil with high residual Nitrogen (Reinhart 2000). The typical rate of Nitrogen application to pineapple fields in Hawaiʻi is 357-446 lbs/ac (400-500 kg/ha).

The use of black plastic mulch between plants is one method employed for weed control in pineapple fields. Herbicides are used between as well as in the mulched beds. Pineapple tolerates potent herbicides so there are many options for which ones to use including herbicides that contain glyphosate; hexazinone; bromacil; and diuron.

6.4.1.2 Irrigation Practices

Field irrigation practices combined with rainfall events have the potential to move both particulate and dissolved forms of nutrients into waterways via overland flow. Nutrients can leach through the root zone when rainfall and irrigation rates result in more water in the soils than is uptaken by plants. The old pineapple fields in the Wahikuli and Honokōwai Watersheds were irrigated using drip irrigation systems at least for the last few decades of cultivation. Old sugarcane fields were irrigated via furrows for at least the first half of the 20th century, and were eventually irrigated using drip lines. Coffee orchards and seed corn fields also use drip irrigation. Drip irrigation allows for precise delivery of water to crops and can be used to apply amendments such as fertilizer or herbicides (Photo WA5, WA6). Some sections of irrigation ditches intercept overland flow and sediments it carries. A portion of the ditch water and sediments are directed to large reservoirs where sediments settle and accumulates over time and is reused in crop fields (J. Rebugio, pers. comm.). Sediments introduced to an irrigation system can create maintenance issues such as clogging filters and emitters.

[80] March 12, 1997 memo to Wendy Wiltse from Wes Nohara RE: Comments/corrections to "N" & "P" pineapple nutrient loads.

6.4.1.3 Current Field Conditions

Active and Fallow Coffee Fields

The majority of active coffee fields were observed to contain coffee trees with ground residue. Fallow fields were observed to contain dense grass cover in most locations that serves to stabilize the underlying soil. The high percentage of vegetative cover within the active and fallow fields provides adequate ground cover and protection to the soil (Photo WA7), and the fields were not observed to substantially contribute to sediment concentrations in runoff. Recently planted trees on the upwind, northern edge of the farm function to mitigate wind impact and protect the trees and plants within the farm (J. Rebugio, pers. comm.).

Fallow Seed Corn Fields[81]

In order to prevent cross-contamination planted seed corn fields were surrounded by fallow (bare) fields (J. Astilla, pers. comm.) (Photo WA8, WA9). These fallow fields remain, are vulnerable to wind and water erosion, and are a large source of the sediment that is transported off the watershed. The amount of sediment lost from the bare fields is a function of rainfall, ground slope, proximity to surface channels, and management practices used on and around individual fields.

SRGII observed management practices in the form of grass buffer strips around some of the seed corn fields, which were designed to filter and trap sediment carried in runoff. Contour berms are aligned between some of the fields, which are used to slow overland flow and trap water and sediments. The most widely used management practice is trapping sediment via detention basins located downslope of the seed corn fields (J. Rebugio, pers. comm.). This practice does not control the rate of erosion off of individual fields, but does trap a percentage of sediments mobilized from the fields that drain and are routed towards the basins. This practice does appear to reduce transport of both coarse and fine sediments off KLMC lands. Several fields in the southern section of Wahikuli Watershed do not have this type of sediment detention basin. In some of these fields overland flow and sediments are routed more directly to gulches that drain to the ocean.

Seed corn farming was done under agreement with Monsanto whereby KLMC prepared the plots for planting and Monsanto planted and harvested the corn (J. Rebugio, pers. comm.). After harvesting the seed corn, fields were left as long as possible with the residual corn plants in place, until the next plantings were scheduled (J. Rebugio, pers. comm.). While there were times where a fair amount of field plots were left open, they were tended with irrigation to foster germination of any fugitive seeds, followed by plowing to remove the weeds and any other germinated plants. This process, known as 'flushing', readies the fields for planting. This activity can span a period of several weeks, somewhat dependent on water availability (J. Rebugio, pers. comm.).

Fields were plowed under three times per year (J. Astilla, pers. comm.). Crop residue left onsite from the previous harvest was tilled under during the first treatment. As a result of repeated plow applications, the soil was observed to be powder-like, making it more susceptible to entrainment in the air by wind erosion and mechanical agents, e.g. tractors resulting in generation of fugitive dust.

[81] In June 2012, during preparation of this report, it was learned that Monsanto will no longer grow seed corn on KLMC property. It is unknown what farming activities will take place on the now-abandoned seed corn fields. Depending on the amount of rainfall, plants will likely be allowed to grow opportunistically on the bare fields until they are cultivated.

Fugitive dust frequently falls out on the Urban District, which is downwind of the fields under normal tradewind weather patterns.

Representative fields were selected to quantify rates of soil loss for each of the major types of agriculture fields. The resulting values support field observations and knowledge of erosion processes. This underscores the potential for extreme erosion rates, soil loss, and potential sedimentation within ocean waters during moderate to heavy rainfall events from many of the bare plots undergoing current cropping practices by seed corn operators (Section 6.7.1.2). In several sections of the seed corn parcels it appears that when a rainfall event occurs, runoff drains unrestricted via overland flow from the crops and surrounding fallow fields downstream along the unstabilized access roads and ultimately into the stream channels.

KLMC monitors the weather forecast days in advance of impending storm events to prepare for storm conditions (J. Rebugio, pers. comm.). Maintenance that is more frequent during the rainy season includes re-conditioning or fortifying water-bars and diversion berms, turning off irrigation, and clearing basins. KLMC also maintains a weather station to provide information to better understand rain events and how they translate to runoff condition.

Fallow Sugarcane Fields

The majority of fallow sugarcane fields were observed to be covered with moderate to high density non-native grasses (Photo WA10). The grass protects the soil particles from detachment during rain and slows overland flow, which also protects the soil from erosion. The grasses would be consumed rapidly if a wildfire were to occur across the fields. There were few signs of active erosion in the form of rills and gullies on the fields, and deposition of recently transported sediments adjacent to the fields was sparse. In general, the fallow cane fields are not eroding at rates significantly above background. However the dirt roads that traverse the fields are actively eroding and appear to be generating significant amount of sediment that are transported offsite towards the ocean.

Fallow Pineapple Fields

The pineapple fields are littered with plastic piping that was used for drip irrigation. Most of the pipe pieces did not show significant signs of degradation and the fate of these pipes and their material (either made of vinyl or polyethelene) is unknown. Piping debris was observed in various locations in the fallow pineapple fields, shredded during previous field tillage operations. This debris was observed on the dirt roads on the edges the fields (Photo HA5) and has been observed by ML&P personnel to be effective in reducing soil erosion in some areas. The pineapple plants still growing on some of the middle to upper fallow fields provide vegetative cover, which helps reduce erosion potential. On other fields in this zone, non-native grasses, shrubs, and trees provide moderate to high coverage of the fields. Fallow pineapple fields in the lower elevations of the agriculture lands are more sparsely covered and there are numerous openings between plants, making them more vulnerable to erosion (Photo HA6). Similar to the sugarcane fields, the dirt road network across most of the fallow pineapple lands are in poor condition and not maintained. The roads are eroding and generating sediment and runoff at accelerated rates, and convey storm water during runoff events.

6.4.1.4 Field Drainage Practices

Pineapple Field Terraces

Pineapple fields were historically planted in a cross-block layout, fitted with a network of 6-foot wide terraces and diversions used to collect and carry surface water runoff generated by rainfall events (W. Nohara, pers. comm.). The terraces are designed to carry water from 5 acre (2 ha) contributing sections at a 1.5-2% grade from the center of the fields outward and off of the fields. The primary reason was to prevent saturated conditions that may have caused pineapple root rot.

The majority of pineapple terraces were observed filled with sediment to a depth of between one and two feet. This sediment accumulation is the result of both unstabilized upslope access roads directing sediment-laden stormwater runoff from the road surface into the terraces and from within the fields. The terraces are intended to receive road and field runoff and direct it at a uniform slow flow rate through the pineapple fields to stream and drainage outlets to minimize erosion. The unmaintained condition of the terraces has inhibited their ability to function as drainage and irrigation channels.

Fine sediment accumulation was observed in stream channels adjacent to both the clogged terraces and the access roads as a result of rainfall events with no prior management practices available for stormwater treatment (Photo HA7). The unmaintained and unstabilized nature of the terraces can lead to substantial contributions to sediment accumulation downstream.

Sugarcane Field Drainage

Unlike pineapple fields, sugarcane fields were kept as wet as possible, utilizing contours to retain surface water and keep soil moisture high. Therefore, rainwater runoff was routed onto and held within fields as much as possible. Other differences in agricultural practices include drip irrigation for sugar vs. foliar feeding for pineapple and the use of impervious plastic mulch on pineapple fields. A logical assumption to make in the differences between irrigation practices and runoff from the two crop fields is that cane probably resulted in transporting soil amendments to groundwater, where as pineapple probably carried more amendment in surface water runoff.

Coffee Field Terraces and Drainage System Regulations

Terraces in active and inactive coffee fields were observed to be in general working condition to capture runoff from field access roads within the region. However, the potential for clogging of terraces exists in both active and fallow fields if terraces are left unmaintained.

Within the coffee farm's agriculture subdivision, regulations and rules are in place requiring the lot owner to design drainage systems to retain/detain storm water as a part of the proposed improvements (J. Rebugio, pers. comm.).

Field Sediment Basins

There are several field sediment detention basins located along the *mauka* edge of the WWRF. KLMC has found that these basins effectively impound and significantly reduce stormwater runoff (J. Rebugio, pers. comm.). KLMC has existing, effective management practices for removing sediment generated on fields (J. Rebugio, pers. comm.).

Diversion Berms

There are many diversion berms and water bars that are maintained to mitigate runoff from entering the larger drainage ways (J. Rebugio, pers. comm.). In areas that do not have basins, KLMC has positioned diversion berms to capture runoff into fallow areas and away from the large drainage ways and gulches; allowing longer drainage travel paths. During utility related activities such as construction work, dust control, and diversion berm maintenance/restoration, contractors and utility companies are required to use practices to rectify ground disturbances and mitigate potential impacts (J. Rebugio, pers. comm.).

6.4.1.5 Infrastructure

Unstabilized (Bare) Field Access Roads

Another main source of erosion and sediment transport within the Agricultural District includes the dirt road network that surrounds and cross all of the agricultural fields (Photo WA11). Many of these dirt roads have definite evidence of erosion and are estimated to be the biggest source within the Agricultural District to sediment transport downstream (J. Astilla, pers. comm.). SRGII agrees with Mr. Astilla that the dirt roads are a significant source, and likely the biggest overall source, of sediment loads delivered offsite under the current landscape conditions. However, SRGII hypothesizes that the fallow seed corn fields have the potential to generate sediment loads at volumes higher than the roads. The road surfaces have been compacted from years of vehicular use, as well as subject to surficial erosion from upstream field runoff concentrating and flowing along the road surface. Runoff has removed loose surface soil particles in many locations, leaving road surfaces hardened and scoured. In contrast, the powder-like and loose nature of soils within the seed corn field fields leaves them uncompacted and vulnerable to dislodging and transport downstream during rainfall events of widely variable intensity.

SRGII inventoried numerous dirt roads in both watersheds and observed many erosion hotspots, primarily roads in the steeper upper sections of the Agricultural District (Photo WA12). This is in part due to lack of maintenance to and/or lack of management practices, including water bars, proper road geometry, kickouts[82], and field terraces. However, removal of sediment and silt accumulations at transition points and reapplication to the access roads or fields is a standard ongoing practice (J. Rebugio, pers. comm.).

The most pronounced signs of erosion are on roads that are aligned straight uphill without angles and extend for long distances at uniform grade. Several stretches contained deep rutting, scouring, and sediment deposits (Photo WA13, WA14). Many access roads also have exposed shoulders that are often equal to or greater in width than the road with itself, effectively doubling the surface area of travel way susceptible to erosion (Photo WA15). The roads effectively function as conduits for runoff and sediment transport during rainfall events, carrying a large volume of sediment and depositing a portion of the load at slope breaks and low points in road grade as flow drops at the end of rainfall events. In several areas, there were indicators that runoff was routed off the road and

[82] A kickout is a drainage outlet location where runoff carried on a road is diverted onto adjacent land. The kickout is normally fitted with an energy dissipater (e.g. covered with rock or material) to protect the kickout area from erosion.

onto and over adjacent fields towards gulches that drain to the ocean. Eventually most of the loose, unconsolidated sediment will be routed off the watershed and into the ocean.[83]

The unmaintained terraces in the fallow pineapple fields and dirt roads within the pineapple field region are the primary hotspot location within the lower regions of the Agricultural District. The lack of maintenance has increased the amount of sediment routed off the roads along the fields and sediment generated on the fields.

During personal communications with John Astilla, he noted that water bars are installed in the roads to divert stormwater back into the fields, but many are not in operating condition. Upon further inspection, SRGII feels that the referenced road water bars may be more accurately characterized as broad based dips. These dips function in some locations to guide stormwater onto the adjacent terraces, however with the clogging of terraces by sediment, the dips may be bypassed and fail to reduce flow volume and energy, allowing erosion of the downstream section of the road.

There are also sections of access roads that do not display visual evidence of erosion and appear to be generally in good shape. Roads fitting this description are not considered hotspots of sediment generation within the watersheds, and are not identified as needing remediation. While the dirt surface of access roads will always present vulnerability to erosive action, the roads themselves are a common element of agricultural industry. In order to mitigate dust, KLMC gravels heavily traveled roads when feasible, and employs water trucks during harvesting season when heavy farm equipment is in use (J. Rebugio, pers. comm.).

Unprotected (Bare) Shoulders of Paved Roadways

Three paved roads provide the primary access to agriculture lands and residential properties on the *mauka* side of Honoapi‘ilani Highway. From north to south they are: Akahele Street, the access road to Kapalua-West Maui Airport; Kakaalaneo Drive, a farm access road; and Puukoli Road, used to access residential neighborhoods and agriculture fields. The latter two roads are located in Wahikuli Watershed, the former in Honokōwai. The shoulders of these roads are dirt, with sparse vegetative cover, and are eroding at accelerating rates. Due to their alignment and relative steep slopes, sediments generated off the shoulders are routed to the S4 storm drain inlets at or near their intersection with the highway. The most problematic is Kakaalaneo Road, while the least problematic is Akahele Street.

Unstabilized Road Crossings at Stream Locations

Unstabilized road and rail stream crossings are failing and eroding at accelerated rates (Photo WA16). As a result, both fine and large sediment particles are input directly into the drainages. Several problematic spots were observed including: the railroad bridge crossing at Wahikuli Gulch above Kā‘anapali Golf Course, and several unnamed dirt roads within active and fallow fields.

Illicit Dumping on Field Access Roads

Illicit dumps with a variety of refuse materials were observed at several locations in gulches draining Wahikuli Watershed (Photo WA17). The observed locations are in somewhat isolated areas out view of the general public. One illicit dump site in is Wahikuli Gulch, and another in an

[83] This statement takes into account that the desilting basins on Honokōwai and Māhinahina Streams will trap a portion of the sediments carried in runoff in their channels.

unnamed tributary to it at the roadway crossings adjacent to the residential subdivision undergoing development *mauka* of Kāʻanapali Golf Course. Observed refuse includes miscellaneous metals, car parts, and barrels. The contents of the barrels are unknown.

Eroding Stream and Gulches

Stream channels are prone to erosion along their bed and banks under both natural and accelerated rates. Sections of various stream channels were inspected within the Agricultural and Urban Districts to identify areas where erosion was accelerated by manmade features or activities.

Honokōwai Structure #8

Honokōwai Structure #8 is an earthen dam. The dam embankment is covered with very little vegetation, and has rills across its surface indicating it erodes during rainfall. Sediment eroded off either face of the dam is delivered into either the reservoir side, or the outlet side. In either case the erosion contributes to sediment loads delivered to the ocean. The debris ports fitted to the outlet structure block passage of large debris on the reservoir side of the dam, however sediment can be carried through the outlet ports when the reservoir water level reaches the level of the outlets (Photo HA8). In addition, the spillway on the south side of dam is unprotected and will contribute sediment when it carries water and under rainfall events.

6.4.1.6 Unauthorized Human Activity

Unauthorized human activity includes the illegal trespassing onto both Agricultural and Conservation District lands. The interface between these lands is used extensively by dirt bike riders, and the numerous single track trails generate and transport significant amounts of sediments. This activity is probably most problematic with respect to erosion and transport of alien plant species. Land owners often report that fences are cut, locks on gates are removed, and obstacles such rock piles erected to close trails are moved by riders.

6.5 Urban District: NPS Pollutant Types and Sources

Urban areas not only alter the surface hydrology, but are also significant sources of NPS pollutants (Schuler et al. 1992). Common activities that generate these pollutants include: driving, illicit disposal of used oils (e.g. cars, cooking), normal wear of automobile brake pads and tires, automobile emissions, automobile fluid leaks, washing cars, landscape maintenance (including the use of pesticides and fertilizers, lawn mower use, discharge of leaves or cuttings into storm drain system), dirt from construction or landscaping activities, improper disposal of waste (including littering, pet waste, food-related, household chemicals, appliances), wash down from loading docks, disposal of wash water from housekeeping activities, lack of maintenance to grease traps, use of metal roofs and gutters, and discharge of chlorinated water (e.g. from pools or fountains).

A survey conducted between March and April 1996 by Kinnetic Laboratories, Inc. at 83 sites within West Maui identified sources of non-stormwater discharges into storm drains or directly into ocean waters (Woodward-Clyde 1996). Visual observations were taken at each location, with sediment found to be the most persistent pollutant, present at 21.9% of sites; followed by litter (19.5%); oil (12.2%); landscape vegetation (8.5%); and other less frequent pollutants resulting from urban use and activities (Table 24).

Table 24. Categorization and Frequency of Urban Area Pollution Observations[84]

Pollutant Source Category	Frequency of Occurrence (% of Sites)
Sediment	21.9
Litter	19.5
Oil	12.2
Landscape Vegetation	8.5
Storage and Maintenance	7.3
Swimming Pool	6.1
Cleaning Activity	4.9
Concrete/Grout	3.7
Paint	3.7
Other	4.9

The urban areas contribute nutrients, sediment, vegetative and manmade debris, pesticides, hydrocarbons, and bacteria to groundwater and surface water runoff (Appendix E.4.2). Construction activities regardless of size can cause generation of NPS pollutants, especially sediment. Nutrient contributions are most probably primarily sourced from application of fertilizers onto golf courses and resort, residential, and commercial landscaping. Parking lots and roadways contribute hydrocarbon pollution when rainfall events direct runoff untreated into drainage systems.

Within the Urban District, the highest NPS pollutant priority hotspots are areas of exposed soil that are actively eroding, or have high erosion potential due to anthropogenic land alteration, activities, and land use. These hotspots are characterized by exposed soil particles on the surface of the earth, with no ground cover to prevent particle dislodging when in contact with rainfall runoff. The soils can easily be transmitted into the coral reef environment when intermixed in stormwater runoff due to their close proximity to the coastal ecosystem.

High priority NPS hotspots feature the following characteristics:

- Exposed soil surfaces that are the result of current or past land development activities. These surfaces lack vegetative cover or hardscaping to stabilize the soils currently, and they are susceptible to erosion and migration due to rainfall runoff.

Medium priority NPS hotspots feature the following characteristics:

- Deposition of pollutants from motor vehicle leakage or maintenance/washing onto impervious surfaces. These pollutants are readily transported off of the impervious surfaces and into drainage channels when they come into contact with rainwater or vehicle washwater.

Low priority NPS hotspots feature one or more of the following characteristics:

- Low pollutant generating surfaces, including stream channels subject to natural erosion processes, and streams hardlined with manmade materials to minimize erosive action.

[84] Excerpted from Woodward-Clyde (1996).

- Impervious areas subject to airport use.
- Extended surface areas with healthy vegetative cover that stabilizes soils and minimizes pollutant generation.

The highest priority hotspots of nutrient generation are those areas that have potential for or readily introduce high nutrient loadings into the coral reef environment, either through surface or groundwater transport.

High priority nutrient hotspots feature one or more of the following characteristics:

- Regular introduction of high nutrient loadings into the groundwater table.
- Regular application of fertilizers on the ground surface on a single property or large geographic area, that results in high nutrient loading to the region.
- Regular application of fertilizers or other nutrient sources on small properties or areas, that when accumulated result in a high overall nutrient loading to the region.

Medium priority nutrient hotspots feature the following characteristics:

- Stream channels subject to natural nutrient generation processes.

Table 25 provides a summary of the pollutant types, pollutant sources, and AOCs within the Urban District. Table 26 summarizes the NPS pollution hotspot areas within the AOCs. See also Figure 30. Hotspots are numbered for reference to Volume 2 of the WHWMP, where management practices are recommended to address selected hotspots.

Table 25. Pollutant Types, Sources, and AOCs within Urban District

Pollutant Source	Areas of Concern
Nutrients	
Fertilizer application: Past and present applications used for golf courses, hotel and resort facilities, commercial and residential landscaping	All areas that apply fertilizers
Animal Waste: Wildlife and domestic animal waste matter	All residential areas and resorts
Vegetative matter: Lawn clippings, plant materials that migrate into waterway	All residential lots, resorts, hotels, commercial businesses, golf courses
Wastewater disposal: Underground Injection Control, cesspools, septic systems, reuse at Kāʻanapali Golf Course	Groundwater shallow and deep seeps at coastline
Soil Losses: Erosion and sediment transport of soils at construction sites	Residential home construction, hotel, resort construction and renovations
Sediment and Particulates	
Infrastructure: Vehicle egress, parking lots, highways, unstabilized and stabilized access roads, closed drainage systems.	All vehicular egress areas of the project area
Exposed soils: Residential and commercial construction activities, unstabilized land	Residential and commercial construction sites and unimproved lands planned for development
Debris/Litter	
Vegetative debris: from landscaping, pruning, and natural vegetative losses	All residential lots, resorts, hotels, commercial businesses, wooded, and natural stream areas
Illegal dumping of household, commercial, and industrial litter	Manmade and natural channels, roadside ditches, culvert crossings

Pollutant Source	Areas of Concern
Organics	
Applied Pesticides: Past and present applications used for golf courses, hotel and resort facilities, commercial and residential landscaping	All residential lots, resorts, hotels, commercial businesses, golf courses
Hydrocarbons	
Vehicle oil and grease on roadways and parking lots	All vehicular egress areas of the project area
Vehicle washwater	Fleet car rental facilities, residential and commercial businesses
Pathogens	
Wildlife and domestic animal waste matter	Residential areas
Onsite wastewater systems, sewage spills	Residential properties on individual sewer systems

Table 26. NPS Pollutant Hotspots within Urban District

Hotspot	Hotspot Location(s)	Priority
1	Unstabilized residential and commercial construction sites	High
2	Wahikuli Gulch and other eroding natural stream channels	Low
3	Unstabilized developed lands (cemeteries, beach park erosion)	High
4	Outdoor vehicle washing	Medium
5	Concrete lined stream channels / basin outlet channels	Low
6	Impervious parking lot and roadway surfaces	Medium
7	Kapalua-West Maui Airport	Low
8	Kāʻanapali Golf Course and other stabilized and landscaped areas	Low
9	Baseyards used to store chemicals, equipment, and offices	Low

Table 27. Nutrient Generation Hotspots within Urban District

Priority	Hotspot Location(s)
High	WWRF Underground Injection Control
Low	Kāʻanapali Golf Course landscaping
Low	Resort, commercial and residential landscaping
Medium	Wahikuli Gulch and other eroding natural stream channels

6.5.1 Descriptions of Select Pollutant Sources

The following are urban sources of NPS pollution that have a high contribution to first flush and extended rainfall events as observed infield by SRGII personnel (Appendix E.4.2).

6.5.1.1 Exposed Soils During Construction

SRGII observed house lots under construction in a subdivision *mauka* of Kāʻanapali Golf Course with exposed dirt on moderate to steep slopes without any erosion management practices in place (Photo WU2). The length of the fill slope was approximately 45 ft (15m) at a grade of 14%. The acreage of the parcels is unknown, and if less than one acre, NPDES permits are not required. However, per Maui County guidelines, a slope with these dimensions warrants some level of protection to prevent sediment transport offsite to the storm water swale adjacent to its toe (Appendix C.5.3).

6.5.1.2 Rental Car Washwater

Carwash runoff generated at the parking lot used by Dollar Car Rental was observed discharging untreated into Hanakaʻōʻō Gulch near Halawai Drive and Honoapiʻilani Highway. The contours of the parking lot direct the spent washwater into a culvert that carries runoff under the highway towards the ocean.

6.5.1.3 Wahikuli Gulch

Wahikuli Gulch is an unlined natural channel along its entire length. Several sections of its channel banks were observed to be highly unstable and susceptible to erosion, especially within the stretches directly *mauka* and *makai* of Honoapiʻilani Highway (Photo WU3). High runoff volumes generated under moderate to high rainfall events likely occur given the size of the contributing watershed area. This likely results in bank erosion and generation of large volumes of sediment. There are no desilting basins on this water way to reduce sediment discharges into the ocean.

6.5.1.4 Hanakaʻōʻō Cemetery

Hanakaʻōʻō Cemetery is located adjacent to Hanakaʻōʻō Beach Park along the south side of Wahikuli Gulch just *mauka* of the ocean (Photo WU4). The cemetery is a representative example of developed lands within the two watersheds that have no permanent land cover, in the form of either impervious or landscaped surfaces, and are a source of sediment transport into the ocean during high volume rain events (Photo WU5). In addition, dust frequently generated by wind gusts is a nuisance to park users and downwind resorts.

6.5.1.5 Kāʻanapali Golf Courses

Due to the extensive grass covering the two Kāʻanapali Golf Courses, erosion and sediment generation are minimal (Photo WU6). Some fraction of total amount of nutrients in fertilizers and pesticides applied to the courses are suspected to leach into soils and groundwater, and/or be carried during overland flow events. However, it is unknown how much, if any, nutrient runoff is being generated and carried to the ocean.

The two Kāʻanapali Golf Courses include 200 acres (81 ha) under turf management, all of which consist of hybrid bermuda grass (C. Trenholme, pers. comm.). Of the 200 acres, 150 acres (61 ha) are irrigated with R-1 treated water from the WWRF (1.2 MGD), and 50 acres (20 ha) are irrigated using KLMC water stored in *mauka* reservoirs within the watershed. The upper or *mauka* nine holes of the course *mauka* of the highway are on KLMC water, and its lower nine holes are irrigated using R-1 water. All 18 holes of the course *makai* of the highway are irrigated using R-1 water. The *mauka* golf course has a small open reservoir filled with WWRF R-1 water used to irrigate the 27 holes.

Gypsum is added as amendment on the *makai* holes because of salts that build up from irrigation with R-1 treated water (C. Trenholme, pers. comm.). The R-1 water is contaminated with brackish groundwater from infiltration along the WWRF collection system and is subject to fluctuating salt content that often reaches high levels. A historically high Phosphorus concentration was also present in the R-1 water as a result of laundry detergent contributions from influent to the WWRF;

subsequently the concentrations have decreased. Most recent available sampling results of the WWRF effluent (December 21, 2011) show a Total Phosphorus measured concentration of 0.35 mg/l. Although the level of Total Phosphorus is monitored in WWRF effluent, it is not subject to specific limits under the requirements of either of the facility's DOH or EPA UIC permits (Section 6.6.2). The most recent sampling data does however exceed State of Hawai'i water quality standards for all streams and open coastal waters, during both wet and dry seasons (Appendix E.2). See Section 6.7.1.3 for additional selected constituent concentrations applicable to both the R-1 water and final effluent injected into the wells (Table 34).

Golf Course Ponds

The two ponds on Kā'anapali Kai Golf Course receive surface water runoff from land in central portions of the Wahikuli Watershed. Flow through the ponds appears to be from north to south with discharge via a buried culvert that daylights offshore fronting the Cove Bar on the Hyatt Regency property. A portion of sediments and particulates carried in runoff and deposited in these ponds is likely sequestered and does not reach the ocean via the culvert outlet. The ponds also likely intercept groundwater containing dissolved nutrients and other pollutants draining the upslope aquifers. The volume and quality of groundwater intercepted by these ponds is unknown. In the mid 1990's the two ponds experienced algae blooms that were hypothesized to be caused by fertilizers applied to the golf course. Remedial actions to rectify the issue included release of herbivorous fish to eat the algae and control its spread (W. Wiltse, pers. comm.).

Fertilizer Practices

Fairways and roughs account for 80% of the golf course cover, on which 30N-1P-9K slow release granular fertilizers are applied at the rate of 1.25 lb/1,000 sq ft (0.57 kg/93 m^2) with 12–13 weeks between applications. This results in approximately four fertilizer applications per year, and equals an average monthly application rate of slightly less than 0.5 lb of Nitrogen/1,000 sq ft/month (0.23 kg/93 m^2/month) (C. Trenholme, pers. comm.). This equates to approximately 20.9 tons (41,817 lb; 18,968 kg) of Nitrogen applied per year to the fairways and roughs. Each fertilization application is conducted over a two week time period on the entire 200 acres (81 ha) with machines. The six acres of golf course greens are fertilized every month with a slightly higher application rate of approximately 0.75 lb/1,000 sq ft/month (0.34 kg/93 m^2/month). This equates to approximately 1.2 tons (2,352 lb; 1,067 kg) of Nitrogen applied per year to the greens. In total, approximately 22.1 tons (44,169 lb; 20,035 kg) of Nitrogen is applied per year over the entire golf course. The R-1 water from the WWRF used to irrigate the golf courses contains various concentrations of Nitrogen and in theory supplements Nitrogen for the grass (Section 6.6.2). The calculations of the amount of fertilizer applied to the greens and other playing surfaces do not take into account the amount of Nitrogen in the R-1 water (C. Trenholme, pers. comm.).

The 1.2 MGD of R-1 water supplied to the courses during the driest periods of the year results in additional Nitrogen loadings of approximately 20,000 lb/yr applied through irrigation (Section 6.7). However, the Kā'anapali Golf Courses report little to no benefit to vegetative growth resulting from the R-1 sourced Nitrogen loads.

In 1997, Soicher and Peterson wrote that the Lahaina District's five golf courses added Nitrogen and Phosphorus to the fairways, greens, and tees. "Tetra Tech, Inc. (1993) reported Nitrogen application rates of 0.98 lb N/1,000 sq ft/month (47.85 kg N/ha/month) on greens and tees, with half that quantity applied to fairways.[85] Phosphorus applications are estimated at 1/10 those of Nitrogen." Soicher and Peterson (1997) go on to say that "Leaching from golf courses is extremely variable with regard to the percentages of leachate (0-84%); mean leakage equal to 10% of the applied Nitrogen is typical." At the time of the study, golf courses within the area were considered to contribute negligibly to groundwater Nitrates when compared with WWRF injectate, sugarcane fertilization, and pineapple cultivation contributions.

Pesticide Practices

Herbicides, insecticides, and fungicides are used on the courses sparingly (C. Trenholme, pers. comm.). When a problem area arises, such as pests or plant disease, it is addressed with chemicals but only as necessary, and always following recommendations on the package label.

CTAHR General Golf Course Maintenance Recommendations

The College of Tropical Agriculture and Human Resources (CTAHR) publishes factsheets and conducts research relating to turfgrass management in the state of Hawaiʻi. Recommendations on fertilizer and pesticide use, as well as other related factors are available at http://turfgrass.ctahr.hawaii.edu/.

Nutrient Application

Golf courses commonly use various hybrid bermuda grass cultivars for golf course fairways, tees, and putting greens, and common bermuda grasses are used for golf course roughs (Brosnan and Deputy 2008). Nitrogen is the nutrient that most affects the quality of bermuda grass. It promotes density, growth, and color of turfgrass, and is the nutrient needed in the highest amount. The most abundant nutrient in the majority of turf fertilizers, it is lost due to volatilization, leaching, and microbial activity on a greater scale than any of the other elements. This in turn requires frequent additions of Nitrogen to satisfy the needs of turfgrass. Deputy (2000) considered Milorganite® one of the most widely used Mainland Nitrogen sources for golf-green turf and it was commonly used on Hawaiʻi's golf courses for this purpose. However, negative odor issues related to the use of Milorganite® has rendered it an uncommon amendment and it may not be used on any courses in Hawaiʻi at this time (C. Trenholme, pers. comm.).

"In Hawaii, mature bermudagrass stands require 9-24 lb of Nitrogen, 1-4 lb of Phosphorus as Phosphate (P_2O_5), and 4½ -12 lb of Potassium as Potash (K_2O) per 1,000 sq ft per year (Brosnan 2008). Nitrogen should be applied monthly at rates of ¾ -2 lb per 1,000 sq ft…Do not apply more than 1 lb of soluble Nitrogen per 1,000 sq ft in any application. Slow-release fertilizers can be applied less frequently and at higher rates than soluble (quick-release) fertilizers; however, do not apply more than 2 lb of Nitrogen per 1,000 sq ft in any single application. A program incorporating both soluble and slow-release Nitrogen sources is recommended. Phosphorus and Potassium can be applied in three or four equal applications during the year" (Brosnan and Deputy 2008). Given that the two Kāʻanapali Golf Courses consist entirely of hybrid bermuda grass, and their rates of nutrient application using slow-release fertilizers are 0.75 lb N/1,000 sq ft/month (32.7 lb N/ac/month) for the greens and 0.5 lb N/1,000 sq ft/month (21.8 lb N/ac/month) for the fairways and roughs, it appears they align with the recommendations set forth by CTAHR.

[85] Based on input from Craig Trenholme, SRGII surmises that Soicher and Peterson (1997) incorrectly state units as 0.98lb N/ac/month instead of 0.98 lb N/1,000 sq ft/month (C. Trenholme, pers. comm.).

Herbicide Application

Herbicides used for turfgrass weed control are classified based on several factors: target plant pest type (including broadleaf, grass, or sedge), appropriate timing of their application, selectivity in affecting different plants, and their mode of action (Brennan et al. 2002). Herbicides vary in their rates of volatility, solubility, and decomposition by microorganisms within the soil. "Some water-soluble herbicides are readily leached from the soil, while others are tightly bound to soil particles and are subject to removal in run-off during soil erosion" (Brennan et al. 2002). Slopes, sandy soils, and erosion prone soils during storm events are vulnerable to lateral movement of soil-active herbicides, causing excessive vegetation destruction and resulting soil erosion. "In areas where complete destruction of vegetation would be an undesirable effect of herbicide treatments, apply contact or translocated herbicides as spot treatments to weeds, or use selective herbicides rather than nonselective herbicides" (Brennan et al. 2002).

Nonselective herbicides such as glyphosate should be applied twice, 30 days apart, on persistent perennial weeds including quackgrass or bermudagrass (Brennan et al. 2002) Perennial broadleaf weeds can be controlled with a selective herbicide in a single application. Herbicides used for pre-emergence weed control can persist in turf for 60 to 90 days, and post-emergence herbicides can persist anywhere between 1-2 days to 3-4 weeks, depending on the herbicide. Pesticide wind drift can damage non-target sites, and depends on factors such as weather conditions, spray characteristics, and operator equipment and skill. Spray droplet size is directly correlated to potential for drift.

Irrigation Practices

The golf course applies irrigation water based on water consumption by turf grass via calculated daily values of evapotranspiration losses. The losses are measured using data collected at several weather stations located within the two courses. The courses are delineated into several irrigation sectors. The irrigation system utilizes a sophisticated computer program to determine water distribution (amounts) for the various sectors. Irrigation water is applied between sunset and sunrise at various flow rates to minimize losses from evapotranspiration and seepage. The irrigation system, and knowledge of the personnel managing the system, translates to an efficient use of water that most likely results in minimal leaching losses and transport of nutrients.

Roadways, Parking Lots and Building Complexes

Sections of embankments and shoulder areas along Honoapiʻilani Highway are exposed, eroding and generating sediment and other particulate matter (e.g. crushed concrete and asphalt). Parking lots, roadways, and other impervious surfaces within the urban areas were observed to be generally clean, free of rubbish, and a low source of sediment generation within the watersheds (Photo WU7). However, sediments discharged onto them from adjacent lands are moved rapidly off their surfaces during runoff events, and in most areas discharged into the S4 and eventually the ocean. Some of the asphalt lots are weathered, resulting in loose particulate matter on their surfaces. Oil, grease, coolant, and brake dust from weathered pads are typical pollutants generated by vehicles that are carried into waterways during runoff events.

Lower Honoapiʻilani Road traverses the entire length of Honokōwai Watershed. This road functions as the corridor for utilities, including the inlets and subsurface storm water sewers that are part of the S4. The road is fitted with curbs and gutters along most of its length (Photo HU1, HU2). 22

storm water inlet vaults were visually inspected for presence of sediments and particulate matter.[86] Each inlet vault contained sediment and particulate matter comprised primarily of asphalt rock, cigarette butts, vegetative litter, and coarse rubbish. The amount of pollutants varied, however, no measurements were made since that would require opening the manhole. Vegetative litter was the predominant material observed in the vaults. In several areas people operating air blowers were directing the ground litter towards the curb and gutter along the road and directly into the inlets. Kinnetic Laboratories, Inc.'s study of West Maui dry weather illicit discharges, conducted between March and April of 1996 found 57% of the 83 sites documented to be completely dry (Woodward-Clyde 1996). Chemical tests were made on eight water samples from sites with water present. In general, chemical tests indicated discharges were from groundwater sources or found to have low levels of deleterious substances. Visual observations were also conducted, resulting in 21.9% occurrence of sediment, 19.5% occurrence of litter, and 12.2% occurrence of oil. Full visual pollutant observations and frequency results are summarized in Table 24.

The Maui County Highway Department conducts periodic street sweeping on both Lower Honoapiʻilani Road and Honoapi'ilani Highway. In addition, the County cleans out catch basins (vaults) along major streets and the highway. The frequency and specific sections of streets that receive cleaning in Wahikuli and Honokōwai Watersheds is unknown. During our field inspections it was obvious the cleaning had not occurred for some time as portions of the roadway had accumulations of sediment, cigarette butts, and general rubbish.

There are approximately 38 condominium complexes, numerous single dwellings, and a shopping center that are accessed off Lower Honoapiʻilani Road. A general summary of the drainage from and generation of NPS on these properties is presented. Details of the drainage network are presented in Section 4.7.1. Most of the parcels fronting the *mauka* side or side streets connected to Lower Honoapiʻilani Road direct storm water runoff to the S4 on Lower Honoapiʻilani Road. The disposal of storm water runoff from parcels on the *makai* side of the road is more varied, with some directing runoff into the S4 on the road others containing it onsite. A few parcels that abut Honokōwai and Māhinahina Streams direct runoff into the channels. Two refuse dumpsters in the receiving area of the Times Supermarket Shopping Center had open lids, exposing the contents inside to rain and had leaks of unknown liquid. No illicit discharges to the storm drains or illegal dumping of pollutants (e.g. cooking grease) were observed on any parcels in this area.

There were no properties in this area noted as generators of large sources of NPS pollutants. Accumulations of sediment and particulate matter were found in small quantities unevenly distributed along roadways, sidewalks, and parking lots. The high amount of directly connected impervious areas to the S4 is of concern in that it increases magnitude of runoff and reduces its time of concentration. Runoff will carry the diffuse NPS pollutants into the three drainage channels and into the ocean.

6.5.1.6 Beach Parks

There are five beach parks along the coast of the two watersheds. From north to south they are: Pōhakukāʻanapali, Honokōwai, Kahekili, Hanakaʻōʻō (Canoe), and Wahikuli Wayside. Each beach park has a parking lot that likely generates NPS pollutants, which are carried into the ocean. Small

[86] The inlet is the opening on the street that directs runoff into a concrete vault below the ground fitted with an outlet pipe that carries runoff to an outfall. Inlets and vaults are often referred to as catch basins.

amounts of terrestrial (soil) sediments are generated in sections where their shorelines have eroded into park lands. Each park appears to have frequent landscape maintenance, although fertilizers and pesticides are not used in beach parks (County of Maui, pers. comm.). Runoff from parking lots, except for Kahekili Beach Park, is routed directly into the ocean without treatment. In general, the parks are a low source of NPS pollutants. The restroom facilities are serviced by the WWRF and there are no known parks with active cesspools or septic tanks.

6.5.1.7 Drainages

Rubbish and vegetated litter were observed in the unnamed open channel located on the south side of Honokōwai Park that empties into the ocean, and Honokōwai and Māhinahina Streams between Lower Honoapiʻilani Road and the ocean. The vegetative litter appeared be to material that was not intentionally dumped into the waterways. Each channel contained deposits of fine terrigenous sediments directly above the ocean. The mouth of each channel was blocked by sand washed up from waves. Waters backed up the channels appeared to be stagnant.

6.5.1.8 Kapalua-West Maui Airport

Pervious areas adjacent to the airport parking lot, and between it and the tarmac, were exposed and showed signs of active erosion. Sediment from these areas and pollutants on the parking lot are routed directly in the S4 and carried in a pipe underneath the shoulder of Akahele Road and into the ocean via Pōhakukāʻanapali Gulch.

6.5.1.9 Grounds Keeping and Maintenance of Resorts and Condominiums

The Kāʻanapali Operations Association (KOA) represents properties located between Honoapiʻilani Highway and the ocean and from the Hyatt Regency north to the Westin Kāʻanapali Ocean Villas. KOA staff maintain common lands in this area, which includes landscaping and infrastructure maintenance on approximately 7 ac (2.8 ha). The resorts and condominiums from the Westin Kāʻanapali Ocean Villas to the northern boundary of Honokōwai Watershed are individually managed.

Observations were made around the grounds of numerous resort and condominium properties during field inspections. Issues with respect to NPS pollutants include use of fertilizer, pesticides, and herbicides; irrigation; disposal of wash water; vehicle fluid spills; uncontained storage of cleaning products and landscape chemicals; unprotected dirt and green waste piles; and accumulation of golf balls in drainage channels. In general the properties were well maintained and relatively free of rubbish and accumulations of vegetative litter (Photo WU8, WU9). The issues identified above were not widespread and primarily isolated to a few areas across both watersheds. It should be noted that this section is not intended to call out specific properties and imply that there are not issues on other parcels. Field inspections were not exhaustive and not every property was inspected. The issues and specific sites presented should be considered representative of general conditions.

The amount of fertilizers, pesticides, herbicides, and irrigation water applied to landscaped areas across the properties varies, and it would not be accurate to generalize their application amounts and schedules. All properties except for the Honua Kai, the Hyatt Regency, and KOA common lands purchase water for irrigating landscaped areas from the Hawaiʻi Water Service Company. In general it stands to reason that lawns and other locations with very healthy well-maintained plants are routinely fertilized, kept free of disease, and watered routinely. It is unknown how much, if any, of the chemicals used in landscape maintenance are transported to the ocean via surface water and groundwater. It is logical to conclude that some of the fertilizers and other chemicals are transported during rainfall events that result in saturated soil conditions and generation of overland flow, or when irrigation water saturates the soil.

Watering of landscaped areas was observed on several parcels during the middle of the day. On four resort properties vegetated areas had standing puddles of water that were observed mid-day, several hours after irrigation water was applied. Puddling usually indicates that the soil below is saturated and that leaching through the soil to groundwater is probably occurring. In a few areas excessive irrigation water generated surface runoff and discharge of water onto impervious surfaces draining into the S4 (Photo WU10). Fertilizer granules were observed on several lawn areas, along vegetated hedges, and in numerous plants (mostly areca palms) in containers. Container plants are used to create a vegetated buffer in areas that host luaus and other gatherings. Maintenance crews were observed at three properties applying chemicals contained in pump tanks with hand sprayers to plants.

During preparation of this report SRGII met with KOA personnel and several representatives from resort and condominiums within the KOA area to discuss management of the properties with respect to landscape maintenance. KOA and several of the properties apply fertilizers in accordance with manufacturer's recommendations. Chemicals such herbicides and pesticides are applied on set application schedules and as needed. The use of foliar (leaf) application is minimal due to concerns with safety and potential impact to resort guests and staff. KOA utilizes recommendations on fertilizer application rates made by scientists from CTAHR.

No nutrient management plans based on soil testing for nutrient concentrations and plant requirements were available for review and are likely not in use. Irrigation schedules and applications rates vary, with some properties using systems with timers and watering at routine intervals and others irrigating when the plants indicate need. It is unknown if properties outside the KOA area adhere to the same management of their landscaped areas since no meetings were held with the numerous other resorts and condominiums.

Beaches were, for the most part free of rubbish, though some heavily used sections fronting a few of the larger resorts along Kāʻanapali coast had moderate amounts of spent drink cups, straws, cigarette butts, and miscellaneous debris. Staff at some of the resorts likely conduct periodic cleaning of the beaches fronting their properties.

Discussion on the surface water runoff system and ground cover of these areas is presented in Section 4.8.3.

6.5.1.10 Maintenance Yards

Several parcels located primarily along Honoapiʻilani Highway have maintenance yards that are used to store equipment and materials used for the upkeep of various properties. A few were noted with containers that had no spill containment system, stained soil from what appeared to be leaking containers, and unimproved dirt parking areas that generate sediments and runoff.

6.5.1.11 Miscellaneous Observations

Ocean water near the mouths of Wahikuli Stream and an unnamed gulch that ends at Wahikuli Wayside Beach Park was observed on four separate days to be turbid and have a reddish hue (Photo WO2). None of the observation days were preceded by a rainfall event, and it was concluded that no recent discharges had occurred. It is probable that fine terrigenous sediments delivered by the gulches to the ocean resuspends daily due to turbulence generated by waves breaking along the shore. A portion of the sediment discharged into the ocean during runoff events likely remains near shore and is not readily transported to deeper waters further offshore.

Although not directly observed, discharge of swimming pool water into the S4, drainages channels, and ocean was suspected at several locations. Discharge of pool water is allowed provided it is dechlorinated.

Culverts under Honoapiʻilani Highway (Photo WO3), an unnamed gulch at Wahikuli Wayside Beach Park, Wahikuli Stream, and Hanakaʻōʻō, Māhinahina, and Pōhakukāʻanapali Gulches all contained sediment deposits and/or rubbish. This indicates that heavy loads of sediments and rubbish are carried in runoff under flow conditions.

6.6 Lahaina Wastewater Reclamation Facility

The Lahaina WWRF sits at 3300 Honoapiʻilani Highway, Lahaina, HI 96791 (Photo HU3). It is owned and operated by the County of Maui Department of Environmental Management. The WWRF first entered service in December 1979.

The Lahaina WWRF has been the subject of studies by various researchers over the past several years. Ongoing research is being performed to determine the effects, if any, of injection well disposal of wastewater at the Lahaina facility on surface water quality of coastal waters in the Kāʻanapali region. SRGII recognizes that there are other contributing sources of Nitrogen to groundwater in the region, however quantifiable information on other sources is not currently available. This section summarizes the WWRF operations and presents some of the available research.

6.6.1 Lahaina WWRF Permitting

The WWRF is subject to Underground Injection Control (UIC) permits administered under the SDWA to dispose of effluent waste water via injection wells from both Hawaiʻi DOH-SDWB and EPA (Appendix C.5.2). Treated effluent from the plant is injected under gravity force into the ground via four injection wells located on the WWRF parcel. The DOH UIC permit needs to be renewed every five years. The last permit expired in 2009 and a renewal has not been issued. Since that time the WWRF has operated under an administrative agreement that extends the permit until September 2012. Similarly, the UIC permit from EPA expired in June 2005 and has also been administratively extended. Although renewals have not been issued, the facility is still subject to requirements of both permits. Since expiration of the permits the facility has operated and complied with the provisions in the permits. This includes monitoring of the effluent water quality (i.e. TSS, BOD5, and Total Nitrogen, reported as TKN, NO_3^- and NO_2^-). In addition, the WWRF periodically samples for bacteria, chemicals, heavy metals, pesticides, and other compounds designated by EPA and DOH-SDWB.

In September 2011, EPA and Maui County negotiated a consent order to provide full disinfection (non-chlorine) of WWRF effluent to R-1 standards by the end of December 2013 (EPA 2011). The goal of treating all of the wastewater at the WWRF to R-1 water disinfection standards is to eliminate the risk that pathogens could contaminate the aquifer or be released into nearby coastal waters.

In April 2012, Earthjustice filed suit in Federal district court on behalf of four Hawaiʻi community groups, alleging claims under the CWA that the effluent from the WWRF is killing coral reefs and triggering invasive algae outbreaks, as well as containing bacteria and pathogens. The complaint asks the court to require the County of Maui to obtain a NPDES permit for its currently unpermitted discharges of pollutants from the WWRF to nearshore West Maui waters.

6.6.2 Summary of Operations

The WWRF receives wastewater influent mainly from residential and resort uses, and the supporting commercial and retail businesses in the region. The service area extends from Kapalua to Lahaina. A residential Wahikuli neighborhood on the north end of Lahaina town, containing approximately 250 homes, was built with cesspools and does not tie in to the WWRF system.

The influent contains a variety of chemicals commonly used in homes such as: drugs, disinfectants, detergents; biological organisms from sewage; and other waste associated with human activities, e.g. rubbish. The WWRF employs primary, secondary, and tertiary effluent treatment methods to both physically and biologically remediate contaminants contained in the inflow water. The tertiary treatment includes the use of sand filters and disinfectants to reduce suspended matter and bacteria respectively. The objective of the WWRF is to remove the physical, chemical, and biological contaminants and produce fluid and solid waste (sludge) that is environmentally safe for disposal or reuse. Class V UIC wells are used for excess final treated effluent disposal at the WWRF. The injection well system consists of four wells fed by gravity flow (County of Maui 2004). The linear distance from the WWRF to the coast is approximately 1,890 feet, and the distance from the closest injection wells to the northern submarine groundwater seep at Kahekili is approximately 2,620 ft (Figure 31).

Table 28. Summary of Lahaina WWRF UIC Wells[87]

Well No.	1	2	3	4
Construction Date	1979	1979	1985	1985
Total Depth (ft)	200	180	225	255
Bottom of Well Elevation (ft)	(-)168	(-)150	(-)200	(-)229

The WWRF is required by DOH to have 100% backup capacity within the wells (Maui County, pers. comm.). Wells No. 3 and 4 are primarily used for disposal of treated effluent, though all four are operational and can be used (Photo HU4, HU5).

The maximum flow rate to the wells is limited to 9 million gallons per day (MGD) per calendar week by both UIC permits (Maui County, pers. comm.). Current inflow rates average approximately 4 MGD. Limits of 30 mg/l of TSS and 30 mg/l of BOD5 for effluent waters are required by the DOH UIC

[87] Excerpted from UIC Permit Renewal.

permit. The EPA UIC permit requires limits of 60 mg/l for TSS and BOD_5 and an action level of 10mg/l for Total Nitrogen. Actual levels are generally below these limits but there are occasional exceedences for Nitrogen. The effluent is required to meet bacterial Maximum Contaminant Levels for total coliform.

Flow rates received at the treatment plant reached historic high volumes during the early 1990s, likely due to cracks in collection pipes that were intercepting groundwater (Maui County, pers. comm.). Refurbishing Maui County owned collection pipes, outreach to the public to reduce water use, and identification of properties with leaks has resulted in average inflow rates now of 4 MGD.

