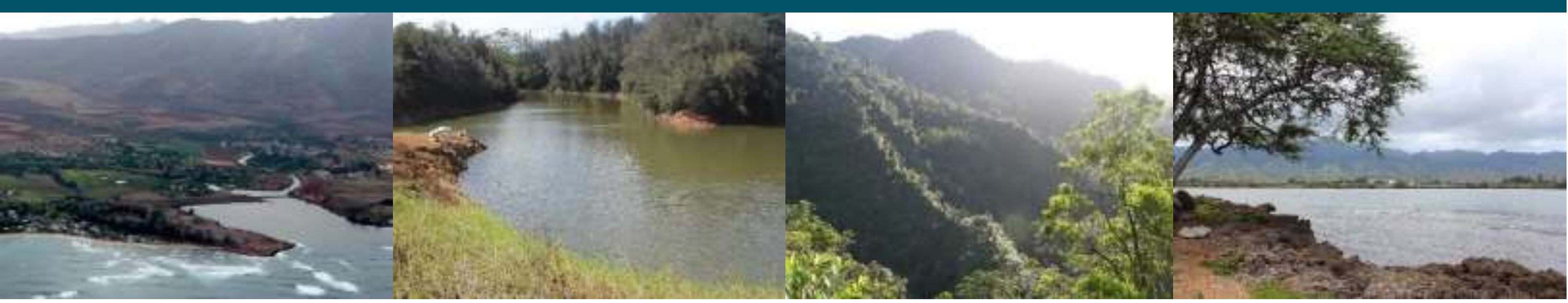
Kaiaka Bay

Watershed-Based Plan

A watershed management plan to assess, protect, and improve water quality in the Kaiaka Bay Watersheds, O'ahu, Hawai'i

Volume 1: Watersheds Characterization

April 2018



Prepared for:

City & County of Honolulu
Department of Facility Maintenance

State Department of Health
Clean Water Branch

Prepared by:

Townscape, Inc.
Environmental & Community Planning

AECOM

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KAIAKA BAY

WATERSHED-BASED PLAN

VOLUME 1: WATERSHEDS CHARACTERIZATION

Prepared For:

City & County of Honolulu – Department of Facility Maintenance &

Hawaiʻi State Department of Health – Clean Water Branch

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ACRONYMS

ADC	Agribusiness Development Corporation
BMP	Best Management Practice
BWS	Honolulu Board of Water Supply
cfs	Cubic feet per second
CFR	Code of Federal Regulations
City	City and County of Honolulu
C-CAP	Coastal Change Analysis Program
CNPCP	Hawaiʻi Coastal Nonpoint Pollution Control Program
CTAHR	College of Tropical Agriculture and Human Resources
CWA	Clean Water Act
CWB	Clean Water Branch
CZM	Coastal Zone Management Program
DBEDT	Hawaiʻi Department of Business, Economic Development and Tourism
DFM	City Department of Facility Maintenance
DLNR	Hawaiʻi Department of Land and Natural Resources
DOFAW	Division of Forestry and Wildlife
DOH	Hawaiʻi Department of Health
DOT	State of Hawaiʻi Department of Transportation
DOT-HWYS	State of Hawaiʻi Department of Transportation Highways Division
DPP	City Department of Planning and Permitting
EA	Environmental Assessment
ENV	City Department of Environmental Services
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPD	Gallons Per Day
HAR	Hawaiʻi Administrative Rules
HSA	Hawaiʻi Stream Assessment
HRS	Hawaiʻi Revised Statutes
ITAM	Army Integrated Training Area Management
JBPHH	Joint Base Pearl Harbor-Hickam
KMWP	Koʻolau Mountains Watershed Partnership
KS	Kamehameha Schools
L	Liter
Lbs	Pounds
LA	Load Allocation
mg	Milligram (1000 mg = 1 gram)
mgd	Millions of Gallons per Day
ml	Milliliter (1000 ml = 1 liter)
MS4	Municipal Separate Storm Sewer System
NAR	Natural Area Reserve
NCTAMS-PAC	Naval Computer and Telecommunications Area Master Station Pacific
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source Pollution
NRCS	Natural Resources Conservation Service
NTU	Nephelometric Turbidity Units (a measure of turbidity)

ACRONYMS (CONTINUED)

OANRP	Oʻahu Army Natural Resources Program
OpenNSPECT	Open Nonpoint Source Pollution and Erosion Comparison Tool
ORC&D	Oʻahu Resource Conservation and Development Council
OSDS	On-site Sewage Disposal System
PCB	Polychlorinated biphenyl (chemical)
PRC	Polluted Runoff Control Program
PS	Point Source Pollution
ROH	Revised Ordinances of Honolulu
SDWB	Safe Drinking Water Branch
SLUD	State Land Use District
SMA	Special Management Area
STORET	EPA STOrage and RETrieval Data Warehouse
SWCD	Soil and Water Conservation District
SWMP	Storm Water Management Plan
TMDL	Total Maximum Daily Load
TMK	Tax Map Key
TSS	Total Suspended Solids
UH	University of Hawaiʻi
UIC	Underground Injection Control
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
U.S.	United States of America
USGS	United States Geological Survey
WARMF	Watershed Analysis Risk Management Framework
WBP	Watershed-Based Plan
WIS	Wahiawā Irrigation System
WLA	Waste Load Allocation
WMP	Watershed Management Plan
WMWP	Waiʻanae Mountains Watershed Partnership
WQS	Water Quality Standards
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The importance of clean water and healthy watersheds cannot be overstated. Hawaiʻi's watersheds provide us with many important natural and cultural resources, including (but not limited to) drinking water, agricultural lands, recreational opportunities, habitat for native plants and animals, and opportunities for traditional and customary Hawaiian practices. The six watersheds that flow into Kaiaka Bay on Oʻahu's North Shore are no exception; these watersheds are referred to as the "Kaiaka Bay Watersheds" in this plan. However, the waters of Kaiaka Bay and the waterbodies that drain into it are known to be polluted with multiple contaminants that exceed State Water Quality Standards.

The objectives of the *Kaiaka Bay Watershed-Based Plan* (WBP) are to assess water quality issues in the Kaiaka Bay Watersheds, describe the main sources of pollutants, and identify key management measures, policy amendments, and education and outreach opportunities that will improve water quality in the watersheds and in Kaiaka Bay. This watershed planning initiative is led by the City and County of Honolulu Department of Facility Maintenance and the State of Hawaiʻi Department of Health Clean Water Branch, who then contracted with AECOM and Townscape, Inc. to develop the WBP.

The Kaiaka Bay Watersheds are comprised of approximately 51,454 acres of land situated between the ridgelines of the Waiʻanae and Koʻolau mountain ranges and extending toward the North Shore, where the streams converge and flow into Kaiaka Bay, located in the beach town of Waialua. The Kaukonahua, Poamoho, and Kiʻikiʻi watersheds are part of the Kiʻikiʻi Stream System and the Helemano, ʻŌpaeʻula, and Paukauila watersheds are part of the Paukauila Stream System. Together, the six Kaiaka Bay Watersheds make up approximately 13.5% of Oʻahu's total land area.

Kaiaka Bay is potentially an important area for marine resources, however, data from surveys conducted by the National Oceanic and Atmospheric Administration indicate that the coral reef ecosystem is not particularly healthy. The nearshore waters of the bay are heavily affected by the streams and the sediments and pollution they carry. Indeed, the word "Kaiaka" means "shadowy sea" in the Hawaiian language, which may be in reference to the turbidity of the water.

The majority of the project area is dominated by non-native vegetation, however, there are areas of native vegetation in the upper portions of the Koʻolau range and at the summit of Mt. Kaʻala. Invasive plants and animals threaten native ecosystems and contribute to erosion and water quality issues.

Roughly half of the total land area in the Kaiaka Bay Watersheds consists of soil types that are classified as highly erodible by water, which has important implications for land management and water quality downstream. These soils are predominantly located in the highest elevations of the watersheds. Additionally, stream channels in the central portions of the watersheds also have highly erodible soils. The geomorphology study conducted by AECOM as part of this WBP concluded that natural erosion processes that occurred in mauka areas and in stream channels are a significant source of sediments and turbidity in the watersheds (AECOM, 2016; Appendix A).

There are four general land use types in the Kaiaka Bay Watersheds: Forest Lands, Agricultural Lands, Developed Areas, and Army Training Areas. Forest Lands include the forested, undeveloped, mauka areas of the Koʻolau and Waiʻanae range. The areas classified as Forest Lands for the purposes of this WBP make up 34% of the project area. The highest elevation forests are actively managed by a number of entities (e.g. ungulate control, fenced exclosures, weed control, etc.). Agricultural Lands, as classified in this WBP, make up 47% of the total project area. These agricultural lands are some of the most productive lands in all of Hawaiʻi. As of 2015, approximately 3,262 acres of agricultural land in the Kaiaka Bay Watersheds are used for pineapple, 2,751 acres are used for pastureland, 1,480 acres are for diversified crops, and 1,094 acres are used for seed production. Other crops include coffee, papaya, fruits, forestry products, and flowers. Dole Food Company, Inc. is the second largest landowner in the Kaiaka Bay Watersheds and focuses primarily on growing a single crop (pineapple), however, only a fraction of the former pineapple lands is currently used for pineapple (the remainder is used for other crops or fallow). Developed Areas, as classified in this WBP, cover 7% of the total project area. The majority of the development is found along the coast (around Haleʻiwa and Waialua) and in the "saddle" between the Waiʻanae and Koʻolau mountain ranges (Wahiawā and Schofield). In the year 2010, there were approximately 48,730 people living in the Kaiaka Bay Watersheds in Developed Areas. Army Training Areas include the U.S. Army's Schofield Barracks West Range and East Range. These areas are used for live fire and maneuver training to accomplish the Army's training objectives.

There are several significant land use changes on the planning horizon that have the potential to impact surface water quality in the Kaiaka Bay Watersheds. Perhaps the most significant change is that Dole has listed thousands of acres of land for sale. Many parcels have already been sold or are under negotiations, while other have yet to be sold. The Agribusiness Development Corporation (a branch of the State Department of Agriculture) has purchased a number of parcels that were formerly owned by Dole as part of the Whitmore Project, a plan to revitalize local agriculture by encouraging and supporting local farmers practicing diversified agriculture. As Dole land is sold, it is likely that the diversity of products produced will continue to increase and the percentage of actively farmed land will also increase. It is also possible that some parcels will be subdivided and developed. The fate of these Dole lands has the potential to significantly impact water quality in the Kaiaka Bay Watersheds.

Every waterbody in the Kaiaka Bay Watersheds is known to be polluted with one or more contaminants, including excessive nutrients, turbidity, sediments, fecal indicator bacteria (i.e. sewage), chemicals, chlorophyll *a,* and trash. The physical and natural characteristics, land use histories, and results of stakeholder outreach can be generally assessed to identify potential sources (point source and nonpoint source) of pollutants in the Kaiaka Bay Watersheds (Table ES-1).

A watershed modeling tool called OpenNSPECT was used to model nonpoint source pollution (sediments and nutrients). The results of the model were analyzed by four general land use types (Forest Lands, Agricultural Lands, Developed Areas, and Army Training Areas) and were assessed along with the previous findings to prioritize the Kaiaka Bay Watersheds for specific management measures to improve water quality (Table ES-2). Prioritizing the watersheds by land use type provides a useful framework for recommending management measures (presented in *Volume 2: Implementation Plan*). It should be noted, however, that the prioritization for pollutant load reductions in specific watersheds should not prohibit the procurement of funding to implement projects in watersheds that were not deemed "priority," since implementing a project in any watershed will have positive effects on water quality.

The Kaiaka Bay WBP consists of two parts: *Volume 1: Watersheds Characterization* (this document), which describes the watersheds in terms of physical and natural features, land uses, water quality issues, and sources of pollution; and *Volume 2: Implementation Plan*, which outlines the key actions and projects necessary to improve water quality in the watersheds as well as provides guidelines for evaluating and monitoring progress.

TABLE ES-1. POLLUTANTS AND POLLUTANT SOURCES BY WATERSHED

Stream System	Watershed	Known Pollutants	Primary Pollutant Sources – Point Source (PS) and Nonpoint Source (NPS) PS (Known)	NPS (Known or Suspected)
Kiʻikiʻi	**Kiʻikiʻi**	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• City MS4*	• Natural erosion processes • Agriculture (soil loss and nutrient/chemical application) • Cesspools and other on-site sewage disposal systems (OSDS) • Urban chemical use • Urban stormwater runoff • Impacts of climate change
	Kaukonahua	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Trash • Chemical contaminants	• Wahiawā WWTP** • City MS4* • Army MS4* • Navy MS4* • State Dept. of Transportation (DOT) MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Cesspools and other OSDS • Urban chemical use • Urban stormwater runoff • Superfund sites and other hazardous waste • Army training • Impacts of climate change
	Poamoho	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• Army MS4* • State DOT MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Soil loss from wildfires • Motorized recreational activities • Superfund sites and other hazardous waste • Impacts of climate change

- Table continued on next page -

TABLE ES-1. POLLUTANTS AND POLLUTANT SOURCES BY WATERSHED (CONTINUED)

Stream System	Watershed	Known Pollutants	Primary Pollutant Sources – Point Source (PS) and Nonpoint Source (NPS)	
			PS (Known)	NPS (Known or Suspected)
Paukauila	**Paukauila**	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• City MS4* • State DOT MS4*	• Natural erosion processes • Agriculture (soil loss and nutrient/chemical application) • Cesspools and other OSDS • Paʻalaʻa Kai Wastewater Treatment Plant (injection well) • Urban chemical use • Urban stormwater runoff • Impacts of climate change
	Helemano	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Possible chemical contaminants	• Army MS4* • State DOT MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Motorized recreational activities • Impacts of climate change
	ʻŌpaeʻula	• Nutrients • Sediments (turbidity)	• N/A	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Impacts of climate change

** MS4 = Municipal Separate Storm Sewer System*
*** WWTP = Wastewater Treatment Plant*

TABLE ES-2. PRIORITY WATERSHEDS FOR MANAGING POLLUTANTS BY LAND USE TYPE

GENERAL LAND USE TYPE	Primary Factors That May Contribute Pollutants	Pollutants of Concern	Priority* Watersheds: Sediments	Priority* Watersheds: Nutrients	Priority* Watersheds: Other Pollutant Types**
Forest Lands	• Natural erosion processes • Feral ungulates • Nonnative & invasive plants • Forest fires	• Sediments and turbidity • Nutrients • Bacteria (from animals and natural sources)	• Kaukonahua • Poamoho • Helemano • ʻŌpaeʻula	• Kaukonahua† • Poamoho† • Helemano† • ʻŌpaeʻula† † *Primarily the forests of the Koʻolau range*	*None‡* ‡ *Not considered significant or feasible to address*
Agricultural Lands	• Natural erosion processes − Highly erodible soils − Steep slopes (gulches) • Grazing • Nonnative & invasive plants • Feral ungulates • Fires • Natural erosion processes • Agriculture practices	• Sediments and turbidity • Nutrients • Chemical contaminants (e.g. pesticides transported in runoff)	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Poamoho	• Poamoho *(pesticides)*
Developed Areas	• Wahiawā WWTP • Wastewater injection wells (Paʻalaʻa Kai WWTP) • MS4s (City, DOT, Army, Navy) • Cesspools and other OSDS • Urban/roadway stormwater runoff • Chemical use • Hazardous waste sites	• Sediments & turbidity • Nutrients • Bacteria & other pathogens • Chemical contaminants • Trash	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Kaukonahua • Paukauila • Kiʻikiʻi *(pollutants associated with urban stormwater runoff)*
Army Training	• Natural erosion processes • Feral ungulates • Nonnative & invasive plants • Army training activities • Forest fires • Controlled burns and other fires	• Sediments and turbidity • Nutrients • Bacteria (from animals and natural sources)	• Kaukonahua	• Kaukonahua	*None‡* ‡ *Not considered significant or feasible to address*

* *Watersheds and other items are listed in no particular order.*

** *Other pollutants are considered secondary pollutants to sediments and nutrients. These pollutants are addressed opportunistically in the Implementation Plan (Volume 2).*

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1 INTRODUCTION

1.1 BACKGROUND: SETTING THE CONTEXT

The City and County of Honolulu Department of Facility Maintenance (DFM) contracted Townscape, Inc. to develop a Watershed-Based Plan (WBP) for the watersheds that drain into Kaiaka Bay on Oʻahu's North Shore, together referred to as the "Kaiaka Bay Watersheds" in this plan. The objectives of this plan are to assess water quality issues in the watersheds, describe the main sources of pollutants, and identify key management measures, policy amendments, and education and outreach opportunities that will improve water quality in the Kaiaka Bay Watersheds and in Kaiaka Bay. The importance of clean water and healthy watersheds cannot be overstated. Hawaiʻi's watersheds provide us with source s of clean water, food, cultural heritage and opportunities for traditional practices, recreational opportunities, industries such as tourism and agriculture, scenic beauty, and habitat for native plants and animals.

The Kaiaka Bay WBP will allow DFM to better understand the major sources of pollution (point and nonpoint) in the watersheds and prioritize mitigation strategies. In doing so, it will provide a greater context for DFM as they implement best management practices (BMPs) and other strategies/programs to comply with their Storm Water Management Plan (SWMP) and with the Waste Load Allocations (WLA) set in place for their Municipal Separate Storm Sewer System (MS4), operated under a National Pollutant Discharge Elimination System (NPDES) permit. An MS4 collects and transports stormwater runoff and discharges the runoff at discreet locations into watersheds without treatment. The WLAs were determined by the State Department of Health (DOH) in a Total Maximum Daily Load (TMDL) calculation for pollution in the North and South Forks of Kaukonahua Stream, a major waterbody in the watershed.

This project was phased to meet funding restrictions and to prioritize tasks. In 2010, Phase I was completed by Townscape, Inc. for the watersheds that drain into both Kaiaka Bay and Waialua Bay (located just to the north of Kaiaka Bay). Phase I consisted of a preliminary watershed profile, initial stakeholder outreach with large landowners, hydrology calibration of a water quality model, water quality data collection, an initial assessment of water quality issues, and identification of preliminary BMPs and next steps. Since completion of Phase I, the project area was modified to no longer include the watershed that drains into Waialua Bay (Anahulu Watershed). This reduced the total area by approximately 11,763 acres. Additionally, a different water quality model called the Open Nonpoint Source Pollution and Erosion Comparison Tool (OpenNSPECT) was selected to be used in the final phases of the project. OpenNSPECT is a watershed model based on Geographic Information Systems (GIS) that was developed by the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management.

The Kaiaka Bay WBP consists of two parts. *Volume 1: Watersheds Characterization* (this document) describes the watersheds in terms of physical and natural features, land uses, water quality issues, and possible sources of pollution. It essentially provides an overview of existing conditions and problem areas and serves as a mechanism to assess natural and anthropogenic processes within the watersheds to determine which of them may be generating pollution. *Volume 2: Implementation Plan* outlines the key actions and projects necessary to improve water quality in the watersheds, as well as a monitoring plan for measuring progress and improvements.

1.2 VISION & GOALS OF THE WATERSHED-BASED PLAN

An overarching vision statement and a clear set of goals provides a framework for developing a WBP. The vision and goals of the Kaiaka Bay WBP are highlighted in the text box below.

Vision

"Water quality in Kaiaka Bay and its contributing streams is improved by reducing land-based pollution to sustain the watersheds' plentiful natural and cultural resources and meet State Water Quality Standards."

Goals

- Measurably reduce erosion and sediment loads from all land use types.
- Measurably reduce nutrient loads from all land use types.
- Address other types of pollutants (e.g. pesticides, hydrocarbons, pathogens, metals, etc.) as opportunities arise or as future needs indicate necessary.
- Improve existing regulations and programs related to watershed management and identify opportunities for new programs.
- Increase the education, understanding, and participation of major landowners and the local community regarding watershed stewardship and water quality monitoring activities.

The vision and goals are referred to throughout the Volume 1 and 2 of this WBP.

1.3 LOCATION & GEOGRAPHIC SCOPE

The project area includes all watersheds that drain into Kaiaka Bay on the north-western coast of the island of Oʻahu in the town of Waialua, totaling 51,454 acres or 80.4 square miles (Figure 1). According to the Hawaiʻi Stream Assessment (HSA, 1990), the area contains two major stream systems: The Kiʻikiʻi Stream System (HSA system 3-6-06s) and the Paukauila Stream System (HSA system 3-6-07s). Each stream system is in turn composed of three separate watersheds. The Kiʻikiʻi Stream System is made up of the Kiʻikiʻi, Kaukonahua, and Poamoho watersheds while the Paukauila Stream System consists of the Paukauila, Helemano, and ʻŌpaeʻula watersheds. Together, the Kaiaka Bay Watersheds make up approximately 13.5% of Oʻahu's total land area.

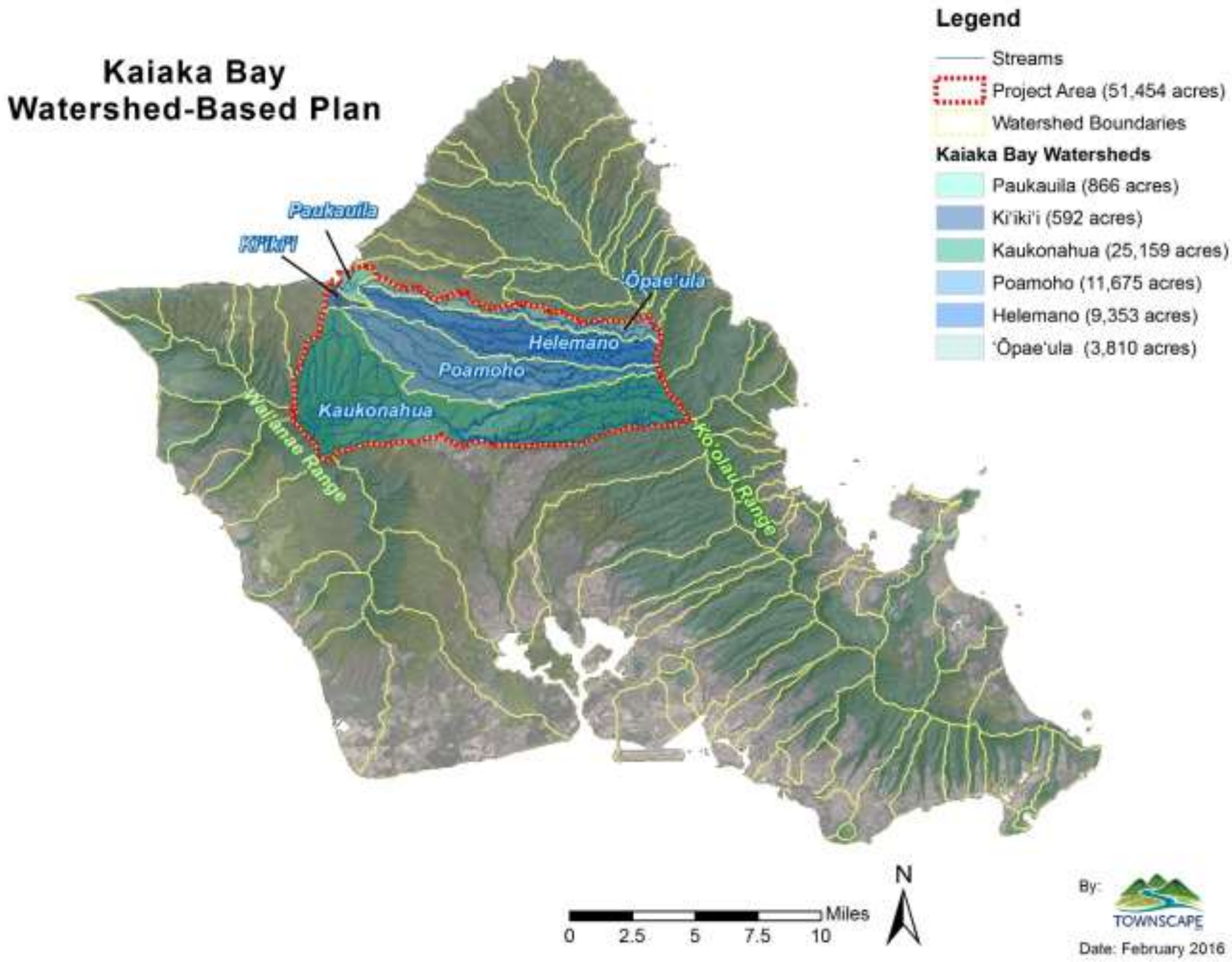


FIGURE 1. KAIAKA BAY WATERSHEDS OVERVIEW

1.4 PLANNING PROCESS & METHODOLOGY

1.4.1 WATERSHED PLANNING

The most important aspects of watershed planning and implementation are to describe the major sources of pollution and to identify potential management practices or projects that can be implemented to improve water quality. To accomplish these objectives, this WBP is being developed in accordance with the Environmental Protection Agency's (EPA) "nine key elements" of watershed plans (Table 1). Following this format will also ensure that projects proposed for implementation under this plan are eligible to qualify for funding under section 319(h) of the federal Clean Water Act (CWA). The EPA's "nine key elements" are integrated into the overall planning process and are covered in *Volume 1: Watersheds Characterization* (this document) and *Volume 2: Implementation Plan* of this WBP.

TABLE 1. EPA NINE KEY ELEMENTS OF WATERSHED-BASED PLANS

EPA's Nine Key Elements of a WBP	
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 where those measures will be needed to implement this plan.
4	Estimate of the amounts of technical and financial assistance needed, associated costs, and the sources and authorities that will be relied on 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 under Element #8 (above).

Using a slightly different approach, the "Hawai'i Watershed Guidance" handbook breaks watershed planning into six main steps which are designed to incorporate the nine key elements and add an additional two steps that are related to the implementation of the WBP and follow-up after implementation (Figure 2). The first two steps are primarily accomplished *Volume 1* (this document), while steps 3

FIGURE 2. SIX STEPS OF WATERSHED PLANNING & IMPLEMENTATION

and 4 are addressed in *Volume 2.* Since steps 5 and 6 are related to the implementation of the WBP and subsequent evaluation; these steps will be undertaken by entities after the completion of the WBP.

In addition to accomplishing Step 1 and Step 2 of the six watershed planning steps outlined by the "Hawaiʻi Watershed Guidance," characterizing the watersheds is also the second official step in the watershed planning process as outlined by the EPA in the "Handbook for Developing Watershed Plans to Restore and Protect our Waters."

Characterizing a watershed is performed via a multi-disciplinary approach that combines quantitative and qualitative science, geospatial analysis, public participation, and stakeholder outreach. This approach helps to blend science, regulatory issues, policies, people, and social/economic issues. At the end of the *Watersheds Characterization*, possible causes of water quality impairments (point and nonpoint sources of pollution) are identified to provide a basis for the development of management recommendations.

1.4.2 STAKEHOLDER OUTREACH

The EPA's nine elements for watershed plans and the six-step process outlined in the "Hawaiʻi Watershed Guidance" provide a framework for the public participation and stakeholder outreach process required for a WBP. In line with these guidelines, stakeholder outreach was conducted throughout the preparation of the *Watersheds Characterization*. See Chapter 6 for a review and summary the stakeholder outreach that occurred during the preparation of the *Watersheds Characterization*.

1.4.3 LITERATURE REVIEW & DATA COMPILATION

One of the first steps of watershed planning is to essentially take an "inventory" of the watersheds, which involves gathering and analyzing existing data on the watersheds in the project area. Townscape, Inc. gathered and assessed water quality data, reports, articles, government records, and other relevant research data. Information from these sources are referenced throughout this document and listed in the references section.

Since there is a lack of comprehensive water quality data for the Kaiaka Bay Watersheds, proposed actions to improve water quality should be made within the context of other planning efforts in the area to ensure compatibility. The following is a summary of some of the related plans that were reviewed for this project.

NORTH SHORE WATERSHED MANAGEMENT PLAN

The Honolulu Board of Water Supply (BWS) is in the process of updating the City's Water Use and Development Plan, as required by the State Water Code and Revised Ordinances of Honolulu Chapter 30, Water Management. BWS has developed a framework of regional Watershed Management Plans (WMP) for each of its eight Development Plan districts, which together will constitute the Oʻahu WMP.

In addition to water use and development, BWS is seeking to account for all the resources in the watersheds by establishing watershed management objectives and strategies specific to each region. The goal of the Oʻahu WMP is "to formulate an environmentally holistic, community-based, and economically viable WMP that will provide a balance between: (1) the protection, preservation, and management of Oʻahu's watersheds, and (2) sustainable groundwater and surface water use and development to serve present users and future generations." The Plan objectives are to promote sustainable watersheds; protect and enhance water quality and quantity; protect Native Hawaiian rights and customary uses; facilitate public participation, education, and project implementation; and meet future water demands at reasonable costs.

BWS released the Final North Shore WMP in 2016 (G70, 2016). The North Shore WMP was funded after completion of the Waiʻanae, Koʻolau Loa and Koʻolau Poko plans, all of which have been adopted by the City.

North Shore Regional Wastewater Alternatives Plan

The North Shore Regional Wastewater Alternatives Plan (Brown and Caldwell, 2012) was initiated by City to evaluate alternatives for wastewater collection, treatment, and disposal for the North Shore region, as defined by the boundaries of the North Shore Neighborhood Board (from Kaʻena Point to Waialeʻe Gulch). The planning period extended through the year 2030.

The plan was intended to update and revise previous wastewater planning efforts for the region and incorporated input from community members to identify ten conceptual alternatives to handling wastewater on the North Shore. Ultimately, a decentralized approach to wastewater management was proposed, a departure from traditional metropolitan regional wastewater management as well as past planning efforts. Decentralized wastewater systems lend themselves to rural, spread-out, communities particularly where the geography makes is difficult to collect and treat at centralized facilities. Specific projects were also recommended in the plan.

Hawaiʻi's Implementation Plan for Polluted Runoff Control

Section 319 of the CWA established a national Nonpoint Source Management Program to address nonpoint source (NPS) pollution. Administered by the EPA under the CWA, the Section 319 program provides funding for state NPS management programs and projects aimed at preventing and reducing NPS pollution. In Hawaiʻi, the DOH Clean Water Branch (CWB) Polluted Runoff Control (PRC) Program administers the State's NPS management program and develops the State's NPS Management Plan to implement watershed-specific strategies to control NPS pollution.

Hawaiʻi's Implementation Plan for Polluted Runoff Control, published in 2000, was the first five-year plan for implementation of activities to be undertaken by State and county agencies, federal agencies, and Hawaiʻi's citizens to control NPS (also known as polluted runoff). Prepared by the Department of Business, Economic Development and Tourism's (DBEDT) Office of Planning Coastal Zone Management (CZM) program and the DOH CWB Polluted Runoff Control Program, the plan addressed the nine key elements required by the EPA for State NPS pollution control programs to be formally recognized by the EPA as Tier I Nonpoint Source States. It also established long and short-term goals and activities to control NPS pollution in Hawaiʻi. In addition, 15-year strategies and 5-year implementation plans were established to prevent and reduce NPS with an evaluation schedule to determine the effectiveness of controls.

HAWAIʻI'S NONPOINT SOURCE MANAGEMENT PLAN: 2015 - 2020

Hawaiʻi's Nonpoint Source Management Plan is the updated version of the 2000 plan: Hawaiʻi's Implementation Plan for Polluted Runoff Control. The plan is intended to guide Hawaiʻi's NPS pollution management efforts by establishing goals, objectives, strategies, and milestones directed at preventing and reducing NPS pollution and improving water quality. In contrast to the 2000 plan, the updated plan sets forth a more coordinated approach among federal, state, and local water quality agencies to implement NPS projects and target pollutants and their sources more effectively.

The plan also advances the State's efforts to obtain full approval of Hawaiʻi's Coastal Nonpoint Pollution Control Program (CNPCP), which was established under Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990. The CNPCP is administered jointly by the DOH and by CZM. Both the PRC and the CNPCP seek to prevent and reduce polluted runoff in order to protect and improve water quality. The plan is meant to facilitate coordination between the PRC and CZM programs and with various federal, state, and local programs to more effectively manage NPS pollution in Hawaiʻi.

NORTH SHORE SUSTAINABLE COMMUNITIES PLAN

The North Shore Sustainable Communities Plan is a City-led planning effort to guide policy, investment, and decision-making for the North Shore Planning District. It describes the vision for the North Shore: scenic open spaces, coastal resources, cultural and plantation heritage, a stable and diverse agriculture industry, principal commercial and civic centers in Haleʻiwa and Waialua, and rural communities.

WAIALUA TOWN MASTER PLAN

The Waialua community, along with the City and County of Honolulu, developed the Waialua Town Master Plan (2005) as an effort to reverse the economic and physical decline after the closure of the Waialua Sugar Company (also known as the Waialua Agriculture Company) in 1996. The main economic priorities were in the areas of agriculture, light industry, retail, residential, visitor, and education. The Plan emphasizes maintenance of Waialua's plantation history; maintenance and enhancement of open space; and shoreline, beach, and stream access, including a Stream Greenbelt Park along Kiʻikiʻi Stream.

1.4.4 GEOGRAPHIC INFORMATION SYSTEMS

GIS is a helpful tool used by planners and resource managers throughout the world to aid in analyzing and visualizing geographic areas and making management decisions. ArcGIS 10.3 was used to analyze and depict spatial relationships between various features in the Kaiaka Bay Watersheds such as land uses, land ownership, land cover, and other relevant features. The resulting outputs were the maps seen throughout this document. Townscape, Inc. compiled a database of GIS data from various sources as noted on each map. Most of the data layers can be obtained from the State Office of Planning, which hosts a web-based databank of GIS layers. Note that the State does not guarantee accuracy of the data it provides. The watershed boundaries used in the maps are from the State watershed polygon layer (wshedpy_n83). Some GIS data were produced by Townscape, Inc. via GPS data collected during field work, which was later imported into ArcGIS. Data layers obtained from various sources were clipped to the project area boundary and/or individual watersheds for analysis and computation of numbers found in tables throughout this report. When it was deemed relevant or interesting, data were calculated for individual watersheds instead of for the entire project area (e.g. amount of highly erodible soils in each watershed). All maps were made using the North American Datum 1983, Universal Transmercator Zone 4 North projection. Satellite imagery used in most of the maps came from the "World View 2" satellite.

1.4.5 FIELD WORK

Field work was conducted to get an overview of the on-the-ground conditions, to verify the accuracy of geospatial data, and to assess possible problem areas identified by stakeholders and the overall planning process. Field activities conducted for *Volume 1: Watersheds Characterization* included multiple surveys of the project area by car, a few site visits to specific locations, and a geomorphological assessment with an AECOM geomorphology expert (field work conducted in Poamoho Stream). The purpose of the geomorphic assessment was to learn more about stream characteristics in the Kaiaka Watersheds and assess sources of sediments (AECOM, 2016; Appendix A).

Assessing Poamoho Stream with AECOM geomorphologist

1.4.6 MODELING NONPOINT SOURCE POLLUTION

OpenNSPECT was used to model nonpoint source pollution (sediments and nutrients) in the Kaiaka Bay Watersheds. OpenNSPECT is an open-source version of the Nonpoint Source Pollution and Erosion Comparison Tool designed by NOAA that examines the relationship between land cover, nonpoint source pollution, and erosion. Townscape, Inc. received training and assistance by NOAA staff in running the model and analyzing the results. Refer to Section 7.3 for more information.

1.5 REGULATORY ENVIRONMENT FOR WATERSHED PLANNING

Understanding the regulatory environment is important for addressing water quality issues and for recommending potential solutions. Numerous agencies at the federal, state and county levels play a role in regulating activities and implementing programs to maintain water quality and control polluted runoff (Table 2). The regulatory relationships between the various federal, state and local laws are complex; some of these regulations are also discussed below.

The framework for many of the applicable regulations comes from the federal Clean Water Act of 1972 (further amended in the 1970s and 1980s). The CWA, administered by the EPA, regulates discharges of pollutants into U.S. waters and sets surface water quality standards. However, many of the administrative and enforcement aspects of the law have been delegated to the individual states. In Hawaiʻi, the agency responsible for pollutant discharges (NPDES permit system) and water quality regulation is the State Department of Health Clean Water Branch through state regulations in the Hawaiʻi Administrative Rules Title 11. Groundwater is regulated separately by the Safe Drinking Water Act (SDWA, 1974 with amendments in the 1980s and 1990s). This law, also administered by the EPA, regulates underground injection wells via the UIC program to prevent contamination of groundwater resources.

While there are many State laws that apply to watershed planning and pollution control, two important regulations are covered under Hawaiʻi Revised Statutes (HRS) §342D and HRS §342E because they allow the State DOH to enforce laws related to controlling sources of pollution (point source and nonpoint source). In fact, under HRS §342E, the DOH can fine NPS polluters up to $10,000 for each offense (each day of each violation constitutes a separate offense). One obstacle to enforcement of the law is that it is often difficult to determine the origin of NPS pollution. To enforce the law, a potential violation would need to be reported to the DOH, followed by an inspection of the property by DOH staff.

Another State law that is relevant to watershed planning is the State Water Code (HRS §174C). The State Water Code recognizes the need for comprehensive water resources planning and requires that each county prepare and adopt a water use and development plan as part of the Hawaiʻi water plan (refer to the description of the North Shore Watershed Management Plan in section 1.4.3 for more information). Additionally, the State Water Code directs the State Commission on Water Resources Management (CWRM) to "Establish an instream flow program to protect, enhance, and reestablish, where practicable, beneficial instream uses of water." Instream flow standards describe the stream flows necessary to protect adequately fishery, wildlife, aesthetic, scenic, or other beneficial instream uses. Interim instream flow standards have been established statewide and are based on the amount of water that was flowing in each stream on the date of adoption. CWRM established the Stream Protection and Management (SPAM) Branch in 2002. The SPAM Branch prepared a Program Implementation Plan in 2005 to "manage and protect Hawai'i's surface water resources through a comprehensive instream use protection program and the establishment of instream flow standards."

One county-level regulation (described in Revised Ordinances of Honolulu [ROH] §14) that is particularly relevant to watershed planning on Oʻahu requires landowners to obtain a permit for certain types of soil disturbing work (e.g. grading and grubbing), including activities for agricultural purposes. However, according to ROH §14-13.5(d), an exclusion to the grading/grubbing permit is available if the farmer/landowner obtains a soil conservation plan that is approved by the applicable Soil and Water Conservation District (SWCD). The law states that the conservation plan "shall be made available to the city and county." While this allowance for an exclusion to a grading/grubbing permit provides incentive for farmers to obtain a conservation plan, there are several issues, including:

- Staffing at agencies that prepare conservation plans is limited, including the SWCDs;
- Farmers often have limited funding to implement BMPs recommended in conservation plans; and
- No entity is designated responsible for follow-up or enforcement to ensure that conservation plans are implemented.

While a variety of funding opportunities may exist for implementing projects and BMPs, funding from federal grants may also be available as specified in section 319 (h) of the CWA when a watershed plan is written in accordance with the EPA guidelines (i.e. the nine key elements are addressed). This mechanism helps to further maximize the success of WBPs by increasing access to funding for the implementation of projects. 319 funds are federal funds that are allocated by the EPA to each state. The DOH CWB administers and distributes 319 funds that are allocated to the State of Hawaiʻi.

TABLE 2. RELEVANT REGULATIONS

REGULATION	ISSUES ADDRESSED BY REGULATION	RESPONSIBLE AGENCY
	FEDERAL	
Clean Water Act	Surface Waters of the U.S.	EPA
Safe Drinking Water Act	Groundwater, Underground Injection	EPA
Coastal Zone Mgmt Act	Coastal Areas, nearshore waters, SMA	NOAA
U.S. Coral Reef Task Force	Nearshore waters/coral reefs	NOAA
CFR §40 – Protection of Environment	Covers all EPA-regulated environmental programs, including water, sewage, pesticides, etc. Provides direction for the enactment of State and local laws.	EPA
	STATE OF HAWAIʻI	
HRS §12-174C	State Water Code – requires the City to develop county water use and development plan (see ROH §30)	DLNR-CWRM
HRS §12-180	Soil and Water Conservation Districts	DLNR
HRS §12-180C	Erosion and Sediment Control; requires the City to enact erosion/sediment ordinances	DLNR→ City
HAR §11-54	Surface Water Quality Standards	DOH-CWB
HAR §11-55	Water Pollution Control (NPDES permits)	DOH-CWB
HAR §11-19	Emergency Plan for Safe Drinking Water	DOH-SDWB
HAR §11-20	Rules Relating to Public Water Systems	DOH-SDWB
HAR §11-21	Cross-connection & Backflow Control	DOH-SDWB
HAR §11-23/23A	Underground Injection Control (UIC program)	DOH-SDWB
HAR §11-25	Certification of Personnel at Water Treatment Plants	DOH-SDWB
HRS §19-340E	Drinking Water Regulations, Action Levels for Contaminants, Drinking Water Financing	DOH-SDWB
HAR §11-61 HRS §19-340F	Certification of Personnel at Wastewater Treatment Plants	DOH-WWB
HAR §11-62/62 appdx	Wastewater Systems (public treatment plants, on-site treatment such as septic tanks)	DOH-WWB
HRS §13-205A	Coastal Zone management, nearshore waters, SMA	DBEDT-Office of Planning
HRS §342 D	Water Pollution	DOH-PRC Program
HRS §342 E	Nonpoint Source Pollution Management and Control	DOH-PRC Program
	CITY & COUNTY OF HONOLULU	
ROH §14	Public Works Infrastructure – includes sewer/wastewater treatment systems, on-site wastewater treatment, storm sewer system, grading and grubbing permits	City-ENV, DDC (WWD)
ROH §25	Special Management Area	City-DPP
ROH §30	Water Management – based on State Water Code; 8 regional WMPs to make up the Oʻahu Water Management Plan	City-DPP, BWS
DPP Admin Rules Title 20	Rules Relating to Water Quality – requires that certain development/redevelopment projects implement LID practices	City-DPP

CFR = Code of Federal Regulations *HAR = Hawaiʻi Administrative Rules*
HRS = Hawaiʻi Revised Statutes *ROH = Revised Ordinances of Honolulu*

2 PHYSICAL & NATURAL FEATURES

2.1 BOUNDARIES OF KAIAKA BAY WATERSHEDS

TABLE 3. SIX KAIAKA BAY WATERSHEDS

Stream System	Watershed	Acres
Kiʻikiʻi	Kiʻikiʻi	592
	Kaukonahua	25,159
	Poamoho	11,675
Paukauila	Paukauila	866
	Helemano	9,353
	ʻŌpaeʻula	3,810
	Total Project Area:	**51,454**

The Kaiaka Bay Watersheds are comprised of approximately 51,454 acres of land that stretches between the ridgelines of the Waiʻanae and Koʻolau mountain ranges (at peak elevations of 4,025 feet and 2,800 feet, respectively) and extends toward the North Shore, where the watersheds drain into the ocean at Kaiaka Bay, located in the town of Waialua. The Kaukonahua, Poamoho, and Kiʻikiʻi watersheds are part of the Kiʻikiʻi Stream System and the Helemano, ʻŌpaeʻula, and Paukauila watersheds are part of the Paukauila Stream System (Table 3). Each watershed is in turn composed of many different streams and tributaries, which eventually converge and flow into Kaiaka Bay (Figure 3).

It should be noted that some departments within the State of Hawaiʻi use different watershed delineations. These departments, which include the State DOH CWB, define the two stream systems as watersheds. Therefore, Kaukonahua and Poamoho are not defined as individual watersheds; they are considered part of the Kiʻikiʻi Watershed. Likewise, these departments do not classify Helemano and ʻŌpaeʻula as individual watersheds and are considered part of the Paukauila Watershed.