A total of six sand filter units provide advanced treatment of wastewater (Maui County, pers. comm.). Three of the units treat the majority of wastewater prior to final disposal in the injection wells. Since October 2011 all injected waste water has been disinfected with chlorine to what would be R-2 level wastewater. The chlorine treatment occurs prior to sand filtration and before discharge into the injection wells. The other three units treat wastewater prior to entering the ultraviolet (UV) channels for disinfection to the R-1 treatment level required for reclamation, rather than injection (Photo HU6). Reclaimed water then flows from the WWRF to the Kāʻanapali Golf Course where it is pumped to the northern links and stored in the upper pond. Approximately 27 of the 36 links are irrigated with the reclaimed water. Reclamation needs vary from zero demand in the winter months to 1.9 MGD on the hottest summer days. Other users of R-1 water are: the Hyatt Regency Resort and Honua Kai condominiums and the Kāʻanapali Operators Association for irrigation of common grounds. An R-1 transmission line also runs from the WWRF *mauka* to a 6.0 MG reservoir adjacent to Honokohau Ditch in Honokōwai Watershed at an approximate elevation of 780 ft msl (240 m), to serve portions of the former agricultural lands makai of the reservoir extending north into Kahoma Watershed. Although these lands are currently fallow, they could use reclaimed water in the future (Figure 32). A thorough description of the WWRF existing infrastructure and service area, as well as potential build out plans of the system, are presented in the 2010 Wastewater Community Working Group Report (County of Maui Department of Environmental Management 2010).

6.6.3 Research on Transport and Fate of Injected Wastewater at WWRF

Research findings on the transport and fate of injected wastewater from the WWRF are presented in this section, along with pollutant loading estimates. Additional studies and further discussion are found in Appendix D.2.

6.6.3.1 Wastewater Presence in Coastal Waters

Recently published research findings by multiple researchers have documented the presence of treated wastewater effluent originating at the WWRF injection wells in submarine groundwater seeps discharging along coastal waters in the Kahekili Beach Park area.

Tummons 2012[88]

In July 2011, University of Hawaiʻi researchers injected 340 lbs (154 kg) of fluorescein dye into two of the WWRF injection wells, and in August 2011 injected 180 lbs (82 kg) of rhodamine into a third well at the facility. Sampling along the coastal seeps was completed twice per day for the first

[88] This information was reported in an *Environment Hawaii* article authored by Tummons (2012).

month, and daily or every other day after that. Flourescein began appearing at the coastline in late 2011 with levels above baseline, and levels have continued to rise – verifying that treated wastewater effluent from the WWRF is reaching coastal waters.[89]

DOH is beginning to monitor the seeps for several wastewater constituents including nutrients and bacterial indicators. David Albright, manager of the groundwater and underground injection control program for EPA Region IX in San Francisco, stated that although the data collected does not show any of the bacterial indicators being sampled for, the failure to detect the indicators may be linked to a chlorination increase at the plant, which began in early October 2011 as a result of the consent order between the County of Maui and the EPA (EPA 2011). He went on to say that additional research involving infrared thermal survey data confirmed a sizeable plume of warmer water around the seeps, and isotopes of Nitrogen taken from samples in the seeps supported the findings of Chip Hunt and Megan Dailer. "Waters that migrate to the coast from the [wastewater] facility and upgradient wells are undergoing significant microbial Nitrate reduction," Mr. Albright said. Infrared thermal surveys of the coast detected a sizable plume of warmer water around the seeps. Since groundwater is usually cooler than ocean water, that the seeps discharge warmer water also tends to confirm the presence of wastewater.

Dailer et al. 2012

Dailer's prior study (2010), generated a two-dimensional model of the WWRF wastewater effluent plume's extent across the Kahekili coral reef (Dailer et al. 2012). Dailer et al. (2012) determined "that the nearshore sites in the south were still located within the wastewater effluent plume and that the offshore sites (at 6.0 m depth) probably underestimated the plume boundaries because the non-saline wastewater effluent is likely more buoyant than the surrounding saltwater." "These results confirm that the wastewater effluent flows through the coral reef at Kahekili into the surface waters, where most of the recreational users (swimmers, snorkelers, canoe paddlers, etc.) are active, and then flows to the south." "The Lahaina WWRF [Wastewater Reclamation Facility] effluent plume (1) affected the majority of the shallow region at Kahekili, (2) rose to the surface waters in the area and (3) generally flowed south with the most predominant current in the area."

Hunt and Rosa 2009

In Hunt and Rosa's study at Lahaina and Kīhei, instrument trolling was used to detect submarine groundwater discharge, followed by a 'multitracer' approach involving analysis for chemical and isotopic constituents in water and macroalgae (Hunt and Rosa 2009). Benthic algae samples, marine water-column sampling, and water-quality sondes were used. Wastewater presence was indicated, as well as denitrification and mixing of effluent with surrounding seawater and groundwater. The Lahaina plume path may be guided by an ancestral course of Honokōwai Stream, as it was detected south of the expected path from the UIC wells to the shoreline. In all likelihood effluent also discharges offshore. "There is some uncertainty as to how far south the Lahaina plume extends, because reclaimed wastewater is also applied as golf-course irrigation and reinfiltration of the reclaimed water may contribute to the apparent effluent signature in water chemistry near Black Rock [*Pu'u Keka'a*]. However the core of the effluent plume is clearly evident near Kahekili Beach Park" (Hunt and Rosa 2009). In addition, the presence of multiple wastewater constituents

[89] The rhodamine dye has not been detected as of April 2012. The dye tracer study is not yet complete and is subject to further interpretation and quality controls before its results are ready for public release.

including tribromomethane, musk fragrances, a fire retardant, and a plasticizer compound was confirmed in both sampled effluent at the WWRF and in submarine springs at Lahaina. Carbamazepine, a pharmaceutical, was also found in both the sampled WWRF effluent and marine-column samples.

6.6.3.2 Pollutant Loading Estimates

Several researchers have measured concentrations of various forms of Nitrogen including Nitrate Nitrogen at and near two submarine groundwater seeps along Kahekili Beach. Estimates of Nitrate Nitrogen loads have been made using measured concentrations collected at both the seeps in the ocean and at the WWRF. Estimates of loads of the various forms of Nitrogen were computed using these concentrations, and mean daily effluent discharge from the WWRF. Between the WWRF and discharge of effluent at the seeps, microbial activity reduces Nitrate concentrations. A mass balance between the seeps and the volume of effluent discharged at the WWRF has not been conducted. Therefore the volume of water coming out of the seeps, and the portion from the WWRF, is unknown.

SRGII generated load estimates based on current average daily flow of WWRF effluent and recent WWRF effluent water quality sampling data (Section 6.7.1.3). These data include selected constituents from the injection well reporting summary sheets and was performed at the facility in compliance with the WWRF reporting schedule. SRGII's load estimates are for the water injected into the ground at the WWRF. A comparison of SRGII's estimates for Total Nitrogen and Total Nitrogen Load versus Dailer et al. (2012) is included in that section as well.

Dailer et al. 2010

Dailer et al. (2010) used County of Maui, Department of Environmental Management annual water reuse and injectate rates from the period of 1997 through 2008 to quantify the Total Nitrogen Load (TNL) estimates for combined injectate from three WWRFs, including the Lahaina WWRF (Dailer et al. 2010). "Monthly average effluent flow rates, percent of effluent reuse and monthly average TN concentration for the period from 2006 to 2008 were used to estimate the daily and annual TNL of the wastewater injectate from the Lahaina, Kīhei and Kahului WWRFs." From 2006 to 2008, the Lahaina WWRF injectate daily TNL ranged from 79 to 97 kg (174-215 lbs) N/day.[90] The annual TNL of the Lahaina WWRF injectate ranged from 28,873 to 35,530 kg (63,609– 78,274 lbs) of N/yr. "Our work suggests that a substantial amount of this loading traveled to the nearby coastal zones."

Hunt 2006

Hunt (2006) estimated groundwater nutrient fluxes in the Kīhei area, which has growth of macroalgae on coral reefs and uses injection wells for wastewater disposal. Wastewater and background nutrient fluxes were estimated but the urban nonpoint flux was not, as wells were sampled only in proximity to the injection wells and not further along the coast. "Despite advanced nutrient removal during wastewater treatment, injection still amounts to a large nutrient load for the region." However, Hunt writes that due to natural nutrient attenuation in the aquifer, "the entire injected load does not necessarily reach coastal waters. Attenuated wastewater nutrient flux,

[90] The Total Nitrogen loading computed by Dailer is lower than that of SRGII, most likely due to the result of variation in the injectate flow rate used in the calculation of TN (Dailer's calculations use a flow value of 3.4 MGD while SRGII uses a value of 4.0 MGD). SRGII's figure is based on personal communications conducted with County of Maui personnel while developing this watershed characterization. See Section 6.7.1.3 for loading values and calculation details.

estimated from a single well within the effluent plume, was roughly 3.5 times the background flux in recharge for both Nitrogen and Phosphorus. Background Nitrogen flux at Kīhei was 4 times as high as in west Maui—perhaps because Kīhei is drier or has more Nitrogen-fixing vegetation—but was one-half to one-third the flux from Hawaii Island golf courses" (Hunt 2006). "Injected nutrient flux per length of coast at Kīhei (before attenuation) is one-third to one-quarter that at Lahaina for Nitrogen and Phosphorus, largely because the Kīhei plume is 2.5 times wider; injected nutrient mass is more closely comparable at both locations."

Soicher and Peterson 1997

Soicher and Peterson (1997) modeled groundwater flow in West Maui and estimated nutrient loads to the ocean from submarine groundwater discharge. They also sampled major streams during storm events and estimated sediment and nutrient loads from stream discharge. On an annual basis, nutrient loads from groundwater were greater than from stream flow. During large rainstorms, the major source of sediments entering streams is runoff from agricultural land.

Soicher and Peterson (1997) states that the "disposal of treated domestic sewage effluent into subsurface injection wells contributes substantial nutrient loads to the coastal waters". A definite link between elevated loads of sediments and nutrients due to sugarcane (a close second place) and pineapple cultivation (distant third place ranking) in the area was also noted. "Although it is presumed that the bulk of the injected nutrients are carried by groundwater into the sea, their detailed fate is not well known because monitor wells do not exist between the injection wells and the coast."

Soicher and Peterson go on to note that during the 1980's/early 1990's, injection of wastewater appears to have been the largest contributor to groundwater Nitrates, followed by sugarcane and pineapple (Soicher and Peterson 1997). Due to WWRF improvements, injected wastewater nutrient concentrations have been more than halved in the late 1990's, thereby substantially reducing total loading compared with the early 1990's.

Area golf courses are thought to contribute negligibly to groundwater Nitrates when compared with the WWRF injection wells, sugarcane, and pineapple growing (Soicher and Peterson 1997). Although not quantified in the study due to lack of data and smaller overall extent compared with other sources, resort and urban landscaping is likely less important with respect to groundwater Nitrates. The data presented in the study did not conclusively single out one particular source to bear the major responsibility for degradation of the West Maui coastal environment, but pointed to wastewater as the largest nutrient source.

6.7 Pollutant Load Estimates, Including Methodology

Pollutant loads, application rates, and peak runoff computations were performed for existing and future conditions within the watersheds.[91] For existing conditions, calculations were performed to determine soil loss rates from existing fields; current and historic nutrient application rates to

[91] "Pollutant load" refers to the total mass per unit time that a given pollutant (e.g. suspended sediment, nutrients) is conveyed off of a watershed by either surface-based or groundwater flow regimes. Load is calculated by multiplying the measured concentration (expressed as mass per volume) of the parameter by the rate of discharge (expressed as volume per unit time). "Application rate" refers to the total mass per unit time that a nutrient is applied to the land, but not necessarily transported off of it; and is calculated by multiplying the amount applied (expressed as mass per area per unit time) by the total area to which applied.

various fields; and loadings for selected pollutants contained in injectate and R-1 treated water from the WWRF.

For future conditions, NPS pollutant loads were estimated that will originate on surfaces associated with future development build out; peak stormwater flows were calculated using the Rational Method to determine the effect of impervious area increases; and loadings for selected pollutants contained in WWRF injectate and R-1 treated water were compared and contrasted under various R-1 production scenarios. The precision of pollutant load and nutrient application rates calculated and presented in this section varies according to the precision of the data available. Therefore, calculations were carried to the same number of significant digits as the least precise measurement included in the equation.

6.7.1 Existing Condition Pollutant Load and Application Rate Estimates

Various pollutant loadings and nutrient application rates derived from major sources in the project area were computed to determine relative contributions. Historic fertilizer use from the sugarcane and pineapple era was also estimated to compare past to present nutrient applications. A summary of these findings is presented in Table 29 - Table 31.[92] Table 29 summarizes the annual Nitrogen, Phosphorus, and Potassium applied during active and historic field cultivation, illustrating that seed corn production requires lower nutrients than any other active or formerly cultivated field; while sugarcane has the highest Nitrogen and Potassium rates. Table 30 summarizes current soil losses from agricultural fields as computed using NRCS RUSLE2 methodology, and demonstrates the high magnitude of annual losses per acre for representative seed corn fields versus other field types. Table 31 illustrates the differences in loadings for selected parameters found in WWRF effluent during the wettest and driest periods of the year, with highest Total Nitrogen and Total Phosphorus loadings occurring during the wettest periods.

Table 29. Annual Estimated Nutrient Application Rates for Active and Former Fields

Nutrient	Application Rate to Current Fields (lb/yr)		Application Rate to Former Fields (lb/yr)	
	Seed Corn	Coffee	Sugarcane	Pineapple
Nitrogen	3,600	100,000	493,000	320,000
Phosphorus	3,600	20,000 – 23,000	76,000	0 – 251,000
Potassium	3,600	100,000	1,080,000 - 1,210,000	553,000

[92] Sediment loss for each of the representative fields was computed using NRCS' RUSLE2 methodology (Section 6.7.1.2). Nutrient contributions from fertilizers used on active agricultural fields were estimated using NPK mix values detailed in Table 23. Pollutant load contributions from the WWRF are calculated based on discharge rate of effluent during wettest and driest periods of the year, and data from the most recent sampling reports furnished from DOH (Section 6.7.1.3).

Table 30. Calculated Sediment Losses for Agricultural Fields

Field Type	Sediment Loss (lb/ac/yr)
Active Coffee Field	280
Fallow Seed Corn Field #1[93]	11,600
Fallow Seed Corn Field #2	58,000
Fallow Seed Corn Field #3	14,000
Fallow Pineapple Field	7,000
Fallow Sugarcane Field	5,800

Table 31. Calculated Average Pollutant Loads Injected to Wells

Pollutant	Injected Pollutant Loads: Wettest Periods (lb/yr)	Injected Pollutant Loads: Driest Periods (lb/yr)	Pollutant Loads Contained in R-1 Water: Driest Periods (lb/yr)
TSS	10,000	10,000	10,000
Biological Oxygen Demand	70,000	30,000	20,000
Nitrate + Nitrite (NO_3^- + NO_2^-)	18,000	23,000	21,000
Ammonia (NH_3) (as N)	50,000	3,600	3,200
Kjeldahl Nitrogen	74,000	12,000	11,000
Total Nitrogen	92,000	35,000	32,000
Total Phosphorus	4,300	1,700	1,500

6.7.1.1 Nutrient Application Rates from Various Fields – Historic vs. Active

Estimated annual application rates (lb/yr) for the actively cultivated fields within the watersheds were calculated to determine Nitrogen, Phosphorus, and Potassium contributions resulting from fertilizer use. Overall, sugarcane and pineapple nutrient application activities yielded substantially higher rates than those of present day fields. These rates were obtained by multiplying the rate specified for each nutrient (obtained from the recommended NPK fertilizer mixes for use in Hawaiʻi and personal communications (Section 6.4.1)) by the total acreage of each field type in active use (Section 4.5.2). Current nutrient application rates were then compared to those generated by historic sugarcane and pineapple production. Total acreage of historic sugarcane field cultivation was determined by adding the existing area covered by seed corn and coffee fields to the area covered by fallow sugarcane fields, since all seed corn and coffee fields were formerly sugarcane. The area currently covered by fallow pineapple fields was used for the historic pineapple acreage.

Historic Fields

Historic cultivation of sugarcane and pineapple within Wahikuli and Honokōwai Watersheds resulted in substantially higher annual nutrients applied than required for present day cultivation (Table 32). These higher amounts were largely due to the larger acreage of fields under cultivation during the sugarcane/pineapple era (4,570 acres historically cultivated vs. 611 acres presently under production; representing an 87% decrease in field surface area under active cultivation). In

93 RUSLE2 was run when seed corn fields were active. Seed corn cultivation has now stopped.

comparison, sugarcane fields had higher quantities of Nitrogen and Potassium applied per year than pineapple fields, and depending on the year, Phosphorus amounts were higher for pineapple than sugarcane.

Historically, sugarcane had more annual Nitrogen and Potassium applied than any of the other field types (pineapple, seed corn, or coffee), a figure nearly double that of pineapple, the second highest contributor. Sugarcane also had more Nitrogen and Potassium applied per year than all active fields (seed corn and coffee) combined. Similarly, pineapple fields had more Nitrogen and Potassium applied than seed corn and coffee combined, and depending on the year, more Phosphorus as well. This resulted in almost 700% more total annual Nitrogen applied to sugarcane and pineapple fields than currently applied to coffee and seed corn fields combined. The range of total historic Phosphorus applications was 200% to 800% higher than the range presently applied to all active fields combined. The range of historic Potassium used was approximate 1,450% higher than active fields combined.

Active Fields

Comparing active field coverage, active coffee fields and seed corn fields are nearly equal: 311 acres coffee vs. 300 acres seed corn. As shown in Table 32, active seed corn fields have low Nitrogen, Phosphorus, and Potassium rates of nutrient application, the lowest of any actively or historically cultivated field. In comparison, coffee fertilizer application rates for Nitrogen and Potassium are almost 600% greater. Phosphorus applied is 120% to 140% higher for coffee than seed corn. Coffee fields also have a much higher magnitude of nutrient application rates per acre required for production for Nitrogen and Potassium in comparison to each of these nutrients for corn.

(Total Field Area) x (Nutrient Application Rate) = Annual Nutrient Application
Example Calculation: (300 ac) x (57 lb/ac/yr) = 17,000 lb/yr Nitrogen

Table 32. Estimated Annual Nutrient Application for Active vs. Historic Agricultural Fields

	Active Fields			Historic Fields		
Field Type	**Seed Corn[94]**	**Coffee[95]**	**Total**	**Sugarcane**	**Pineapple**	**Total**
Approximate Land Area Cultivated (ac)	300	311	**611**	3,022	1,548	**4,570**
Application Rate: Nitrogen (lb/ac/yr)	57	200-300	**-**	163	207	**-**
Total Loading: Nitrogen (lb/yr)	17,000	100,000	**117,000**	493,000	320,000	**813,000**
Application Rate: Phosphorus (lb/ac/yr)	57	50-75	**-**	25	0-162	**-**
Total Loading: Phosphorus (lb/yr)	17,000	20,000-23,000	**37,000-40,000**	76,000	0-251,000	**76,000-327,000**
Application Rate: Potassium (lb/ac/yr)	57	200-300	**-**	357-402	357	**-**
Total Loading: Potassium (lb/yr)	17,000	100,000	**117,000**	1,080,000-1,210,000	553,000	**1,633,000-1,763,000**

94 Seed corn fields are distributed across 1,288 acres, with a total of 600 acres in rotation and active crops grown on 300 acres each year.

95 Approximately 50% of coffee fields are under cultivation at any one time (out of a total of 622 acres).

6.7.1.2 Agricultural District – RUSLE2

The Revised Universal Soil Loss Equation was originally developed as a tool used for prediction of long term annual average rates (soil loss) of rill erosion on agricultural fields, expressed in pounds per acre per year (lb/ac/yr) (Box 7). RUSLE2 has been used extensively by NRCS, other government agriculture agencies, and by practitioners in the private sector. RUSLE2 is not an accurate prediction of the actual loads but is most useful in relative comparisons of different practices or land uses.

Box 7. Revised Universal Soil Loss Equation (RUSLE2)[96]

The RUSLE2 uses five dimensionless variables to compute estimates of soil loss and is expressed as A = R x K x LS x C x P, where A is the soil loss (lb/ac/yr). The variables within the equation include the rainfall and runoff factor (R), which varies according to the geographic location of the fields within the watershed and takes into account intensity and storm duration; the soil erodibility factor (K), which represents the soil types within a particular field and their susceptibility to transport in runoff; the slope length-gradient factor (LS), which accounts for the steepness of slope and length of downhill travel across an individual field; the crop vegetation and management factor (C), which represents crop type, tilling, and management factors related to field production; and the support factor (P), which takes into account any farming practices including direction of planting. The higher the value of any one of these variables, the higher the expected soil loss for that field, demonstrating that soil loss from any particular field is a product of many factors.

Soil loss can now be calculated using computer methodology. For the project area, erosion contributions from representative agricultural fields were calculated by Adam Reed of NRCS using RUSLE2, a program that calculates the rill and interrill erosion caused by rainfall and runoff events (Figure 33).[97] The USDA-Agricultural Research Service developed RUSLE2 and it is used extensively by NRCS field office personnel.

The program utilizes databases with data specific to the climate, soils, and crop management templates for the Crop Management Zone of the area. By selecting the appropriate databases based on the field being evaluated, individual data for the field can then be entered. Individual field data inputs include length of continual slope; average slope steepness across the field measured as a percentage; characteristics of the crop contour farming that is employed; and any additional barriers, diversions, and drainage measures that may be used.

RUSLE2 outputs a T value, expressed in tons/ac/yr, a best estimate of the tolerable amount of soil that can be lost for the individual field. This value is a measurement of whether crop field production is sustainable and can be maintained long term under current conditions. The T value is then compared to the calculated field soil loss due to erosion, also expressed in tons/ac/yr.

Observations made by SRGII clearly indicate that fields used for seed corn cultivation within the project area have substantially more exposed bare ground surface compared to any other actively cultivated or fallow field in Wahikuli and Honokōwai Watersheds. The RUSLE2 model was used to compare erosion rates between active coffee, three fallow seed corn, fallow pineapple, and fallow sugarcane fields located across the two watersheds. The three seed corn fields represent the condition of approximately 70 percent of the acreage used for seed corn cultivation in Wahikuli Watershed. The three seed corn fields were selected to represent a range of ground slopes that are found across the corn fields.

As shown in Table 33, calculated soil losses for the three representative seed corn Fields #1, #2, and #3 all exceed the tolerable soil losses by a substantial percentage; whereas the active coffee, fallow pineapple, and fallow sugarcane fields all have soil losses that are less than the tolerable losses. This shows that estimates of soil losses from the three seed corn fields were significantly higher as compared to the estimates from the active coffee, and fallow sugarcane and pineapple

[96] Due to the many variables involved in calculating soil losses for a specific field, the units of lb/ac/yr output by RUSLE2 must be retained (and cannot be reduced to lb/yr by simply multiplying by the number of acres of field type).

[97] Rill erosion is caused by the development of a concentrated flow of water in a very small channel that begins to cut into the soil surface layer producing a rill. Interrill erosion is caused by the impact of rain on the surface and the sheeting action of water moving across the surface.

fields. As expected, the highest estimates of soil loss for seed corn occurred on the field with the steepest slope. Seed corn Field #2 with a slope of 14%, under existing condition (bare ground), had the highest soil loss estimates of all fields.

Although the model did not incorporate hypothetical scenarios of incorporating grass cover or full corn crop cover over the bare fields, it is a logical assumption that adding either of these cover types would reduce erosion rates proportionally. These calculations do not incorporate additional reductions in erosion rates that would result from installation of any management practices within the fields that could further reduce erosion rates and transport of sediment into the ocean.[98]

Table 33. Calculated Soil Loss for Agricultural Fields (RUSLE2)[99]

	Active Bare Seed Corn Field #1	Active Bare Seed Corn Field #2	Active Bare Seed Corn Field #3	Active Coffee Field	Fallow Pineapple Field	Fallow Sugarcane Field
Slope Length Horizontal (ft)	150	150	150	150	150	150
Average Slope Steepness (%)	8.0	10	5.0	7.0	13	15
Calculated Soil Loss (tons/ac/yr)	7.1	16	7.6	0.092	3.5	2.7
Calculated Soil Loss (lb/ac/yr)	**14,200**	**32,000**	**15,200**	**184**	**7,000**	**5,400**
T Value -Tolerable Soil Loss (tons/ac/yr)	2.0	5.0	5.0	5.0	5.0	5.0
Difference between Calculated Soil Loss and Tolerable Soil Loss (tons/ac/yr)	5.1	11	2.6	-4.908	-1.5	-2.3
Difference between Calculated Soil Loss and Tolerable Soil Loss (lb/ac/yr)	**10,200**	**22,000**	**5,200**	**-9,816**	**-3,000**	**-4,600**
Exceedance of Calculated Soil Loss Over Tolerable Soil Loss	360%	320%	150%	-98%	-30%	-46%
Representative Field Area (ac)	6	9	17	3	23	95

Of the field types, seed corn soil losses were the highest, which is logical given the extensive bare field ratio associated with crop production and the susceptibility of fields to erosion from rainfall events. A seed corn field in the steepest sections of the Agricultural District has a calculated soil loss that is over 800% greater than similarly sloped fallow pineapple fields (58,000 lb/ac/yr vs. 7,000 lb/ac/yr), and 1,000% greater than similarly sloped fallow sugarcane (58,000 lb/ac/yr vs. 5,800 lb/ac/yr). The RUSLE2 analysis also shows the unsustainability of seed corn fields within the environment due to tolerable soil losses (T value) being exceeded by the calculated soil loss in all three of the representative seed corn field scenarios run (by 190%, 480%, and 250% respectively). Whereas all other field types had calculated soil losses that were substantially lower than the T value (97% for coffee fields; 30% for fallow pineapple fields; and 42% lower for fallow sugarcane

[98] WMSWCD is currently working with KLMC to obtain a management and cultural practices plan, which may affect the results of the RUSLE2 calculations as presented.

[99] The RUSLE2 model was run when seed corn was actively cultivated. Model runs using RUSLE2 on active seed corn were accurate for fields and cover conditions at that time. Seed corn cultivation has now stopped. Bare fields have been left fallow and grasses and other plants have started to grow on the fallow fields.

fields), this indicates these field types represent a more sustainable field condition in terms of reduced impact from sediment entering into the surrounding environment.

6.7.1.3 Calculated WWRF Pollutant Loadings

Loading rates were calculated for several pollutants found in WWRF effluent, during dry and wet seasons. These calculations included estimates of rates of pollutant injection into the WWRF wells during the wettest periods of the year; as well as loading rates for both pollutants injected into the wells and loading rates transmitted through the R-1 level reclaimed water for irrigation needs on urban lands. Loading rates are based on concentrations cited in the required semi-annual WWRF sampling data for 2011, the most recent results available.[100] The data set includes results from a sampling event on December 21, 2011, representing the wettest periods when there is no R-1 water produced and full injection of effluent occurs; and results from a sampling event on June 15, 2011, representing the driest periods when R-1 production for customer irrigation needs is highest.[101] The representative wet and dry period results were compared to determine (1) the variation in pollutant loading rates injected over the course of the year; and (2) the effect that R-1 level reclamation for land irrigation needs has on the rates of pollutant injection into the wells during the driest periods.

Wettest Periods – Zero R-1 Water Production

SRGII calculated estimated daily, weekly, monthly, and yearly pollutant loading rates injected into the WWRF wells based on the wettest periods of the year, when the maximum amount of effluent is disposed into the injection wells and zero reclaimed water is produced and transmitted to the Kāʻanapali Golf Courses or resort customers for irrigation needs. These rates were calculated based on the measured concentrations of selected parameters included in the most recently available WWRF laboratory sampling results (December 21, 2011) (Table 34). The concentration of each parameter was multiplied by the final effluent average daily injection rate of 4.0 MGD and a conversion factor, to obtain the daily loading rate (lb/day) of the parameter. This value was then converted into the equivalent weekly, monthly, and yearly loading rate. It is important to note that these values are rates of injection, and not the absolute loadings; as the concentrations of measured constituents varies with each sampling event.

SRGII calculated Total Nitrogen Load (TNL) by multiplying Total Nitrogen (TN) by the injectate flow rate and a conversion factor. The resulting TNL calculated by SRGII is higher than that cited by Dailer et al. (2010) in their research. In Dailer's research, the WWRF effluent Total Nitrogen (TN) value for the 11-year period between 1997 and 2008 is assumed to be an average of 7.1 mg/l. In comparison, the calculated TN value based on the data cited in Table 34 results in a value of 7.6 mg/l; 0.5 mg/l (8.1%) higher than Dailer's. Between 2006 and 2008, Dailer cites a TNL of 174–215 lbs (79–97 kg) N/day, and an annual TNL of the WWRF effluent from between 63,609–78,274 lbs (28,873–35,530 kg) of N/yr. Calculated values of TNL based on most recent sampling data show a value of 92,000 lb/yr (74,000 lbs/yr Kjeldahl Nitrogen +18,000 lbs/yr Nitrate + Nitrite) (42,000

[100] Effluent constituent concentrations were obtained from Chauncey Hew of the UIC Program, DOH-SDWB on February 28, 2012.

[101] Cited pollutant loading rates are based on two representative sampling events, and are considered representative. Detailed analysis of sample data sets over a longer time series is necessary for increased accuracy.

kg/yr). This represents a value 14,000 lb/yr (6,400 kg/yr), or 18%, higher than the maximum value in the range cited by Dailer.[102]

Driest Periods – Maximum R-1 Water Production

To determine the effects of R-1 water reclamation on the magnitude of pollutant loadings disposed into the injection wells, SRGII calculated estimated daily, weekly, monthly, and yearly pollutant loading rates injected into the WWRF wells based on the driest periods of the year (when there is the maximum demand for reclaimed water). These well loading rates were then compared to those of the R-1 water transmitted to the Kāʻanapali Golf Courses or resort customers for irrigation needs. Both well and R-1 loading rates were calculated based on the measured concentrations of selected parameters included in the most recently available dry season WWRF laboratory sampling results (June 15, 2011) (Table 35). The concentrations shown apply to both the final effluent disposed into the injection wells, and the R-1 water used for irrigation purposes, as the R-1 treatment process involves only additional disinfection treatment for land application. For the injectate, the concentration of each parameter was multiplied by the average daily injection rate of 2.1 MGD (WWRF average daily flow of 4.0 MGD minus 1.9 MGD used for R-1) and a conversion factor, to obtain the daily loading rate (lb/day) of the parameter. This value was then converted into the equivalent weekly, monthly, and yearly loading rate. This process was repeated for the R-1 water, using a maximum daily rate of 1.9 MGD produced and transmitted to customers. These values are rates of injection, and not the absolute loadings; as the concentrations of measured constituents varies with each sampling event.

Comparison of Selected Pollutant Loadings – Wettest Vs Driest Periods

Current production rates of R-1 water are responsible for diverting approximately 47% of pollutant loadings from disposal into the injection wells during the driest periods of the year (1.9 MGD of R-1 water produced and transmitted out of a total 4.0 MGD total effluent). The remaining 53% of effluent is ultimately disposed into the injection wells. While this represents a substantial portion of pollutant loadings diverted from being injected during dry periods, fluctuations in measured concentrations of some of the constituents offset the advantage of diverting effluent to some extent, as evidenced by the increase in TSS loading rates during the driest periods. Findings for selected pollutants are described in detail in this section.

Total Suspended Solids

The yearly loading rate of TSS injected into the wells during the driest and wettest periods is 10,000 lbs, despite the fact that maximum production of R-1 water is taking place and the flowrate of injection is reduced from 4.0 MGD to 2.1 MGD. The TSS measured concentration doubles from 1 mg/l (during the wettest periods) to 2 mg/l (during the driest periods), accounting for the steady loading rate, and counterbalances the reduced effluent flow. During the driest periods, the R-1 system diverts a substantial loading of TSS from the injection wells. Approximately 10,000 lb/yr is transmitted for land application, equal to 100% of the total TSS injected during the wettest periods.

[102] The TN loading computed by SRGII is higher than that presented by Dailer, most likely the result of variation in the injectate flow rate used in the calculation of TN. Dailer cites an average value of 3.4 MGD for the 2008 injection rate of effluent; while SRGII uses a value of 4.0 MGD, provided by the County during personal communications as the current injection rate during the wettest periods when no reclaimed water is used by the Kāʻanapali Golf Course.

Total Nitrogen

There is a significant decrease in the loading rate of Total Nitrogen into the injection wells during the driest periods of the year in comparison to the wettest periods, due to both the production of R-1 water for customer needs, and a reduction in concentration during the driest periods. The yearly loading rate of Total Nitrogen injected into the wells during the wettest periods is approximately 92,000 lb/yr. In contrast, during the driest periods this value is 35,000 lb/yr, representing a 62% reduction in loading. This reduction is due to a combination of lower measured concentration during the driest periods (5.56 mg/l) in comparison to that of the wettest periods (7.6 mg/l); as well as the diversion of Total Nitrogen from injection well disposal at the rate of 32,000 lb/yr by the R-1 system, a figure equivalent to 35% of the Total Nitrogen rate of injection during the wettest periods.

Total Phosphorus

A substantial decrease in Total Phosphorus loadings injected into the wells during the driest periods is calculated. A yearly Total Phosphorus loading rate of 4,300 lb/yr is calculated for the wettest periods, while the value drops to 1,700 lb/yr during the driest periods, a reduction of approximately 60%. This reduction is due in part to the variation in measured concentration (0.35 mg/l during the wettest periods, and 0.26 mg/l during the driest periods), but is also the result of significant pollutant loadings diverted from disposal into the injection wells due to R-1 water production. The R-1 water diverts Total Phosphorus from injection during the driest periods at a rate of 1,500 lbs/yr, a figure equivalent to 35% of the Total Phosphorus loading injected during the wettest periods.

6.7.2 Future Conditions and Pollutant Load Estimates

With active sugarcane and pineapple cultivation phased out within both watersheds, and pineapple cultivation limited to occasional fruit harvest within selected fields, new crops within Wahikuli Watershed have begun to take their place. Seed corn, active for just over a decade, has recently ended; now coffee is the sole crop grown on KLMC lands. Development plans for large portions of both Wahikuli and Honokōwai Watersheds will bring residential and resort uses to former agricultural areas.

In the next several years, multiple master planned community and residential development projects are proposed within the lower and middle portions of the Agricultural District, and there are plans to improve or redevelop current lands within the Urban District as well (Section 3.3.3). These projects will bring urbanization further *mauka* of the highway, with single and multi-family housing on areas historically used for crop production. Urban impervious developed surfaces within the proposed developments including buildings, houses, pavement, sidewalks, and landscaped areas, will cover the existing bare or sparsely vegetated surfaces of the fallow and active agricultural fields and access roads that currently populate these portions of the Agricultural District. The upper regions of the Agricultural District will remain fallow fields and access roads, and if left unmanaged will continue to contribute substantial sediment loadings to the ocean. Legacy pollutants from historic fertilization of pineapple and sugarcane fields that have made their way into the underlying soils may migrate through the underlying soils of both the upper regions and the future developed areas, with their future contributions to water quality unknown.

Conversion from mg/l to lb/day: (X mg/l) x (X MGD) * 8.34 lb/gal = Total lb/day

Example Calculation: (1 mg/l) x (4.0 MGD)*(8.34 lb/gal) = 30 lb/day

Table 34. Calculated Average Pollutant Load Injected to Wells During Wettest Periods

		Injected Into Wells (Q=4.0 MGD)			
Pollutant	**Measured Concentration (mg/l)**	**Daily (lbs)**	**Weekly (lbs)**	**Monthly (lbs)**	**Yearly (lbs)**
TSS	1	30	200	1,000	10,000
Biological Oxygen Demand	6	200	1,000	6,000	70,000
Nitrate + Nitrite (NO_3^- + NO_2^-)	1.50	50	350	1,500	18,000
Ammonia (NH_3) (as N)	4.1	140	960	4,100	50,000
Kjeldahl Nitrogen	6.1	200	1,400	6,200	74,000
Total Nitrogen[103]	7.6	250	1,800	7,700	92,000
Total Phosphorus	0.35	12	82	350	4,300

Example Calculation: (2 mg/l) x (2.1 MGD) x (8.34 lb/gal) = 40 lb/day

Table 35. Calculated Average Pollutant Load Injected to Wells and Reclaimed for Land Use During Driest Periods

		Injected Into Wells (Q=2.1 MGD)				Applied To Land Within R-1 Water (Q=1.9 MGD)			
Pollutant	**Measured Concentration (mg/l)**	**Daily (lbs)**	**Weekly (lbs)**	**Monthly (lbs)**	**Yearly (lbs)**	**Daily (lbs)**	**Weekly (lbs)**	**Monthly (lbs)**	**Yearly (lbs)**
TSS	2	40	200	1,000	10,000	30	200	1,000	10,000
Biological Oxygen Demand	4	70	500	2,000	30,000	60	400	2,000	20,000
Nitrate + Nitrite (NO_3^- + NO_2^-)	3.66	64	450	1,900	23,000	58	410	1,800	21,000
Ammonia (NH_3) (as N)	0.56	9.8	69	300	3,600	8.9	62	270	3,200
Kjeldahl Nitrogen	1.90	33	230	1,000	12,000	30	210	910	11,000
Total Nitrogen	5.56	97	680	3,000	35,000	88	620	2,700	32,000
Total Phosphorus	0.26	4.6	32	140	1,700	4.1	29	120	1,500

103 Total Nitrogen (TN) is calculated by adding the measured concentrations of Kjeldahl Nitrogen and Nitrate plus Nitrate (NO_3^- + NO_2^-). Total Nitrogen was not shown in the December 21, 2011 or June 15, 2011 sampling results; however Kjeldahl Nitrogen and Nitrate plus Nitrate were listed as separate parameters and their measured concentrations have been summed to yield TN.

Future development projects proposed in the current Urban District will increase the impervious and landscaped areas along the coastline and lower elevations. During construction activities, temporary and localized areas of erosion and sediment generation from construction and grading activities, as well as soil stockpiles, will be introduced. These NPS pollution sources will replace the significant sediment loads that currently originate throughout the agricultural lands on surfaces of variable vegetative cover. A large reduction in erosion rates of soils upon completion of construction activities associated with these development areas is anticipated. This is due to the permanent stabilization of the soil through the introduction of vegetative and impervious surfaces, however the introduction of new urban area pollutants that accompany these surficial alterations will cause changes in surface runoff composition as well. A discussion of the impact of future land development on runoff rates and pollutant generation is provided in Appendix G.1.

Annual pollutant loading estimates for NPS pollutants generated off future land developments, as well as loadings due to increased influent requiring WWRF treatment in the project area were computed, and a summary of these loadings is presented in Table 36. Pollutant load contributions from the WWRF are calculated based on discharge rate of effluent during wettest and driest periods of the year, and data from the most recent sampling reports furnished from DOH (Section 6.7.1.3).

Table 36. Estimated Future Annual Pollutant Loadings Resulting from Build Out of Proposed Future Development Projects

		WWRF Injected Pollutant Loads (lb/yr)		
Pollutant	Urban Area Storm Event-Generated Loads (lb/ac/yr)[104]	Wettest Periods No R-1 Use (5.6 to 6.0 MGD)	Driest Periods Assuming 0% R-1 Production for Future Development (3.7 to 4.1 MGD)	Driest Periods Assuming 100% R-1 Production for Future Development (2.1 MGD)
TSS	105 – 153	20,000	20,000	10,000
Biological Oxygen Demand	-	100,000	40,000 – 50,000	30,000
Nitrate + Nitrite (NO_3^- + NO_2^-)	-	25,000 - 27,000	41,000 – 45,000	23,000
Ammonia (NH_3) (as N)	-	70,000 - 74,000	6,200 – 6,900	3,600
Kjeldahl Nitrogen	-	100,000 - 110,000	21,000 – 23,000	12,000
Total Nitrogen	3.86 – 5.60	130,000 - 140,000	62,000 – 68,000	35,000
Total Phosphorus	0.50 – 0.73	5,900 - 6,300	2,900 – 3,200	1,700

6.7.3 NPS Pollutant Loads Resulting From Future Land Use

6.7.3.1 Typical Urban Runoff Pollutant Concentrations

The Simple Method to Calculate Urban Stormwater Loads presents stormwater pollutant concentrations for urban land areas, including both national median concentrations and concentrations from various source areas within the urban environment (driveways, lawns, roads, etc.) (Table 37 and Table 38).[105]

[104] Assumes range of between 50% to 75% impervious cover for future developments.

[105] Produced by the New York State Department of Environmental Conservation http://www.dec.ny.gov/docs/water_pdf/simple.pdf

Table 37. National Median Concentrations for Chemical Constituents in Stormwater

Constituent	Concentration
TSS	54.5 mg/l
TP	0.26 mg/l
TN	2.00 mg/l
Cu	11.1 µg/L
Pb	50.7 µg/L
Zn	129 µg/L

Table 37 illustrates that TSS (54 mg/l) is a far more prevalent constituent of typical urban stormwater runoff than Total Nitrogen (2.00 mg/l) or Total Phosphorus (0.26 mg/l). The data in Table 38 shows that by far, the primary source of TSS within urban areas comes from lawns. This is somewhat intuitive, as lawns generally have a high potential for disturbance, erosion, and sediment generation depending on intensity of use, climate factors, and other variables. The primary source of Total Nitrogen is from rural highways, but also has significant overall contributions from lawns. High Nitrogen concentrations are logical for lawn areas considering the fertilizer loads applied to lawn areas and vegetative matter generated on these surfaces over time. Total Phosphorus concentrations are mainly sourced from lawns and contained in fertilizers applied.

Table 38. Pollutant Concentrations from Source Areas

Constituent	TSS (mg/l)	TP (mg/l)	TN (mg/l)	Cu (µg/L)	Pb (µg/L)	Zn (µg/L)
Residential Roof	19	0.11	1.5	20	21	312
Commercial Roof	9	0.14	2.1	7	17	256
Residential Street	172	0.55	1.4	25	51	173
Rural Highway	51	-	22	22	80	80
Urban Highway	142	0.32	3.0	54	400	329
Lawns	602	2.1	9.1	17	17	50
Landscaping	37	-	-	94	29	263
Driveway	173	0.56	2.1	17	-	107

6.7.3.2 Urban Stormwater Loads Resulting From Future Use – Simple Method

The Simple Method is a tool for estimating urban area stormwater runoff pollutant loads, expressed in pounds per year (lb/yr). It provides reasonable estimates of changes in pollutant export resulting from urban development, and is most appropriate for use when comparing relative changes in pollutant loadings from different land use and stormwater management scenarios. However, it is inappropriate for use when evaluating relatively similar development scenarios, such as those with total impervious cover variation of only a few percentage points. The Simple Method only estimates loads generated during storm events, and does not include pollutants associated with baseflow volume, which is usually not considered significant unless there are illicit wastewater connections or treatment plant flows to consider. It also does not estimate pollutants carried via groundwater.

Box 8. Simple Method

The Simple Method uses three variables to estimate annual load of chemical constituents found in runoff and is expressed as L = 0.226 x R x C x A, where L is the annual load (lbs) of the constituent. The variables within the equation include the annual runoff (R), expressed in inches, which is a product of annual runoff volume and a runoff coefficient (Rv) calculated based on impervious cover in the subwatershed; the pollutant concentration (C), expressed in mg/l; and the contributing drainage area (A) being analyzed, expressed in acres. The higher the value of any one of these variables, the higher the calculated annual load for the parameter under analysis, demonstrating that annual pollutant load is a product of several site-specific factors.

SRGII utilized the Simple Method to calculate estimated annual loading rates for TSS, Total Nitrogen, and Total Phosphorous generated on areas that are part of larger parcels planned for future development. These parcels are shown on the County of Maui Long Range Planning Division map (Section 3.3.3, Figure 7). Loadings were computed for future full build-out conditions, assuming the completion of construction for all future development projects. Loadings resulting from both conventional and Low Impact Development (LID) construction approaches were analyzed and compared, with assumptions made to determine the difference in impervious and landscaped areas that could be expected upon project build-out in each of the scenarios. This difference in impervious and landscaped areas under the two scenarios is directly responsible for variation in the pollutant loadings generated.

6.7.3.3 Peak Runoff Rates Resulting From Future Land Use – Rational Method

The Rational Method equation is a simple tool used for predicting peak rate of runoff, expressed in cubic feet per second (cfs) (Box 9). It is commonly used by engineers and other hydrologic professionals for determining peak discharge from small drainage areas, and is most effective in drainage basins smaller than 200 acres. The accuracy of Rational Method results is dependent on several factors, including assumed uniform rainfall intensities; fairly homogeneous surfaces; and high percentage of impervious surfaces throughout the basins under analysis.[106]

Box 9. Rational Method

The Rational Method uses three variables to compute peak rate of runoff and is expressed as Q = C x i x A, where Q is the peak rate of runoff (cfs). The variables within the equation include the runoff coefficient (C), an empirical coefficient representing the relationship between rainfall and runoff, which varies in value according to land uses and soil conditions of the watershed, is weighted to account for these variations, and is highest for impervious areas; the average intensity of rainfall (i), expressed in in/hr, for a selected design storm recurrence interval (2-year, 10-year, 50-year, etc) of duration equal to the Time of Concentration (Tc), which is a summation of the flow regimes which occur along the hydraulic flow path; and the contributing drainage area (A) being analyzed, expressed in acres. The higher the value of any one of these variables, the higher the calculated peak rate of runoff for the watershed or drainage area under analysis, demonstrating that runoff rate is a product of several site-specific factors.

SRGII utilized the Rational Method to calculate expected peak runoff rates for two representative areas that are part of larger parcels planned for future development. These parcels are shown on the County of Maui Long Range Planning Division map (Section 3.3.3, Figure 7). Calculations were completed in accordance with Maui County Department of Public Works and Waste Management's *Rules for the Design of Storm Drainage Facilities in the County of Maui* (1995). Runoff rates were computed for future full build-out conditions assuming the completion of construction for all future development projects. Runoff rates resulting from both conventional and LID construction approaches were analyzed and compared, with assumptions made to determine the difference in impervious and landscaped areas that could be expected upon project build-out in each of the

[106] http://water.me.vccs.edu/courses/CIV246/lesson11.htm

scenarios. The process used to determine the Rational Method variables is presented in Appendix G2. Computed peak flows are presented in Table 39.

For determination of weighted runoff coefficient, in the conventional development scenario it was assumed that 30% of the land area would be impervious, and 70% would be grass/landscaped. For the LID scenario, stormwater will be captured and filtered by natural practices that will effectively reduce the peak flow. These conditions are assumed to be the computational equivalent of one-half of the impervious area contributing to runoff than under the conventional development scenario. Therefore the LID scenario assumed 15% impervious area and 85% grass/landscaped area.

As shown in Table G1, the peak rate of runoff resulting from a hypothetical 10-acre conventional development is approximately 13 cfs, as compared to an LID approach that would yield 9.2 cfs peak flow, a reduction of approximately 30%. Similarly, for a 100-acre conventional development, the value of 130 cfs for conventional development peak flow is 30% higher than LID at 92 cfs. This reduced flow rate is the result of LID approaches more closely approximating natural (pre-development) runoff conditions, and promoting groundwater recharge through incorporation of natural infiltration areas.

Table 39. Rational Method Summaries – Future Development

	Subwatershed Area "A" (Acres)	Weighted Runoff Coefficient "C"	Time of Concentration "Tc" (minutes)	Rainfall Intensity "i" (in/hr)	Peak Rate of Runoff "Q" (cfs)
Future Conditions: Conventional Development Subwatershed Summaries					
1	10	0.375	15	3.5	13
2	100	0.375	15	3.5	130
Future Conditions: LID Development Subwatershed Summaries					
1	10	0.263	15	3.5	9.2
2	100	0.263	15	3.5	92

6.7.3.4 Wastewater Generation from Future Development

Wastewater generated from future developments within the Kāʻanapali region will result in a substantial increase in the quantity of influent transmitted to the WWRF for treatment and disposal/reclamation. The percentage of this influent ultimately disposed into the injection wells will be largely dependent on the future customer base served by the R-1 transmission system. The impacts of future development on wastewater generation, treatment, and reuse is discussed in this section. For the purposes of this discussion, it is assumed that all future development properties will become part of the Maui County WWRF customer base.

According to the Maui County Department of Planning's Long Range Division, a total of 7,510 single family, 2,047 multi-family, and 521 timeshare and hotel units have been identified as part of future developments within the Kāʻanapali region (Table 4). This is a grand total of 10,078 units identified for construction. Each of these units will be built as part of a development project currently identified by the Long Range Division as either "Planned/Committed," "Planned/Designated," or "Proposed" (Section 3.3.3).

The range of predicted future wastewater flows resulting from full build-out of these projects has been estimated using 2010 Census household data and per capita flow rates referenced from EPA documentation. Assuming a full build-out of 10,078 units with a year-round average household unit size of 2.89[107] people, and a median daily per capita wastewater flow of between 54 and 67 gallons/person/day,[108] a calculated estimate of between 1.6 and 2.0 MGD of additional influent could be directed from these developments to the WWRF for disposal and/or reuse. These calculated flow rates are 40% to 50% greater than the average daily rate of 4.0 MGD currently disposed into the injection wells during the wettest periods of the year (when there is zero water reclaimed and transmitted to the Kāʻanapali Golf Courses or resort properties) and present a substantial increase in pollutant loadings. A grand total of 5.6 to 6.0 MGD would be received, treated, and subsequently injected into the wells as final effluent if R-1 reclamation is not utilized.

Loading rates of selected pollutants have been calculated for both current (4.0 MGD) and future conditions (5.6-6.0 MGD) for wettest periods of the year (when injection flowrate is highest and R-1 demand is zero) and driest periods of the year (when R-1 demands are highest). Currently, WWRF influent is sourced from residential and resort uses as well as supporting commercial and retail businesses in the region. For the purposes of this analysis, it is assumed that future developments will follow this trend, delivering measured constituent concentrations of the same magnitude to WWRF influent. Table 40 contrasts current and future calculated pollutant loadings to the injection wells during the wettest periods of the year (with no R-1 production) and the difference in magnitude of these loadings, based on daily, weekly, monthly, and yearly time intervals. The most recent available wet period WWRF sample laboratory results (December 21, 2011) were used for concentrations of selected wastewater parameters cited in the table (Section 6.7.1.3). Table 41 contrasts current and future calculated pollutant loadings to the injection wells during the driest periods of the year under various scenarios of R-1 production. Calculated loadings for 0%, 30%, 60%, and 100% treatment of effluent from future developments to R-1 levels are presented. The most recent available dry period WWRF sample laboratory results (June 15, 2011) were used for concentrations of selected wastewater parameters cited in the table (Section 6.7.1.3). The loadings are presented in daily, weekly, monthly, and yearly time intervals. Concentrations shown apply to both the final effluent disposed into the injection wells and the R-1 water used for irrigation purposes, as R-1 treatment involves only additional disinfection treatment for land application.

Comparing Table 40 and Table 41, during the wettest and driest periods of the year (if no R-1 water is produced to reclaim future development inflow), TSS loadings injected into the wells are predicted to be equal at 20,000 lb/yr. If 100% of influent from the developments occurs, then the TSS loadings will reduce by 100%, to a rate of 10,000 lb/yr. For Total Nitrogen, 130,000 lb/yr to 140,000 lb/yr is predicted for injection during the wettest periods. During the driest periods, if zero R-1 water is produced from future development effluent, this loading rate will drop to 62,000 lb/yr to 68,000 lb/yr (the result of reduced Total Nitrogen loadings (5.56 mg/l during driest periods; 7.6 mg/l during wettest periods) coupled with a reduced injectate flow (1.9 MGD of R-1 being produced to supply the golf courses and selected resorts)). However, if 100% of R-1 is produced from the development influent, this loading rate can be reduced even further to 35,000 lb/yr. For Total Phosphorus, a similar decrease is evident. During the wettest periods with zero R-1 water production from future development effluent, 5,900 lb/yr to 6,300 lb/yr is injected. During the

[107] http://quickfacts.census.gov/qfd/states/15/15009.html

[108] http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008chap3.htm

driest periods with zero R-1 production from the future development effluent, 2,900 lb/yr to 3,200 lb/yr is expected; and with 100% R-1 production, 1,700 lb/yr is expected.

As Table 40 illustrates, the expected 40% to 50% increase over present day flowrate of effluent into the injection wells and groundwater table from future development (during the wettest periods of the year) will bring increased pollutant loading rates of the same magnitude (because there is zero R-1 water produced during this time). Therefore, TSS is calculated to increase 10,000 lb/yr; Total Nitrogen by 38,000‑48,000 lb/yr; and Total Phosphorus is expected to increase by a rate of 1,600‑2,000 lb/yr. The trend seen in Table 41 clearly demonstrates that integrating R-1 production into future developments has a significant impact on the pollutant loadings entering the groundwater during the driest periods of the year – whether integrated at the 30%, 60%, or 100% level. Whereas 0% future R-1 production will result in TSS rates of 20,000 lb/yr; Total Nitrogen rates of 62,000 – 68,000 lb/yr; and Total Phosphorus rates of 2,900 – 3,200 lb/yr, these rates reduce to the present day injection rates of 10,000 lb/yr of TSS; 35,000 lb/yr of Total Nitrogen; and 1,700 lb/yr of Total Phosphorus, if 100% of future effluent is reclaimed during the driest periods. This represents a 100% reduction in TSS, 43% to 49% reduction in Total Nitrogen; and 41% to 47% reduction in Phosphorus if 100% of future development influent is reclaimed versus 0%.

As discussed in Section 6.7.1.3, the 1.9 MGD of R-1 water currently meeting customer demand diverts approximately 47% of pollutant loadings from disposal into the injection wells during the driest periods of the year. Meeting irrigation needs for the landscaped grounds and other water demands of future developments can be done by incorporating R-1 water production to the maximum extent possible. This will both decrease the overall quantity of influent to be treated/injected, as well as decreasing the loading rate of pollutants directly disposed into the WWRF wells. Extending the R-1 water production period to year-round will result in the greatest benefit to water quality, with injectate flowrates and loading rates reduced throughout all seasons. Another potential practice to reduce loadings may be the construction of greywater lines within future developments for reuse of water onsite for irrigation or other suitable purposes. Both R-1 system expansion and greywater line construction would need to be designed and reviewed for feasibility by appropriate agencies.

There will also be a corresponding demand for potable water for future developments, equal to or greater than the predicted increase to wastewater flow rates of 1.6 to 2.0 MGD. Additional demands for landscape irrigation, water for recreational pools, and other uses will likely increase potable water demand rates. These rate increases in Wahikuli and Honokōwai Watersheds alone represent an increase of between 67% and 83% in the current 2.4 MGD currently produced at the Māhinahina WTF for its entire service area of Lahaina, Nāpili, Wahikuli, Kahana, and ʻAlaeloa.

Conversion from mg/l to lb/day: (X mg/l) * (X MGD) * 8.34 lb/gal = Total lb/day

Example Calculation: (1 mg/l)*(5.6 MGD)*(8.34 lb/gal) = 50 lb/day

Table 40. Current and Future Calculated Pollutant Loadings Injected to Wells During Wettest Period

	Pollutant		TSS	Biological Oxygen Demand	Nitrate + Nitrite ($NO_3^- + NO_2^-$)	Ammonia (NH_3) (as N)	Kjeldahl Nitrogen	Total Nitrogen	Total Phosphorus
	Measured Concentration (mg/l)		1	6	1.50	4.1	6.1	7.6	0.35
Current (4.0 MGD)	Daily	(lbs)	30	200	50	140	200	250	12
	Weekly	(lbs)	200	1,000	350	960	1,400	1,800	82
	Monthly	(lbs)	1,000	6,000	1,500	4,100	6,200	7,700	350
	Yearly	(lbs)	10,000	70,000	18,000	50,000	74,000	92,000	4,300
Future (5.6 – 6.0 MGD)	Daily	(lbs)	50	300	70 - 74	190 - 200	280 - 300	350 - 380	16 - 17
	Weekly	(lbs)	300	2,000	490 - 520	1,300 - 1,400	2,000 - 2,200	2,500 - 2,600	110 - 120
	Monthly	(lbs)	1,000 - 2,000	9,000	2,100 - 2,300	5,800 - 6,200	8,600 - 9,200	11,000	490 - 530
	Yearly	(lbs)	20,000	100,000	25,000 - 27,000	70,000 - 74,000	100,000 - 110,000	130,000 - 140,000	5,900 - 6,300
Loading Increase (MGD)	Daily	(lbs	20	100	20 - 24	50 - 60	80 - 100	100 - 130	4 - 5
	Weekly	(lbs)	100	1,000	140 - 170	340 - 440	600 - 800	700 - 800	28 - 38
	Monthly	(lbs)	0 – 1,000	3,000	600 - 800	1,700 - 2,100	2,400 - 3,000	3,300 - 3,300	140 - 180
	Yearly	(lbs)	10,000	30,000	7,000 - 9,000	20,000 - 24,000	26,000 – 36,000	38,000 – 48,000	1,600 - 2,000

Conversion from mg/l to lb/day: (X mg/l) * (X MGD) * 8.34 lb/gal = Total lb/day
Example Calculation: (2 mg/l)*(2.1 MGD)*(8.34 lb/gal) = 40 lb/day

Table 41. Current and Future Calculated Pollutant Loadings Injected to Wells During Driest Periods

	Pollutant		TSS	Biological Oxygen Demand	Nitrate + Nitrite $(NO_3^- + NO_2^-)$	Ammonia (NH_3) (as N)	Kjeldahl Nitrogen	Total Nitrogen	Total Phosphorus
	Measured Concentration (mg/l)		2	4	3.66	0.56	1.90	5.56	0.26
Current: 1.9 MGD R-1 Production (2.1 MGD Injected)	**Daily**	**(lbs)**	40	70	64	9.8	33	97	4.6
	Weekly	**(lbs)**	200	500	450	69	230	680	32
	Monthly	**(lbs)**	1,000	2,000	1,900	300	1,000	3,000	140
	Yearly	**(lbs)**	10,000	30,000	23,000	3,600	12,000	35,000	1,700
Future: 0% R-1 Production (3.7 – 4.1 MGD Injected)	**Daily**	**(lbs)**	60 – 70	100	110 – 120	17 – 19	58 – 64	170 – 190	8.0 – 8.8
	Weekly	**(lbs)**	400 – 500	900	780 – 870	120 – 130	410 – 450	1,200 – 1,300	56 – 61
	Monthly	**(lbs)**	2,000	4,000	3,400 – 3,800	520 – 570	1,800 – 1,900	5,200 – 5,700	240 – 270
	Yearly	**(lbs)**	20,000	40,000 – 50,000	41,000 – 45,000	6,200 – 6,900	21,000 – 23,000	62,000 – 68,000	2,900 – 3,200
Future: 30% R-1 Production (3.2 – 3.5 MGD Injected)	**Daily**	**(lbs)**	50 – 60	100	98 – 110	15 – 16	51 – 55	150 -160	6.9 - 7.5
	Weekly	**(lbs)**	400	700 – 800	680 – 740	100 – 110	360 - 380	1,000 – 1,100	49 – 53
	Monthly	**(lbs)**	2,000	3,000 – 4,000	3,000 – 3,200	450 – 490	1,500 – 1,700	4,500 – 4,900	210 – 230
	Yearly	**(lbs)**	20,000	40,000	36,000 – 39,000	5,400 – 5,900	18,000 – 20,000	54,000 – 59,000	2,500 – 2,700
Future: 60% R-1 Production (2.7 – 2.9 MGD Injected)	**Daily**	**(lbs)**	50 – 48	90 -100	83 – 88	13 – 13	43 – 46	130	5.9 – 6.2
	Weekly	**(lbs)**	300	600 – 700	580 - 620	89 – 94	300 – 320	890 – 940	41 – 44
	Monthly	**(lbs)**	1,000	3,000	2,500 – 2,700	390 – 410	1,300 – 1,400	3,800 – 4,100	180 – 190
	Yearly	**(lbs)**	20,000	30,000	30,000 – 32,000	4,600 -4,900	16,000 – 17,000	46,000 – 49,000	2,200 – 2,300
Future: 100% R-1 Production (2.1 MGD Injected)	**Daily**	**(lbs)**	40	70	64	9.8	33	97	4.6
	Weekly	**(lbs)**	200	500	450	69	230	680	32
	Monthly	**(lbs)**	1,000	2,000	1,900	300	1,000	3,000	140
	Yearly	**(lbs)**	10,000	30,000	23,000	3,600	12,000	35,000	1,700

6.8 Summary

NPS pollutants are derived from various sources within Wahikuli and Honokōwai Watersheds, and are greatly influenced by human and animal behaviors, land conditions, and natural processes. NPS pollutants are transported primarily in surface water and groundwaters, but some can also be dispersed through wind borne means, such as sediment.

6.8.1 Pollutant Hotspots

Within the Conservation District, the highest priority NPS pollutant hotspots are the main dirt bike trail along the conservation area; locations with populations of feral ungulates (pigs); eroding sections of natural stream channels and bedding; and areas of wildfire potential.

Within the Agricultural District, the highest priority NPS pollutant hotspots are the steep upper segments of the dirt access roads within the pineapple and seed corn field regions, running perpendicular to the contours; the bare seed corn fields; and the outlets of pineapple field terraces and access roads where they intersect stream channels. Additional inputs are sourced from components of agricultural development and production and include soil amendments, irrigation practices, current field conditions, field drainage practices, and associated infrastructure. Since sugarcane and pineapple production has ceased, the amount of fertilizers and pesticides being applied in the Wahikuli and Honokōwai Watersheds on agriculture lands has decreased. Generally, fertilizers and herbicides are the main amendments applied to fields and on crops for seed corn, coffee, and sugarcane production, while pineapple fields incorporate fungicides as well (although all sugarcane and pineapple fields are now fallow).

Within the Urban District, the highest priority NPS pollutant hotspots are unstabilized residential and commercial construction sites; and unstabilized developed lands such as cemeteries and beach park erosion areas. Highest priority nutrient generation hotspots include the WWRF injection wells; and landscaping activities associated with the two Kāʻanapali Golf Courses as well as those associated with resort, commercial, and residential uses. Based on interviews with Kāʻanapali Golf Course personnel, the fertilizer application rates appear to align with recommendations from CTAHR.

6.8.2 Lahaina Wastewater Reclamation Facility

The WWRF is subject to two UIC permits administered under the SDWA: one from DOH, and one from EPA. Both permits have expired, and the facility is operating under administrative agreement, subject to requirements of both permits. Monitoring of effluent quality is part of permit provisions. Disposal of effluent consists of four gravity-fed sewage treatment effluent wells. The maximum well flow rate is 9 MGD, with current levels averaging 4 MGD.

Various researchers have studied the fate of WWRF injectate over the past several years. Researchers have confirmed presence of wastewater from the WWRF in coastal seeps through the use of dye testing (Tummons 2012). Dailer (2012) confirmed wastewater effluent flows through the Kahekili coral reef and into surface waters, then flowing southward. Hunt and Rosa (2009) surmised the WWRF effluent plume path may be guided by an ancestral course of Honokōwai Stream. Their research confirmed the effluent plume's presence at Kahekili Beach Park, as well as presence of tribromomethane, musk fragrances, a fire retardant, and a plasticizer compound sampled at both the WWRF and in the submarine springs. Carbamazepine, a pharmaceutical, was also found in WWRF effluent and marine column samples.

Several researchers have measured concentrations of various forms of Nitrogen including Nitrate Nitrogen at and near two submarine groundwater seeps along Kahekili Beach. Dailer et al. (2010) determined a daily TNL from 79 to 97 kg (174-215 lbs) N/day between 2006 to 2008; and annual TNL of 28,873 to 35,530 kg (63,609– 78,274 lbs) of N/yr. "Our work suggests that a substantial amount of this loading traveled to the nearby coastal zones." Soicher and Peterson (1997) found that during the 1980's and early 1990's, WWRF injection appears to have been the largest contributor to groundwater Nitrates. WWRF improvements are cited as the reason for 50% reduction in nutrient concentrations by the early 1990's. It was surmised that wastewater is the largest nutrient source contributing to degradation of the coastal environment of West Maui.

6.8.3 Pollutant Loading and Nutrient Application Estimates

6.8.3.1 Field Application of Nutrients

Estimated annual nutrient application of Nitrogen, Phosphorus, and Potassium was calculated for both active fields and during the historic sugarcane and pineapple era within the project area. Values were based on CTAHR fertilizer mix recommendations and personal communications. Sugarcane had the highest Nitrogen and Potassium application of all fields historic and active, and depending on the mix used, pineapple was highest in Phosphorus applied. Seed corn fields have the lowest nutrient application for all three nutrients analyzed. The total acreage of coffee fields in production at one time covers an area approximately equal to that planted in seed corn during cultivation. However, higher fertilizer application rates result in Nitrogen and Potassium annual applications 600% higher, and Phosphorus annual applications 140% higher, for coffee than those that were required for seed corn production.

6.8.3.2 Calculated Soil Loss for Agricultural Fields - RUSLE2

The RUSLE2 was used to compare erosion rates between the various fields within the watersheds: active coffee, fallow seed corn, fallow sugarcane, and fallow pineapple. Calculated soil losses for seed corn fields were found to substantially exceed tolerable rates for all three of the representative fields evaluated (190% exceedance for Field #1; 480% for Field #2; and 250% for Field #3), whereas coffee, sugarcane, and pineapple fields all had losses less than the tolerable soil loss value. The highest soil loss calculated for seed corn was Field #2, which had the steepest slope of the three fields evaluated.

6.8.3.3 Calculated WWRF Pollutant Loadings

Loading rates were calculated for several pollutants found in WWRF effluent during the driest and wettest periods of the year. These rates were then compared, to determine the variation in pollutant loading rates injected over the course of the year and the effect that R-1 level reclamation for land irrigation needs has on the rates of pollutant injection into the wells during the driest periods. During the wettest periods of the year all effluent (avg. 4.0 MGD) is disposed into the injection wells; and during the driest periods of the year the maximum amount of R-1 water (1.9 MGD) is produced for customer irrigation needs within the watershed. Concentrations of selected parameters were taken from the WWRF sampling results for 2011, including a sampling event in July (representing driest period) and December (representing wettest period).

R-1 water production currently diverts 47% of pollutant loadings from disposal into the injection wells during the driest periods of the year; however fluctuations in concentrations of some wastewater constituents offset the advantage of diverting effluent from the wells to an extent. TSS loading rates to the injection wells during the driest periods are roughly equal to the wettest periods, (10,000 lb/yr) despite the advantage of diverting 1.9 MGD of effluent flow through the use of R-1 water. The equivalent loading is due to the fact that measured TSS concentration doubles from 1 mg/l during the wettest periods to 2mg/l during the driest periods. Despite the increase in concentration and equivalent loading injected, R-1 still diverts 10,000 lb/yr of TSS from being injected during the driest periods; equal to 100% of the total TSS loading injected during the wettest periods.

Total Nitrogen loading rates significantly decrease during the driest periods of the year, with a 62% reduction below the wettest period rate (35,000 lb/yr driest periods vs. 92,000 lb/yr wettest periods). This decrease is due to lower measured concentration of Total Nitrogen coupled with R-1 use during the driest periods. Similarly, Total Phosphorus loading rates also had substantial decreases during the driest periods of the year, with a 60% reduction below the wettest period rate (1,700 lb/yr vs. 4,300 lb/yr). This decrease was due to lower measured concentration of Total Phosphorus coupled with R-1 use during the driest periods, similar to the trend of the Total Nitrogen loading rate.

6.8.3.4 Future Conditions and Pollutant Loading Estimates

Multiple master planned community and residential development projects proposed within the watersheds will increase urbanization further *mauka* of the highway, with single and multi-family housing on areas historically used for crop production. The urbanization will likely result in a reduction of sediment pollutants derived from the land, however NPS pollutants associated with urban land use will replace them. Urbanization will also likely increase surface runoff volumes due to increase in impervious surface.

Peak Runoff Rates Resulting from Future Land Use – Rational Method

The Rational Method was used to estimate peak rates of runoff from two representative areas of the Agricultural District planned for future development. Post-development condition scenarios were run using the Rational Method input data included in the Maui County regulations for design of stormwater facilities. Two future build out scenarios are: conventional storm water management design and LID design. When comparing future development runoff under these scenarios, volume is greater and time to peak is shorter for the conventional storm water management as compared to LID. Under any future build out conditions, the peak runoff volumes are estimated to be greater than existing conditions, due primarily to increases to impervious surface area under build out conditions.

Wastewater Generation from Future Development

A total of 10,078 units have been identified as part of future developments within the Kāʻanapali region, according to the Maui County Department of Planning's Long Range Division. Predicted future wastewater flows from these development projects was estimated at between 1.6 and 2.0 MGD, resulting in a 40% to 50% increase over the existing 4.0 MGD average flow rate. If concentrations of measured parameters remain the same, there will be a corresponding increase in pollutant loading rates of 40% to 50% as well. To mitigate the expected increases and higher influent, treatment of future development influent to R-1 standards and subsequent distribution to an increased customer base within the Kāʻanapali region may be the most viable option, as well as extending the R-1 water production period to year-round if possible. If zero future development influent is reclaimed during the driest periods of the year, TSS, TN, and TP loadings are expected to be 20,000 lb/yr, 62,000 to 68,000 lb/yr, and 2,900 to 3,200 lb/yr, respectively. If 100% of future development influent is reclaimed during the driest periods of the year, TSS, TN, and TP loadings are expected to be 10,000 lb/yr, 35,000 lb/yr, and 1,700 lb/yr, respectively. This means that full reclamation of future development influent can reduce TSS levels by 100%; TN levels by 43% to 49%; and Phosphorus levels by 41% to 47% during the direst periods of the year, versus none being reclaimed. Construction of greywater lines for reuse of water onsite may also be a consideration for future developments to reduce influent generation.

7. Next Steps

Volume 1: Watershed Characterization provides important baseline information. Filling in identified data and information gaps will provide a higher level of detail of specific NPS pollutants coming from various sources. *Volume 2: Strategies and Implementation* presents strategies for management of the NPS pollutants that adversely impact water quality and the coral reef ecosystem.

7.1 Data and Information Gaps

Data and information contained in this WHWMP represent the best available at the time of writing. During preparation of this watershed characterization, some data and information that was known to exist was not acquired. In a few cases the entity that houses the data was not authorized to release it, or the data was provisional and not releasable. Some of this information has been requested and may be received during preparation of *Volume 2: Strategies and Implementation*. If and when this occurs, the data will be reviewed for applicability to the WHWMP. If warranted, the characterization will be amended.

Research information gaps were found concerning legacy nutrient use in the Kāʻanapali region, for both agricultural and urban areas. An accurate nutrient balance for the watersheds was unable to be completed based on currently available data. Future detailed studies of nutrient transmission rates from legacy applications during crop production would be highly desirable. Several researchers have touched on this topic, but a conclusive study has not been conducted. Similarly, a watershed water balance was not completed as part of this WHWMP. Concurrent to preparation of this report the USGS is conducting water balance study for the larger west Maui area including the watersheds in the WHWMP. Their study is expected to provide quantifiable information regarding stream and groundwater flows which can be used in water resources allocations, and water quality investigations.

Other data and information that does not exist or data with temporal gaps, or data sets that are spatially limited were identified (e.g. groundwater monitoring, fertilizer application rates in urban areas). In addition, there are studies and investigations that were identified that if conducted would aid in better understanding the transport and fate of pollutants on and under the two watersheds. Various topics for studies and investigations that will assist in filling data and information gaps will be presented *Volume Two: Strategies and Implementation* of the WHWMP.

7.1.1 Modeling Efforts

Hydrologic models are used to estimate or verify processes occurring on the watershed of interest including fluxes of surface water and groundwaters. For example, to estimate changes to stream flow when land cover is changed. From a water quality perspective, models can be used to estimate baseline or naturally occurring water quality conditions and changes due to anthropogenic impacts such as fertilizer applications. Accuracy of any type of hydrologic model is a function of the data inputs used, the complexity of the hydrologic system being investigated, and the modeler's experience and knowledge of the processes of the watershed they are working on.

Initially, the WHWMP was going to include a comprehensive modeling effort to quantify NPS pollutant loading rates that originate within the project area watersheds. The purpose of this effort was to analyze existing contributions from each of the major pollutant sources within the various Land Use Districts. Upon review of the compiled data acquired from research studies, stakeholder meetings held during the creation of this WHWMP, and observations made during field visits to the project area, it became apparent that comprehensive modeling could not be conducted due to data and information gaps. Since there is currently limited surface water and groundwater quality data available in the Kāʻanapali region, calibrating and verifying pollutant yield output from models is difficult and would be of questionable accuracy.

Some quantifiable data does exist regarding the potential amounts of pollutant loadings on lands within the project area (e.g. fertilizer on agricultural fields, Section 6.7.1). These data were used as input values for simple models to determine selected loading rates (Section 6.7). The RUSLE2 model was used to estimate and compare calculated soil losses from six selected agricultural fields within Wahikuli and Honokōwai Watersheds (Section 6.7.1.2).

The Nonpoint-Source Pollution and Erosion Comparison Tool (N-SPECT), can be used to investigate potential water quality impacts from development, other land uses, and climate change. Although N-SPECT was designed to be broadly applicable to various regions, it operates most accurately in medium-to-large watersheds having moderate topographic relief, and as such would not likely yield accurate results in the Conservation District portion of the project area. The model may be more appropriate for analysis of the Agricultural and Urban Districts, when the necessary resources become available for analysis.

A water balance analysis is another type of model that can provide information on the flow of water into and out of the watersheds. The USGS is currently conducting a multi-year water budget analysis for West Maui. While their data will not be available for use in this project, the results can eventually be incorporated into an updated WHWMP.

Limited modeling efforts will be conducted to quantify load reductions for specific pollutants with data available in the discussion of recommended management practices for the watersheds (in *Volume 2: Strategies and Implementation*).

7.1.2 Other

The S4 within the Kāʻanapali region was not available in GIS format at the time of writing of this Watershed Characterization. Therefore, analysis of the drainage network was based on review of high resolution aerial photographs; onsite observations of existing site grades, drainage structures, and runoff flowpaths; discussions with stakeholders; and previous research. Acquisition of GIS data will help provide a more detailed understanding of the Urban District drainage network. Knowing the exact layout of drainage structures and piping networks can aid in the determination of how to best remediate areas of NPS pollutant generation and incorporate management practices prior to runoff entering the S4. GIS data will also provide a schematic of the interconnected as-built conditions of drainage network and flow paths from various locations within the region.

7.2 Potential Implementation Projects

Potential implementation projects addressing NPS pollutants found in the Agricultural and Urban Districts will be outlined in *Volume 2: Strategies and Implementation*. These will range from preventive actions (e.g. nutrient management plans, reservoir operation plans) to treatment practices that will address erosion control, nutrient remediation, upgrades to dam structures, alternatives for disposal of WWRF effluent, future development projects, and water conservation.

Opportunities to establish and/or continue public-private sector partnerships to address land-based pollution threats to coral reefs and improve understanding of the impacts of different land uses and management practices on reducing pollutant loads to coastal waters will be identified.

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Appendix A. Figures

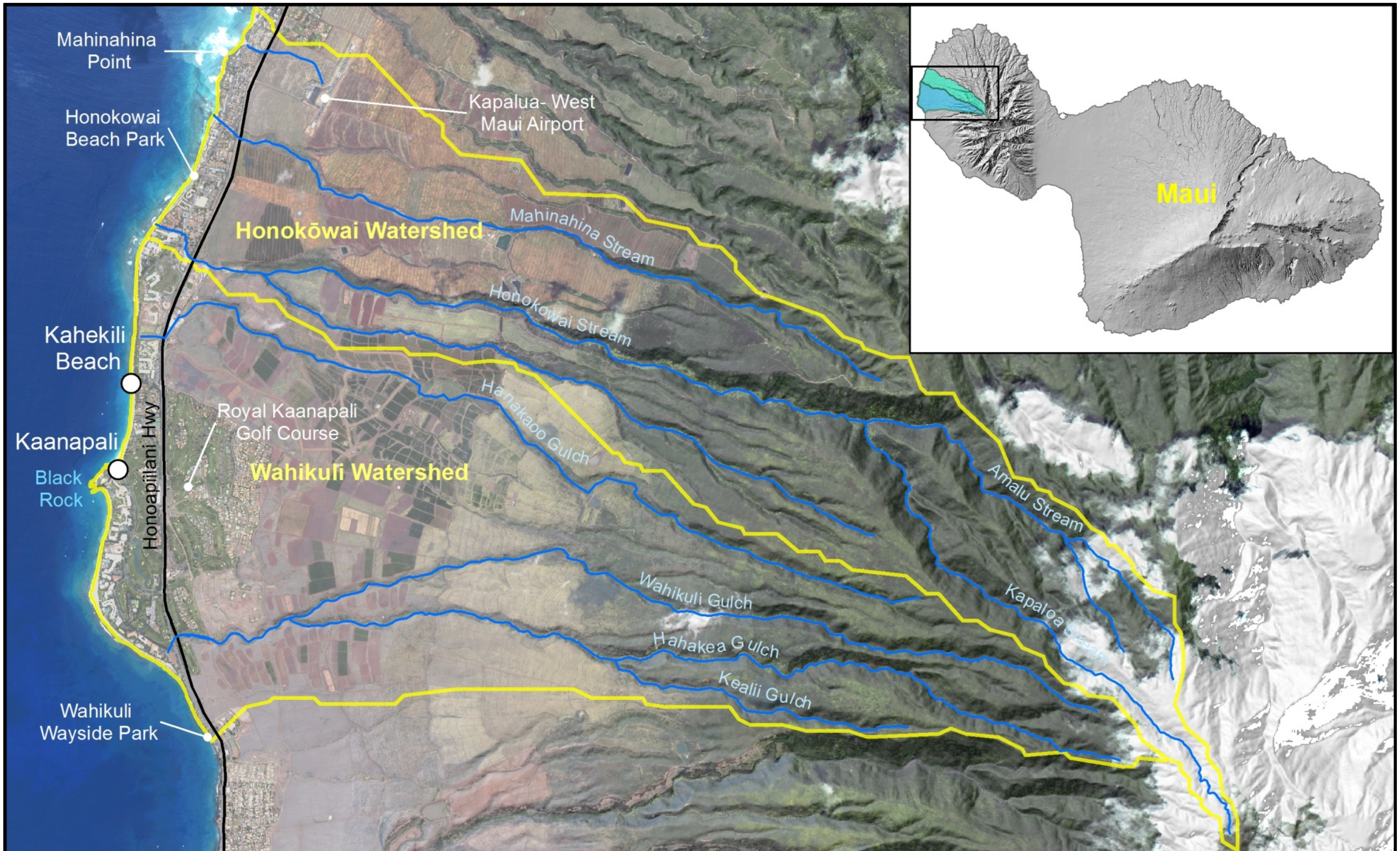

Figure 1.
Wahikuli-Honokōwai WMP Project Area

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

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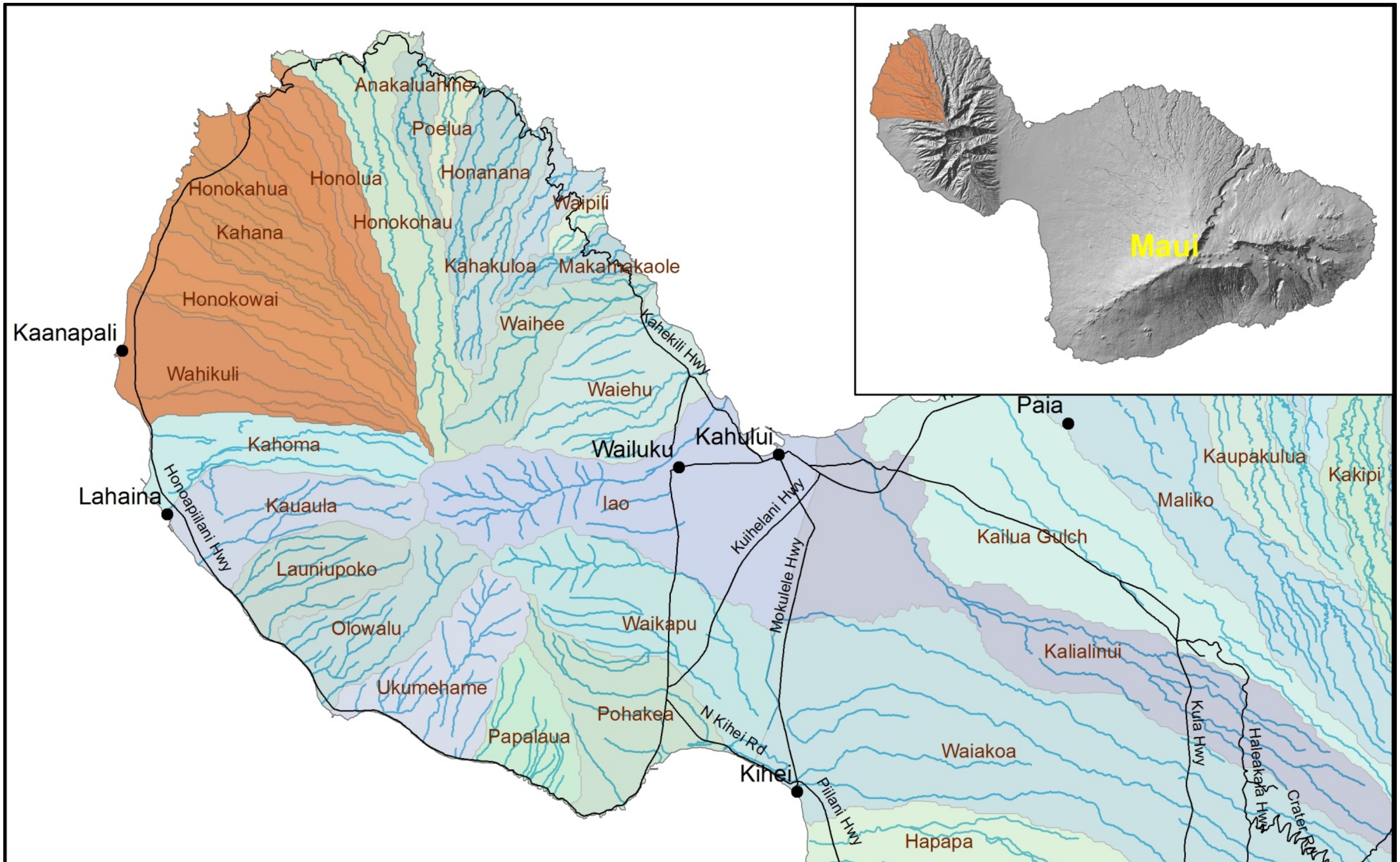

Figure 2.
West Maui Ridge to Reef Initiative

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

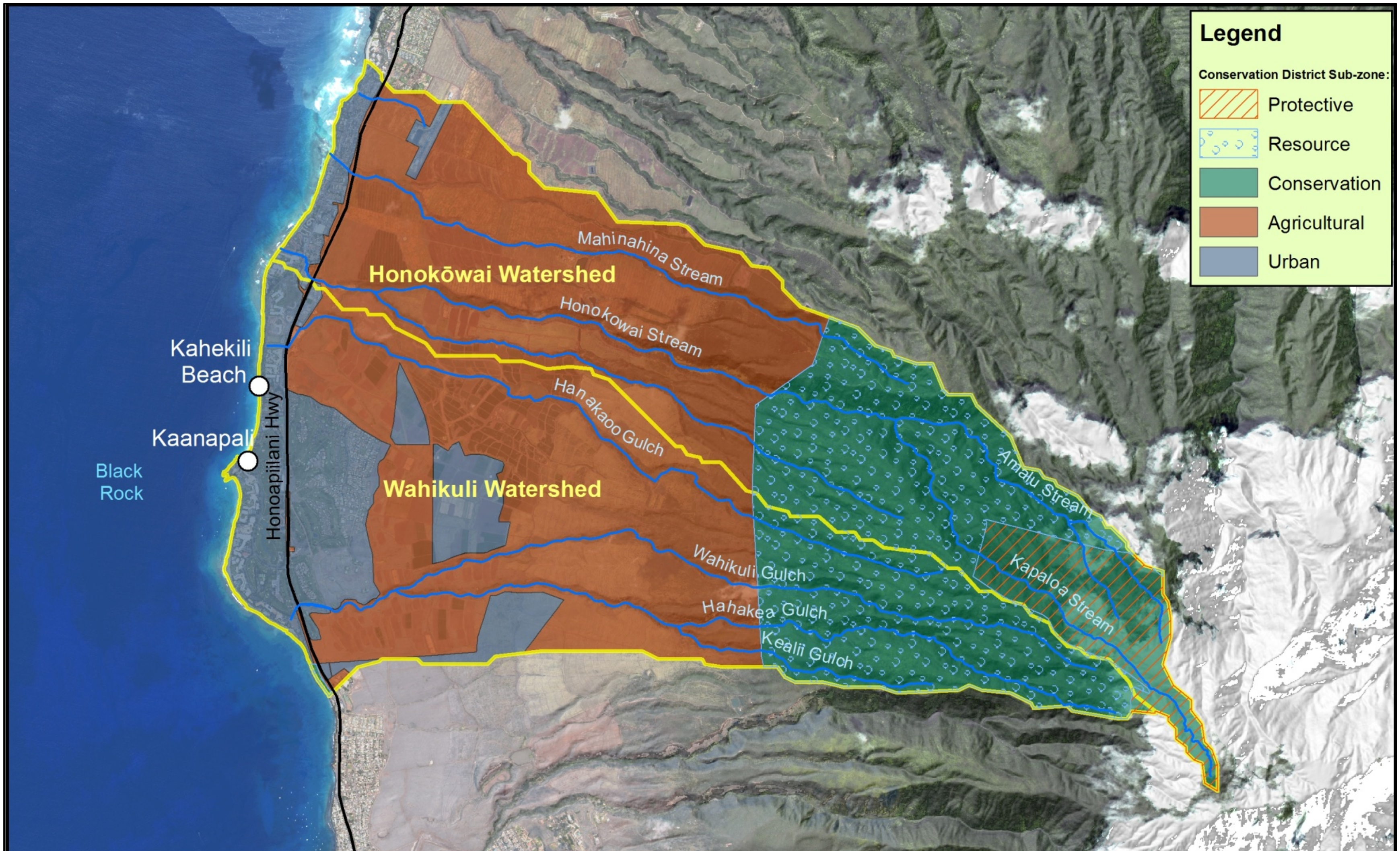

Figure 3.
State Land Use Districts

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

1

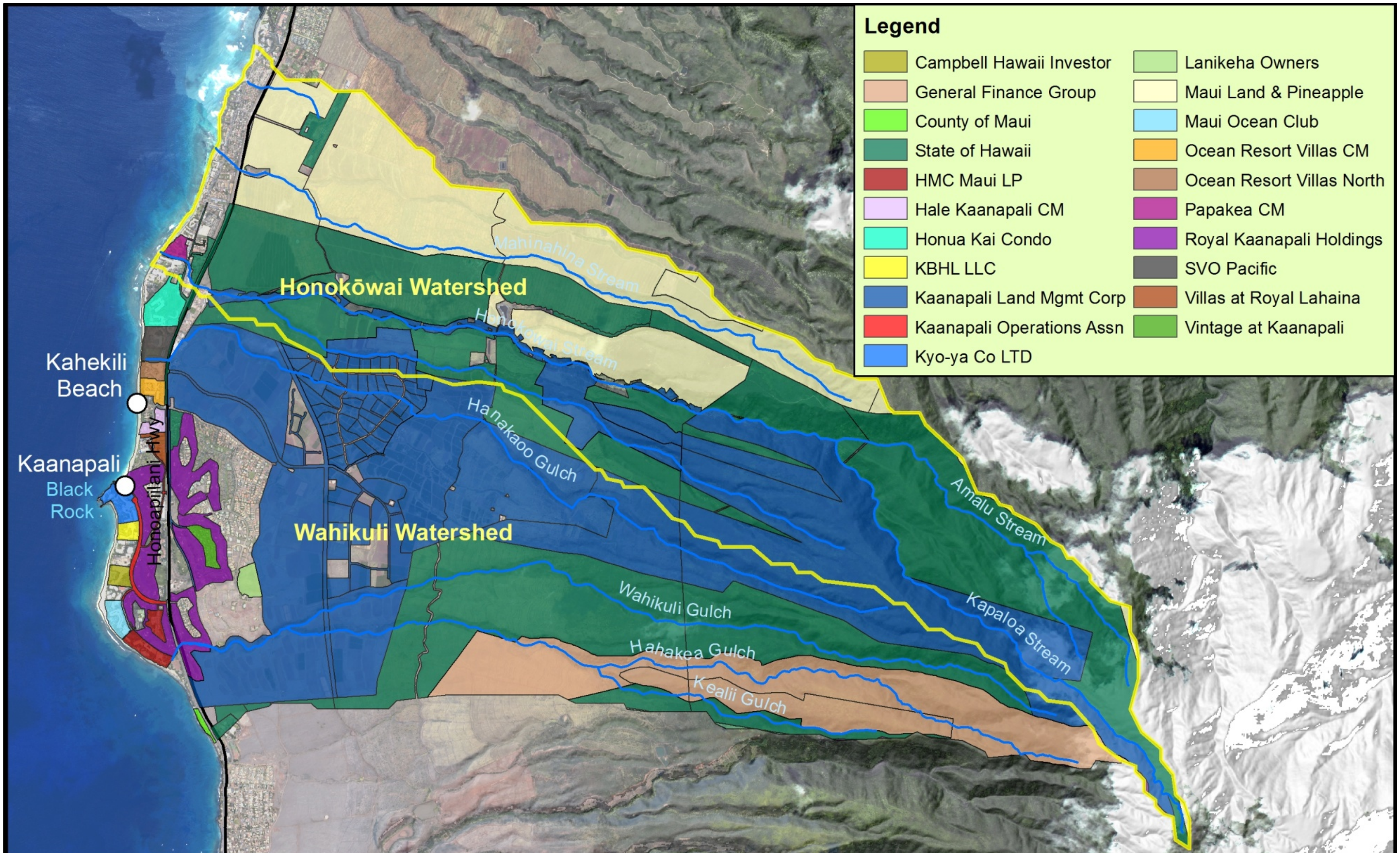

Figure 4.
Major Land Owners in Honokowai and Wahikuli Watersheds

Source: State of Hawaii Data Repository, Maui County
Aerial image acquired in 2011 (NOAA)

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Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

1

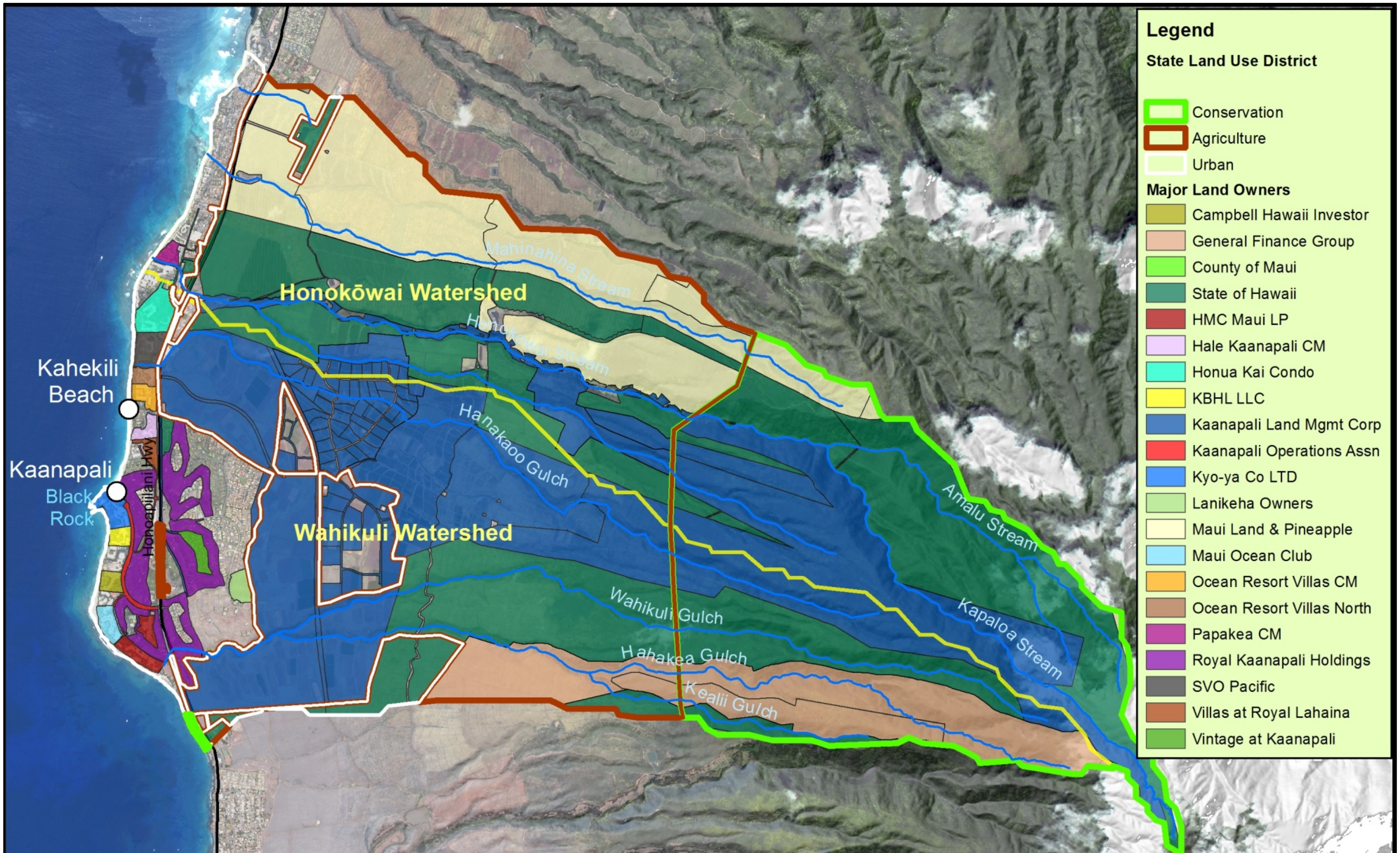

Figure 5.
Major Land Owners and SLUD in the Honokowai and Wahikuli Watersheds

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

1

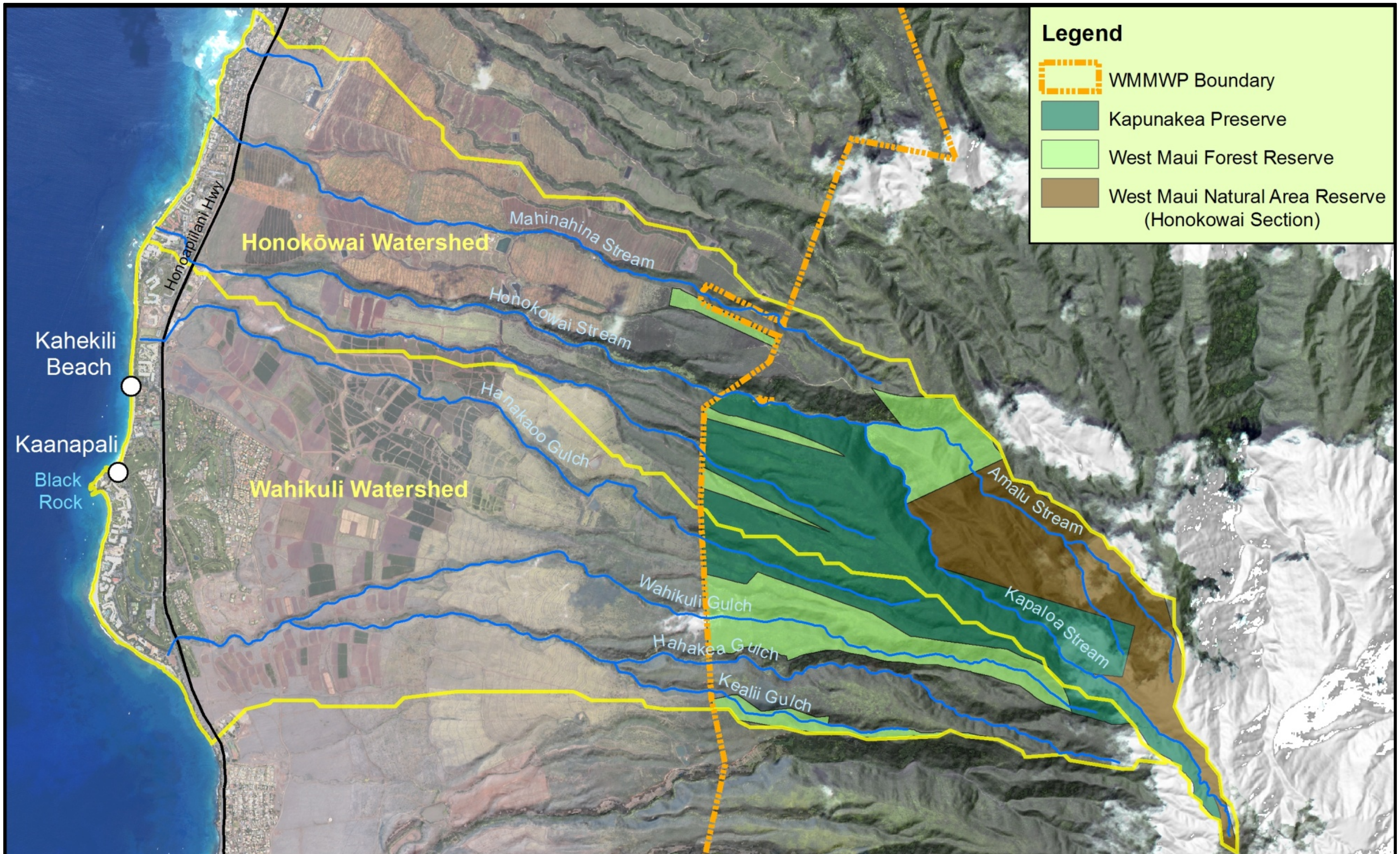

Figure 6.
Forest Reserve Lands

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, WMMWP (boundary)
Aerial image acquired in 2011 (NOAA)

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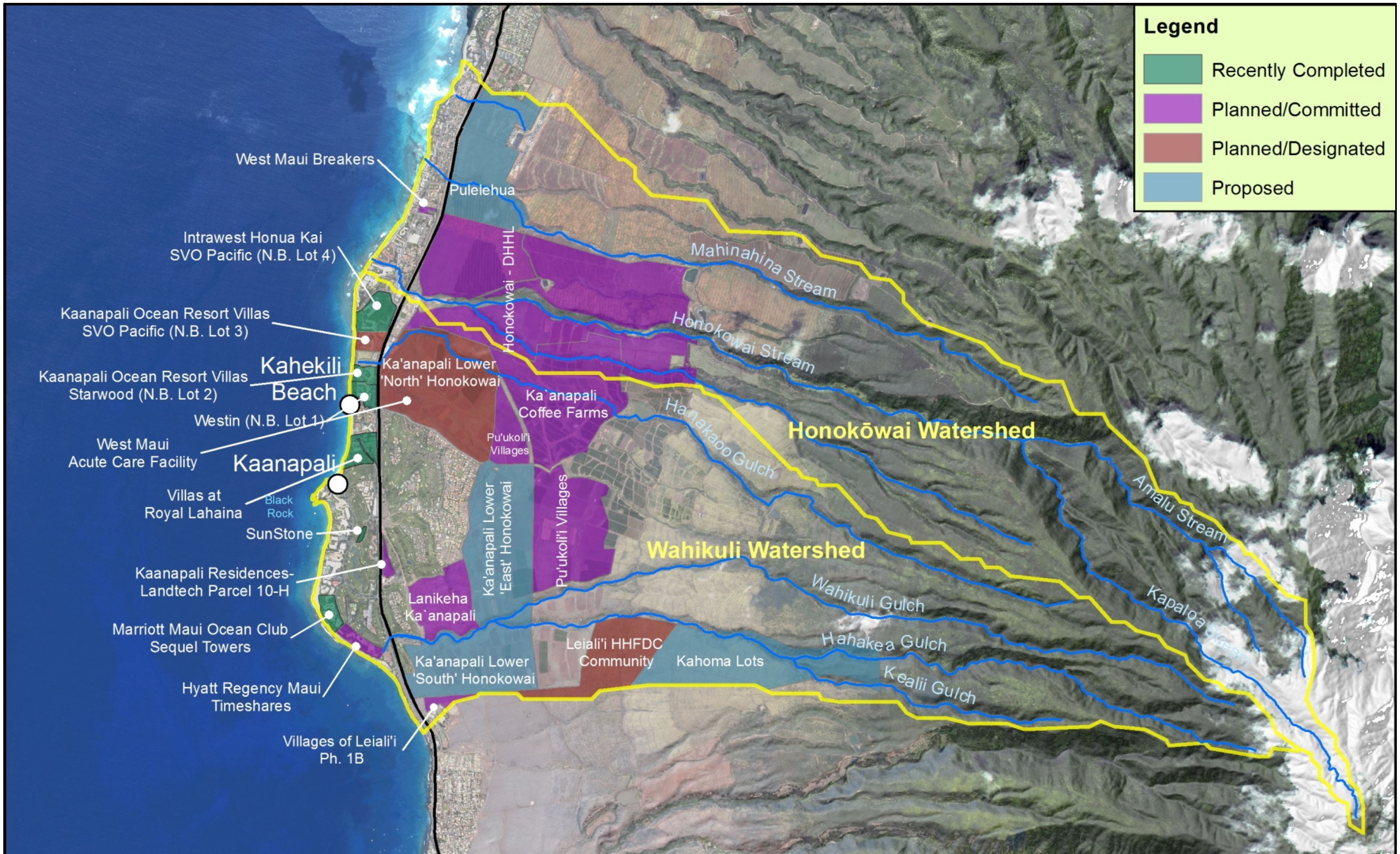

Figure 7.
County of Maui Long Range Planning

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, Maui County
Aerial image acquired in 2011 (NOAA)