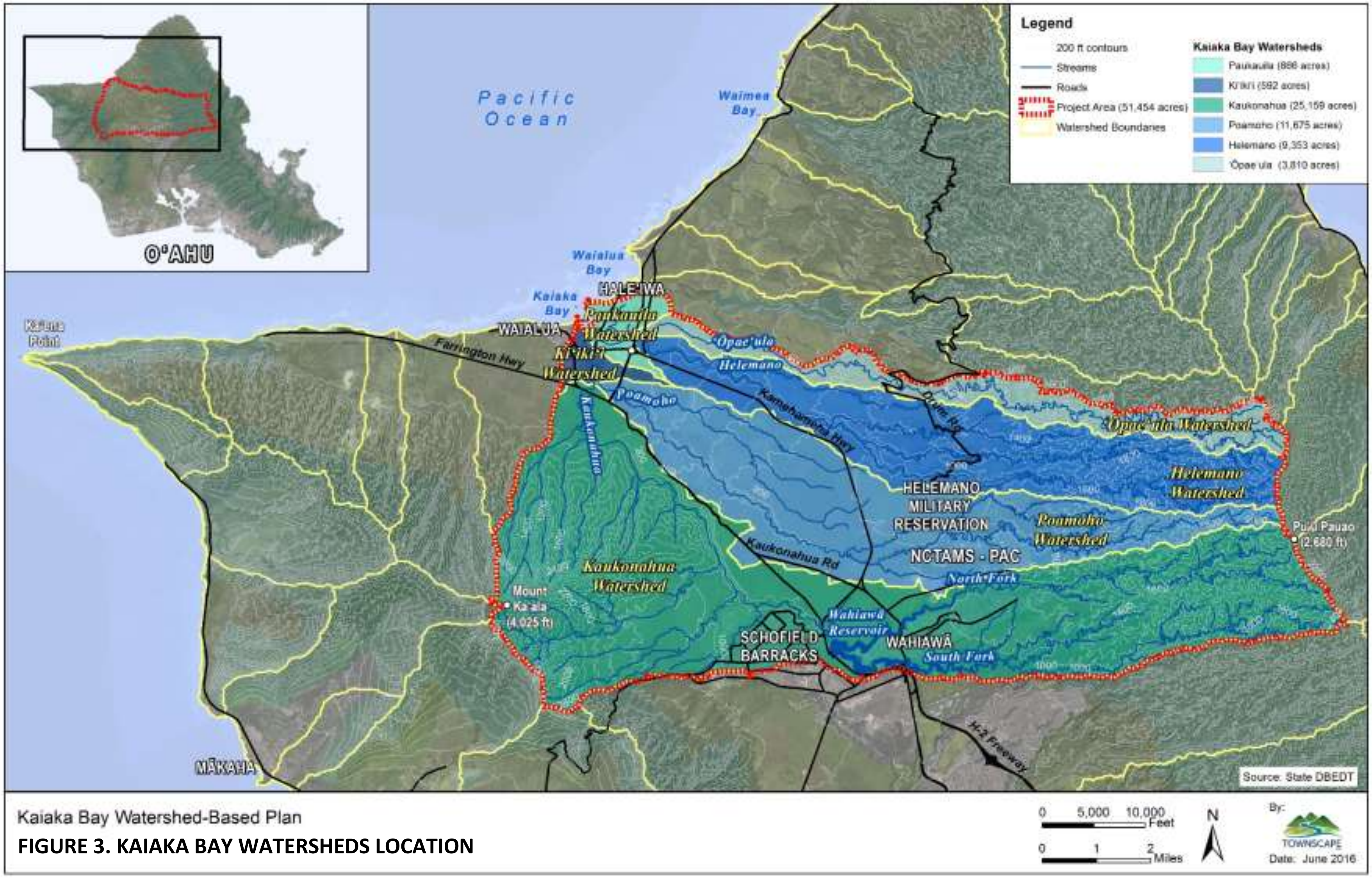
2.2 GEOLOGY

The Hawaiian Islands emerged from volcanic eruptions in the Pacific Ocean with the movement of tectonic plates over an active hotspot. Oʻahu's two volcanoes (Waiʻanae and Koʻolau) started as separate undersea volcanoes over three million years ago. With continued eruptions, the two volcanos eventually joined to form the Island of Oʻahu. The Kaiaka Bay Watersheds are composed of rock and sediment that is derived from both volcanos. Approximately 74% of the land in the Kaiaka Bay Watersheds (38,021 acres) is derived from theoleiitic basalt from pāhoehoe and ʻaʻā lava flows from the Koʻolau volcano, dating roughly 1.8 to 3 million years ago. The remaining land originates from lava flows from the Waiʻanae volcano, or is a result of the process of erosion on deposits from either volcano (Figure 4).

2.3 TOPOGRAPHY

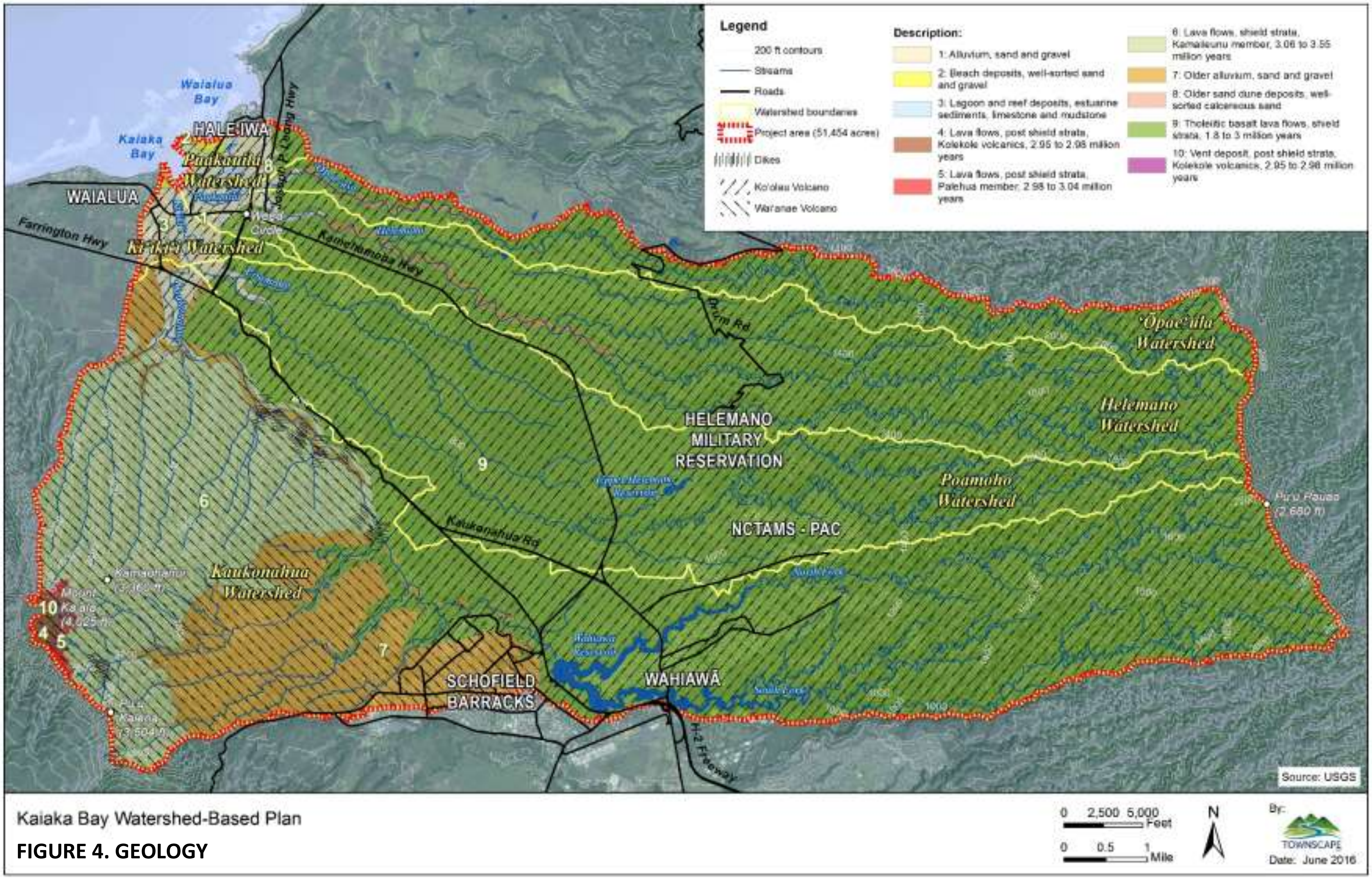
The topography of the watersheds varies greatly in slope as well as elevation, ranging from relatively flat terrain to nearly vertical cliffs near the summit of Mt. Kaʻala (Figures 5 and 6). The Koʻolau mountain range on the eastern border of the project area are characterized by a network of winding gulches with steep ridges dividing them. To the west, the Waiʻanae range creates steep topography with ridges and gulches that are relatively large. Mt. Kaʻala is the highest point in the project area, as well as on all of Oʻahu, at 4,025 feet. Despite the range in elevation, much of the project area is defined by gently sloping topography until around the 1,200-foot elevation.

As part of the geomorphology assessment conducted for this WBP, assessment of LiDAR data for Poamoho Stream revealed steep canyon walls with gentler slopes within the narrow valley. The alignment of the stream indicates that the stream energy impacts the slopes by removing supporting sediments that have been deposited from slope failures (landslides). The sediments are then transported downstream. The geomorphology report also described the upper areas of the watersheds as “source reaches” where steep slopes are a prominent feature and landslides are the predominant sources of sediments in the streams (AECOM, 2016; Appendix A).



Kaiaka Bay Watershed-Based Plan

FIGURE 3. KAIAKA BAY WATERSHEDS LOCATION



Kaiaka Bay Watershed-Based Plan

FIGURE 4. GEOLOGY

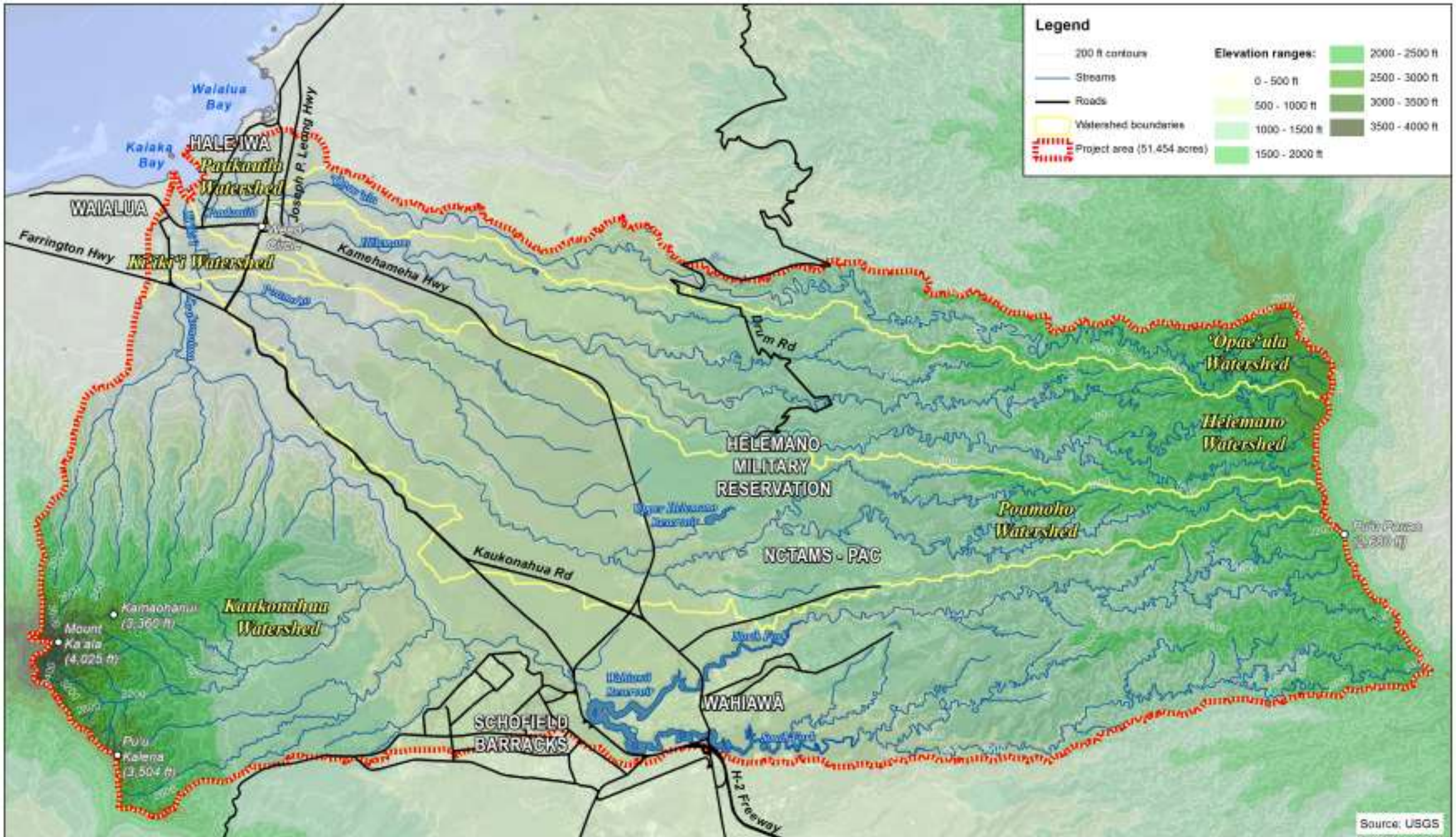
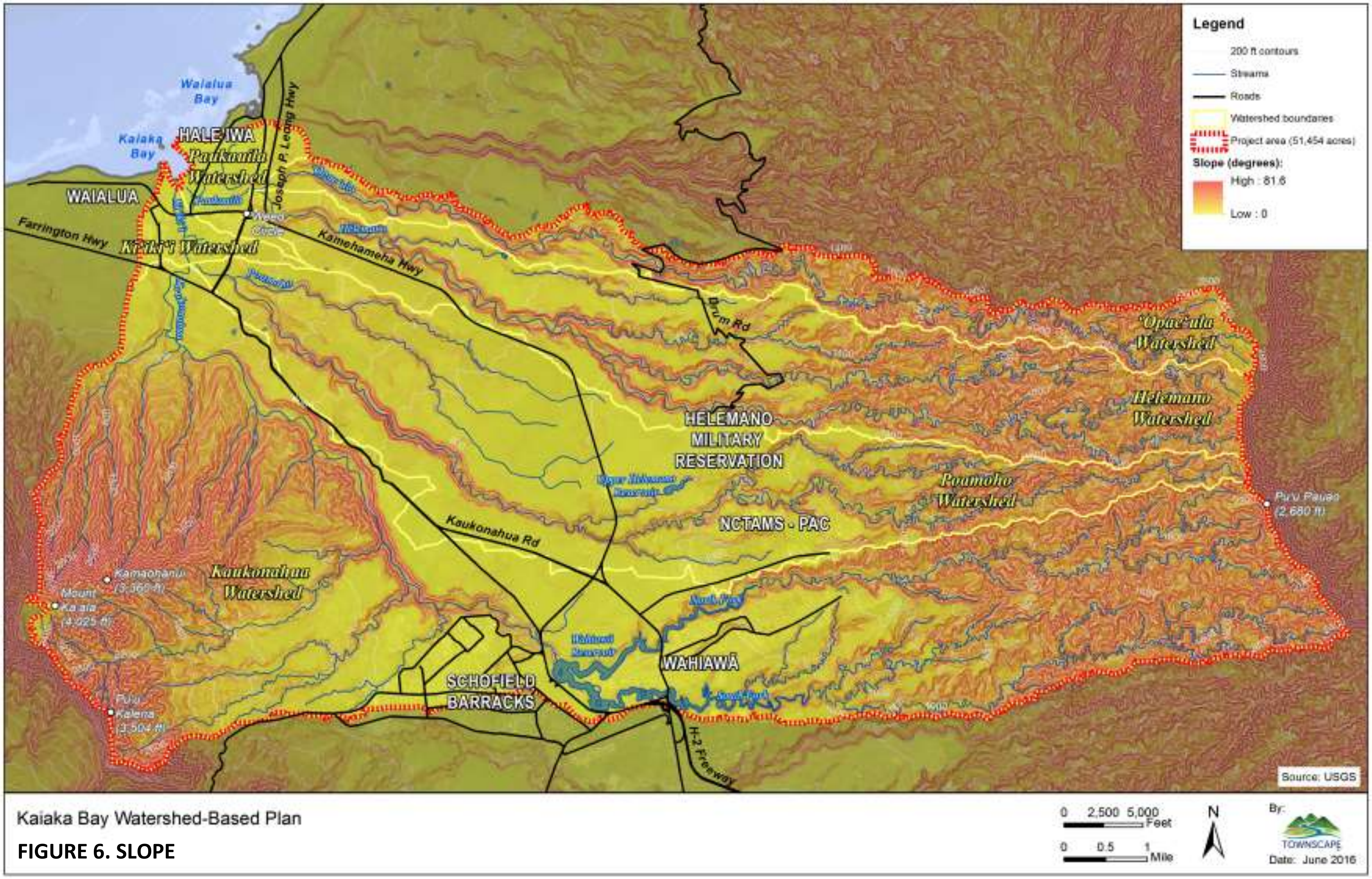


FIGURE 5. ELEVATION



Kaiaka Bay Watershed-Based Plan

FIGURE 6. SLOPE

2.4 CLIMATE

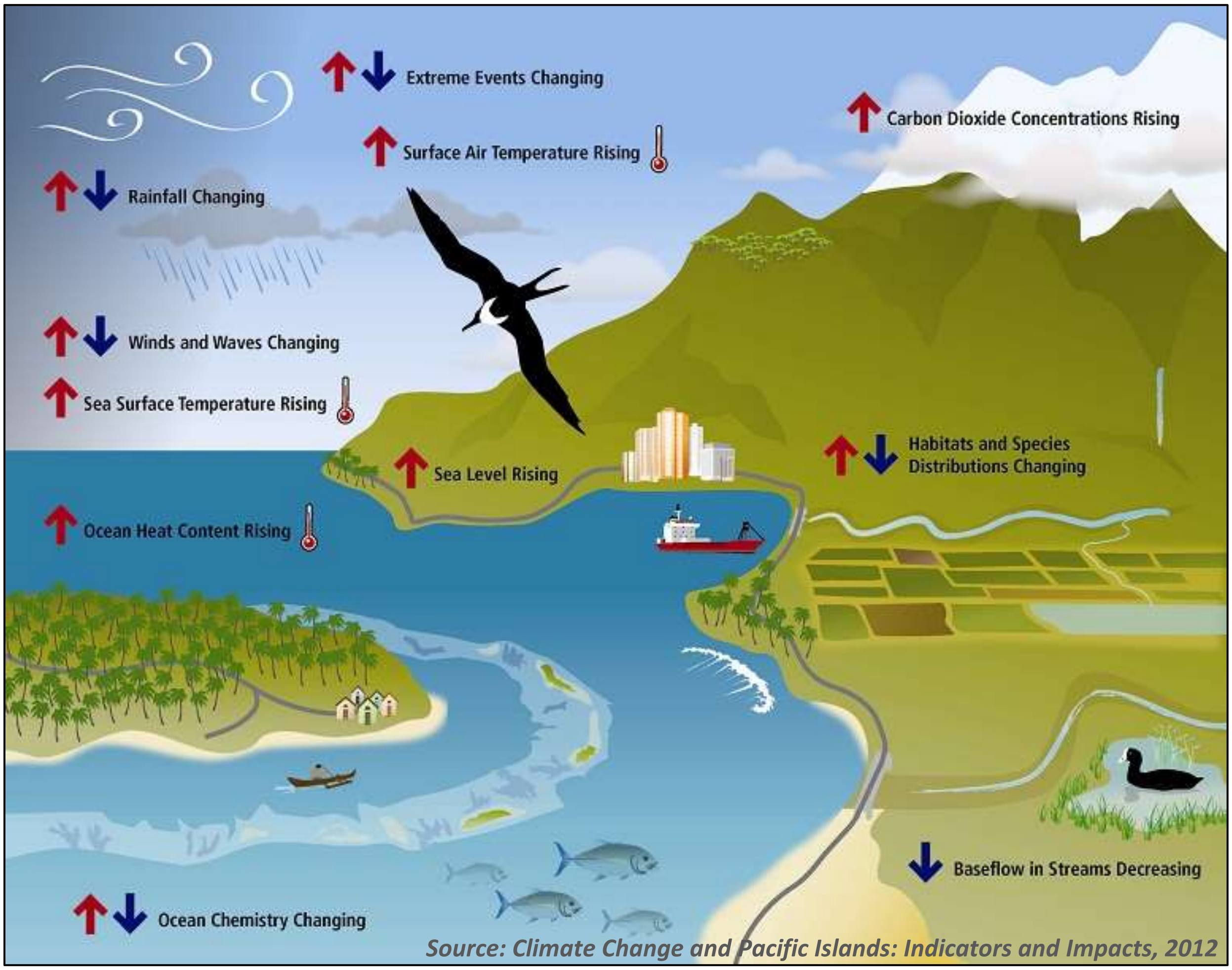
The climate in the Hawaiian Islands is generally influenced by the characteristic northeasterly trade winds, which carry with them moisture picked up over the ocean. The trade winds usually vary between 10 to 20 miles per hour and are steadier during the summer (90% of the time during June to August) than during the winter (50% of the time between January and March). During the winter months, strong, easterly Kona winds associated with tropical storms often produce large swell events that travel for thousands of miles until reaching the shores of Hawaiʻi. These high surf events play a key role in natural beach processes like rip current formation, erosion, and reef growth (G70, 2016).

Rainfall in the Hawaiian Islands is often the result of orographic lift, where the warm, moist air carried by the trade winds is forced to higher elevations over the mountains, thus cooling and resulting in condensation and rainfall over the summit areas. On Oʻahu, the trade winds first sweep across the northern end of the Koʻolau mountain range before moving toward the leeward side of the island. As a result, the amount of rainfall in the Koʻolau range is much higher than in the Waiʻanae range (Figure 8). In the Kaiaka Bay Watersheds, the mean annual rainfall at the summit of the Koʻolau range exceeds 270 inches, while the maximum mean annual rainfall at the summit of the Waiʻanae range (Mount Kaʻala) peaks at about 80 inches. The beach town of Waialua can receive as little as 30 inches on average each year (Oki, 1998). During heavy storms, 24-hour rainfall can exceed 10 inches over coastal areas and 20 inches over the mountainous interior of the Koʻolau range (Oki and Brasher, 2003).

Rainfall from large storms causes dramatic increases instream flows which eventually discharge into the ocean. In fact, it is estimated that storms are responsible for roughly half of the total fluvial water discharge that reach coastal waters in Hawaiʻi. Peak storm flows (100-year storm) estimated for Kiʻikiʻi Stream are 39,000 cfs; and for Paukauila Stream, 18,700 cfs (Hawaiʻi OP CZM and Hawaiʻi DOH PRC, 2000). Suspended sediments and associated particulate nutrients are delivered almost exclusively in storm runoff, so storms could be responsible for large pulses of both dissolved and particulate nutrients to coastal systems (Hoover, 2002). Major storm events have a significant impact on erosion processes in Hawaiʻi and result in large amounts of sediments being washed into drainages. In fact, studies have shown that the majority of annual suspended-sediment transport in watersheds on Oʻahu occurs during a few large storms. Additionally, nutrients such as total phosphorus and nitrate have also been shown to significantly increase in streams during storm events (DeVito et al., 1995). See section 7.2.1.1 for details about how storm events affect water quality in watersheds.

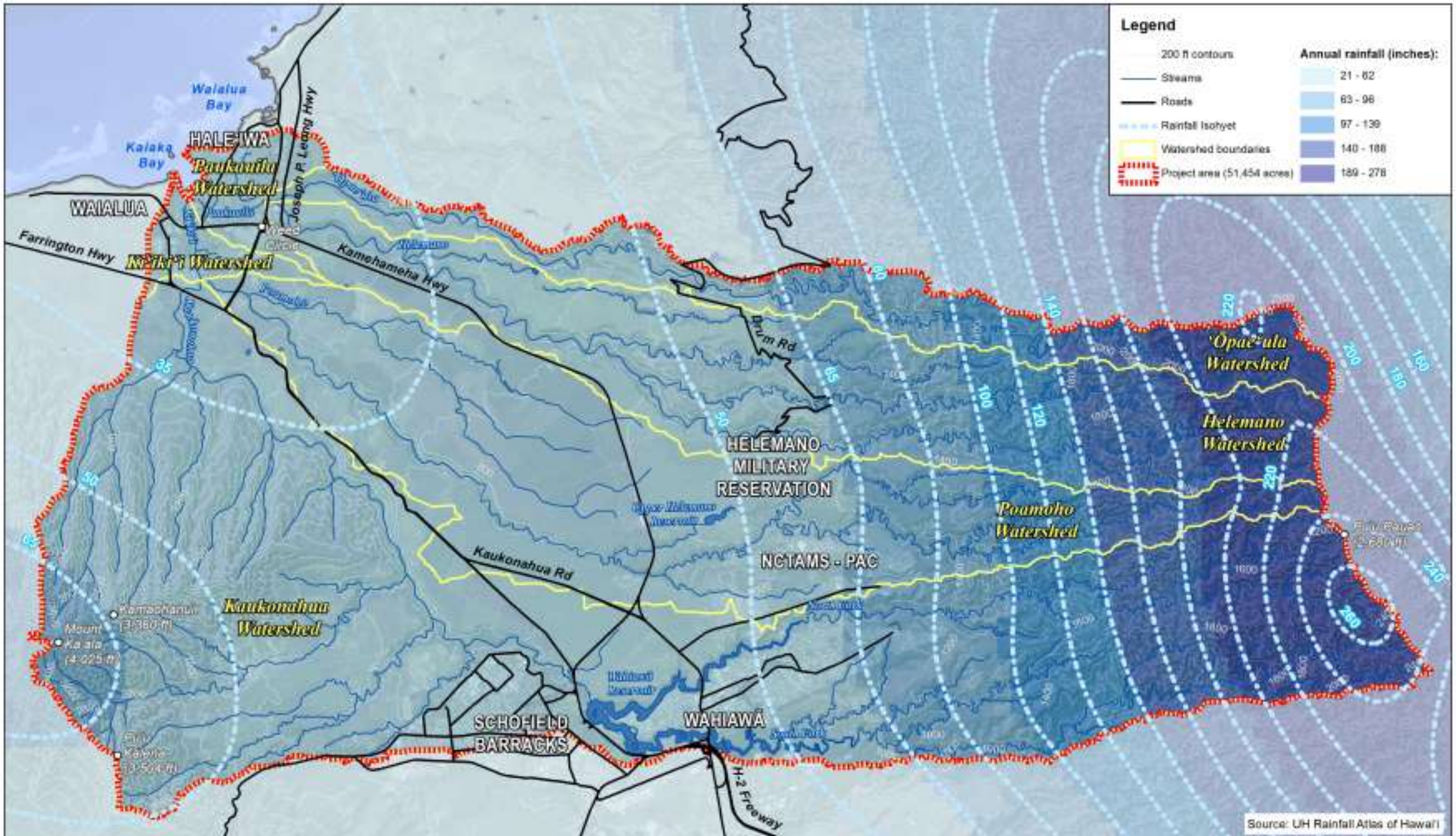
The mild temperatures around the island are attributed to the large heat capacity of the surrounding ocean. While temperatures vary by month and elevation, the warmest month is typically August (mean temperature of 80.5° F) and the coolest month is typically February (72.0° F; Oki, 1998). The small temperature difference between the warmest and coolest months is largely attributable to the influence of the surrounding ocean, the persistence of the cooling trade winds, and the small seasonal variation in solar radiation (Oki and Brasher, 2003).

The effects of global climate change can be detected in Hawaiʻi's climate patterns (Figure 7). Air temperature has increased by 0.08°F per decade between 1919 and 2005 and a general downward trend in rainfall has been documented over the last century, especially during the past 20 years (a 15% decrease). However, the severity of storms has increased as indicated by a 12% increase in rain intensity. The severity and frequency of droughts, flooding, and wildfires have increased as well. During the past century, the ocean has become warmer at a rate of 0.22°F per decade and the sea level has risen at rate of approximately 0.6 inches per decade. The ocean has also become more acidic as a result of an increase in carbon dioxide in the atmosphere that mixes with seawater (G70, 2016). Because these trends are likely to continue, the impacts of these changes on Hawai'i's watersheds, coastal communities, and marine ecology are predicted to become more pronounced over time (see section 7.2.15).



Source: Climate Change and Pacific Islands: Indicators and Impacts, 2012

FIGURE 7. IMPACTS OF CLIMATE CHANGE IN HAWAI'I



Kaiaka Bay Watershed-Based Plan

FIGURE 8. AVERAGE RAINFALL

2.5 SOILS

Soils are naturally occurring materials that are formed by various physical, chemical, and biological processes. They are made up of mineral matter, organic matter, air, and water (Oki and Brasher, 2003).

Hawaiʻi has a high diversity of soils relative to its size and the Kaiaka Bay Watersheds are no exception. There are 53 soil types from 26 soil series throughout the Kaiaka Bay Watersheds, however, approximately 60% of the total land area is dominated by soils of the following three series: Rough Mountainous Land, Wahiawā, and Helemano (see Figure 9 and Table 6). Most soils in the watersheds have volcanic origins, however, some are derived from coral reef and sedimentary deposits.

DOMINANT SOIL SERIES

Soils in the Rough Mountainous Land series are the most predominant in the watersheds, covering approximately 14,433 acres. These soils are characterized by very steep land broken by numerous, intermittent, deep V-shaped drainages, creating narrow ridges and steep slopes. In the Kaiaka Bay Watersheds, these soils are found on the slopes of the Koʻolau range and extend to the summit of the mountain range. This land type is important for watershed health and ecosystem functioning.

Soils in the Wahiawā series are the second most abundant, covering about 10,225 acres (much of the Schofield Plateau). These soils are well-drained reddish-brown silty clays that formed in residuum and old alluvium derived from basic igneous rock. They have characteristics that typically make them ideal for cultivation. For soils on less steep slopes (WaA, WaB, WaC), the erosion hazard is slight to moderate and runoff is slow to medium.

The Helemano soil series is also common in the Kaiaka Bay Watersheds, covering 6,145 acres. It is mostly found on the steep slopes of gulches in the central area of the watersheds and along the slopes of Mt. Kaʻala. The series consists of only one soil type (HLMG), which is characterized as a well-drained reddish-brown silty clay with severe erosion hazard, medium to very rapid runoff, and moderately rapid permeability. The soil is not suitable for agriculture but is important for other ecosystem services.

GENERAL SOIL CHARACTERISTICS (ERODIBILITY, PERMEABILITY, & WATER CAPACITY)

Roughly half of the total land area in the Kaiaka Bay Watersheds (26,240 acres) consists of soil types that are classified as highly erodible by water, which has important implications for land management and water quality downstream. However, these soils also have a relatively high infiltration rate (3.0 inches per hour), which means that precipitation intensity would need to exceed the infiltration rate for runoff to occur (AECOM, 2016; Appendix A). These soils are predominantly located in the highest elevations of the watersheds— along the steep, forested slopes of Mount Kaʻala in the Waiʻanae range and in the forested mauka areas of the Koʻolau range (Figure 9). When steep areas are cleared and tilled, erosion becomes a significant concern. Some of the steeper areas in the watersheds were used for sugarcane and pineapple agriculture in the past, however, most of the former plantation lands located on steep slopes are no longer used for intensive agricultural production and, if used, are mainly dedicated to pasture (G70, 2016). Additionally, stream channels in the central portions of the watersheds also have highly erodible soils.

The watershed with the largest acreage of highly erodible soils is Kaukonahua with 16,551 acres (Table 4). The Kaukonahua Watershed is the largest watershed of the six and drains land from both mountain ranges. The Helemano and ʻŌpaeʻula watersheds also have a significant portion of the land classified as highly erodible (56% and 74%, respectively). It is likely that a large amount of sediments is being transported in streams in these watersheds where they eventually reach Kaiaka Bay.

TABLE 4. HIGHLY ERODIBLE SOILS BY WATERSHED

Stream System	Watershed	Acres	% of Watershed
Kiʻikiʻi	Kiʻikiʻi	0	0%
	Kaukonahua	16,551	66%
	Poamoho	3,616	31%
Paukauila	Paukauila	0	0%
	Helemano	5,259	56%
	ʻŌpaeʻula	2,815	74%
Total for Project Area		**28,240**	**55%**

The remainder of the area in the Kaiaka Bay Watersheds primarily consists of soils that are well-drained, meaning that permeability is moderate to rapid, with low susceptibility to water erosion if the soil is aggregated with strong structure. However, repeated agricultural practices such as tilling can cause soils to compact, resulting in decreased rates of infiltration which may increase surface runoff and erosion. Soils with high permeability should be managed carefully to keep pesticides from reaching groundwater. The soils near Waialua have reduced permeability; therefore, surface runoff, ponding, and occasional flooding are a concern in these areas. Additionally, because of the predominance of shrink-swell clays near Waialua, some of the soils can become very sticky and difficult to manage when wet and form large cracks when dry (G70, 2016).

Susceptibility to wind erosion is also low in clay soils, which are common throughout the watersheds, however, wind erosion can be more of a concern in the coastal areas because of strong trade winds. Clay soils are also known to have a relatively high water capacity (an estimate of the capacity of soils to hold water available for use by plants). Pesticides move at a slower rate through finer textured soils containing more clay, and may be more likely to cling to these soils. Other notable characteristics of Hawaiian soils include the ability of the soils to adsorb nitrate due to their unusual positive charge at low pH, and the ability to adsorb viruses (G70, 2016).

Suitability for Agriculture

In total, 20,532 acres have soils that are described by the NRCS as "prime farmland if irrigated." This makes up approximately 40% of the total project area (Table 5). The vast majority of the prime farmland is located in the Kaukonahua and Poamoho watersheds (nearly 16,000 acres). The ʻŌpaeʻula Watershed has proportionally the least amount of prime agricultural land, with only 692 acres (18% of total watershed).

TABLE 5. PRIME FARMLAND IF IRRIGATED BY WATERSHED

Stream System	Watershed	Acres	% of Watershed
Kiʻikiʻi	Kiʻikiʻi	485	82%
	Kaukonahua	7,930	32%
	Poamoho	7,665	66%
Paukauila	Paukauila	669	77%
	Helemano	3,091	33%
	ʻŌpaeʻula	692	18%
Total for Project Area		**20,532**	**40%**

Suitability for agriculture is further refined by the “Land Capability Classification” (LCC) provided by the USDA. Soil classifications are represented by roman numerals I-VIII, with lower values representing soils that are best suited for agriculture. Letters represent sub-classifications: *e* indicates that erosion is the main limitation, *w* indicates that water in or on the soil could interfere with plant growth, *s* indicates that the soil is limited because it is shallow, droughty, or stone, and *c* indicates that the chief limitation is climate that is too cold or too dry. Five different soil types are ranked as ideal (LCC score I) when irrigated: Kawaihapai clay loam (KlA), Kunia silty clay (Kya), Wahiawā silty clay (WaA), Waialua silty clay (WkA), and Waipahu silty clay (WzA). Together, these ideal soils constitute approximately 6,489 acres of land, or 13% of the total area.

There are also approximately 10,192 acres that are designated as “Prime Agricultural Land” by the Hawaiʻi Department of Agriculture, which delineates “Agricultural Lands of Importance to the State of Hawaiʻi” (ALISH; see Figure 10). Prime agricultural land is described as land that is best suited for the production of food, feed, forage, and fiber crops where there are ideal soil and climatic characteristics to economically produce high yields of crops. Of the ALISH prime land, soils in the Wahiawā series are the most common, covering approximately 5,175 acres. There are also 3,888 acres of ALISH “Unique Lands,” which are used for the production of specific high-value food crops, but do not have all the qualities of ideal farmland. An additional 2,510 acres are designated as “Other Important Agricultural Land,” which signifies land that is potentially important for agriculture but has limitations, such as seasonal wetness, erodibility, limited rooting potential, slope, flooding, or droughtiness.

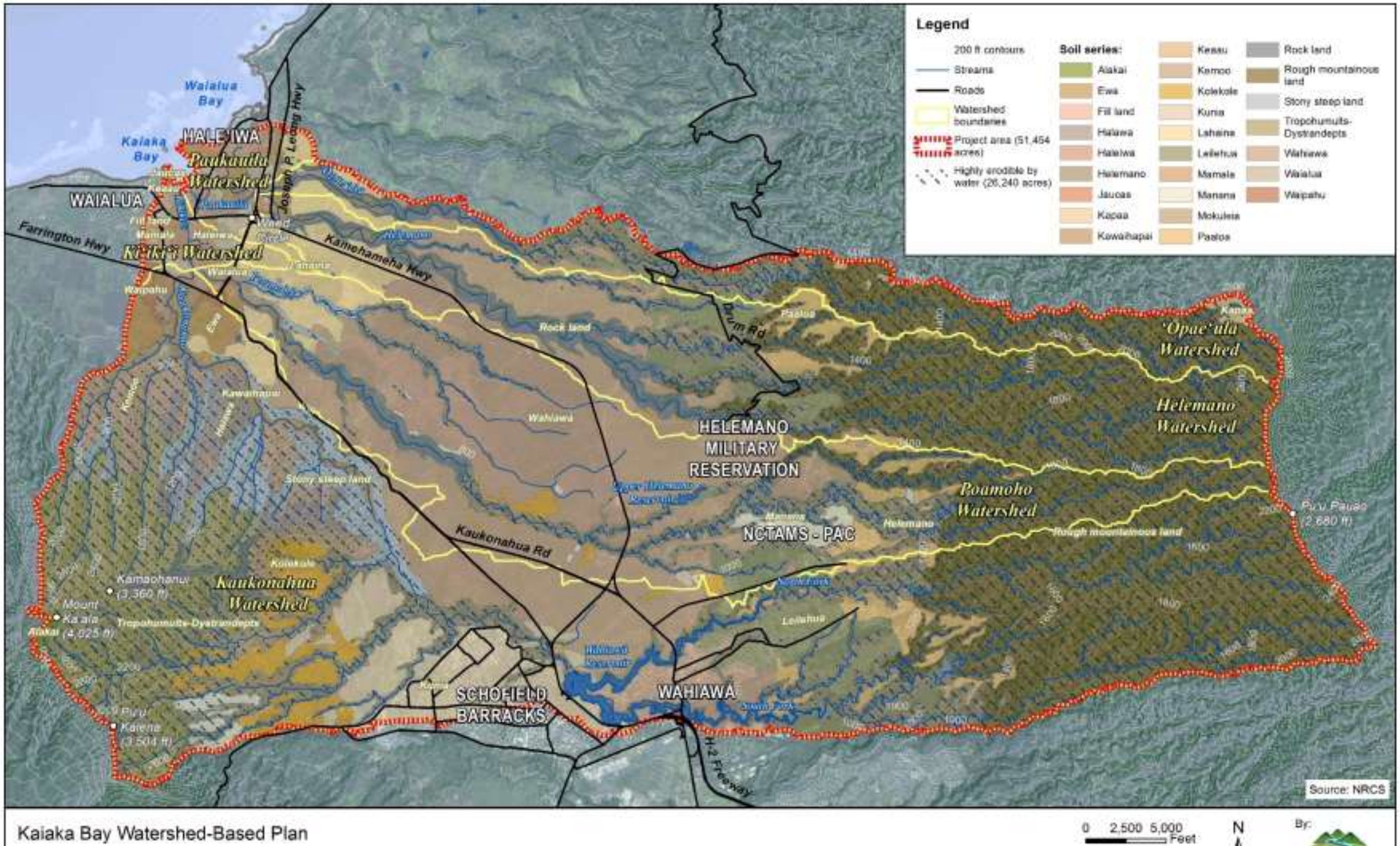


FIGURE 9. SOILS

TABLE 6. SOIL DETAILS

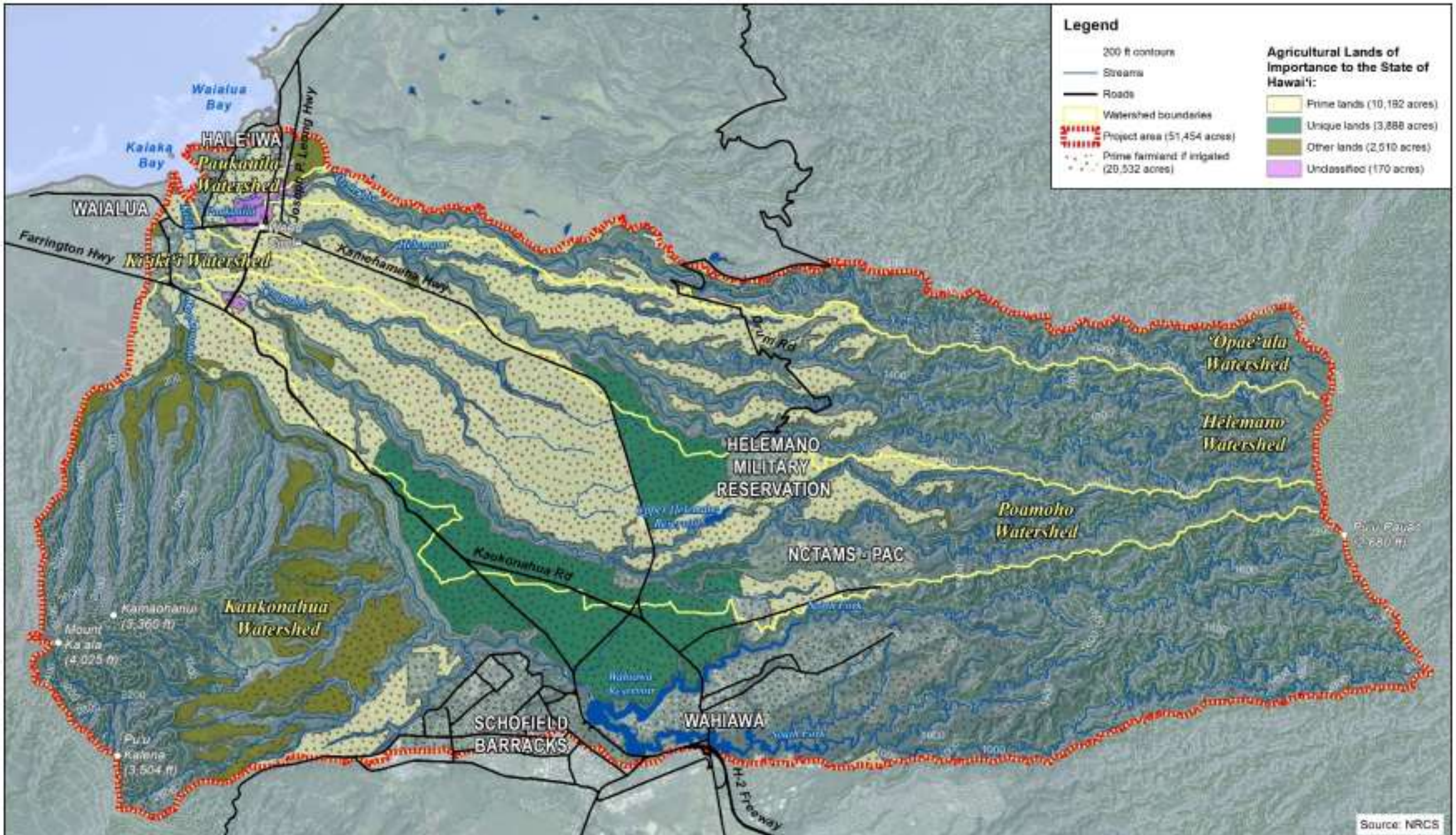
Symbol	Soil type	Slope	Erodibility	LCC *	Prime Ag.**	Acres	% Total Area
Alakai Series						**61**	**0.1%**
rAAE	Alakai mucky peat	0 - 3 %	Potentially high	VII w	No	61	0.1%
ʻEwa Series						**559**	**1.1%**
EaB	ʻEwa silty clay loam	3 - 6 %	Not high	IV c / II e	Yes	356	0.7%
EaC	ʻEwa silty clay loam	6 - 12 %	Potentially high	IV e / III e	Yes	91	0.2%
EmA	ʻEwa silty clay loam, moderately shallow	0 - 2 %	Not high	IV s / II s	Yes	99	0.2%
EwC	ʻEwa stony silty clay loam	6 - 12 %	Potentially high	IV e / III e	Yes	13	0.0%
Fill Land						**35**	**0.1%**
Fd	Fill land	Varies	Not high	N/A	No	13	0.0%
FL	Fill land, mixed	Varies	Not high	N/A	No	23	0.0%
Hālawa Series						**702**	**1.4%**
HJE	Hālawa silt loam	20 - 35 %	High	VI e	No	226	0.4%
HJF2	Hālawa silt loam, eroded	35 - 70 %	Not high	VII e	No	476	0.9%
Haleʻiwa Series						**542**	**1.1%**
HeA	Haleʻiwa silty clay	0 - 2 %	High	III c / II e	Yes	542	1.1%
Helemano Series						**6,145**	**11.9%**
HLMG	Helemano silty clay	30 - 90 %	High	VII e	No	6,145	11.9%
Jaucas Series						**33**	**0.1%**
JaC	Jaucas sand	0 - 15 %	Potentially high	VI e / IV s	No	33	0.1%
Kapaʻa Series						**74**	**0.1%**
KIG	Kapaʻa silty clay	40 - 100%	High	VII e	No	74	0.1%
Kawaihapai Series						**740**	**1.4%**
KlA	Kawaihapai clay loam	0 - 2 %	Not high	II c / I	Yes	150	0.3%
KlB	Kawaihapai clay loam	2 - 6 %	Potentially high	II e / II e	Yes	136	0.3%
KlC	Kawaihapai clay loam	6 - 15 %	Potentially high	III e / III e	Yes	1	0.0%
KlaB	Kawaihapai stony clay loam	2 - 6 %	Potentially high	II e / II e	Yes	267	0.5%
KlbC	Kawaihapai very stony clay loam	0 - 15 %	Potentially high	VI s	No	185	0.4%
Keaʻau Series						**27**	**0.1%**
KmbA	Keaʻau clay	0 - 2 %	Not high	VI w	No	27	0.1%
Kemoʻo Series						**1,256**	**2.4%**
KpD	Kemoʻo silty clay	12- 20 %	High	IV e	No	181	0.4%
KpE	Kemoʻo silty clay	20 - 35 %	High	VI e	No	389	0.8%
KpF	Kemoʻo silty clay	35 - 70 %	High	VII e	No	685	1.3%
Kolekole Series						**1,308**	**2.5%**
KuB	Kolekole silty clay loam	1 - 6 %	Potentially high	III e / II e	Yes	715	1.4%
KuC	Kolekole silty clay loam	6 - 12 %	Potentially high	III e / III e	Yes	276	0.5%
KuD	Kolekole silty clay loam	12 - 25 %	High	IV e / IV e	No	316	0.6%
Kunia Series						**1,893**	**3.7%**
KyA	Kunia silty clay	0 - 3 %	Not high	III c / I	Yes	1,578	3.1%
KyB	Kunia silty clay	3 - 8 %	Potentially high	III c / II e	Yes	302	0.6%
KyC	Kunia silty clay	8 - 15 %	Potentially high	III e / III e	No	13	0.0%

- Table continued on next page -

TABLE 6. SOIL DETAILS (CONTINUED)

Symbol	Soil type	Slope	Erodibility	LCC *	Prime Ag.**	Acres	% Total Area
Lahaina Series						**1,699**	**3.3%**
LaB	Lahaina silty clay	3 - 7 %	Potentially high	III c / II e	Yes	994	1.9%
LaC	Lahaina silty clay	7 - 15 %	Potentially high	IV e / IV e	Yes	535	1.0%
LaC3	Lahaina silty clay, severely eroded	7 - 15 %	Potentially high	IV e / IV e	No	170	0.3%
Leilehua Series						**2,046**	**4.0%**
LeB	Leilehua silty clay	2 - 6 %	Potentially high	II e / II e	Yes	1,781	3.5%
LeC	Leilehua silty clay	6 - 12 %	Potentially high	III e / III e	Yes	264	0.5%
Mamala Series						**92**	**0.2%**
MnC	Mamala stony silty clay loam	0 - 12 %	Potentially high	VI s / III s	No	92	0.2%
Manana Series						**506**	**1.0%**
MpC	Manana silty clay	8 - 15 %	Potentially high	III e / III e	Yes	12	0.0%
MpD	Manana silty clay	15 - 25 %	High	IV e / IV e	No	8	0.0%
MoB	Manana silty clay loam	2 - 6 %	Potentially high	III e / II e	Yes	231	0.4%
MoC	Manana silty clay loam	6 - 12 %	Potentially high	IV e / III e	Yes	107	0.2%
MoD2	Manana silty clay loam, eroded	12 - 15 %	High	VI e / VI e	No	148	0.3%
Mokulēʻia Series						**12**	**0.0%**
Ms	Mokulēʻia loam	Coastal plains	Not high	VI s / II s	Yes	12	0.0%
Paʻaloa Series						**1,395**	**2.7%**
PbC	Paʻaloa clay	2 - 12 %	Potentially high	III e	Yes	492	1.0%
PaC	Paʻaloa silty clay	3 - 12 %	Potentially high	III e	Yes	903	1.8%
Rock Land						**1,698**	**3.3%**
rRK	Rock land	Varies	Potentially high	VII s	No	1,698	3.3%
Rough Mountainous Land						**14,433**	**28.1%**
rRT	Rough mountainous land	Varies	High	VIII e	No	14,433	28.1%
Stony Steep Land						**1,470**	**2.9%**
rSY	Stony steep land	40 - 70 %	High	VII s	No	1,470	2.9%
Tropohumults-Dystrandepts Association						**3,629**	**7.1%**
rTP	Tropohumults-Dystrandepts association	30 - 90 %	High	VII e	No	3,629	7.1%
Wahiawā Series						**10,224**	**19.9%**
WaA	Wahiawā silty clay	0 - 3 %	Not high	II c / I	Yes	4,265	8.3%
WaB	Wahiawā silty clay	3 - 8 %	Potentially high	II e / II e	Yes	5,022	9.8%
WaC	Wahiawā silty clay	8 - 15 %	Potentially high	III e / III e	Yes	878	1.7%
WaD2	Wahiawā silty clay, eroded	15 - 25 %	High	IV e	No	60	0.1%
Waialua Series						**395**	**0.8%**
WkA	Waialua silty clay	0 - 3 %	Not high	III c / I	Yes	383	0.7%
WlB	Waialua stony silty clay	3 - 8 %	Potentially high	III e / II e	Yes	12	0.0%
Waipahu Series						**113**	**0.2%**
WzA	Waipahu silty clay	0 - 2 %	Not high	IV c / I	Yes	113	0.2%

** The listed land capability classifications (LCC) are listed as non-irrigated / irrigated (if available)*
*** Prime farmland if irrigated*



Kaiaka Bay Watershed-Based Plan

FIGURE 10. AGRICULTURAL SUITABILITY OF SOILS

2.6 LAND COVER TYPES

Most of the vegetation in the watersheds is classified as non-native forest and shrubland (41.1% of the total area) or agriculture (21.5% of the total area), according to the USGS GAP analysis. There are some areas of native vegetation in the upper portions of the Koʻolau mountains (Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula watersheds) and at the summit of Mt. Kaʻala with mixed native/non-native forest on the slopes of Kaʻala (Kaukonahua Watershed). The majority of the watersheds are dominated by non-native species and invasive species. For more information about how invasive species can affect water quality, see section 7.2.2. Refer to Table 8 and Figure 11 on the following pages for details regarding the different land cover types as identified by the USGS GAP analysis program.

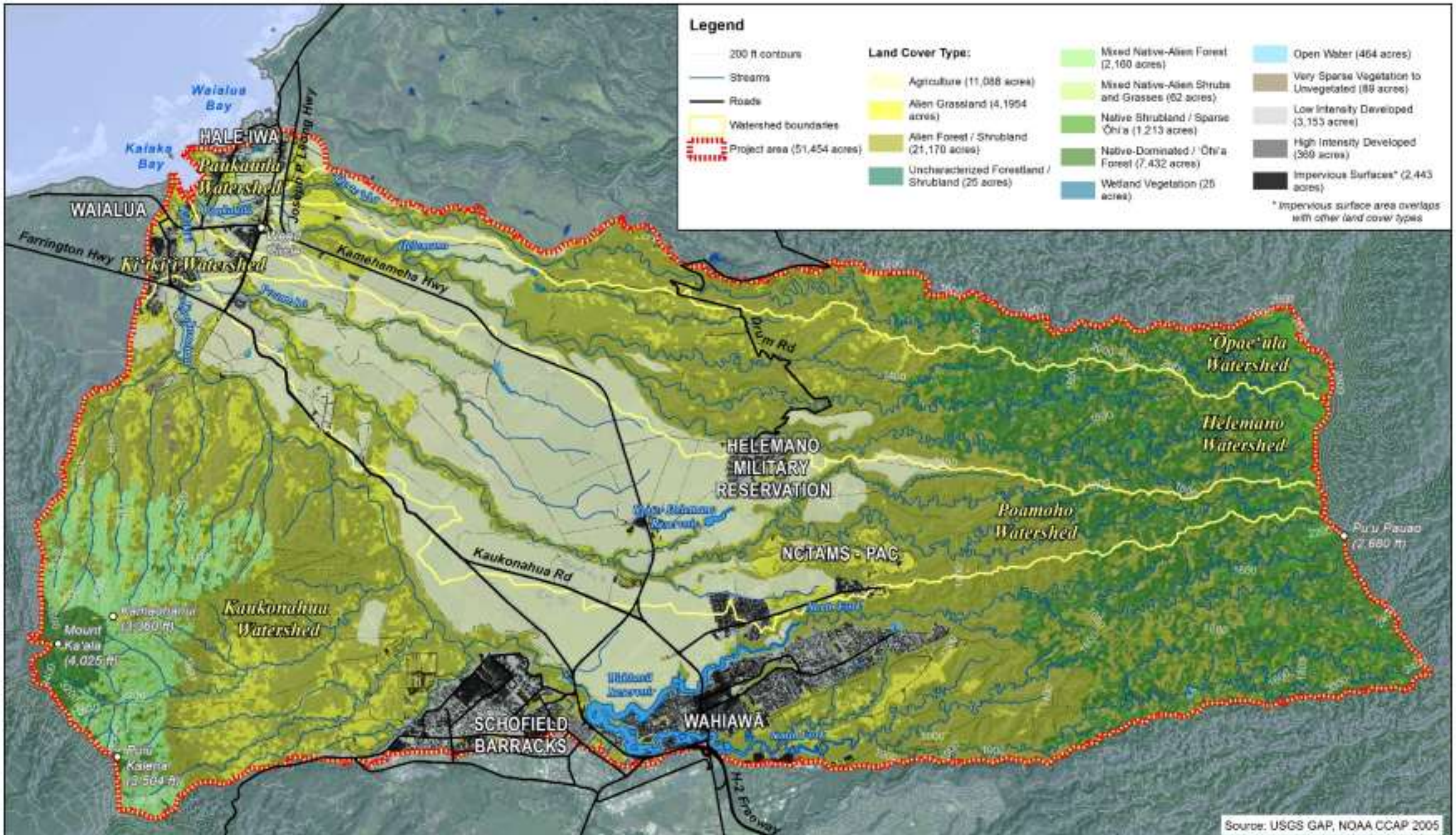
Impervious surfaces associated reduce infiltration and increase surface runoff, altering the natural pathways by which stormwater runoff (and the pollutants it may transport) reaches streams. According to the NOAA C-CAP (Coastal Change Analysis Program) dataset from 2005, impervious surfaces cover about 5% of the total project area (2,443 acres; see Table 7 and Figure 11). Not surprisingly, the majority of the impervious surfaces are located in the Urban State Land Use District (see section 3.2.1 for more information about the Land Use Districts). The Conservation District has a negligible amount of impervious surface. The Kaukonahua Watershed has by far the most impervious surfaces out of the six watersheds, with 1,568 acres. Impervious surfaces in the Kaukonahua Watershed are located mainly in Schofield Barracks and Wahiawā (Figure 11).

TABLE 7. IMPERVIOUS SURFACE BY LAND USE DISTRICT AND WATERSHED (NOAA C-CAP, 2005)

Stream System	Watershed	Acres Impervious Surface – Urban District	Acres Impervious Surface – Agriculture District	Total Acres Impervious Surface	% of Watershed
Kiʻikiʻi	Kiʻikiʻi	98	27	126	21%
	Kaukonahua	1,229	339	1,568	6%
	Poamoho	77	361	438	4%
Paukauila	Paukauila	101	51	152	18%
	Helemano	5	109	114	1%
	ʻŌpaeʻula	1	43	44	1%
Total for Project Area		**1,511**	**932**	**2,443**	**5%**

TABLE 8. LANDCOVER TYPES (USGS GAP)

	Kiʻikiʻi Stream System			Paukauila Stream System			Total Acres/Type	% of Project Area
	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula		
Alien Forest/Shrubland	46	11,194	3,244	80	4,616	1,991	21,170	41.1%
Agriculture	259	2,500	6,340	383	1,356	250	11,088	21.5%
Native-Dominated/ ʻŌhiʻa Forest	0	3,405	660	0	2,345	1,023	7,432	14.4%
Alien Grassland	86	2,487	760	128	546	189	4,195	8.2%
Low Intensity Developed	170	2,062	529	227	132	32	3,153	6.1%
Mixed Native-Alien Forest	0	2,160	0	0	0	0	2,160	4.2%
Native Shrubland/ Sparse ʻŌhiʻa	0	528	55	0	335	295	1,213	2.4%
Open Water	4	398	53	7	6	5	473	0.9%
High Intensity Developed	25	285	32	16	7	4	369	0.7%
Very Sparse Vegetation to Unvegetated	2	73	2	12	0	0	89	0.2%
Mixed Native-Alien Shrubs & Grasses	0	62	0	0	0	0	62	0.1%
Wetland Vegetation	0	4	0	14	7	0	25	0.05%
Uncharacterized Forestland/ Shrubland	0	0	0	0	3	22	25	0.05%
Total Acres	**592**	**25,159**	**11,675**	**866**	**9,353**	**3,810**	**51,454**	**100%**



Kaiaka Bay Watershed-Based Plan

FIGURE 11. LANDCOVER TYPES

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: June 2016

2.7 MAJOR SURFACE WATER FEATURES

This section reviews some of the major surface water features in the Kaiaka Bay Watersheds, including stream systems, manmade agricultural water features, wetlands, and the marine environment (Figure 12).

2.7.1 STREAM SYSTEMS

The Kaiaka Bay Watersheds have two major perennial stream systems: the Kiʻikiʻi Stream system and the Paukauila Stream system (HSA, 1990). The Kiʻikiʻi Stream System includes the Kiʻikiʻi, Kaukonahua, and Poamoho watersheds and the Paukauila Stream System consists of the Paukauila, Helemano, and ʻŌpaeʻula watersheds.

The Kiʻikiʻi System is comprised of two major tributaries, Kaukonahua and Poamoho streams. Kaukonahua Stream is the State of Hawaiʻi's longest stream at 33 miles. The North and South forks of Kaukonahua Stream originate in the northwestern Koʻolau mountain range. The two forks join at the Wahiawā Reservoir (also known as Lake Wilson). Below the reservoir, Kaukonahua Stream receives runoff from Schofield Barracks and from a number of gulches originating in the Waiʻanae mountain range. The Poamoho Stream drains parts of the Leilehua Plateau and the northwestern Koʻolau mountains. Kaukonahua and Poamoho streams merge together on the coastal plain to form Kiʻikiʻi Stream. Kiʻikiʻi Stream then joins Paukauila Stream at its mouth and finally drains into Kaiaka Bay. A number of stream diversions are present in the stream system; see section 2.7.2 for details. In total, the Kiʻikiʻi Stream System drains an area of approximately 37,426 acres into Kaiaka Bay.

Poamoho Stream

The major tributaries of the Paukauila Stream System are the ʻŌpaeʻula and Helemano streams. ʻŌpaeʻula and Helemano Streams originate in the northern Koʻolau mountains and cross forested mountainous lands and large expanses of pineapple and diversified agriculture. The two streams flow together on the coastal plain to form the Paukauila Stream. Paukauila Stream flows through the town of Haleʻiwa and merges with Kiʻikiʻi Stream at Kaiaka Bay. A number of stream diversions are present in the stream system; see section 2.7.2 for details. In total, the Paukauila Stream System drains an area of approximately 14,029 acres into Kaiaka Bay.

Paukauila Stream at the confluence of ʻŌpaeʻula and Helemano streams in Haleʻiwa

The HSA (1990) classifies the Kiʻikiʻi and Paukauila stream systems as medium-sized systems, defined as having flows between 20 and 80 cfs (cubic feet per second). Groundwater that seeps through caprock into these watersheds adds approximately 10.9 cfs of freshwater to the streams. Several streams in the four larger watersheds (Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula) are perennial in their upper reaches but intermittent in their lower reaches, primarily due to surface water diversions for agricultural use. While the upper reaches of the streams have moderate slopes, the lower reaches traverse a low-lying and relatively flat coastal plain in the vicinity of Waialua and Haleʻiwa towns, where stream flows slow down and become tidally influenced. Flooding in the lower reaches of the stream systems (in the Kiʻikiʻi and Paukauila watersheds) occurs frequently due to heavy rainfall or high surf. Peak storm flows (100-year storm) estimated for Kiʻikiʻi Stream are 39,000 cfs and 18,700 cfs for Paukauila Stream (Hawaiʻi OP CZM and Hawaiʻi DOH PRC, 2000).

Left: Upper Kaukonahua Stream; Right: Lower Kaukonahua Stream, located near Waialua

The HSA (1990) also classifies the quality of each stream in terms of aquatic, riparian, cultural, and recreational resources. For each resource category, the assessment assigns stream rankings of Outstanding, Substantial, Moderate, Limited and Unknown. Table 9 indicates the rankings of the two stream systems for each category. Kiʻikiʻi stream system was also classified as having statewide "Blue Ribbon" outstanding resources for recreation and is a candidate for protection for recreational purposes.

TABLE 9. STREAM RESOURCES RANKINGS

Stream System	Aquatic Resources	Riparian Resources	Cultural Resources	Recreational Resources
Kiʻikiʻi	**M** (presence of one "indicator native species")	**S**	Unclassified	**O**
Paukauila	**O** (abundance of at least one "indicator species"; presence of candidate endangered species *ʻoʻopu nākea* [*Lentipes concolor*])	**S**	Unclassified (associated taro cultivation)	**S**

Notes: M = Moderate; S = Substantial; O = Outstanding

2.7.2 MANMADE AGRICULTURAL WATER FEATURES

Much of the land that lies between the two mountain ranges is part of the Schofield Plateau and has been heavily utilized for agriculture. Consequently, the region's water resources are essential for irrigating crops and a network of dams, diversions, ditches, and reservoirs have been constructed to collect, store, and distribute water across the watersheds.

Aerial view of a portion of the Wahiawā Reservoir, surrounded by neighborhoods of Wahiawā

The agricultural irrigation system on the North Shore was first developed in the early 20th century by the Waialua Sugar Company, a subsidiary of Castle and Cooke, to irrigate sugarcane fields throughout the North Shore. By 1906 there were four surface water collection systems, creating the largest water storage capacity in Hawaiʻi and more than quadrupling the sugar yield. This was primarily accomplished by constructing a dam in 1906 at the confluence of the North and South Forks of Kaukonahua Stream to create the Wahiawā Reservoir (also known as Lake Wilson). The Wahiawā Reservoir is the largest freshwater impoundment in Hawaiʻi, with a storage capacity of 9,200 acre-feet or 3,066 million gallons (G70, 2016).

The water in Wahiawā Reservoir comes primarily from the North and South Forks of Kaukonahua Stream, however, a portion of the Poamoho Stream is diverted into the North Fork of Kaukonahua via the Poamoho Tunnel. Additionally, the reservoir receives treated effluent water from the Wahiawā Wastewater Treatment Plan (WWTP) and runoff from the town of Wahiawā. Approximately 20 million gallons per day (mgd) flow into the reservoir from the streams and approximately two mgd is from the Wahiawā WWTP's effluent. See section 7.1.2 for more information. In addition to its function for irrigation purposes, the reservoir helps to prevent, reduce, and delay flooding that can occur in times of excessive rain. However, in extreme storm events, the Wahiawā Reservoir overflows the spillway and water rushes down Kaukonahua Stream toward the town of Waialua. Castle and Cooke owns a portion of the reservoir along with Sustainable Hawai`i, LLC. Sustainable Hawaiʻi owns and operates the dam and Dole Food Company, a subsidiary of Castle and Cooke, operates the reservoir and the ditch.

The Wahiawā Reservoir is a crucial aspect of the Wahiawā Irrigation System (WIS), an extensive network of ditches and reservoirs operated by Dole Foods that spans 30 miles across the watersheds. Today, the Wahiawā Reservoir releases 8.9 mgd of irrigation water into the WIS on average (G70, 2016). The water released from the reservoir flows into the Wahiawā Reservoir Ditch where it is directed into additional ditches that are fed by other stream diversions. Eventually, irrigation water is distributed to fields across the North Shore region.

The additional ditch systems that feed into the WIS include the Kemoʻo Ditch system, Helemano Ditch system, and the ʻŌpaeʻula Ditch system. Kemoʻo Ditch branches off of the Wahiawā Reservoir Ditch and transports water to Waialua. The Helemano Reservoir Ditch is fed by water stored in the Upper Helemano Reservoir (also called Tanada Reservoir), located in the Poamoho Watershed. The Upper Helemano Reservoir is the second largest active reservoir in the Kaiaka Bay Watersheds with a capacity of 228 million gallons. It stores water that has been diverted from the Poamoho Stream and from the southernmost fork of Helemano Stream. The ʻŌpaeʻula Ditch diverts base flow water from ʻŌpaeʻula Stream and Kawaiʻiki Stream (outside of the watershed) into the ʻŌpaeʻula Reservoir. Dole owns and operates the Wahiawā Reservoir Ditch, Kemoʻo Ditch, and Helemano Reservoir Ditch. Kamehameha Schools owns the ʻŌpaeʻula Ditch.

Part of the WIS and the outfall of Wahiawā Reservoir into Kaukonahua Stream

Left: Helemano 6 Reservoir and Wahiawā Reservoir Ditch; Right: Helemano Reservoir

The WIS originally had a capacity of 50 mgd, which supported 12,000 acres of sugarcane and 5,000 acres of pineapple. Today, approximately 8,100 acres can be irrigated under the existing WIS configuration. The WIS currently provides 9 mgd (from recent USGS gage readings) to about 5,500 acres of diversified crops (including seed corn, pasture grass, and tree crops) and to additional acreage of pineapple. Dole Foods and Kamehameha Schools are the primary users of surface water in the watersheds, although much of Kamehameha Schools' lands on the North Shore are not included in the Kaiaka Bay Watersheds. There are also some smaller users of surface water but in very small quantities.

There are currently twelve reported stream diversions in the Kaiaka Bay Watersheds according to the State Commission on Water Resource Management database of stream diversions lists. The listed stream diversions were derived from maps submitted to CWRM by water use declarants and stream diversion works permit applicants. The diversions in the upper reaches of the Kaiaka Bay Watersheds primarily feed ditches and reservoirs of the irrigation system that supports agriculture throughout the Diversions in the lower reaches were primarily created to feed ʻauwai and fishponds near the coast. It is estimated that today as much as 70% of the streams in the Kaiaka Bay Watersheds are diverted for agriculture (Hawaiʻi OP CZM and Hawaiʻi DOH PRC, 2000).

In addition to the reservoirs previously mentioned, there are numerous others located throughout the Kaiaka Bay Watersheds. The larger reservoirs are regulated under the State Department of Land and Natural Resources (DLNR) Dam Safety Program (according to a certain size criteria) while the remainder are not regulated. Several reservoirs are no longer used or are in need of maintenance. One example is Ku Tree Reservoir which is located in the upper reaches of the Kaukonahua Watershed on Army lands. The Ku Tree Reservoir was the second largest reservoir in the Kaiaka Bay Watersheds with a capacity of 300 million gallons but it was drained in 1983 and will be decommissioned at a later date. Helemano 16 has also been drained and will eventually be decommissioned and removed. Helemano 11, ʻŌpaeʻula 2, and 15 were recently decommissioned.

2.7.3 WETLANDS

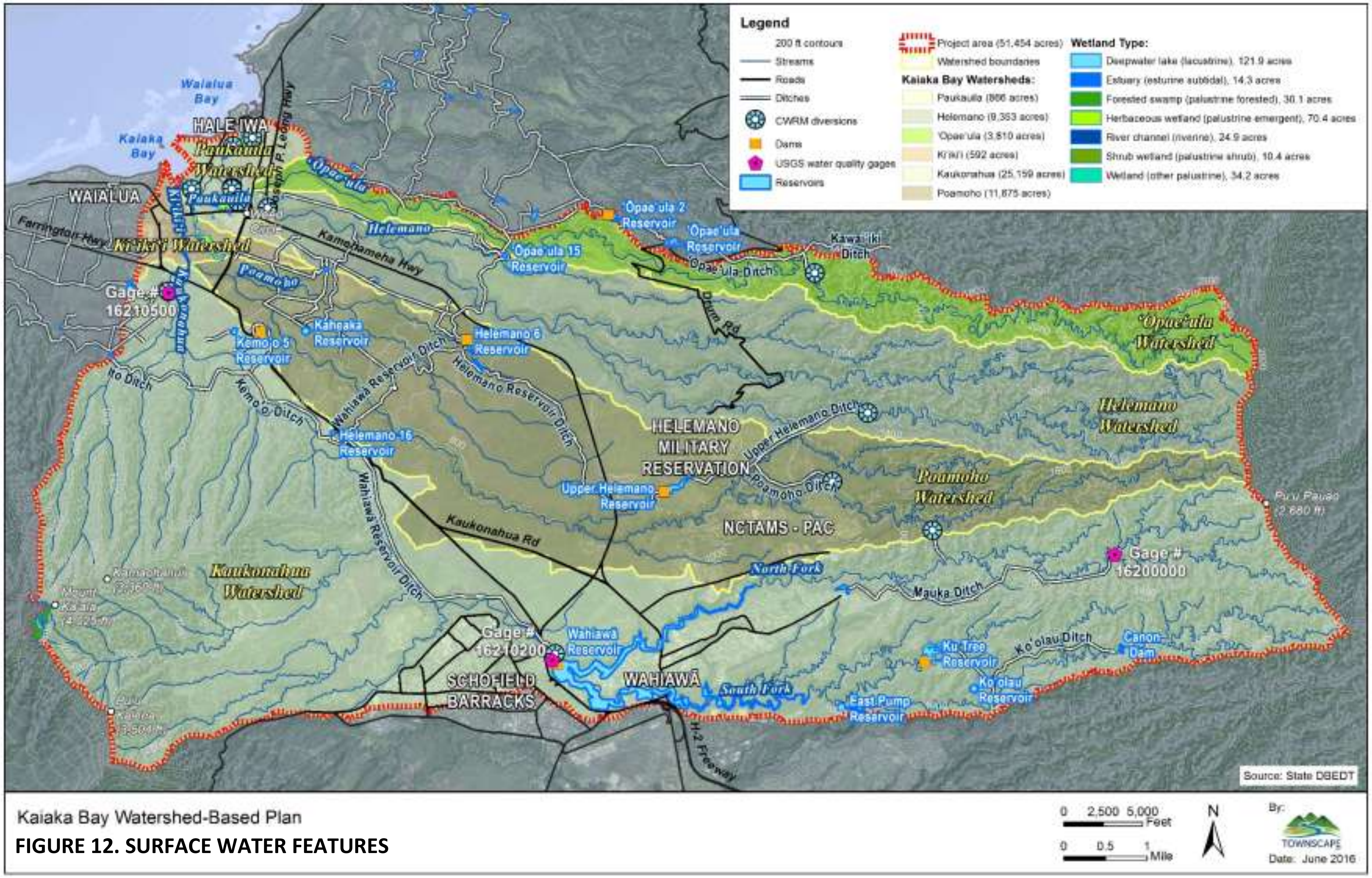
Other notable water features in the Kaiaka Bay Watersheds include various types of wetlands, including freshwater wetlands, estuaries, and forested wetlands. Of note is the Haleʻiwa Marsh, located in the Paukauila Watershed in the town of Haleʻiwa. The marsh drains through an unnamed tributary to Paukauila Stream, which then flows into Kaiaka Bay.

There are several remote areas in the Koʻolau range that likely contain wetlands. The Peahinaīʻa Pond (also known as "Frog Pond") and the Lehua Makanoe Bog are both located in the ʻŌpaeʻula Watershed. The Lehua Makanoe Bog, located near the summit, has been determined to be Oʻahu's only true bog and has bog-specific plant species, many of which are very rare. Both areas have been fenced by the Army for protection (the Army leases these lands for training purposes). There is also a pond located near the summit in the Poamoho Watershed. In all three cases, there is insufficient data to determine if these areas are regulated wetlands (U.S. Army Environmental Command, 2008).

2.7.4 KAIAKA BAY & NEARSHORE MARINE ENVIRONMENT

Kaiaka Bay is formed from two peninsulas of land, creating a distinct, curving bay. The shoreline is mostly rocky with small pockets of sand. The nearshore waters of the bay are heavily affected by the streams and the sediments and pollution they carry. Indeed, the word "Kaiaka" means "shadowy sea" in the Hawaiian language, which may be in reference to the turbidity of the water. For information about the biological resources of the marine environment (including the coral reef ecosystem), see section 2.9.2.

Left: Kaiaka Bay looking makai (north) towards the open ocean. Right: View of the bay looking west, towards the Waiʻanae mountain range.



Kaiaka Bay Watershed-Based Plan

FIGURE 12. SURFACE WATER FEATURES

2.8 GROUNDWATER

According to the DLNR, the Kaiaka Bay Watersheds overlie significant portions of the Central and North Aquifer Sector Areas and a very small portion of the Pearl Harbor Aquifer Sector Area in the southeast corner of the project area. The Aquifer Sector Areas are further divided into Aquifer System Areas. The study area encompasses most of the Wahiawā Aquifer System Area and the Waialua Aquifer System Area, a portion of the Mokulēʻia Aquifer System Area, and a very small portion of the Waipahu-Waiawa Aquifer System Area. Negligible portions of the Mākaha and Waiʻanae Aquifer System Areas are included at the summit of Mt. Kaʻala. Table 10 shows the sustainable yields for each Aquifer System Area, according to DLNR.

TABLE 10. DLNR AQUIFER SYSTEMS AND SUSTAINABLE YIELDS

DLNR SECTOR AREA	DLNR SYSTEM AREA	DOH AQUIFER SYSTEM	SUSTAINABLE YIELD (mgd)
Central	Wahiawā	Wah-1, Koo-1	23
North	Waialua	Lua-1, Lua-2, Lua-3	25
	Mokulēʻia (portion)	Mok-1, Mok-2, Mok-3	8
Pearl Harbor	Waipahu-Waiawa (portion)	Wai-1, Wai-2	104
TOTAL with Mokulēʻia and Waipahu-Waiawa			**160**
TOTAL without Mokulēʻia and Waipahu-Waiawa			**48**

DOH further breaks down the Aquifer System Areas into smaller aquifer classifications of aquifers according to details regarding the type of aquifer and the current status (see Figure 13 and Table 11). According to DOH, all of the aquifer systems have a high level of vulnerability to contamination and are either currently used for drinking water or could potentially be used for drinking water. Additionally, they are all classified as “irreplaceable” resources.

Groundwater is discharged through springs and outflows to the ocean, and from withdrawals from wells. There are a number of springs along the shoreline of the North Shore. Additionally, groundwater that seeps through caprock to the surface adds approximately 7.05 mgd of freshwater to streams in the Kaiaka Bay Watersheds (HSA, 1990). Consequently, the water quality of groundwater affects the quality of surface waters, and vice versa.

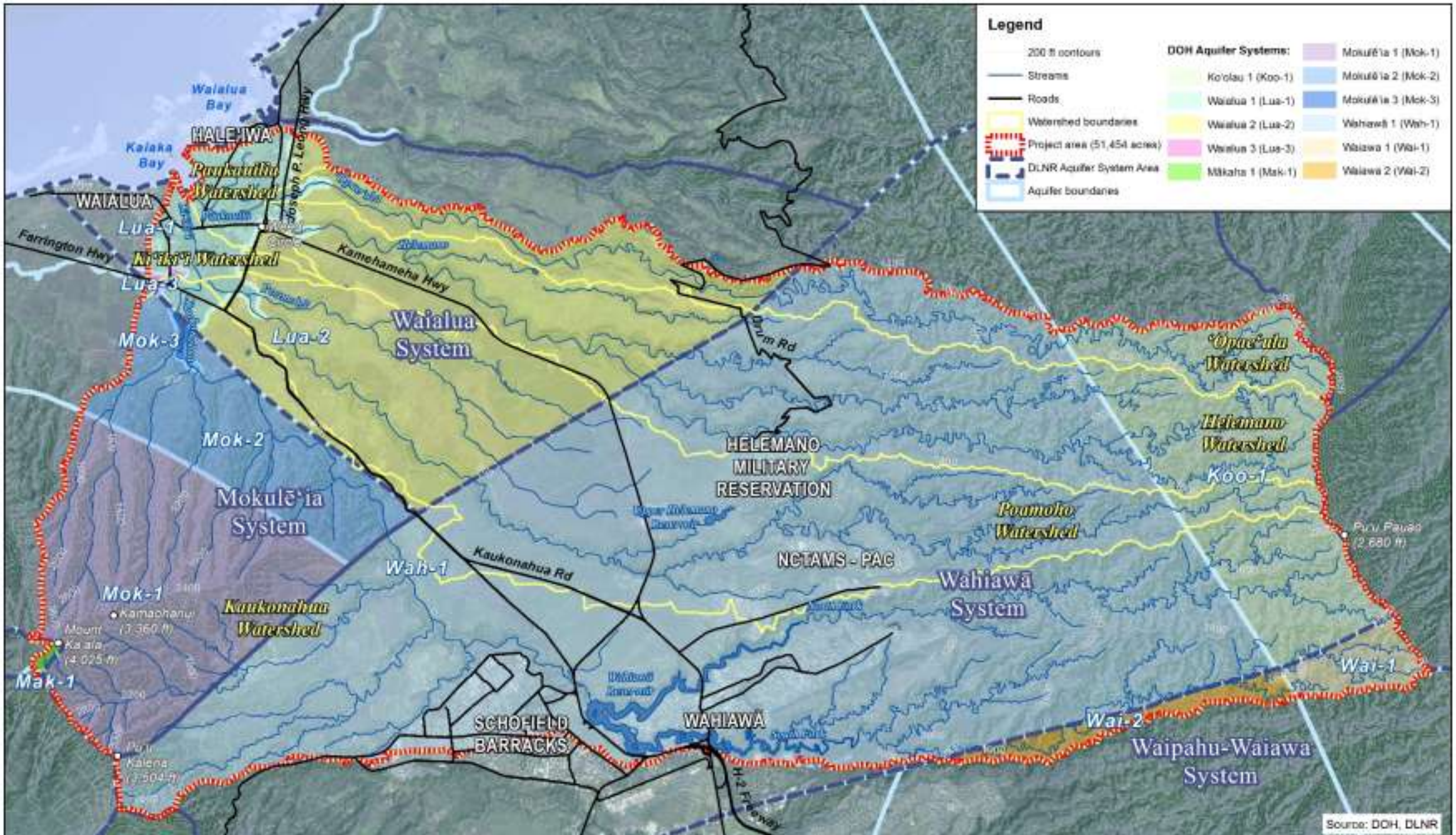
The DOH Safe Drinking Water Branch (SDWB) is charged with protecting Hawaiʻi’s drinking water sources from contamination and assuring that owners and operators of public water systems provide safe drinking water to the community. The groundwater quality in the Kaiaka Bay Watersheds is generally considered high, however, contaminants have been detected at multiple wells in the past. Groundwater sampling conducted over the past two decades from wells located in the lower reaches of the Helemano Watershed and within the Kaukonahua Watershed (mostly around Wahiawā) has detected a number of different chemical contaminants which are suspected or known to be carcinogenic to humans, including 1,2,3-trichloropropane (TCP), carbon tetrachloride, tetrachloroethylene (TCE), and 1,2-dibromo-3-chloropropane (DBCP; DOH, 2016). Baleto et al. (1996) conducted groundwater sampling at wells located on the North Shore and in Central Oʻahu and found a total of fourteen contaminants including DBCP, Atrazine, and TCE. Note that the presence of these contaminants in groundwater does not necessarily mean they are present in surface waters. The extent, progression, and source(s) of most groundwater contaminants are not well known. Moreover, their effects on animals, plants, soil microbiology, ecology and receiving waters within the Kaiaka Bay Watersheds have yet to be studied.

All lands in the project area are classified by DLNR as groundwater management areas. The State Water Code defines groundwater management areas as “a geographic area which has been designated…as requiring management of the ground…water resource.” Under such designation, any “withdrawal, diversion, impoundment, or consumptive use of water,” with the exception of domestic consumption of water by individual users and catchment systems, must first be permitted by CWRM. In addition to the water use permits required in groundwater management areas, CWRM regulates the construction, development, and abandonment of new ground and surface water sources in both designated and non-designated areas through a permitting system.

The significance, vulnerability, and water quality of the aquifers in the Kaiaka Bay Watersheds support the need for a better understanding of water quality issues to promote long term sustainability of water resources and better management strategies.

TABLE 11. CHARACTERISTICS OF DOH AQUIFER SYSTEMS

			Type		Status				
Aquifer Code	Aquifer System	Acres in Project Area	Hydrology	Geology	Developmental Stage	Utility	Salinity	Uniqueness	Vulnerability
Koo-1	Koolau	4,766.6	High level, unconfined	Dike compartments	Currently used	Drinking	Fresh	Irreplaceable	High
Lua-1	Waialua	1,444.4	Basal, unconfined Lower aquifer: basal, confined	Sedimentary Lower aquifer: flank	Currently used Lower aquifer: Currently used	Ecologically important Lower aquifer: Drinking	Low Lower aquifer: Low	Irreplaceable Lower aquifer: Irreplaceable	High Lower aquifer: Low
Lua-2	Waialua	8,620.0	Basal, unconfined	Flank	Currently used	Drinking	Fresh	Irreplaceable	High
Lua-3	Waialua	42.6	Basal, unconfined	Flank	Currently used	Drinking	Fresh	Irreplaceable	High
Mak-1	Makaha	39.1	High level, confined or unconfined	Dike compartments	Currently used	Drinking	Fresh	Irreplaceable	High
Mok-1	Mokuleia	4,985.9	High level, unconfined	Dike compartments	Potential use	Drinking	Fresh	Irreplaceable	High
Mok-2	Mokuleia	2,593.1	Basal, unconfined	Flank	Currently used	Drinking	Fresh	Irreplaceable	High
Mok-3	Mokuleia	56.8	Basal, unconfined Lower aquifer: basal, confined	Sedimentary Lower aquifer: flank	Currently used Lower aquifer: Currently used	Ecologically important Lower aquifer: Drinking	Low Lower aquifer: Low	Irreplaceable Lower aquifer: Irreplaceable	High Lower aquifer: Low
Wah-1	Wahiawa	27,781.0	High level, unconfined	Dike compartments	Currently used	Drinking	Fresh	Irreplaceable	High
Wai-1	Waiawa	552.3	High level, unconfined	Dike compartments	Potential use	Drinking	Fresh	Irreplaceable	High
Wai-2	Waiawa	543.1	Basal, unconfined	Flank	Currently used	Drinking	Fresh	Irreplaceable	High



Kaiaka Bay Watershed-Based Plan

FIGURE 13. AQUIFER SYSTEMS

2.9 BIOLOGICAL RESOURCES

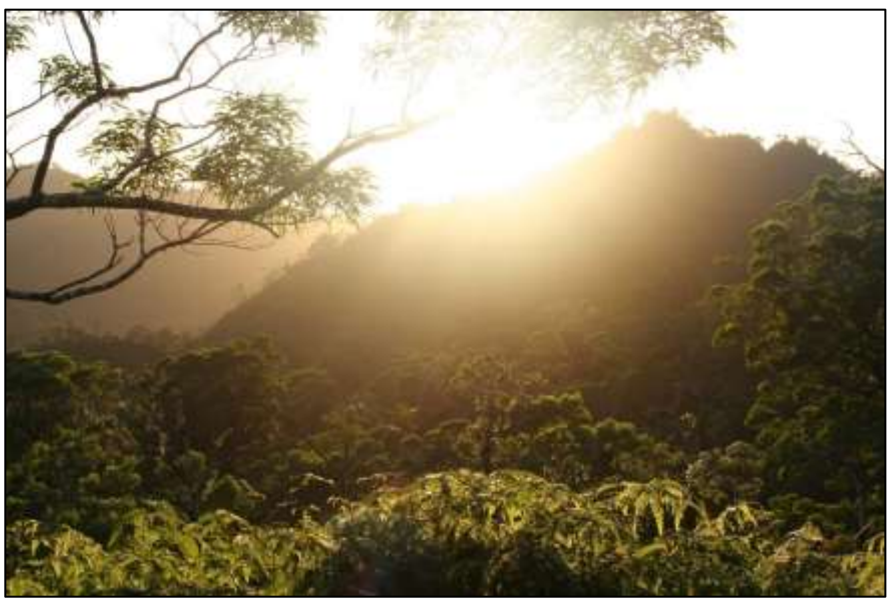
2.9.1 TERRESTRIAL BIOLOGICAL RESOURCES & CRITICAL HABITAT

The watersheds host a diversity of native flora and fauna, especially in the mountainous (mauka) areas. However, many native species and their habitats are threatened by invasive species. Invasive species can include plants (*e.g.,* strawberry guava), animals (*e.g.,* rats and pigs), or invertebrates (*e.g.,* wasps) that either directly or indirectly affect native species and/or their habitats. For more information about how invasive species can affect water quality, see section 7.2.2.

According to information from DLNR, the density of threatened and endangered plants is low in the makai (toward the sea) areas of the watersheds and increases in the mauka areas (see Figure 14). There are 13,957 acres of land that are designated as having a “high” to “very high” density of threatened or endangered plants, representing over a quarter of the total land area. In contrast, the lower elevations consist of 21,342 acres of land that are described has having little to no threatened or endangered plants (approximately 42% of the land area).

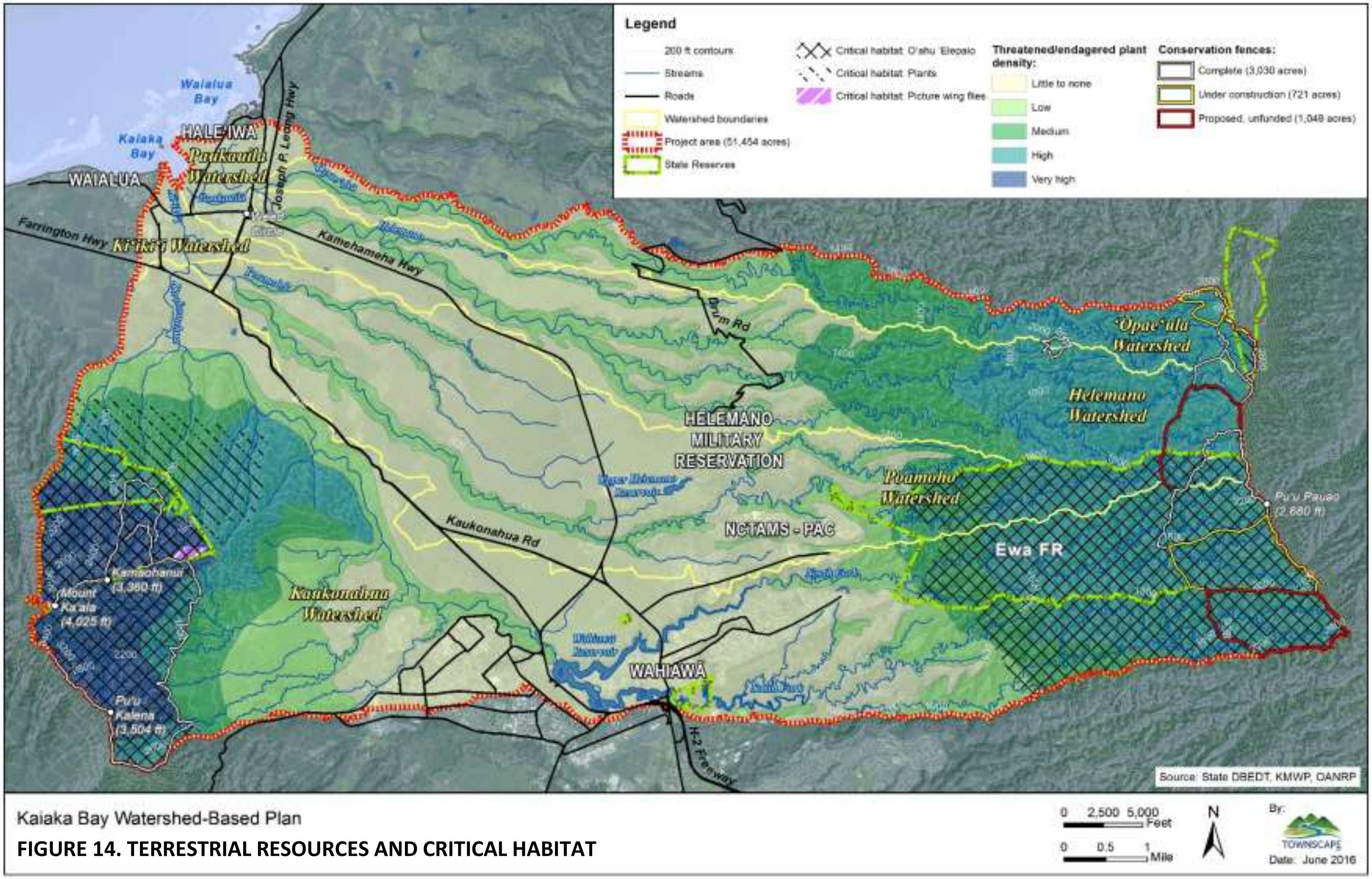
The slopes and summit of Mt. Kaʻala provide habitat for many threatened and endangered species, including some of the rarest plants in the state, endangered picture wing flies, and an endangered forest bird, the Oʻahu ʻelepaio. The area has 3,477 acres of land that are designated as critical habitat for the Oʻahu ʻelepaio, 48 acres of critical habitat for the picture wing flies, and 13,162 acres of critical habitat for 34 different plant species (overlapping land).