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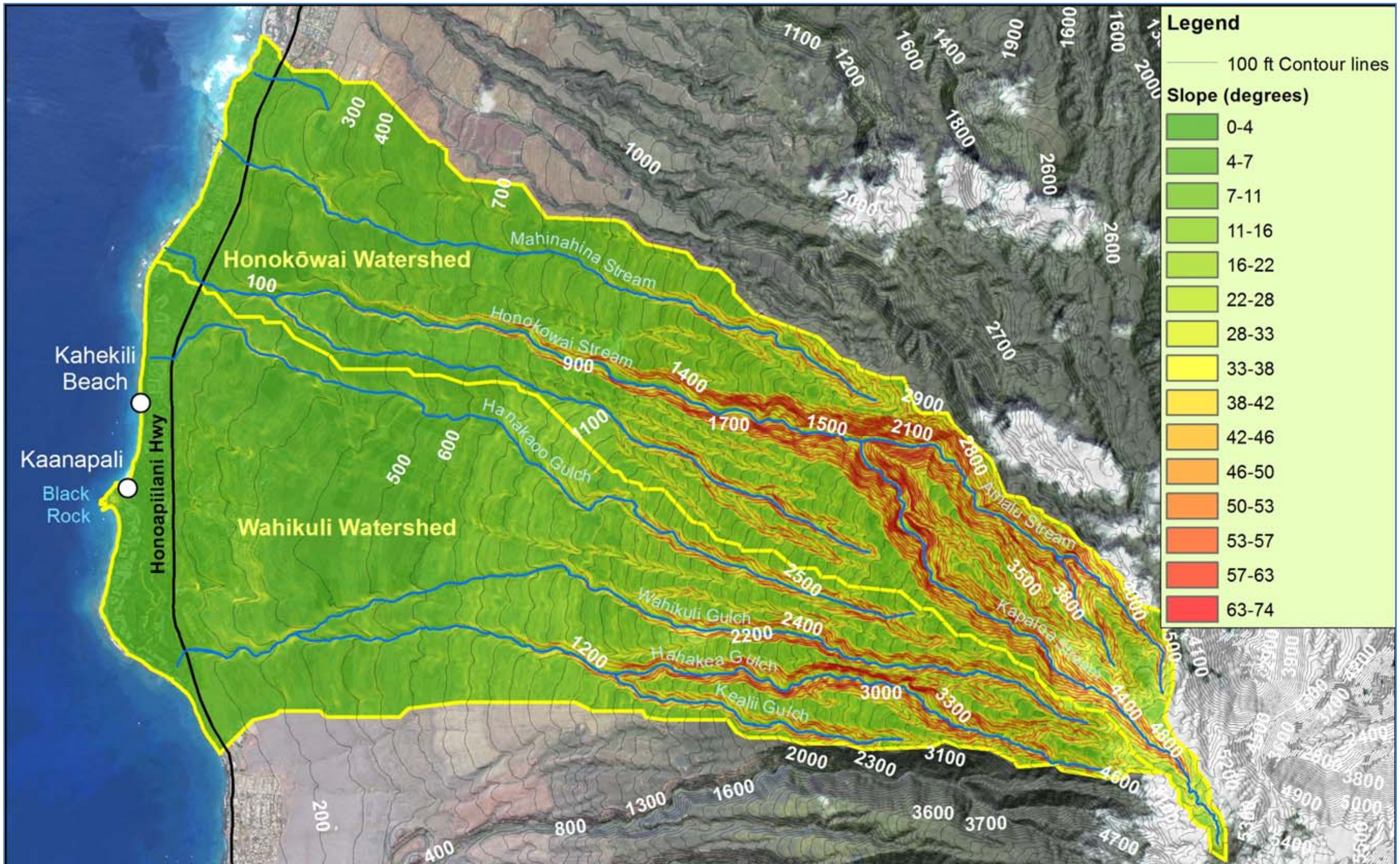

Figure 8.
Topography

Source: State of Hawaii Data Repository, SOEST
Aerial image acquired in 2011 (NOAA)

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

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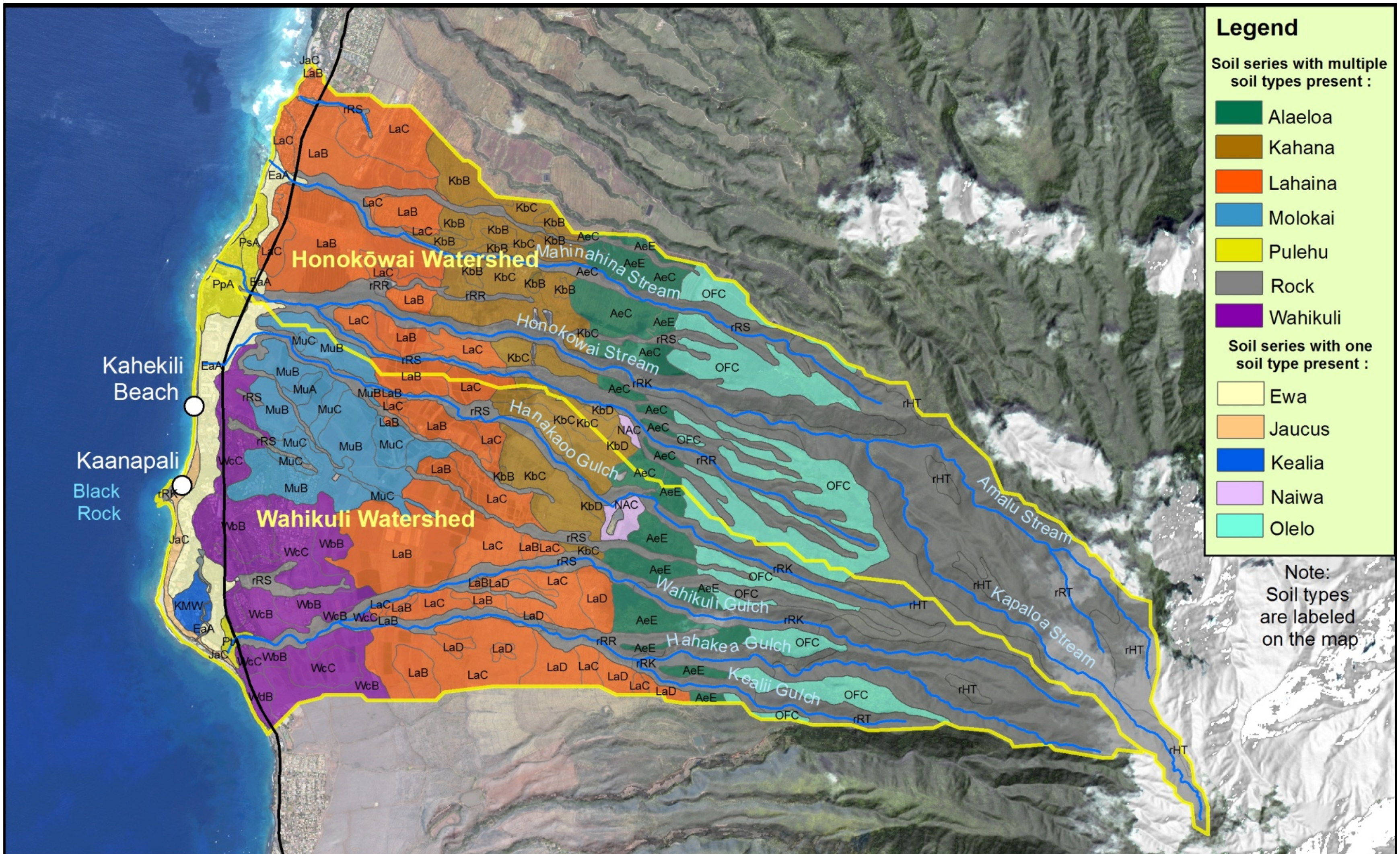

Figure 9.
Soil Types

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, NRCS
Aerial image acquired in 2011 (NOAA)

N

0 0.5 1 2 Miles

Legend

Soil Types by Series - Percentages Listed are % Slope

Soil series with multiple soil types present :

Alaeloa Series

AeC (Alaeloa silty clay) 7-15 %
AeE (Alaeloa silty clay) 15-35 %

Kahana Series

KbB (Kahana silty clay) 3-7 %
KbC (Kahana silty clay) 7-15 %
KbD (Kahana silty clay) 15-25 %

Lahaina Series

LaB (Lahaina silty clay) 3-7 %
LaC (Lahaina silty clay) 7-15 %
LaD (Lahaina silty clay) 15-25 %

Molokai Series

MuA (Molokai silty clay loam) 0-3 %
MuB (Molokai silty clay loam) 3-7 %
MuC (Molokai silty clay loam) 7-15 %

Pulehu Series

PpA (Pulehu silt loam) 0-3 %
PsA (Pulehu clay loam) 0-3 %
PtA (Pulehu cobbly clay loam) 0-3 %

Rock Series

rHT: Hydrandepts- Tropaquods association
rRK: Rock land
rRR: Rough broken land
rRS: Rough broken and stony land
rRT: Rough montainous land

Wahikuli Series

WbB (Wahikuli silty clay) 3-7 %
WcB (Wahikuli stony silty clay) 3-7 %
WcC (Wahikuli stony silty clay) 7-15 %
WdB (Wahikuli very stony silty clay) 3-7 %

Soil series with one soil type present :

Ewa Series

EaA (Ewa silty clay loam) 0-3 %

Jaucus Series

JaC (Jaucus sand) 0-15 %

Kealia Series

KMW (Kealia silt loam)

Naiwa Series

NAC (Naiwa silty clay loam) 3-20 %

Olelo Series

OFC (Olelo silty clay) 3-15 %

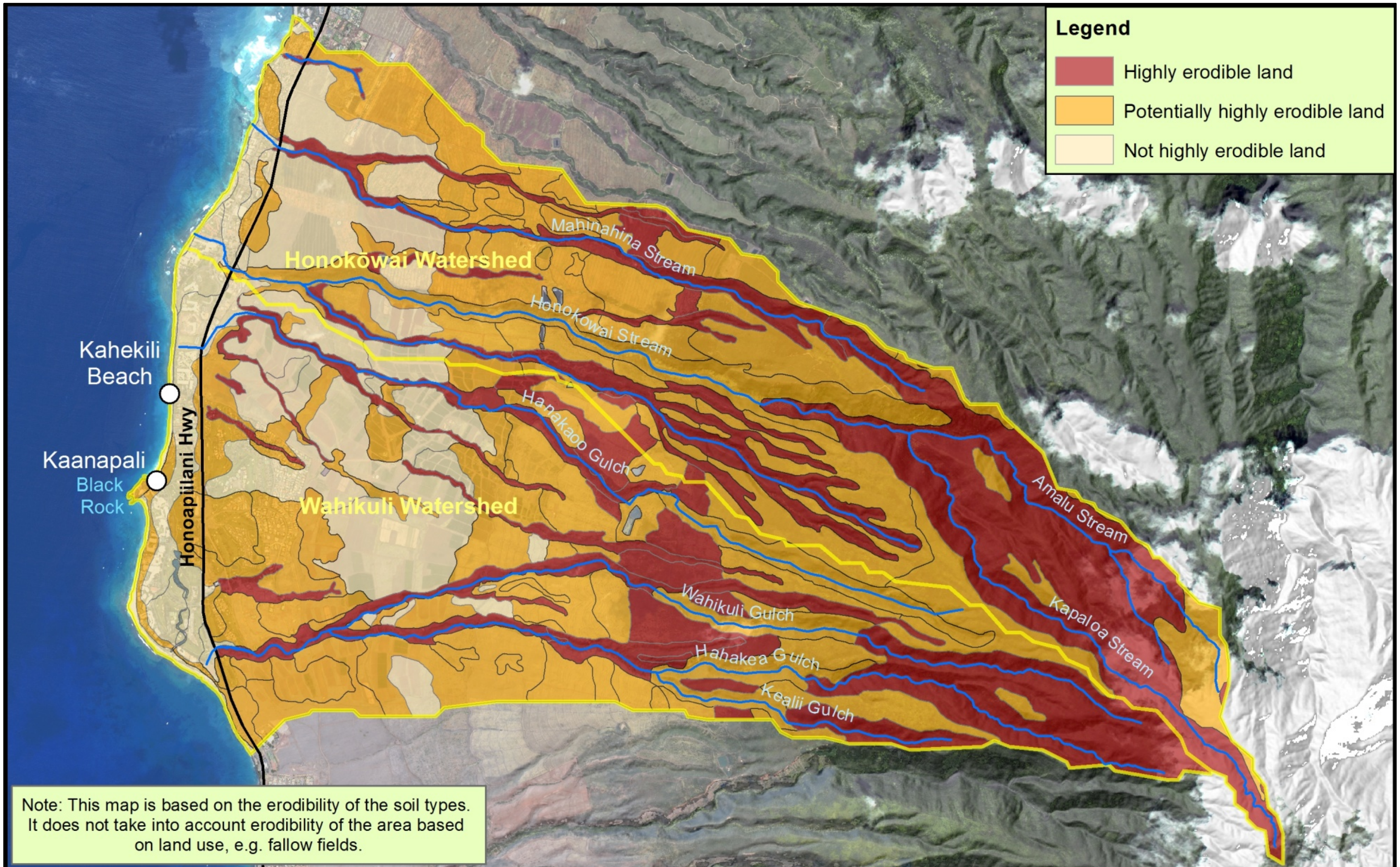

Figure 10.
Soil Erodibility

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, NRCS
Aerial image acquired in 2011 (NOAA)

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0 0.5 1 2 Miles

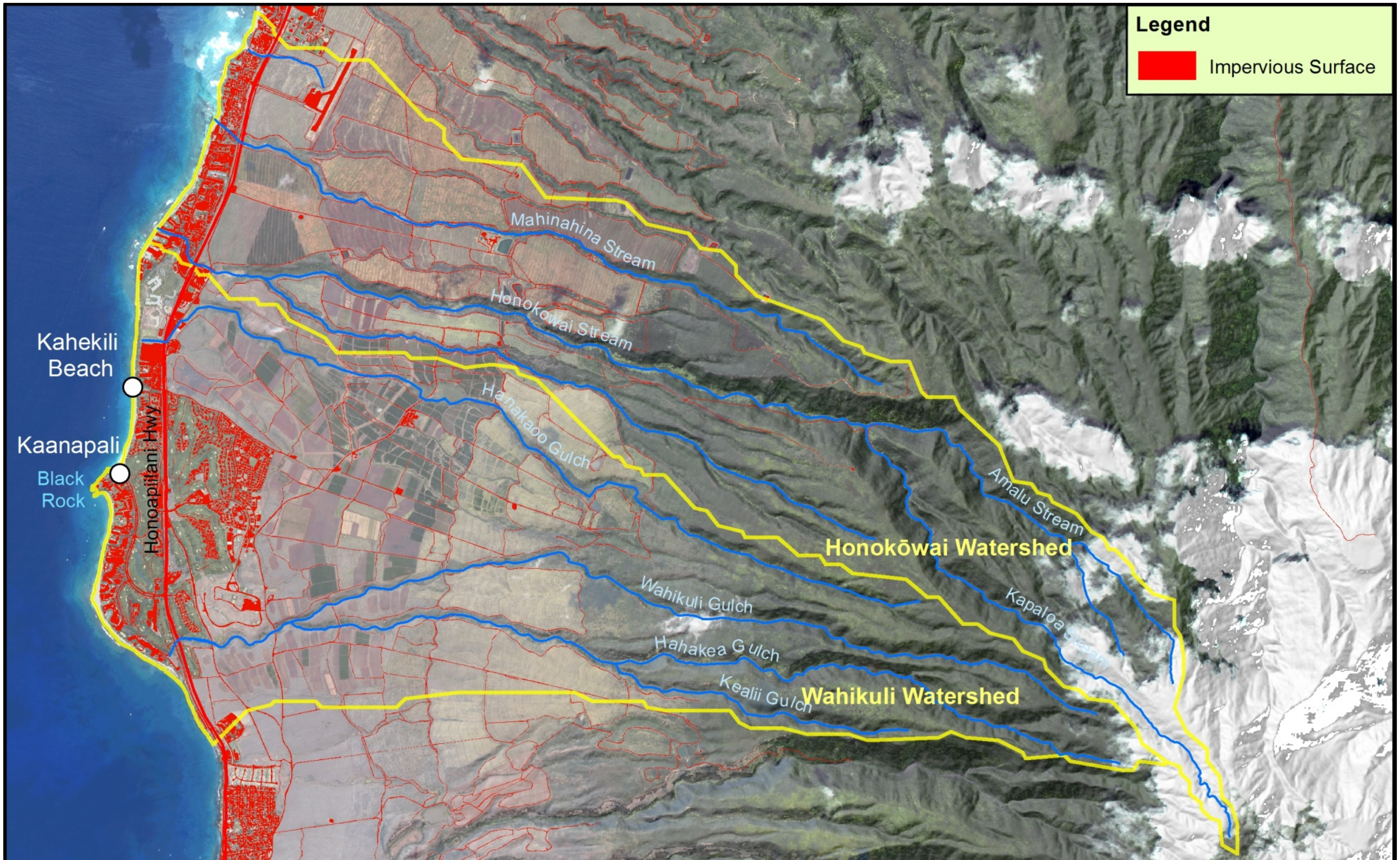

Figure 11.
Impervious Surfaces

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, NOAA
Aerial image acquired in 2011 (NOAA)

N

0 0.5 1 2 Miles

1

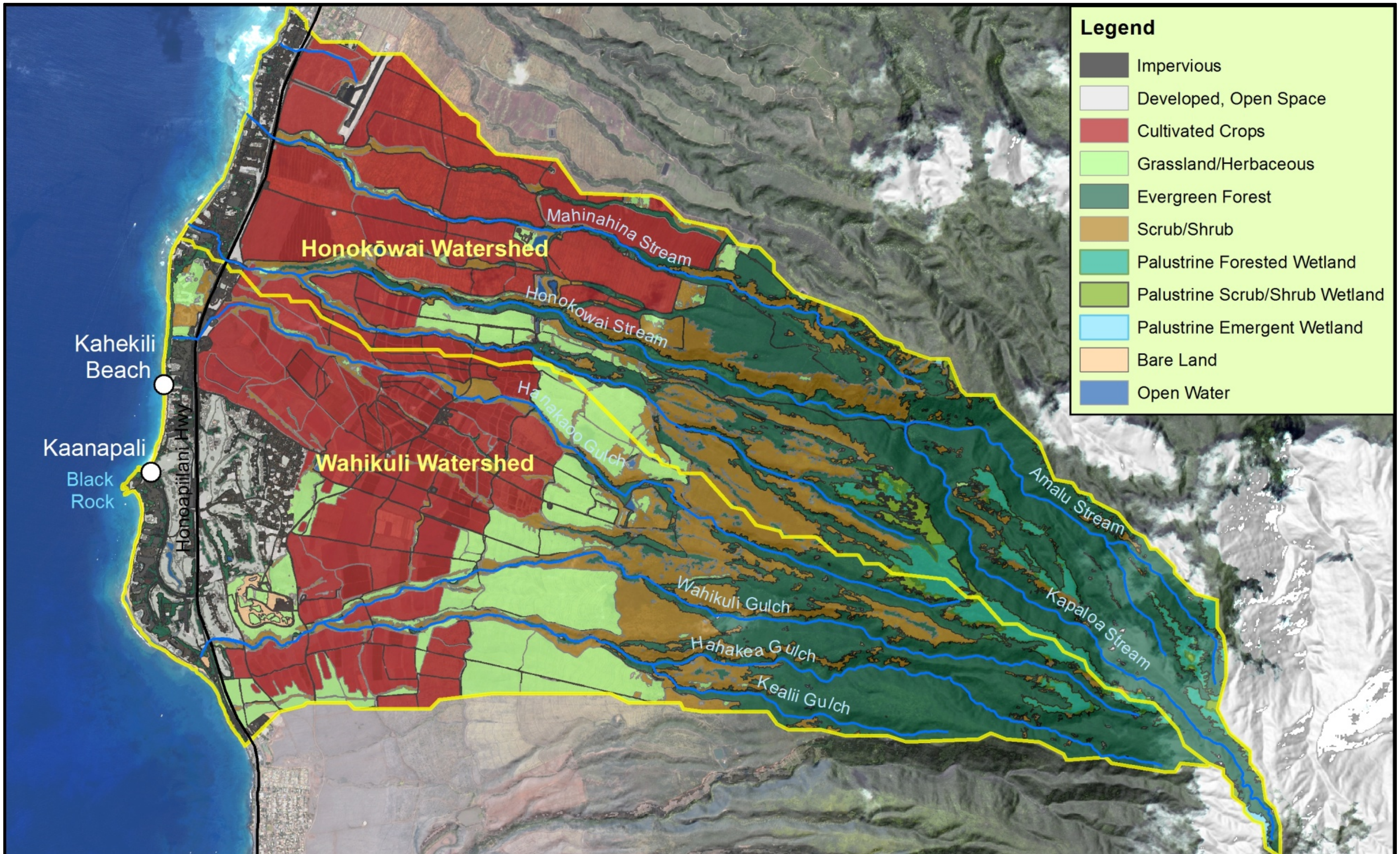

Figure 12.
Land Cover (C-CAP)

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, NOAA (C-CAP, 2005)
Aerial image acquired in 2011 (NOAA)

N

0 0.5 1 2 Miles

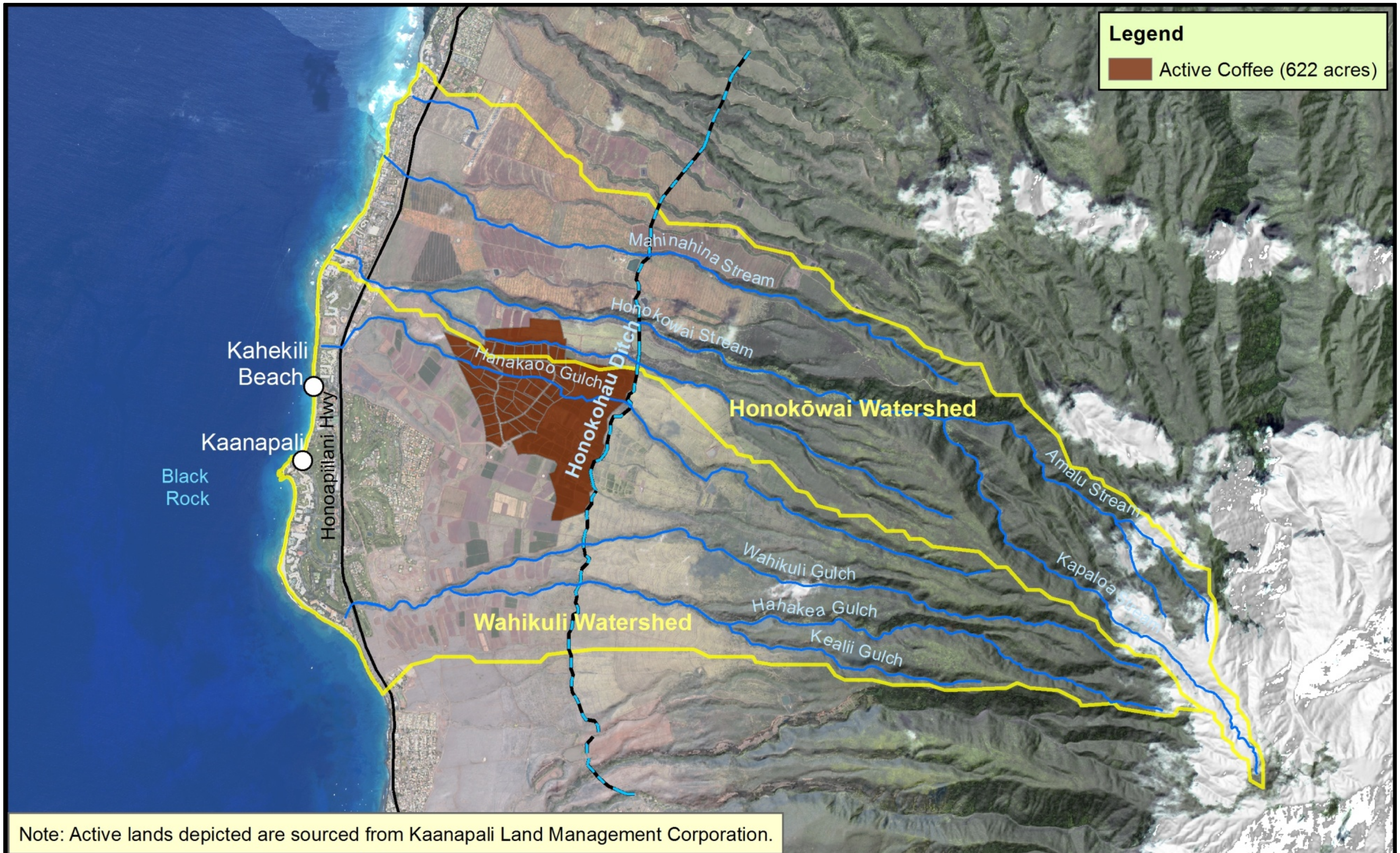

Figure 13.
Current Agricultural Lands

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

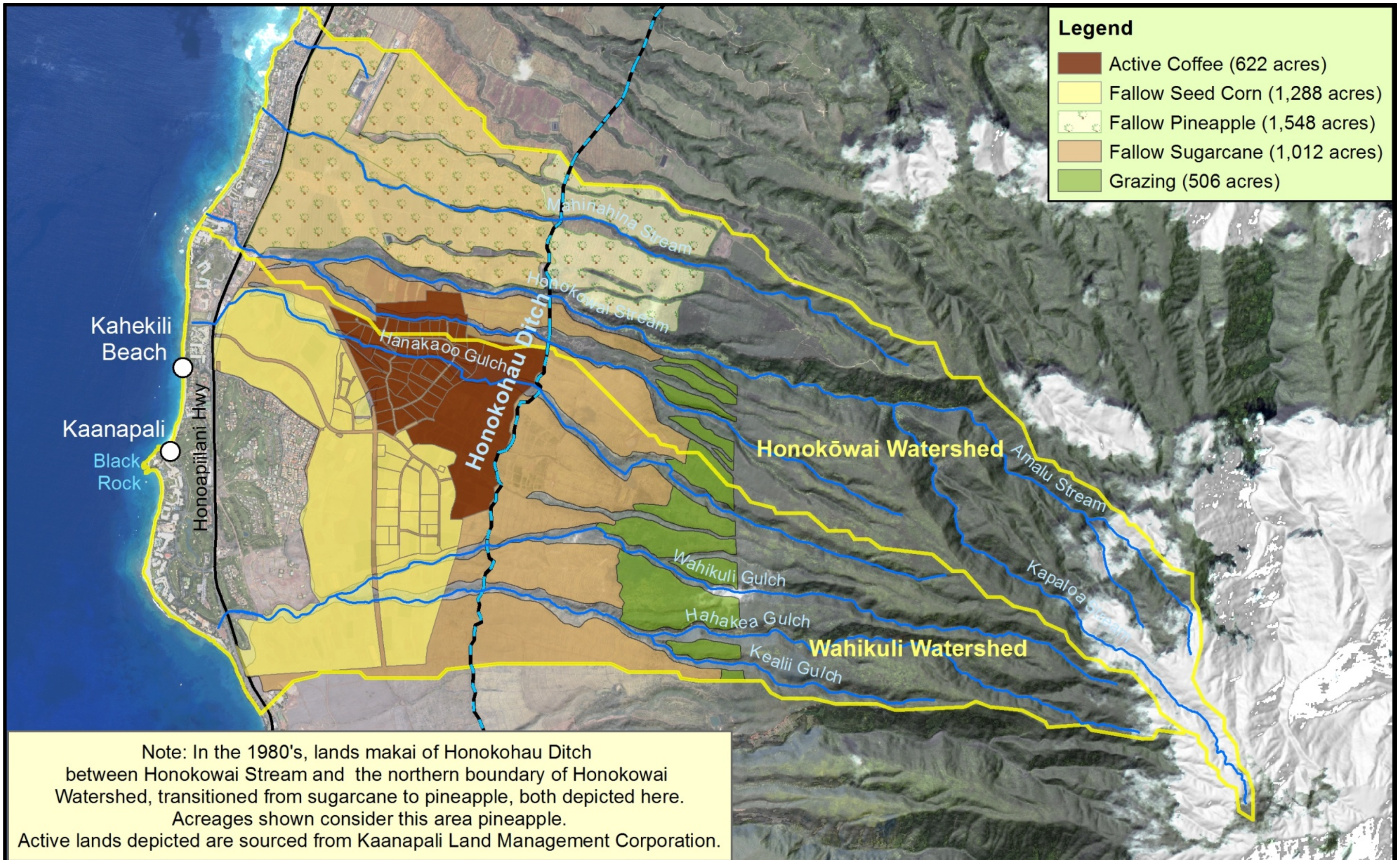

Figure 14.
Agricultural Fields: Active and Fallow

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

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0 0.5 1 2 Miles

1

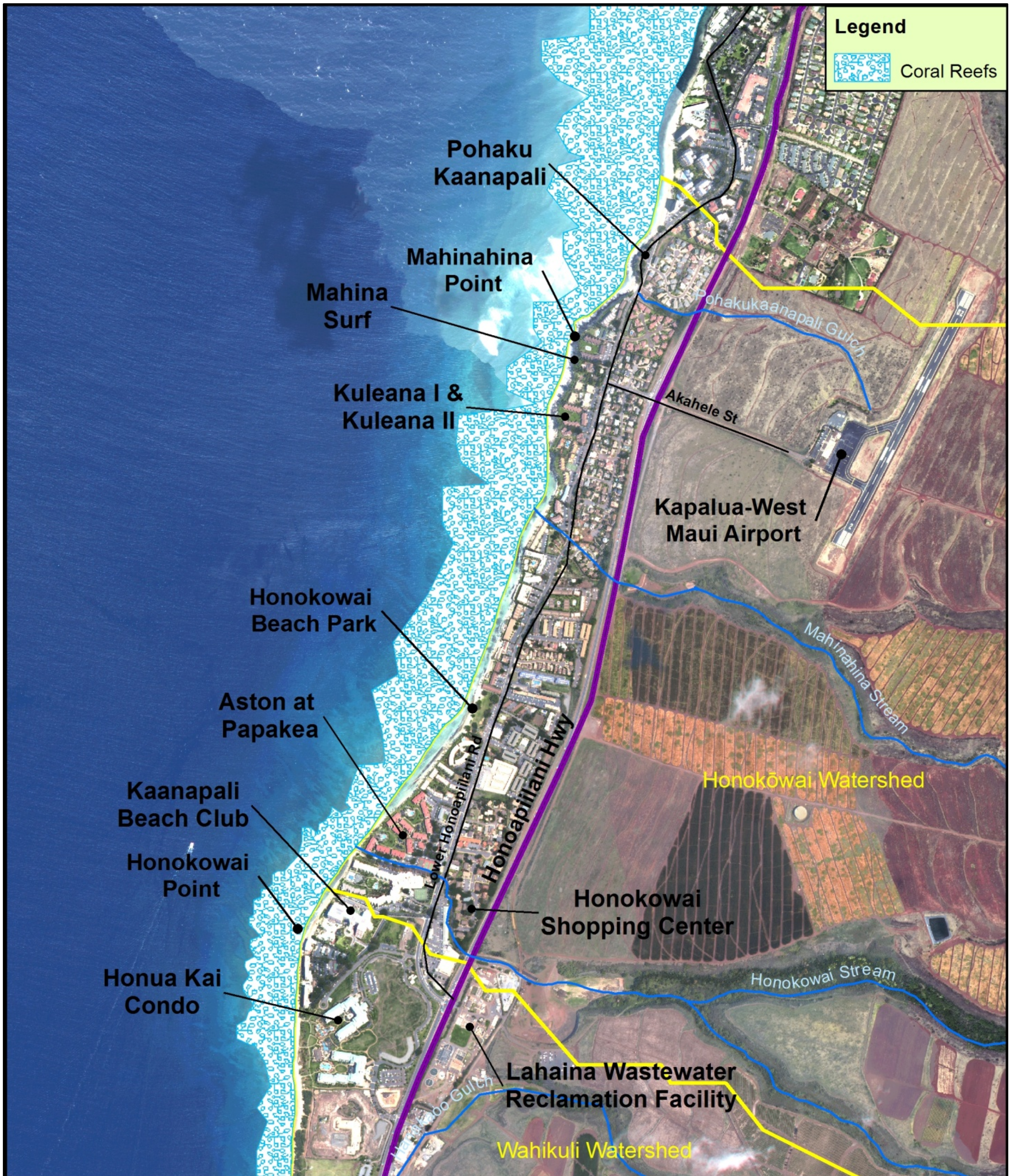


Figure 15.
Coastal Place Names, Honokowai Watershed

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

N

0 0.125 0.25 0.5 Miles

Figure 16.
Coastal Place Names, Wahikuli Watershed

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

N

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

0 0.25 0.5 1 Mile

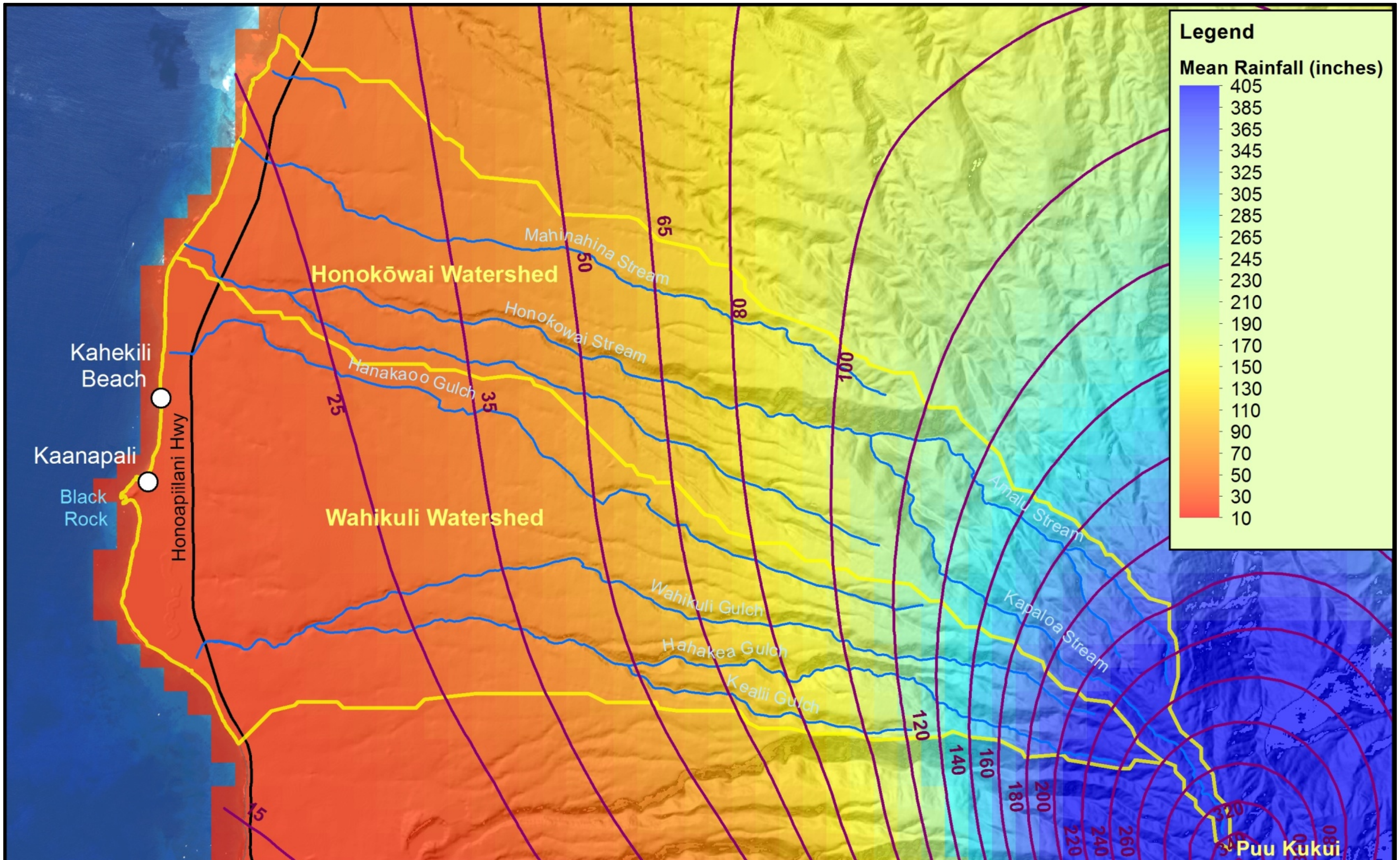


Figure 17.
Mean Annual Rainfall

Source: State of Hawaii Data Repository, Hawaii Rainfall Atlas

N

0 0.5 1 2 Miles

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

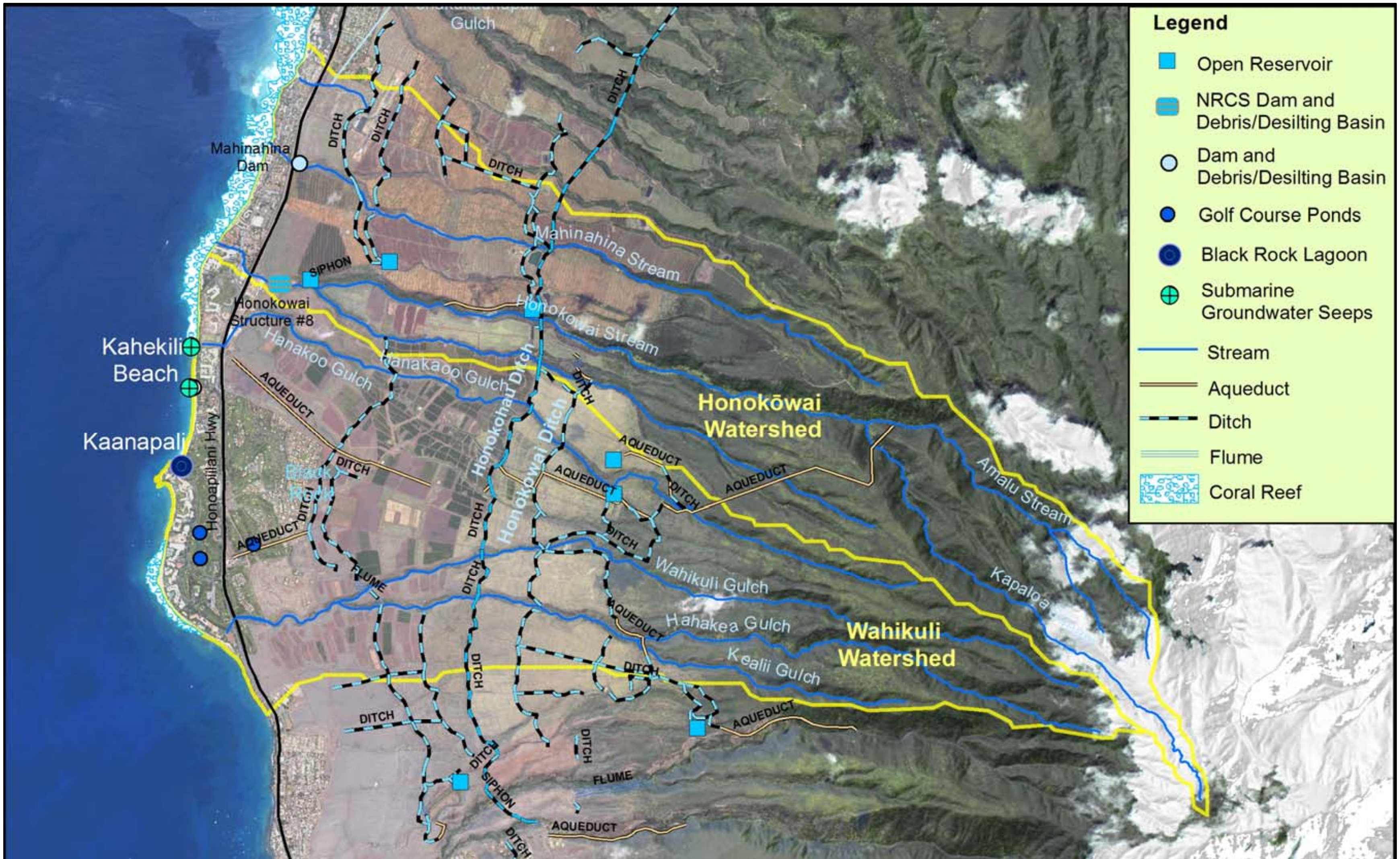


Figure 18.
Hydrographic Features

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

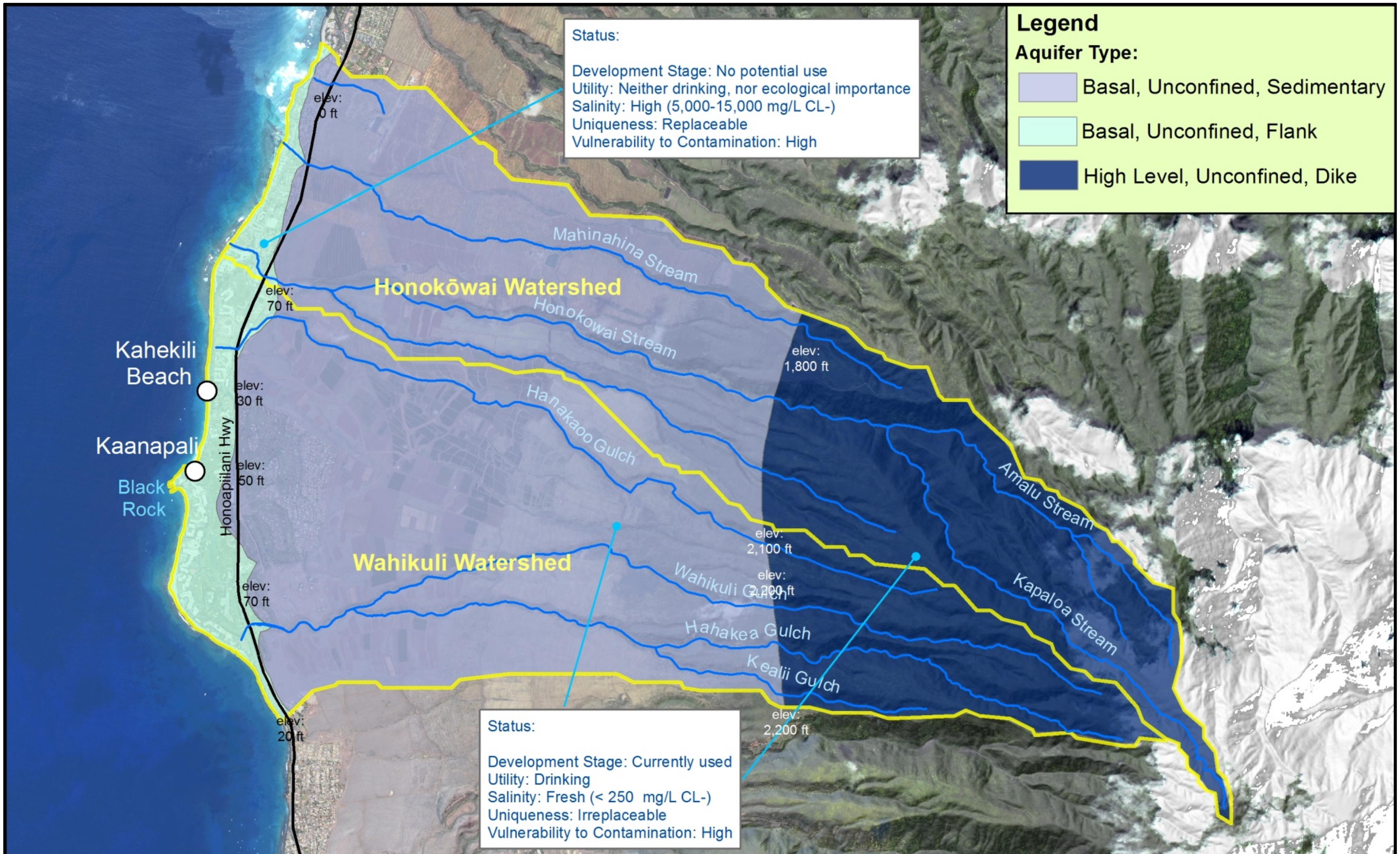


Figure 19.
Aquifers

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

N

0 0.5 1 2 Miles

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

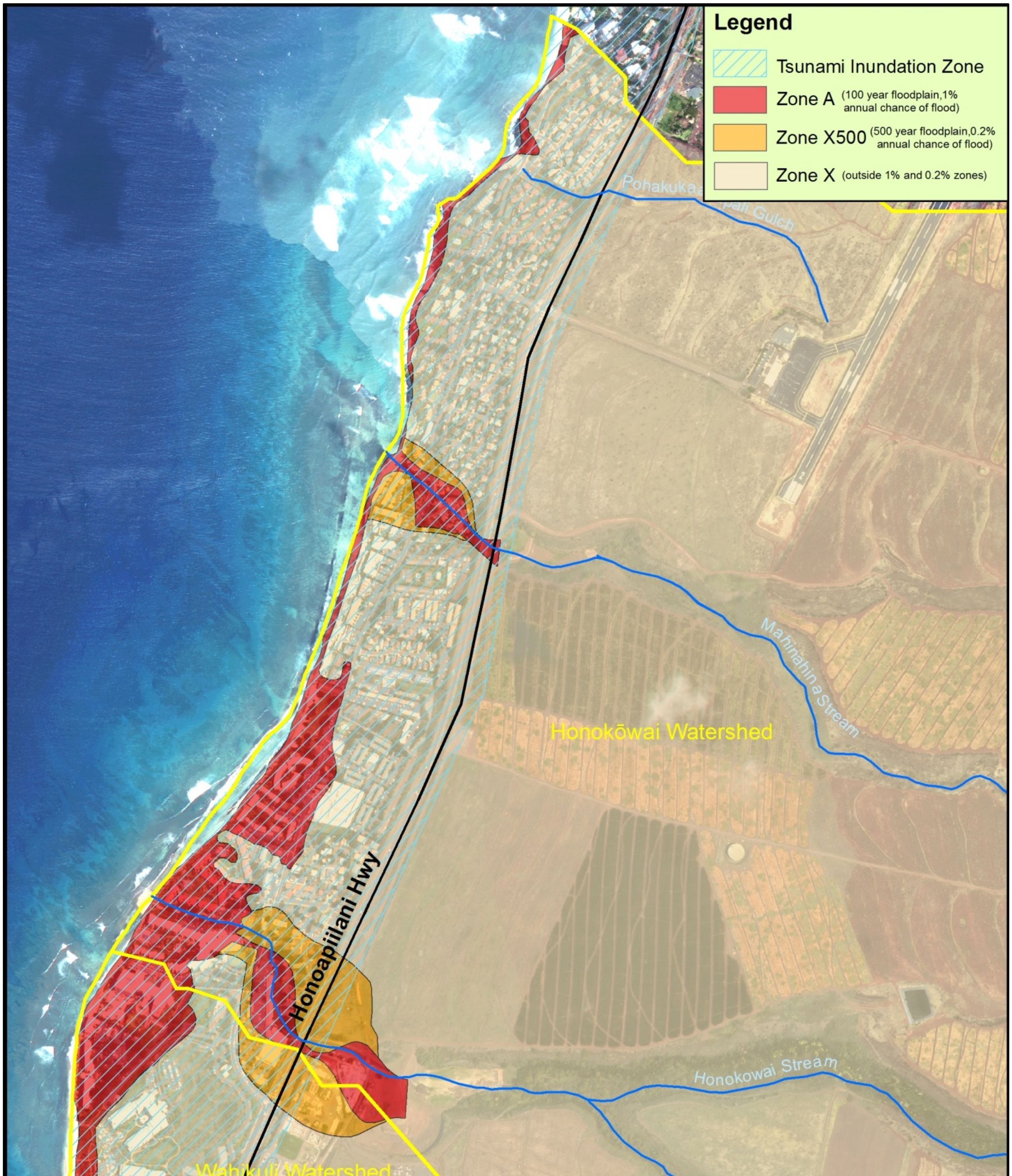


Figure 20.
Flood Insurance Rate Map, Honokōwai Watershed

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

N

0 0.125 0.25 0.5 Miles

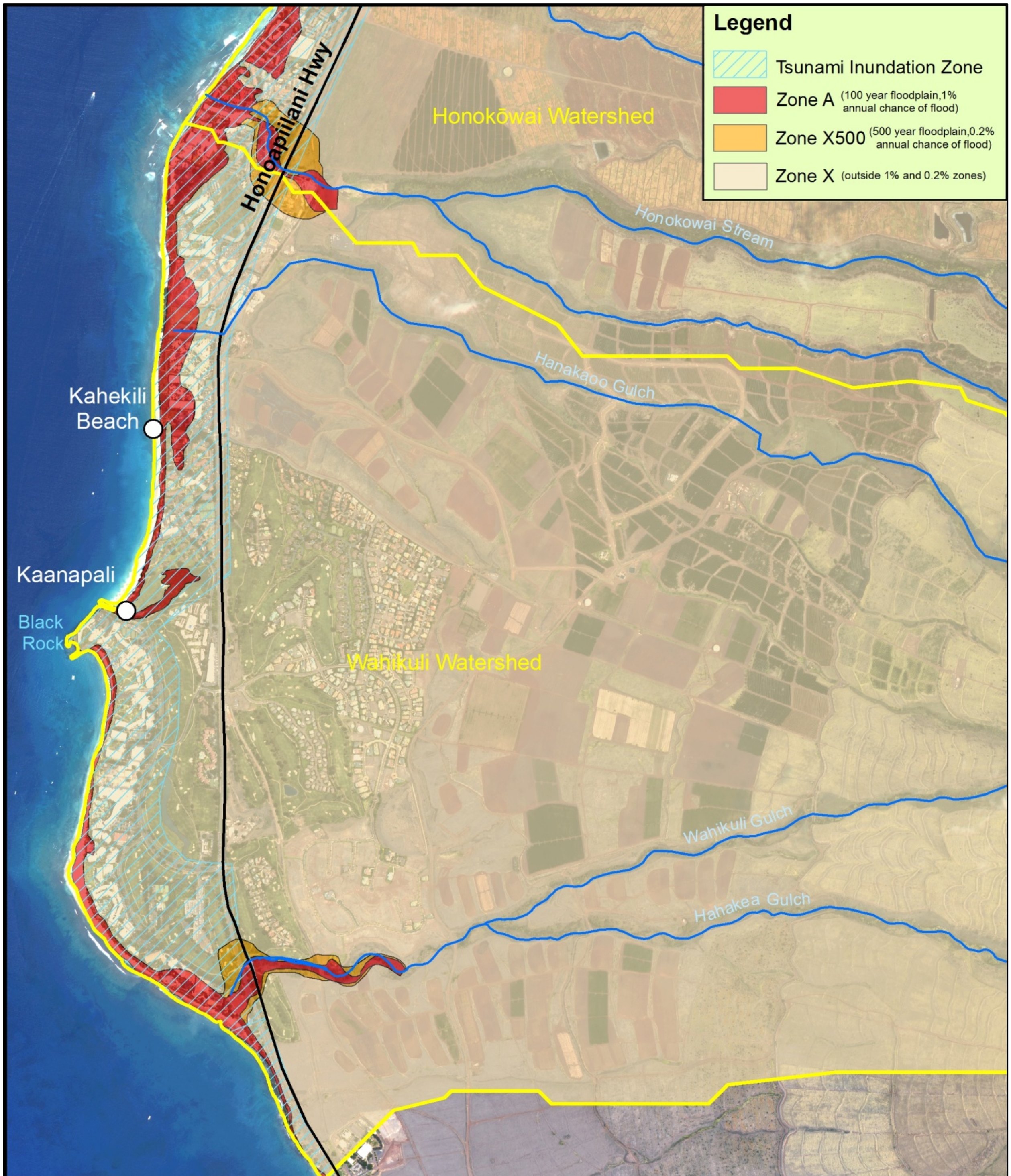


Figure 21.
Flood Insurance Rate Map, Wahikuli Watershed

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

N

0 0.25 0.5 1 Mile

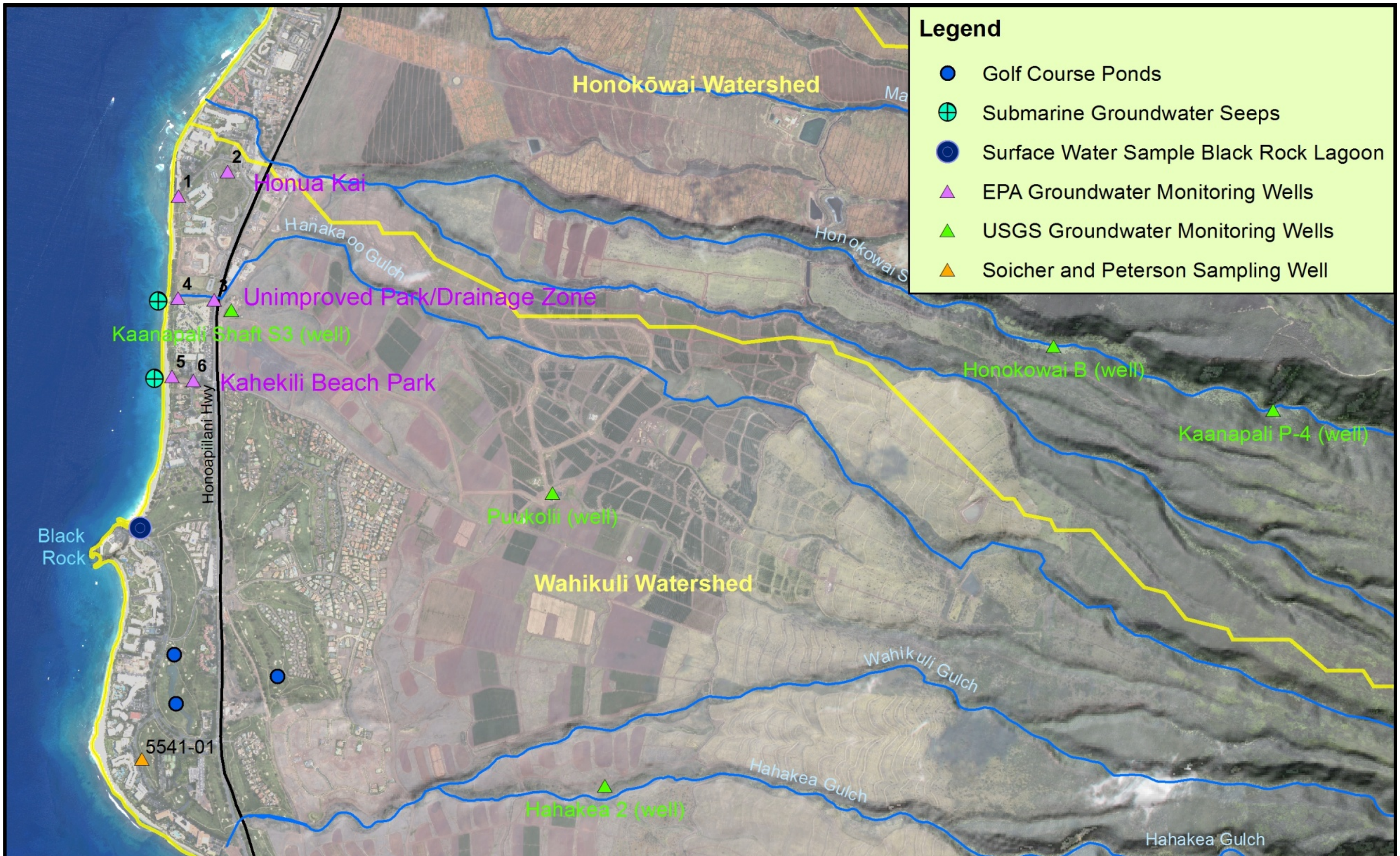


Figure 22.
Surface and Groundwater Monitoring Locations

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, USGS, Environmental Assessments, LLC (2011), Dailer et al.(2010)
Aerial image acquired in 2011 (NOAA)

N

0 0.375 0.75 1.5 Miles

1

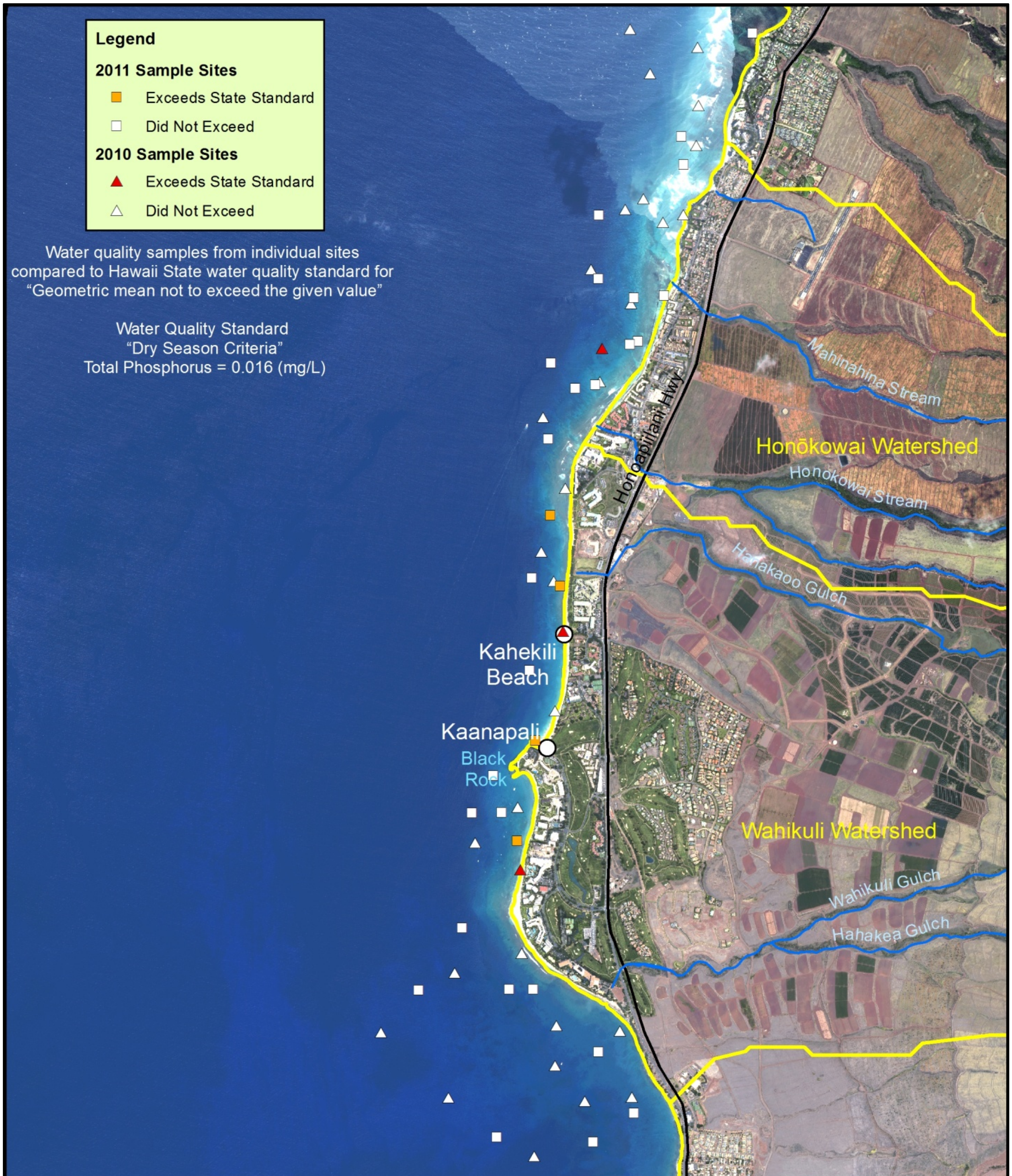


Figure 23.
2010 & 2011 Water Quality Sampling: Total Phosphorus

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Department of Health
Aerial image acquired in 2011 (NOAA)

N

0 0.4 0.8 1.6 Miles

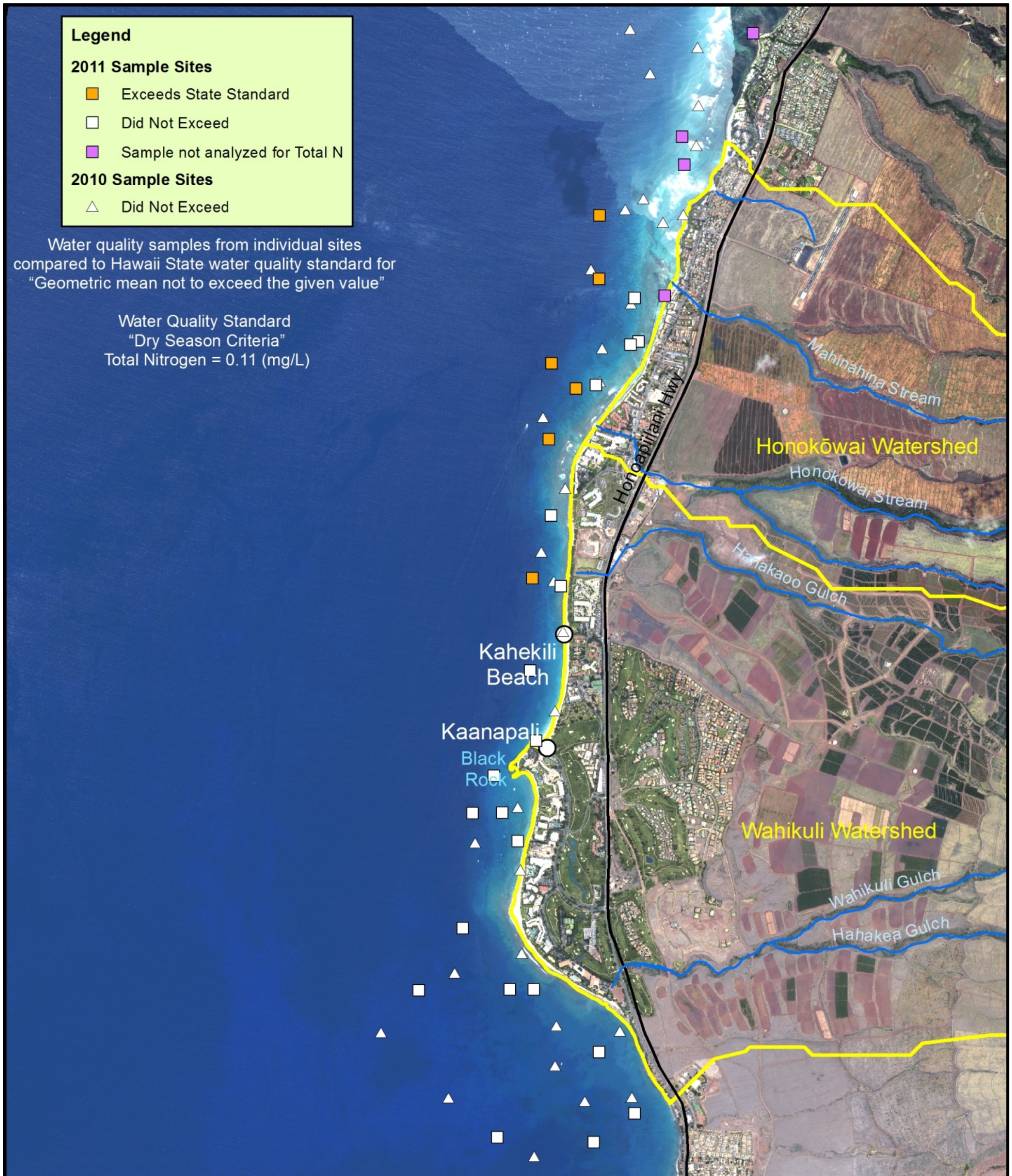


Figure 24.
2010 & 2011 Water Quality Sampling: Total Nitrogen

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Department of Health
Aerial image acquired in 2011 (NOAA)

N

0 0.375 0.75 1.5 Miles

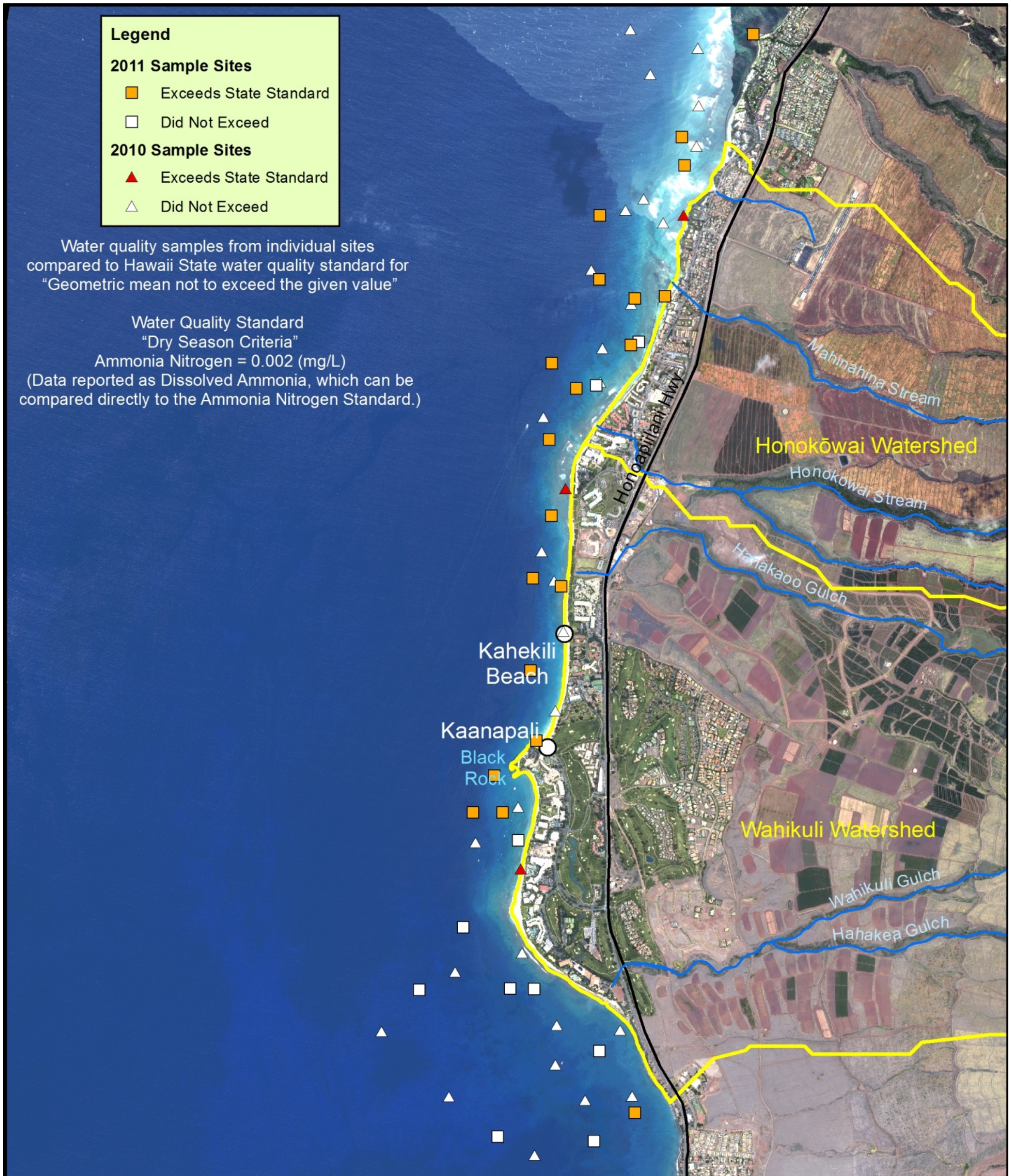


Figure 25.
2010 & 2011 Water Quality Sampling: Dissolved Ammonia

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Department of Health
Aerial image acquired in 2011 (NOAA)

N

0 0.375 0.75 1.5 Miles

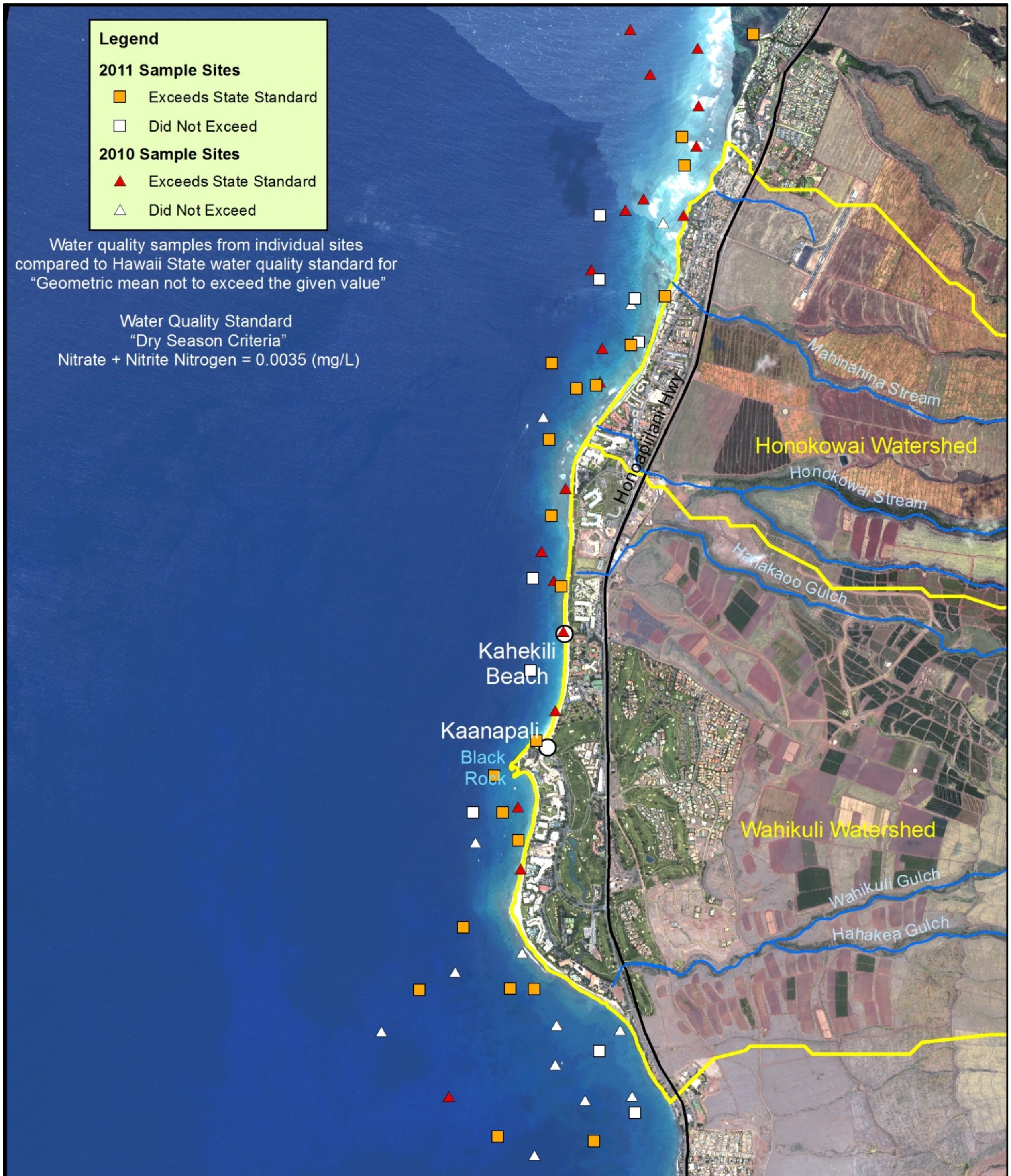


Figure 26.
2010 & 2011 Water Quality Sampling: Nitrate + Nitrite Nitrogen

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Department of Health
Aerial image acquired in 2011 (NOAA)

N

0 0.4 0.8 1.6 Miles

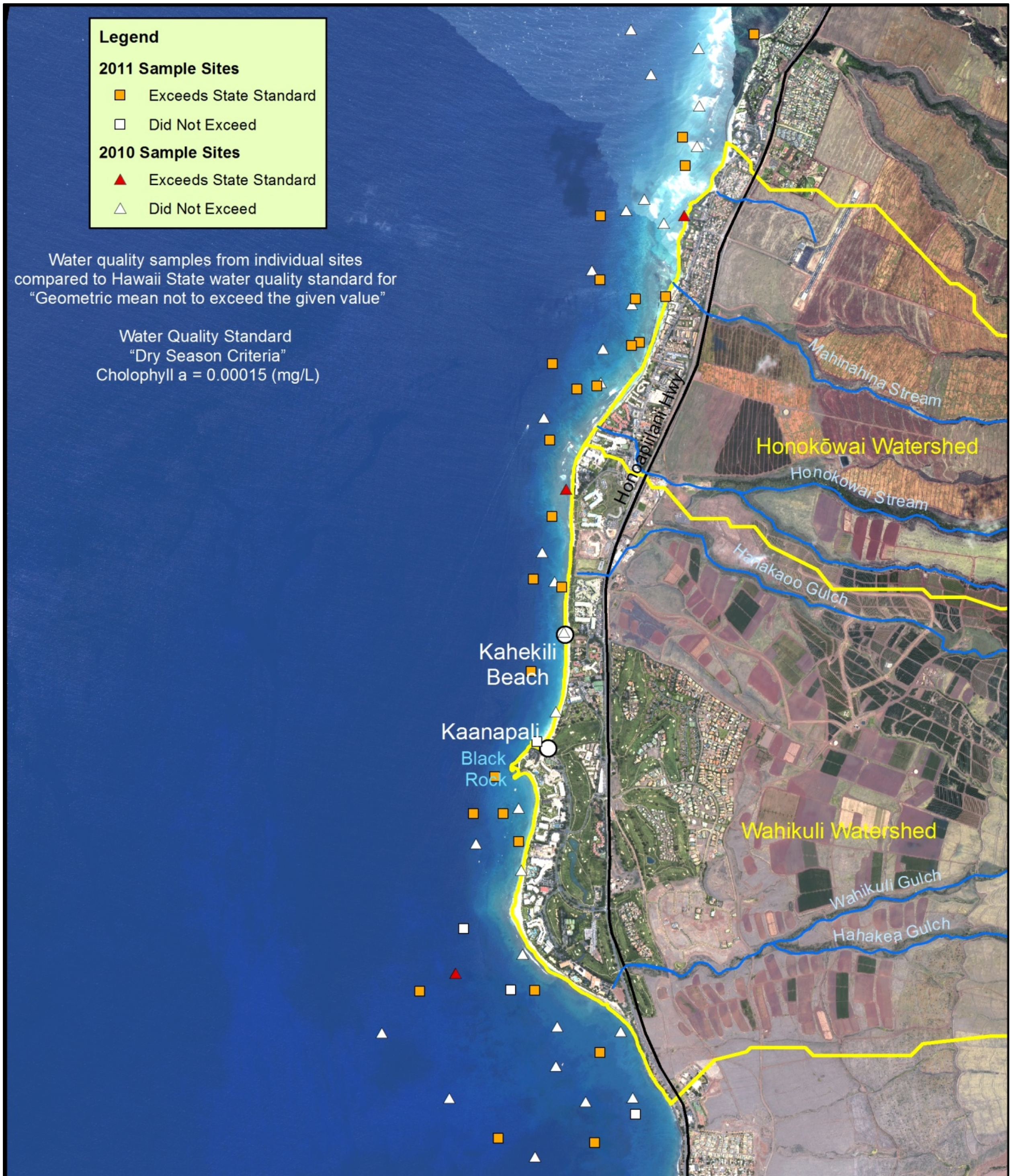


Figure 27.
2010 & 2011 Water Quality Sampling: Chlorophyll a

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Department of Health
Aerial image acquired in 2011 (NOAA)

N

0 0.4 0.8 1.6 Miles

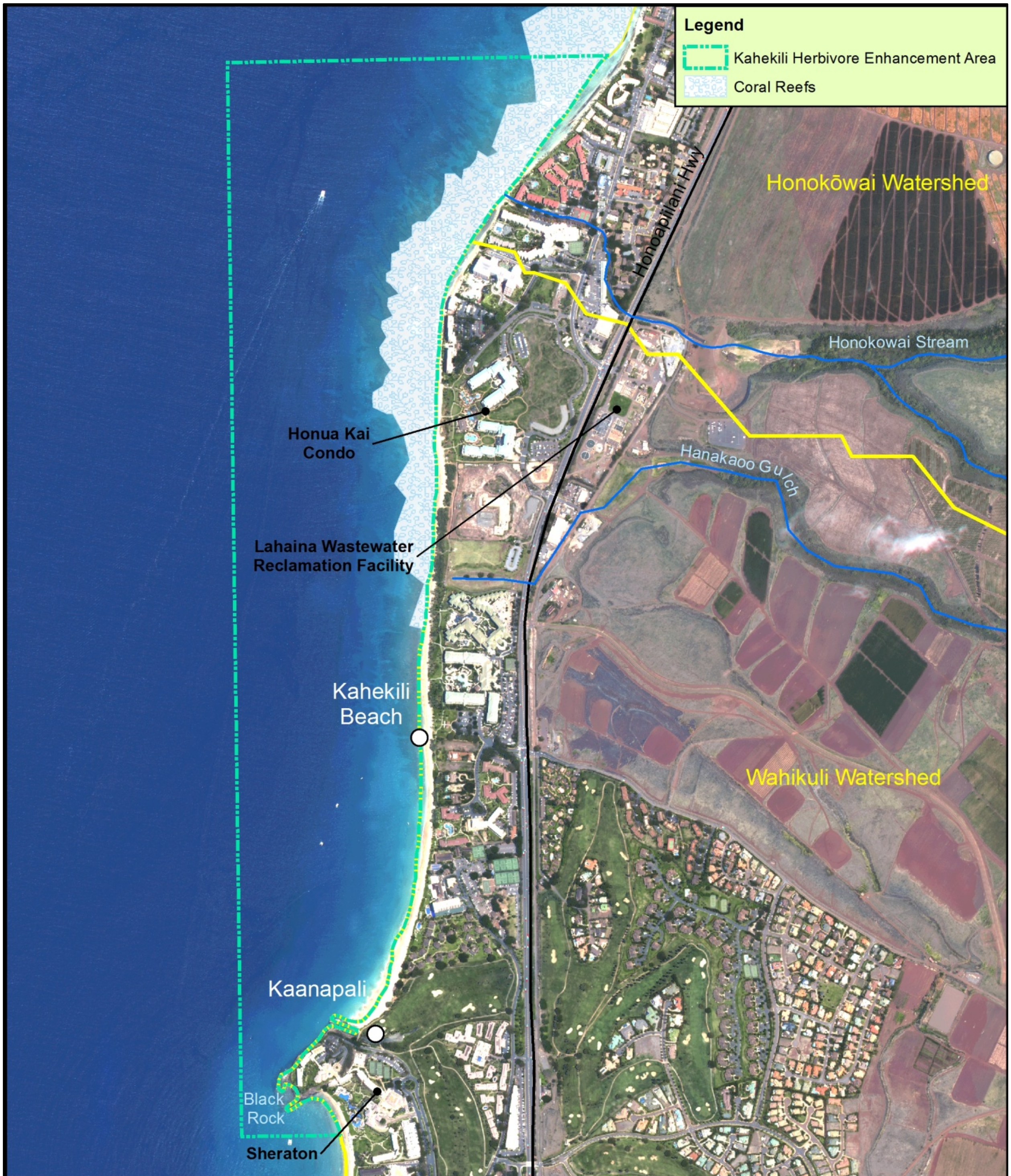


Figure 28.
Kahekili Herbivore Enhancement Area

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

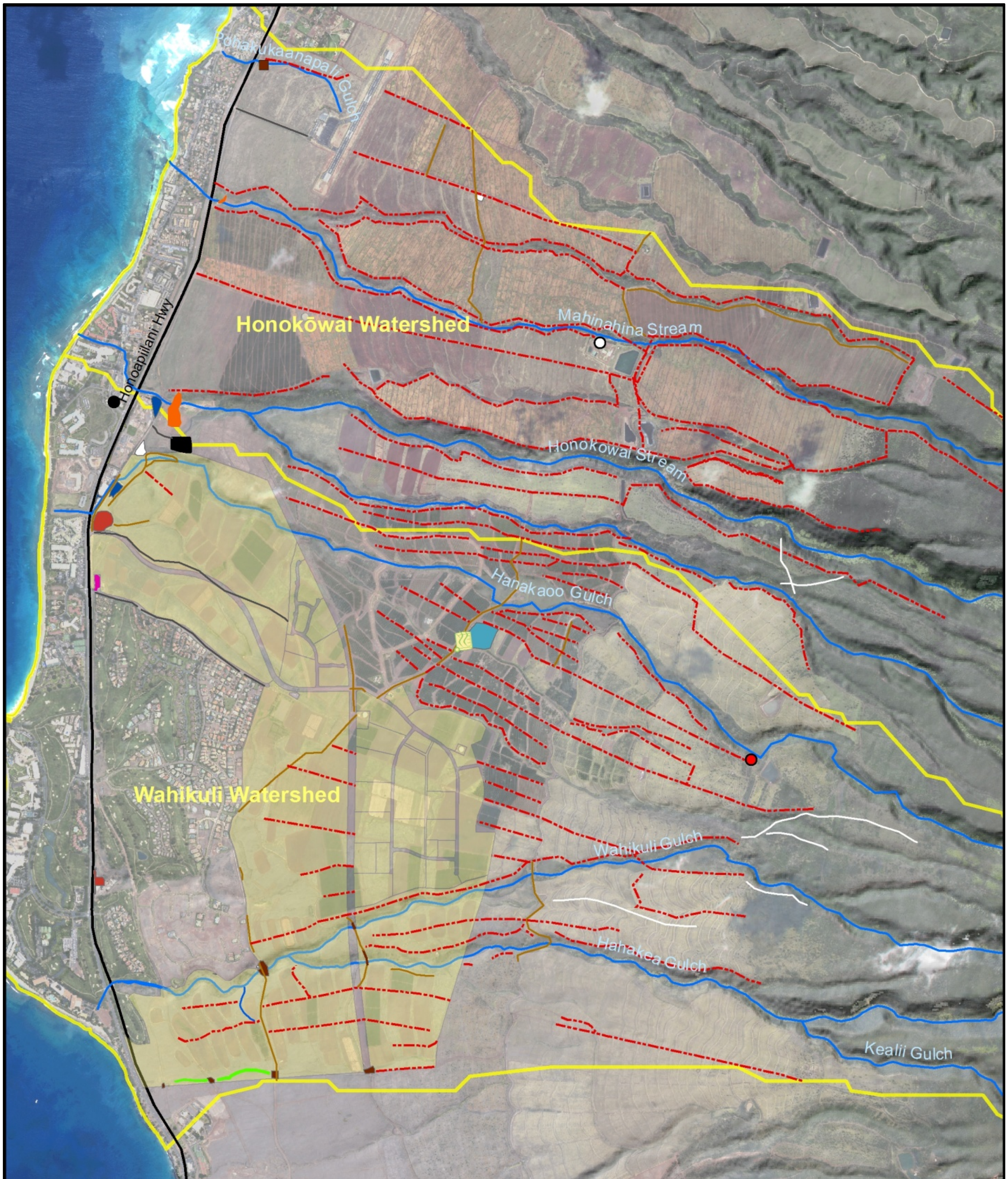


Figure 29.
Hotspots in Agricultural District

Source: State of Hawaii Data Repository, SRGII fieldwork
Aerial image acquired in 2011 (NOAA)

N

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

0 0.375 0.75 1.5 Miles

1

2

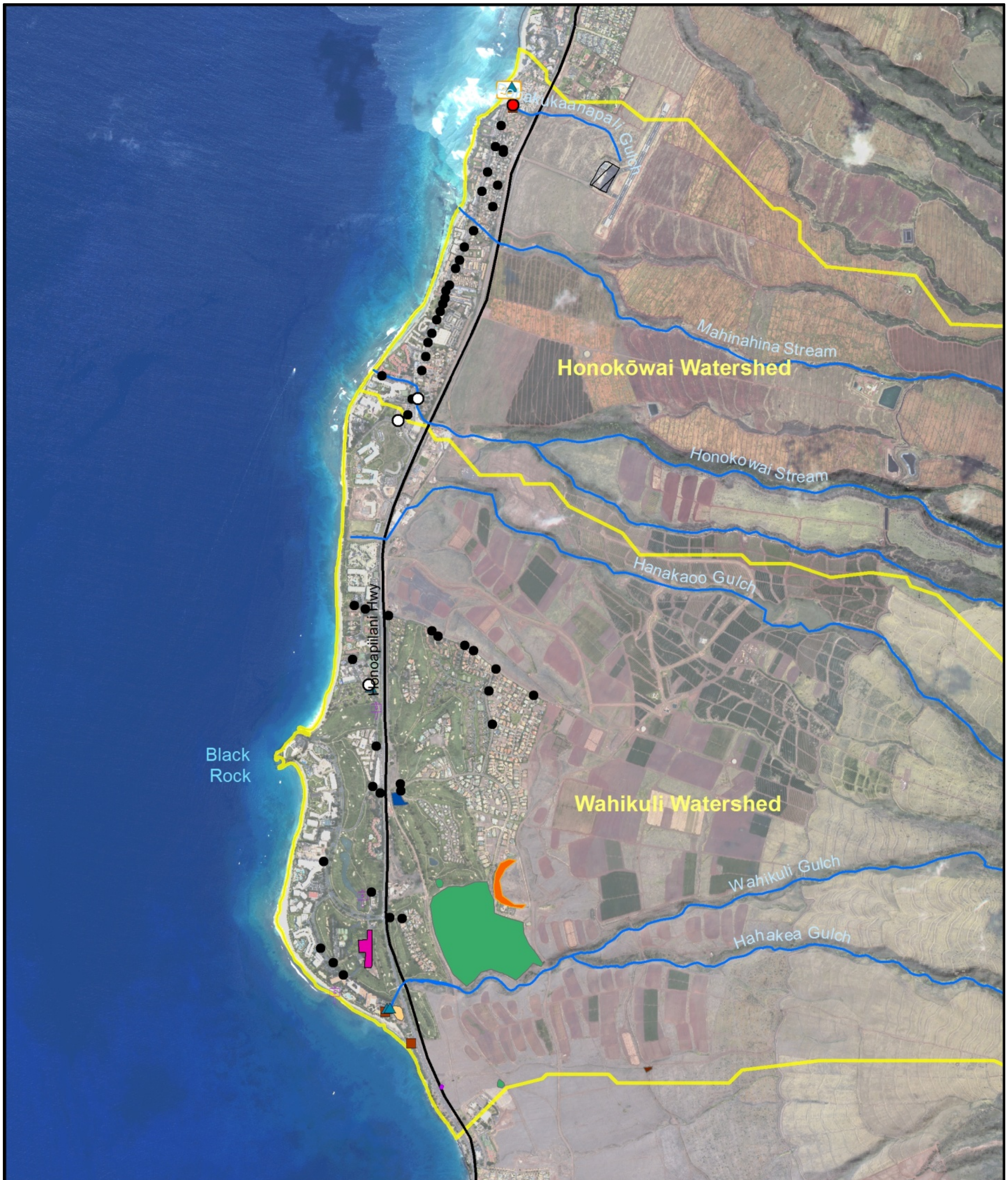


Figure 30.
Hotspots in Urban District

Source: State of Hawaii Data Repository, SRGII fieldwork
Aerial image acquired in 2011 (NOAA)

N

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

0 0.425 0.85 1.7 Miles

Legend (Figures 29-30)

Hotspots (Urban)	Hotspots (Urban)
Accelerated Erosion	Cemetery
Stormwater Inlet	Dam Erosion
Miscellaneous	Dirt Road Crossing Gulch
Outfall Stormwater	Impervious Area Runoff
Parking Lot Runoff	Lahaina Wastewater Reclamation Facility
Sediment Deposition	Maintenance Yard - Agricultural
Shoreline Erosion	Maintenance Yard - Other
Hotspots	Miscellaneous
Dirt Road Uphill	Parking Lot Dirt - Other
Dirt Road Along Contour	Parking Lot Paved
Dirt Road Crossing Gulch	Stream Bank Erosion
Irrigation Ditch Bank	Sediment Pile or Loose Material
Miscellaneous	Corn Fields with High Erosion Potential
Paved Road Shoulders	
Stream Bank Erosion	

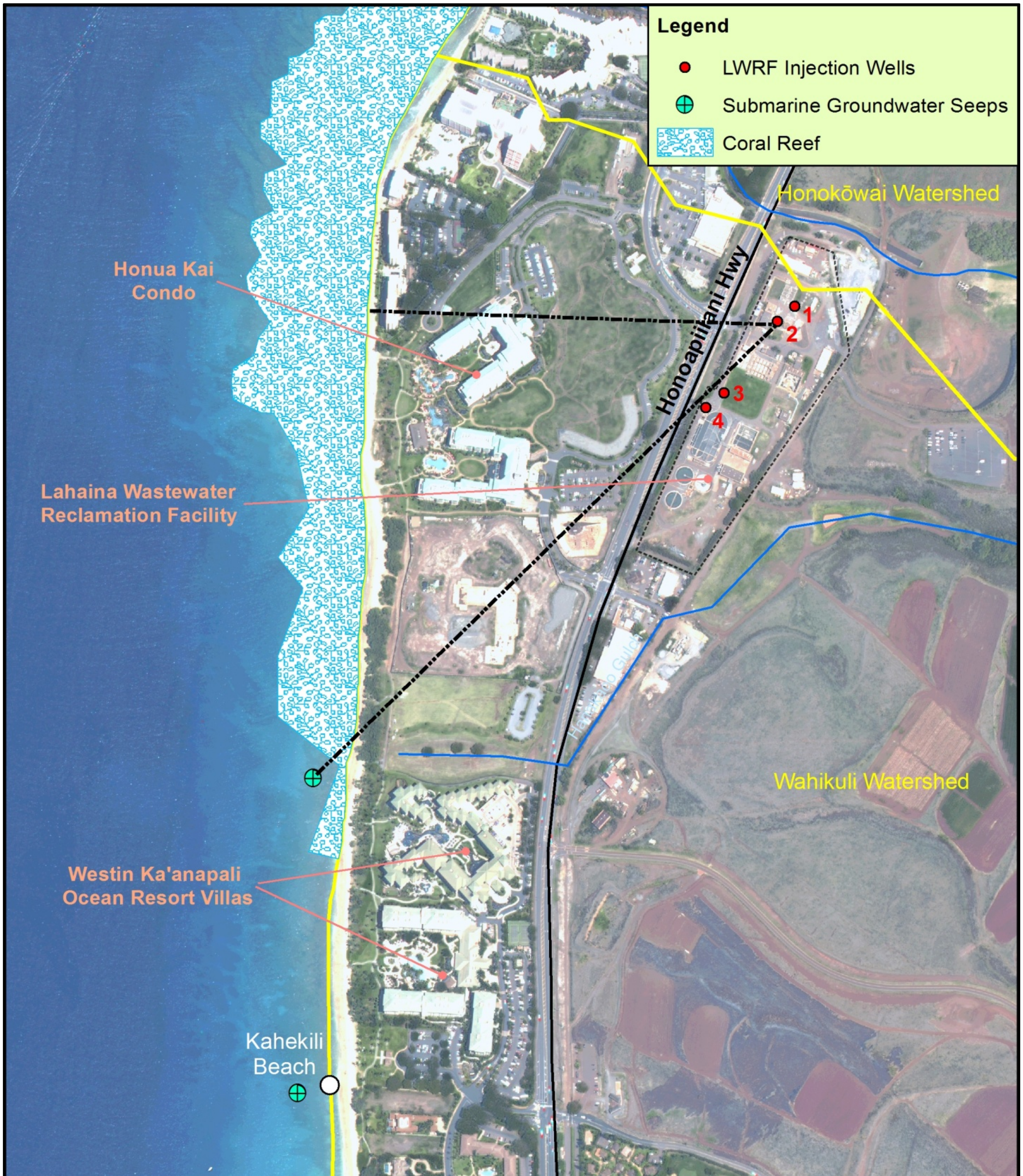


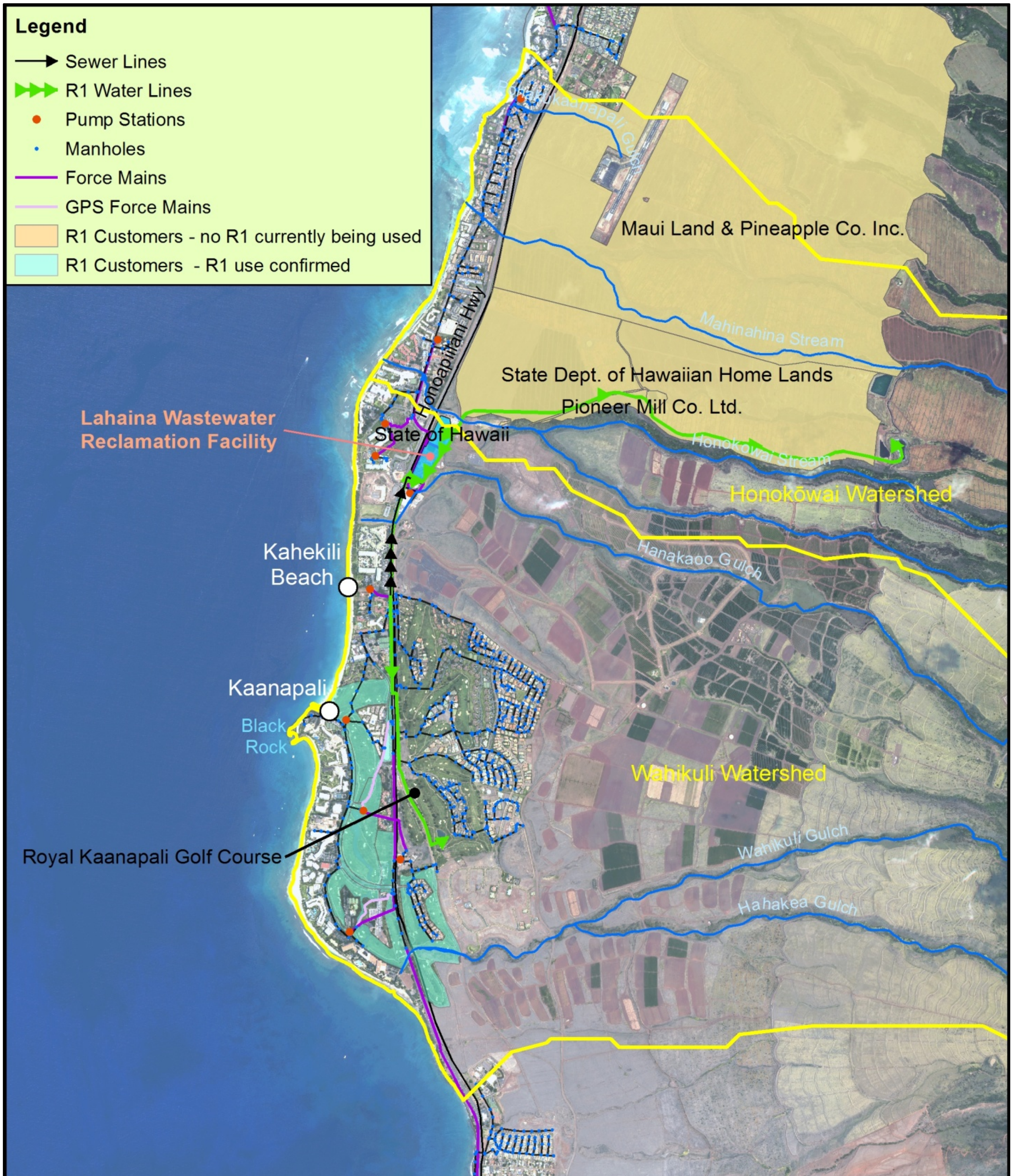
Figure 31.
Lahaina WWRF and Submarine Ground Water Seeps

Source: State of Hawaii Data Repository, Maui County
Aerial image acquired in 2011 (NOAA)

N

0 0.05 0.1 0.2 Miles

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012



1

Figure 32.
Sanitary Sewer System and Lahaina WWRF

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Source: State of Hawaii Data Repository, Maui County
Aerial image acquired in 2011 (NOAA)

N

0 0.375 0.75 1.5 Miles

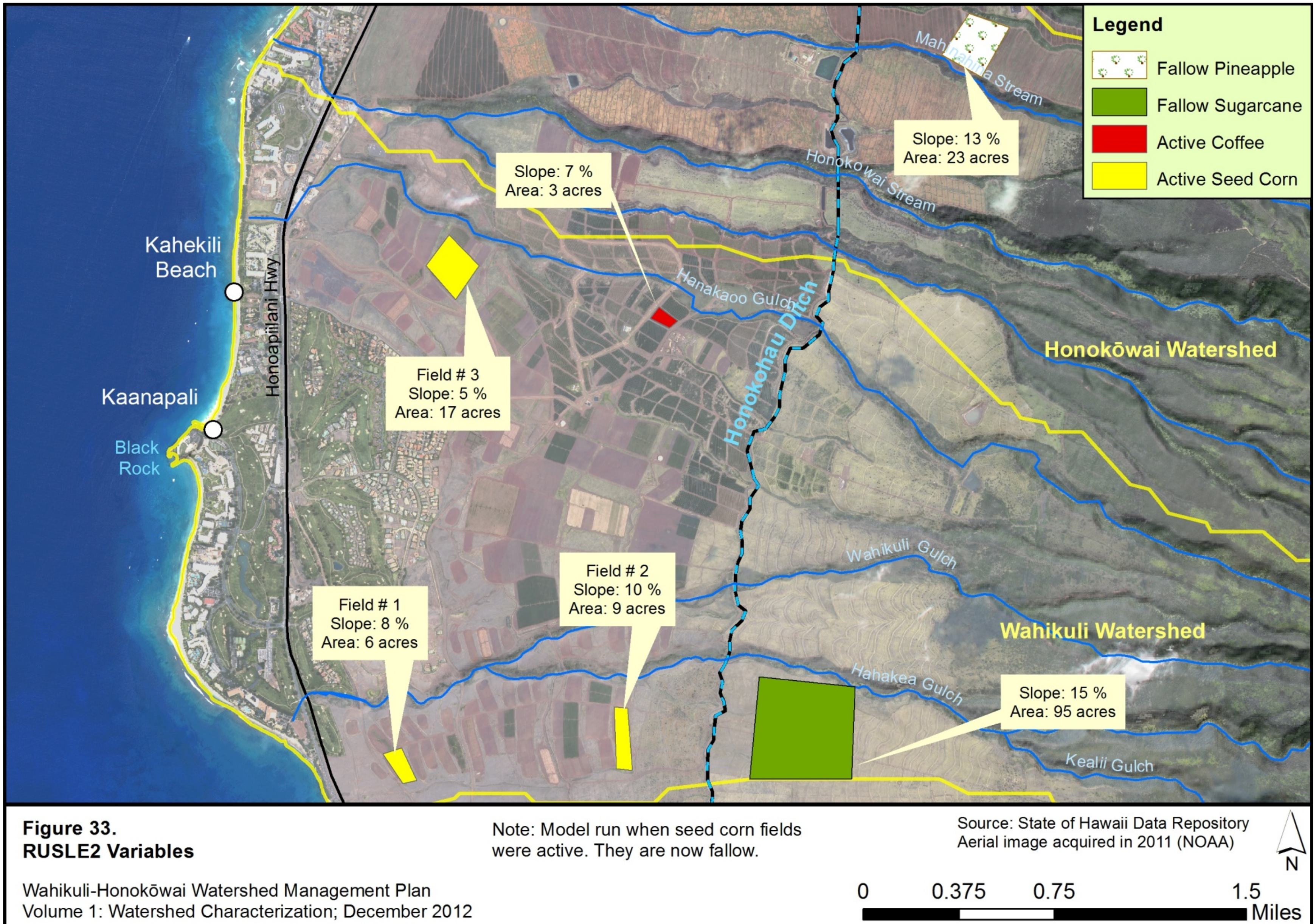


Figure 33.
RUSLE2 Variables

Note: Model run when seed corn fields were active. They are now fallow.