The slopes and summit of the Koʻolau mountains are also home to many threatened or endangered species. There are approximately 6,603 acres that are designated as critical habitat for the Oʻahu ʻelepaio, as well as small pockets of land along the summit that are critical habitat for 23 species of endangered plants. There are also populations of endangered Hawaiian tree snails, or kāhuli, near the summit of the Koʻolau range.



Native plants dominate in the upper reaches of the watersheds (Poamoho Watershed pictured)

As seen in Figure 14, much of the mauka areas are designated as Forest Reserves or Natural Area Reserves. In addition, some of the highest elevations in the project area have fences to protect the habitat from degradation by feral ungulates (see section 3.2.2 for more information).



Kaiaka Bay Watershed-Based Plan

FIGURE 14. TERRESTRIAL RESOURCES AND CRITICAL HABITAT

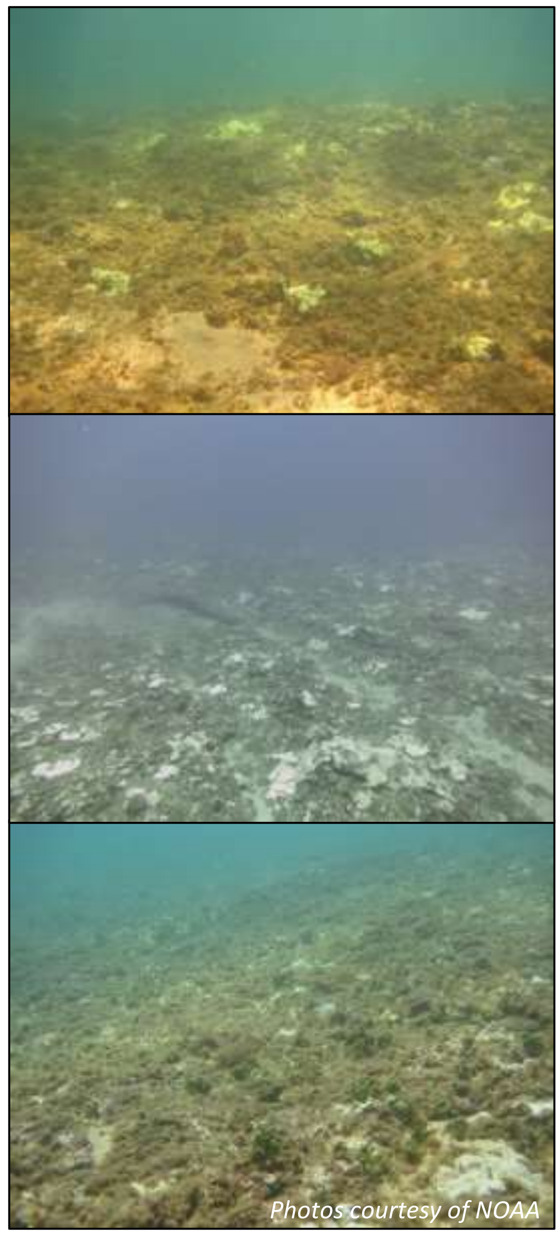
2.9.2 Marine Biological Resources

In addition to the terrestrial biological resources, Kaiaka Bay is potentially an important area for marine resources. It provides habitat for green sea turtles, an assortment of fish species, coral reef ecosystems, and marine mammals. The endangered ʻoʻopu nākea *(Lentipes concolor)* is known to have habitat in the Kaiaka Watersheds as well; Kaiaka Bay may provide habitat for part of the lifecycle of this amphidromous fish. The bay is also known to be a breeding area for hammer head sharks. It is also located just south of the Hawaiian Islands Humpback Whale National Marine Sanctuary, which was created by Congress in 1992 to protect humpback whales and their habitat in Hawaiʻi.

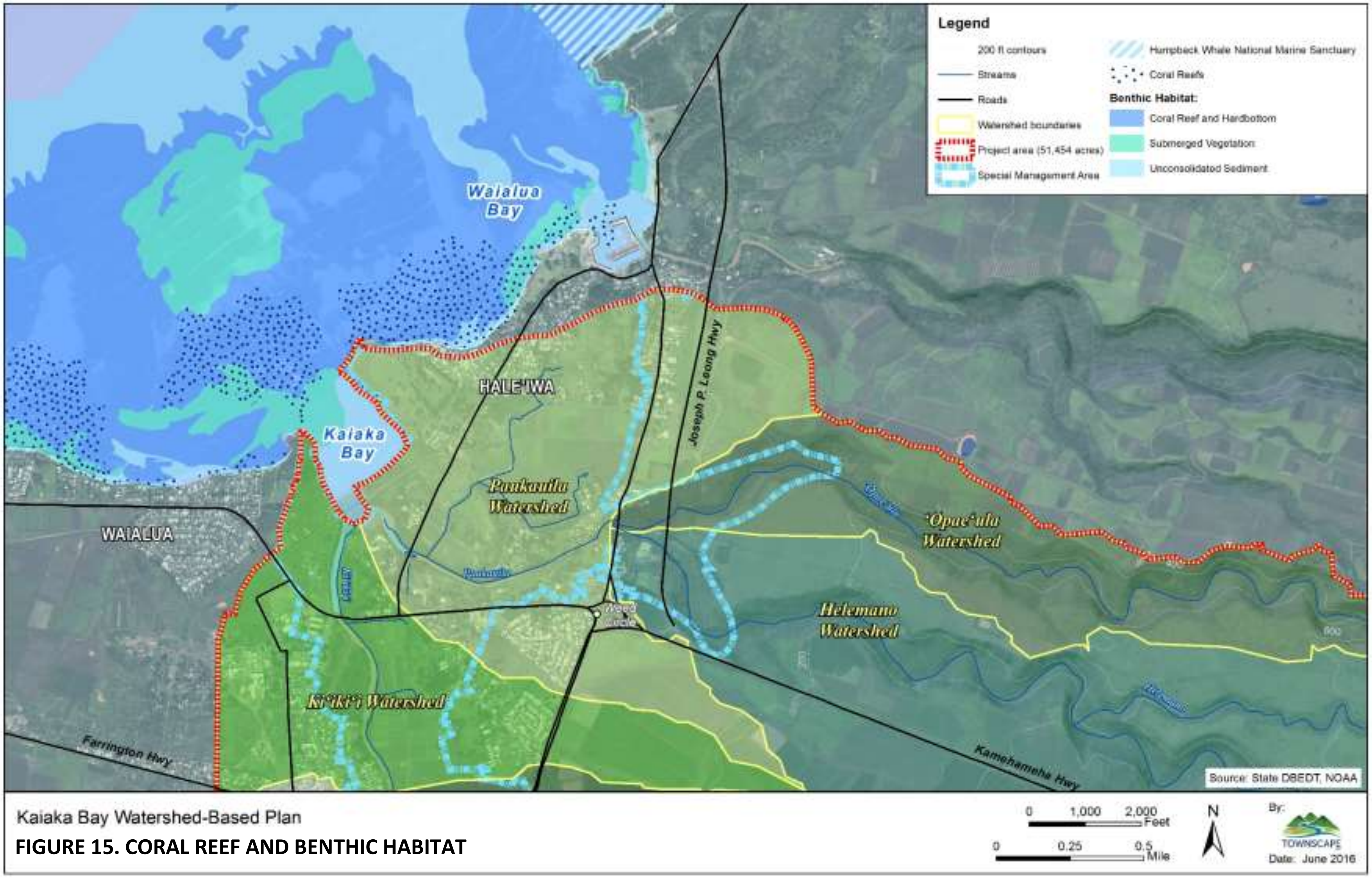
According to one source, the reefs in Kaiaka Bay are predominantly characterized by a limestone pavement consisting of fossilized coral. Figure 15 shows the location of coral reefs and types of benthic habitat in Kaiaka Bay and in the surrounding area.

The National Oceanic and Atmospheric Administration conducts routine monitoring of coral reef ecosystems throughout the United States. The sampling sites are randomly selected and are relatively small. In recent history, NOAA monitored the reef in Kaiaka Bay at three locations during 2012, 2013, and 2015 (a different site each year; see photos at right). While it is difficult to draw any strong conclusions about the reef ecosystem from only a few small sampling sites, the data indicate that in general there is a relatively low cover of live coral (average of 6.2%) compared to the average for all sampling areas on the North Shore (10.6%) or Oʻahu in general (11.6%). The reef at each of the sampling sites was found to be relatively flat. The average total fish biomass at the three sites in Kaiaka Bay was very low (4.0 grams per square meter), which is less than half of the average fish biomass for all sampling areas on the North Shore and a third of the average total fish biomass for the island of Oʻahu. The average number of species (richness) was also low in Kaiaka Bay compared to other areas. As one would expect in a polluted waterbody, the cover of macroalgae in Kaiaka Bay was found to be high (average of 34.5%) compared to the average for all sampling areas on the North Shore (average of 18.8%) or Oʻahu in general (average of 16.6%).

One possible reason the reef ecosystem in Kaiaka Bay is relatively flat and is not as not as healthy as other areas on Oʻahu may be due in part to the fact that the bay is heavily impacted by high waves and storms. Studies have indicated that the reef was much healthier about 5,000 years ago, about the time researchers think that an extraordinarily large swell associated with strong El Niño years began hitting the Hawaiian Islands (G70, 2016).



Three NOAA sampling sites in Kaiaka Bay



Kaiaka Bay Watershed-Based Plan

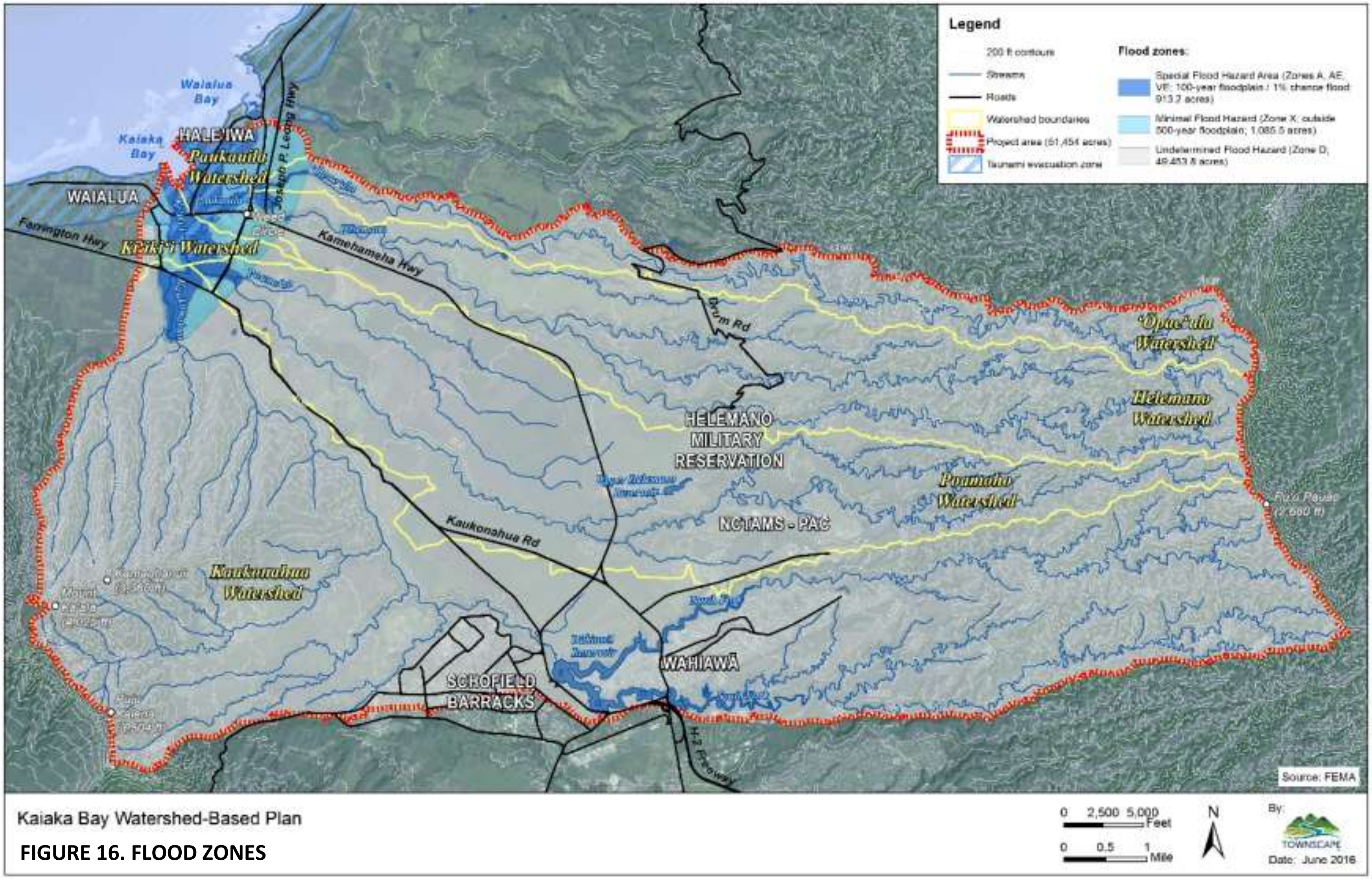
FIGURE 15. CORAL REEF AND BENTHIC HABITAT

2.9.3 HAZARD AREAS

Areas subject to coastal flooding or tsunami inundation are identified on Flood Insurance Rate Maps provided by the Federal Emergency Management Agency for the National Flood Insurance Program. Insurance rates are based on flood probability. The majority of the Kaiaka Bay Watersheds (approximately 96% of the area) are classified as Zone D, where the flood hazard is “undetermined but possible” (Figure 16). Approximately 1,086 acres are in Zone X, where there is minimal flood hazard and lies outside of the 500-year floodplain. The land nearest the shore and directly adjacent to stream channels is classified as a “Special Flood Hazard Area” (Zones A, AE, VE), and lies within the 100-year floodplain with a 1% annual chance of flood. The tsunami evacuation zone extends about 3,600 feet inland from the shoreline, overlapping most of the Special Flood Hazard Area.

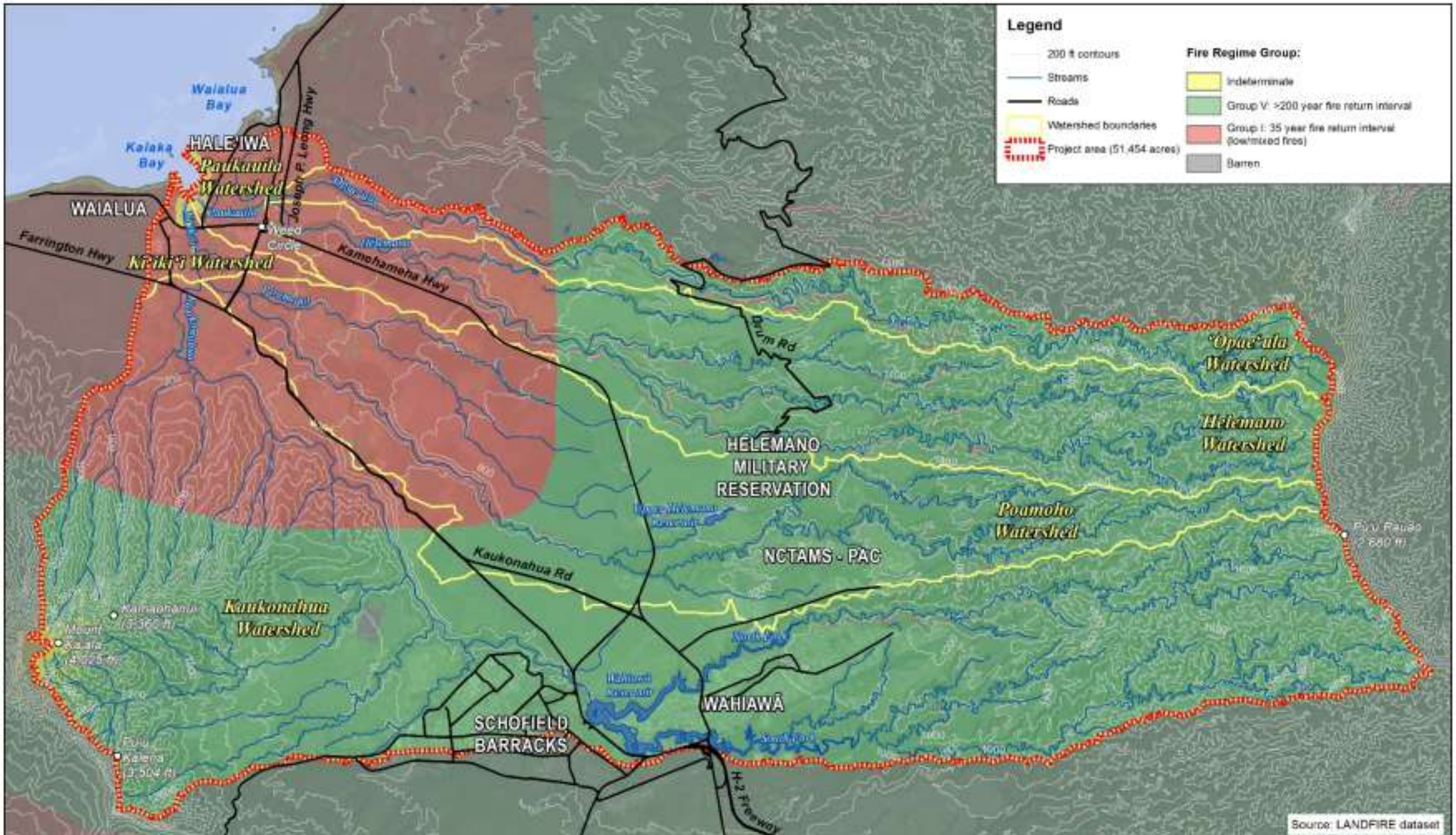
The fire risk throughout the Kaiaka Bay Watersheds varies by elevation (Figure 17). The LANDFIRE dataset classifies the lower elevations (from 0 feet to approximately 900 feet elevation) as “Fire Regime Group I,” with a 35-year fire return interval for low and mixed severity fires. The majority of the area is classified as “Fire Regime Group V,” with greater than a 200-year fire return interval. The area on the summit of Mt. Kaʻala is classified as “Indeterminate” fire risk for unknown reasons. A small area on the slopes of the Waiʻanae mountains near Schofield Barracks is labeled as “Barren” land. Note that the Fire Regime Groups are intended to be general characterizations of the presumed historical fire regimes based on interactions between vegetation dynamics, fire spread, fire effects, and spatial context. They do not account for many human activities that are associated with incidental fires. Therefore, some areas may be over- or under-represented in terms of fire risk in the dataset.

The risk of hazards such as flooding and fires have implications for considering management strategies to improve water quality. Water quality is an obvious concern in areas that are prone to flooding; flooding events can exacerbate the negative environmental effects of poor water quality. Fire risk is important to consider because areas that are more prone to fire may also be more prone to erosion due to reduced ground cover and exposed soils. Erosion can contribute to reduced water quality in streams and nearshore marine environments.



Kaiaka Bay Watershed-Based Plan

FIGURE 16. FLOOD ZONES



Kaiaka Bay Watershed-Based Plan

FIGURE 17. FIRE RISK

3 USE OF KAIAKA BAY WATERSHEDS

3.1 PAST LAND USE HISTORY

3.1.1 NATIVE HAWAIIAN USE

Traditional Hawaiian land management involves a complex system of land divisions. Large areas of land are divided into moku, the largest units within each island. Oʻahu is divided into six moku. Moku were then further divided into ahupuaʻa. While ahupuaʻa vary in shape and size depending on the resources of the area, they typically extend from mauka to makai and sometimes capture an entire watershed. In the Kaiaka Bay Watersheds, however, the six watersheds are generally smaller than the ahupuaʻa boundaries of the area. Each ahupuaʻa was ruled by an aliʻi (Hawaiian chief or royalty) and administered by a designated headman, or konohiki. Within each ahupuaʻa there were further land divisions that served different purposes.

Under historic Hawaiian management, the ahupuaʻa system was a holistic approach that recognized the interconnectedness between land and sea and all the plants and animals within the ahupuaʻa. Resources were managed for the collective good of residents in the ahupuaʻa and exchanges made between mauka and makai inhabitants allowed most ahupuaʻa to remain fairly self-sufficient. The concept of private property did not exist. In today's context of watershed planning, the ahupuaʻa concept provides a useful approach that recognizes the ecological connections between mauka and makai resources and the complex interactions and dependencies that exist among ecological, economic, and sociocultural uses.

The ahupuaʻa system classifies the land that makes up the Kaiaka Bay Watersheds as falling mostly within the moku of Waialua, which extends from Mokulēʻia to the west and Waimea to the northeast and up to Wahiawā to the south (Figure 18). Of Waialua Moku's 14 ahupuaʻa, the watersheds of Kaiaka Bay cover all or parts of three: Kamananui, Paʻalaʻa, and Kawailoa (a small portion). Southern portions of the Kaiaka Bay Watersheds are a part of the Waiʻanae Uka ahupuaʻa of the moku of Waiʻanae. Waiʻanae Moku was mostly on the west side of Oʻahu, separated from Waialua by the Waiʻanae Mountains. The Waiʻanae Uka ahupuaʻa runs from the crest of the Waiʻanae Mountains south of Mt. Kaʻala, across the plateau area and up to the crest of the Koʻolau range (Sterling, et. al., 1997). Re-districting in 1913 created the moku of Wahiawā, which included the ahupuaʻa of Wahiawā from the Waialua Moku and Waiʻanae Uka from the Waiʻanae Moku (Sterling, et. al., 1997). Many still consider Waiʻanae Uka a part of the Waiʻanae Moku.

The area covered by the Kaiaka Bay Watersheds was historically an important region for the Hawaiian people and remains so today. As can be expected from a place with the word "wai" in its name, water resources were abundant in Waialua. There were many springs, streams, tributaries, pools, shorelines, and near shore areas that had individual names, indicating their importance.

Hawaiians understood how to utilize the many resources of the area. In fact, ancient Waialua was once considered the poi bowl (breadbasket) of Oʻahu. Agricultural terraces were also constructed throughout the watershed, with large features between Helemano and Poamoho Streams and the flatlands west of Poamoho. Smaller terraces were also located in the lower flatlands of Poamoho and Kaukonahua valleys and at the bottom of Kaukonahua Canyon (Sterling, et. al., 1997). In Kamananui, it was likely that sweet potato and bananas were planted at home sites along the ridge and near taro patches at the bottom of the gulch. Wild taro and bananas grew in Manawai Valley and presumably in the other five valleys that run up toward Puʻu Kane. At Kamananui are the remains of "the longest irrigation ditch of which there is any memory" among native Hawaiians (Sterling, et. al., 1997). Terraced areas in Waiʻanae Uka were irrigated by Kioea and Waikōloa Streams.

The marine resources were also important to the Hawaiian people. There were several fish ponds in the area that provided an important source of protein. They used watch towers to improve near shore fishing success and to assess areas associated with sharks. Sea salt was also collected from salt pans near the shoreline.

Many aliʻi lived in the area, visiting the birthing stones at Kūkaniloko during child birth. This site is arguably one of the most sacred places on Oʻahu, located near the geographic piko (navel) of the island. The aliʻi visited the site to give birth and believed that the gods specially recognized children born at the site. There were several heiau in the area that were reportedly destroyed by sugarcane and pineapple agriculture. Additionally, many important battles for control of the island were fought between rivals on the central plains surrounding Kūkaniloko. Today, the area is owned by the Office of Hawaiian Affairs and is recognized on the National Register of Historic Places.

It is also known that Kapukapuakea Heiau once existed at the east end of Kaiaka Bay (where today's Kaiaka Bay Beach Park is located). The heiau was very important because it was where the aliʻi nui (ruling chiefs) of Oʻahu were vested to rule. It was also said to have connections to other heiau, and is linked linguistically to a heiau on Molokaʻi. It is also linked to a temple called Taputapuatea in the Society Islands where, after 600 years of dispute, an ancient Polynesian alliance was recently reaffirmed. Nothing remains of the Kapukapuakea Heiau today.

Also adjacent to Kaiaka Bay in the center of Kaiaka Bay Beach Park is Pōhaku Lānaʻi, a large piece of limestone rock that is known to have been used as a lookout for schools of fish in the ocean. It is said that Pōhaku Lānaʻi floated ashore from Kahiki (Tahiti).

Pōhaku Lānaʻi at Kaiaka Bay Beach Park

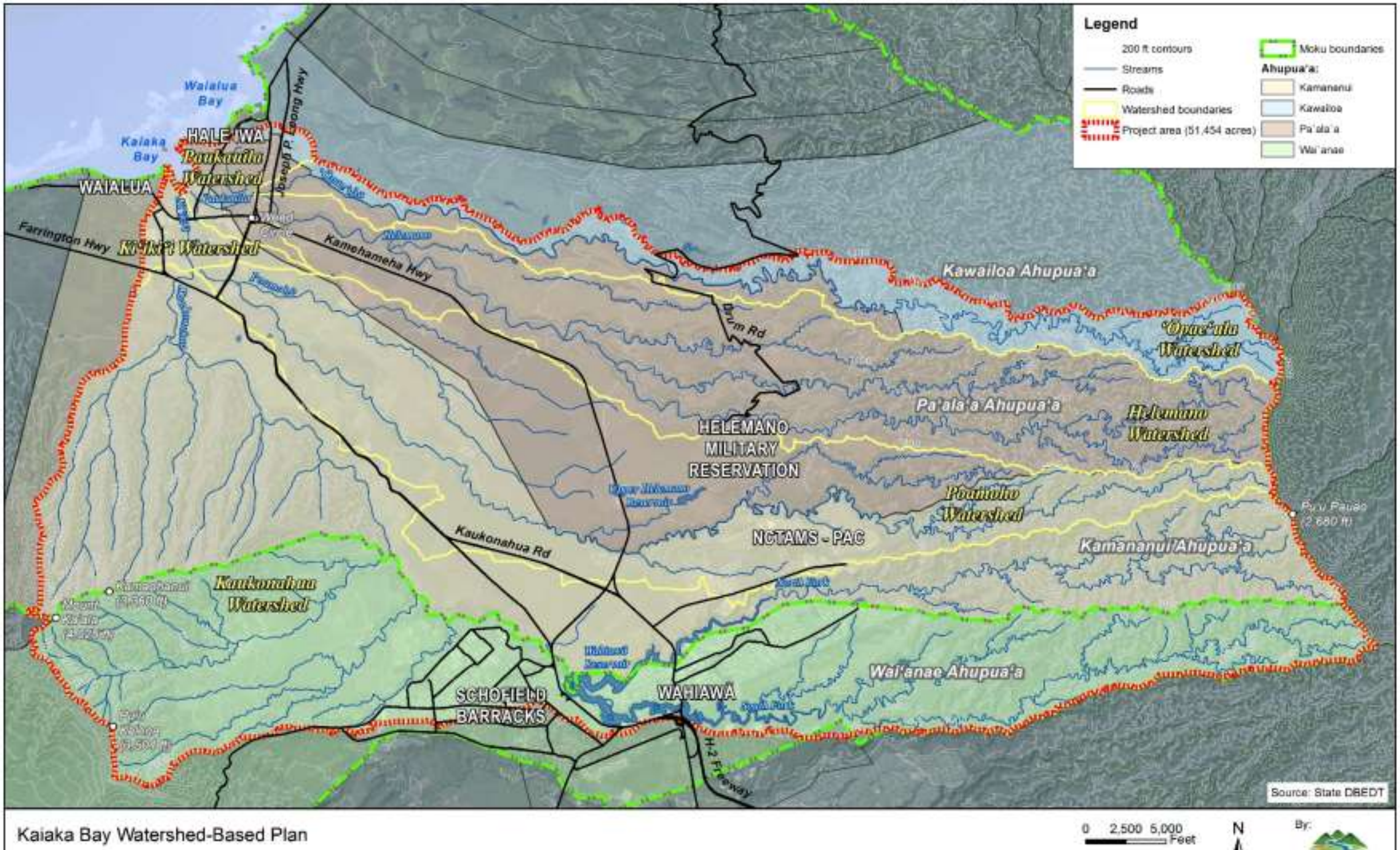


FIGURE 18. HISTORIC LAND DIVISIONS

3.1.2 POST-CONTACT HISTORIC LAND USE

Pineapple field workers surrounded by a field of ready-to-harvest pineapples in Central Oʻahu, circa 1940

The Kaiaka Bay Watersheds have been in large-scale agricultural production since the late 1800's. Agriculture was the economic mainstay of the central Oʻahu plains for generations. The most notable operation was the Waialua Sugar Company which was owned by Castle and Cooke. The Waialua Sugar Company produced sugar from 1899 to 1996 (Kinoshita, 1999). The first crop, grown on 300 acres and harvested in 1889, produced 1,741 tons of sugar (Dorrance, 2000). Innovations in agricultural operations, including mechanical loading of harvested cane, hydroelectric power, and irrigation reservoirs and wells, helped to increase production dramatically. During peak production in the 1970s, over 120 fields averaging 100 acres in size produced 80,000 tons of sugar per year (Kinoshita, 1999). Other historical land uses include pineapple production on 2,100 acres of land owned by the George Galbraith Estate and leased to Del Monte Fresh Produce and Castle and Cooke.

Pineapple is still the dominant crop cultivated in the Kaiaka Watersheds

International competition has resulted in a dramatic decline in large-scale agriculture in Hawaiʻi. Del Monte ceased their pineapple operations in Poamoho in 2004, leaving Dole Food Co. as the sole remaining pineapple grower on the island. Waialua Sugar Company, the last sugar plantation on Oʻahu, closed in 1996. Agricultural operations in the area are now in pineapple and diversified crops, including coffee, seed crops, and sunflowers.

Significant portions of land in Kaiaka Bay Watersheds have also been used for military purposes. The U.S. Army's 17,725-acre Schofield Barracks was established in 1908 as a base for mobile defense troops. In the late 1930s, Schofield's population was up to 20,000. Following the attack on Pearl Harbor in 1941, Schofield became a supply base and command center for the war in the Pacific; as many as 100,000 soldiers at a time may have been housed at Schofield during World War II (Federal Facilities Assessment Branch, 1998). In the mid-1950s, the Army headquartered the 25th Infantry Division at Schofield. After the Vietnam War, many facilities at Schofield were renovated and the civilian population in the vicinity expanded.

The Naval Computer and Telecommunications Area Master Station Pacific site (NCTAMS-PAC), located near Wahiawā, was originally established in 1940 as a temporary Naval Radio Station; however, with increasing need to expand radio receiving facilities, NCTAMS-PAC expanded and was made a permanent facility of the Navy. The area is now referred to as the Joint Base Pearl Harbor-Hickam (JBPHH)-Wahiawā Annex. The JBPHH-Wahiawā Annex continues to operate and maintain communications facilities at present and also provides residential housing (Federal Facilities Assessment Branch, 1998).

The area now known as Kaiaka Bay Beach Park has had a of variety historical land uses and an interesting recent history. Prior to World War II, the property was owned by Bishop Estate and leased to Pālama Settlement which ran the Pālama Fresh Air Camp, a program that offered different recreational activities on site. After a tsunami destroyed the cabins and dining facility at the camp in 1946, Pālama Settlement chose not to renew the lease with Bishop Estate. After that, the land was used by farmers and the occasional camper. When a local developer offered to purchase the parcel from Bishop Estate with the intention of building a condominium complex and golf course, the community rose in opposition and began trying to procure funds to purchase the land from Bishop Estate at the then market price of $1.3 million. Local government officials took the community's request for funding to the Hawaiʻi State Legislature in 1974 and successfully secured the funds to purchase the land, making Kaiaka Bay Beach Park the first ocean park to be acquired and developed by the State. In 1979, under Executive Order, the City was granted custody of the park until ownership was officially transferred to the City in 1992. A portion of the beach park is now called the Bill and Peggy Paty Kaiaka Bay Beach Park in honor of two community members who were very involved in preventing the development from occurring in the 1970s.

Kaiaka Bay Beach Park was renamed in honor of community members who helped to prevent the park from being developed

3.2 CONTEMPORARY USE AND MANAGEMENT

3.2.1 STATE LAND USE DISTRICTS

A little more than half of the land in the Kaiaka Bay Watersheds are designated as State Land Use "Agriculture" (see Figure 19 and Table 12). This reflects both the historic and current use of the area, although farming activity has declined recently. Urban areas are found along the coast (around Haleʻiwa and Waialua) and in the "saddle" between the Waiʻanae and Koʻolau mountain ranges (Wahiawā and Schofield).

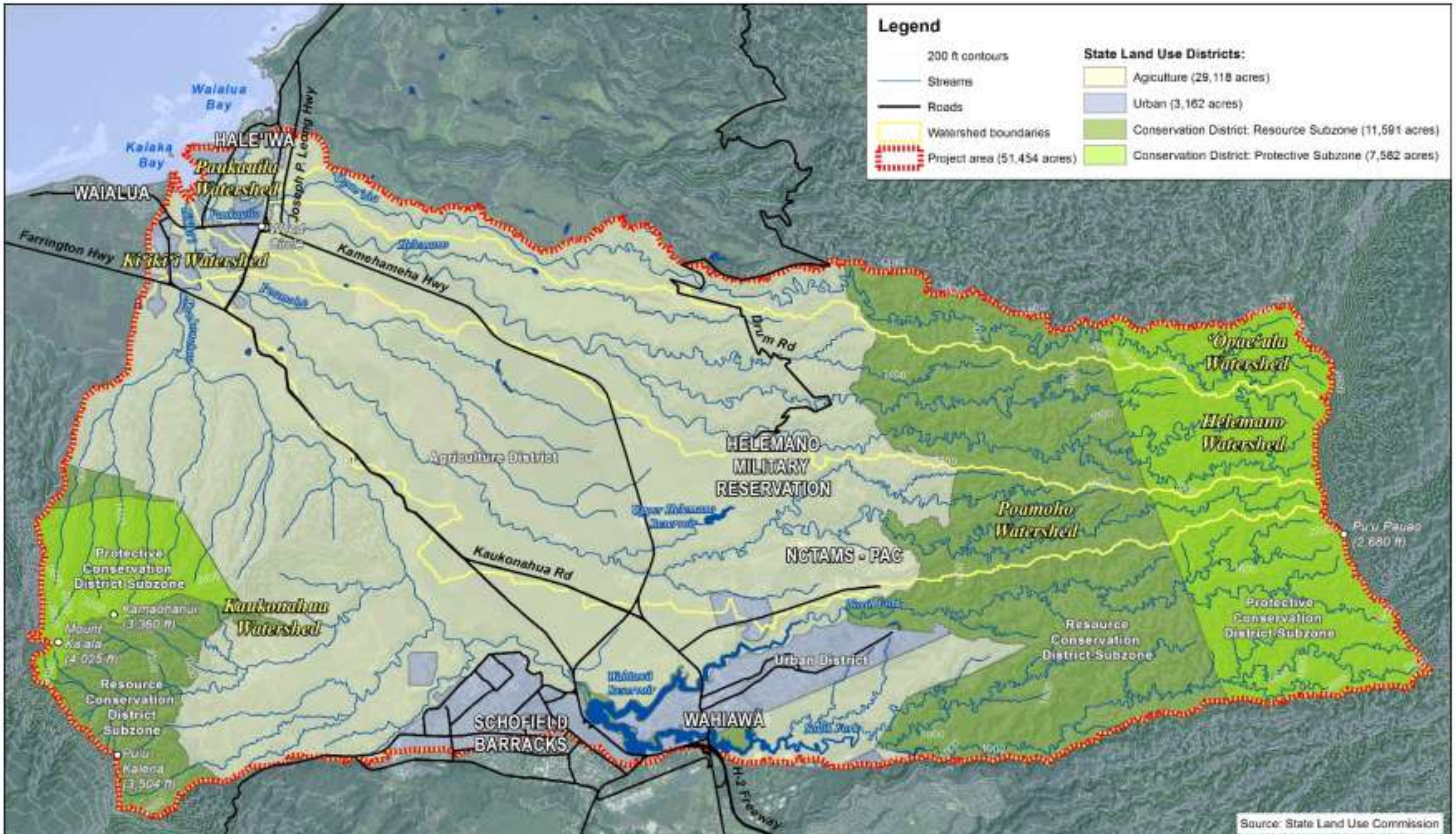
Most of the upper elevations in both the Waiʻanae and Koʻolau mountain ranges are forested lands that are classified as Conservation Lands, much of which are designated as reserves (see next section). In addition, the land around the Wahiawā Reservoir is also in the Conservation District.

The Conservation District is further classified by the State into Conservation Subzones. In the Kaiaka Bay Watersheds 7,582 acres of the Conservation District are in the Protective Subzone and 11,591 acres are in the Resource Subzone. The Protective Subzone is the highest level of resource protection and is the most restricted land classification in the state. The Resource Subzone offers the most flexible land use possibilities for Conservation Land.

The Conservation District is primarily in forest reserve

TABLE 12. KAIAKA BAY WATERSHEDS STATE LAND USE DISTRICTS

		Agriculture		Conservation		Urban		
	Watershed	**Acres**	**% of Watershed**	**Acres**	**% of Watershed**	**Acres**	**% of Watershed**	**Total Acres**
Kiʻikiʻi System	Kiʻikiʻi	344	58%	0	0%	247	42%	**592**
	Kaukonahua	11,752	47%	10,954	44%	2,453	10%	**25,159**
	Poamoho	9,547	82%	2,016	17%	112	1%	**11,675**
Paukauila System	Paukauila	531	61%	0	0%	334	39%	**866**
	Helemano	5,256	56%	4,088	44%	9	0%	**9,353**
	ʻŌpaeʻula	1,688	44%	2,116	56%	7	0%	**3,810**
	Total Acres	**29,118**	*n/a*	**19,174**	*n/a*	**3,162**	*n/a*	**51,454**
	% of Project Area	**57%**	*n/a*	**37%**	*n/a*	**6%**	*n/a*	**100%**



Kaiaka Bay Watershed-Based Plan

FIGURE 19. STATE LAND USE DISTRICTS

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: June 2016

3.2.2 RESERVES & PROTECTED AREAS

Much of the mauka lands in the State Conservation District are designated as Forest Reserves or Natural Area Reserves (NAR) by the DLNR Division of Forestry and Wildlife (DOFAW; Figure 20). State Forest Reserves are multi-use land areas that are meant to provide a variety of public uses and benefits. NARs are designated to preserve in perpetuity natural areas with relatively intact native flora and fauna communities, as well as unique geological sites. DOFAW develops management goals for individual Forest Reserves and NARS that reflect the resources it contains. While hiking is allowed in both Forest Reserves and NARs, natural resource management in NARs is generally more extensive because they are such ecologically and culturally valuable ecosystems. Management activities include fencing, weed removal, out-planting native and endangered plants, ungulate control, and predator control.

The Kaiaka Bay Watersheds include portions of two Forest Reserves: ʻEwa Forest Reserve is in the Koʻolau range and Mokulēʻia Forest Reserve is in the Waiʻanae range. There are also portions of two designated NARs, Kaʻala NAR and Kaluanui NAR, as well as the proposed Poamoho NAR. The Kaʻala NAR extends from the Waiʻanae summit down the slopes of Mount Kaʻala in the Kaukonahua Watershed. While only a small portion of the Kaluanui NAR extends into the upper elevation of the ʻŌpaeʻula Watershed in the Koʻolau range, it is significant since a new fence is currently being constructed in the summit area of the watershed to protect the NAR. The proposed Poamoho NAR is located in the upper reaches of the Kaukonahua and Poamoho watersheds, in the Koʻolau range. One portion of the fence for the proposed NAR is completed while the remaining portion is currently under construction.

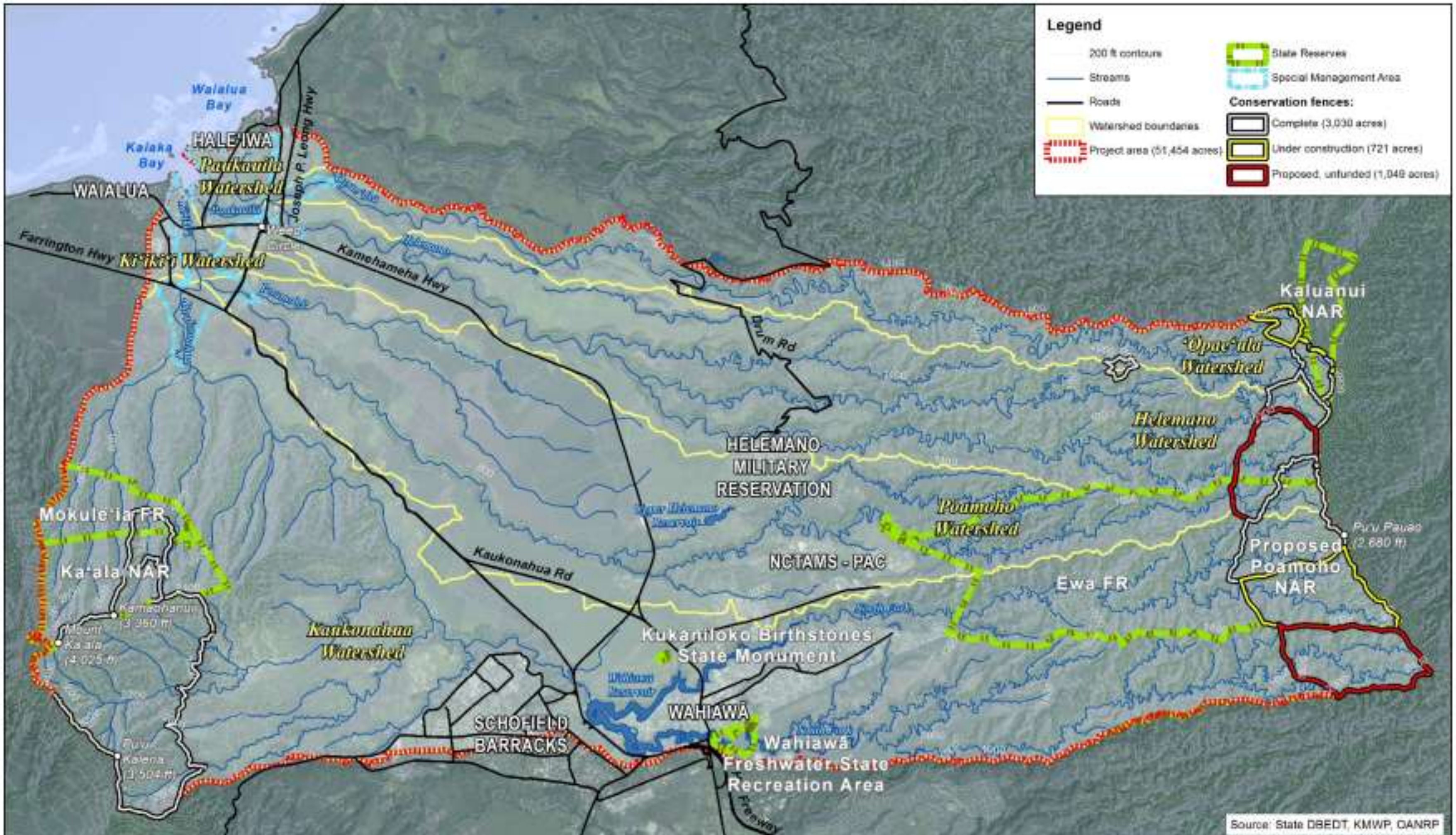
DOFAW partners with other agencies and organizations to build and maintain fences and conduct management activities, including the Koʻolau Mountains Watershed Partnership (KMWP), the Oʻahu Army Natural Resources Program (OANRP), and others. OANRP maintains fenced areas to protect important resources in the upper elevations of the Koʻolau range as well as in the Waiʻanae range, including the second largest fence on the island, located on the slopes below Mount Kaʻala behind Schofield Barracks' West Range. In total, approximately 3,030 acres of land have been fenced for conservation purposes in the Kaiaka Bay Watersheds, while another 721 acres of land currently have fences that are being constructed (including the portion of the Kaluanui NAR fence that is inside the project area).