Source: State of Hawaii Data Repository
Aerial image acquired in 2011 (NOAA)

Wahikuli-Honokōwai Watershed Management Plan
Volume 1: Watershed Characterization; December 2012

Appendix B. Photographs

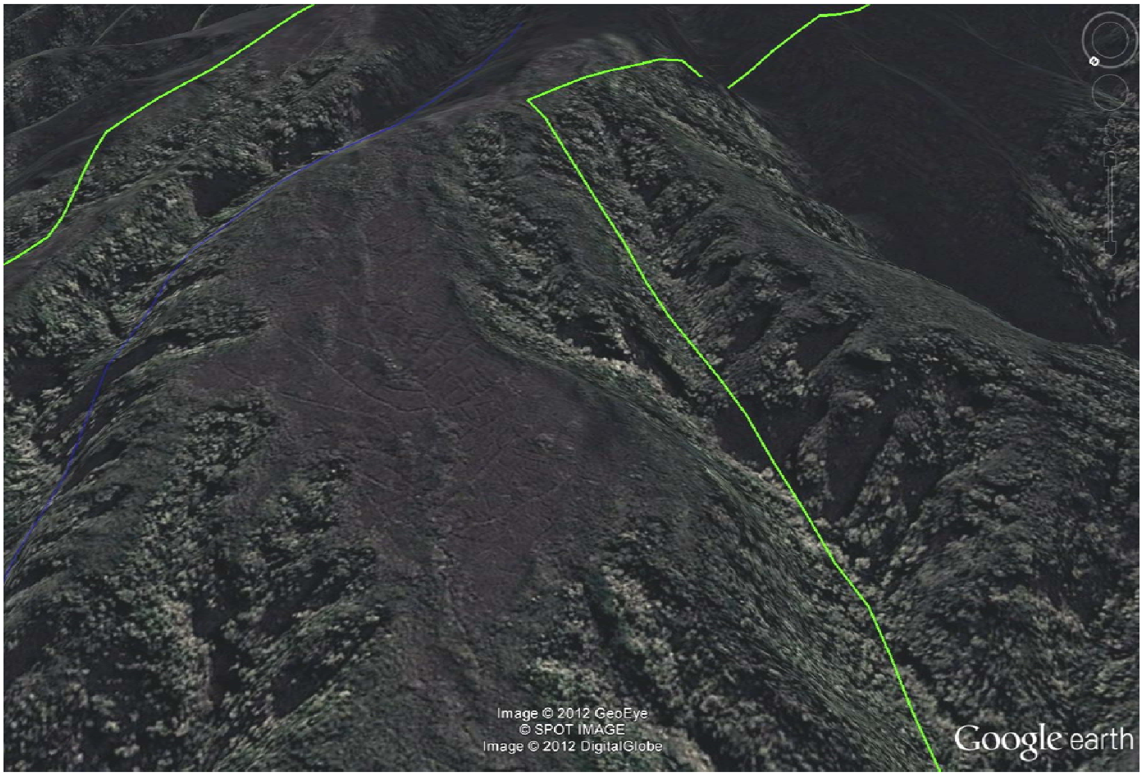
WAHIKULI AND HONOKŌWAI WATERSHEDS OVERALL

WH1: Project Area with Streams – *Mauka* to *Makai* View

WH2: Project Area with Streams – *Makai* to *Mauka* View

CONSERVATION DISTRICT (All Conservation District Photos Courtesy of WMMWP Staff)

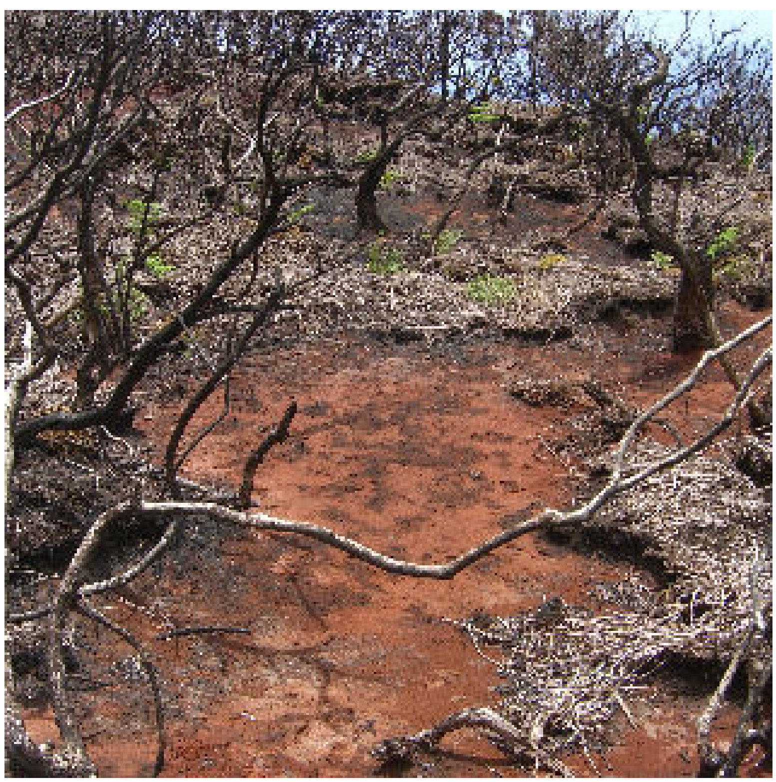
CD1: Conservation District Lands – Trails and Exposed Ground (center)



CD2: Recreational Dirt Bike Trails Expose Soils and Result in Accelerated Erosion

CD3: Example of Area Disturbed by Feral Ungulate: Presence of Ungulates Causes Trampling of Native Vegetation, Creates Trails, Wallows, Exposes Soils to Erosion, and Other Issues

CD4: Damage Caused By Wildfire in West Maui Region: Results in Bare and Exposed Landscape Highly Vulnerable to Erosion



WAHIKULI WATERSHED, AGRICULTURAL DISTRICT

WA1: Wahikuli Agricultural Fields – *Makai* of Honokōhau Ditch
Coffee in Upper Left, Seed Corn in Center; (Urban & Golf Course Areas Shown to Right)

WA2: Honokōhau Ditch

WA3: Example of Pollutant Input From Historic Agricultural Use: Sediment Loss Due to Erosion From Irrigation Basin

WA4: Sign in Seed Corn Field, Warning of Herbicide Application

WA5: New Seed Corn Plantings with Irrigation Tubing

WA6: Typical Seed Corn Field, Salt Residue, and Algae

WA7: Coffee Fields (Typical) with Healthy Growth of Vegetative Ground Cover
(Note Eroding Access Road Shoulder in Foreground)

WA8: Bare Field Surrounding Seed Corn Plot, Typical

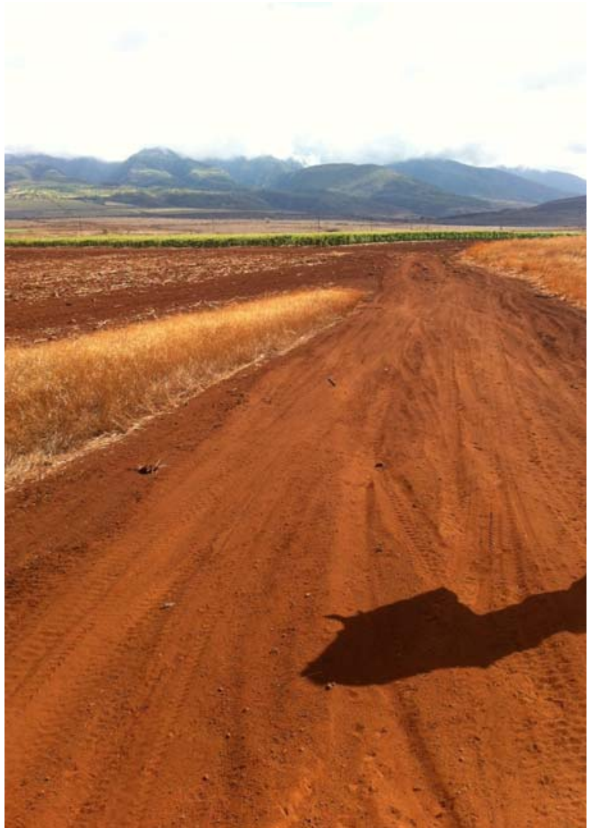
#

WA9: Seed Corn with Bare Exposed Fields, Typical

WA10: Fallow Sugarcane Field (Typical) with High Density Grass Cover

#

WA11: Typical Access Road, Part of Road Network for Seed Corn Field Region



WA12: Exposed Eroding Road in Upper Agricultural District, Running *Mauka* to *Makai* (No BMPs Present)

WA13: Access Road in Sugar Cane Region Running *Mauka* to *Makai* and Showing Hardened Surface and Gully Erosion (Looking in the *Mauka* Direction)

WA14: Exposed Heavily Eroding Road in Upper Elevations of Agricultural District, Running *Mauka* to *Makai* (No BMPs Present)

WA15: Access Road with Exposed Shoulder as Wide as Road (Coffee Field Region); Similar to Erosion Occurring on Shoulders of Lower Elevation Paved Roads

 #

WA16: Wahikuli Gulch Road Crossing Showing Erosion of Slope

#

WA17: One of Several Illicit Dumps in Wahikuli Watershed Gulches

WAHIKULI WATERSHED, URBAN DISTRICT

WU1: Landscaped Resort with Typical Storm Drain Tying Into S4

WU2: Residential Home Construction (No BMPs Present to Prevent Soil Migration Off Property)

WU3: Erosion of Wahikuli Gulch, *Mauka* of Honoapiʻilani Highway

#

WU4: Hanakaʻōʻō Cemetery, With No Permanent Land Cover, Exposed Soils

WU5: Wahikuli Gulch at North End of Hanakaʻōʻō Beach Park – Sediment Discharging Into Gulch Near Ocean From Hanakaʻōʻō Cemetery

WU6: Typical Golf Course View, Erosion and Sediment Generation Minimal

WU7: Typical Resort Parking Lot, Clean, Free of Rubbish, Low Sediment Generation

WU8: Typical Resort View: Well Maintained, Relatively Free of Rubbish and Vegetative Litter

WU9: Typical Landscape, Resort Marriott: Well Maintained, Relatively Free of Rubbish and Vegetative Litter

#

1 WU10: Runoff Discharging Onto Impervious Surface Due to Irrigation, During Dry Weather

2

3 **WAHIKULI WATERSHED, OCEAN AREA**

4 WO1: Invasive Algae - *Hypnea musciformis* (red) and *Ulva fasciata* (green)

5

WO2: Wahikuli Wayside Beach Park at Outfall – Turbid Ocean Water During Dry Conditions

WO3: Wahikuli Wayside Beach Park at Drainage Outfall With Rubbish and Sediment Presence – Close Proximity to Turbid, Reddish Ocean Water

HONOKŌWAI WATERSHED, AGRICULTURAL DISTRICT

HA1: Honokōwai Stream: Concrete Lined From Honokōwai Structure #8 To Mouth

HA2: Honokōwai Dam, View From Embankment Looking Towards *Mauka* Side

HA3: Debris Level In Honokōwai Structure #8

HA4: Māhinahina Dam, View towards *Mauka* Side

HA5: Irrigation Tubing Strewn Along Access Road In Pineapple Field Region

HA6: Lower Fallow (Vegetated) Pineapple Fields and Access Road With Vehicle (*Mauka* to *Makai* view)

HA7: Erosion at Discharge Point of Pineapple Terrace Into Natural Stream Channel

HA8: Honokōwai Structure #8; Concrete Outlet Control Structure With Horizontal Outlet Debris Ports Visible

HONOKŌWAI WATERSHED, URBAN DISTRICT

HU1: Lower Honoapi‘ilani Road, Typical Storm Water Drainage Inlet

HU2: Lower Honoapi‘ilani Road,
Typical Parking Lot Sloped to Road Fitted with Drainage Inlets

HU3: Lahaina Wastewater Reclamation Facility, Aerial

HU4: Lahaina Wastewater Reclamation Facility, Injection Well # 2

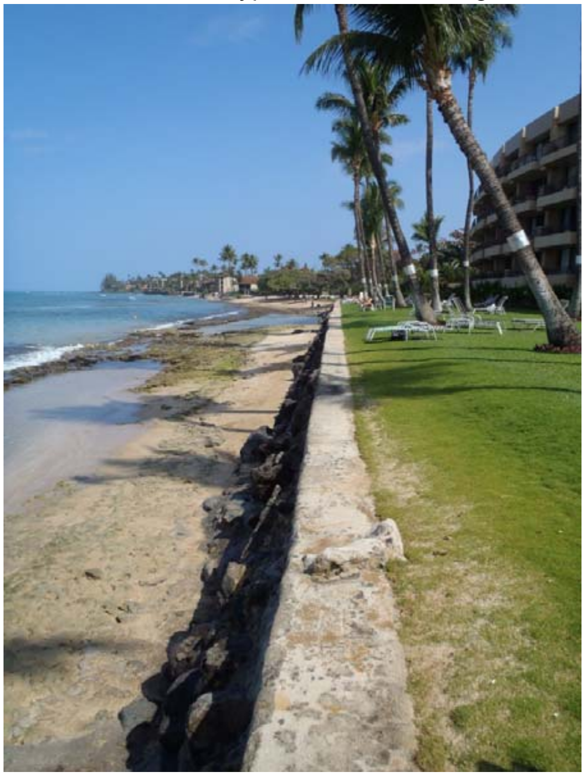
#

HU5: Lahaina Wastewater Reclamation Facility, Injection Well # 4

HU6: Lahaina Wastewater Reclamation Facility, Injection Well # 1 and R1 pipes

HONOKŌWAI WATERSHED, OCEAN AREAS

HO1: Hardened Shore Erosion, Typical Non-native Algae Present On Rocks



MISCELLANEOUS PHOTOS, HONOKŌWAI AND WAHIKULI WATERSHEDS

MWA1: Single Track Dirt Bike Trail

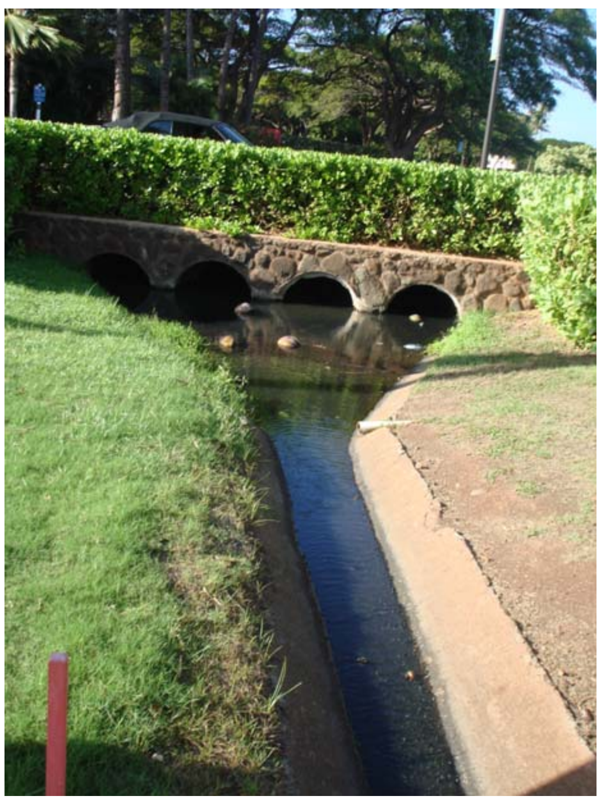
MWA2: Conservation District Interface with Agricultural District, Roads, Trails, and Exposed Ground on Steep Slopes

MWU1: Interface of Wahikuli Urban and Agricultural Lands, Showing Road with Storm Drain Inlets Tying Into S4

#

MWU2: Typical Residential Road With Storm Drain Inlets

MWU3: Drainage Ditch, Dry Weather Period Flow Drains into Golf Course Ponds



MWU4: Eroding Shoreline Along Resort Beach

#

MWU5: Air View, South Half Resort Area

#

MWU6: View Looking *Mauka* over Sheraton, Black Rock Lagoon bottom center

MWU7: View Up Swale and Outlet into Black Rock Lagoon

#

MWU8: View Up Swale at Black Rock Lagoon, Discolored Water

MWU9: Kahekili Beach Looking North Towards Honua Kai at Top of Image

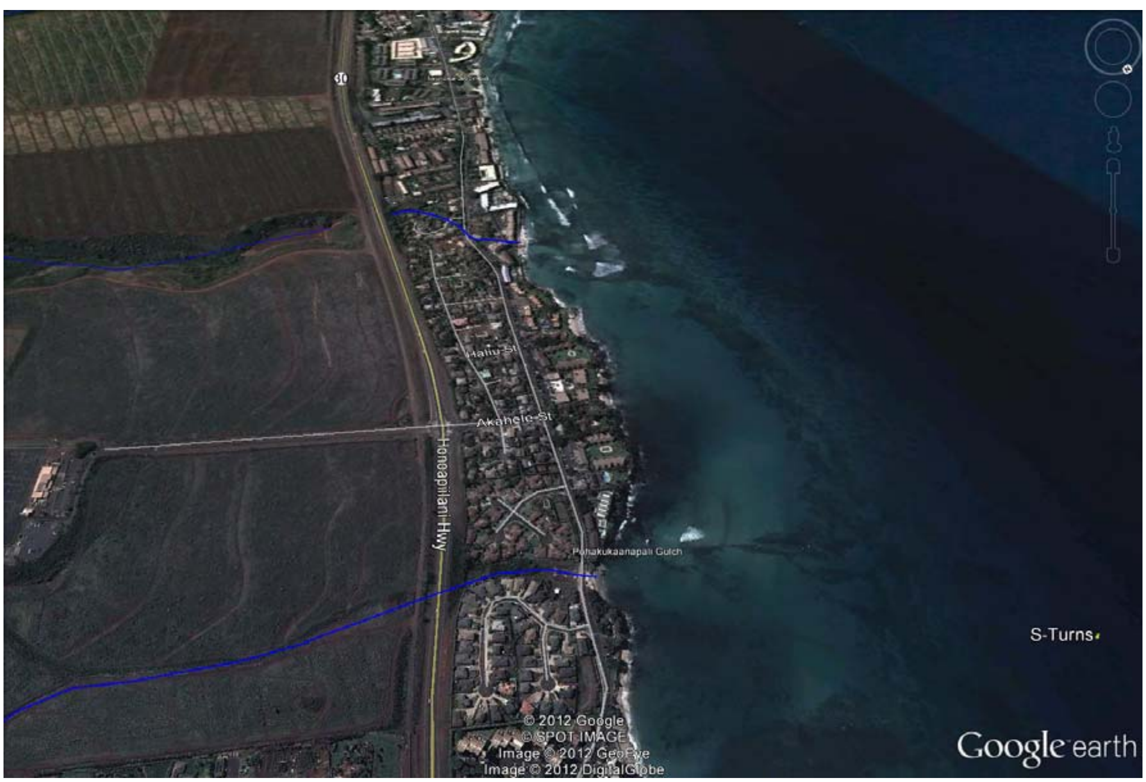
MWU10: Storm Water Outfall, Basin Water from
Highway *Mauka* Residential, Connects to Black Rock Lagoon

MWU11: North Section of Wahikuli Watershed, Looking *Makai*

#

MHU1: South Section of Honokōwai Watershed, Looking *Makai*

MHU2: North Section of Honokōwai Watershed, Looking South



MHU3: Honokōwai Beach Park, Storm Drain Channel

Appendix C. Regulatory Environment

Understanding the regulatory environment is essential for establishing a clear picture of water quality issues and ultimately solutions. There are numerous Federal, State and county agencies that have responsibility related to implementing activities related to controlling polluted runoff and maintaining water quality (Table C1). Some of these entities have a role in promoting both regulatory and voluntary approaches. Implementation of management measures is most effectively done through economic incentives or by regulatory drivers. Regulatory approaches work best when adequate mechanisms are in place to provide oversight and enforcement. This section summarizes the key agencies and regulations that address point source and NPS pollutants. A comprehensive list of agencies, their roles in implementing management measures for NPS, and applicable regulatory authority was developed in association with the overall guidance for Hawai'i (Stewart 2010a, b) (Table C1).

C.1. Coral Reef Conservation

At the Federal level coral reef conservation is primarily addressed by NOAA and the U.S. Coral Reef Task Force (USCRTF). The NOAA Coral Program brings together expertise from many NOAA programs and offices and works to reduce harm to and restore the health of, coral reefs by addressing national threats and local management priorities through the conservation activities. NOAA also maintains the Coral Reef Information System (CoRIS) website.

The USCRTF was established in 1998 by Executive Order 13089 to lead U.S. efforts to preserve and protect coral reef ecosystems. The USCRTF accomplishes this by helping build partnerships, strategies and support for on-the-ground action to conserve coral reefs. In 2002 the task force called for the development of Local Action Strategies (LAS) to help focus action for the reduction of key threats to coral reefs to the local level. The goals and objectives of the Hawaii LAS (climate change and marine debris, lack of public awareness, coral reef fisheries, land-based pollution sources and recreational impacts to reefs and aquatic invasive species) were designed to be in line with those found in the U.S. National Action Plan to Conserve Coral Reefs. The Kā'anapali-Kahekili region has been selected by the USCRTF as a priority partnership site.

At the State level, the primary agency responsible for coordinating Hawai'i's coral reef management efforts in the MHI is the DLNR-DAR.[109] The Coral Reef Working Group (CRWG) was established to help provide guidance for DAR's coral program. The CRWG contains key members of Federal and State agencies involved in coral reef management. In order to provide a cohesive strategy for coral reef management in Hawai'i, DAR and the CRWG developed *The Hawai'i Coral Reef Strategy for 2010-2020* (State of Hawaii 2010). This strategy incorporates the six multi-agency LAS and identifies four priority goals and five priority objectives for coral reef management.

The Kā'anapali-Kahekili region is one of two priority sites (M-7) identified by the CRWG for funding and technical assistance to fulfill the priority objective "Reduce key anthropogenic threats to two priority nearshore coral reef sites by 2015 using *ahupua'a*-based management".[110] This assists in

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[109] http://www.hawaiicoralreefstrategy.com/

[110] *Ahupua'a*. A land division usually extending from the uplands to the sea (Pukui and Elbert 1986). As used by the ancient Hawaiians, an *ahupua'a* includes the entire watershed and also tidepools and ponds, near-shore waters along the beach, and the sea out to and including the coral reef (Parham et al. 2008).

obtaining Goal #1: "Coral reefs undamaged by pollution, invasive species, marine construction and marine debris"; Goal #2: "Productive and sustainable coral reef fisheries and habitat"; Goal #3: "Coral reef ecosystems resilient to climate change, invasive species and marine disease"; and Goal #4: "Increased public stewardship of coral reef ecosystems." It also correlates to the NOAA Coral Programs's National Goals and Objectives for Coral Reef Conservation: Land-Based Sources of Pollution Impacts Objective 1.3: "Implement watershed management plans and relevant LAS within priority coral reef ecosystems and associated watersheds to improve water quality and enhance coral reef ecosystem resilience. Where needed, develop (or update) watershed management plans that incorporate coral reef protection measures." This WMP supports these goals and objectives.

C.2. Overview of Clean Water Act in Regulating Water Pollution

The first major breakthrough in controlling water pollution in the United States came with the Federal Water Pollution Control Act of 1948. With the growing awareness and the evolving environmental movement of the 1960s, it was extensively amended in 1972 and thereafter known as the CWA. Further major amendments came in 1977. The CWA regulates pollution discharges into navigable waters of the United States and sets water quality standards for surface waters with the goal of making them swimmable and fishable and "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". The first phase of the Act was aimed specifically at point source pollutants. It prohibits the discharge of any pollutant from a point source into navigable waters, unless special permits are obtained under the NPDES (Section C.3). At the Federal level, the CWA is administered by the EPA. In Hawaiʻi State and local governments are responsible for the day-to-day implementation of programs designed to meet the requirements of the CWA.

A big challenge, however, is the regulation of NPS because they cannot be specifically identified. This was partially addressed in the amendment known as the Water Quality Act of 1987, which essentially made one big NPS, stormwater, a regulated point source by regulating industrial and urban stormwater systems via NPDES permits. Other NPS pollution issues are addressed via projects and grants given to states to address agricultural runoff and other NPS problems.

Under CWA Section 305(b), states are required to periodically report to EPA on the quality of all water resources in the state and whether these waters are fully supporting water supply use, recreation activities and aquatic life. Section 303(d) requires states to identify waters of the state where water quality standards are not met and where uses are not supported. Surface waters that do not meet water quality standards after technology and regulation-based control measures are applied are listed on each state's 303(d) list, also known as the "list of impaired waters" (Section 5.3). The Section 303(d) List includes those waters (and associated pollutants) that do not support uses, and which require development of a TMDL strategy.

C.3. Point Source Pollution Regulations

Point source pollution is primarily controlled using regulatory approaches. Amendments to the CWA in 1972 (Section 402), required by Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA), introduced a permit system for regulating point sources that discharge pollutants into the ocean and other water bodies. Point source pollutants have identifiable sources and discharge locations such as the outfall of a waste water treatment plant. The amendments provided the statutory basis for the NPDES permit program, which prohibits the discharge of any pollutant from a point source into navigable waters, unless special permits are obtained. This applies to industrial and municipal polluters and excludes homes on cesspools and septic systems. In 1987, Congress added Section 402(p) to the CWA, requiring the regulation of storm water discharges. In 1990, Phase I of the NPDES storm water program was established, requiring a NPDES permit to discharge storm water runoff from the Municipal Separate Storm Sewer System (MS4) in large or medium municipalities that had populations of 100,000 or more. A ruling in 1999 created Phase II, which expanded the NPDES program to apply to all urbanized MS4. The Stormwater NPDES Permitting Program is managed by EPA and the implementation has been delegated to State agencies in most parts of the country, including Hawaiʻi. In Hawaiʻi, the Department of Health is the permitting authority for the NPDES program. Although Phase II of the stormwater regulation program under the CWA requires small municipalities with an MS4 to obtain an NPDES permit, the storm sewer system on Maui has not been designated as an MS4.

Effluent disposal at wastewater treatment facilities may involve injection of wastewater into the groundwater table using Class V shallow injection wells, a process known as UIC. These groundwater inputs are regulated under the Safe Water Drinking Act (Section C.5.2).

C.4. Non-Point Source Pollution Regulations

Non-point source pollutants, such as excessive amounts of sediment, nutrients, and bacteria, come from a variety of diffuse sources such as stormwater, agricultural and urban runoff, erosion, feral animals and leaking septic tanks. NPS pollutants are the focus of this WMP. The hydrologic cycle moves these pollutants through watersheds and ultimately into the ocean. A watershed-based approach is necessary as the Kāʻanapali region waters are impaired by land-based pollutants. According to EPA, NPS pollution is the nation's largest source of water quality problems. At present, about 40% of freshwater surface waters in the country are not meeting standards of swimmability and fishability, mostly due to the challenges of remediating NPS pollution. Regulating NPS pollutants via permits is impossible due to their diffuse nature, so alternative methods such as enlisting communities to take responsibility are used. Since MS4s are now under permitting programs, stormwater problems have been reduced on a nationwide basis (Section C.3). However, there is no designated MS4 in the Kāʻanapali region, so stormwater is a NPS pollutant for the area.

The NPS that are impairing the water quality in the Kāʻanapali region are the result of the condition of the landscape, natural processes, and the activities that occur on it. Projects eligible for CWA Section 319 funding must be part of a watershed based plan or comprehensive implementation that addresses EPA's nine elements (Box C1).

Federal agencies involved in funding NPS pollution reduction programs are EPA via grants and various programs under the CWA; NOAA under the Coastal Zone Management Act (CZMA) (Section C.5.1); U.S. Department of Agriculture (USDA) via incentive-based conservation programs; DOT for Federal roads, and Department of the Interior via technical and financial assistance.

States have their own polluted runoff control programs. In Hawaiʻi, two programs exist specifically to implement polluted runoff controls. The Polluted Runoff Control Program[111], administered by the DOH-CWB and funded under CWA Section 319, and the Coastal Nonpoint Pollution Control Program, funded under CZARA Section 6217 (Section C.5.1). To meet the program components

[111] Formerly known as the Nonpoint Source Pollution Control Program. Established through 1987 Water Quality Act amendments to the CWA.

required under Section 6217, the State developed the *Hawaiʻi's Coastal Nonpoint Pollution Control Program Management Plan* (CZMP 1996). In an effort to guide coordination between the DOH and Coastal Zone Management (CZM) pollution control programs, the State established a plan entitled *Hawaiʻi's Implementation Plan for Polluted Runoff Control* (DOH and CZMP 2000). More recent documents addressing NPS pollutant control include: *Hawaiʻi's Management Measures for the Coastal Nonpoint Source Pollution Control Program* (Stewart 2010a) and *Agency Programs, Projects, and Funding Opportunities that Support Ahupuaʻa, Watershed, and Ecosystem-based Management* (CZMP 2009). There is also a comprehensive document covering the agencies that can help implement management measures, *Responsible Agencies and Authorities - A Supplemental for Hawaii Management Measures* (Stewart 2010b).

Box C1. EPA's Nine Key Components for Watershed-Based Plans

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.
2. An estimate of the load reductions expected from management measures.
3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.
4. 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.
5. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.
6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established.

C.5. Other Regulations

C.5.1. Coastal Zone Management Act

In 1990, while reauthorizing the CZMA, Congress enacted Section 6217 of CZARA entitled "Protecting Coastal Waters". Section 6217 requires States with approved CZM programs, including Hawaiʻi, to develop programs to implement NPS pollutant controls. CZM programs have been developed pursuant to Federal requirements by States with coastal lands in order to manage their coastal and ocean resources. States with approved CZM Programs are eligible for Federal funds.

At the Federal level, the CZM Program is administered by NOAA's Office of Ocean and Coastal Resource Management. State and local governments are responsible for the day-to-day implementation of programs designed to meet the requirements of the CZARA. The Coastal Nonpoint Pollution Control Program is part of the State CZM Program and is administered jointly by the DBEDT Office of Planning and DOH-CWB. The Hawaii CZM Program is a broad management framework incorporating regulatory authorities of state and county agencies to provide greater coordination of existing laws. County governments play a crucial role in implementing the Hawaii

CZM Program by regulating development in geographically designated SMA. Through their respective SMA permit systems, the Counties assess and regulate development proposals in the SMA for compliance with the CZM objectives and policies and SMA guidelines set forth in Chapter 205A, HRS. No development can occur in the SMA unless the appropriate agency first issues an approval. Development is defined to include most uses, activities and operations on land and in the water.[112]

The Hawaii CZM Program also has jurisdiction over the State's Ocean Resource Management Plan, mandated by Chapter 205A, HRS, which focuses on facilitating comprehensive ocean resources management throughout the State. The network of government (Federal, State, County), academic and community partners is working across physical and jurisdictional boundaries to improve management of activities affecting Hawai'i's ocean and coastal resources. The West Maui Watershed Plan is an example of on-the-ground implementation efforts coordinated in part through this program.

C.5.2. Safe Drinking Water Act

The SDWA, enacted in 1974, regulates all current and potential drinking water sources, above and below ground. EPA is responsible for determining minimum quality standards to protect tap waters from contaminants that are detrimental to human health. Underground injection is used for many industrial discharges. Since underground injection wells have the potential to contaminate aquifers, injection wells are regulated under the SDWA. Under this legislation, EPA established the UIC Program that federally mandates minimum standards that must be adopted by each state's individual UIC program. In Hawai'i, the implementation of SDWA standards has not been delegated to the State, however the DOH-SDWB has developed a program to address many sources of UIC that are permitted by rule by EPA. There are multiple statutory requirements, both Federal and State, which regulate the implementation.[113]

[112] http://hawaii.gov/dbedt/czm/program/sma.php

[113] **Federal**: Safe Drinking Water Act of 1974, 92-523; Safe Drinking Water Act Amendments of 1986, 99-339; Lead Contamination Control Act of 1988; Safe Drinking Water Act Amendments of 1996, 104-182; 40 Code of Federal Regulations (CFR) Parts 35, 124, 141, 142, 144, 145, 146, and 148; **Hawai'i Revised Statues**: Chapter 340 E, Chapter 340 F; **Hawai'i Administrative Rules**: HAR Title 11, Chapter 19, Emergency Plan for Safe Drinking Water; HAR Title 11, Chapter 20, Potable Water Systems; HAR Title 11, Chapter 21, Backflow and Cross-Connection Control; HAR Title 11, Chapter 23, Underground Injection Control, 1991; HAR Title 11, Chapter 23a, 12/21/2000 Amendment, Underground Injection Control; HAR Title 11, Chapter 25, Certification of Operating Personnel in Water Treatment Plants.

The State UIC program was established under HAR §11-23 and 23A, with the intent of:

- Protecting the quality of Hawai‘i's underground sources of drinking water from chemical, physical, radioactive, and biological contamination that could originate from injection well activity.
- Processing permits and project reviews for new and renewal permits, modifications, and abandonment of injection wells.
- Evaluating geologic logs of soil and rock, injectivity tests, geologic maps, and groundwater quality profiles to determine the viability of subsurface injection.
- Maintaining inventory and database of all injection well files.
- Organizing and conducting site inspections to verify the location and performance of injection wells and to verify compliance with all testing or well closure plans.
- Conducting site investigations to identify problems such as unpermitted facilities and correction of deficiencies.
- Enforcing UIC rules and permit conditions.
- Serving the public by providing information and technical assistance.

According to HAR §11-23 and 23A, injection well operators are required to obtain a UIC permit from Hawai‘i DOH and comply with the conditions of the permits. According to §11-23, Section 18A ("Monitoring and Reporting Requirements"), "the operator of any injection well or wells shall keep detailed records of the operation of the well or wells, including, but not limited to, the type and quantity of injected fluids, and the method and rate of injection for each well". According to the Code of Federal Regulations §144.51, the conditions for each permit shall be written into the permit either expressly, or by reference. Conditions are specified for each permit and include explicit monitoring and reporting requirements.

The Hawai‘i DOH, Environmental Management Division, Wastewater Branch formulates and enforces all wastewater rules and regulations in Hawai‘i. HAR §11-62 'Wastewater Systems' is the codification of these regulations and covers all public wastewater treatment and disposal systems as well as private WWTPs and Onsite Wastewater Treatment Systems throughout the State, from individual cesspools to major municipal wastewater treatment plants.

C.5.3. County of Maui Planning and Zoning

Three plans, the *Countywide Policy Plan*, the *Maui Island Plan* and the *West Maui Community Plan*, were developed to provide general guidance on how growth will be accommodated in Maui County. The *Maui County Code* provides ordinances with more specific details on land use planning and zoning in terms of development.

C.5.3.1. Countywide Policy Plan (2010)[114]

HRS Chapter 46 grants the counties the power to regulate land development through zoning, though zoning must be based on a general plan. On Maui, the General Plan has been updated by the *County of Maui 2030 General Plan Countywide Policy Plan,* the *Maui Island Plan,* and nine *Community Plans*. The *Countywide Policy Plan* provides broad goals, objectives, policies, and implementing

[114] The Countywide Policy Plan can be viewed at http://www.co.maui.hi.us/index.aspx?NID=420.

actions to set forth the desired direction of the County's future as well as a policy framework for the *Maui Island Plan* and the nine *Community Plans*.

C.5.3.2. Draft Maui Island Plan (2009)[115]

The *Maui Island Plan* is a blueprint that provides direction for future growth, the economy, social, and environmental decisions on the island through the year 2030. Chapter 7, *Land Use*, provides an overview of Maui's past and current land use patterns and explores future land use challenges and opportunities. The chapter provides policy direction that will "enhance Maui's agricultural lands and protect the rural character and scenic beauty of the countryside". Chapter 8, *Directed Growth Plan*, outlines how Maui will grow over the next two decades, including the location and general character of new development, taking population projections into account. Urban and rural growth boundaries are established for the County with the intent of protecting farms and natural areas from sprawl and promoting efficient use of land, and the efficient provision of public facilities and services. According to the land use forecast, approximately 3,500 additional residential units are needed to accommodate projected growth in the West Maui region.

"The urban growth and rural growth boundaries take into account growth projections through 2030, the availability of infrastructure and services, environmental constraints, and an approximate density of land development to determine the placement of the boundary". The space inside the two boundary types, referred to as Urban and Rural Growth Areas, are separated into 1) Agricultural land overlay districts, 2) Protection area types and 3) Growth boundary types. Each is further broken down into twelve distinct types with a description of characteristics, purpose, and implementation strategies. For example, within the Agricultural land overlay districts, the Community Ag type includes a mixture of lot sizes and small commercial and subsistence agricultural operations interspersed with residential uses. Although delineated land types and boundaries designated by the county do not always coincide with the State Land Use District boundaries, three of the four growth boundary types that include some type of town center, are located in the Urban State Land Use District. The plan spells out implementation of the directed growth strategy for specific areas of the island, including West Maui.

C.5.3.3. West Maui Community Plan (1996)[116]

The *West Maui Community Plan*, prepared by the Maui County Council (1996), details planning goals, objectives, policies, and implementation considerations regarding land use and activities taking place in the Lahaina Judicial District, and their relation toward reaching the goals that have been set within the plan. The plan includes a land use map with the zoning designations for 16 categories. The categories include conservation, agriculture, rural, several related to residential and business, public facilities, open space and park, and areas reserved for future growth. All zoning requests and/or proposed land uses and developments must be consistent with the *West Maui Community Plan*.

While the plan was intended to guide decision making in the region through the year 2010, and thus is due to be updated, much of the content (goals, objectives, policies, and implementation

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115 The *Draft Maui Island Plan* can be viewed at http://www.co.maui.hi.us/index.aspx?NID=1503. *Directed Growth* maps are included. Revisions to the draft plan were made in 2010.

116 The *West Maui Community Plan* can be viewed at http://www.co.maui.hi.us/documents/Planning/Long%20Range%20Division/Maui%20Community%20Plans/westmaui.pdf

considerations regarding land use and activities) is still relevant. The plan contains 13 objectives for the West Maui region in general including: protect and enhance the quality of the marine environment; ensure that appropriate lands are available to support the region's present and future agricultural activities; establish an appropriate supply of urban land within the region to meet the needs of the community over the next 20 years; and preserve the current State Conservation District and State Agricultural District boundaries. The plan specifically discusses the importance of the natural environment and the threat that developments or projects may have potentially adverse impacts on water quality, whether it be potable or nearshore and off shore waters.

C.5.3.4. Maui County Code[117]

The Maui County Code contains specific ordinances related to planning and zoning. Titles 16 (Buildings and Construction), 18 (Subdivisions), and 19 (Zoning) cover details of land use and development including permitted uses, design standards, and building requirements. Two new ordinances related to development and stormwater were approved in December 2011. Chapter 16.26, effective July 7, 2012, requires that "post-construction stormwater quality best management practices, as may be required by the director of public works, shall be implemented for property on which any new structure(s) will be situated or for any work such as remodeling, reconstruction, repairs, additions, and similar work where the cost of the work of a period of twelve months exceeds fifty percent of the replacement value of the existing structure(s) before work is started". There are some exceptions to this ordinance. Chapter 18.20.135, effective July 7, 2012, requires "post-construction stormwater quality best management practices, as may be required by the director, shall be implemented for all subdivisions". Requirements do not apply to any subdivision that received preliminary subdivision approval prior to the effective date.

Title 20 covers Environmental Protection including topics such as soil erosion, sedimentation control, and wastewater. For example per Maui County Code Chapter 20.08.080 Grubbing and Grading Permit Review, a review of drainage and erosion control plans for land use changes, developments, and subdivisions must be submitted to the SWCD and DLNR Historic Preservation Division.

C.5.3.5. Conservation District

HAR Title 13, Chapter 5 regulates land use in the State's 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 the public health, safety and welfare. Conservation lands are further subdivided into five subzones.[118] Four of these subzones are arranged in a hierarchy based on environmental sensitivity ranging from the most environmentally sensitive to the least sensitive. They are: protective (most sensitive); limited; resource; and general (least sensitive). The fifth is the special subzone and is applied in special cases to allow a unique land use on a specific site. For each subzone, the chapter describes the objective of the level of protection and identifies permitted uses along with the procedures necessary to obtain permission to engage in that use. Conservation lands in the Wahikuli and Honokōwai Watersheds are classified as protective and resource.

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[117] The Maui County Code can be viewed at http://library.municode.com/index.aspx?clientID=16289&stateID=11&statename=Hawaii

[118] http://hawaii.gov/dlnr/occl/frequently-asked-questions-1

C.5.3.6. Agricultural District

HRS §205 (Land Use Commission), the *Countywide Policy Plan*, the *Draft Maui Island Plan*, the *West Maui Community Plan*, and *Maui County Code* all discuss land use and development in the Agricultural District with an emphasis on preserving and protecting agricultural resources. Chapter 19.30A of the *Maui County Code* details district standards (e.g. lot area, setbacks maximum developable area), limitations on resubdivision, permitted uses, special uses, private agricultural uses, agricultural leases, substandard agricultural lots and exemptions. The district standards specify that within the Agricultural District the maximum developable area is ten percent of the total lot area. This restriction applies to farm dwellings, but does not apply to other structures used to support agriculture. The *Draft Maui Plan* recommends that the district standards regarding two acre lots be changed to avoid increased fragmentation of agricultural lands and require either fewer two acre lots per maximum number of permitted lots or clustering of two acre lots.

C.5.3.7. Urban Lands

The *Countywide Policy Plan*, the *Draft Maui Island Plan*, the *West Maui Community Plan*, and *Maui County Code of Ordinances* set forth specific policies for Urban lands regarding density, development of commercial and recreational facilities, residential dwellings and urban services (e.g. wastewater treatment facilities), and the maintenance of open space and scenic roadway corridors. Policies provide specifics on uses, structures, parcel and lot area, setback requirements, minimum distance between buildings, parcel dimension requirements, access/driveways, building height, utilities and service, public access, and permit requirements. Specific requirements may be written into permits.

C.5.4. County of Maui BMP Regulations

In 1998, the County of Maui revised their grading ordinance to require all projects (including those not requiring grading permits) to use Best Management Practices (BMPs) for the control of erosion, sedimentation, and dust to maximum practicable extent. Several other major changes were also made to the ordinance, such as stricter requirements for grading permits for projects within the SMA, and requiring that grading permit applications be accompanied by an erosion control plan showing BMPs.[119]

The County of Maui requires a Grading Permit for any excavation or fill, or temporary storage of sand, soil, gravel, rock, or other similar materials.[120] The grading permit system is broken down into major and minor permits, which must be submitted to the Department of Public Works.

A Minor Grading Permit applies to sites less than one acre in size and having a maximum height/depth of excavation or fill less than 15 feet.[121] Sites meeting these requirements must submit a Grading Plan, BMP Plan, and if necessary, an Engineering Slope Hazard Report. A Major Grading Permit is required when an area larger than one acre is disturbed, or a maximum height/depth of excavation or fill greater than 15 feet is proposed. Sites meeting these requirements must submit the following plans prepared by a Licensed Engineer: a Grading Plan, an Erosion Control Plan, A Drainage Plan and Report, and an Engineer's Soils Report (only if the

[119] http://water.epa.gov/polwaste/nps/success319/innov_hi.cfm

[120] http://www.co.maui.hi.us/index.aspx?NID=1223

[121] http://www.co.maui.hi.us/documents/Public%20Works/DSA/Engineering%20Plan%20Review%20Section/2012_02Feb_GradingPermitIn_2.PDF

maximum height of excavation or fill exceeds 15 feet), and if necessary, an Engineering Slope Hazard Report.

A Grubbing Permit is required for any areas greater than one acre in size that have ground cover uprooted from the surface of the ground and do not incorporate grading changes. A Grubbing Plan and BMP Plan are required for all Grubbing Permits. Additional requirements apply to properties along the shoreline.

In 2012, an amendment was made to the Uniform Building Code to include post-construction stormwater quality BMPs as required by the director of public works for applicable remodeling and reconstruction projects. This amendment excluded single-family dwellings and accessory structures unless they were part of subdivisions (Chapter 16.26, Maui County Code).

C.6. Community-Based Initiatives

Parallel to Federal and State programs, and often supported by available funding, community-based initiatives are an important mechanism for both preventive and treatment control of NPS pollutants. There are numerous stakeholders that are affected by NPS pollutants since ultimately they impact water quality of ocean waters. Community engagement, education, and volunteer programs are an integral part of a comprehensive solution to reduce NPS pollutants. The conservation lands of West Maui benefit from the efforts of the WMMWP and their partners, many of which are private landowners. Some of these same landowners have land in the agricultural and urban districts. Condominium and resorts owners also have a vested interest in ensuring the health of the region's waters. NOAA worked with the National Fish and Wildlife Foundation and DLNR-DAR to hire a Watershed Coordinator, who is an on-the-ground resource and facilitator of watershed planning and implementation efforts in the West Maui region.

Table C1. Agencies with Responsibility for Controlling Polluted Runoff and Monitoring and Maintaining Water Quality

Federal Agencies
NOAA Jointly administers Coastal Nonpoint Pollution Control Program, which falls under CZARA Section 6217, with EPA. Administers Coral Program to address threats to coral reef ecosystems, including land-based pollutants.
U.S. Army Corps of Engineers (USACE) Charged with protection of the Nation's aquatic resources which is accomplished by: implementing the Nationwide Permits system for certain activities; regulating construction activities in navigable waters and dredging of harbors; regulating the discharge of fill material in wetlands and other U.S. waters; and conducting ecosystem restoration, flood damage reduction, water control projects and various water quality studies. Administers CWA Section 404.
U.S. Coast Guard Responsible for administration of a maritime protection program to prevent and control pollution in U.S. navigable waters. Enforces laws against individuals and companies that pollute marine waters.
USDA Farm Services Agency Responsible for most of the Federal financial support regarding farming activities such as farm plans to reduce erosion or control animal impacts on water.

USDA Natural Resources Conservation Service (NRCS) Provides technical assistance for agricultural production and cultivation, conservation activities, and economic management. Advocates proper agricultural production methods and the use of management practices to minimize adverse environmental impacts. Works closely with the 16 Soil and Water Conservation Districts (SWCD) in Hawaiʻi. Assists in developing conservation plans to treat existing and potential resource problems and has funding to assist with the installation of management practices. Provides permitting expertise and coordination with permitting agencies. Sponsors the Environmental Quality Incentives Program (EQIP), a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years. These contracts help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland.
U.S. Environmental Protection Agency (EPA) (Region 9) Responsible for providing clean and safe surface water, groundwater, and drinking water and protecting and restoring aquatic ecosystems (Office of Water). Provides funding and technical support for implementation of the Hawaiʻi Polluted Runoff Control Program through CWA Section 319. For Hawaiʻi, permitting activities have been delegated to the State. Jointly administers Coastal Nonpoint Pollution Control Program, which falls under CZARA Section 6217, with NOAA.
USGS Pacific Islands Water Science Center Collects information needed to understand U.S. water resources and provide access to water data, publications and maps. Collect, analyze, and interpret water-quality data and information on the transport, fate and remediation of contaminants.
State Agencies
DOH Environmental Planning Office Water Quality Management Program: Responsible for setting the State's water quality goals (Water Quality Standards), evaluating the progress in achieving these goals, and long-range planning to solve water quality problems. Planning Review Program: Reviews development projects with potential environmental impacts and coordinates departmental evaluations on mitigative measures. Implements environmental policies and standards at the earliest stages of the planning process for statewide project developments.
DOH Environmental Management Division: Clean Water Branch Responsible for enforcing and revising water quality standards. Water quality standards are maintained through monitoring and enforcement, sponsorship of polluted runoff control projects, review of permit issuance and public education. Administers Section 319 grants programs and NPDES permit process, regulates sewage treatment and disposal, hazardous waste and solid waste, and reviews and issues permits for industrial storm water discharge, construction storm water discharge, MS4 permits and NPDES.
DOH Environmental Management Division: Safe Drinking Water Branch Responsible for enforcing the Federal Safe Drinking Water Act, which covers waters that are potential sources of drinking water, both surface and underground. Administers Underground Injection Control Program (UIC) as required by SDWA and directed by EPA. Administers Groundwater Protection Program, which is a non-regulatory program whose goal is to protect human health and sensitive ecosystems by protecting groundwater resources. Its focus is on water quality assessment, and on developing pollution prevention and protection measures.
DOH Environmental Management Division: Wastewater Branch Administers engineering and financial functions related to water pollution and municipal and private wastewater treatment. In charge of reviewing/approving and monitoring of all sewage and wastewater treatment systems including septic tanks and cesspools. Provides engineering, design, facility approval/audit, environmental assessment, grant/loan award, inspection of new facilities. Implements Statewide Wastewater Operator Training Center and supports the State board Operating Personnel in Wastewater Treatment Facilities. The three sections within the Wastewater Branch are: Planning/Design, Construction/Operations and Grants Management.
Department of Transportation Responsible for the developing and implementing strategies to control polluted runoff from transportation facilities (i.e. public highways and trails, airports, and commercial harbors). Authorized to enforce polluted runoff control mechanisms for commercial harbors, highways, roads and bridges, including through NPDES permits.
DBEDT Office of Planning Oversees the Hawaiʻi CZM Program. This program guides appropriate land and water uses and activities through coordination of State and county agencies and ensuring compliance with laws, regulations and management policies, including the requirements of the CZMA. The CZM Program employs a variety of regulatory and non-regulatory techniques to address coastal issues and uphold environmental laws.

Department of Land and Natural Resources (DLNR) Manages State-owned terrestrial and submerged lands and regulates uses in the designated conservation districts. Administers the State's designated marine life conservation districts, marine and freshwater fisheries management areas, wildlife sanctuaries, and natural area reserves. Provides funding to the 16 local SWCDs through the Hawaiʻi Association of Conservation Districts.	
DLNR Commission on Water Resource Management (CWRM) The Commission's staff is comprised of the Surveying, Planning, Ground-Water Regulation, and Stream Protection and Management Branches. Oversees the instream use protection program, which recommends appropriate interim and final instream flow standards. Issues permits for well construction, modification of existing well or pump installation, and alterations of stream channels and diversions.	
DLNR Engineering Division Oversees the flood and dam safety program. Provides for the inspection and regulation of construction, enlargement, repair, alteration, maintenance, operation, and removal of dams or reservoirs to protect the health, safety, and welfare of the citizens of the State by reducing the risk of failure of the dams or reservoirs.	
DLNR Division of Aquatic Resources Manages the state's aquatic resources and ecosystems through programs in commercial fisheries and resource enhancement; aquatic resources protection, habitat enhancement, and education; and recreational fisheries. Sets overall water conservation, quality and use policies; defines beneficial and reasonable uses; protects ground and surface water resources, watersheds and natural stream environments; establishes criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establishes procedures for regulating all uses of Hawaiʻi's water resources.	
DLNR Division of Forestry and Wildlife Responsible for the management of State-owned forests, natural areas, public hunting areas, and plant and wildlife sanctuaries. Program areas cover watershed protection; native resources protection, including unique ecosystems and endangered species of plants and wildlife; outdoor recreation; and commercial forestry. Manages State Forest Reserve System and Natural Area Reserves System in part to protect upper watershed areas.	
DLNR Land Division Responsible for managing State-owned lands in ways that will promote the social, environmental and economic well-being of Hawaiʻi's people and for ensuring that these lands are used in accordance with the goals, policies and plans of the State. Responsible for leasing State agricultural lands to agricultural operators under Chapter 171, HRS. One of the lease conditions is that the operators work with the local soil and water conservation districts to develop and implement a conservation plan.	
Department of Agriculture Regulates activities to protect agricultural industries and natural resources against insects, diseases and pests. Controls all eradication services directed against weed and insect pests, and controls the sale and use of pesticides. 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, was transferred from DLNR to the State Department of Agriculture (DOA) (Section 171-3(b), HRS).	
Soil and Water Conservation Districts (SWCD) Conducts soil and water conservation activities within their respective boundaries. Works closely with the USDA NRCS to assist the needs of agricultural producers and the community through conservation planning, and technical assistance with management or conservation practices.	
Maui County Agencies	
Department of Planning Offers technical advice to the Mayor, County Council and commissions; proposes zoning legislation; drafts updates to the General Plan, Maui Island Plan and Community Plans; presents reports and recommendations on development proposals; and oversees programs on cultural resources, census and geographic information, flood plain permits and other special projects and permits. The Maui Planning Department is responsible for virtually all county land use-related permits. This includes shoreline setback variances and Special Management Area permits.	
Department of Planning – Long Range Division Responsible for formulating long range planning activities to meet Department goals to facilitate the development of a desirable living environment through dialogue with the community and the application of professional planning principles. Coordinates long range planning activities with other County departments, State and Federal agencies to meet the Long Range goals of the department and to maintain cooperation between the various agencies.	