TABLE 13. ACREAGES OF FENCED CONSERVATION AREAS

Mountain Range	Fence Status	Approx. Acres
Koʻolau	Complete	930
Koʻolau	Under construction	721*
Koʻolau	Proposed, unfunded	1,049
Waiʻanae	Complete	2,100

** Includes only the portion of the Kaluanui NAR fence that is within the Kaiaka Bay Watersheds (approximately 459 acres are outside of the project area).*

In addition to these reserves, a portion the land around the Wahiawā Reservoir is set aside as a Wahiawā Freshwater State Recreation Area and is managed by DLNR's Division of State Parks.



Kaiaka Bay Watershed-Based Plan

FIGURE 20. RESERVES AND PROTECTED AREAS

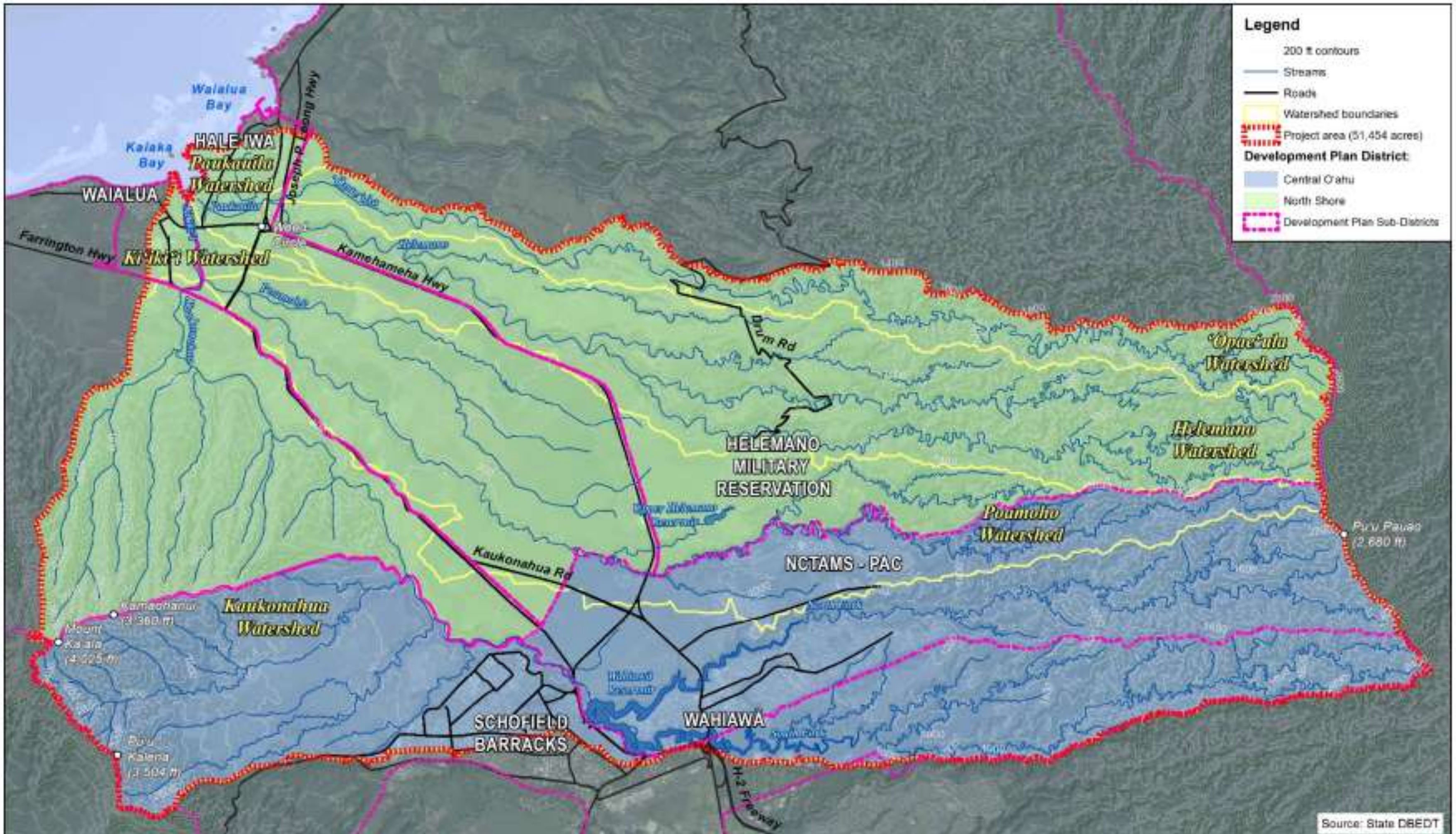
3.2.3 City & County Planning Districts & Zoning

The Kaiaka Bay Watersheds fall into two different City and County of Honolulu Planning Districts: The North Shore Planning District and the Central Oʻahu Planning District. The land in the North Shore Planning District includes the sub-districts of Waialua, Haleʻiwa, and Kawailoa, and the land in the Central Oʻahu Planning District includes the sub-districts of Wahiawā/Whitmore and Schofield/Wheeler (Figure 21).

City zoning reflects a distribution of land uses similar to the State Land Use District designations with the largest percentage of land zoned for agriculture (46%) generally located in the gently-sloping mid-elevations (see Figure 22 and Table 14). Preservation-zoned lands also account for a large percentage (38%) with "restricted" designations for the mauka forest reserves and "general" designations in the urbanized areas of Wahiawā and Haleʻiwa. Zoning for military use is also a major designation in the watershed, with 14% of the land zoned for use by the U.S. Army (East and West Ranges of Schofield Barracks and Helemano Military Reservation) and the U.S. Navy (JBPHH-Wahiawā Annex, previously referred to as NCTAMS-PAC).

TABLE 14. CITY & COUNTY ZONING

Zoning District	Acres	% of Project Area
Residential	**1,498**	**3%**
R-20	76	0%
R-10	103	0%
R-7. 5	381	1%
R-5	866	2%
A-1	3	0%
A-2	69	0%
Business	**110**	**0%**
B-1 Neighborhood Business	23	0%
B-2 Community Business	86	0%
Industrial	**51**	**0%**
I-1 Limited	2	0%
I-2 Intensive	49	0%
Agriculture	**23,389**	**45%**
Ag-1 Restricted	20,253	39%
Ag-2 General	3,136	6%
Country	**138**	**0%**
Preservation	**19,292**	**37%**
P-1 Restricted	19,124	37%
P-2 General	168	0%
F-1 Military and Federal	**6,956**	**14%**
TOTAL	**51,434**	**100%**



Kaiaka Bay Watershed-Based Plan

FIGURE 21. CITY & COUNTY PLANNING DISTRICTS

0 2,500 5,000 Feet
0 0.5 1 Mile
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By: TOWNSCAPE
Date: June 2016

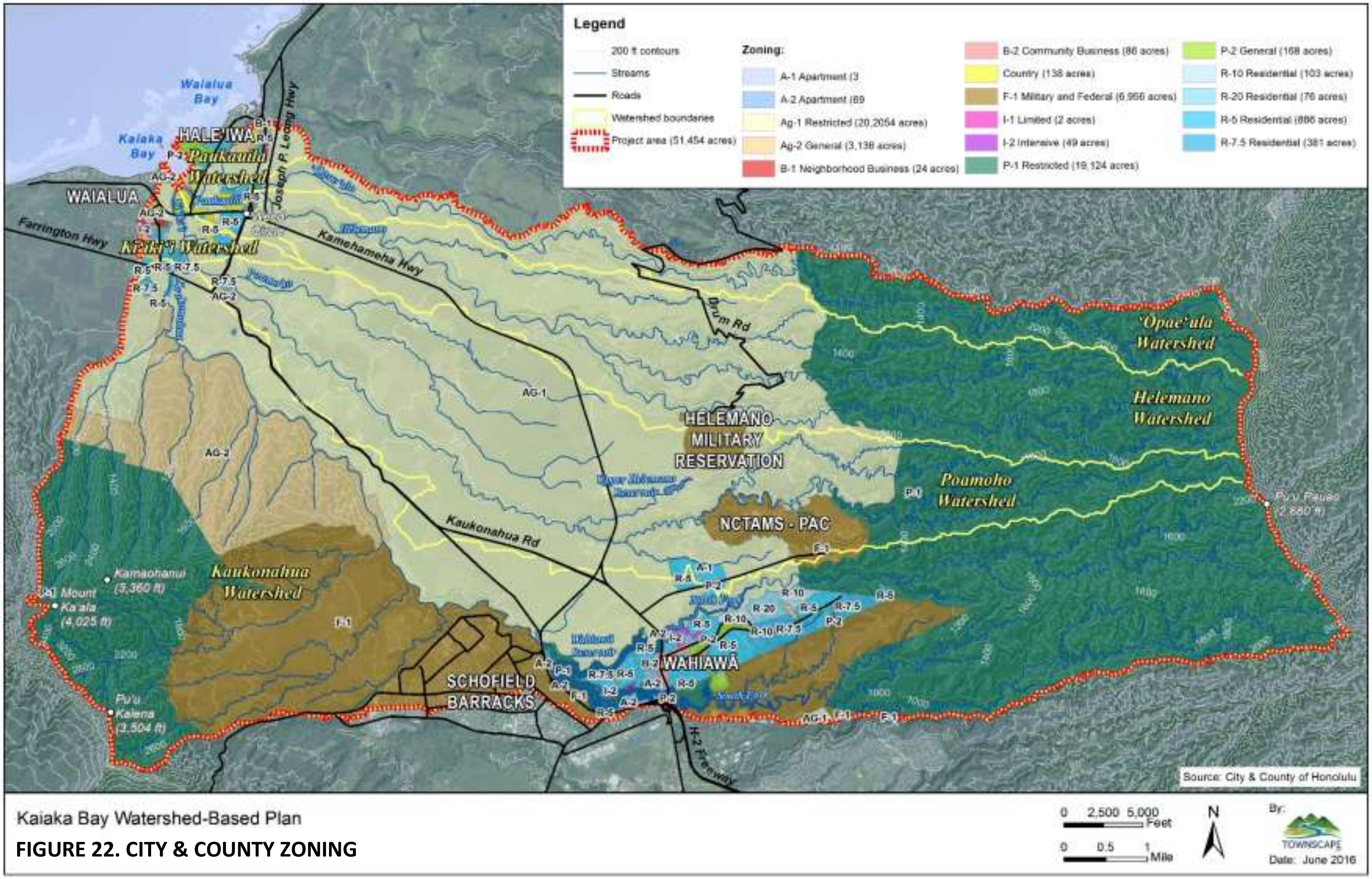


FIGURE 22. CITY & COUNTY ZONING

3.2.4 LAND OWNERSHIP

As of April 2018, the top five land owners in the Kaiaka Bay Watersheds together own approximately 80% of the total land (see Figure 23 and Table 15). The Federal Government (including the U.S. Army and U.S. Navy) is the largest landowner, with 12,445 acres, followed by Dole Food Company, the State of Hawaiʻi, Kamehameha Schools, and the Agribusiness Development Corporation (a branch of the State Department of Agriculture). The City and County of Honolulu owns 245 acres, located in the towns of Wahiawā, Waialua, and Haleʻiwa.

TABLE 15. ACREAGE OF FIVE LARGEST LANDOWNERS BY WATERSHED (APRIL 2018)

Stream System	Watershed	Federal Government	Dole Food Company	State of Hawaiʻi	Kamehameha Schools	Agribusiness Development Corporation
Kiʻikiʻi	Kiʻikiʻi	0	203	11	0	5
	Kaukonahua	11,509	490	4,918	1	1,067
	Poamoho	886	4,333	1,770	61	3,088
Paukauila	Paukauila	0	35	11	276	0
	Helemano	49	5,378	8	3,148	519
	ʻŌpaeʻula	0	878	54	2,705	0
Total Acres		**12,445**	**11,317**	**6,773**	**6,191**	**4,680**
% of Project Area		**24%**	**22%**	**13%**	**12%**	**9%**

The United States of America utilizes its land in the Kaiaka Bay Watersheds for military purposes. Most of the land is owned by the U. S. Army and is used for Schofield Barracks Main Post, West Range, and East Range. Other military installations include the Army Helemano family housing area and the Naval Computer and Telecommunications Area Master Station Pacific.

Top: A pineapple field located in Central Oʻahu today; Bottom: Army-owned lands of East Range training area in the Kaukonahua Watershed

Dole's lands are used for agriculture. Historically, Dole grew pineapple on most of the land, however, now only a fraction of the former pineapple lands is currently being used to grow pineapple. Much of the irrigation water infrastructure in the watersheds are owned by Dole, including ditches, reservoirs, dams, wells, and diversions. Dole also leases many parcels of land to tenants to be used for agriculture and ranching. In recent years, Dole has sold thousands of acres of land, some of which has been purchased by agencies such as the Agribusiness Development Company. Land ownership in the watersheds will continue to change as Dole sells selected parcels.

The majority of the State-owned property in the Kaiaka Bay Watersheds is in the mauka conservation lands with the different types of reserves (see section 3.2.2). Other State-owned lands are those generally under State facilities, such as schools, or State Parks.

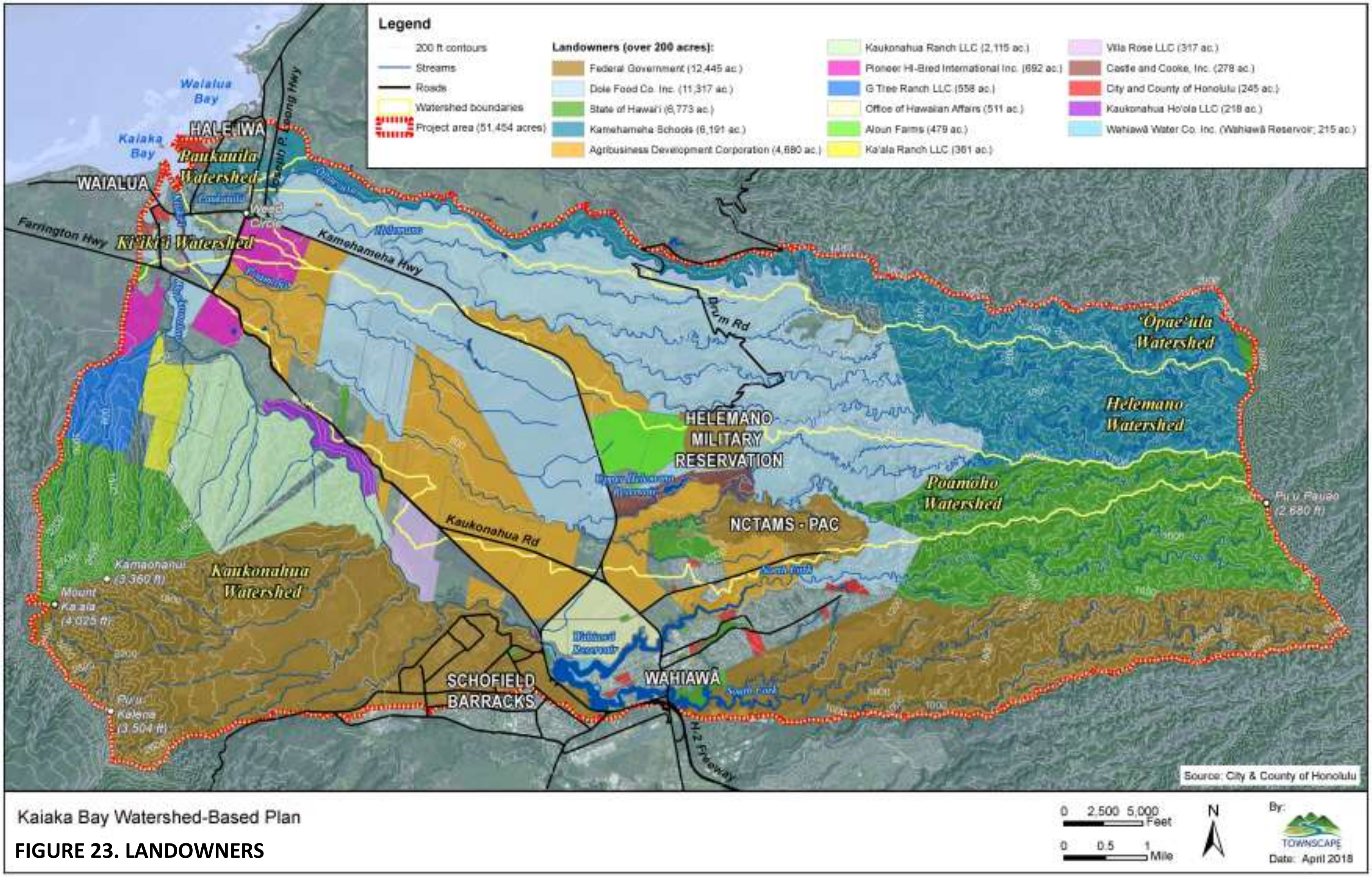
Kamehameha Schools owns much of the mauka portions of the ʻŌpaeʻula and Helemano streams. According to a land use plan produced in 2009, plans for the area included continuing the existing diversified agriculture in the lower portions of the watershed, investigating opportunities for alternative energy development such as solar, wind, and hydro-power in the mid-regions, and stewardship of the forested uplands (Kamehameha Schools, 2009).

Some of Kamehameha Schools' lands are leased to small farmers

ADC has recently become a large landowner in the Kaiaka Bay Watersheds (as part of the Whitmore Project, see section 3.3.2). In 2012, ADC purchased the former Galbraith Estate lands (along with the Office of Hawaiian Affairs). The first crop (watermelon) grown by Sugarland Farms was harvested from the former Galbraith Estate land in May 2016. Prior to that, the last harvest on the property was pineapple in 2004. ADC has also purchased thousands of acres of land that was formerly owned by Dole. The State established ADC in 1994 and tasked it with a top priority of transitioning Hawaiʻi's agriculture industry from an industry dominated by sugar and pineapple to one based on a greater diversity of crops.

Photo credit: Senator Donovan Dela Cruz via Facebook

Watermelons grown on the former Galbraith Estate lands, now owned by ADC



Kaiaka Bay Watershed-Based Plan

FIGURE 23. LANDOWNERS

3.2.5 LAND USE TYPES

RESIDENTIAL

The urbanized areas of the Kaiaka Bay Watersheds are clustered around the towns of Wahiawā and along the coast at Waialua and Haleʻiwa. Wahiawā also supports many military families, as a neighbor to Schofield Barracks.

According to projections that were calculated by the City Department of Planning and Permitting (DPP) in 2009, in 2010 there were approximately 48,730 people living in 14,742 housing units in the five sub-district areas covered by the Kaiaka Bay Watersheds. DPP projects the population to decrease by 1,944 people by the year 2035, but smaller household sizes will mean an increase of 527 housing units by 2035 (Table 16).

Most of the population resides in the town of Wahiawā and the Army's Schofield Barracks. There are smaller clusters of housing in the rural towns of Haleʻiwa and Waialua and along the coast, but much of the Kaiaka Bay Watersheds is undeveloped.

TABLE 16. 2010 AND 2035 PROJECTED POPULATION

Development Plan Sub-Area	Population		Housing Units	
	2010*	Year 2035, Projected	2010*	Year 2035, Projected
Waialua	3,249	3,085	1,028	1,055
Haleʻiwa	4,198	4,365	1,290	1,447
Kawailoa	3,779	3,674	1,290	1,361
Wahiawā/Whitmore	20,359	19,466	6,783	7,050
Schofield/Wheeler	17,145	16,196	4,351	4,356
TOTAL	**48,730**	**46,786**	**14,742**	**15,269**

** 2010 data represent projections made by DPP in 2009.*

IMPERVIOUS SURFACES

Impervious surfaces cover about 5% of the total project area (2,443 acres), per the NOAA C-CAP dataset from 2005 (see Table 7 and Figure 11 in section 2.6). Not surprisingly, the majority of the impervious surfaces are in the Urban State Land Use District. The Conservation District has a negligible amount of impervious surface. The Kaukonahua Watershed has by far the most impervious surfaces out of the six watersheds, with 1,568 acres. Impervious surfaces in the Kaukonahua Watershed are located mainly in Schofield Barracks and Wahiawā.

AGRICULTURE, LIVESTOCK, & RANCHING

The agricultural lands in the watersheds are some of the most productive lands in the state. As presented in section 2.5 (Table 5), approximately 40% of the land in the project area is categorized as "prime farmland" by the NRCS.

Statewide, agriculture has shifted away from large plantations of a single crop toward diversified agriculture, even though the total land used for crop production in the State is less than half of what it was 30 years ago. Much of the former plantation lands have been fallow for many years. Dole Foods is one of the last large landowners that focuses primarily on a single crop (pineapple) in the Kaiaka Bay Watersheds. The company also leases a significant number of parcels to farmers. Dole is currently in the process of selling some of their land (see section 3.3.1 for more details). As Dole land is sold, it is likely that the diversity of products produced will continue to increase and the percentage of actively farmed land will also increase. It is also possible that some parcels will be subdivided and developed.

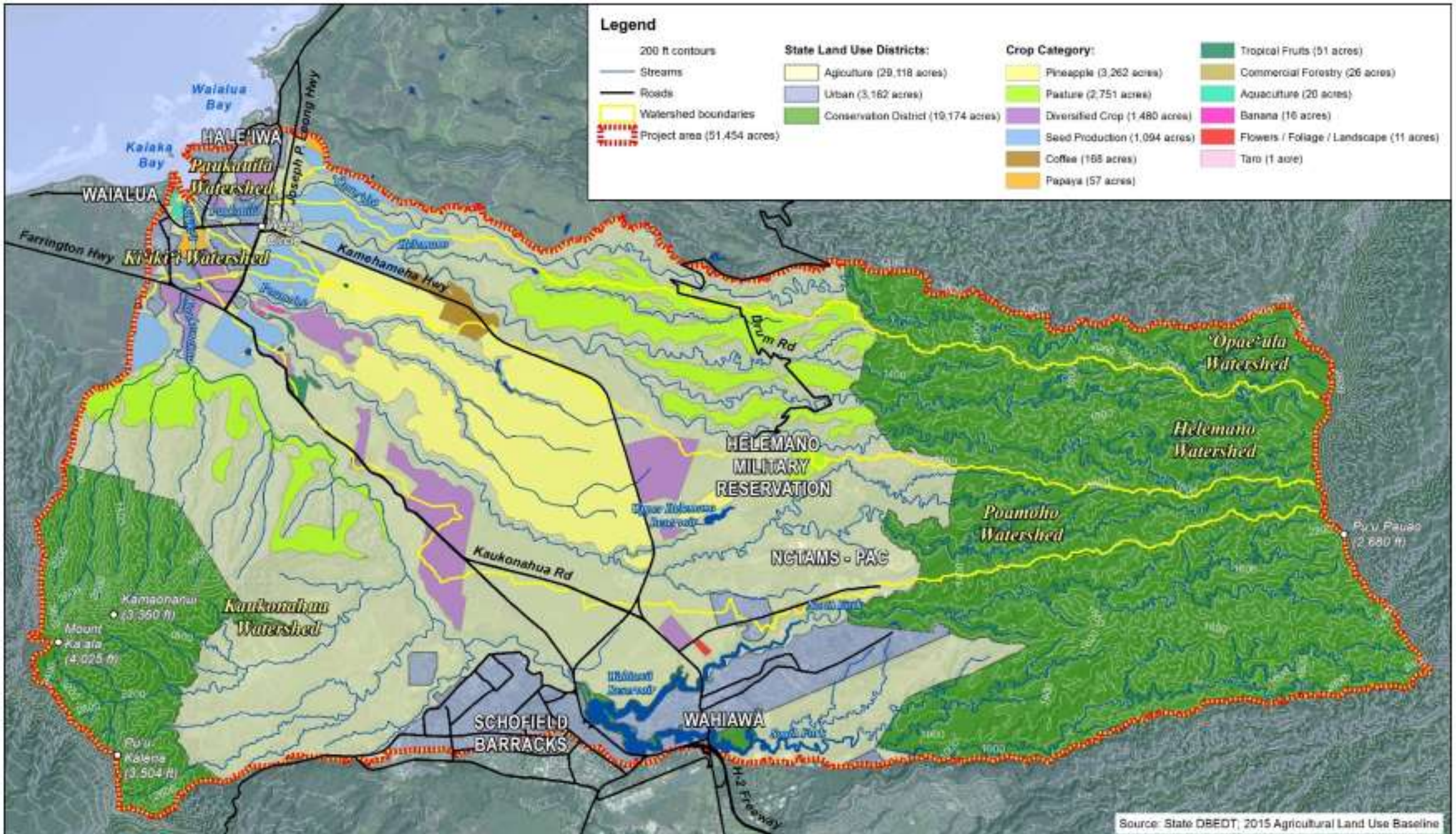
According to data available from the 2015 Statewide Agricultural Land Use Baseline Study, there are four major agricultural land use types in the Kaiaka Bay Watersheds: approximately 3,262 acres of agricultural land are currently used for pineapple, 2,751 acres are used for pastureland, 1,480 acres are for diversified crops, and 1,094 acres are used for seed production (Table 17, Figure 24). Pineapple is grown primarily in the Poamoho Watershed. The majority of the pastureland is found in the central portion of the Helemano Watershed and on the slopes of the Waiʻanae range in the Kaukonahua Watershed. Other crops include coffee, papaya, fruits, forestry products, and flowers.

Pineapple is still the predominant agricultural product grown in the Kaiaka Watersheds

TABLE 17. AGRICULTURAL LAND USE TYPES (STATE AGRICULTURAL LAND USE BASELINE STUDY, 2015)

Crop	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula	Total Acres / Ag Type	% of Project Area
Pineapple	5	0	2,985	0	271	0	3,262	6.3%
Pasture	0	980	63	0	1,509	199	2,751	5.3%
Diversified Crop	75	396	880	102	22	5	1,480	2.9%
Seed Production	96	278	167	85	268	200	1,094	2.1%
Coffee	0	0	30	0	138	0	168	0.3%
Papaya	40	0	0	17	0	0	57	0.1%
Tropical Fruits	0	7	44	0	0	0	51	0.1%
Commercial Forestry	0	2	25	0	0	0	26	0.1%
Aquaculture	20	0	0	0	0	0	20	0.04%
Banana	0	0	11	0	0	5	16	0.03%
Flowers/Foliage	0	11	0	0	1	0	11	0.02%
Taro	1	0	0	0	0	0	1	0.002%
Total Agricultural Acres	**238**	**1,674**	**4,205**	**205**	**2,209**	**409**	**8,939**	**17.374%**

In addition to cattle ranches, there are also numerous farms/ranches that raise other types of livestock, including chickens, goats, and pigs.



Kaiaka Bay Watershed-Based Plan

FIGURE 24. AGRICULTURAL LAND USE TYPES

0 2,500 5,000 Feet
0 0.5 1 Mile
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By: TOWNSCAPE
Date: June 2016

Recreation

Opportunities for recreation occur throughout the watersheds. The Army allows recreational use of certain areas for hiking, fishing, and hunting by military personnel. In the mauka portions of the watersheds, the public can enjoy hiking on several different trails (DOH, 2009). Two of the most well-known trails are the Poamoho Trail and the Schofield-Waikāne Trail. The Poamoho Trail is located mauka of Helemano Military Reservation. A permit from DLNR DOFAW is required to gain access the area and trail use is limited to weekends and holidays. The Schofield-Waikāne Trail is located Koʻolau side of Kaukonahua Watershed. Permits from both the Schofield Military and DLNR DOFAW are required to gain access to the trail.

Pig hunting is allowed in designated areas. There are three areas on Schofield Barracks East Range are open for hunting during the week when not in use for military training, with certain restrictions (DOH, 2009). The entire ʻEwa Forest Reserve, part of Oʻahu Hunting Unit C, is open to public hunting on weekends and State holidays only. The Mokulēʻia Forest Reserve, part of Oʻahu Hunting Unit E, is open to the public from February to October on weekends and State holidays. In both Forest Reserves, bag limits are designed to reduce impacts to native resources; each hunter may bag one pig per day.

People also fish in the Wahiawā Reservoir and picnic in the park next to the reservoir.

The Wahiawā Reservoir is frequently used for recreational activities such as fishing and kayaking

Kaiaka Beach Park consists of approximately 53 acres of open space, ideal for picnicking or having social gatherings. There are also several designated campsites are at the northern end of the park. A permit is required to camp, however, currently camping is banned due to a fire on the property.

Photo credit: Paul Topp

The North Shore's coastline and near shore waters are world-famous

Near Shore Waters Use

The near shore waters of Kaiaka Bay are used by residents and tourists for recreational activities such as surfing, jet skiing, fishing from the shore, and occasionally swimming, although the poor water quality of the bay does not make it a popular swimming site.

MILITARY TRAINING

The U.S. Army's Schofield Barracks was established in 1908 and spans across a total of 17,725 acres, much of which is within the project areas (largely the Kaukonahua Watershed). The post was established in 1908 to provide mobile defense of Pearl Harbor and the entire island. It provides support for the 25th Infantry Division (Light) and 45th Corps Support Group (Forward), and houses the U.S. Army Garrison, Hawaiʻi, which provides and coordinates all installation facilities, services, and logistics in Hawaiʻi. The population of Schofield Barracks was 16,370 at the 2010 census.

There are two main training areas at Schofield: East Range and West Range. East Range covers over 5,000 acres of the forested slopes of the Koʻolau range in the Kaukonahua Watershed. No live fire is permitted in East Range; the area is used primarily for infantry training and maneuvers, air assault and airborne operations, and limited battalion and company-level training and evaluation missions (DOH, 2009). Approximately 2,200 acres of land in East Range are used for unrestricted training (U.S. Army Environmental Command and U.S. Army Corps of Engineers, 2009). The West Range, located on the slopes of the Waiʻanae range below Mt. Kaʻala, is used for live fire training and other maneuvers. Approximately 1,200 acres of West Range are used for unrestricted maneuver training while another 8,600 acres are part of the firing range, impact area, or are for restricted training (U.S. Army Environmental Command and U.S. Army Corps of Engineers, 2009). West Range is primarily an open grassland and is occasionally managed with prescribed burns to reduce fuel-loads and maintain open space for live-fire training. A fire break road is maintained at the boundary of the forested area and the open grassland of West Range to prevent any incidental fires from spreading into the forest.

To the north of East Range, the Army holds long-term leases on much of the land near the summit of the Koʻolau range within the project area for additional training area (no live fire permitted). The Army calls this area the Kawailoa Training Area (the entire Kawailoa Training Area spans 23,348 acres and extends to the north outside of the project area). The overall steepness limits training in the region to helicopter maneuvers, small single-file units marching along ridgelines, and jungle survival training (U.S. Army Environmental Command, 2008).

Other military installations include the Army's Helemano Military Reservation, which is primarily a family housing area, and the Navy's JBHH-Wahiawā Annex (formerly referred to as NCTAMS-PAC). Drum Road, a paved road used by the Army, starts at Helemano Military Reservation and heads in a northerly direction across the Helemano and ʻŌpaeʻula watersheds (and beyond). Drum Road was paved primarily for the training needs of the Stryker Brigade, however, the majority of the Strykers have now left Hawaiʻi.

3.3 FUTURE LAND USE PLANS

Land uses in the Kaiaka Bay Watersheds have shifted dramatically over the past decades and will continue to do so in the coming decades. There are a number of significant plans and projects in progress that have the potential to affect water quality in the Kaiaka Bay Watersheds, many of which are related to the fact that Dole is currently in the process of selling thousands of acres of land in the watersheds. Some of the major plans are described below.

3.3.1 DOLE LANDS FOR SALE

In recent years, Dole Food Company, Inc., has listed approximately 20,000 acres of agricultural and conservation land located between the area of Central O'ahu and the North Shore for sale, much of which is in the Kaiaka Bay Watersheds. As of April 2018, much of that land has been sold. During the development of this WBP (between 2016 and 2018), Dole sold over 5,800 acres of land. Many of the parcels have been fallow for years and have grown a vegetated cover (forest, scrubland, or grassland), while other parcels are currently leased on a month-to-month basis to farmers. The fate of these Dole lands has the potential to significantly impact water quality in the Kaiaka Bay Watersheds, especially since the current agricultural zoning permits subdivision of agricultural parcels which makes the properties attractive to parties seeking to develop land for other purposes.

Image from the Star Advertiser showing Dole land for sale on O'ahu (April 8, 2016)

3.3.1.1 AGRICULTURAL PLANS FOR FORMER DOLE LANDS

The Hawai'i State Constitution (Article XI, Section 3) mandates the State to protect agricultural lands, promote diversified agriculture, and increase the Hawai'i's self-sufficiency. The State Agribusiness Development Corporation was established to help encourage diversified agriculture, initiate projects, and provide solutions to issues facing O'ahu's agriculture industry. Of the Dole lands that have been posted for sale, ADC identified 8,003 acres as "high interest to the State" for farming because of the location and the availability of water and other infrastructure. These "high interest" lands are located on both sides of Kamehameha Highway between Poamoho Village and Waialua. ADC has since purchased many parcels that were formerly owned by Dole and intends to make these lands available to farmers for long-term leasing for food production.

3.3.1.2 OTHER PLANS FOR FORMER DOLE LANDS

As of March 2016, the State DLNR has been trying to purchase approximately 3,000 acres of conservation and agricultural land from Dole, consisting of four parcels located in the Helemano and Poamoho watersheds. DLNR is seeking approximately $8.8 million from the United States Forest Service Forest Legacy Program, City and County of Honolulu, and State Legacy Land Conservation Program to complete the purchase. Upon acquisition, the land will be added to the State Forest Reserve System. One of the future public uses for the land that the DLNR is considering may include motorized recreation activities, which could have detrimental consequences on water quality. Non-motorized recreation activities are also being considered, including hiking, biking, camping, and public hunting. Additionally, forestry management, rare species habitat enhancement, and watershed protection will also be conducted by DOFAW staff.

3.3.2 WHITMORE PROJECT

The Whitmore Project is a plan spearheaded by Senator Dela Cruz to revitalize local agriculture by purchasing agricultural lands (e.g. from landowners such as Dole), constructing a produce-processing and agricultural technology park at Dole's Whitmore warehouses, providing workforce housing for farmers in Wahiawā, and developing a curriculum focused on agriculture in partnership with schools in Wahiawā. There is also major commercial aspect to the Whitmore Project; the plan is to have retail shops for each farm that sell value-added items in addition to produce to increase agri-tourism in the area and increase revenues for farmers. The hope is that local food production will be expanded, more jobs will be created, and farmers will be able to earn a living-wage.

The planning team and others visiting a warehouse in Wahiawā that was purchased by the State for the Whitmore Project

The Agribusiness Development Corporation will be the state agency managing the farmland in the Whitmore Project. In its entirety, the Whitmore Project is estimated to be $200 million project.

DIVERSIFIED AGRICULTURE

The first crops that were harvested as part of the Whitmore Project occurred in May 2016 (watermelon grown by Sugarland Farms). The crops were grown on former Galbraith Estate land, which hadn't been farmed in over a decade. Additional farmers growing crops such as banana, avocado, Asian greens, taro stems, and green onion are also joining as part of the Whitmore Project.

USE OF RECYCLED WASTEWATER FOR IRRIGATION

Treated effluent from the Wahiawā Wastewater Treatment Plant is currently discharged into the Wahiawā Reservoir, which releases an average 8.9 mgd of water into the Wahiawā Irrigation System (G70, 2016). The effluent is currently characterized as R-2 recycled water quality by DOH, indicating that it achieves a median fecal coliform limit of 23 per 100ml, however, in recent years the median fecal coliform quantity of the effluent has been within the requirements for R-1 water (median fecal coliform limit of 2.2 per 100ml); see section 7.1.1 for more information. The effluent is still rated as R-2 primarily because it lacks secondary containment. Because the effluent is considered R-2, the entire Wahiawā Irrigation System supply is also considered R-2 water. The use of R-2 water is limited to irrigating crops where the water doesn't come in contact with edible parts of a plant, such as orchard crops (e.g., papaya and coffee) or crops that are processed sufficiently to kill pathogens. It can also be used on seed corn and trees.

The Wahiawā WWTP is currently undergoing renovations so that the effluent will officially be classified by the DOH as R-1 quality (median fecal coliform limit of 2.2 per 100ml), which can then be used for irrigation of a wider variety of crops, including vegetables. In the reclaimed wastewater irrigation system, the effluent from the WWTP will be piped to a recycling facility instead of being discharged into the reservoir. Plans and designs for the recycling facility are currently underway. Pipelines from the

Wahiawā WWTP to ADC's Galbraith lands for the R-1 irrigation water will also need to be constructed, in addition to the construction of reservoirs to store irrigation water. Construction is expected to begin by the year 2020. ADC is planning on using the R-1 recycled water for irrigating crops on the former Galbraith Lands as part of the Whitmore Project, as are other producers throughout the North Shore. To accomplish these objectives, the City and ADC are entering into a Memorandum of Understanding, and the BWS is assisting where possible.

At the close of the 2016 legislative session it was announced that the upcoming state budget includes $26 million for new construction and repairs for irrigation systems.

Pumped-Storage Hydroelectricity

Another project that is being considered as part of the Whitmore Project is the idea of using the Wahiawā Reservoir Dam to produce pumped-storage hydroelectricity that can be offered to farmers at discounted rates. Pumped-storage hydroelectricity can be generated when water is pumped to a higher elevation so it can be used to spin turbines located downhill. The water pumps can be powered by wind or solar energy during daylight hours and during the night when there is a lack of wind or sun, the stored water can be released to produce hydropower. In this process, water is not taken from streams to produce power; instead, it is simply moved up- and downhill to generate electricity.

3.3.3 'Ohana Farm Parcels Project

Aloun Farms is selling 35 parcels of agricultural land located on 427 acres between Kamehameha Highway and the Helemano Military Reservation (Poamoho Watershed). Each parcel will be a farmland "condominium" where buyers can farm the land themselves, lease land back to Aloun to farm, or have Aloun farm under a service contract. There is concern over the potential for investors to buy parcels and use them for homes, since City regulations allow "farm dwellings" on agriculture land as accessories to farming without clear definitions or enforcement of the required farming. The condo rules for the property will have protections for farm operations, however, they will not restrict whether buyers can build homes. Currently, Aloun is growing crops including zucchini, leeks, sweet onions, string beans, sweet corn, broccoli, Napa cabbage, and avocados on the property. Any parcels that don't sell will continue to be farmed by Aloun, which plans to establish a processing facility onsite.

3.3.4 Expanded Army Training

Since 2013, the U.S. Army has been conducting "jungle training" in the forests located in Schofield Barracks East Range. The jungle training course is known as the Jungle Operations Training Center. Jungle training involves preparing soldiers for navigating and working in thick vegetation and challenging terrain. The military is focusing more on the Pacific as a hotspot for future conflict, therefore, this type of training is becoming more important to the military.

Soldiers participating in "jungle training" at Schofield Barracks

The Army is considering ways to expand jungle training on Oʻahu, which includes increasing the land area used for the training. Jungle training does not involve live-fire training or much vehicular access, however, if the Army expands these operations, there will be a lot more foot traffic in the forested areas of the watersheds (in East Range and Army-leased land in the Poamoho watershed). Moreover, with increased jungle training (and more people in the area), there could be an increase in the number of forest fires.

3.3.5 PROPOSED DEVELOPMENT PROJECTS

There are several proposed development projects in the Kaiaka Bay Watersheds, especially near Haleʻiwa/Waialua. Some of the projects are summarized below.

BACKYARD HALEʻIWA

Backyard Haleʻiwa, LLC is proposing a 7.5-acre mixed-use project in Haleʻiwa that includes a 156-unit apartment building, a 30,000-square-foot commercial building, off-street public parking, and a 6,000-square-foot indoor farmer's market facility. The proposed development would be on undeveloped, former sugarcane land in the Paukauila Watershed, located between the existing Haleʻiwa Town and Joseph P. Leong Highway [Tax Map Key (TMK) 6-2-005: 002].

In order for the project to move forward, a change in zoning from general preservation (P-2) and restricted agricultural (AG-1) to neighborhood business (B-1) and low-density apartment mixed use (AMX-1) would be required, as well as a change in the State Land Use District from Agricultural to Urban. In response to a preliminary plan for the proposed development, the North Shore Neighborhood Board voted unanimously in February 2015 to oppose any zoning changes that did not keep with Haleʻiwa's "country character." A Draft Environmental Assessment (EA) was published in September 2015 with an anticipated "Finding of No Significant Impact".

HALEʻIWA PLANTATION VILLAGE

A residential development called the Haleʻiwa Plantation Village is proposed to be developed on two adjacent lots on Achiu Lane in Haleʻiwa (TMKs 6-6-009: 002 and 6-6-010: 003). The land in question is currently undeveloped. The development would include 29 residential lots, 30% of which will be available as affordable housing opportunities. In addition to housing, the project includes extension of Kilioe Place, on-site parking, a stormwater detention basin for flood control, and a private underground wastewater treatment facility. Treated wastewater effluent will be chlorinated, disinfected, and pumped to two wastewater disposal wells located on TMK (1) 6-6-009: 002 (Parcel 2). The project will require a Special Management Area Use Permit, among others, and a zoning change from agricultural (AG-2) to residential (R-5). The Final EA for the project was submitted in March 2016.

A portion of a jurisdictional (federally regulated) wetland, Haleʻiwa Marsh, exists on Parcel 2. Haleʻiwa Marsh drains through an unnamed tributary to Paukauila Stream, which then flows into Kaiaka Bay. While most the wetland lies to the north of the proposed development, 0.70 acres of the wetland exists in Parcel 2. The wetland will remain intact in the development and a land buffer around the wetland will serve as passive recreation area and help protect the wetland. However, the Final EA states that most of the existing vegetation that "surrounds the wetland and buffer area on Parcel 2 will be uprooted to clear the lots and prepare the lots for sale." There is also a 0.68 acre isolated and non-jurisdictional (not regulated) wetland on Parcel 3 that will be developed. It was deduced that the wetland is likely a remnant of former kalo loʻi (taro ponds). According to the Final EA, the development of this isolated wetland is in concurrence with the U.S. Army Corps of Engineers.

In August 2017, the Honolulu City Council sided with an advisory board and an overwhelming community view to reject the proposal to rezone the agricultural land for residential use.

NORTH SHORE GATEWAY PROJECT

The North Shore Gateway Project is proposed two-story, 4,000 square foot office and retail building located on a 20,407 square-foot property located at the southern end of Haleʻiwa town, across from Weed Circle next to 7-Eleven (TMK 6-2-007:015).

The property is zoned as Neighborhood Business (B-1) and is in the Urban State Land Use District. It is also located in the Haleʻiwa Special Design District; a Special District permit was submitted in November 2015. In the works for over 6 years, the project is estimated to cost $1 million and is slated to be completed by the first quarter of 2017.

3.3.6 INCREASED MANAGEMENT/PROTECTION OF CONSERVATION LANDS

There are a number of projects planned (or in progress) that are specifically aimed at protecting and improving the natural resources in the watersheds.

As discussed in section 3.2.2 (Reserves & Protected Areas), several new fences are being constructed in the upper portions of the Kaiaka Bay Watersheds in the Koʻolau range. The western most portion of the Kaluanui NAR fence covers a portion of the Koʻolau summit in the ʻŌpaeʻula Watershed. While the entire fence will cover approximately 546 acres, 91 acres are in the ʻŌpaeʻula Watershed. In addition, the southern half of the fence for the proposed Poamoho NAR is also currently being constructed in the Kaukonahua Watershed in the Koʻolau range (630 acres). In the future, additional fences may be constructed in the Koʻolau range and in the Waiʻanae range. KMWP has proposed an additional 1,049 acres of land to be fenced in the Koʻolau range, although these fences have not yet been funded.

In addition to the increased level of protection the fences provide to the watersheds, the designation of the Poamoho NAR will also bring with it a higher level of protection and management.