Department of Environmental Management – Wastewater Reclamation Division Wastewater Administration manages short and long term tasks and projects related to the wastewater system (sewers, cesspools, wastewater capital improvement projects). The Wastewater Facilities program is responsible for the management, operation, maintenance, and repair of all County wastewater and pumping facilities in order to provide the consistent and reliable level of performance necessary to protect public health and the environment. The Wastewater Collection System is responsible for the management, installation, maintenance, and repair of all County wastewater collection lines, force mains, and manholes.
Department of Water Supply – Water Resources and Planning Division Conducts permit and environmental reviews, regulatory compliance, planning information systems, water resource management and conservation.
Department of Water Supply – Engineering Division Develops and maintains water supply standards and conduct studies for feasibility of pipeline alignment and sites for reservoirs, pump stations, and other facilities. Reviews all development plans for conformity with departmental standards, prepares plans and specifications for water supply projects, coordinates and prepares plans and specifications for projects to be advertised for competitive bidding. Administers DWS Capital Improvement Projects (CIP) and coordinates consultant contracts, prepares and administers agreements with public agencies and private developers, prepares plans and specifications for in-house projects, conducts studies, tests, and investigations on water resources.
Department of Public Works Protects the public's health, safety, property, and environment by developing and operating the County's infrastructure and administering its building codes. Directs and oversees the three operating divisions in the Department: Development Services Administration, Engineering Division, and Highways Division. Administers County grading ordinances.

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Appendix D. Summary of Previous Reports and Information

Watershed and stream resources in West Maui have been studied by a range of public and private entities including University of Hawaiʻi researchers, State and Federal agencies (e.g. Hawaiʻi DLNR DAR, U.S. DOI, USFWS, USACE, USGS) and non-governmental organizations (e.g. TNC, WMMWP). Available information ranges from previous plans developed for management of the West Maui watersheds to the amount and type of anthropogenic inputs found in the waters of Maui.

D.1. Watershed Reports

Several key reports characterize overall health of the project area watersheds and provide guidance with respect to water quality and watershed degradation. These efforts are largely concentrated in the agricultural and urban areas. In addition, the *West Maui Watershed Owner's Manual* (1997) was prepared while pineapple and sugarcane were actively cultivated within the watersheds, and the management practices primarily address reduction of soil erosion and pollutant transport from these fields. The majority of these fields are presently fallow and unmaintained.

West Maui Watershed Island of Maui Section 905(B) WRDA 1986 Analysis Report Reconnaissance (US Army Corps of Engineers 2009)

A reconnaissance study was performed to confirm the need for aquatic ecosystem restoration and watershed planning in the study area; determine Federal interest in pursuing a watershed project; define the scope, cost, and schedule of the feasibility study and Environmental Impact Statement for the project; and gain non-Federal sponsor commitment. The reconnaissance study documented that the primary problems in the watershed include impacts to stream resources, impacts to groundwater quality and quantity, watershed degradation, impacts to coral reefs and nearshore waters, flooding, and sedimentation. In addition, general concerns documented by this study included those associated with climate change, land ownership, transparency of regulations, and education and outreach. The document outlines: public concerns; problems and opportunities; planning goals, objectives and constraints; scenarios to address identified planning objectives; and the need for an integrated watershed plan. Details regarding the development of the integrated watershed plan, including feasibility, are also discussed.

West Maui Mountains Watershed Management Plan

The *West Maui Mountains Watershed Plan* was prepared by the WMMWP in 1999. The plan stresses the importance of watershed management and outlines the cost and contents of a comprehensive management plan for the 50,000 acres (20,234 ha) of forest and watershed vegetation occupying the summit and slopes of the West Maui Mountains. The plan describes existing watershed management programs and recommends key actions for programs for six focus areas of management priority: feral animal control; weed control; human activities management; public education and awareness; water and watershed monitoring and management. A revision of the plan is currently in preparation that documents successful efforts and outlines future planned actions.

West Maui Watershed Owner's Manual

The *West Maui Watershed Owner's Manual*, prepared by the West Maui Watershed Management Advisory Committee (1997) is a collection of recommendations for protecting and improving water quality and ocean resources for West Maui. It recommends responsible actions and specific tasks for watershed users and residences, including the managers and owners of large agricultural parcels and government agencies. It is a comprehensive plan that seeks to protect coastal and drinking water by recommending actions to control erosion from agriculture and construction, improved management practices for agriculture landscaping and fertilizer use, better drainage designs, and for more effective algae removal programs. Current watershed management planning efforts (i.e. this WHWMP) are using this as a resource to update recommendations.

D.2. Research Studies

The transport and fate of wastewater effluent injected into wells on the WWRF property, and its impacts to coastal water quality, have been the subject of several scientific studies. The studies include use of analytical methods to quantify and/or verify the hydrologic connectivity of groundwater at the injection wells to submarine groundwater seeps in the ocean, and the water quality in the vicinity of the seeps. In general the analytical methods used include: biogeochemical characterizations; water quality sampling and analysis; bioassays; multi-dimensional hydrogeological modeling using tracers; and mapping sea surface temperatures. The studies support the statement that injected wastewater effluent is hydrologically connected to at least two submarine seeps in the nearshore waters along Kahekili Beach and that the ambient ocean water quality in the vicinity of the seeps is impacted. Questions about the hydrology and water quality that still exist include: what part of the total volume injected is discharged into the ocean out the two seeps and their vicinity; and what are the impacts to flora, fauna, and humans living and swimming in the water.

Some of the research scientists have concluded that altered ocean water quality from the treated waste water effluent is adversely impacting flora and fauna in the ocean, and introducing pathogens that can transmit disease to humans. Specifically, that the pollutant load, which is the product of Nitrate Nitrogen and volume of water discharged out the seeps, stimulates excessive growth of macroalgae, resulting in degradation to the coral reef ecosystem. In addition, since the effluent is not disinfected prior to treatment, bacteria and other pathogenic microbial organisms are introduced into ocean waters.

The issue is complex and there are disparate conclusions among researchers, persons familiar with the issues, regulators, and Maui County officials. What does seem to be mutually agreed on is that water quality in the ocean along Kahekili Beach has been impaired. The main disputed points include: what is the cause of coral decline and nuisance algal proliferation, what is the role of effluent from LWRF, and what are the contributions of pollutants from sources other than the WWRF effluent.

Lahaina Injection Wells Release Wastewater to Coast, Tests Find (Tummons 2012)

In 2011, fluorescein dye was injected into the WWRF injection wells by University of Hawaiʻi researchers. Samples containing levels of fluorescein above baseline levels appeared at the coastline within several months, confirming the hydrologic connectivity of groundwater between the WWRF and two submarine groundwater seeps along the north part of Kahekili Beach. Sea surface temperature measurements made using thermal infrared equipment show that a plume of warmer water is emanating from the groundwater seeps.

Algal δ(15)N Values Detect a Wastewater Effluent Plume in Nearshore and Offshore Surface Waters and Three-Dimensional Model the Plume Across a Coral Reef on Maui, Hawaii, USA (Dailer et al. 2012)

The Kahekili coral reef is located approximately 984 ft (300 m) south of the Class V injection wells at the WWRF. Approximately 3-5 MGD of effluent is disposed into these wells. Prior research documented that the nearshore region of Kahekili is subject to percolation of wastewater effluent from the injection wells. Using algal bioassays from the nearshore region to 328 ft (100 m) offshore and throughout the water column from the surface to the benthic waters, significantly more δ(15)N[122] indicative of wastewater effluent was documented in algae at the surface rather than the benthos (bottom). The algal bioassays allowed generation of a three-dimensional model of the Kahekili coastal region wastewater plume. The highest δ15N values (~30-35 0/00) were located over freshwater seeps and surface sample effluent detection extended to 1,640 ft (500 m) south and 328 ft (100 m) offshore of the freshwater seeps (~8-11 0/00). The data shows that the WWRF effluent plume "(1) affected the majority of the shallow region at Kahekili, (2) rose to the surface waters in the area and (3) generally flowed south with the most predominant current in the area."

Using δ15N Values in Algal Tissue to Map Locations and Potential Sources of Anthropogenic Nutrient Inputs on the Island of Maui, Hawai'i, USA (Dailer et al. 2010)

Macroalgal blooms in the coastal waters of Maui occur only in areas of substantial nutrient input from sources such as wastewater effluent and agricultural fertilizers (Dailer et al. 2010b). From 1997 to 2008, the three County of Maui WWRFs injected an estimated total volume of 193 million cubic meters (51 billion gallons) of effluent with a Nitrogen mass of 1.74 million kilograms (3.84 million pounds). Dailer et al. (2010b) used algal δ15N signatures to map anthropogenic Nitrogen through coastal surveys and algal deployments along the near-shore and offshore areas of Maui. This research demonstrates the usefulness of algal δ15N values in distinguishing between natural and anthropogenic derived Nitrogen and identifying the extent that algal blooms are incorporating anthropogenic derived Nitrogen sources. Generally, algae collected from areas with low anthropogenic impacts had low δ15N values. The highest average value from a low impact site was significantly lower than those of algae collected from sites adjacent to the urban areas. Effluent was detected in areas proximal to the WWRF's operating Class V injection wells in Lahaina, Kīhei, and Kahului through elevated algal δ15N. The highest δ15N values in this study were found among algae collected adjacent to the County WWRF's.

A Multitracer Approach to Detecting Wastewater Plumes from Municipal Injection Wells in Nearshore Marine Waters at Kihei and Lahaina, Maui, Hawaii (Hunt and Rosa 2009)

Hunt and Rosa (2009) used a variety of sampling methods to locate and collect submarine groundwater discharge samples at Kīhei and Lahaina in areas of very shallow water close to shore. Water and macroalgae were analyzed to look for a suite of chemical and isotopic constituents. The results confirmed the presence of wastewater constituents in the samples collected from both locations. Wastewater presence was further confirmed at submarine springs near Lahaina by the presence of tribromomethane, two musk fragrances, a fire retardant, and a plasticizer compound that were all also detected in sampled effluent at the treatment plant. The results also revealed evidence of modifying processes such as denitrification and mixing of effluent with the surrounding

[122] Delta 15N (δ15N) is a nitrogen isotope whose abundance in benthic sediment is used to determine the contribution of wastewater and sewage to total nitrogen.

groundwater and seawater. Hunt and Rosa concluded that despite evidence of natural attenuation of nutrients within the effluent plumes and modifying processes, the plumes still constitute large nutrient fluxes to the nearshore environment.

Response of Nearshore Marine Water Chemistry to Termination of Sugarcane Agriculture; West Maui, Hawaii (Dollar 2001)

Results of previous studies conducted by Dollar (Dollar et al. 1999, Dollar and Andrews 1997) implicated sugarcane production as a major contributor to groundwater nutrient flux in the nearshore area and a possible factor in the proliferation of algae. This study was carried out approximately one year after the termination of sugarcane production in the West Maui area. The study continued sampling in areas used in previous work, prior to the termination of sugarcane production, in order to look at changes in groundwater nutrient discharge to the nearshore zone and possible correlations between the reductions in groundwater nutrient discharges and algal abundance. Ocean water samples were collected along with water samples from wells at locations inland from agricultural fields (both sugarcane and pineapple) and more towards the coast. Results reveal little to no indication of a reduction of nutrient subsidies to groundwater. This was attributed to the fact that flushing of the aquifer of agricultural nutrients is likely to take 2 to 10 years.

Coastal Water Quality in the Kihei and Lahaina District of the Island of Maui, Hawaiian Islands: Impacts from the Physical Habitat and Groundwater Seepage: Implications for Water Quality Standards (Laws 2001)

This study was funded by DOH and was prompted by algal blooms in the nearshore waters that brought public attention to water quality issues. Water samples were repeatedly collected at 27 different beaches in Kīhei and West Maui-Lahaina districts during 2000-2001. Water quality was assessed in terms of nutrient concentrations, turbidity, suspended solids, and Chlorophyll a. Onshore to offshore transects revealed that turbidity and concentrations of Nitrate and Chlorophyll a declined dramatically with the distance from the shoreline. Laws (2001) concluded that "the dramatic gradients in water quality within the first 100 m from the shoreline and the fact that some violations of water quality criteria within that zone appear to be the result of natural phenomena, underscore the difficulty of assessing the quality of coastal waters based on traditional parameters".

Terrestrial Nutrient and Sediment Fluxes to the Coastal Waters of West Maui, Hawaii (Soicher and Peterson 1997)

Soicher and Peterson (1997) examined the nutrient and sediment budgets from terrestrial sources entering coastal waters in the Lahaina District. Although the results did not reveal a definitive causal relationship between algae blooms and terrestrial nutrients and sediment loading, they indicated that the then active sugarcane and pineapple cultivation were contributing elevated loads of nutrients and sediments to the coastal waters. The data also indicated that disposal of treated domestic sewage effluent into subsurface injection wells contributes substantial nutrient loads to the coastal waters. Golf courses were not found to significantly contribute to the nutrient and sediment loading of coastal waters in the area. Soicher and Peterson also concluded that although groundwater discharges a greater annual nutrient load than streams, the groundwater discharges are evenly distributed in time and dispersed over a larger area of shoreline whereas streams have short periods of intense discharge in a few discrete locations and thus may have a substantial local impact on coastal water quality.

Assessment of Nutrient and Sediment Contributions from Four Land Use Classifications (Stevenson 1997)

Stevenson (1997) studied nutrient and sediment contributions from four categories of land use: forested reserve, sugarcane fields, pineapple fields, and urban areas. The forested reserve was found to contribute generally low levels of TN and TSS; and particularly low levels of Ammonium-Nitrogen when compared to agricultural sites. Extremely low concentrations of Total Phosphorus were also noted. Urban samples were compared to NURP EMCs. Urban-sourced TSS was found to be within the normal ranges for all samples but one - an outfall that discharged to Māhinahina drainage channel and had a contributing residential area with several single family homes undergoing construction. Urban area Total Phosphorus samples fell outside the NURP EMCs, with a geometric mean of the grab samples below the NURP ranges. The geometric mean for Dissolved Phosphorus exceeded NURP ranges, and the primary source was from fertilizers applied within the urban area.

Summary of Ongoing University of Hawaiʻi Mānoa Research

On February 14, 2012 Wendy Wiltse and Hudson Slay of the Honolulu Office of EPA and Kathy Chaston of NOAA met with Andy Hood (SRGII). EPA provided a verbal summary of three ongoing research studies being conducted by University of Hawaiʻi Mānoa scientists. The studies are necessary to provide critical data about the fate and transport of effluent waste water injected into the ground at the WWRF. Three independent, but related research studies are summarized below. Results are preliminary and no data and/or reports are available at this time to present or cite in this report.

Thermal infrared air surveys were conducted in May 2011 to identify sea surface temperatures along the Kāʻanapali/Kahekili shorelines. Thermal sensors attached to a small airplane measured sea surface water temperatures along flights paths aligned parallel to and over near shore waters. The sensors can detect very small temperatures differences and map areas of varying water temperature. The sensors measured a plume of warm water in the immediate area of two submarine groundwater seeps that discharge just off the shoreline fronting the Westin Villa Resorts and the open parcel to its north. The seeps are commonly known as the Kahekili Beach seeps. An unknown volume of the water discharged out the seeps is thought to be sourced from treated waste effluent injected into the ground at the WWRF. The plume of warm water is approximately 2 degrees Celsius higher than the ambient ocean water. There is no definitive explanation as to why the water from the seeps is warmer than the ocean water. Three hypotheses for the warm water are: treated waste water is warm and it flows to seeps without losing temperature; the injected waste water heats up due to microbial activity; or the waste water is warmed by geothermal processes. The latter two potential reasons for the warm water imply that water injected into the ground at the WWRF warms as it flows towards the seeps.

A tracer study using dye injected into the WWRF wells is being conducted to determine the fate and transport of WWRF effluent into coastal waters. Three wells on the WWRF parcel were injected with dye chemicals, Fluorescein and Sulfo Rhodamine B. Water samples are collected to detect the dyes along the shoreline in the water at depths of approximately 5 to 10 ft (1.5 to 3.0 m) in the vicinity of the two submarine groundwater seeps fronting the Westin Condominiums. The Fluorescein dye injected into WWRF Wells 3 and 4 in late July 2011 was detected at the seeps in late October 2011 and continues to be detected. The Sulfo Rhodamine B dye was injected into WWRF Well 2 in mid-August 2011 and has yet to be detected at the seeps or other sampling locations. Well 2 is approximately 100 ft (300 m) further *mauka* on the WWRF parcel than Wells 3 and 4. This distance is not significant and does not explain why the second dye has not been detected. It is surmised that either Sulfo Rhodamine B is attaching to particles in the aquifer and getting bound up (sorbed), or water from Well 2 is flowing along a different path than water from Wells 3 and 4. Regardless of the fate of Rhodamine, the Fluoroscein dye confirms a hydraulic connection between the effluent discharged at Wells 3 and 4 and the seeps.

Nitrogen is being sampled in the effluent injected at the WWRF, the ocean seeps, and wells *mauka* of the WWRF. Nitrogen concentrations in samples collected from the upland wells are less than the effluent concentrations. Nitrogen concentrations in samples from the effluent and the upland wells are higher than the ambient concentration in the open ocean and exceed water quality standards for nutrients in open coastal waters. The use of stable isotopes of Nitrogen collected at the seeps indicates that the effluent and upland *mauka* well waters concentration of Nitrate form of Nitrogen are reduced by microbes in the groundwater. The reduction of Nitrate Nitrogen has also been reported by Hunt and Rosa (2009) and Dailer et al. (2010).

The preliminary results of these three research studies support the hypothesis that effluent waste water injected at the WWRF is reaching the ocean and discharging out the two submarine springs at Kahekili. What is unclear is how much of the total volume injected at the WWRF is discharged at the two springs. Also unknown is what the other sources of Nitrogen are and how much Nitrogen is carried in groundwater discharged at the seeps and other locations along the shore.

Two other research studies are being conducted to quantify the transport, fate, and water quality associated with the effluent discharges from the WWRF. These two studies are being conducted by graduate students in the Department of Geology and Geosciences at the University of Hawaiʻi at Mānoa were presented during the Water Resource Sustainability Issues on Tropical Islands Conference held in Honolulu, November 14-16, 2011. SRGII attended the conference and the summary of the two studies is based on written abstracts distributed at and notes made during the presentations.

Locating and Quantifying Coastal Groundwater Discharges Potentially Originating from A Wastewater Treatment Facility was presented by Christine Waters. This study utilized a geochemical survey to distinguish ocean water from submarine groundwater discharged along the coast and at three seeps near Kahekili Beach Park. The goal of the study is to "verify or negate the relationship between injected effluent and groundwater discharges at the coast". Preliminary results show that effluent from the WWRF is discharged along the coast and at the seeps. How much of the groundwater discharged at the coast is from the WWRF was not conclusively determined. Further analysis and results from the field data collected have yet to be reported.

Geochemical Composition of Ground and Nearshore Marine Waters Kaʻanapali, Maui, Hawaiʻi was presented by Joseph Fackrell. The objective of this study was to test the conclusion made by Hunt and Rosa (2009) and Dailer et al. (2010) that effluent from the WWRF was entering the nearshore waters and to better understand the geochemical composition of both ground and nearshore marine waters. Fackrell used a stable isotope of Nitrogen to conduct analysis on water collected at various locations in the study area. The preliminary conclusion is that there is a strong hydrologic link and geochemical correlation between the WWRF effluent and discharge at the seeps along Kahekili Beach. Fackrell's research is continuing and results he presented were preliminary.

A Quantitative Assessment of Water Quality and Marine Communities in an Area Fronting the Development of the North Beach Project Site (Former Ka'anapali Airstrip), West Maui, Hawaii: November 2010 Dry Period Survey (Brock 2011)

The Brock (2011) study examined water quality data for 21 sites, including the six groundwater wells, and additional separate control sites, located along a 3,280 ft (1 km) section of coastline along North Beach in Kāʻanapali, located north of *Puʻu Kekaʻa* (Black Rock) adjacent to Kahekili Beach Park (Table D1). The research was part of a 10-year study begun in 1998 as part of an SMA permit for development on four lots totaling approximately 99 acres (40 ha).

Twenty biannual surveys were completed for six groundwater monitoring wells located on the land between the Honua Kai Resort and Kahekili Beach Park between 2001 and 2010. These wells are located across four lots included in the project site, stretching south from the present location of Honua Kai Resort to the border of Kahekili Beach Park. Wells 1, 4, and 5 are located on the *makai* side of the site in close proximity to the marine sampling locations. Wells 2, 3, and 6 are located on the *mauka* side of the site in proximity to the highway. The well locations are shown in Figure 22.

The study found weak gradients in some water quality parameters in both the study area and at the control site. In coastal surface waters these parameters decrease in a seaward direction, and include Nitrate Nitrogen, Orthophosphate and Silica. In November 2010, parameters including Nitrate Nitrogen and Total Nitrogen exceeded open coastal water quality standards for dry conditions. The standards were not met at the control sites, and are comparable to other sites within the State that were also out of compliance. The data suggests that non-compliance with water quality standards is not related to the development of the Honua Kai parcel, but rather a coast-wide phenomena. The study finds no upward trend through time in the parameter means from stations offshore of North Beach, except during large rain events that occur along the entire coast in the area. Measured nutrient concentrations found in wells are confirmed to be from inland sources passing underneath the project site.

The study recognizes Hunt and Rosa (2009) as determining WWRF effluent is reaching the shoreline. However Brock's study finds only a small nutrient concentration increase of groundwater near the shoreline, suggesting that groundwater containing the effluent has little impact to the receiving waters from a biological resource perspective. The study surmises that the effluent wastewater effluxing from (flowing out) groundwater at the southern area of the parcel and Kahekili Beach Park may be from the treated R-1 water used to irrigate Kāʻanapali Golf Course. Brock surmises that the use of R-1 water to irrigate the golf course for 30 years and data collected from the wells support his hypothesis. His claim that the golf course has been using R-1 water to irrigate for 30 years is questionable given that R-1 water from WWRF has only been available since 1996. Brock presents an alternative hypothesis that the local geology prevents injection well effluent from reaching wells on the northern part of the project site and instead rises further from the point of release and appearing in southern wells on the site.

The population increase in Lahaina over the 10 year study period has led to increase volume of wastes treated by the WWRF. Nutrient increases would be expected proportional to this as well as responses in the biota of receiving waters. However the sampling program has not found evidence of either of these. Therefore the majority of treated effluent is believed to be diffusely percolating over a broad area and functioning as designed.

The research conducted between 2001 and 2010 suggests that construction and maintenance activities occurring on the subject parcel are having no negative impact on marine biota or water quality in the receiving waters fronting the site.

Table D1. Groundwater Well Measured Concentrations

Excerpted from Brock (2011); All values in (µg/L)

Sample Date	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen	Nitrate (NO_3^-)	Ammonium (NH4+)	Total Nitrogen
	Well 1			Well 2			Well 3			Well 4			Well 5			Well 6		
2/1	104.58	78.26	616.28	-	-	-	777.14	24.92	1256.08	398.3	20.44	1001.7	2356.9	47.04	3307.64	4880.82	7.98	5684.28
8/1	ND	267.26	1275.12	172.76	26.6	2571.38	-	-	-	482.86	3.22	1926.12	3068.1	72.24	5010.88	5099.92	13.86	6629.7
2/2	3.54	341.13	1481.48	166.79	22.08	366.1	5.93	5508.17	11193.56	3251	3	5913.6	-	-	-	5649.21	9.71	8309.14
8/2	6.74	319.9	800.24	86.85	123.34	665.7	23.43	920.78	3653.02	533.43	16.66	1504.3	-	-	-	5526.61	2.08	8561.14
2/3	3.77	296.24	1902.46	-	-	-	-	-	-	2591.68	3.15	4329.92	4377.94	1.53	6341.72	5880.28	4.83	9655.8
9/3	ND	320.37	834.12	12.01	208.29	802.62	-	-	-	1656.23	1.49	2376.5	4648.62	1.09	5929.42	7214.25	1.94	8115.66
3/4	-	-	-	84.74	1.19	170.38	-	-	-	3735.15	1.86	8383.06	-	-	-	7743.8	1.72	12520.48
8/4	125.86	203.14	868.42	19.56	86.1	651.56	5.02	21.47	516.04	136	7.48	610.4	4987.5	47.87	6849.78	5549.44	3.54	7034.16
2/5	101.05	149.17	1146.6	49.58	91.8	760.9	1440.65	31.4	3571.26	1595.19	1.98	2654.26	-	-	-	3804.07	0.98	5916.82
8/5	12.46	388.64	832.44	29.4	161.56	738.08	375.34	3.78	1539.86	1299.76	1.82	1702.12	-	-	-	-	-	-
2/6	171.97	156.51	1196.58	47.1	141.71	1139.74	95.56	20.67	1071	817.42	18.84	1127.42	-	-	-	-	-	-
8/6	28.38	33.82	974.82	28.52	135.36	819.84	8.09	70.33	1776.6	94.35	8.74	741.58	245.46	31.14	1189.3	-	-	-
2/7	56.95	163.7	665.84	110.49	65.5	727.58	-	-	-	776.51	6.46	1252.72	119.39	132.43	1376.2	-	-	-
8/7	28.56	195.58	1302.28	34.58	139.86	1249.08	270.2	13.58	1438.78	538.16	10.36	3175.2	486.92	82.32	3392.48	161	14.56	1310.54
2/8	709.91	13.47	2583.56	9673.96	0.95	12630.94	2913.41	0.24	4635.26	2211.15	13.23	3998.68	501.84	52.99	2547.02	-	-	-
8/8	-	-	-	-	-	-	2047.85	11.85	3235.82	494.5	1527.77	5073.04	59.19	829.96	4068.26	1.79	11	2135.28
3/9	-	-	-	-	-	-	100.77	5.74	1736.7	938.59	4.19	1957.2	357.77	804.72	7820.12	54.41	72.32	1840.44
8/9	-	-	-	-	-	-	1701.2	10.06	3371.2	2484.05	14.39	3013.64	47.3	110.5	1348.76	1294.19	2.1	1680
4/10	-	-	-	-	-	-	9.94	24.22	845.18	1249.64	32.62	2414.44	157.64	71.96	1345.96	17136.42	35.7	23895.2
11/10	-	-	-	35.84	14	604.94	92.54	0	553.28	1704.5	116.06	2806.02	403.76	61.04	1979.04	354.2	4.62	1707.58
Mean	97	195	1177	754	87	1707	658	444	2693	1349	91	2798	1246	168	3750	4707	12	6962

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Appendix E. Background Information on Water Quality and NPS Pollutants

E.1. Understanding Water Quality

The impacts of pollutants on water quality and ultimately coral reef health, is a driving force behind this WMP. This section provides readers basic information about water quality to support their understanding of pollutant sources and how they affect various water quality parameters and watershed resources.

E.1.1. Water Quality Standards

As defined by the Federal Water Quality Standards Regulation (40 CFR §131.2) a water quality standard defines the water quality goals for a water body, or portion thereof, by designating the use or uses to be made of the water, by setting criteria necessary to protect the uses, and by protecting water quality through antidegradation provisions (EPA 1994). States adopt water quality standards to protect public health or welfare, enhance the quality of water, and serve the purposes of the CWA. The Regulation describes State requirements and procedures for developing, reviewing, revising, and adopting water quality standards, and EPA requirements and procedures for reviewing, approving, disapproving, and promulgating water quality standards as authorized by CWA Section 303(c).

HAR Chapter §11-54 defines the general policy of water quality antidegradation, as well as the state standards for particular pollutants for Hawaiʻi waters. The state standards for pollutants are defined by both narrative and numerical criteria (Appendix E.2). §11-54-1.1 defines a general policy of water quality antidegradation for all water types:

a) Existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

b) Where the quality of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the director finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the state's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the director shall assure water quality adequate to protect existing uses fully. Further, the director shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control.

c) Where high quality waters constitute an outstanding national resource, such as waters of national and state parks, and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.

State waters are classified as either inland waters or marine waters with specific water quality criteria set forth for streams, estuaries, embayments, open coastal waters and oceanic waters. For this area of West Maui, criteria for streams, open coastal waters, and oceanic waters are applicable.

“Streams” means seasonal or continuous water flowing unidirectionally down altitudinal gradients in all or part of natural or modified channels as a result of either surface water runoff or groundwater influx, or both. Streams may be either perennial or intermittent and include all natural or modified watercourses. “Open coastal waters” means marine waters bounded by the 183 meter or 600 foot (100 fathom) depth contour and the shoreline, excluding bays named in subsection (a) of HAR Chapter §11-54-6.

The format of Hawai‘i’s water quality standards differs from other states’ standards in that many of the criteria are expressed as geometric means of a representative data set, and are not intended for comparison with single sample values. The geometric mean indicates the central tendency or typical value of a set of numbers. The geometric mean normalizes the range being averaged so that no range dominates the weighting.

The criteria also contain allowances for rainfall events in the form of less strict “10 percent” and “2 percent” criteria. The “not to exceed the given value 10% of the time” means that the standard is exceeded if greater than 10% of the samples are higher than the appropriate standard for the season of interest. A sample size of 50 to 90 to show exceedance of the corresponding “10% of the time” criterion is preferred by DOH. The “not to exceed the given value 2% of the time” means that the standard is exceeded if greater than 2% of the samples are higher than the appropriate standard for the season of interest. A sample size of 250 to 450 to show exceedance of the corresponding “2% of the time” criterion is preferred.

Hawai‘i’s water quality standard categories are further refined by inclusion of a wet or dry criterion, defined either by calendar date by levels of freshwater input. Inland waters including springs and seeps, ditches and flumes, natural freshwater lakes, reservoirs, low wetlands, coastal wetlands, saline lakes, and anchialine pools, define wet and dry season based on the calendar date. “wet” season is November 1 through April 30 and “dry” season is May 1 through October 31. For estuaries, there is no specification for “wet” and “dry” season. For open coastal waters, “wet” criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile. “Dry” criteria apply when the open coastal waters receive less than three million gallons per day of fresh water discharge per shoreline mile.

E.1.2. Background versus Above Background Levels

Quantifying the amount of a substance, often reported as a concentration and expressed as mass per volume, is necessary to determine if its concentration is polluting the waters. In many instances it is necessary to sample a substance over time to determine if the level of the substance is increasing, and/or if it is higher than natural background levels. Background levels, often referred to as ambient conditions, exist for living and non-living substances in, and phenomena occurring on, the watershed. Background inherently implies reference to a time frame that may be difficult to quantify. Above background levels are simply levels of a substance that are higher than background.

Issues concerning the comparison and reporting of background versus above background levels occur when background levels are unknown or vary with time and space across the watershed. Water quality in the Kā‘anapali region has been sampled from a variety of sites over the last two decades. When compared to water quality standards, the concentrations of several parameters have often exceeded these standards (Section 5.3).

E.1.3. Physical Water Quality

There are various physical parameters that are tested when water quality monitoring is performed. These are not necessarily introduced contaminants, but normal parameters that are a function of the hydrologic cycle and biogeochemical processes taking place in the watershed. Parameters may fluctuate naturally with time and space or due to human alterations and activities in the watershed. Physical parameters such as pH, TSS, and temperature are tested to assess whether levels are normal or unusual, for either natural or unnatural reasons. Results of such testing are looked at holistically because combinations of factors and types of pollutants can cause certain problems due to synergistic effects.[123] For example, if there is an influx of agricultural runoff into a waterbody, the excess nutrients may result in an algal bloom. This causes an increase in plant biomass and then plant die-off and decomposition, leading to higher levels of suspended solids. The decomposing bacteria in turn increase the BOD and reduce the amount of DO in the water column, making it difficult for other aquatic organisms to survive. Physical water quality parameters typically tested for are shown in Box E1.

Box E1. Physical Water Quality Parameters

pH: pH is a measurement of Hydrogen ions and refers to a liquid's level of acidity or alkalinity. It is presented on a logarithmic scale of 0-14, with levels lower than 7 meaning acidic and levels higher than 7 meaning alkaline. pH has a direct effect on the solubility and biological availability of nutrients and toxic metals. Lower pH levels make toxic metals more soluble. pH is extremely important in water quality due to these synergistic effects.

Dissolved oxygen (DO): This is the amount of oxygen in the water column. In order for an aquatic ecosystem to be balanced, there are certain DO levels required to sustain aquatic organisms. If the level of DO is unusually low, this could indicate an unbalanced state such as eutrophication, where excess plant matter and its decomposition has caused a hypoxic environment.

Biological oxygen demand (BOD): BOD is an indirect measure of organic pollution. It measures the amount of DO needed for aerobic bacteria to decompose the organic material in a given water sample. If the BOD is high, this can point towards an increase in plant matter so this is an indirect indicator of eutrophication.

Temperature: Temperature varies naturally based on daytime and season. However, there are certain temperature ranges that are healthy for an aquatic ecosystem. If the temperature falls below or above that range, it affects the biological activity in that ecosystem. Wastewater effluent, runoff and other discharges can affect the temperature of a waterbody.

Total suspended solids (TSS): This is a measurement of particulate matter in the water. Water samples are filtered and the weight of the remaining particulates provides a measurement of particulate matter in the water column.[124]

Turbidity: This parameter is linked to many things, e.g. directly to the amount of TSS in the water. Turbidity is a measure of water clarity. It is measured in "Nephelometric Turbidity Units" or NTU, which is a measurement of how light is scattered by particulates in the water. Turbid waters can be caused by sediments, phytoplankton and other particulates. High turbidity reduces light penetration which affects plant photosynthesis. Settling particulates can also kill hatching larvae and clog fish gills.

Total dissolved solids: These are minerals or salts and trace elements that occur naturally, as well as plant nutrients such as Nitrogen and Phosphorus. The former generally affect the taste and clarity of water without having negative ecological impacts. The latter can cause ecological problems.

Salinity: This measures the amount of salt in the water and is generally used in estuaries and coastal waters. There are certain salinity levels that are healthy for certain ecosystems and an influx of freshwater into estuaries or the ocean can

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[123] Synergy: the interaction of elements that when combined produce a total effect that is greater than the sum of the individual elements, contributions, etc. (source: dictionary.com)

[124] TSS concentrations and turbidity both indicate the amount of solids suspended in water. However, TSS is a measure of the suspended solids in wastewater, effluent, or waterbodies determined by tests for "total suspended non-filterable solids", whereas turbidity is a measure of water clarity and how much the material suspended in water decreases the passage of light through the water (EPA 2012). TSS allows for the calculation of the total quantities of material within or entering a waterbody, turbidity does not.

have a negative impact on the aquatic organisms. Even treated wastewater, when directly released into the ocean, is sometimes considered pollution not just because of the nutrients and bacteria, but because of the dilution it causes in the seawater.

Electrical conductivity: This measurement is an estimate of the total dissolved ions/minerals in the water and varies naturally depending on the geology and other factors in a watershed. Electrical conductivity measurements can help determine possible pollution problems in the water as various pollutants from wastewater, agricultural and urban runoff may cause an increase in electrical conductivity.

Chlorophyll a: This measures the amount of Chlorophyll, the cell component of plants that makes them green. This measurement is an indirect way of estimating plant (algae) biomass in the water.

Stream flow: Stream flow is a measure of water velocity. It is subject to seasonal variation. Stream flow has a direct effect on several water quality parameters as it affects temperature, DO and the distribution of various substances. It can also potentially alter habitat. Problems can arise during storm events when heavy rainfall causes high velocity and streambank erosion, which in turn affects the amount of TSS and turbidity. It can also physically damage habitat. Stormwater runoff is a contributor to variable flows that can negatively impact aquatic ecosystems.

E.1.4. Chemical Water Quality

Nutrients such as Nitrogen and Phosphorus are used as chemical water quality parameters since nutrient pollution can lead to disturbances in fresh and saltwater ecosystems. Nitrogen and Phosphorus are natural elements with their own respective biogeochemical cycles.

Nitrogen is naturally present in the environment, in soil, in the atmosphere and all living things. It makes up 78% of air. It is present in multiple organic and inorganic forms such as Ammonium, Nitrite and Nitrate and Nitrogen gas. The Nitrogen cycle is a complex sequence of conversions of various Nitrogen states to other states as it moves through the environment, the ground, water, and atmosphere (Box E2). Nitrogen is an important source of food for plants and in order for them to use it, bacteria "fix" the Nitrogen, i.e. convert it to a usable form. For example, Ammonium (NH_4^+) present in the soil from decomposed animal excretions gets converted to Nitrite and later Nitrate, which can be absorbed by plants. These ionic forms later get converted back into Nitrogen gases that enter the atmosphere, completing the cycle.

Phosphorus is a mineral that is present in the terrestrial environment in water, soil, and sediments and whose biogeochemical cycle excludes any atmospheric stage. Phosphorus is most commonly found in rocks and ocean sediments in the form of phosphate salts. The phosphate salts are released through weathering of rocks and move through the system tightly bound to soil molecules and delivered with sediments because Phosphorus is not highly soluble. Phosphorus drains from the land to the ocean, but a considerable amount is deposited in ocean sediment from the shells and bones of marine organisms and by precipitation and settling of phosphates. In most soils the Phosphorus absorbed by plants comes from organic molecules that undergo decomposition and release Phosphorus in plant-available inorganic forms. Phosphorus is an important nutrient for plants.

Box E2. Understanding Nitrogen

The Forms of Nitrogen. Nitrogen load inputs into the ocean are of concern due to their potential to adversely impact the Bay by stimulating primary productivity of the food chain and triggering harmful algal blooms. Nitrogen from treated waste water effluent, fertilizers, human and animal waste, and decomposing vegetation (including food waste) are all likely sources of Nitrogen found in the ocean.

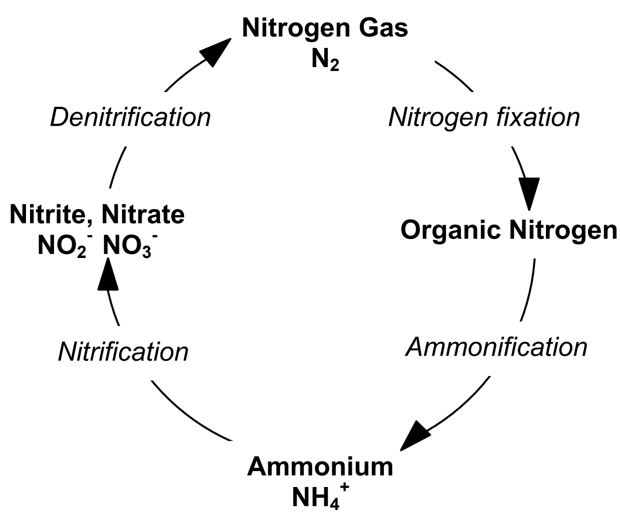
Nitrogen in Living Things. Nitrogen is a component of amino acids and urea. Amino acids are the building blocks of all proteins. Proteins comprise not only structural components such as muscle, tissue and organs, but also enzymes and hormones essential for the functioning of all living things. Urea is a byproduct of protein digestion. The term "organic Nitrogen" is used to describe a Nitrogen compound that had its origin in living material. The Nitrogen in protein and urea is organic Nitrogen. Organic Nitrogen can be introduced to the environment from sanitary waste systems including waste water treatment plants, septic and cesspool systems, from humans and animals, as discarded food material, or as ingredients of cleaning agents.

Ammonification. Many of the transformations of Nitrogen in both soluble and particulate forms are mediated by bacteria that use different forms of Nitrogen. During the processes of decomposition, the Nitrogen in proteins is transformed eventually to Ammonia (NH_3) or Ammonium (NH_4^+) by certain kinds of bacteria. These processes are called ammonification. Nitrogen in the liquid or leachate from waste water systems is primarily Ammonium. Some of the leachate discharged into the ground becomes adsorbed to soil particles and is effectively immobilized from further transport.[125]

Nitrification. Some kinds of bacteria change Ammonia (NH_3) to Nitrite or Nitrite to Nitrate. These processes are called nitrification. Nitrification is an aerobic process and can occur only in the presence of oxygen.[126] The Nitrate form of Nitrogen is the one most used for plant growth, and is the most mobilized form in groundwater. Nitrate in ocean waters is often the primary reason for triggering algal blooms, which can create nuisance mats of floating algae in and on the water, and lead to stress on fishes and other aquatic organisms due to the use of oxygen in the water by bacteria that "feed" on the algae. The Ammonium form of Nitrogen is also used by plants, but is not as mobile in water and therefore not as problematic with respect to triggering algal blooms in the ocean.

Denitrification. Some bacteria species in soils can take Nitrate and change it back to Nitrogen gas through a process called denitrification. Denitrification is an anaerobic process. This means it only takes place when no oxygen or extremely low concentrations of oxygen are available and a source of carbon for the bacteria is present in the soil. The amount of Nitrate in groundwater that is denitrified prior to entering the ocean is unknown, as is the amount in Nitrate form. In general, denitrification probably lowers some of the Nitrate reaching the ocean, which reduces the potential threat of algal blooms.

Simplified Nitrogen Cycle. In summary, Nitrogen cycles through the air, water, and soils, with many transformations controlled by the actions of specialized bacteria. Some of these transformations require aerobic conditions while others occur only under anaerobic conditions. Under the best case scenario bacteria will regulate the amount of Nitrogen in forms transported in surface water and groundwater discharged in the ocean that can potentially disrupt the food chain and trigger algal blooms.



Simplified Nitrogen cycle, *italics* denote processes and **bold** the different forms of Nitrogen.

Nutrients become a problem in the environment when excess amounts are present in watersheds and are eventually delivered to the ocean. While Nitrogen and Phosphorus are extremely important nutrients for terrestrial and aquatic plants, excess concentrations disrupt the ecological balance of aquatic ecosystems. The atomic ratio of Carbon, Nitrogen and Phosphorus, is relatively consistent for all marine biomass (dead and living) from coastal to open ocean regions. The ratio, called the

125 Absorbed means taken into soil particle. Adsorption means to stick to the outside of a soil particle.

126 Aerobic means occurring in the presence of oxygen. Anaerobic means in an environment of little to no oxygen.

Redfield ratio, is C:N:P = 106:16:1. The Redfield ratio may be used to estimate carbon and nutrient fluxes and which nutrient is the limiting factor for growth.

Nutrients support the growth of aquatic plants, including algae, which provide a food source for other aquatic organisms and produce oxygen via photosynthesis. However, when nutrient levels are high, they can lead to eutrophication, which is an excessive production of plant biomass in the water, leading to decomposition and a hypoxic environment. An example is the stimulation of algae growth that can block sunlight from reaching other aquatic organisms and leads to a die-off of larger amounts of algae, which is decomposed by bacteria in a natural process. These bacteria use more oxygen than under normal conditions, reducing the amount of oxygen available to other aquatic organisms. The reduction in sunlight and oxygen makes it difficult for other aquatic organisms to survive.

Because Nitrogen and Phosphorus stimulate plant growth, they are used as chemical fertilizers in agricultural production to increase yield. Agricultural runoff is a significant contributor of nutrients to the Nation's waterbodies. The EPA has ranked Nitrogen and Phosphorus pollution as one of the top causes of degradation in U.S. waters for over a decade. Sources of these nutrients are agricultural runoff as well as wastewater from leaking septic tanks and wastewater treatment effluent.

E.1.5. Biological Water Quality

Microbes in fresh and salt water can come from a variety of sources within a watershed, and be contained in both surface water and groundwater. Suspected sources are feral ungulates contributing fecal matter, birds, domestic animals (i.e. dogs, cats), livestock, and human sewage via leaking septic tanks or wastewater seepage. Some bacteria strains occur naturally in the environment. Microbial contamination is an environmental health concern as different types of bacteria and other microorganisms such as *Giardia, Cryptosporidium and Staphylococcus* can transmit disease and cause infections in humans. Transmission of water borne diseases is through contact with contaminated water (i.e. during surfing or swimming), or ingesting contaminated water. According to EPA, pathogens are the second most frequent cause of water quality impairments under the CWA. The increased interaction of humans and domestic and feral animals is stimulating the evolution of new pathogens. Several microorganisms that used to live only within animals have evolved to infect humans (e.g. avian flu) (EPA WQ strategy document).

E.1.5.1. Enterococci

Pollutants from sewage-related sources are both an environmental issue and a public health concern, since sewage can contain harmful pathogens that cause a variety of illnesses in humans. Sewage can affect ocean and freshwater systems through point and non-point sources (i.e. sewage treatment facilities (point source) and cesspools (non-point source)) (Hartz et al. 2008). To decide whether coastal waters are safe for swimmers, Hawai'i DOH monitors bacteria levels in ocean waters. There are multiple disease-causing agents that can be present in sewage and it is unfeasible to test for each one. Therefore, agencies throughout the world, including the World Health Organization, EPA, and DOH, use fecal indicator bacteria to determine if sewage contamination is present. Past indicators include fecal coliform and *Escherichia coli* (*E. coli*). In 1988, the Federal standard for assessing marine water health risks officially became bacteria of the genus *Enterococcus* (DOH FAQs and Hartz et al. 2008). Indicator bacteria are not pathogens themselves, but rather they are bacteria naturally present in the feces of warm-blooded birds and mammals. Finding high levels of *enterococci* in water is an indicator that fecal contamination may have occurred near the testing site. EPA established *enterococci* as an indicator because studies over many years have shown a positive correlation between high levels of *enterococci* and gastrointestinal illnesses caused by sewage-related bacteria and viruses. *Enterococci* is also used due to it being a good indicator in saltwater. *Enterococci* die off in the water column at about the same rate, making it a useful tool in determining when waters are swimmable (DOH FAQs and DOH Rationale document, 2009).

The Federal standard for *enterococci* is set at 35 CFU/100ml. The current standards used to determine safe swimming conditions in Hawaiʻi are: Inland waters – 33 CFU/100ml in 5 or more samples, single sample maximum 89 CFU/100ml; Coastal waters within 300m of the shore – 35 CFU/100 ml in 5 or more samples, single sample maximum 104 CFU/100ml (HAR §11-54). One important consideration is that *enterococci* have also been found to naturally occur in Hawaiian soils where they are able to survive longer than in water (up to 28 days in laboratory conditions) (Craig et al. 2002; Fujioka et al. 1991). In the event of heavy rains, streambank erosion can cause increased levels of *enterococci* in streams and the ocean that are not from a sewage-related source. Therefore, *enterococci* is not an ideal indicator to use in Hawaiʻi and DOH is working on identifying other indicator organisms (DOH FAQs). To address the issues of soil presence, DOH has developed a "toolbox approach" to further narrow down whether elevated levels of *enterococci* are related to sewage. To do this, they test for additional organisms (i.e. *Clostridium perfringens*) when *enterococci* levels are high. Although these organisms are not officially recognized by EPA as indicators, DOH Clean Water Branch is allowed to use them as a secondary indicator to trace human sewage. Other modern tools used by scientists in the past few years have been DNA markers to trace contaminated waters by their fecal source, e.g. pig, human or ruminant.

E.2. State of Hawaii Water Quality Standards[127]

(Source: Department of Health - Amendment and Compilation of Chapter 11-54 of Hawaii Administrative Rules, May 27 2009)

Toxic Pollutants - Applicable to ALL WATERS

	Freshwater		Saltwater		
Pollutant	Acute (µ/L)	Chronic (µ/L)	Acute (µ/L)	Chronic (µ/L)	Fish Consumption (µ/L)
Acenapthene	570	ns	320	ns	ns
Acrolein	23	ns	18	ns	250
Acrylonitrile*	2,500	ns	ns	ns	0.21
Aldrin	3	ns	1.3	ns	0.000026
Aluminum	750	260	ns	ns	ns
Antimony	3,000	ns	ns	ns	15,000
Arsenic	360	190	69	36	ns
Benzene*	1,800	ns	1,700	ns	13
Benzidine*	800	ns	ns	ns	0.00017
Beryllium*	43	ns	ns	ns	0.038
Cadmium	3+	3+	43	9.3	ns
Carbon tetrachloride*	12,000	ns	16,000	ns	2.3
Chlordane*	2.4	0.0043	0.09	0.004	0.00016
Chlorine	19	11	13	7.5	ns
Chloroethers-					
ethy (bis-2)*	ns	ns	ns	ns	0.44
isopropyl	ns	ns	ns	ns	1,400
methyl (bis)*	ns	ns	ns	ns	0.0006
Chloroform*	9,600	ns	ns	ns	5.1
Chlorophenol (2)	1,400	ns	ns	ns	ns
Chlorpyrifos	0.083	0.041	0.011	0.0056	ns
Chromium (VI)	16	11	1,100	50	ns
Copper	6+	6+	2.9	2.9	ns
Cyanide	22	5.2	1	1	ns
DDT*	1.1	0.001	0.013	0.001	0.000008
metabolite TDE*	0.03	ns	1.2	ns	ns
Demeton		0.1	ns	0.1	ns
Dichloro-					
benzenes*	370	ns	660	ns	850
benzidine*	ns	ns	ns	ns	0.007
ethane (1,2)*	39,000	ns	38,000	ns	79
ehenol (2,4)	670	ns	ns	ns	ns
propanes	7,700	ns	3,400	ns	ns
propene (1,3)	2,000	ns	260	ns	4.6
Dieldrin*	2.5	0.0019	0.71	0.0019	0.000025

127 Although the State standards for most parameters are presented in micrograms per liter (µg/L), the tables (except for Toxic Pollutants) have been converted to milligrams per liter (mg/L) to be consistent with how data are presented in scientific publications.

Pollutant	Freshwater Acute (µ/L)	Freshwater Chronic (µ/L)	Saltwater Acute (µ/L)	Saltwater Chronic (µ/L)	Fish Consumption (µ/L)
Dinitro-					
o-cresol (2,4)	ns	ns	ns	ns	250
toluenes*	110	ns	200	ns	3
Dioxin	0.003	ns	ns	ns	$5.0x10^{-9}$
Diphenyl-hydrazine (1,2)	ns	ns	ns	ns	0.018
Endosulfan	0.22	0.056	0.034	0.0087	52
Endrin	0.18	0.0023	0.037	0.0023	ns
Ethylbenzene	11,000	ns	140	ns	1,070
Fluoranthene	1,300	ns	13	ns	18
Guthion	ns	0.01	ns	0.01	ns
Heptachlor*	0.52	0.0038	0.053	0.0036	0.00009
Hexachloro-					
benzene*	ns	ns	ns	ns	0.00024
butadiene*	30	ns	11	ns	16
Cyclohexane-					
alpha*	ns	ns	ns	ns	0.01
beta*	ns	ns	ns	ns	0.018
technical*	ns	ns	ns	ns	0.014
cyclopentadiene	2	ns	2	ns	ns
ethane*	330	ns	310	ns	2.9
Isophorone	39,000	ns	4,300	ns	170,000
Lead	29+	29+	140	5.6	ns
Lindane*	2	0.08	0.16	ns	0.02
Malathion	ns	0.1	ns	0.1	ns
Mercury	2.4	0.55	2.1	0.025	0.047
Methoxychlor	ns	0.03	ns	0.03	ns
Mirex	ns	0.001	ns	0.001	ns
Napthalene	770	ns	780	ns	ns
Nickel	5+	5+	75	8.3	33
Nitrobenzene	9,000	ns	2,200	ns	ns
Nitrophenols*	77	ns	1,600	ns	ns
Nitrosamines*	1,950	ns	ns	ns	0.41
Nitroso-					
dibutylamine-N*	ns	ns	ns	ns	0.19
diethylamine-N*	ns	ns	ns	ns	0.41
dimethylamine-N*	ns	ns	ns	ns	5.3
diphenylamine-N*	ns	ns	ns	ns	5.3
Pyrrolidine-N*	ns	ns	ns	ns	30
Parathion	0.065	0.013	ns	ns	ns
Pentachloro-					
ethanes	2,400	ns	130	ns	ns
benzene	ns	ns	ns	ns	28
phenol	20	13	13	ns	ns
Phenol	3,400	ns	170	ns	ns

Pollutant	Freshwater		Saltwater		
	Acute (µ/L)	Chronic (µ/L)	Acute (µ/L)	Chronic (µ/L)	Fish Consumption (µ/L)
2,4-dimethyl	700	ns	ns	ns	ns
Phthalate esters					
dibutyl	ns	ns	ns	ns	50,000
diethyl	ns	ns	ns	ns	590,000
di-2-ethylhexyl	ns	ns	ns	ns	16,000
dimethyl	ns	ns	ns	ns	950,000
Polychlorinated biphenyls*	2	0.014	10	0.03	0.000079
Polynuclear aromatic hydrocarbons*	ns	ns	ns	ns	0.01
Selenium	20	5	300	71	ns
Silver	1+	1+	2.3	ns	ns
Tetrachloro-					
Ethanes	3,100	ns	ns	ns	ns
benzene (1,2,4,5)	ns	ns	ns	ns	16
ethane (1,1,2,2)*	ns	ns	3,000	ns	3.5
ethylene*	1,800	ns	3,400	145	2.9
phenol (2,3,5,6)	ns	ns	ns	440	ns
Thallium	470	ns	710	ns	16
Toluene	5,800	ns	2,100	ns	140,000
Toxaphene*	0.73	0.0002	0	0.0002	0.00024
Tributylin	ns	0.026	ns	0.01	ns
Trichloro-					
ethane (1,1,1)	6,000	ns	10,400	ns	340,000
ethane (1,1,2)	6,000	ns	ns	ns	14
ethylene*	15,000	ns	700	ns	26
phenol (2,4,6)	ns	ns	ns	ns	1.2
Vinylchloride*	ns	ns	ns	ns	170
Zinc	22+	22+	95	86	ns

ns - No standard has been developed

* - Carcinogen

\+ - The value listed is the minimum standard. Depending on hardness of receiving waters ($CaCO_3$), higher standards may be calculated using formula from EPA Water Quality Criteria (EPA 440/5-86-001)

Compounds listed in plural are mixtures of isomers. Numbers listed refer to total allowable concentration of any combination of isomers in compound.