4 Water Quality Standards & Classifications

4.1 Overview Water Quality Parameters & Pollutant Sources

Water quality pollutants can come from both natural and anthropogenic inputs and can be separated by physical, chemical and biological parameters. Often the results of water quality testing are analyzed holistically because some physical, chemical, and biological pollutants have a synergistic relationship. For example, influx of agricultural runoff may introduce fertilizers into a waterbody, which increases the nutrient content of the water. This may result in an algal bloom leading to a rapid increase in plant biomass, followed by a rapid plant die-off. The aerobic decomposition of the dead plant matter results in an increase in the biological oxygen demand in the water and increased levels of suspended solids. The excessive oxygen consumption by the decomposing bacteria results in a decrease in dissolved oxygen in the water column, making it difficult for other aquatic organisms to survive. This process is known as “eutrophication.” Therefore, addressing one water quality problem may have a cascade effect and thereby improve other problems.

There are various water quality indicators that are tested for water quality analyses, some of which are specifically regulated by water quality standards. Levels of these parameters may fluctuate naturally with time and space, or unnaturally due to anthropogenic pollutants. Some of the most common indicators of water quality used are listed below in Table 18.

TABLE 18. WATER QUALITY PARAMETERS

Physical	Chemical	Biological
• Temperature • Total Suspended Solids (TSS) • Turbidity • Electrical conductivity • Chlorophyll *a* • Stream flow*	• pH • Dissolved oxygen • Biological oxygen demand • Salinity • Nitrogen • Phosphorus	• *Enterococci* • *Clostridium perfringens*

** Stream flow is not necessarily an indicator of water quality, but is a typical measurement taken during water quality sampling to assess overall stream condition*

In terms of pollutant sources, we distinguish between two different types of pollution: point source or nonpoint source. Point source (PS) pollution is discharged from a distinct and known point, such as a sewage outfall pipe. The CWA allows for the limited and regulated discharge of certain pollutants from point sources directly into surface waters via NPDES permits. In Hawaiʻi, NPDES permits are administered by the DOH CWB. Nonpoint source pollution, on the other hand, is essentially any pollution that is not from a point source. NPS, commonly called polluted runoff, comes from a variety of sources that may or may not be known and cannot be traced back to a specific point. Polluted runoff occurs when rainwater moves on the surface or through the ground and picks up pollutants from a variety of sources, including agricultural fields, streets, parking lots, residential areas, and the upper reaches of watersheds. The polluted runoff eventually makes its way into streams and then into the nearshore coastal waters. Significant pollutant types include sediments, nutrients, toxins, floatables, and pathogens. Because rainfall often comes in torrential bursts, nature provides very little chance for NPS to settle out before it impacts the surface and groundwater systems on which we depend.

In the Kiʻikiʻi Stream System, Kaukonahua Stream collects runoff from mountainous forested zones of the Koʻolau and Waiʻanae mountain ranges, from military training areas, from urban areas of Wahiawā and Schofield Barracks, and from large agricultural areas between Wahiawā and Waialua. Poamoho collects runoff mainly from mountainous forested zones and agricultural lands. Kiʻikiʻi Stream collects additional runoff from the rural areas surrounding Waialua town.

In the Paukauila Stream System, Helemano and ʻŌpaeʻula streams collect runoff from mountainous forested zones and agricultural lands and Paukauila Stream collects additional runoff from the rural areas near Waialua and Haleʻiwa.

The text box below lists pollutants that are often associated with runoff from various land uses.

Potential Runoff Pollutants Associated with Nonpoint Sources

Agricultural Lands: *sediments and turbidity, nutrients, pesticides, bacteria (from animal wastes)*

Urban areas: *sediments and turbidity, debris, nutrients, pesticides, bacteria (from cesspools and/or sewage releases), chemical contaminants*

Forested areas*: sediments and turbidity, nutrients, bacteria (from feral animal wastes)*

Military training areas: *sediments and turbidity, nutrients, pesticides, chemical contaminants (from historic dumpsites and releases)*

While PS pollutants are regulated by the CWA by issuing NPDES permits, NPS pollution is largely unregulated and has been identified as the greatest remaining water quality issue in the nation. In Hawaiʻi, unmanaged NPS pollution is the reason that many waterbodies remain impaired. This recognition comes not only from water quality officials and local scientists but also from the public (Hawaiʻi OP CZM and Hawaiʻi DOH PRC, 2000).

4.2 National Regulations & State Water Quality Management Program

As part of the federal Clean Water Act section 303(d) ("Impaired Waters and Total Maximum Daily Loads") requirements, all states are required to report to Congress on the condition of their surface waters. This results in the production of the 303(d) list, which needs to be submitted to the EPA every two years on even-numbered years. The 303(d) list is a database of each state's impaired and threatened waters and includes information on attainment or non-attainment of the state's water quality standards. Based on this list, states prioritize which water bodies are in need of a Total Maximum Daily Load assessment. TMDLs are the maximum amount of pollutants a water body can handle and still be able to meet water quality standards. TMDLs are intended to guide actions that will control sources of pollution so as to achieve and maintain WQS (see section 4.4 for the TMDL for Upper Kaukonahua Stream).

TMDL regulations require the evaluation of "all existing and readily available information" in developing the 303(d) list. Due to funding restrictions, some states may not be able to regularly monitor all water bodies to test for all possible pollutants. The lack of water quality data can hinder the TMDL process. In

Hawaiʻi, select nearshore marine recreational waters throughout the State are regularly monitored to ensure the safety of recreational users such as swimmers, surfers, and divers. Additionally, data collected by outside organizations, such as community-based water quality monitoring programs, could potentially aid in providing additional data.

In Hawaiʻi, the DOH Water Quality Management Program is responsible for setting statewide water quality standards (WQS) as required by the CWA and set into law in HAR Chapter §11-54, for assessing the condition of the State's waters against the WQS, for preparing the State's 303(d) list, and for developing TMDLs for pollutant-impaired water bodies on the 303(d) list. WQS are a measure to evaluate the physical, biological, and chemical health of their surface waters. Consequently, WQS and TMDLs established by the Water Quality Management Program must meet CWA requirements and obtain EPA approval.

Hawaiʻi's WQS vary according to type of water body. The classification system identifies the protected uses and numeric water quality data for each surface water class, including streams, estuaries, embayments, open coastal waters and oceanic waters. The water classes are categorized as either marine or inland, with different subclasses for each. In the Kaiaka Bay Watersheds, the WQS for many of these water classes are applicable and are described in the following section.

4.3 WATER QUALITY STANDARDS IN THE KAIAKA BAY WATERSHEDS

The water classifications and corresponding WQS for marine waters and inland waters within the Kaiaka Bay Watersheds are described below. Refer to Figure 25 for a map of the different water classifications within the watersheds.

4.3.1 WQS FOR MARINE WATERS

The marine waters of Kaiaka Bay and the marine waters outside of the bay are classified as a Class A embayment, described as follows:

> ***Marine Waters Class A:*** *for recreational purposes and aesthetic enjoyment. Other uses are permitted as long as they are compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters.*

The WQS that apply to Class A embayments are presented in Table 19.

TABLE 19. WATER QUALITY STANDARDS - EMBAYMENTS

Parameter	Geometric mean not to exceed the given value		Not to exceed the given value more than 10% of the time		Not to exceed the given value more than 2% of the time	
	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
Total Nitrogen (µg/L)	200.00	150.00	350.00	250.00	500.00	350.00
Ammonia Nitrogen (µg/L)	6.00	3.50	13.00	8.50	20.00	15.00
Nitrate/Nitrite (µg/L)	8.00	5.00	20.00	14.00	35.00	25.00
Total Phosphorus (µg/L)	25.00	20.00	50.00	40.00	75.00	60.00
Chlorophyll *a* (µg/L)	1.50	0.50	4.50	1.50	8.50	3.00
Turbidity (NTU)	1.5	0.40	3.00	1.00	5.00	1.50

Note: A geometric mean is calculated by finding the (25-30 days) geometric mean of 25-30 samples taken within a month. The wet season is from November-April; the dry season is from May-October.

Note that Waialua Bay, located just to the north of Kaiaka Bay, is designated as Marine Waters Class AA, which has the same WQS but a different description of the water class (Figure 25). The description for Class AA waters places less emphasis on the waters being used for recreation and more emphasis on preserving their "natural pristine state."

4.3.2 WQS for Inland Waters

The inland surface water bodies in the Kaiaka Bay Watersheds are classified into Class 1 and 2 Inland Waters. Class 1 Inland Waters are further classified into Class 1.a. and Class 1.b. The objectives for these water body classifications are described below along with a table of WQS for the water body class.

Inland Waters Class 1: *The objective of Class 1 waters is that they remain in their natural state as nearly as possible with an absolute minimum pollution from human sources. Throughout all Class 1 waters, any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination is prohibited. Class 1 waters are grouped into Class 1.a waters and Class 1.b waters.*

Class 1.a: *All inland flowing waters within natural reserves, preserves, sanctuaries, and refuges established by the DLNR under Chapter 195 HRS (Natural Area Reserves), within State and National Parks, or within fish and wildlife refuges. Uses to be protected in class 1.a include scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, and compatible recreation and aesthetic enjoyment.*

Class 1.b: *All inland flowing waters in protective subzones designated under HAR Chapter 13-5 (Conservation District). Protected for domestic water supplies, flood processing, protection of native breeding stock, the support and propagation of aquatic* *life, baseline references from which human-caused changes can be measured, scientific and education purposes, compatible recreation and aesthetic enjoyment.*

Inland Waters Class 2: *All inland flowing waters in areas not otherwise classified. Protected for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. Uses must be compatible with the protection and propagation of fish, shellfish, and wildlife, and with the recreation in and on these waters.*

The Kaiaka Bay Watersheds have inland waterbodies that fall into each one of the classes (Figure 25). The WQS that apply to all streams in Hawai'i (HAR Chapter 11-54-5.2[b]) are presented in Table 20.

TABLE 20. WATER QUALITY STANDARDS - STREAMS

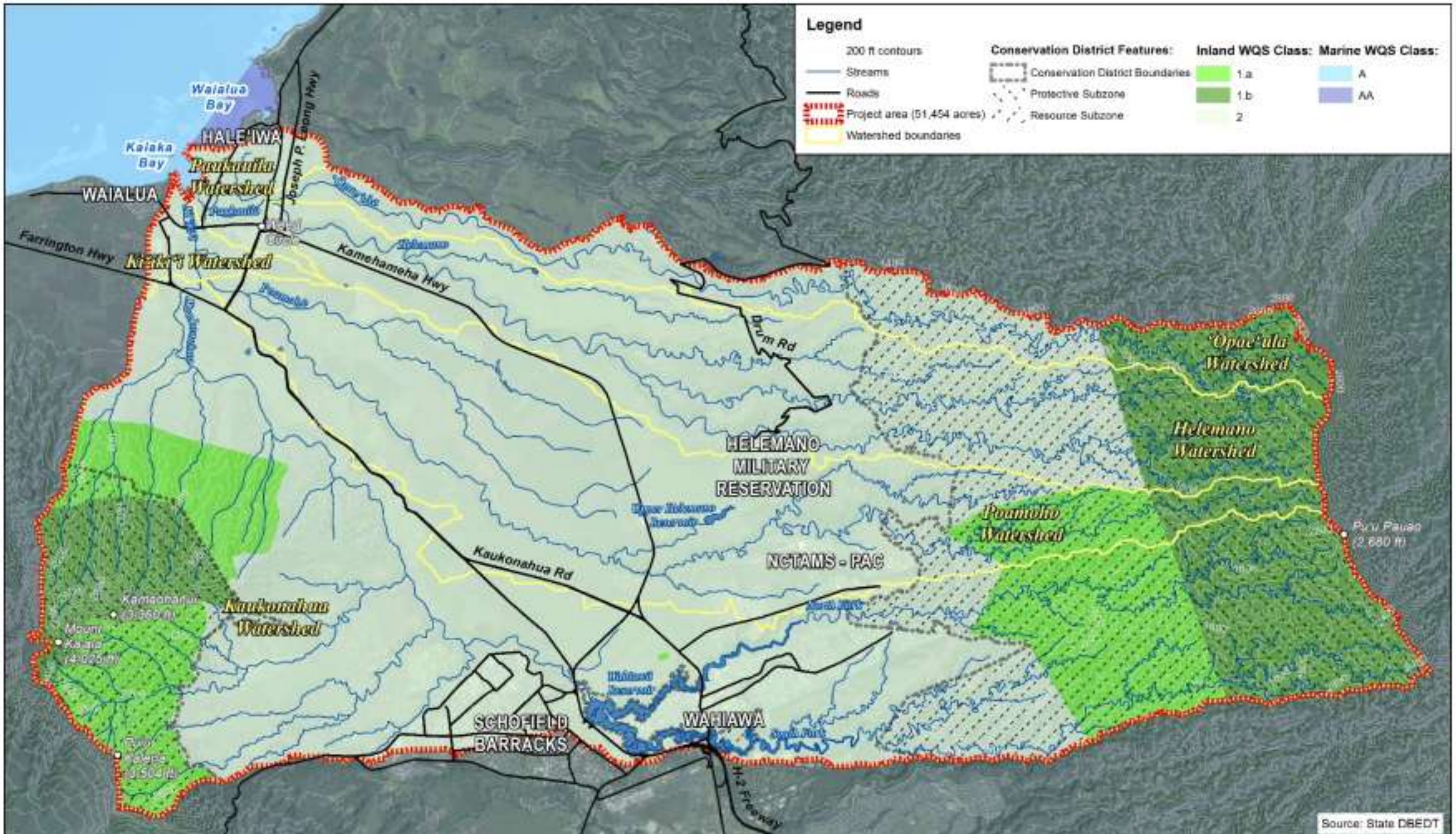
Parameter	Geometric mean not to exceed the given value		Not to exceed the given value more than 10% of the time		Not to exceed the given value more than 2% of the time	
	Wet season	Dry Season	Wet season	Dry Season	Wet season	Dry Season
Total Nitrogen (µg/L)	250.0	180.0	520.0	380.0	800.0	600.0
Nitrate/Nitrite (µg/L)	70.0	30.0	180.0	90.0	300.0	170.0
Total Phosphorus (µg/L)	50.0	30.0	100.0	60.0	150.0	80.0
TSS (mg/L)	20.0	10.0	50.0	30.0	80.0	55.0
Turbidity (NTU)	5.0	2.0	15.0	5.5	25.0	10.0

4.3.3 WQS for Recreational Area Waters

The WQS have criteria that apply specifically to inland and marine recreational areas (HAR Chapter 11-54-8). The purpose of these criteria is to protect human health from illnesses associated with pathogens from poorly treated sewage. These criteria use *Enterococcus* as an indicator organism for the presence of sewage. However, *Enterococcus* can originate from sources other than human fecal matter, such as soils. To compensate for the uncertainty, the DOH also monitors for *Clostridium perfringens*, an anaerobic bacterium, which serves as a secondary tracer to confirm that high bacterial numbers are the result of sewage related discharge.

Inland criteria are applicable to the terrestrial portions of the Kaiaka Bay Watersheds and marine criteria are applicable to Kaiaka Bay.

Inland recreational waters: *Enterococcus* bacteria content shall not exceed a geometric mean of 33 colony-forming units per 100 milliliters (CFU/100ml) in not less than five samples spaced over a period of 25 to 30 days. No single sample shall exceed 89 CFU/100ml.
Marine recreational waters (within 300 meters or 1,000 feet of the shoreline, including natural public bathing and wading areas): Enterococcus bacteria content shall not exceed a geometric mean of 35 CFU/100ml in not less than five samples over a 25 to 30-day period. No single sample shall exceed the single sample maximum of 104 CFU/100ml.



Kaiaka Bay Watershed-Based Plan

FIGURE 25. MARINE & INLAND SURFACE WATER CLASSES

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: June 2016

4.4 Upper Kaukonahua TMDLs

DOH has begun the process of establishing TMDLs for Kaukonahua Stream and is using a phased approach. Above the Wahiawā Reservoir in Upper Kaukonahua Stream, turbidity TMDLs and total nitrogen TMDLs were calculated for different stream flows and seasons for both the north and south forks of the stream (Table 21). A total of 3,651 acres of land make up the North Fork subwatershed and 3,863 acres make up the South Fork subwatershed (although only 2,620 acres were assessed in the TMDL calculations). EPA approval of the Upper Kaukonahua TMDLs was received on January 25, 2010. In future phases, DOH is anticipating establishing TMDLs for Lower Kaukonahua and for Wahiawā Reservoir. No TMDLs have been established for any other streams in the Kaiaka Bay Watersheds.

TMDLs are allocated to point sources regulated by NPDES permits (Waste Load Allocations) and non-point sources (Load Allocations). In Upper Kaukonahua Stream, WLAs were determined for two MS4s located in North Fork Kaukonahua: one operated by the City and County of Honolulu and the other operated by the U.S. Navy (see section 7.1.2 for more details on these MS4s). The total area covered under the NPDES permits for the two MS4s totals 120 acres, which DOH considers urban land in the TMDL calculations. There are no point sources in South Fork Kaukonahua.

For calculating the Load Allocations (LAs) for nonpoint sources in Upper Kaukonahua, the remaining lands were designated as either conservation or agricultural. In North Fork Kaukonahua, approximately 94% of the land (3,426 acres) was determined to be conservation and the remainder (105 acres) was designated as agriculture. All the land in South Fork Kaukonahua was designated as conservation (2,620 acres).

The TMDL calculations for turbidity indicate that load reductions are required under all flow conditions. The North Fork requires significant reductions during the elevated and high flow conditions in both the wet and dry seasons. The percent reduction required for WLA and LA is relatively equal for each parameter and percent reduction required for each MS4 is also relatively equal for each parameter. In the South Fork, the greatest turbidity reductions are required for all flow conditions during the dry season and for wet season stable flow.

The TMDL calculations for total nitrogen indicate that the greatest load reductions are required primarily at elevated flow conditions during the wet season. For North Fork during the wet season, the percent reduction required for WLA and LA is relatively equal for each parameter and percent reduction required for each MS4 is also relatively equal for each parameter. In the dry season, no load reductions are required for the North Fork and the conservation lands that make up the South Fork require relatively small load reductions.

TABLE 21. EXISTING LOADS, TMDLS, AND LOAD REDUCTIONS REQUIRED FOR UPPER KAUKONAHUA

Flow Duration Curve Interval[1]	Wet Season*			Dry Season*		
	High	Elevated	Stable	High	Elevated	Stable
Turbidity (NTU-tons/day)						
North Fork						
TMDL	**13.1**	**2.29**	**0.094**	**2.53**	**0.84**	**0.029**
Existing Load	64.4	4.57	0.16	9.15	2.09	0.035
% Reduction Required	79.7%	49.8%	42.9%	72.3%	59.8%	17.1%
Waste Load Allocation	0.612	0.108	0.0031	0.119	0.039	0.0010
WLA – Navy MS4	*0.22*	*0.04*	*0.001*	*0.043*	*0.014*	*0.0003*
WLA – City MS4	*0.39*	*0.07*	*0.002*	*0.076*	*0.025*	*0.0006*
Load Allocation	12.47	2.18	0.091	2.41	0.8	0.0281
Agricultural	*0.370*	*0.065*	*0.004*	*0.072*	*0.024*	*0.0012*
Conservation	*12.1*	*2.12*	*0.087*	*2.34*	*0.776*	*0.0269*
South Fork						
TMDL	**8.61**	**1.23**	**0.07**	**2.24**	**0.74**	**0.02**
Existing Load	14.09	2.15	0.19	16.10	4.83	0.13
% Reduction Required	38.9%	42.7%	63.7%	86.1%	84.6%	85.0%
Waste Load Allocation	0	0	0	0	0	0
Load Allocation	8.61	1.23	0.07	2.24	0.74	0.02
Conservation	*8.61*	*1.23*	*0.07*	*2.24*	*0.74*	*0.02*
Total Nitrogen (lbs/day)						
North Fork						
TMDL	**1,063**	**135**	**10.6**	No TMDLs required		
Existing Load	1,139	234	14.2			
% Reduction Required	6.7%	42.4%	25.4%			
Waste Load Allocation	543	68.8	2.79			
WLA – Navy MS4	*195*	*24.6*	*1.0*			
WLA – City MS4	*349*	*44.1*	*1.79*			
Load Allocation	520	65.8	7.8			
Agricultural	*122*	*15.4*	*3.69*			
Conservation	*398*	*50.3*	*4.08*			
South Fork						
TMDL	**592**	**115**	**7.27**	**117**	**30.7**	**4.97**
Existing Load	706	152	7.58	142	36.2	5.64
% Reduction Required	16.2%	24.1%	4.1%	18.0%	15.2%	11.9%
Waste Load Allocation	0	0	0	0	0	0
Load Allocation	592	115	7.27	117	30.7	4.97
Conservation	*592*	*115*	*7.27*	*117*	*30.7*	*4.97*

**Wet Season November-April, Dry Season May-October*

[1]*Curve Intervals are 0-4% flow duration (High), 4-20% flow duration (Elevated), and 20-100% flow duration (Stable)*

Other notes: *The Margin of Safety (MOS) for each parameter is zero*

TMDL = LA + WLA + MOS

5 AVAILABLE WATER QUALITY DATA IN THE KAIAKA BAY WATERSHEDS

5.1 KIʻIKIʻI SYSTEM WATER QUALITY

The watersheds that make up the Kiʻikiʻi Stream System (Kiʻikiʻi, Kaukonahua, and Poamoho) have known water quality issues, including excessive nutrients, turbidity, suspended sediments, fecal indicator bacteria, and chemical contaminants. Data pertaining to each watershed are presented in the subsequent sections.

5.1.1 KIʻIKIʻI WATERSHED

Known Water Quality Issues:

- Total nitrogen
- Turbidity
- Nitrate & nitrite
- Total phosphorus
- Fecal indicator bacteria

While the State's 2014 303(d) list indicates that there is inadequate data to assess the water quality of Kiʻikiʻi Estuary, data from various studies indicate that waterbodies within the Kiʻikiʻi Watershed are impaired with excessive nutrients, turbidity, and fecal indicator bacteria. Nutrients generally include nitrogen compounds and phosphorus compounds.

Kiʻikiʻi Stream is polluted with excessive nutrients, turbidity, and fecal indicator bacteria

During the summer of 2007, water samples were taken at various locations in the Kaiaka Bay Watersheds, including in the Kiʻikiʻi Watershed, as part of a study conducted by UH CTAHR (Yost et al. 2009). Only one sample was collected at each location, during base flow conditions, so the results represent instantaneous concentrations rather than average for the streams. The set of samples was intended to represent a snapshot of water quality in the watershed and to introduce water quality monitoring methods to interested stakeholders of Waialua and Haleʻiwa. Analysis of the samples indicated that nutrient levels exceeded water quality standards for nitrate/nitrite and total phosphorus in all instances but one (Table 22).

TABLE 22. NUTRIENT SAMPLING RESULTS, KIʻIKIʻI WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	Nitrate + Nitrite (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)
Waialua Beach/Haleʻiwa Rd	11KBWW	0.082	0.152	0.23
Kiʻikiʻi Bridge (Kiʻikiʻi Stream near Kaiaka Bay; saline water)	12KBWW	0.163	0.151	0.32
WQS (geomean, dry)		0.030	N/A	0.030

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season.

As part of the same CTAHR study, Yost et al. (2009) also analyzed water samples for analysis of five fecal indicator bacteria: *Escherichia coli*, enterococci, *Clostridium perfrigens*, F+ Coliphages, and phages of bacteroides. WQS exist for *Enterococcus* bacteria in inland recreational waters (89 CFU/100ml for a single sample); there are no WQS for other fecal indicator bacteria. The presence of high levels of other fecal indicator bacteria can be used as secondary indicators of sewage. Note that baseline levels of *E. coli* occur naturally in Hawaiian soils and streams. Only one sample was taken within the Kiʻikiʻi Watershed, in Kiʻikiʻi Stream (Table 23). Analysis of the sample revealed high concentrations of *E. coli* bacteria (greater than 2,419 Most Probable Number (MPN)/100 ml) and *Enterococcus* bacteria (272 MPN/100 ml). The study recommended additional sampling during the rainy season to assess the effect of rainfall runoff on potential sewage releases in the Haleʻiwa and Waialua town areas.

TABLE 23. FECAL INDICATOR BACTERIA SAMPLING RESULTS, KIʻIKIʻI WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	*E. Coli* (MPN/100 ml)	Enterococci (MPN/100 ml)	*C. perfringens* (CFU/100 ml)	F+ Coliphages (PFU/100 mL)	*Bacteroides* phages (PFU/100 mL)
Kiʻikiʻi Bridge (Kiʻikiʻi Stream near Kaiaka Bay; saline water)	12KBWW	>2,419.6	272	0	<10	<1
Recreational WQS (single sample)		N/A	89	N/A	N/A	N/A

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season.

5.1.2 KAUKONAHUA WATERSHED

Known Water Quality Issues:

- Turbidity
- Total nitrogen
- Nitrate & nitrite
- Total phosphorus
- Trash
- Possible chemical contaminants
- Fecal indicator bacteria

The State's 2014 303(d) list indicates that the lower portions of Kaukonahua Stream are impaired with excessive concentrations of total nitrogen, nitrate/nitrite, and turbidity (turbidity is noted to be two times the WQS). This portion of the stream has a medium priority for TMDL development. Based on visual observations dating between 2001 and 2004, the 303(d) list indicates that the Wahiawā Reservoir is impaired with excessive total nitrogen, nitrate/nitrite, total phosphorus, turbidity, and trash. Upper Kaukonahua Stream, including the North Fork and South Fork of the stream, is listed on the 303(d) list as being impaired with total nitrogen and turbidity. TMDLs were developed for Upper Kaukonahua Stream and were approved in 2010 (refer to section 4.4 and Table 21).

Part of the Phase I (Waialua-Kaiaka) study included calibration of a water quality model. To complete this calibration, a set of water quality gages were installed by USGS, with data available starting in 2013. One gage is located in the North Fork of Upper Kaukonahua in the Conservation District (#162000000), another gage is located directly below the Wahiawā Reservoir (#16210200), and the third is located near Waialua (#16210500). Turbidity numbers for all three gage locations are extremely elevated, with average annual turbidity results between 7.7 and 32.8 NTU, exceeding both wet and dry season water quality standards in all samples. The gages also measure suspended sediments, which can be calculated in terms of tons per year per square mile. Data from 2013 and 2014 indicate that suspended sediment loads are the highest at the gage located in the forested North Fork Kaukonahua and are the lowest at the gage located below the Reservoir (Table 24). The Wahiawā Reservoir essentially acts as a giant "sediment trap" for much of the sediments that are coming out of the forested Koʻolau range.

TABLE 24. ANNUAL SEDIMENT YIELD AT KAUKONAHUA STREAM USGS GAGES (TONS/YR/MI^2)

	North Fork (#162000000)	Below Reservoir (#16210200)	Waialua (#16210500)
2013	281	1.1	17.8
2014	819	4.8	43.0

In 2000 and 2001, DOH collected and analyzed water samples taken from the lower reaches of Kaukonahua Stream. The results of this sampling effort found that nitrate levels far exceed both the wet and dry season WQS (0.07 mg/l and 0.03 mg/l, respectively). Nitrate concentrations ranged between 0.22 to 1.03 mg/l.

Analysis of single water samples taken by Yost et al. (2009) during the summer of 2007 from various locations in the Kaukonahua Watershed indicated that nutrient levels exceeded water quality standards for nitrate/nitrite and total phosphorus in a number of samples (Table 25).

TABLE 25. NUTRIENT SAMPLING RESULTS, KAUKONAHUA WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	Nitrate + Nitrite (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)
Wahiawā Reservoir Spillway Bridge	20KBWW	0.07	0.101	0.18
Kaarsten Thot Bridge (Wahiawā Reservoir, North Fork)	25KBWW	0.0004	0.078	0.21
Otake Bridge (Kaukonahua Stream near Waialua)	15KBWW	0.9	0.094	0.26
Haona Street Backyard	14KBWW	0.269	0.474	0.3
Kaukonahua Ditch	27KBWW	0.712	0.092	0.7
WQS (geomean, dry)		0.030	N/A	0.030

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

According to an Environmental Assessment conducted by Calvin Kim & Associates and Gerald Park Urban Planner in 1999 for modifications of the Wahiawā WWTP, mean total nitrogen concentrations in the North Fork of Wahiawā Reservoir have generally been lower than in the South Fork (where the WWTP outfall is located) and in the reservoir basin (Calvin Kim & Associates and Gerald Park Urban Planner, 1999).

High nutrient loads in the Wahiawā Reservoir have been associated with algal blooms and fish kills. In 2002 and 2003, high nutrient concentrations in the Reservoir were associated with the explosive growth of the floating aquatic fern *Salvinia molesta,* which covered approximately 90% of the lake's surface within a few months. The *S. molesta* infestation clogged waterways, obstructed irrigation pumps, prevented light from reaching aquatic plants, reduced the oxygen content of the water, harmed aquatic life, and posed the threat of negatively impacting human health. Intensive mechanical removal of the fern was required.

Yost et al. (2009) also analyzed water samples for the presence of fecal indicator bacteria. Only one sample was taken within the Kaukonahua Watershed (Table 26). Analysis of the sample revealed high concentrations of *E. coli* bacteria (greater than 2,419 MPN/100 ml) and *Enterococcus* bacteria (712 MPN/100 ml).

TABLE 26. FECAL INDICATOR BACTERIA SAMPLING RESULTS, KAUKONAHUA WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	*E. Coli* (MPN/100 ml)	Enterococci (MPN/100 ml)	*C. perfringens* (CFU/100 ml)	F+ Coliphages (PFU/100 mL)	*Bacteroides* phages (PFU/100 mL)
Otake Bridge (Lower Kaukonahua)	15KBWW	>2,419.6	712	0	<10	<1
Recreational WQS (single sample)		N/A	89	N/A	N/A	N/A

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Groundwater sampling from wells within the Kaukonahua Watershed (mostly around Wahiawā) conducted over the past two decades has detected a number of different chemical contaminants which are suspected or known to be carcinogenic to humans, including 1,2,3-trichloropropane (TCP), carbon tetrachloride, tetrachloroethylene, and 1,2-dibromo-3-chloropropane (DBCP). While the presence of these contaminants in groundwater does not necessarily indicate they are present in surface waters, it is known that seepage occurs two-ways: from surface waters into groundwater and from groundwater back into surface waters. Consequently, some of these chemical contaminants may occasionally be present in waterbodies within the Kaukonahua Watershed.

Atrazine, one of the most commonly used herbicides in the United States, has also been detected in Kaukonahua Stream at concentrations as high as 185 parts per trillion, which is below the legal limit for human exposure (three parts per billion).

Pollutants in water bodies have negative effects on biological communities. In the process of developing TMDLs for Upper Kaukonahua Stream, the DOH found that no native fauna was present in the upper reaches of Kaukonahua Stream (DOH, 2009). Chemicals known as polychlorinated biphenyls have been detected in fish from in the South Fork of Upper Kaukonahua Stream and in the Wahiawā Reservoir (Anthony et al. 2004). Periodic fish kills have been recorded in the Reservoir since the 1960s, of which ten events were suspected to have been caused by toxic substance releases (Calvin Kim & Associates and Gerald Park Urban Planner, 1999). Moreover, data from Secchi disk depth measurements in the Reservoir have indicated that net primary productivity (i.e. oxygen production by phytoplankton via photosynthesis exceeding respiration) is limited to the upper meter (or roughly three feet) of the water column (Calvin Kim & Associates and Gerald Park Urban Planner, 1999).

Upper Kaukonahua TMDL Sampling Data & Estimated Pollutant Load Calculations

As part of the TMDL development process for Upper Kaukonahua Stream, water quality sampling was conducted over a period of four years to assess baseline levels of pollutant loads in the stream. A total of 58 sampling events occurred at three sampling locations: North Fork Kaukonahua at USGS gage, (high elevation, native forest), North Fork Kaukonahua at Flower Farm (entire North Fork subwatershed above the Wahiawā Reservoir), South Fork Kaukonahua at USGS gage (almost entire South Fork subwatershed above Wahiawā Reservoir). Analysis of the water samples indicated that WQS for turbidity, nitrate/nitrite, and total nitrogen were exceeded in at least one instance (Table 27). Further analysis indicated that turbidity and total nitrogen were the main pollutants of concern.

TABLE 27. TMDL STUDY BASELINE SAMPLING

Sample Location		TSS (mg/L)	Turbidity (NTU)	Nitrate + Nitrite (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
North Fork Kaukonahua at USGS gage	Geomean (Wet)	1.19	6.66	0.0258	0.188	0.0073
	Geomean (Dry)	1.52	1.70	0.0249	0.114	0.0076
North Fork Kaukonahua at Flower Farm	Geomean (Wet)	3.18	11.8	0.0299	0.287	0.0102
	Geomean (Dry)	1.18	5.16	0.0175	0.128	0.00843
South Fork Kaukonahua at USGS gage	Geomean (Wet)	1.97	11.1	0.0526	0.217	0.00666
	Geomean (Dry)	2.82	8.91	0.030	0.193	0.00837
WQS Standard (Wet)		20	5.0	0.07	0.25	0.05
WQS Standard (Dry)		10	2.0	0.03	0.18	0.03

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season.

The TMDL development process also involved estimating the current pollutant loadings for the entire subwatersheds of the north and south forks of Upper Kaukonahua Stream. Pollutant loads were assessed according to point sources (WLAs) and nonpoint sources (LAs). Furthermore, existing LAs were assessed according to land use type (conservation or agricultural). Since over 94% of land in Upper Kaukonahua consists of forested lands in the Conservation District, the clear majority of pollutants are coming from these lands (Table 28). Vegetative cover in Upper Kaukonahua is roughly 60% forest and 40% scrub (NOAA C-CAP land cover data). This forest/scrub cover is approximately 40-50% native (GAP land cover data).

Upper Kaukonahua Stream at USGS gage – one of the sampling locations for TMDL development

TABLE 28. ESTIMATED EXISTING POLLUTANT LOADS FOR UPPER KAUKONAHUA

Flow Duration Curve Interval[1]	Wet Season*			Dry Season*		
	High	Elevated	Stable	High	Elevated	Stable
Turbidity (NTU-tons/day)						
North Fork (3,651 acres)						
Existing Load	**64.4**	**4.57**	**0.16**	**9.15**	**2.09**	**0.035**
Existing Waste Load Allocation	3.02	0.214	0.0055	0.429	0.098	0.0012
WLA – Navy MS4 (43 acres)	*1.08*	*0.077*	*0.002*	*0.154*	*0.035*	*0.0004*
WLA – City MS4 (77 acres)	*1.94*	*0.138*	*0.0035*	*0.276*	*0.063*	*0.0008*
Existing Load Allocation	61.3	4.36	0.159	8.72	1.99	0.0339
Agricultural (105 acres)	*1.82*	*0.13*	*0.007*	*0.259*	*0.059*	*0.0014*
Conservation (3,426 acres)	*59.5*	*4.23*	*0.152*	*8.46*	*1.93*	*0.0325*
South Fork (2,620 acres)						
Existing Load	**14.09**	**2.15**	**0.19**	**16.1**	**4.83**	**0.13**
Existing Waste Load Allocation	0	0	0	0	0	0
Existing Load Allocation	14.09	2.15	0.19	16.1	4.83	0.13
Agricultural (0 acres)	*0*	*0*	*0*	*0*	*0*	*0*
Conservation (2,620 acres)	*14.09*	*2.15*	*0.19*	*16.1*	*4.83*	*0.13*
Total Nitrogen (lbs/day)						
North Fork (3,651 acres)						
Existing Load	**1,139**	**234**	**14.2**	**125**	**39.3**	**5.28**
Existing Waste Load Allocation	582	119	3.74	63.8	20.1	1.39
WLA – Navy MS4 (43 acres)	*209*	*42.8*	*1.34*	*22.9*	*7.19*	*0.5*
WLA – City MS4 (77 acres)	*374*	*76.6*	*2.4*	*41*	*12.9*	*0.89*
Existing Load Allocation	557	114	10.42	61	19.2	3.89
Agricultural (105 acres)	*131*	*26.8*	*4.95*	*14.3*	*4.5*	*1.84*
Conservation (3,426 acres)	*426*	*87.4*	*5.47*	*46.7*	*14.7*	*2.04*
South Fork (2,620 acres)						
Existing Load	**706**	**152**	**7.58**	**142**	**36.2**	**5.64**
Existing Waste Load Allocation	0	0	0	0	0	0
Existing Load Allocation	706	152	7.58	142	36.2	5.64
Agricultural (0 acres)	*0*	*0*	*0*	*0*	*0*	*0*
Conservation (2,620 acres)	*706*	*152*	*7.58*	*142*	*36.2*	*5.64*

**Wet Season November-April, Dry Season May-October*
[1]Curve Intervals are 0-4% flow duration (High), 4-20% flow duration (Elevated), and 20-100% flow duration (Stable)
Other notes: The Margin of Safety (MOS) for each parameter is zero

5.1.3 POAMOHO WATERSHED

Known Water Quality Issues:

- Total nitrogen
- Turbidity
- Nitrate & nitrite
- Total phosphorus
- Fecal indicator bacteria

Based on visual observations dating between 2001 and 2004, the State's 2014 303(d) list indicates that Poamoho Stream is impaired with excessive concentrations of total nitrogen, nitrate/nitrite, total phosphorus, and turbidity. The stream is designated as a low priority for TMDL development.

Water quality sampling conducted by DOH in 2000-2001 in the lower reaches of Poamoho Stream indicated nitrate concentrations ranging between 0 0.94 to 1.13 mg/l. These concentrations exceeded the WQS for both the wet and dry seasons (0.07 mg/l and 0.03 mg/l, respectively).

Additionally, analysis of single water samples taken by Yost et al. (2009) during the summer of 2007 from various locations in the Poamoho Watershed indicated that nutrient levels exceeded water quality standards for nitrate/nitrite and total phosphorus in all instances but one (Table 29).

TABLE 29. NUTRIENT SAMPLING RESULTS, POAMOHO WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	Nitrate + Nitrite (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)
Helemano Corner	2KBWW	0.063	0.032	0.021
Thompson Corner Bridge (makai)	17KBWW	0.06	0.119	0.2
Upper Poamoho Stream Bridge	23KBWW	0.03	0.08	0.21
Upper Poamoho Stream Bridge (downstream of Upper Helemano Reservoir)	24KBWW	0.079	0.127	0.24
WQS (geomean dry)		0.030	N/A	0.030

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Yost et al. (2009) also analyzed water samples for the presence of fecal indicator bacteria. Only one sample was taken within the Poamoho Watershed (Table 30). Analysis of the sample revealed high concentrations of *E. coli* bacteria (greater than 2,419 MPN/100 ml) and very high concentrations of *Enterococcus* bacteria (1,986.3 MPN/100 ml).

TABLE 30. FECAL INDICATOR BACTERIA SAMPLING RESULTS, POAMOHO WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	*E. Coli* (MPN/100 ml)	Enterococci (MPN/100 ml)	*C. perfringens* (CFU/100 ml)	F+ Coliphages (PFU/100 mL)	*Bacteroides* phages (PFU/100 mL)
Poamoho Stream Bridge (West of Thompson's Corner)	No ID	>2,419.6	1,986.3	0	<10	<1
Recreational WQS (single sample)		N/A	89	N/A	N/A	N/A

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Stream bioassessment sampling in Poamoho Stream in 1999 also classified the stream as having impaired biotic integrity, indicating the presence of very few or no native stream fauna (Kido, 2009). This could be due to a lack of water in the lower reaches of the stream caused by diversions of stream flow for irrigation, modifications of the natural stream channel associated with urbanization near the coast, degraded or removed riparian buffer zones, and/or degraded near-shore marine environments.

Poamoho Stream; photo taken at a location in the central portion of the watershed

5.2 PAUKAUILA SYSTEM WATER QUALITY

Like the Kiʻikiʻi Stream System, the watersheds that make up the Paukauila Stream System (Paukauila, Helemano, and ʻŌpaeʻula) have known water quality issues, including excessive nutrients, turbidity, suspended sediments, chemical contaminants, and fecal indicator bacteria. Data pertaining to each watershed are presented in the subsequent sections.

5.2.1 PAUKAUILA WATERSHED

Known Water Quality Issues:

- Total nitrogen
- Turbidity
- Nitrate & nitrite
- Total phosphorus
- Fecal indicator bacteria

Based on visual observations dating between 2001 and 2004, the State's 2014 303(d) list indicates that Paukauila Estuary is impaired with excessive concentrations of total nitrogen, nitrate/nitrite, total phosphorus, and turbidity. The estuary is designated as a low priority for TMDL development.

Water quality sampling conducted by DOH in 2000-2001 revealed high concentrations of nutrients. In support of these findings, analysis of single water samples taken by Yost et al. (2009) during the summer of 2007 from various locations in the Paukauila Watershed indicated that nutrient levels exceeded water quality standards for nitrate/nitrite and total phosphorus in all instances (Table 31). Levels of ammonia were also elevated in the waterbodies sampled.

TABLE 31. NUTRIENT SAMPLING RESULTS, PAUKAUILA WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	Nitrate + Nitrite (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)
Shingon Mission Ditch	33KBWW	0.812	0.198	0.22
Pake Ditch/Paʻalaʻa Rd (Paukauila tributary)	3KBWW	1.955	0.029	0.25
HCGA/Pake Ditch	5KBWW	0.437	0.182	0.28
Paukauila Bridge (mauka)	10KBWW	0.779	0.292	0.33
Paukauila Stream at Paʻalaʻa Rd (Waialua)	0KBW	0.058	0.293	0.36
Waialua Beach Road	9KBWW	0.903	0.152	0.39
Long Bridge South (Paukauila Stream; saline water)	8KBWW	1.032	0.383	0.37
Long Bridge North (Paukauila Stream at Kaiaka Bay)	7KBWW	0.83	0.335	0.43
WQS (geomean dry)		0.030	N/A	0.030

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Yost et al. (2009) also analyzed water samples for the presence of fecal indicator bacteria. Four samples were taken within the Paukauila Watershed (Table 32). Analysis of the sample revealed high concentrations of *E. coli* bacteria and *Enterococcus* bacteria (exceeding the WQS in all samples). There were also high concentrations of *Clostridium perfringens*, a secondary indicator of the presence of sewage. There is currently no WQS for *C. perfringens*.

TABLE 32. FECAL INDICATOR BACTERIA SAMPLING RESULTS, PAUKAUILA WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	*E. Coli* (MPN/100 ml)	Enterococci (MPN/100 ml)	*C. perfringens* (CFU/100 ml)	F+ Coliphages (PFU/100 mL)	*Bacteroides* phages (PFU/100 mL)
Paukauila Bridge (ʻŌpaeʻula Stream)	10KBWW	>2,419.6	512	13	<10	<1
Paukauila Bridge (Helemano Stream)	10KBWW	>2,419.6	1,205	104	<10	<1
Pake Ditch/Paʻalaʻa Rd (Paukauila tributary)	3KBWW	770.1	1,046.2	40	<10	<1
Long Bridge South (Paukauila Stream)	8KBWW	>2,419.6	305	30	<10	<1
Recreational WQS (single sample)		N/A	89	N/A	N/A	N/A

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

5.2.2 Helemano Watershed

Known Water Quality Issues:

- Total nitrogen
- Turbidity
- Nitrate & nitrite
- Total phosphorus
- Possible chemical contaminants

Based on visual observations dating between 2001 and 2004, the State's 2014 303(d) list indicates that Helemano Stream is impaired with excessive concentrations of total nitrogen, nitrate/nitrite, total phosphorus, and turbidity. The stream is designated as a low priority for TMDL development.

Groundwater sampling from wells located in the lower reaches of the Helemano Watershed conducted over the past two decades has detected a number of different chemical contaminants which are suspected or known to be carcinogenic to humans, including 1,2,3-trichloropropane (TCP), carbon tetrachloride, tetrachloroethylene, and 1,2-dibromo-3-chloropropane (DBCP). While the presence of these contaminants in groundwater does not necessarily mean they are present in surface waters, it is known that seepage occurs two-ways: from surface waters into groundwater and from groundwater back into surface waters. Consequently, some of these chemical contaminants may occasionally be present in waterbodies within the Helemano Watershed.

Stream bioassessment sampling in Helemano Stream in 1999 also classified the stream as having impaired biotic integrity, indicating the presence of very few or no native stream fauna (Kido, 2009). This could be due to a lack of water in the lower reaches of the stream caused by diversions of stream flow for irrigation, modifications of the natural stream channel associated with urbanization near the coast, degraded or removed riparian buffer zones, and/or degraded near-shore marine environments.

5.2.3 ʻŌPAEʻULA WATERSHED

Known Water Quality Issues:

- Total nitrogen
- Nitrate & nitrite
- Total phosphorus
- Turbidity

Based on visual observations dating between 2001 and 2004, the State's 2014 303(d) list indicates that ʻŌpaeʻula Stream is impaired with excessive concentrations of total nitrogen, nitrate/nitrite, total phosphorus, and turbidity. The stream is designated as a low priority for TMDL development.

ʻŌpaeʻula Stream, looking mauka from Kamehameha Highway in Haleʻiwa

In 1995, the UH Water Resources Research Center conducted a study called the "Kaiaka Monitoring Project" to assess nonpoint source pollution loading from agricultural areas, which were at the time in sugarcane plantation (DeVito et al., 1995). As part of the study, grab samples and storm flow samples were collected in the upper and lower reaches of ʻŌpaeʻula Stream (at the lower limit of the forest reserve and in the lower portion of the agricultural areas) on a weekly basis between March 1992 and April 1993. Analysis of water quality samples revealed that ʻŌpaeʻula Stream had concentrations of nitrate/nitrite and total nitrogen well above the wet season WQS (Table 33). The lower reaches of the stream had concentrations of total phosphorus and turbidity that also exceeded WQS. Concentrations of TSS, turbidity, total phosphorus, and nitrate significantly increased during storm events. The study also concluded that, on a per-acre basis, the ʻŌpaeʻula Watershed contributed significantly more nonpoint source pollutant loading than the Anahulu River (with the exception of filtered phosphorus), from both upper and lower watershed zones. The Anahulu River System, located to the north of the ʻŌpaeʻula Watershed, was part of the first phase of this study (Waialua-Kaiaka), but is no longer part of this second phase.

TABLE 33. POLLUTANT CONCENTRATIONS IN ʻŌPAEʻULA STREAM (DEVITO ET AL. 1995)

SAMPLING LOCATION	GEOMETRIC MEAN					
	TSS (mg/l)	Turbidity (NTU)	Nitrate/nitrite (mg/l)	Ammonia (mg/l)	Total N (mg/l)	Total P (mg/l)
Upper ʻŌpaeʻula	5.10	3.68	0.14	<0.05	0.73	0.03
Lower ʻŌpaeʻula	8.98	8.33	0.27	0.07	1.22	0.12
WQS (wet)	20.0	5.0	0.07	N/A	0.25	0.05

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season.

As part of the same study, DeVito et al. (1995) estimated average daily loading rates for Upper and Lower ʻŌpaeʻula Watershed during a portion of the sampling period (November 1992 through March 1993) using a mass loading equation. The estimated loading rates provide an indication of the amount of pollutants originating in the forested zones of the watershed (Upper ʻŌpaeʻula) and the amount originating in the cultivated zones of the watershed (Lower ʻŌpaeʻula). The numbers indicate that agricultural areas in the lower reaches of the watershed contributed more nitrate/nitrite, total phosphorus, and suspended sediments than the upper watershed's forested zones during the sampling period (Table 34). The upper reaches of the watershed appear to have been a greater source of total nitrogen and ammonia than the lower reaches.

TABLE 34. ESTIMATED POLLUTANT LOADINGS IN ʻŌPAEʻULA STREAM (DEVITO ET AL. 1995)

Constituent	Parameter	Upper ʻŌpaeʻula	Lower ʻŌpaeʻula
	Drainage Area (acres)	1,907	3,834
Nitrate + Nitrite	Total Daily Load (lb/day)	10.9	**31.7**
	Loading Rate (lb/ac/day)	0.00569	**0.00827**
Total Phosphorus	Total Daily Load (lb/day)	7.8	**19.4**
	Loading Rate (lb/ac/day)	0.00409	**0.00507**
Suspended Sediments	Total Daily Load (ton/day)	2.5	**7.9**
	Loading Rate (ton/ac/day)	0.00129	**0.00205**
Ammonia	Total Daily Load (lb/day)	**1.6**	1.9
	Loading Rate (lb/ac/day)	**0.000835**	0.000498
Total Nitrogen	Total Daily Load (lb/day)	**64.6**	111.6
	Loading Rate (lb/ac/day)	**0.0339**	0.0291

*Note: Numbers shown in **bold** represent the portion of the watershed that was estimated to contribute the majority of that specific pollutant.*

In interpreting the results of DeVito et al. (1995), it should be considered that agriculture in the ʻŌpaeʻula Watershed has changed dramatically since the conclusion of the study. In the last two decades, there has been a shift away from large, plantation style agriculture toward diversified agriculture and seed corn cultivation. It is likely that changes in crops and agricultural practices have affected pollutant loadings in ʻŌpaeʻula Stream, however, the potential effects of the shift in agricultural practices on water quality are not well-documented.

Water quality sampling conducted by DOH in 2000-2001 in the lower reaches of ʻŌpaeʻula Stream indicated nitrate concentrations ranging between 0.57 to 2.81 mg/l. These concentrations exceeded the WQS for both the wet and dry seasons (0.07 mg/l and 0.03 mg/l, respectively).

In a study conducted between 1997 and 2000, Hoover (2002) found that daily sediment discharges in ʻŌpaeʻula Stream were extremely variable, ranging between three to four orders of magnitude. The average daily minimum sediment load was 0.00312 metric tons per day and the average daily maximum sediment load was 97.8 metric tons per day.

Stream bioassessment sampling in ʻŌpaeʻula Stream in 1999 also classified the stream as having impaired biotic integrity, indicating the presence of very few or no native stream fauna (Kido, 2009). This could be due to a lack of water in the lower reaches of the stream caused by diversions of stream flow for irrigation, modifications of the natural stream channel associated with urbanization near the coast, degraded or removed riparian buffer zones, and/or degraded near-shore marine environments.

5.3 KAIAKA BAY WATER QUALITY DATA

Known Water Quality Issues:

- Fecal indicator bacteria
- Total nitrogen
- Nitrate & nitrite
- Turbidity
- Chlorophyll a
- Possible chemical contaminants

The State's 2014 303(d) list indicates that Kaiaka Bay is impaired with enterococci, total nitrogen, nitrate/nitrite, turbidity, and alpha-chlorophyll (or chlorophyll a; a measure of algal presence or "bloom"). The bay is designated as a low priority for TMDL development.

Kaiaka Bay, pictured above, is impaired with excessive turbidity, nutrients, chlorophyll a, and fecal indicator bacteria

DOH conducted turbidity measurements in Kaiaka Bay between 2004 and 2007. Results indicated turbidity levels ranging from 0.7 to 31.3 NTU for single samples. Since turbidity, to some extent, reflects sediment loads, these relatively high turbidity levels indicate significant sediment runoff is affecting the bay's water quality. As seen in the aerial photograph to the right, sediments from Paukauila Stream and Kiʻikiʻi Stream do not settle out and are deposited in the bay. According to Janik (1993), sediments in Kaiaka Bay may be toxic because contaminants may be bound to them. The contaminants may escape detection by binding onto sediment, but their effects can still be exerted. Janik (1993) also stated that the water and sediment in Kaiaka Bay may be toxic to some species. Moreover, dissolved oxygen levels in the bay have slowly diminished since 1990 (Janik, 1993). Dissolved oxygen is necessary for marine animals to "breathe."

Analysis of single water samples taken by Yost et al. (2009) during the summer of 2007 from two locations in Kaiaka Bay indicated that nutrient levels exceeded water quality standards for nitrate/nitrite ammonia, and total phosphorus in all instances but one (Table 35).

TABLE 35. NUTRIENT SAMPLING RESULTS, KAIAKA BAY (YOST ET AL. 2009)

Sample Location	Sample ID	Nitrate + Nitrite (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)
Kaiaka Bay (Cane Haul Bridge)	6KBWW	0.043	0.073	0.4
Kaiaka Park	1KBWW	0.001	0.071	0.34
Marine Embayment WQS (geomean dry)		0.005	0.0035	0.02

Note: Numbers highlighted in red indicate that the pollutant concentration exceeds the WQS standard for the applicable season. Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Yost et al. (2009) also published results from water quality sampling conducted by Janik et al. (1994) for several locations in and around Kaiaka Bay. While Yost et al. (2009) pointed out that the point samples were not duly published with specified sampling, handling, and analytical methods as required by the EPA, the results showed high concentrations of nutrients that supported the listing of the waterbodies as impaired on the 303d list.

According to the 1993 DOH "Hawai'i Ambient Water Quality Monitoring Program Report" fecal bacteria are a continuing problem. Analysis of the samples taken from two locations in Kaiaka Bay in 2007 by Yost et al. (2009) revealed relatively high concentrations of *E. coli* bacteria (2,419.6 MPN/100 ml and 1,986.3 MPN/100 ml; see Table 36). A sample collected along the coast to the west of Kaiaka Bay (at 'Aweoweo Beach) had a significantly lower concentration of *E. coli* (220 MPN/100ml).

TABLE 36. FECAL INDICATOR BACTERIA SAMPLING RESULTS, POAMOHO WATERSHED (YOST ET AL. 2009)

Sample Location	Sample ID	*E. Coli* (MPN/100 ml)	Enterococci (MPN/100 ml)	*C. perfringens* (CFU/100 ml)	F+ Coliphages (PFU/100 mL)	*Bacteroides* phages (PFU/100 mL)
Kaiaka Bay (Cane Haul Bridge)	6KBWW	2,419.6	<10	0	<10	<10
Kaiaka Park	1KBWW	1,986.3	<10	0	<10	<10
Marine Recreational WQS (single sample)		N/A	104	N/A	N/A	N/A

Note: Refer to section 5.1.1 for more information on water quality samples taken by Yost et al. (2009).

Data from sampling conducted by DOH in Kaiaka Bay between 2004 and 2007 revealed *Enterococcus* bacteria counts that ranged from not detected to 340 CFU/100ml, well above the 104 CFU/100ml WQS for a single sample. The WQS was exceeded in six of the 34 samples collected over the four-year period. Two additional sampling dates in 2009 detected *Enterococcus* bacteria counts of 10 CFU/100ml and 42

CFU/100ml. DOH also analyzes samples for *Clostridium perfringens* as a complementary indicator of the presence of sewage. *C. perfringens* concentrations in the samples collected in Kaiaka Bay between 2004 and 2007 ranged from not detected to 13 CFU/100ml (data accessed from the EPA's STORET database). There is currently no WQS for *Clostridium perfringens*.

The results of the sampling conducted by Yost et al. (2009) and DOH to assess the levels of fecal indicator bacteria in Kaiaka Bay do not identify the sources of bacteria. It is likely that some of the bacteria are resultant of on-site sewage disposal systems (such as cesspools). See section 7.2.9 for more discussion on on-site sewage disposal systems.

5.4 Summary of Water Quality Issues By Watershed

The data presented in this chapter provided evidence that the waterbodies of the Kaiaka Bay Watersheds are polluted with excessive nutrients, turbidity, sediments, fecal indicator bacteria (i.e. sewage), chemicals, chlorophyll *a,* and trash (Table 37). It should be noted that the information presented in this chapter and in Table 37 should not be considered exhaustive nor complete since other data may exist and was not discussed. The important conclusion is that every waterbody in the Kaiaka Bay Watersheds is polluted with multiple contaminants. Chapter 7 provides an overview of the possible sources of pollutants in the watersheds, both point source and nonpoint source.

TABLE 37. KNOWN POLLUTANTS BY WATERSHED

	Ki'iki'i Stream System			Paukauila Stream System			Marine Embayment
	Ki'iki'i Watershed	Kaukonahua Watershed	Poamoho Watershed	Paukauila Watershed	Helemano Watershed	'Ōpae'ula Watershed	Kaiaka Bay
Total Nitrogen	X	X	X	X	X	X	X
Nitrate/ Nitrite	X	X	X	X	X	X	X
Total Phosphorus	X	X	X	X	X	X	-
Turbidity	X	X	X	X	X	X	X
Fecal Indicator Bacteria	X	X	X	X	X	-	X
Possible Chemical Contaminants	-	X	-	-	X	-	X
Trash	-	X	-	-	-	-	-
Chlorophyll *a*	-	-	-	-	-	-	X

Note: A black 'X' denotes pollutants that have been detected at excessive levels; a red 'X' denotes pollutants listed in the 2014 303(d) list; boxes with a dash (no 'X') do not necessarily indicate that the pollutant is not a concern, rather the dash represents a lack of data.

6 SUMMARY OF STAKEHOLDER CONSULTATIONS

6.1 PROCESS

In order for a WBP to be more than just a document, it is important to reach out to interested and relevant community members, landowners, organizations, government agencies, and decision-makers to learn about key issues and discuss important and realistic management measures. Many management measures are only implementable with the support of landowners and the local community. By directly involving key stakeholders in the planning process, the *Implementation Plan* (Volume 2 of this WBP) was developed with the input from the same people whose cooperation will be required for successful implementation. This maximizes the ultimate success of the WBP. This chapter presents information garnered through the stakeholder outreach process conducted during the preparation of the *Watersheds Characterization*. It is hoped that the summary of stakeholder consultations provides further context and additional information in understanding the important issues and current land uses in the Kaiaka Bay Watersheds.

One of the objectives of the stakeholder consultation process was to bring together and blend science, regulatory issues, policies, people, and social/economic issues through discussions with a broad range of people who are affected by, interested in, or could affect activities related to the development of the Kaiaka Bay WBP. These included community members, landowners, businesses, elected officials, and various organizations and agencies.

From December 2015 to July 2017, a total of 23 small group and individual meetings were conducted either in person or over the telephone that involved approximately 34 individuals. More informal communication via email and telephone was also conducted (not included in the aforementioned total). The purpose of these discussions was to inform people about the Kaiaka Bay WBP, identify important values and issues, learn about current land uses and management practices, and gather additional information. Announcements were also made at the North Shore and Wahiawā-Whitmore neighborhood board meetings.

The various individuals, organizations, and agencies that were consulted in this phase of the stakeholder outreach process are listed and described below. A number of other individuals, organizations, and agencies were also contacted but are not listed as no meeting or discussion occurred as a result.

Community and Non-Governmental Organizations

- **Wahiawā-Whitmore Neighborhood Board; North Shore Neighborhood Board**
  The purpose of Oʻahu's Neighborhood Board System is to assure and increase community participation in the decision-making process of local government.

- **Oʻahu Resource Conservation & Development Council**
  The Oʻahu Resource Conservation & Development Council is an independent non-profit entity that has a broad objective of improving the quality of life in local communities. Recent projects have focused on assisting rural enterprises and farmers, while fostering education and adoption of sound conservation practices on rural lands.

- **North Shore Community Land Trust**
  The North Shore Community Land Trust is an independent, non-profit organization that works to protect open space and natural areas on Oʻahu's North Shore from development.

- **Surfrider Foundation**
  The Oʻahu Chapter's mission is to protect the island's oceans, beaches, waves, and near shore ecosystems, while also preserving public access to these resources. The organization conducts water quality testing, beach clean-ups, and community outreach projects.

- **Koʻolau Mountains Watershed Partnership**
  The Koʻolau Mountains Watershed Partnership is a voluntary alliance of major public and private landowners and partners working together to protect the forested mauka areas of the Koʻolau mountain range.

- **Dole Foods, Inc.**
  Dole has been growing pineapple and other crops in the Kaiaka Bay Watersheds for over 100 years. They are the second largest landowner in the Kaiaka Bay Watersheds, with over 11,000 acres.

- **Kamehameha Schools, Land Assets Division**
  The mission of Kamehameha Schools is to improve the capability and well-being of Hawaiians through education. Kamehameha Schools is a major landowner in the Kaiaka Bay Watersheds (over 6,000 acres).

- **DuPont Pioneer**
  DuPont Pioneer grows seed corn and other crops on 692 acres of land within the Kaiaka Bay Watersheds.

Public Agencies

- **Natural Resources Conservation Service**
  The NRCS is an agency of the United States Department of Agriculture that provides technical assistance to farmers and other private landowners and managers.

- **National Oceanic and Atmospheric Administration**
  NOAA is a scientific agency within the United States Department of Commerce focused on the conditions of the oceans and the atmosphere.

- **U.S. Army**
  The federal government is the largest landowner in the Kaiaka Bay Watersheds; most of the land under federal jurisdiction is owned by the Army. The Army also leases thousands of acres from the State and Kamehameha Schools in the mauka portion of the Koʻolau range for training purposes. Several divisions/departments within the Army were contacted, including:
  - **Directorate of Public Works Environmental Division**
    - Clean Water Program
    - Oʻahu Army Natural Resources Program

  - **Integrated Training Area Management**
- **U.S. Navy**
  The Navy owns approximately 694 acres of land that is primarily within the Poamoho Watershed, an area referred to as JBPHH-Wahiawā Annex (previously known as NCTAMS-PAC). The Naval Facilities Engineering Command was consulted to learn about their stormwater program.

- **U.S. Geological Survey**
  USGS is federal research agency with the bureau of the United States Department of the Interior. USGS scientists study the landscape of the United States, its natural resources, and the natural hazards that threaten it. The USGS has no regulatory responsibility.

- **Hawaiʻi Department Land and Natural Resources**
  The State of Hawaiʻi is the third largest landowner in the Kaiaka Bay Watersheds, with over 6,500 acres of primarily forest land. The land is managed by the DLNR, whose mission is to "enhance, protect, conserve and manage Hawaiʻi's unique and limited natural, cultural and historic resources held in public trust for current and future generations of the people of Hawaiʻi nei, and its visitors, in partnership with others from the public and private sectors." DLNR is divided into different divisions that pertain to the management of different resources. The following divisions were consulted as part of the stakeholder outreach:
  - **Division of Forestry and Wildlife**
  - **Division of Aquatic Resources**

- **West Oʻahu Soil and Water Conservation District**
  The SWCDs are legally constituted self-governing sub-units of the Hawaiʻi state government to help protect and sustain Hawaiʻi's natural environment. The mission of the West Oʻahu SWCD is to "coordinate and facilitate partners and governmental agencies in identifying and implementing projects and practices with cultural sensitivity to assure the protection of Hawaiʻi's environment."

- **Agribusiness Development Corporation**
  ADC's mission is to acquire and manage selected high-value lands, water systems, and infrastructure for commercial agricultural use, in partnership with farmers, ranchers, and aquaculture groups. It also directs research into areas that will lead to the development of new crops, markets, and lower production costs.

- **University of Hawaiʻi at Mānoa, College of Tropical Agriculture and Human Resources**
  The mission of the College of Tropical Agriculture and Human Resources is to create and deliver knowledge that "supports and strengthens families, agricultural and food systems, and the natural environment."

Elected Officials

Several members of the local government were consulted in order to notify them of the project, to garner their support, to collect their input and information, and to identify other key stakeholders. Elected officials consulted include:

- Senator Donovan Dela Cruz, Senate District 22
- Senator Gil Riviere, Senate District 23
- Representative Oshiro, House District 46
- Representative Pouha, House District 47
- Office of City Councilmember Ernest Y. Martin, District 2

6.2 KEY FINDINGS & IMPORTANT ISSUES

This section presents some of the key findings and most important issues related to water quality and watershed planning that came out of the initial stakeholder outreach process. These findings do not represent all topics discussed during the meetings, rather, they highlight some of the important issues and relevant ideas that were useful in guiding the preparation of *Volume 2: Implementation Plan*. They are listed in no particular order.

There is a need for more water quality data, monitoring, and research.

- It is not known how the State WQS compare to natural levels of pollutants that may have occurred in water bodies in the watersheds before human disturbance.
- The effects of feral ungulates and non-native plants on water quality is not well studied, however, it is generally understood and accepted that these invasive species have negative impacts on water quality.
- USGS water quality gages can be prohibitively expensive and require on-going maintenance.
- Multiple people expressed support for a community-based water quality monitoring program, although there are many logistics and expenses involved that would need to be figured out.
- An obstacle to water quality monitoring is that water quality sampling that meets DOH standards is difficult to achieve. Testing of water samples can also be very expensive.

Cesspools should be replaced with better wastewater treatment systems wherever possible.

- There have been discussions for decades about the need for better wastewater treatment on the North Shore.
- In addition to the $10,000 tax credit that is available to certain landowners, there should be additional incentives or funding available to replace cesspools (e.g. 319 funds or a State revolving fund), since the cost for replacement may be $20,000.

Treated R-2 wastewater from the Wahiawā WWTP is currently discharged into the Wahiawā Reservoir; upgrades to the WWTP are underway to improve the quality of the effluent to R-1 along with the construction of water recycling facility.

- Upon completion of the upgrades, R-1 water will be pumped into the recycling facility instead of being discharged directly into the reservoir.
- R-1 water can be used on a wider variety of crops which will decrease the need for using groundwater sources for irrigation.
- While many are optimistic that the upgrades to the Wahiawā WWTP will result in improved water quality in the Wahiawā Reservoir, others are more skeptical that there will be significant improvements since there are also many nonpoint sources of pollution that affect water quality in the reservoir.

Flooding in the lower elevations is an on-going problem.

- Flooding in the towns of Waialua and Haleʻiwa have been a major issue in the past and there continues to be a lot of community concern over the issue.
- There are ongoing concerns about the safety of the Wahiawā Reservoir dam. The water level behind the dam is currently regulated by opening/closing valves in the spillway. When storms are forecasted, water is let out in preparation, thereby increasing reservoir capacity.
- The focus of the Kaiaka Bay WBP is on water quality of surface waters and not on flooding, however, the two issues can be interrelated. Recommendations to improve water quality should address issues related to flooding when possible.

With the sale of Dole lands, there are many possible scenarios on the horizon that could impact water quality.

- There will likely be increased diversified agriculture in the watersheds.
  - There is the possibility that new management of the land can allow for new agricultural practices to help protect water quality in the watersheds. However, there are also concerns that degradation of natural resources (e.g. soil loss, water quality issues) will increase when currently fallow fields are sold and become actively used for agriculture again.
- New landowners wanting to lease land to farmers will likely charge higher rents than Dole does now.
- Some parcels will be subdivided into smaller parcels and may open some doors for development of “gentlemen farms” that are used more for residential purposes than for agricultural purposes. Zoning changes may also ensue.

The Whitmore Project is a State-led initiative to revitalize farming in Central Oʻahu; impacts this project may have on water quality are unknown.

- The State ADC has purchased some of Dole’s former parcels and is in discussions with Dole about the purchase of additional parcels. ADC also purchased nearly 1,500 acres of former Galbraith Estate lands to lease to farmers.
  - As with the previous finding, there is the possibility that new management of the land can allow for new agricultural practices to help protect water quality in the watersheds.
    - For example, farmers selected for ADC lands as part of the Whitmore Project are required to take classes on pesticides, erosion control, and other BMPs.
    - ADC also requires all farmers to complete and implement soil conservation plans for their individual farm plots.
  - However, it is also possible that there may be negative impacts on water quality as a result of currently fallow fields becoming actively used for agriculture again.

The NRCS, SWCD, and ORC&D serve as important resources to farmers but are all short-staffed.

- Each of the agencies expressed the need for more staff and funding to reach out to more farmers and develop more farm plans and conservation plans. They also identified the need for more follow-up with farmers after they have received a conservation plan and the need for more outreach to farmers, especially to non-English speakers.
- None of these agencies are involved in enforcement; they are non-regulatory and are intended to be a resource for farmers. Farmers work with them voluntarily.

There is no entity that is responsible for the enforcement of implementing conservation plans when they are obtained as exclusions from the City's grading/grubbing permit.

- There is no follow-up or enforcement to ensure that farmers are implementing their conservation plans.
- It should be made more clear who is responsible for follow-up and enforcement. This may be a role for the watershed coordinator that was discussed in the previous key finding.

There is a need for a watershed coordinator position that focuses on agricultural issues.

- An interagency watershed coordinator could serve as an advocate for farmers and coordinate with all relevant agencies to help smooth and expedite the process for farmers to get a farm/conservation plan. It may be ideal if the coordinator works for a non-governmental organization (e.g. ORC&D), however, the coordinator should have a contract or agreement with the City to coordinate the exclusion process to the grading/grubbing permit.

Farmers often do not have the financial resources to implement BMPs or conservation plans, however many BMPs save money in the long-term.

- Introducing new practices is sometimes difficult; there are often new expenses that come along with implementing a new management practice. However, the long-term results are usually worth the initial up-front cost.
    - For example, DuPont Pioneer dramatically reduced their use of mechanical and chemical methods of weed/pest control by using cover crops which resulted in a savings of approximately $300/acre per year.
- Cost-sharing should be explored with 319 funds; if 319 funds were available to pay for a portion of the cost of procuring and implementing a conservation plan, there would be more incentive for farmers to fund the remaining portion. Implementation is usually a one- to two-year process, so there should be funding for the appropriate length of time. Smaller farmers should get a more generous cost-sharing deal than large farmers.

The system of leasing farmland to tenants is a common practice; landowners should ensure that tenants are using BMPs and follow conservation plans when possible.

- There is concern that relying on individual tenants to use best management practices on their land may not yield effective results because of the discontinuity of leased parcels and the lack of coordination in management practices among farmers. Moreover, the areas between leased parcels is sometimes not managed at all. Accountability is perceived as a major issue.
- In contrast, it was also expressed that such leases can provide opportunities, resources, and support for small farmers, such as the ability to learn about and implement best management practices to conserve resources.
- It would be ideal if large landowners created a master conservation plan for all their lands, underwrite the costs of installing key BMPs (especially any BMPs that cross lease boundaries) and then support/enforce all their present/future tenants to follow the plan.

Increasing educational opportunities and outreach programs for the public (including children), landowners, and farmers is the long-term solution to protecting natural resources.

- Community outreach should strive to educate people on issues related to water quality and watershed management. Creating an awareness of how daily activities can impact water quality and the significance of water quality is important.

- Increased education and outreach related to agriculture is needed.
  - Programs for farmers to become educated on local regulations, how to obtain certifications, and gain an understanding of the significance of BMPs are needed. These programs should be accessible to those who are not native English-speakers.
  - Community outreach related to agriculture should aim to spread an awareness of the significance/value of agriculture, the need for BMPs, or how/why pesticides/fertilizers are regulated the way they are.
  - The State Department of Education is collaborating with ADC to create opportunities for students to learn about local agriculture and prepare them for careers in this field. One of the biggest challenges in expanding local sustainable agriculture is a lack of farmers and potential workforce.

Conservation lands are considered a major source of sediments to the watersheds.

- The forested conservation lands are a major source of sediments in the Kaiaka Bay Watersheds. Data from the USGS water quality gages support this statement.

Intensive management in the Conservation District (e.g. fencing or other ecosystem restoration) should be focused in the highest elevations.

- The area near the summit of the Koʻolau range is dominated by native species. The Koʻolau Mountains Watershed Partnership does not believe these areas are major sources of pollution to the watersheds, however protection of these resources prevents further degradation of water quality. Much of the summit area has been fenced to protect the habitat from feral pigs. Funding is needed for further protection and management.
- The middle elevation forests are much more likely to be a major source of sediments in the watershed as these forests are characterized by invasive plants, feral ungulates, and deep stream channels. There is very little management that occurs in these areas, however, it is not realistic at this point in time to recommend that an organization or agency attempt restoration of these degraded, middle elevation forests due to funding issues and the inherent difficultly of managing a severely degraded forest.

Fires are a major threat to the watersheds and can have detrimental impacts to water quality.

- Fires are a major concern related to water quality. Fires are becoming more common on Oʻahu; they are almost always caused by humans.
- Fire prevention, management, and restoration programs are very important for protecting water quality in the watersheds. More funding is needed for these programs.

There are a number of proposed developments that may have detrimental impacts on water quality, including on or near wetlands.

- Any development on or near a wetland has potential to have negative effects on water quality.
- Wetland protection should be a priority in *Volume 2: Implementation Plan*.

The U.S. Army has a number of programs and projects at Schofield Barracks related to watershed management and water quality, however, several issues and obstacles were noted.

- One obstacle is that there is not enough funding or trained staff to maintain stormwater infrastructure and existing and new low-impact design features.

- As training needs change and increase, there may be increased impacts to the watersheds.
- The primary objective of the Army in Hawaiʻi is to train soldiers, therefore, watershed management practices that go beyond legal requirements may be a low priority for implementation.
  - It was suggested that there may be the most potential for the Army to implement new BMPs when they are directly related to safety concerns.

7 Discussion & Assessment of Pollutant Sources

The physical and natural characteristics, land use histories, and water quality data that were described in the preceding chapters can be generally assessed to identify potential sources of pollutants in the Kaiaka Bay Watersheds. The first two sections of this chapter provide an overview of suspected or known land-based sources of surface water pollution in the watersheds, including point sources (section 7.1) and nonpoint sources (section 7.2). In many cases, it is not possible to quantify pollutant loads from individual pollutant sources due to a lack of data and research. Where relevant, information from studies in other watersheds are presented to help elucidate some of the processes that may be occurring in the Kaiaka Bay Watersheds.

Section 7.3 presents the analysis of the modeling results for nonpoint source pollution (sediments and nutrients). The section summarizes the key findings and indicates which areas should be prioritized for management to reduce specific pollutants.

The final section of this chapter (section 7.4) synthesizes the data and information presented in this document, including the discussion of point and nonpoint source pollution (7.1 and 7.2, respectively) and the findings from the modeling analyses (7.3), to present a summary of management priorities by watershed for each main pollutant type. The prioritization is used in *Volume 2: Implementation Plan* to identify implementation strategies that most effectively reduce overall pollutant-loading and ultimately improve water quality in Kaiaka Bay.

To provide a general context for understanding the potential sources of pollution in a watershed, Table 38 provides an overview of the major sources and impacts of various pollutant types in a watershed. The table is not necessarily specific to the Kaiaka Bay Watersheds but is a useful reference for further discussion and analysis. Generally, pollutants are transported primarily in surface and ground waters. The relative amount of each pollutant type carried in surface water and ground water varies based on the physical and chemical properties of the pollutant, the transporting agent, and its position within the watershed.

TABLE 38. MAJOR CATEGORIES OF POLLUTANTS, SOURCES, AND RELATED IMPACTS IN WATERSHEDS

Pollutant Type	Major Sources (PS and NPS)	Related Impacts
Nutrients (e.g. nitrogen, phosphorus)	Wastewater effluent; applied fertilizers; urban runoff; livestock operations; forests; construction soil losses; natural generation	Algal growth; reduced clarity; lower dissolved oxygen; release of other pollutants; visual impairment; recreational impacts; water supply impairment
Solids (clean and contaminated sediments)	Agriculture (fields and roads); urban runoff; construction sites; disturbed areas (e.g. disturbed soils as a result of pig digging or motorized recreational vehicles); degraded forest ecosystems; stream bank and shoreline erosion	Increased turbidity; reduced clarity; lower dissolved oxygen; deposition of sediments; smothering of aquatic habitat; sediment and benthic toxicity
Oxygen-depleting substances	Biodegradable organic material such as plant, fish, or animal matter; manure; sewage/wastewater effluent; food processing waste; antifreeze; other applied chemicals	Suffocation/stress on fish resulting in fish kills and/or reduced fish reproduction; aquatic larvae kills; increased anaerobic bacteria activity resulting in noxious gases or foul odors; release of particulate-bound pollutants
Pathogens (e.g. bacteria, viruses, protozoans)	Domestic and natural animal wastes; urban runoff; wastewater effluent; landfills; natural generation	Human health risks via drinking water supplies, consumption of contaminated aquatic and marine organisms, or other incidental ingestion or contact
Metals (e.g. lead, copper, cadmium, zinc, mercury, chromium, aluminum)	Industrial and military activities; automobiles; metal roofs; gutters; landfills; corrosion; urban runoff; soil erosion; atmospheric deposition; contaminated soils	Toxicity of water column and sediment; bioaccumulation in aquatic species
Hydrocarbons (e.g. oil, grease)	Industrial and military activities; automobiles	Toxicity of water column and sediment; bioaccumulation in aquatic species; lower dissolved oxygen; coating of aquatic organism gills/impact on respiration
Organic chemicals (e.g. pesticides, synthetic chemicals, polychlorinated biphenyls [PCBs])	Applied pesticides; industrial and military activities; pharmaceuticals; historically contaminated soils/wash-off (e.g. PCB transformer sites)	Toxicity of water column and sediment; bioaccumulation in aquatic species
Inorganic acids and salts (e.g. sulphuric acid, sodium chloride)	Irrigated lands; landfills	Toxicity of water column and sediment

** Modified from Wahikuli-Honokōwai Watershed Management Plan, Volume I (SRGII, 2012)*

7.1 POINT SOURCES

7.1.1 WASTEWATER TREATMENT PLANTS

There are two wastewater treatment plants in the Kaiaka Bay Watersheds that are permitted to discharge treated effluent into waterbodies. In general, treated effluent is nutrient-rich and is a source of suspended sediments and other contaminants.

Note that the City also operates the Paʻalaʻa Kai WWTP, an underground wastewater injection well. Since injection wells are considered a possible nonpoint source, the Paʻalaʻa Kai WWTP is discussed in section 7.2.

WAHIAWĀ WTTP

Since 1928, the Wahiawā WWTP has discharged treated effluent into the Wahiawā Reservoir at a depth of 44 feet. The WWTP, operated by City and County of Honolulu, serves the city of Wahiawā, Whitmore Village and the U.S. Naval Computer and Telecommunications Area Master Station military facility near Whitmore Village. The plant operates and is authorized to discharge under a 1995 Consent Decree (Civil No. 94-00765 DAE-KSC) between the City, DOH, and EPA. The Consent Decree applies the requirements of a NPDES permit, which expired March 1, 1994.

Photo credit: City & County of Honolulu

Aerial photo of the Wahiawā WWTP, situated on the shore of the Wahiawā Reservoir

Originally a primary treatment plant, the WWTP was expanded and upgraded to provide activated sludge secondary treatment in 1967. In 2002, the quality of the WWTP effluent was raised to tertiary treatment. The effluent is characterized as R-2 recycled water quality by DOH, indicating that it achieves a median fecal coliform limit of 23 per 100ml.

A sign next to a ditch alongside Kaukonahua Road warns of the dangers of swimming and fishing in R-2 water

Because the treated effluent entering the Wahiawā Reservoir is rated as R-2, the entire Wahiawā Irrigation

System supply is also considered R-2 recycled water. The use of R-2 water for irrigation is limited to certain crops.

The Wahiawā WWTP is currently undergoing renovations so that the effluent will be classified as R-1 quality (median fecal coliform limit of 2.2 per 100ml), which can then be used for irrigation of a wider variety of crops, including vegetables. As evident in Table 39, the median fecal coliform in recent history has fallen within the requirements for R-1 (average of 0.91 per 100 ml). Once the WWTP completes all required upgrades to officially achieve R-1 status, the State Agribusiness Development Corporation is planning on using the R-1 recycled water for irrigating crops on the former Galbraith Lands in Wahiawā, as are other producers throughout the North Shore. It has been noted that water quality in the Wahiawā Reservoir may improve once the upgrades to the WWTP are completed.

The table below presents averages for flow and water quality parameters for two periods: January 2004 to June 2009 (as reported in Phase I of this study) and December 2014 to April 2016. While the effluent from the WWTP is still a source of pollutants in the Wahiawā Reservoir, the data indicate that the total pollutant load has decreased over time.

TABLE 39. AVERAGE WAHIAWĀ WWTP POLLUTANT LOADINGS

Constituent	January 2004 – June 2009 Average	December 2014 – April 2016 Average
Flow (mgd)	1.80	1.48
Total Nitrogen (lbs/day)	319.8	147.8
Total Phosphorus (lbs/day)	27.6	24.2
Effluent TSS (lbs/day)	143.52	12.32
Fecal coliform (#/100ml)	5.94	0.91

One possible concern with increased use of recycled wastewater for irrigation is the risk of contaminating surface waters and ground water aquifers with “emerging contaminants” (e.g. pharmaceuticals) that are not filtered out of recycled water. This risk has not been fully evaluated and there is no related data available.

Schofield Barracks WWTP

The Schofield Barracks WWTP, owned and operated by Aqua Engineers since 2006, is permitted to release its effluent into Kaukonahua Stream (NPDES permit # 0110141). However, under normal operation, the WWTP effluent is released into the Wahiawā Reservoir Ditch below the reservoir outlet under agreement with Dole, thus the wastewater does not enter the stream. In rare occasions, such as when repairs to the ditch are required, the WWTP effluent is released directly into Kaukonahua Stream, just below the Wahiawā Reservoir. Consequently, the WWTP is not a consistent source of pollutants to waterbodies within the Kaiaka Bay Watersheds since the effluent is typically directed into the Wahiawā Irrigation System and used throughout the North Shore.

The WWTP effluent flow averages approximately 2.2 mgd and is characterized as R-1 recycled water quality as of July 2016. Plans exist to use the R-1 effluent for irrigation purposes on the nearby Leilehua Golf Course, athletic fields, parade grounds, parks, and Kunia farms (some or most of which are outside of the Kaiaka Bay Watersheds).

7.1.2 MUNICIPAL SEPARATE STORM SEWER SYSTEMS

In the Kaiaka Bay Watersheds, there are four different NPDES permit-holders that operate MS4s: The U.S. Navy, the City and County of Honolulu, the U.S. Army, and the State of Hawaiʻi Department of Transportation Highways Division (DOT-HWYS).

U.S. NAVY MS4 (JBPHH-WAHIAWĀ ANNEX)

The U.S. Navy holds a Small MS4 Permit (HI S000257), issued in February of 2015, that covers all Navy facilities on Oʻahu, including the JBPHH-Wahiawā Annex located within the Kaukonahua and Poamoho Watersheds (also referred to as NCTAMS-PAC). The MS4 permit requires that the Navy develop and comply with a Storm Water Management Plan that outlines specific projects to reduce pollutant loads in stormwater. The current SWMP was finalized in 2016.

DOH's TMDL study for Upper Kaukonahua estimated that the pollutant loadings into the North Fork of Kaukonahua Stream show that during stable stream flows, the Navy's MS4 contributes to turbidity in the stream by 0.002 NTU during the wet season (approximately 1.3% of total turbidity) and 0.0004 NTU during the dry season (approximately 1.1% of total turbidity; see Table 28 in section 5.1.2). The MS4 is also estimated to contribute 1.34 pounds of total nitrogen per day during the wet season in stable stream flows (approximately 9.4% of total nitrogen load) and 0.5 pounds per day during the dry season in stable stream flows (approximately 9.5% of total nitrogen). During high and elevated stream flows, the estimated loads for both turbidity and total nitrogen significantly increase.

According the Upper Kaukonahua TMDL study, the discharge monitoring reports for JBPHH-Wahiawā Annex indicate that contributions to the MS4 from discharged stormwater is associated with industrial activities, however, the TMDL study found that there is no industrial activity inventory provided for the facility in its annual reports. Approximately 43 acres within the MS4 service area on JBPHH-Wahiawā Annex drain to the North Fork of Kaukonahua Stream.

The TMDL study requires load reductions in turbidity and total nitrogen in order to meet State WQS (Table 21 in section 4.4). During the wet season, the turbidity load allocation for the Navy's MS4 is 0.001 NTU in stable stream flows and 0.0003 NTU during the dry season in stable stream flows. The load allocation for total nitrogen during the wet season in stable stream flows is 1.0 pounds per day.

CITY AND COUNTY OF HONOLULU MS4

The City and County of Honolulu holds a Large MS4 Permit (HIS000002) that covers most urbanized areas on Oʻahu that are serviced by/connected to City-managed drainage infrastructure. This includes storm sewers of Wahiawā, Haleʻiwa, and Waialua towns. The current permit was issued by the DOH in January of 2015 and expires in January of 2020.

The MS4 permit requires that the City develop and comply with a Storm Water Management Plan that outlines specific projects to reduce pollutant loads in stormwater. The current SWMP was finalized in 2016.

DOH's TMDL study estimated the pollutant loadings from the City's MS4 that drain into the North Fork of Kaukonahua Stream (Table 28 in section 5.1.2). They estimated that the 74 acres of land that are serviced by the MS4 in the North Fork Kaukonahua subwatershed contributes to turbidity by 0.0035

NTU during the wet season in stable stream flows (approximately 2.2% of total turbidity), and 0.0008 NTU during the dry season in stable stream flows (approximately 2.3% of total turbidity). The MS4 is also estimated to contribute 2.4 pounds of total nitrogen per day during the wet season in stable stream flows (approximately 16.9% of total nitrogen load) and 0.89 pounds per day during the dry season in stable stream flows (approximately 16.9% of total nitrogen). During high and elevated stream flows, the estimated loads for both turbidity and total nitrogen significantly increase.

The TMDL study requires load reductions in turbidity and total nitrogen in order to meet State WQS (Table 21 in section 4.4). During the wet season, the turbidity load allocation for the City's MS4 is 0.002 NTU in stable stream flows and 0.0006 NTU during the dry season in stable stream flows. The load allocation for total nitrogen during the wet season in stable stream flows is 1.79 pounds per day.

U.S. Army MS4 (Schofield Barracks)

The U.S. Army holds an MS4 permit (HI S000090), issued in 2014, that covers all the developed areas at Schofield Barracks (the training ranges are not included). Approximately 20,000 service members and dependents reside at Schofield. Approximately 70% of the stormwater runoff collected in the MS4 drains into Kaukonahua Stream below the Wahiawā Reservoir via a number of different outfalls while the remaining 30% drains into the Waikele Watershed.

The Army's MS4 permit also covers the Helemano Military Reservation, which provides office space for military personnel and housing for approximately 9,200 service members and dependents across 282 acres. Stormwater from the northern portion of Helemano Military Reservation is discharged into Helemano and Poamoho Streams, however, the majority of the Helemano Military Reservation area drains into a large sedimentation basin on the southwest corner of the installation.

The MS4 permit requires that the Army develop and comply with a SWMP that outlines specific projects to reduce pollutant loads in stormwater. The SWMP was finalized in October of 2015 and the Army is currently working towards meeting all the requirements of the permit as outlined in the SWMP. Improving the maintenance of stormwater receptors and sediment retention basins beneath buildings is a priority. Moreover, new regulations require that any new construction projects must include Low Impact Development features that minimize the impacts of the project on hydrological systems.

State of Hawaiʻi Department of Transportation Highways Division MS4

The State Department of Transportation Highways Division (DOT-HWYS) holds a Large MS4 Permit (HIS00001) that covers all lands under their jurisdiction. The MS4 permit became effective in October 2013, and will expire in September 2018. In 2006, the EPA and DOH issued a Consent Decree to DOT-HWYS, which stipulates stormwater requirements in addition to those set forth in the MS4 Permit. The Consent Decree was terminated in April 2016.

The DOT Right-of-Way in the Kaiaka Bay Watersheds is approximately 209 acres and includes:

- H-2 (a small portion)
- Wilikina Drive
- Whitmore Avenue
- Kamananui Road
- Kamehameha Highway

- Kaukonahua Road (from Weed Circle to Farrington Highway)
- Farrington Highway
- Joseph P. Leong Highway

There are 114 inlets where stormwater enters the MS4 and 73 outfalls where the stormwater is discharged into waterways or vegetated areas (Figure 26).