Criteria for All Streams

Parameter	Geometric Mean not to exceed given value	Not to exceed given value more than 10% of the time	Not to exceed given value more than 2% of the time
Total Nitrogen (mg/L)			
Wet season*	0.25	0.52	0.8
Dry season*	0.18	0.38	0.6
Nitrate + Nitrite Nitrogen (mg/L)			
Wet season	0.07	0.18	0.3
Dry season	0.03	0.09	0.17
Total Phosphorus (mg/L)			
Wet season	0.05	0.1	0.15
Dry season	0.03	0.06	0.08
Total Suspended Solids (mg/L)			
Wet season	20.0	50.0	80.0
Dry season	10.0	30.0	55.0
Turbidity (N.T.U.)			
Wet season	5.0	15.0	25.0
Dry season	2.0	5.5	10.0

* - Wet season: November 1 - April 30

** - Dry season: May 1 – October 31

L - Liter

N.T.U. - Nephelometric Turbidity Units. Comparison of intensity of light scattered by sample under equal conditions. Higher intensity = higher turbidity

mg - Milligram or 0.001 grams

Additional stream water quality parameters:

Enterococci	33 CFU/100ml in 5 or more samples, 89 CFU/100ml in single sample
pH Units	Not to deviate more than 0.5 units from ambient conditions; not to be lower than 5.5 or higher than 8.0
Dissolved Oxygen	Not less than 80%, determined as a function of water temperature
Temperature	Not to vary more than one degree Celsius from ambient conditions
Specific Conductance	Not to exceed 300 micromhos/centimeter

Criteria for Open Coastal Waters

Parameter	Geometric Mean not to exceed given value	Not to exceed given value more than 10% of the time	Not to exceed given value more than 2% of the time
Total Nitrogen (mg/L)			
Wet season*	0.15	0.25	0.35
Dry season*	0.11	0.18	0.25
Ammonia Nitrogen (mg/L)			
Wet season	0.0035	0.0085	0.015
Dry season	0.002	0.005	0.009
Nitrate + Nitrite Nitrogen (mg/L)			
Wet season	0.005	0.014	0.025
Dry season	0.0035	0.010	0.020
Total Phosphorus (mg/L)			
Wet season	0.02	0.040	0.060
Dry season	0.016	0.030	0.045
Chlorophyll a (mg/L)			
Wet season	0.0003	0.000945	0.00175
Dry season	0.00015	0.0005	0.001
Turbidity (N.T.U.)			
Wet season	0.0005	0.00125	0.002
Dry season	0.0002	0.0005	0.001

* - Wet season criteria apply when the open coastal waters receive more than three million gallons per day of fresh water discharge per shoreline mile.

** - Dry season criteria apply when the open coastal waters receive less than three million gallons per day of fresh water discharge per shoreline mile.

L - Liter

N.T.U. - Nephelometric Turbidity Units. Comparison of intensity of light scattered by sample under equal conditions. Higher intensity = higher turbidity

mg - Milligram or 0.001 grams

Additional water quality parameters:

Enterococci	35 CFU/100ml in 5 or more samples, 104 CFU/100ml in single sample
Clostridium perfringens	>50CFU/100ml
pH Units	Not to deviate more than 0.5 units from a value of 8.1, except at coastal locations where and when freshwater from stream, storm drain or groundwater discharge may decrease pH to 7.0
Dissolved Oxygen	Not less than 75%, determined as a function of water temperature and salinity
Temperature	Not to vary more than one degree Celsius from ambient conditions
Salinity	Not to vary more than 10% from natural or seasonal changes considering hydrologic input and oceanographic factors

State of Hawaii Effluent Monitoring Standards

(Source: Department of Health - Amendment and Compilation of
Title 11, Chapter 62 of Hawaii Administrative Rules, January 14, 2004)

Parameter	Standard	Sampling Schedule
BOD	Not to exceed 30 mg/L for arithmetic mean of composite samples Not to exceed 60 mg/L for grab sample	Large facilities**: Composite sampling at least weekly Small Facilities: Grab sampling at least monthly
TSS	Not to exceed 30 mg/L for arithmetic mean of composite samples Not to exceed 60 mg/L for grab sample	Large facilities: Composite sampling at least weekly Small Facilities: Grab sampling at least monthly
Total Daily Flow	Specified in permit	Monitored weekly
Pathogens in sludge: Fecal coliform OR *Salmonella sp.*	Not to exceed 1000 MPN/g of total solids (based on dry weight) Not to exceed 3 MPN/g of total solids (based on dry weight)	Seven samples must be analyzed before sludge is used, disposed, etc.

*Composite sample results are based on one or more analyses in a 30-day period. For this, at least eight samples are required. They have to be done under flow proportional conditions (i.e. either the time interval between each aliquot or the volume of each aliquot must be proportional to either the stream flow at the time of sampling or the total stream flow since the collection of the previous aliquot).

**Large facilities have a design flow higher than 100,000 gallons per day. Small facilities have a design flow of less than 100,000 gallons per day.

E.3. Effects of Erosion and Vegetation on Hydrology

E.3.1. Erosion and Sedimentation

Soil is formed by chemical weathering and to a lesser degree, physical weathering of rock material. Soils are generally found in the location where they formed and develop horizons or layers that contain different levels of organic material, chemical concentrations, texture, colors and thickness.

Sediment is material that includes soils and fragments of rocks and other debris that were transported from their original locations via wind and water. Thus, sediments are a depositional feature. After long periods, some sediment can weather and develop into soils. Sediments generally do not contain horizons but may contain graded zones or layers differentiated by particle sizes.

This distinction between soil and sediment is critical when designing restoration and erosion control bioengineering strategies. For example, installing vegetative cover to an area that has a developed soil profile may only require planting of either seed or container stock and supplemental water, while an area that has sediments would require soil amendments such as fertilizers and physical site preparation to support plant establishment. Additionally, the volume of sediments and their locations can yield clues as to the condition of a watershed and can lead to diagnosing or discovering the location of sediment source.

E.3.2. Non-native (Introduced) Vegetation

Non-native plants, introduced either on purpose or inadvertently, have displaced native plants that evolved on the island over millions of years. Some scientists hypothesize that non-native forest canopy structure and plant types are less effective than a forest covered with native vegetation in controlling erosion rates, capturing rainfall, and maintaining recharge to high level aquifers. However, publications supporting this hypothesis were not found during a literature search. Recent research has shown that non-native forest trees use more water compared to native trees, resulting in a decrease of groundwater recharge and other alterations to the hydrologic cycle (T. Giambelluca, pers. comm.).

In many areas the removal of vegetation and the physical damage to the ground surface changes the ratio of rainfall to runoff. In forested areas dominated by native plants the canopy structure and ground cover is often dense and multi-storied. The vegetation in native forests plays a significant role in the hydrologic cycle by directly intercepting rain, which protects the ground surface from raindrop erosion; temporarily storing water on its surfaces; and facilitating infiltration of water into the ground and recharge of high level aquifers. Removal of native forest and encroachment by non-native plants reduce these functions, and often leads to increases in surface erosion, reduction of groundwater recharge, and increases in surface water runoff.

E.3.3. Climatic Controls on Plants and Erosion

Weather patterns and the climate regime that affect the project area have a significant impact on the erosion process. For most of the year trade winds dominant the weather pattern and rainfall amounts from individual trade showers is often low (<0.01 inch). During dry periods between the brief trade showers evapotranspiration often exceeds rainfall. This causes soil moisture to drop to levels that make it difficult for plants to pull water from the soil. This may cause plants to become stressed, and dormancy and die off may occur. Plants that evolved in this type of climatic regime developed growth strategies to accommodate dry periods in order to maintain vigor and root tensional strength. Following the dry period, winter rains frequent the island chain. Plants such as annual invasive grasses that have died off and lost stems have a reduced canopy, which exposes ground surfaces surrounding the plants. Additionally, roots lose tensional strength and their ability to hold soil particles is reduced. The winter rainfall events that occur in the early part of the rainy season occur the when soil is most vulnerable and erodibility[128] is high. The frontal winter storms differ from the summer trade wind dominated showers in that precipitation intensity and amounts are higher and more erosive.

E.3.4. Effects of Fire on Plants and Erosion

Subsequent to fire the landscape is often bare and exposed, which increases the vulnerability to accelerated erosion and, in steep areas, landslides. This scenario is exacerbated by non-native vegetation that is not drought tolerant and dies back during the dry summer months or periods of drought. In watersheds where this scenario has played out, erosion rates and sediment loads carried in runoff have been observed to be extreme (A. Hood, pers. comm.).

The potential indirect adverse effects are a consequence of the alteration of the natural fire regime. This includes the alteration of the vegetation at the local ecosystem and landscape levels of the affected watersheds. Combined with the direct effects on soil and its biota, the result could be the overall degradation of watershed health and native biodiversity. These indirect effects could also include reduced water quality and available water resources, and of the loss of ecosystem level watershed services, such as groundwater infiltration, aquifer recharge, flood control, nutrient cycling, and others.

E.4. NPS Pollutant Transport

Transport of NPS pollutants and their delivery to receiving waters is a function of several variables that ultimately determine their fate and condition. The distance between the NPS pollutant source and the receiving water body, as measured along the pathway the NPS pollutant is carried, plays a major role in determining the travel time and condition of the NPS pollutant. For example, Nitrogen discharged in effluent water at the WWRF in its Nitrate form (NO_3^-) is denitrified due to the relatively long travel time it takes for water to flow from the WWRF to the ocean.

Sediment load is not only a function of the area of erodible soil, but other factors such as proximity of the source to drainage courses, rainfall patterns, and condition of the flow path it is transported along. Therefore, a single moderately sized hotspot sediment source that is located in immediate proximity to a receiving water can contribute a significant load compared to multiple or larger sites that are farther from the receiving water or that are attenuated[129] during transport over the watershed.

Many NPS pollutants are associated with sediments that are transported primarily in surface water. Thus sediment laden runoff from a farm field likely is likely transporting a portion of chemicals applied to fields (e.g. fertilizers and pesticides). Several forms of Phosphorus attach directly onto sediment particles and sediment movement is the primary transport mechanism.

[128] Erodibility is a term used to describe a soil's susceptibility to erosion.

[129] Attenuation of sediment occurs as flow carrying the particles encounters vegetated areas where sediment can be filtered by plant material, and deposited along the flow paths in flat and depression areas, commonly referred to as sinks.

Nutrients migrate into the soils via groundwater infiltration and surface water runoff. During rainfall events, nutrients, sediment, chemicals, and bacterial pollutants are carried overland into the stream channels, where they are carried in runoff to the ocean.

Several classes of NPS pollutants, including nutrients, can be found in two forms: dissolved and particulate matter. Dissolved forms of pollutants are so small that they are in solution and move at the rate of the solution (water) they are dissolved in. The dissolved form is primarily associated with pollutant transfer through soils and contamination of groundwater, though it can also be readily carried in surface runoff. Particulate matter is a mobile form of substrate and is the form most commonly transported in surface water runoff. Control and sequestration of NPS pollutants, whether they are dissolved or in particulate form, is a challenge. The most effective approach to reducing NPS loads to the ocean is to reduce their generation at the source.

E.4.1. Agricultural Activities

Farming activities can expose soil and change surface water flow patterns, both of which can increase rates of erosion and loads of sediments and other NPS pollutants delivered into the ocean. Application of fertilizers and pesticides introduces nutrients and chemicals to fields, which can be leached into groundwater via irrigation water. Leaching occurs when irrigation rates are higher than plant uptake. Fertilizers that leach below the root zone are not available to the plants, are wasteful to the applicator, and costly to the groundwater. It is unknown if fertilizer application rates in the project area are applied based on information such as soil nutrient levels, plant requirements, and irrigation applications.

Under certain weather conditions wind picks up dust and soil particles and carries them to downwind locations. In addition, fugitive dust generated by motorized vehicles can be transported from the ground into the air.

E.4.2. Urban Activities

Due to the S4 and impervious surfaces in the urban areas, NPS pollutants can be quickly routed off the landscape during rainfall and rapidly delivered to the ocean. A certain portion of NPS pollutants, such as the Ammonium and Nitrate forms of Nitrogen, are carried in groundwater to the ocean. Runoff generated in the Conservation and Agricultural Districts that makes its way to the Urban District is routed rapidly due the S4 system. The water received into the Urban District is not detained and NPS pollutants are not attenuated.

Large amounts of NPS pollutants are associated with a phenomenon referred to as the *first flush*. During dry periods, impervious surfaces accumulate NPS pollutants generated by human activities or from atmospheric dry fall. The time interval between runoff-generating rainfall events is referred to as the accumulation phase. The *first flush* is the first big rainfall event occurring after the accumulation phase. It contains the highest concentration of contaminants and generates the highest pollutant loads at its receiving waters (Scholze et al. 1993).

E.5. Causal Impacts of Land Based Pollutants on Selected Ocean Resources

Coral reef ecology is primarily based on processes of reproduction and recruitment, which are dependent on water and substratum quality. Pollutants and related synergistic[130] effects can cause mortality and disease in species; hinder ecological functions; impede growth, reproduction and larval development; and cause trophic structure and dynamic changes (NOAA Coral Program 2009). The casual relationship between coral reef ecosystems and impacts from ocean based extractive and contact activities such as fishing, swimming and diving and the deposition of land based activities in ocean waters is complex. Research by scientists and anecdotal observations by persons who utilize the ocean for economic gain and/or recreational opportunities are in agreement that policies to prevent overfishing and protection of key fish resources, limit inputs of land based pollutants, and minimize physical impacts to coral reef are necessary to protect and maintain healthy coral reefs (Davidson et al. 2003).

This section provides some specific examples of adverse impacts that land-based pollutants have on the ocean environment within the project area. While this is not a comprehensive list of pollutants and their impacts, it presents examples of the cause and effect relationship that activities within the watershed are currently having on the coastal ocean environment in West Maui.

E.5.1. Sediment

Within the MHI, sediment is probably the leading pollutant from land based sources that causes the alteration of reef community structure (Friedlander et al. 2008). Sediment delivery to nearshore waters during runoff events has increased as coastal areas are developed, floodplains filled, storm drains constructed, and streams channelized (Friedlander et al. 2008). Studies conducted on the transport rate of suspended sediments carried in storm water runoff have found that flows that occur 2% of the time are responsible for delivering up to 90% of the total annual load (Soicher and Peterson 1996; S. Izuka, presentation). Suspended sediments carried in streams and gulches to the ocean are known locally as ‘red dirt’, and the resulting plumes can often be seen for days or weeks.

Fine terrigenous sediment entering the nearshore ocean affects corals in two ways: (1) suspended in seawater, the sediment drastically reduces the amount of light reaching coral reefs and other shallow benthic systems; and (2) as the sediment settles, it can bury corals or cause them to expend a large amount of energy keeping their surfaces clean (http://soundwaves.usgs.gov/2004/11/). This can result in changes to community structure, reduced species richness and reductions in colony size (Fabricus 2005). Sediment within the ocean environment induces mortality of coral polyps and limits coral colonization. Accumulated sediments prevent coral recovery through re-suspension and interference with fertilization, larval development and settlement in corals (NOAA Coral Program 2009). In addition, sediment particles often carry nutrients attached via sorption[131], encouraging algal growth (Davidson et al. 2003) (Section E.5.2). Terrigenous sediments have also been found to act as flocculants, meaning they attract bacteria suspended in the water that attach to the sediment particles. When the sediment particles become weighted down by the bacteria, they sink to ocean floor where the bacteria can become concentrated and use up the available oxygen. This results in an anoxic layer along the floor of the ocean. The anoxic layer adversely impacts organisms that normally dwell on and just above the ocean floor (R. Richmond, presentation).

[130] Synergy is the interactions of two or more activities or materials that combine to create a single result.
[131] Sorption is a process by which one substance attaches to another through either chemical or physical bonding.

E.5.2. Nutrients

Nutrients, including Nitrogen and Phosphorus, are sourced from sewage, wastewater, and fertilizer runoff from agricultural fields, urban lawns, and golf courses (Section 6.1). Research into the effects of nutrients on two ocean resources, coral reefs and green sea turtles, is discussed in this section.

E.5.2.1. Effects on Coral Reefs

Nutrient inputs from external sources must be very low in order to promote productive and species rich coral reefs (Global Coral Reef Alliance 2012). In a study performed on the Great Barrier Reef, Kinsey and Davies (1979) estimated that long term Nitrogen and Phosphate enrichment caused a greater than 50% rate of suppression of coral reef calcification, inhibiting coral growth.

Excessive amounts of nutrients, particularly Nitrogen and Phosphorus, promote the rapid growth of algae that compete with juvenile and adult corals for space on benthic reef surfaces, can affect success of coral settlement, and in extreme cases can result in eutrophication of reef waters (Global Coral Reef Alliance 2012, NOAA Coral Program 2009, McClanahan et al. 2002).

Soicher and Peterson (1997) researched possible contributing factors to severe algae blooms in the Lahaina District of Maui. Although they could not confirm a definitive causal relationship between algal growth and terrestrial nutrients, they reported elevated loads of nutrients being supplied to coastal waters from agricultural activities and disposal of treated domestic sewage effluent into subsurface injection wells. Subsequent to this research much of the active agriculture in the area has ended. However, this part of the West Maui coastline has continued to have nuisance algal blooms. The Redfield ratio indicates that a change in the nutrient regime, specifically a reduction in Nitrogen or Phosphorus, will limit algae growth. Friedlander et al. (2008) attributes the continuation of algal blooms on Maui in general to the input of anthropogenic nutrients. A reduction in the amount of anthropogenic nutrients, specifically Nitrogen or Phosphorus, being transported from land to coastal waters may result from changes in land use and improved sewage treatment.

E.5.2.2. Effects on Green Sea Turtles

A study of 3,939 stranded Hawaiian green sea turtles over a 28 year period found that the rate of incidence of Fibropapillomatosis, a tumor-forming disease linked to a herpesvirus, increases in watersheds with high eutrophication levels, and in particular watersheds with high Nitrogen footprints (Van Houtan et al. 2010). Further analysis revealed “strong epidemiological links” between disease rates and presence of invasive macroalgae that the turtles feed on.

E.5.3. Effect of Chemical Pollutants on Coral Reefs

There are a wide range of anthropogenically derived chemical pollutants that may affect coral reef ecosystems. The range of compounds includes: pesticides, trace metals, petroleum hydrocarbons and pharmaceuticals. van Dam et al. (2011) conclude that while short-term pulse-like pollution, such as an oil spill, can have a direct and severe impact on a coral reef system, recurring pollution may exert subtle effects on lower trophic levels of the system, affecting species fitness and adaptation.

van Dam et al. (2011) collated and assessed available information on different chemical stressors in the marine environment and the effects on reef-building corals. Using that information they summarized the main contaminant groups, sources, and concerns in regards to tropical coral reefs (Table E1).

Table E1. Potential Effects of Chemical Pollutants on Coral Reefs[132]

Contaminant Group	Sources	Main Concerns
Insecticides	Agricultural and urban runoff	Survival, reproduction, early life transitions and genetic effects. (Bioaccumulation for persistent OC pesticides)
Herbicides	Agricultural and urban runoff, antifouling applications, ballast water discharge	Photosynthesis and calcification
Metals	Agricultural runoff, various urban and industrial sources, and antifouling applications	Bioaccumulation, survival, reproduction, growth and behavior

Pesticides (insecticides, herbicides and fungicides) interfere with coral reproduction and growth (NOAA 2006). Markey et al. (2007) studied the effects of four classes of insecticides on corals and determined that even at very low levels, insecticides inhibited the settlement and metamorphosis stages of corals. Lewis et al. (2009) contend that exposure to herbicides reduces productivity of coral reefs. A study conducted by Råberg et al. (2003) confirms that in laboratory experiments *Porities cylindrica* exposed to low levels of 2,4-D and diuron, two commonly used herbicides, demonstrated reduced primary production rates.

Most scientists agree that although more studies on the effects of long term exposure of coral reefs to chemical pollutants are needed, prolonged low level exposure to this type of pollution reduces the resilience of coral reef organisms to other forms of environmental stress (van Dam et al. 2011, Lewis et al. 2009).

Table E2. Land Based Pollutants and Potential Toxicity

Chemical	Source	Location Documented	Toxicity to Environment
AHTN	Musk fragrance	Wastewater Seep at Kahekili	Ability to harm environment; listed on Toxic Substances Control Act inventory; Can cause harm to aquatic life if ingested.
Atrazine	Pesticide	West Maui Drinking Water Well	Banned in EU in 2004. Endocrine disruptor effects, possible carcinogenic effect
Carbamazepine	Antiepileptic	Wastewater Seep at Kahekili	Ecotoxicity not available.
Chlordane	Pesticide		Highly toxic to fresh water invertebrates and fish. Bioaccumulates in bacteria and in marine and freshwater fish species. Soil half-life is 4 years, and it may persist in soils for as long as 20 years. Several studies have found chlordane residues in excess of 10% of the initially applied amount 10 years or more after application.

[132] Excerpted from van Dam et al. (2011).

Chemical	Source	Location Documented	Toxicity to Environment
DBCP	Pesticide	West Maui Drinking Water Well	Toxic to aquatic organisms.
DDT	Pesticide		A serious environmental hazard due to bioaccumulation and transport up the food chain. Degrades extremely slowly in the environment and is removed very slowly from animal tissue.
Dieldrin	Pesticide		When released into the soil, this material is expected to readily biodegrade. When released into the soil, this material is expected to leach into groundwater. When released into the soil, this material is expected to have a half-life between 1 and 10 days. When released into water, this material may biodegrade to a moderate extent. May be toxic to aquatic life.
EDB	Pesticide	West Maui Drinking Water Well	Highly toxic compound The toxic dose of EDB to non-target organisms range from 10-100 ppm, a range that is much higher than has ever been found in surface waters. No specific lethal dose values for wildlife species were found.
Excel 90 Sticker	Surfactant	Urban District Land Application	Algae/Lemna Growth Inhibition: Not known Toxicity to Fish and Invertebrates: Not Known Toxicity to plants: Not known Toxicity in birds: Not known
HHCB	Musk fragrance	Wastewater Seep at Kahekili	Ability to harm environment; listed on Toxic Substances Control Act inventory; Can cause harm to aquatic life if ingested
Mirex	Pesticide		When released into the soil, this material is expected to readily biodegrade. When released into the soil, this material is expected to leach into groundwater. When released into the soil, this material is expected to have a half-life between 1 and 10 days. May be toxic to aquatic life.
Monterey Weedhoe	Herbicide	Urban District Land Application	Algal/Lemna Growth Inhibition: Acute toxicity; slight. Toxicity to Fish and Invertebrates: Acute toxicity; slight. Toxicity to Plants: Acutely toxic. Toxicity in Birds: Acute toxicity; slight. Avg half-life 180 days
Roundup	Herbicide	Urban District Land Application	Environmental Precautions: Small quantities - low environmental hazard Large quantities- minimize spread; keep out of drains sewers ditches and waterways. Formulations vary from "practically nontoxic" to "highly toxic" dependent on animal studied.

Chemical	Source	Location Documented	Toxicity to Environment
Sencor	Herbicide	Urban District Land Application	This product is very toxic to aquatic organisms. It has a low hazard to earthworms and bees. DO NOT contaminate streams, rivers or waterways with Sencor 480 or the used containers. Metribuzin is moderately adsorbed on soils with high clay content. It is rapidly degraded in soil with microbial breakdown the major mechanism of loss. Photodecomposition in water is very rapid (DT50 < 1 day). On soil surfaces under natural light conditions the DT50 is 14 – 25 days.
Sulfamethoxazole	Antibiotic	Wastewater Seep at Kahekili	No ecological data available.
Tris(2-butoxyethl) phosphate	Plasticizer / Flame Retardant	Wastewater Seep at Kahekili	No ecological data available.
TCP	Pesticide	West Maui Drinking Water Well	No ecological data available.
Tribromomethane	Flame Retardant	Wastewater Seep at Kahekili	Carcinogenic effects.
Tris (dichloroisopropyl) phosphate	Flame Retardant	Wastewater Seep at Kahekili	No ecological data available.
TurfMark	Herbicide	Urban District Land Application	Chronic Toxicity: None known Mutagenic Effects: None known Teratogenic Effects: None known Developmental Toxicity: None known

E.5.4. Pathogens

Microbial (bacterial and viral) assemblages are normally found in sewage effluent (Dailer et al. 2010). In the Kāʻanapali region, there is evidence of sewage effluent from the Lahaina WWTF encompassing the nearshore marine environment that is used for recreation (Section 6.6.3.1). The presence of bacteria in ocean waters poses serious threats to human health. Sewage effluent can be successfully disinfected with ultraviolet light (UV, 254 nm) irradiation which kills more than 99% of coliform, fecal coliform, fecal streptococci and heterotrophic bacteria.

Land-based inputs may both directly contribute land-derived pathogens and/or exacerbate the effect of in situ pathogens on coral reef ecosystems. As coral reefs become stressed, they are more susceptible to viral and bacterial infections.

E.5.5. Sunscreens

The tourism industry brings recreational ocean users to West Maui and exposes the sensitive coastal habitat to sunscreen that has been applied to the skin. Sunscreen has been documented as a contributor to bleaching of hard corals in areas where there is a high level of human recreational use, by promoting viral infections (Danovaro et al. 2008). During laboratory tests, sunscreen even in low quantities caused large amounts of coral mucous (zooxanthellae and coral tissue) release within 18-48 hours, with complete coral bleaching within 96 hours. Four typical sunscreen ingredients were found to cause complete coral bleaching at very low concentrations: butylparaben, ethylhexylmethoxycinnamate, benzophenone-3, and 4-methylbenzylidene camphor (Danovaro et al. 2008).

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Appendix F. Soils

Figure 9 illustrates the soil series in Wahikuli and Honokōwai Watersheds as classified by the NRCS.[133] These series come from four major soil orders: Inceptisols, Oxisols, Mollisols and Ultisols (Table F1).

F.1. Soil Series

Inceptisols are poorly developed soils with minimal development of soil horizons. The Kahana series, of the Inceptisols order, is an agriculturally important soil of Maui and occupies the intermediate uplands of West Maui from 100-1,200 ft (30-36 m). Kahana series soils formed from basic igneous rock that has weathered in place. Kahana series silty clays are one of the two major series of soils found throughout the agricultural area of both the Wahikuli and Honokōwai Watersheds.

Oxisols are highly weathered tropical soils with low nutrient holding capacity and high iron and aluminum oxides. The Lahaina series, of the Oxisols order, is an agriculturally important soil of Maui and occupies the intermediate uplands of West Maui up to 1,500 ft (457 m). Lahaina series soils formed in place from basic igneous rock with alluvial deposits and may contain fragments of coral, sand and gravel. Lahaina series silty clays are one of the two major series of soils found throughout the agricultural area of both the Wahikuli and Honokōwai Watersheds.

The Molokai series, of the Oxisols order, are very deep, well-drained soils that occupy the uplands of West Maui from sea level up to 1,500 ft (457 m). Molokai series soils formed in material weathered from basic igneous rock. Molokai series silty clay loams are found in the urban and agricultural areas of the Wahikuli Watershed, with small patches in the agricultural area of the Honokōwai Watershed.

Mollisols are moderately weathered, fertile soils with high organic carbon and high base saturation. The Wahikuli series, of the Mollisols order, are generally naturally productive soils and are often used for agriculture. These soils occupy the upland areas of West Maui from sea level to 600 ft (183 m). Wahikuli series soils formed in material weathered from basic igneous rock. Wahikuli series silty clays are found in the urban and agricultural areas of both the Wahikuli Watershed.

The Pulehu series, of the Mollisols order, are well drained soils that occupy the upland areas of West Maui from sea level to 300 ft (91 m). The Pulehu series formed from alluvium washed from basic igneous rock. Pulehu series silt and clay loams are found in small patches in the urban area of the Honokōwai Watershed.

Ultisols are strongly acidic soils with good physical properties and depleted in Calcium, Potassium and Magnesium. The ‘Alaeloa series, of the Ultisols order, are deep well drained soils that formed in material weathered from basic igneous rock and occur in West Maui from 100-1,500 ft (30-457 m). The Olelo series, of the Ultisols order, are deep well drained soils that formed from basic igneous rock and occur in upland areas of West Maui from 2,000-3,500 ft (610-1,067 m). The ‘Alaeloa silty clays are found in the upper part of the agricultural area of both watersheds, extensively throughout the Wahikuli Watershed, and in small patches in the Honokōwai Watershed. Olelo silty

[133] Detailed information on the soil series can be found at http://soils.usda.gov/technical/classification/scfile/index.html.

clays are woodland soils found throughout the conservation area of both Wahikuli and Honokōwai Watersheds.

The majority of the conservation areas of both watersheds consist of rough mountainous land, rough broken land and rock land, where the parent soil material, basaltic lava, still remains to be weathered. These upland soils are classified as having very severe erosion hazard.

F.2. Soil Erodibility

The potential for soil to erode considers the physical and chemical properties along with the climatic conditions where it is located. Figure 10 details the potential erodibility of the soils in the Wahikuli and Honokōwai Watersheds.

In the Conservation District, the soils are classified as a combination of highly erodible and potentially highly erodible. The Agricultural District has a mixture of highly erodible land, potentially highly erodible land and not highly erodible land. In the Urban District, the majority of soils are classified as not highly erodible land, although some areas are potentially highly erodible. The majority of soils classified as highly erodible fall under the soil series of rock land, rough broken land, rough broken and stony land and rough mountainous land. The majority of soils classified as potentially highly erodible are of the Wahikuli series, Kahana series and the Lahaina series with 7 percent or more slope. The majority of soils classified as not highly erodible land are of the Molokai series and the Lahaina series with a slope of less than 7 percent.

Table F1. Major Soils

Soil Order	Soil Series	Texture	Color	Runoff Rate	Permeability	Drainage	Typical Use	Location Found
Inceptisols	Kahana	Silty clay	Dark reddish brown	Slow to medium pace	Moderately rapid	Good	Pineapple, irrigated sugarcane, some pastureland	Wahikuli and Honokōwai: agricultural area
Oxisols	Lahaina	Silty clay	Dark reddish brown	Slow to rapid pace	Moderate	Good	Pineapple, irrigated sugarcane	Honokōwai: agricultural and urban areas; Wahikuli: agricultural area.
	Molokai	Silty loam or clay loam	Dark reddish brown	Slow to rapid pace depending on slope	Moderate	Good	Pineapple, irrigated sugarcane, pasture	Wahikuli: agricultural and urban areas
Mollisols	Wahikuli	Silty clay	Dark reddish brown	Medium pace	Moderate	Good	Irrigated sugarcane, with small areas used for urban and recreation	Wahikuli: agricultural and urban areas
	Pulehu	Silty clay	Dark brown	Slow to medium pace depending on slope	Moderate	Good	Irrigated sugarcane, pasture and truck crops	Wahikuli and Honokōwai: urban area
Ultisols	‘Alaeloa	Silty clay	Dark reddish brown	Slow to rapid pace depending on slope	Moderately rapid	Good	Pastureland, small areas used for truck crops	Wahikuli and Honokōwai: Upper part of the agricultural areas; extensively throughout the Wahikuli Watershed, and in small patches in the Honokōwai Watershed
	Olelo	Silty clay	Dark reddish brown	Slow	Moderately rapid	Good	Woodland	Wahikuli and Honokōwai: conservation area

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Appendix G. Supporting Information for Future Land Development Calculations

G.1. Impact of Future Land Development on Runoff Rates and Pollutant Generation

G.1.1. Background

Future construction and land development activities within the Wahikuli and Honokōwai Watersheds will result in the generation of increased runoff volumes and a shift in NPS pollutants from those associated with agricultural lands use to those common to the urban environment. Lands currently agricultural in nature, dominated by crop plots, soils with varying cover types and intensity, and dirt access roads, will slowly be replaced with impervious roadways and driveways, buildings, grassed and landscaped surfaces, and other cover types typically associated with urbanized areas.

When rainfall droplets contact a pervious surface, infiltration into the soils underlying the surface occurs, as water molecules begin to fill the voids within the soil. This process continues until the point of saturation is reached; at which time infiltration ceases, and overland flow of runoff occurs. In general, soils have varying states of porosity and overland flow occurs at different points within a given storm event, according to the soils present across the landscape and their in-situ characteristics. When a pervious surface is replaced by impervious cover, no rainfall penetrates into the ground and surface runoff results for all but the very smallest rainfall amount. A higher runoff volume is therefore generated with greater frequency during storm events occurring within the watershed. As such, when future impervious and landscaped areas are introduced onto lands that are currently agricultural and highly pervious, the result is generation of higher frequency, higher volume runoff events. These generated runoff volumes travel over the urbanized areas with increased velocity, because there is less friction present between the water and surface molecules. The flowpaths that runoff follows as it travels across the developed lands become susceptible to the erosion process and must be designed accordingly to prevent scouring and sediment migration. Once runoff volumes reach major stream and drainage channels adjacent to or downstream from the developments, the inherent kinetic energy of the runoff causes the conveyance systems to become highly vulnerable to erosive action. The runoff also pulses nutrients, sediment, and other NPS pollutants through the channels at a higher magnitude than previously under the agricultural regime. In order to mitigate this erosion, runoff volumes must be managed within developed sites prior to discharge to the conveyance channels. This is done through a system of practices designed to manage stormwater runoff onsite.

Within the existing project area, there is a given sediment load associated with the use of land for agricultural purposes. The RUSLE2 method was used to approximate this load (Section 6.7.1.2). As future development transitions these agricultural lands into urbanized areas, impervious and landscaped surfaces will slowly replace former crop fields and dirt access roads. As a result of the increase in impervious area, the volume of runoff generated on these lands will increase proportionately; however the volume of sediment and nutrient loadings generated will decrease proportionally for a given storm event. Other NPS pollutants commonly associated with urban areas will become constituents of the generated runoff and pose a risk to the health of the watersheds.

The extent to which stormwater and pollution generated on these future development sites will affect the coral reef ecosystem will be largely dependent on the approach taken during the design and layout phases of the developments. While features such as roads, buildings, and landscaped areas will most likely be common elements of all future developments, runoff and pollution generated from their construction and use can be largely influenced by the way stormwater is managed onsite. Natural and vegetative treatment features can be designed into the developments at strategic locations, to integrate with or replace the typical elements of a stormwater conveyance and treatment system, including closed S4's, drainage channels, and large detention basins.

This section discusses two general approaches toward land development and their effects on runoff and pollution generation: conventional, or traditional construction; and Low Impact Development (LID). Future development projects occurring in the Kāʻanapali region may choose, or be required (dependent on regulatory requirements and site-specific conditions) to implement various strategies associated with either or both of these approaches. This section discusses the overall effect these approaches may have on pollutant loadings within the project area upon future build-out.

G.1.2. Conventional Land Development

Conventional land development refers to the traditional approach toward layout and design of buildings, roadways, utilities, and stormwater management facilities within the built environment. The general approach is to convey stormwater away from surfaces and into the stormwater conveyance system as quickly as possible. Stormwater management, in the form of water quality treatment and/or reduction of peak flow rates from the development, may or may not be required depending on the regulations that apply to the individual site. If stormwater treatment is required, a large detention basin or other structure(s) may be constructed to address quantitative or qualitative treatment. Otherwise, site drainage is typically routed to a suitable outlet if treatment in either form is not required. Runoff within a conventional land development project may typically land on an impervious surface and be rapidly directed into an open or closed S4 system, where it is routed to the pond or management facility. Stormwater infrastructure is designed to capture and route runoff to a specific dedicated area(s) of a site, rather than retain it onsite or close to the source of the runoff. Large detention basins, closed drainage piping networks, catch basins, grass swales, and large extents of DCIA are common elements of a conventional land development project. Historically, conventional design methods have been the basis for most land development and infrastructure construction.

G.1.3. Low Impact Development

Low Impact Development integrates various approaches and practices designed to reduce runoff of stormwater and pollutants from the site at which they are generated (EPA 2007). LID techniques employ infiltration, evapotranspiration, and reuse of rainwater to manage water and water pollutants at the source. The resulting impact on rivers, streams, lakes, coastal waters, and groundwater due to development is thereby reduced or prevented. LID designs usually incorporate more than one type of practice or technique to provide integrated runoff treatment for a site. For example, in lieu of a detention pond treating and managing stormwater runoff from a new subdivision, a bioretention area may be implemented in each yard, roof downspouts disconnected from driveway surfaces, curbs removed, and grassed swales installed in common areas to treat runoff as close to the source as possible.

LID has the added advantage of disconnecting DCIA and mitigating the large volumes of runoff typically associated with interconnected impervious areas discharging into S4's. LID practices promote treatment of runoff and pollutants from impervious areas as close to the source as possible, and as such surface flow lengths are limited and significant runoff volumes typically generated over adjacent developed surface areas is minimized. LID has gained acceptance over the last few decades as a viable alternative to conventional design, particularly in sensitive environmental areas where impacts from pollution and increased runoff can be detrimental to the surrounding ecosystem.

The main difference between LID and conventional land development is that the LID approach specifically retains and treats stormwater and pollutants as close to the source of their generation as possible; while the conventional method directs them away from the developed site to a specified location with or without quantitative or qualitative treatment prior to discharge.

G.1.4. Influence of Construction Methodology on Impervious Area and Runoff Volumes

Generally speaking, the volume of runoff and pollutants generated on a developed site will increase in proportion to the surface area of impervious and landscaped areas constructed. The impervious area generated through construction of buildings on a site is typically fixed, regardless of the development approach used. However, it is often possible to replace the impervious area typically associated with construction of gutters, catch basins, and closed drainage systems with landscaped, natural features that manage stormwater. Incorporation of natural features usually results in a decrease in impervious area. While roadway travel lanes, parking lot spaces, and other variables are typically determined by municipal regulations and ordinances, incorporating LID practices in lieu of standard S4 structures can have a pronounced effect on the overall volume of stormwater and associated pollutants generated and transported from the development. EPA (2007) states that LID strategies can be used to preserve open space and thereby reduce the amount of impervious surfaces associated with development; this in turn reduces runoff volumes associated with typical increases in impervious coverage.

Successful LID pilot projects such as Seattle, Washington's 2nd Avenue SEA Street Project have incorporated LID treatment swales in lieu of conventional street curb and gutter systems, and reduced design street width by 44%, from 25 feet to 14 feet (EPA 2007). Final constructed design of the project reduced impervious coverage by more than 18%. On-site retention of runoff was verified through hydrologic monitoring, which indicated a 99% reduction in total potential surface runoff, with the last recorded event of runoff occurrence taking place in December 2002. The Crown Street redevelopment project in Vancouver, British Columbia similarly saw a 25% reduction in design street width, from 28 feet to 21 feet, through the implementation of roadside vegetated swales and structural grass (a grid and soil structure that supports the grassed surface and prevents soil compaction and root damage). The site's stormwater model predicted 90% retention of annual runoff volume onsite with the remaining 10% treated by the system of vegetated swales.

In Section 6.7.3.3, the Rational Method is utilized to compute peak runoff rates for a representative drainage area within the watersheds. The results give general insight on the magnitude of runoff changes that will occur from construction of future development projects in the Kāʻanapali region. A comparison of flows conventional development versus LID construction methodology is included in the analysis.

G.2. Determination of Rational Method Variables

This section discusses the process used to determine Rational Method variables included in the calculation of peak runoff rates. Peak rates were calculated for future development conditions (evaluating conventional and LID approaches) for a 10-acre and 100-acre hypothetical development area within the Kāʻanapali region. Variables and calculations were determined in accordance with Maui County Department of Public Works and Waste Management's *Rules for the Design of Storm Drainage Facilities in the County of Maui* (1995).

G.2.1. Storm Recurrence Interval

The existing and future development drainage subwatersheds delineated in the analysis are less than 100 acres in size, therefore the 10-year, 1-hour storm recurrence interval was selected (Table G1).

Table G1. Selection of Storm Recurrence Interval

Drainage Subwatershed Area	Recurrence Interval
100 Acres or Less	10-Year, 1-Hour Storm
Greater Than 100 Acres and All Streams	100-Year, 24-Hour Storm (NRCS Hydrograph Method)
Less Than 100 Acres and Contributes to Major Stream or Channel with Total Drainage Area Greater Than 100 Acres	10-Year or 50-Year Storm, Whichever is Applicable

G.2.2. Runoff Coefficient Determination

Runoff coefficients were determined using the County of Maui guidelines (Table G2). These values were then weighted, according to the percentage of land cover within each of the scenarios, in order to determine the overall composite coefficient.

Table G2. Runoff Coefficient Comparison Table

Type of Drainage Area	Runoff Coefficient "C"
Residential	
Single-Family Areas	0.50
Multi-Units, Detached	0.60
Multi-Units, Attached	0.75
Industrial	
Light Areas	0.80
Parks, Cemeteries	0.25
Unimproved Areas	
General	0.30
Buildings/Roads	

Type of Drainage Area	Runoff Coefficient "C"
Asphalt Streets	0.95
Driveways/Walkways	0.85
Roofs	0.95
Lawns	
Sandy, Soil, Flat, 2%	0.10
Sandy, Soil, Avg, 2-7%	0.15
Sandy, Soil, Steep, 7%	0.20
Heavy Soil, Flat, 2%	0.17
Heavy Soil, Avg, 2-7%	0.22
Heavy Soil, Steep, 7%	0.35

G.2.3. Determination of Time of Concentration

Time of Concentration (Tc) is the time required for a drop of water to travel from the most hydrologically remote point in the subwatershed to the point of collection. For the scenarios analyzed, the Tc was calculated to be approximately 15 minutes, based on the ground cover characteristics (bare soil, grass, etc.) and length and topographical slope values for the overland flow route.

G.2.4. Determination of Rainfall Intensity

Rainfall intensity (i) is a value that expresses rainfall in terms of inches per hour, and is determined by using given intensity-duration curves with the 10-year 1-hour rainfall data map for Maui and Tc value as input parameters. It was determined to be approximately 3.5 in/hr.

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Appendix H. Community Input

H.1. List of Persons Consulted

The following individuals were consulted during the development of the WHWMP, either through personal communication, interviews, or attendance at meetings.

Asakura, Roland, DOH CWB Compliance Section
Brosius, Chris, WMMWP
Bulson, Gary, Kāʻanapali Operations Association
Critchlow, Paul, County of Maui, Department of Planning
Fukunaga, Chad, KLMC
Ganske-Cerizo, Ranae, NRCS
Gazmen, Glenn, Kāʻanapali Operations Association
Goode, David, County of Maui, Department of Public Works
Halverson, Robert, County of Maui, Department of Parks and Recreation
Hashimoto, Carl, NRCS
Hayama, Michael, NRCS
Hedani, Wayne, Kāʻanapali Operations Association
Hew, Chauncey, DOH Safe Drinking Water Branch, UIC Program
Jorgensen, Mary, County of Maui, Department of Planning
Kaniaupio-Crozier, Pomaikaʻi, ML&P
Kukahiko, Earl, County of Maui, Department of Public Works, Highways Division
Medeiros, Bill, County of Maui, Geographic Information Systems Program
Matsui, Patrick, County of Maui, Department of Parks and Recreation
McLane, Sarah, WMMWP
Migita, Reef, DOH CWB Permitting Section
Nims, Kira, WMSWCD
Nohara, Wes, Puu Kane Farms LLC
Okubo, Watson, DOH CWB Monitoring & Analysis Section
Ornellas, Daniel, DLNR Land Division
Pogue, Pam, County of Maui Board of Water, Water Resources & Planning Program
Rebugio, Jeff, KLMC
Reed, Adam, NRCS Pacific Islands Area
Rollins, Scott, County of Maui, Lahaina Wastewater Reclamation Facility
Segura, Mike, Kāʻanapali Operations Association
Slay, Hudson, EPA
Takeno, Ty, County of Maui, Department of Public Works
Thomson, Richelle, County of Maui, Department of Corporation Counsel
Trenholme, Craig, Kāʻanapali Golf Course Superintendent
Wiltse, Wendy, EPA
Yamashige, Eric, County of Maui, Department of Public Works, Highways Division
Yamashita, Cary, County of Maui, Department of Public Works
Yamashita, David, County of Maui, Department of Planning

H.2. Public Input

The following notes were compiled from the breakout groups at the June 27, 2012 public meeting to review the *Draft KKWMP (now WHWMP) Volume 1: Watershed Characterization.*

KKWMP: Public Meeting to Review Characterization Draft, 6/27

Breakout Group Input

(Please note, numbers refer to how many times the idea was raised)

Agriculture:

- Ban petroleum based fertilizers
- Hold many natural farming workshops
- (2) Create more sustainable ag for local communities
- Restoration of ag lands when they are abandoned (exiting EIS)
- Require ground cover on fallow fields, plant fast growing seeds
- Use sand bags (other materials) to slow water flow (vetiver grass?); create baffles (terraces) which should catch more sediment and are inexpensive
- USDA monies for mid-large farmers- what about smaller families/farms? Funds to help smaller properties to develop run-off reduction projects
- (2)Fallow lands should be made available for local community food production, community gardens
- Develop water resources to make fallow lands farmable for local communities
- (4)Restore stream flow- get rid of diversions, allow minimal flow for overall ecology of our ahupuaʻa
- Expedite process of dealing with dilapidated properties and vehicles- hotline or response team
- Use vetiver grass which is non-invasive, sterile, great for stabilization, can remain alive with burning and roots run 3x the depth of the plant height (easily 15')

Urban:

- More transfer stations for green waste and make it easier for all recycling
- Grading restrictions during the wet season
- More trash cans along the coastal and resort areas as it is currently difficult to help clean-up
- Clean accumulated trash before they open Hanakaoʻo Stream (flood gates?)
- More regular maintenance of sediment basins- remove accumulated sediment
- PROBLEM- when it rains, roof drains connected to the sewer system plus inflow and infiltration increase hydraulic flow such that bio-solids are lost to injection wells and effluent receives less treatment making pollution discharge higher- SOLUTION- inspect/correct illegal storm-water. Continue collection system improvements, use grey water to irrigate green roofs for urban cooling.
- Create filter systems for drains

- Create funding for regular treatment of water ways
- Paint signs on all street drain ways, "all drains lead to the ocean"
- Rain gardens, training in how to make and what works
- Adopt a gulch
- Keka'a Open Space Park (lot 2) is a good example of a gravel parking lot with plastic cones under that allow for infiltration and storm water treatment (BMP from Joe Pluta)
- Use hollow paving stones
- Use cheaper homeowner versions like plastic lattice nailed to the ground
- Expedite process to deal with dilapidated properties
- Vetiver bank stream stabilization
- More, smaller retention basins high up on properties
- Expand restored dunes and wetlands like at Honua Kai
- Dive boats traveling further to get guests to a nice dive site- seen big changes and Molokini and more fuel used.
- Have a higher capacity for R-1 water use
- More regulatory structure to prevent degradation of the reef

Urban Challenges/Observations:

- Lower road, north of watershed boundary has lots of runoff
- Should injection wells be addressed first before watershed?
- (2)See sick turtles where there is development, consistent with degraded high run-off areas

General

- Make sure plan includes a funding mechanism so that it can be sustainable
- Simplify the message about the run-off. People think this is a land development plan- assumed that it is a land development plan based on language and maps and lines. Terms are wrong- don't use the word develop- "creating a water, soil and conservation plan". Bring it to each home dweller, every local resident flushes the toilet. Clarify that the plan is needed to get funding to stop pollution. Go for the heart strings. Talk about fixing our problems.

Additional ideas submitted following the meeting:

1. Make management plan sustainable, plan for efforts and actions to continue and grow once initial funding has ended.
2. Impose an EIS Law for ag lands contingent with selling or leasing the land. (Make sure the pesticides, herbicides, and garbage is all removed and left in its natural state)
3. Create rain garden infrastructure and landscaping as a mandate to all new developments (make water catchment and retention planning, a developers or home buyers and land buyers responsibility)
4. Invest in new or old technologies that held reduce flood, erosion and run-off.
5. Restore stream flow
6. Remove invasive species
7. Keep gulches clean, create an adopt-a-gulch program

8. Sandbag fallow land in terraces, using Kohala method
9. Prohibit fallow lands, hold ag owners accountable for their dirt whether through air or runoff, must plant cover crop
10. Take care of the drainage ways - keep them debris free - plant natives to help hold the soil - keep them clear of axis deer and other erosion makers.
11. Water retention basins - retain (hold) and divert rain water
12. Building and landscaping infrastructure should include rain gardening and other catchment technologies within their design
13. Don't build in the flood zones areas, and save wetlands.
14. Limit the amount of toxins allowed in the soil.
15. Limit road spraying
16. Do away with injection wells
17. Work towards 100% wastewater reuse
18. Fallow ag lands should be offered to local farmers, for local food production with access to water.
19. Storm drains should ALL be labeled, so the public understands "All drains lead to the ocean"
20. Better waste management and more environmental enforcement
21. Organize seasonal waterways clean-up days for neighborhoods, by watersheds or mokus
22. Create a renewable funding mechanism.
23. Host or invite guest speakers of areas who have been successful with watershed restoration. I.e. Malora Corela, Thomas Jamboluca
24. Let Hawaiian practitioner teach ahupuaʻa or hanamoku system.
25. Create an awareness campaign, and an educational forum with workshops and or trainings on how to minimize pesticides and herbicides use on lawns, and encourage edible organic gardening instead, rain gardens, catchment barrels, learning to create permeable penetrable areas on the property.

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