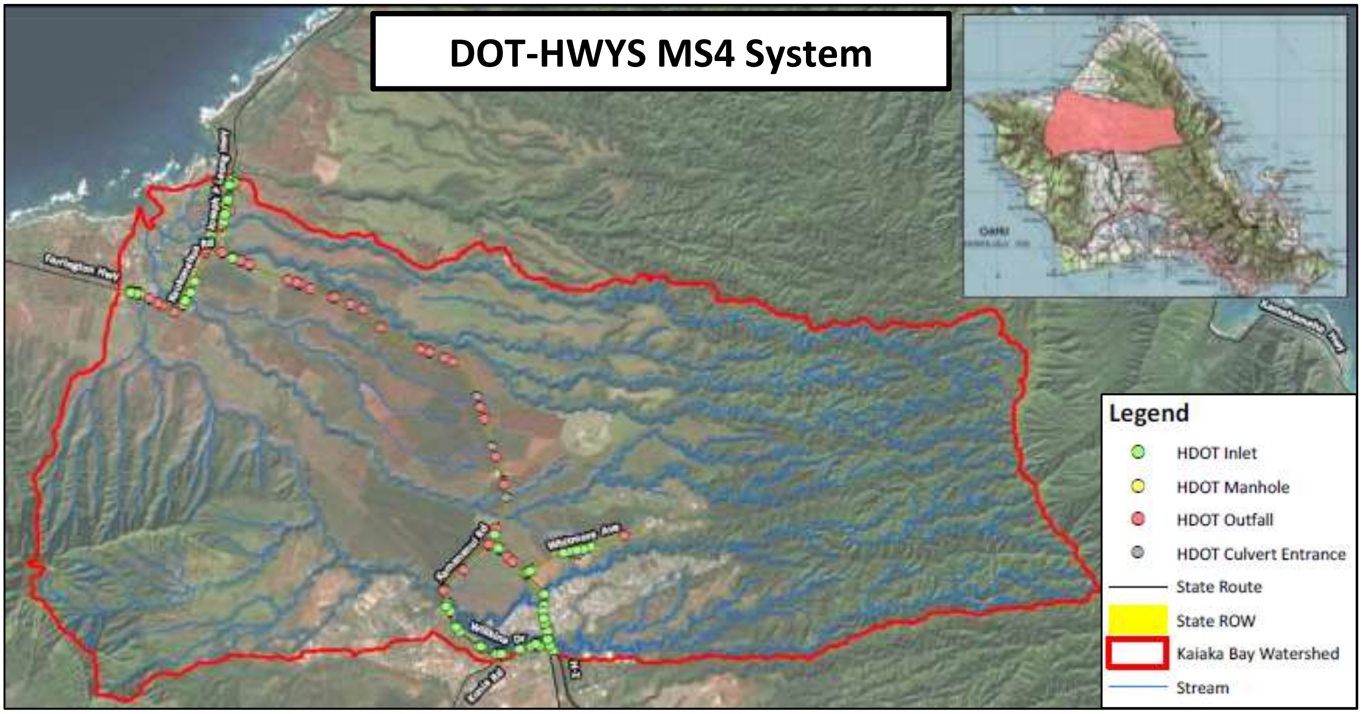


FIGURE 26. HDOT HIGHWAYS MS4 SYSTEM
Map graphic prepared by HDOT-HWYS and Enviroservices

The MS4 permit and Consent Decree require that the DOT-HWYS develop and comply with a SWMP that outlines specific projects to reduce pollutant loads in stormwater. The SWMP was finalized in 2015. Their SWMP specifies that inlets and outfalls are inspected twice a year to ensure functionality and permit compliance. Depending on the location in the Kaiaka Bay Watersheds, street sweeping occurs every 5 to 15 weeks along the State roadways. DOT-HWYS has not implemented any erosion control projects in the Kaiaka Bay Watersheds, however, they follow BMPs for all construction projects as outlined in the SWMP. All commercial industrial facilities that have the potential to discharge into the MS4 are inspected on a schedule according to prioritization criteria (either once or twice every five years). DOT-HWYs also conducts on-going outreach to

A portion of the State's MS4 along Joseph P. Leong Highway education the public on stormwater and water quality issues.

7.2 NONPOINT SOURCES

Nonpoint source pollution has been identified as the greatest remaining water quality issue in the nation and is the reason that many of Hawaiʻi's waterbodies remain impaired. Since nonpoint source pollution results from how we choose to use our land and the activities we conduct, we all hold the key to its prevention. This section reviews many of the natural and anthropogenic factors that can contribute to NPS in the Kaiaka Bay Watersheds, however, there are undoubtedly other factors that are not described here.

For most of the potential sources of NPS pollution, it is unknown how significant they may be relative to other sources. Aside from the DOH TMDL study for Upper Kaukonahua Stream, to our knowledge no research has been conducted to date in the Kaiaka Bay Watersheds to specifically quantify pollutant loadings from various nonpoint sources. However, data from studies in other watersheds in Hawaiʻi can be useful to gain insight into some of the processes that be occurring in the Kaiaka Bay Watersheds. Regardless of this lack of data, it is important to develop a management plan that suggests potential solutions that can help ensure the health of the region's ecosystems and communities.

7.2.1 EROSION PROCESSES

Erosion occurs as a result of natural processes that lead to the removal and transport of earth materials from the surface. These powerful processes are driven by forces related to gravity, surface water runoff, ocean waves, and wind. On Oʻahu, most erosion occurs as a result of mass wasting events, including rock falls, landslides, mudflows, soil avalanches, and soil creep, in combination with the transportation of earth materials by running water, waves, and wind. The deep valleys and gulches that are incised more than a thousand feet in the Koʻolau and Waiʻanae mountain ranges are a result of erosion by streams (Oki and Brasher, 2003).

Erosion of soils can result in finer sediments (clay- and silt-sized particles) becoming suspended in waterbodies, known as suspended sediments. Elevated levels of suspended sediments in waterbodies can lead to increased turbidity, which limits light penetration and impairs photosynthesis for aquatic plants. Suspended sediments are also harmful to aquatic and marine ecosystems because they can raise water temperatures, lower dissolved oxygen concentrations, hinder the ability of fish and other organisms to find food, damage coral reefs, and harm the gills of fish. Moreover, many pollutants can bind to soil particles be transported and deposited in new areas where they can accumulate (Oki and Brasher, 2003). This property amplifies the importance of erosion and sediment control in improving water quality. For example, total phosphorus concentrations generally increase with increasing

Turbidity and suspended sediments in Poamoho Stream suspended-sediment concentrations in Hawaiʻi because phosphate is retained by certain components that are common in Hawaiian soils. Because of these effects, the NRCS Local Work Group has identified sheet and rill soil erosion as a high priority resource concern on Oʻahu. However, a lack of monitoring data currently precludes any reliable estimates of the origins of suspended sediments in water bodies (NRCS, 2009).

Erosion is thought to primarily occur in mauka conservation lands, stream banks, and agricultural lands, however, with limited monitoring data in the Kaiaka Bay Watersheds it is very difficult to make reliable estimates as to the origins of sediments. It is understood, however, that the lower watershed areas are significantly affected by the accumulation of sediments transported from the upper elevations. This sedimentation can lead to clogged streams, an increased likelihood of flooding, and reduced downstream water quality. It can also accumulate to essentially create new land, albeit land that is prone to flooding. For example, one stakeholder anecdotally mentioned that near the town of Waialua, sediments that have been accumulating for years on the stream bank have built up to create new land that people are beginning to cultivate.

Since erosion is known to be a significant contributor of suspended sediments and turbidity to Hawaiian watersheds, the major factors that influence erosion should be understood and assessed in order to develop strategies to improve water quality. Sediment yield is a function of several natural and anthropogenic factors, including climate, weather, topography, soil types, land use, and land cover. Many of these factors are interrelated and have many different characteristics that can interplay to influence the overall erodibility of the land.

7.2.1.1 Storms & Erosion

Major storm events have a significant impact on erosion processes in Hawaiʻi and result in large amounts of sediments being washed into drainages. Doty et al. (1981) measured annual sediment loads in several forested watersheds on Oʻahu. The data indicated that about 90 percent of the annual sediment loads was produced during approximately two percent of the year as a result of storm events. Rising stream flow resulting from rain storms caused TSS concentrations to rapidly increase, commonly peaking within two hours. After storms, TSS concentrations returned to pre-storm conditions at a similarly rapid rate.

In agreement with these findings, Izuka (2012) found that during a three-year study in the Waikele Watershed on Oʻahu, more than 90 percent of the total sediment yield was a result of one major storm event that occurred on December 11, 2008. This storm generated a peak stream flow of 22,600 cubic feet per second, which was the highest flow measured by the stream flow gage in the 59-year period of record.

Data from studies in the Kaiaka Bay Watersheds also indicate that storm events are major factors that influence erosion and have significant impacts on water quality. Hoover (2002) found that storm events are very important in the upper ʻŌpaeʻula Watershed: between 1997 and 2000, storm contributions to sediment discharge in ʻŌpaeʻula Stream ranged between 31 and 77% of the total. Hoover (2002) also found that daily sediment discharges were extremely variable in ʻŌpaeʻula Stream, ranging between three to four orders of magnitude. DeVito et al. (1995) also found that concentrations of TSS, turbidity, total phosphorus, and nitrate significantly increased during storm events in ʻŌpaeʻula Stream.

The results from these studies indicate that the vast majority of suspended-sediment transport in watersheds on Oʻahu occurs during a few large storms and that the Kaiaka Bay Watersheds are no exception. They also indicate the great variability of suspended sediment yields in streams. The dynamic nature of the streams in the Kaiaka Bay Watersheds presents inherent obstacles for establishing water quality standards and assessing water quality.

7.2.1.2 Slope & Erosion

The topography of a watershed affects where and how erosion occurs. Soil type, land use, and land cover interact with slope to influence erosion processes. There is limited data available to explain the role of slope alone in influencing erosion in Hawaiʻi, however, a study in the Waikele Watershed found that 98-100% of the annual suspended sediment yield came from hillslopes (the areas between stream channels) versus the stream channels themselves (Izuka, 2012). Izuka (2012) surmised that in the years following major storm events, hillslope sediment supplies may be depleted because they have been washed into drainages, thereby causing an increase in sediments in steam channels. This process could result in inaccurate observations and assumptions that the majority of sediments are coming from stream channels instead of the hillslopes.

In contrast to the findings of Izuka (2012), the findings of the geomorphic assessment conducted for this WBP suggest that the majority of suspended sediments in streams in the Kaiaka Bay Watersheds may be coming from the stream channels themselves (AECOM, 2016; Appendix A).

7.2.1.3 Land Use / Land Cover & Erosion

Land use and land cover types can significantly influence rates of erosion and water quality, however, because there are so many variables within land uses and land cover types, only general trends and analyses are discussed in this section. More specific factors related to land use and land cover types (e.g. agricultural practices, invasive species composition, and other human activities) are discussed separately in later sections. In general, the studies and data reviewed in for this section present two conflicting theories: 1) Agricultural lands are the biggest sources of suspended sediments in watersheds; and 2) Mauka, forested lands are the biggest sources of suspended sediments in watersheds.

Theory #1: Agricultural Lands are the Main Contributors of Suspended Sediments

Izuka (2012) quantified the amount of sediments coming from forests, agricultural lands, and urban areas in four different subbasins of the Waikele Watershed. The results indicated that the vast majority of suspended sediments in the watershed were coming from agricultural lands— about an order of magnitude higher than forests and two orders of magnitude higher than urban areas (Table 40). The substantial effect of agriculture on increasing soil erosion is well known, although the effect differs by crop type, cultivation method, and land management (see section 7.2.4 for more information about the potential effects of agricultural practices in the Kaiaka Bay Watersheds). Of the suspended sediments coming from forested areas, the wetter forests of the Koʻolau range are known to contribute more sediments than the drier forests of the Waiʻanae range (as much as 60 percent lower suspended sediment yields). Urban lands were not found to be a major source of sediments in the Waikele Watershed. Izuka (2012) speculated that the pavement, buildings, storm drains, and maintained grassy areas in the urban area probably reduced erosion by water.

The results from Izuka (2012) can be used to make inferences on sources of suspended sediments in the Kaiaka Bay Watersheds. The Waikele Watershed is comparable to the Kaiaka Bay Watersheds because they have similar histories of land use and topographical features: both have a comparable mix of urban land, forested land, and agricultural land. Additionally, both watersheds incorporate drainages from both the Koʻolau and Waiʻanae mountain ranges.

TABLE 40. COMPARISON OF KAIAKA BAY WATERSHEDS TO RESULTS OF SUSPENDED SEDIMENTS STUDY IN THE WAIPAHU SUBBASIN (WAIKELE WATERSHED)

Watershed Characteristics	Kaiaka Bay Watersheds		Waipahu Subbasin of Waikele Watershed			
	Square Miles	*% Total Area*	Square miles	*% Total Area*	Estimated Suspended Sediment Yield (tons/yr/mi^2)	*Estimated % Total SS Yield*
Agriculture	30.0	*37%*	11.5	*34%*	5,580 - 6,440*	*89 - 97%*
Conservation/Forest	45.5	*57%*	16.9	*50%*	193 - 772	*3 - 11%*
Urban	4.9	*6%*	5.2	*15%*	12 - 50	*0 - 1%*
Total	***80.4***	***100%***	***33.6***	***100%***	***5,785 - 7,262***	***100%***

** Based on a study period in which average suspended sediment yield was about 2.7 times greater than the long-term mean. The long-term suspended sediment yield from agricultural land may be closer to 2,070 to 2,390 tons per year per square mile (tons/yr/mi^2), which is comparable to previous studies of agricultural sediment yield from areas in the Waikele watershed as well as areas outside Hawaiʻi.*

In the Kaiaka Bay Watersheds, DeVito et al. (1995) used a mass loading equation to provide an indication of the amount of suspended sediments (and other pollutants) originating in the forested zones of ʻŌpaeʻula Watershed (Upper ʻŌpaeʻula) and the amount originating in the cultivated zones of the watershed (Lower ʻŌpaeʻula). The results indicated that agricultural areas in the lower reaches of the watershed contributed more suspended sediments than the upper watershed's forested zones during the sampling period (refer to Table 33 in Chapter 5 for details). These results are in accordance with the results of Izuka (2012) in the Waikele Watershed: agricultural lands are a major source of suspended sediments in watersheds.

Theory #2: Mauka, Forested Lands are the Main Contributors of Suspended Sediments

The geomorphology report suggested that agricultural lands may *not* be a major source of sediments in the Kaiaka Bay Watersheds (AECOM, 2016; Appendix A). Instead, it was observed that most sediments were coming from the mauka, forested portions of the streams. This finding was based on a number of visual observations of erosion, landslides, and other indicators (e.g. no observation of black plastic sheeting used for pineapple cultivation in the stream bed).

Observation of sediments washed toward Poamoho Stream from a pineapple field

However, some of the information and observations from the geomorphology study imply that agricultural land uses and the lower reaches of the streams can be sources of sediments (though not the most significant sources). Samples of water from different points along Poamoho Stream were photographed to compare color and turbidity. The water collected nearest the Dole Plantation was bright orange and very turbid, while water upstream and downstream was much clearer. Additionally,

Multiple areas with recent slope failure were observed during fieldwork for the geomorphology study of the lower and middle portions of Poamoho Stream

erosion and landslides were observed in the middle portion of the southern fork of Poamoho Stream, indicating sources of SS in areas below the forested portion of the stream. Runoff from agricultural fields into gulches was also observed.

The geomorphology report's overall conclusion that a significant amount of suspended sediments in streams come from the mauka, forested areas is generally supported by data collected at the three USGS water quality gages located in the Kaukonahua Watershed. The data from the gages in Kaukonahua Stream indicated that the highest sediment loads were detected at the gage located above the Wahiawā Reservoir (#162000000) in 2013 and 2014 (281 and 819 tons/yr/mi^2, respectively; refer to Table 24 in Chapter 5). The total suspended sediment yield recorded at the gage directly below the reservoir (#16210200) was very low in 2013 and 2014 (1.1 and 4.8 tons/yr/mi^2), while the gage located near Waialua (#16210500) showed slightly higher sediment loads in 2013 and 2014 (17.8 and 43.0 tons/yr/mi^2). When interpreting this data, it should be recognized that the Wahiawā Reservoir essentially functions as a large sediment retention basin. The other watersheds in the study area do not have comparable reservoirs to trap sediments.

Data from other watersheds also provide support for the conclusion that a significant amount of SS are coming from forested areas. Data from a USGS gage Honouliuli Tributary near Waipahu (#16212480) show that in 2013 the total SS yield was 37 tons/yr/mi^2 and in 2014 the total SS yield was 430 tons/yr/mi^2. While there are no data from downstream gages with which to compare, these data provide evidence that relatively high yet extremely variable amounts of sediments come from mauka areas. During years with above average rainfall, SS loads in streams in forested/mountain areas are sometimes in the range of 800-1,000 tons/yr/mi^2 (Ron Rickman, USGS, personal communication; Oki and Brasher, 2003).

7.2.1.4 Soils & Erosion

Certain soils are more prone to erosion by wind or water. Roughly half of the total land area in the Kaiaka Bay Watersheds (26,240 acres) consists of soils that are classified as highly erodible by water. These soils are located in the highest elevations of the watersheds— along the forested slopes of Mount Kaʻala in the Waiʻanae range and in the forested mauka areas of the Koʻolau range (refer to Figure 9). This fact is in agreement with the supposition that the majority of sediments in the streams is coming from mauka areas (theory #2 described in section 7.2.1.3). However, these soils also have a relatively high infiltration rate (3.0 inches per hour), which means that precipitation intensity would need to exceed the infiltration rate for runoff to occur (AECOM, 2016; Appendix A).

The remainder of the area in the Kaiaka Bay Watersheds primarily consists of soils that are well-drained, meaning that permeability is moderate to rapid, with low susceptibility to wind erosion. However, agricultural practices such as tilling can cause soils to compact, resulting in decreased rates of infiltration which may increase surface runoff and erosion. The soils near Waialua are less permeable, however, and surface runoff, ponding and occasional flooding are more of a concern in these areas (G70, 2016).

7.2.1.5 Implications

Understanding natural erosion process and the sources of sediment in a watershed is essential to developing strategies to improve water quality. However, some of the information presented in this chapter about the factors that influence erosion processes is incomplete and inconsistent. While some data show that erosion from agricultural lands contributes the most suspended sediments to watersheds on Oʻahu, other information exists that indicates that forested areas may be the main sources of sediments in watersheds. Moreover, there are differing conclusions about whether or not stream channels or the hillslopes between stream channels were the main sources of sediments.

Despite these differences and inconsistencies, it is clear that heavy rain events have a major impact on suspended sediment concentrations and annual suspended sediment loads in a watershed. However, mitigation for major storm events would be very difficult since they are often unpredictable and cannot be controlled. Moreover, Hawaiian ecosystems have evolved a certain resilience to natural disturbances such as tropical storms and flash flooding over millions of years. While the impacts of invasive species and human activities may be less dramatic than a tropical storm in the short-term, they are unremitting and compound rapidly, making it difficult for ecosystems to readjust.

Therefore, in terms of reducing erosion to improve water quality, the Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Forested and agricultural areas should both be considered major contributors of suspended sediments and turbidity to the watersheds.
- Recommended management practices should focus on reducing anthropogenic sources of erosion and restoring healthy ecosystem functions.
- Areas with steep slopes and highly erodible soils (in all land use types) should be a priority for implementing measures to reduce soil loss.

7.2.2 NONNATIVE & INVASIVE PLANTS

Many nonnative and invasive plant species have the ability to outcompete native Hawaiian plants and dramatically alter ecosystems. Not only does this lead to a loss of native diversity, but many of these species fail to hold soil adequately or alter the plant community so that soils no longer function effectively to retain moisture. As a result, erosion and runoff is increased, leading to degradation of water quality in streams as well as reduced groundwater recharge. Additionally, some invasive plants such as miconia (*Miconia calvescens*) and strawberry guava (*Psidium cattleianum*) have been shown to use more water than native species.

In the Kaiaka Bay Watersheds, nonnative plants are dominant over native plants, except in some of the highest elevations. Many invasive plant species are common in the watersheds, including strawberry guava, Christmas berry (*Schinus terebinthifolius*), Guinea grass (*Megathyrsus maximus*), and Koster's curse (*Clidemia hirta*). All of these species are known to displace native forest plants and kill understory growth, causing erosion of watershed land. Strawberry guava also can leave a chemical in the soil that prevents other plants from growing there later, a trait known as allelopathy.

Some of the State's most invasive plants have also been found in the Kaiaka Bay Watersheds, including miconia and cane tibouchina (*Tibouchina herbacea*), both of which are listed on the Hawaiʻi State Noxious Weed List. The forests of the Koʻolau range in the Kaiaka Bay Watersheds provide habitat for these species. In fact, miconia seedlings are occasionally found in the vicinity of the Wahiawā Botanical Garden (near Wahiawā Reservoir) since a mature plant was removed from the area in the mid 1990s (after miconia's invasive potential was known). OISC has conducted ground surveys for 800 meters around the site of that mature plant and never found any other mature plants. The only known population of cane tibouchina on Oʻahu is located in the upper reaches of the Poamoho Watershed. These species are prolific seeders and are easily spread by animals and humans. Left uncontrolled, they can form dense, monotypic stands that shade out native understory plants. A miconia stand essentially creates an "umbrella" over the watershed with its large leaves, reducing the amount of rainwater that seeps into the watershed. Additionally, the shallow root system of miconia creates unstable soil layers that can contribute to erosion and degrade the quality of surface waters.

Two highly invasive plant species have been found in the Kaiaka Watersheds: Miconia calvescens *(left) and* Tibouchina herbacea *(right).*

7.2.2.1 Implications

Since invasive plant species are significant threats to the Kaiaka Bay Watersheds, the Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Projects that are focused on control of invasive species and on the restoration of native ecosystems should be promoted and funded.
  - Collaborate with organizations such as KMWP and the Oʻahu Invasive Species Committee (OISC) that are actively involved in such efforts.
- Education and outreach programs would be valuable to teach the public about the effects of nonnative and invasive plants in Hawaiian watersheds and how to prevent their spread.

7.2.3 Feral Ungulates

Nonnative feral ungulates (hooved mammals including pigs, goats, and cows) can have large impacts in Hawaiian watersheds. In the Kaiaka Bay Watersheds, pigs (*Sus scrofa*) are the most common species of feral ungulate, although cattle sometimes escape fenced areas and roam free in the lower reaches of the Waiʻanae range (see section 7.2.6). Moreover, the damage to Hawaiian ecosystems caused by feral pigs is thought to be more significant than the impacts of any other invasive species, especially in wet forests such as the forests of the upper reaches of the Koʻolau range in the Kaiaka Bay Watersheds (Dunkell, Bruland, Evensen, and Walker, 2011).

Seeds can be dispersed and germinate in pig feces

Feral pigs impact native flora and fauna through digging and rooting for food sources (plants and soil invertebrates). They also make large wallows, which further disturbs the soil. It is estimated that a single feral pig in a Hawaiian rainforest can potentially disturb up to 200 square meters of soil surface in a single day (Anderson et al., 2007). The rooting and digging activities of pigs are known to cause soil compaction, erosion, and nutrient runoff, although there have been limited studies to document or quantify these types of effects. Additionally, feral pigs spread invasive species when seeds are dispersed through their feces. One example of an invasive plant that is commonly dispersed by pigs is strawberry guava; it has been estimated that a single pig can disperse around eight million strawberry guava seeds a month during the peak fruiting season in a densely-infested area (West Maui Mountains Watershed Partnership, 2016). Moreover, their rooting behavior is believed to cause disturbances that may further enhance the spread of invasive species. Feral pigs also negatively affect native seedling regeneration by trampling and feeding on plants. Pigs are also thought to be a source of fecal contaminants in Hawaiian watersheds, including enterococci and other harmful pathogens, though little research has been conducted to investigate the role of feral pigs as a potential source of fecal indicator bacteria in surface runoff. Uncontrolled pig populations in Hawaiian rain forests are capable of doubling every four months (Katahira et al., 1993).

To better understand the impacts of feral pigs on Oʻahu's watersheds, two studies were conducted in 2007 in a forested area in the upper portion of the Mānoa Watershed on Oʻahu (Dunkell, Bruland, Evensen, and Litton, 2011; and Dunkell, Bruland, Evensen, and Walker, 2011). The studies measured runoff volume, TSS in runoff, and the levels of enterococci from fenced (pigs excluded) and unfenced plots at seven different sites. The results from the studies were not consistent: runoff volumes from fenced and unfenced plots were highly variable, as were TSS concentrations and levels of enterococci. Pig exclusion had no effect on TSS nor enterococci, however, significant reductions in runoff volume from pig exclusion plots were observed at one site, and two other sites showed a similar trend. TSS was found to significantly correlate with soil moisture and coarse woody debris cover, both of which can be directly influenced by feral pigs. Runoff volume and levels of enterococci in soil were significantly correlated to levels of enterococci in runoff.

7.2.3.1 Implications

It is well documented that feral pigs and other ungulates have significant impacts on Hawaiian watersheds and ecosystem functions, despite the fact that few studies have been able to quantify these impacts. In the Kaiaka Bay Watersheds, pigs pose a major threat to the health of the watersheds. While some fences to exclude ungulates have been constructed at the summit of the Koʻolau range as well as in the Waiʻanae range, there is still much forested area that exists in all the in the Kaiaka Bay Watersheds that is inhabited by pigs (refer to Figure 20).

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Funding for programs that maintain existing fences and construct new fences in the upper elevations of the watersheds (in both the Waiʻanae and Koʻolau ranges) should be a priority to protect and improve the health of the watersheds.
- Education and outreach programs would be valuable to teach the public about the impacts of feral ungulates on Hawaiian watersheds and the importance of fences in conservation lands
- Hunting programs should be encouraged where appropriate.

7.2.4 Soil Loss From Agricultural Lands

As discussed in section 7.2.1 (Erosion Processes), agricultural lands have been found to be a major source of suspended sediments in watersheds on Oʻahu. Soil loss from agricultural areas is dependent on numerous factors including the amount and intensity of rainfall, soil condition, topography, crop type, field management practices, the number of field roads, and land use factors. Moreover, important changes occur in crop soil biota in response to erosion which can result in a further decreased resistance to erosion (Janik, 1994). Soil that is lost from agricultural lands can be washed into drainages and contribute to the suspended sediment load in streams.

Bare soil exposed in pineapple field access roads in the Kaiaka Watersheds

Significant soil loss can occur during periods when a field is bare. It can also occur as a result of tilling, plowing, discing, or any other disturbance of the soil. Soil loss is also correlated with the proportion of unpaved access roads in a field. Pineapple fields are known to have a higher proportion of road areas than other large-scale crops. Indeed, soil loss from pineapple fields has been shown to be higher than that from sugarcane fields, caused by the high proportion of unpaved access roads and longer periods of exposed field during tillage and the early growth stage (Oki and Brasher, 2003).

7.2.4.1 IMPLICATIONS

While there is a lack a data to show how much soil loss occurs as a result of current agricultural land uses in the Kaiaka Bay Watersheds, it is well documented that soil loss does occur on agricultural lands, especially in pineapple fields. Agricultural lands in the Kaiaka Bay Watersheds were historically dominated by pineapple and sugarcane fields. Today, pineapple is still cultivated on a significant proportion of the land in the watersheds, along with other diversified crops.

To reduce soil loss from agricultural lands in the Kaiaka Bay Watersheds, the Kaiaka Bay Watershed-Based Plan should recommend management practices based on the following considerations:

- The implementation of best management practices for agricultural lands should be promoted and funded (e.g. cover cropping, creating sediment retention basins, using vegetated buffers, etc.).
- Education and outreach programs should be promoted to teach farmers and agricultural landowners about the relevance and importance of best management practices.
- Conservation Plans and Farm Plans should be encouraged, promoted, and made more attainable to farmers.

7.2.5 NUTRIENT & CHEMICAL CONTAMINANTS FROM AGRICULTURE LANDS

Fertilizers (a source of nutrients) and pesticides (a source of chemical contaminants) have been applied widely for agriculture in the Kaiaka Bay Watersheds, with fertilizer use dating back to 1900 or earlier and pesticide use dating back to the 1950s (Hunt, 2004).

Studies have shown that streams in agricultural areas generally have higher concentrations of dissolved nutrients than streams in undeveloped and urban areas on Oʻahu, including total nitrogen, nitrate, and phosphorus (Anthony et al., 2004; Hoover, 2002). Additionally, runoff from pineapple fields has been shown to have higher total nitrogen concentrations than runoff from sugarcane fields (Anthony et al. 2004). According to Oki and Brasher (2003), 200 to 300 pounds per acre of nitrogen is used for each pineapple crop cycle. Phosphorus, potassium, and magnesium also are used where necessary in much smaller amounts.

The agricultural use of pesticides, including herbicides, insecticides, fungicides, and nematicide fumigants, represents the most significant use of pesticides among all other uses on Oʻahu. Nematicide fumigants have been applied in pineapple cultivation since the 1940s to control to control nematodes that attack the roots of pineapple plants. These fumigants have historically represented a significant proportion of the total pesticides applied to crops in the Kaiaka Bay Watersheds (Hunt, 2004; Oki and Brasher, 2003). Herbicides have been applied variously, but use on sugarcane and pineapple crops has been particularly intensive, with annual application rates as much as five times those of major temperate-region field crops (Hunt, 2004).

Fertilizers and pesticides applied to crops can be washed off fields during rain events and can flow into streams. They have also been shown to contaminate groundwater, which can then contaminate stream water since groundwater contributes to the base flow of streams. Intensive use, year-round cultivation practices, and proximity of agricultural lands to streams in the Kaiaka Bay Watersheds may enhance the possibility of transport to streams. Factors that influence the amount of pesticides and fertilizers that may be transported to streams in runoff from agricultural lands include the amount and intensity of rainfall, antecedent rainfall or irrigation, topography, soil type and condition, crop type and practices, pesticide application rates and timing, and pesticide properties (Anthony et al., 2004.)

7.2.5.1 Implications

To prevent further contamination of waterbodies in the Kaiaka Bay Watersheds with nutrients and pesticides used on agricultural lands, the Kaiaka Bay WBP should recommend management practices based on the following considerations:

- The implementation of best management practices to reduce contaminated runoff from agricultural lands should be promoted and funded.
- The use of integrated pest management practices to reduce the need for pesticides should be promoted and funded.
- Education and outreach programs should be promoted to teach farmers and agricultural landowners about the relevance and importance of best management practices and integrated pest management practices that can reduce the use of pesticides.
- Conservation Plans should be encouraged, promoted, and made more attainable to farmers.
- Organic farming should be encouraged.

7.2.6 Ranching & Livestock

The grazing of cattle and other livestock can cause streambank erosion, increase runoff, and increase sediment and bacterial loads in streams. Grazing can also cause soil compaction and alter plant and animal communities (Dunkell, Bruland, Evensen, and Litton, 2011). In Hawaiʻi, unchecked cattle grazing has been attributed with the loss of biodiversity and soil erosion (G70, 2016). Rotation of the livestock and not allowing grazing of bare ground can help to prevent overgrazing. Cattle have been known to escape out of fenced areas into natural areas where they can degrade watersheds; this has occaionally been an issue in the past in the lower Kaukonahua Watershed. Nutrients are also a concern especially if the livestock are continually brought to a single area for watering each day instead of rotating the location as their waste can become concentrated. There are several cattle ranching operations in the Kaiaka Bay Watersheds, as well as at least one piggery. A chicken egg farm is planned for the future in the Kaukonahua Watershed.

7.2.6.1 Implications

While the exact number is unknown, it is known that there are numerous cattle ranching opperations that currently exist in the Kaiaka Bay Watersheds, on the slopes of both the Waiʻanae mountain range and the Koʻolau mountain range.

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- It is important that ranchers have adequate means to maintain fenced enclosures.
- Grazing should not be allowed in sensitive or important areas of watersheds (e.g. along streams in mauka/forested areas).
- Guidelines for proper animal waste management should be promoted when relevant.

7.2.7 SOIL LOSS FROM WILDFIRES

Hawai'i's ecosystems are thought to be especially vulnerable to fires because there is not a long history of anthropogenic fires compared to that of the continents. Before the first Polynesians arrived in the Hawaiian Islands approximately 2,000 years ago, the only source of fire was lightning or lava flows. The vast majority of fires today are caused by humans and occur much more frequently than before humans inhabited the islands. Humans have increased the incidence of wildfires in Hawaiʻi not only by intentionally or accidentally starting them, but also by introducing fire-prone plant species such as nonnative grasses.

A study by Trauernicht et al. (2015) found that there has been a more-than-fourfold increase in acreage burned annually statewide over the last 108 years. The study estimated that between 2005 and 2011, there were 1,007 wildfires statewide that burned an average of approximately 20,000 acres. The frequency of fires on Oʻahu is relatively high compared to the other islands; there are on average 600 wildfires on Oʻahu each year, however, many fires are small (under ten acres).

When landscapes burn, soils are often left exposed without vegetative cover. Subsequent rain events can cause massive hillslope erosion and mudslides, creating a major sediment source that can impact water quality. Moreover, the bare ground left after a fire is often colonized by invasive species which can permanently displace native cover. Many invasive species reduce forest moisture and make fires more common.

In August of 2015, a large fire burned approximately 500 acres in the ʻEwa Forest Reserve, located in the upper reaches of Kaukonahua Watershed. The fire burned forest that was dominated by nonnative species in the lower elevations and native-dominated forest in the upper elevations. According to DLNR DOFAW, in some places the vegetation was burned down to bare soil. In other places, a thick, wet mat of decomposing ferns appeared to have protected the soil. The same month a small fire was also ignited in Schofield Barracks East Range, also in the Kaukonahua Watershed. The effects of these fires on surface water quality in the watershed are unknown, but they likely increased erosion and sediment runoff, at least in the short-term.

7.2.7.1 IMPLICATIONS

Fires are a major threat to the Kaiaka Bay Watersheds. Fires can cause soil loss and increased sediments in surface waters. Therefore, the Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Funding for programs that work to prevent fires, respond to fires, and conduct post-fire restoration is needed.
- Preventative measures such as the development of more firebreaks and an increase in grazing to reduce fuel-loads should be recommended.
- Projects and programs that aim to restore native ecosystems should be promoted.

7.2.8 Motorized Recreation Activities

Off-road vehicles and dirt bikes can destroy native vegetation and expose soils, resulting in accelerated erosion and sedimentation. Trails and four-wheel drive roads can become drainage ways that carry runoff and sediment and transport plant debris, nonnative plant species, and nutrients to streams.

While the frequency and location of these activities in the Kaiaka Bay Watersheds is not well documented, they could negatively impact water quality. The State is currently in the process of trying to purchase over 3,000 acres of conservation and agricultural land from Dole, located in the Helemano and Poamoho watersheds. Future public use for these lands may include motorized recreation activities, which could have detrimental consequences on water quality.


Photo credit: The Honolulu Advertiser

A biker on the eroded landscape at Kahuku Motocross Park, Oʻahu (outside of the Kaiaka Watersheds)

7.2.8.1 Implications

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Land use plans should *not* promote the use of motorized recreation activities in areas that are prone to erosion, near streams, or contain important natural/cultural resources.
- Education and outreach programs to teach the public about the potential impacts of motorized recreational activities (and how to mitigate the impacts) should be promoted.

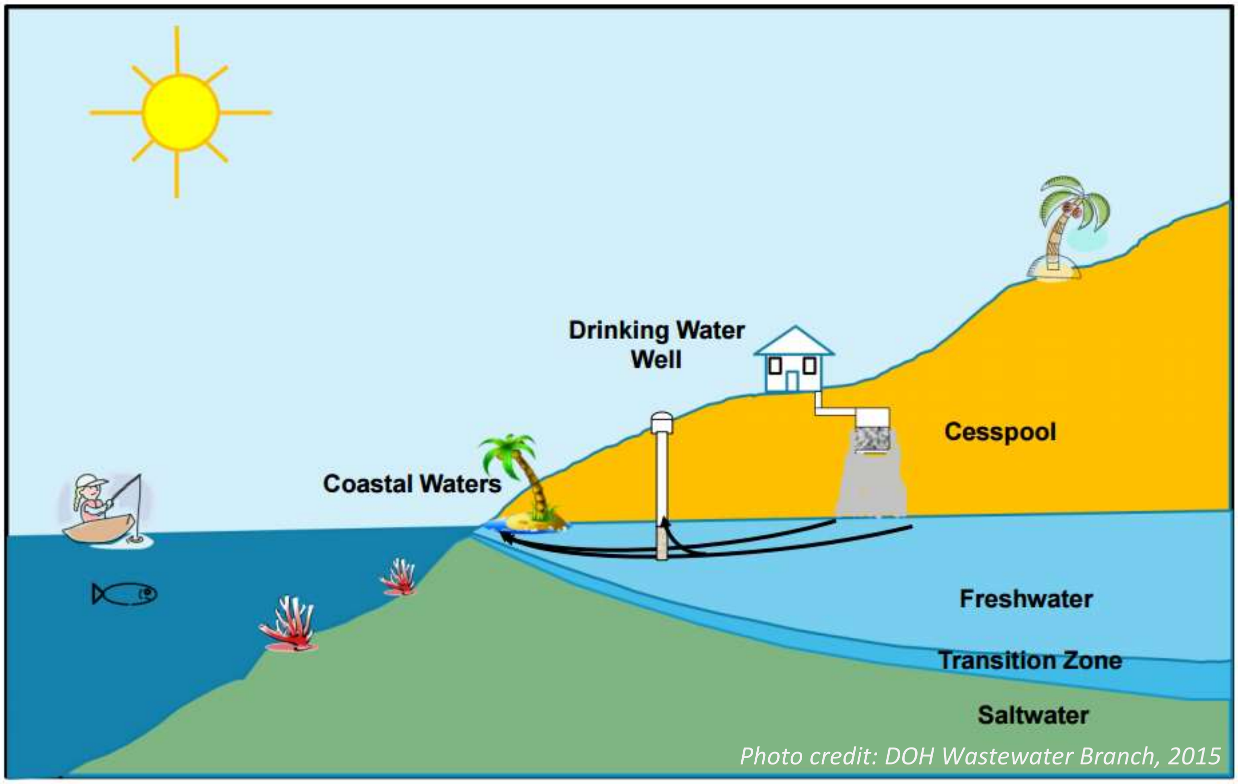
7.2.9 Cesspools & Other On-Site Sewage Disposal Systems

On-site sewage disposal systems (OSDS) are private wastewater treatment systems. The majority of the wastewater on the North Shore (including the towns of Waialua and Haleʻiwa) is handled by various types of OSDS, including cesspools and various types of septic systems. There are also OSDS located near Wahiawā and in other areas of the watersheds (refer to Figure 27).

Some types of OSDS treat wastewater to a certain degree, however, cesspools do not. Cesspools are essentially holes in the ground that collect sewage without treatment. Over time, the solids settle to the bottom and the wastewater effluent seeps into the surrounding soil. Cesspools fail easily due to the buildup of sludge at the bottom, which causes clogging of the system.

According to the DOH (2015), the typical nitrogen concentration in cesspool effluent is twice the concentration compared to OSDS that receive some treatment. Additionally, 96% of the nitrogen released from OSDS on Oʻahu comes from cesspools.

A concerning issue is that many cesspools in the Kaiaka Bay Watersheds have been in service for over 50 years and are deteriorating. A study conducted in 1992 estimated that about 40% of the cesspools on the North Shore are failing (Brown and Caldwell, 2012). Through deteriorating cesspools, contaminants typically found in wastewater can migrate to the groundwater where they can find their way to streams and shorelines, posing potential health risks to terrestrial and aquatic environments and human populations.



Cesspool leachate may impact nearshore waters, perennial streams, wetlands, and drinking water wells

Cesspools are used more widely in Hawaiʻi than in any other state. Hawaiʻi was also the last state to ban the construction of new cesspools, a law that passed in March of 2016. A state law (HRS §123-16.5) was passed in 2015 (and amended in 2017) that allows property owners to receive a $10,000 tax credit for replacing their cesspool and upgrade to another type of OSDS or connect to an existing wastewater system if the cesspool is located within 200 feet of the ocean, streams, or marsh areas, if it is shown to impact drinking water sources or recreational waters. The tax credit is also available to landowners with cesspools that have to potential to connect to an existing centralized wastewater system. In July 2017, Act 125 was passed to amend HRS Chapter 342D to require that by 2050, every cesspool in the state must be either upgraded to a septic or aerobic system or connected to a sewage system (with certain exemptions).

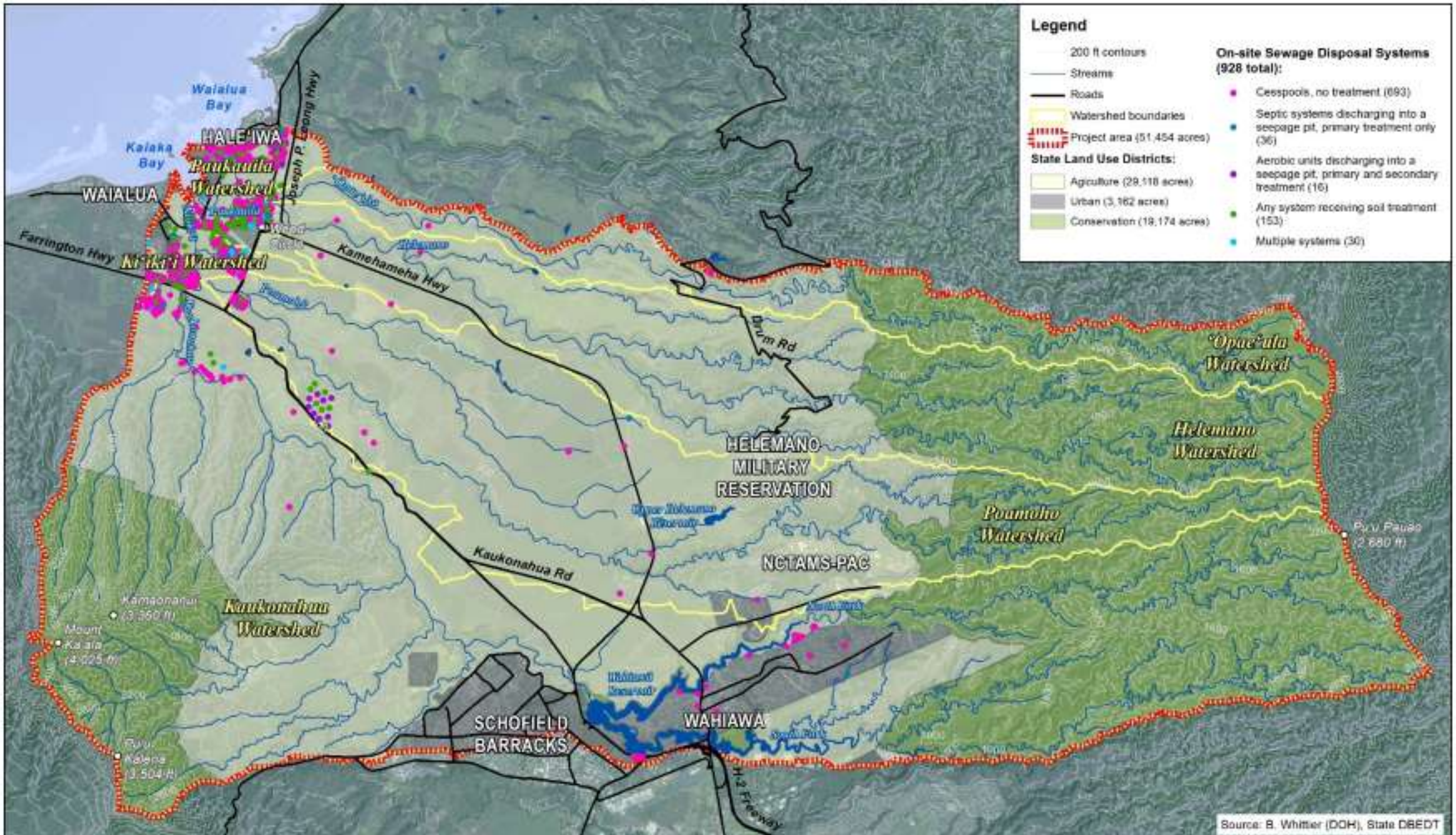
The DOH currently estimates there are 928 properties with approximately 1,015 OSDS within the Kaiaka Bay Watersheds, 71% of which are cesspools. Of the 722 cesspools in the Kaiaka Bay Watersheds, 79 qualify for the $10,000 tax credit for upgrading to a better system qualify and another 33 potentially qualify. Ten OSDS on seven properties in the Waialua and Haleʻiwa area are listed in the EPA's "large-capacity cesspool" database (Bob Whittier, personal communication and unpublished data). The construction of large-capacity cesspools has been banned by the EPA since 2000 and a ban on existing large-capacity cesspools has been in place since 2005. The current status of the ten large-capacity cesspools in the Kaiaka Bay Watersheds is not known.

Waialua is categorized in a 2017 report to the legislature as a "Priority 3" area for the State's prioritization of areas with cesspools that should be replaced. Priority 3 areas are described as having "potential impacts to sensitive waters" (DOH, 2017). According to the report, approximately 10 percent of the 1,080 cesspools in the Waialua area are located with 200 feet of the shoreline, increasing the health risk to swimmers and surfers. The report states that “nitrate concentration in groundwater resulting from cesspool and other OSDS leachate approaches the drinking water limit of 10 mg/L.” It goes on to say that while there are no drinking water sources in this area, the pollutants from OSDS and 14 different wastewater injection wells ultimately discharge into Kaiaka Bay.

The estimated daily flux and nutrient content of the effluent for the different classes of OSDS in the Kaiaka Bay Watersheds are shown in Table 41 (Bob Whittier, unpublished data). The precise relationship between OSDS effluent and surface water quality in the project area is not known.

TABLE 41. OSDS EFFLUENT AND NUTRIENT FLUX IN THE KAIAKA BAY WATERSHEDS

Properties with OSDS Types	# Properties	Total # OSDS	Total Effluent (gal/day)	Total Nitrogen (kg/day)	Phosphorus (kg/day)
Cesspools, no treatment	693	696	298,203	98.2	21.4
Septic systems discharging into a seepage pit, primary treatment only	36	39	15,695	3.4	0.7
Aerobic units discharging into a seepage pit, primary and secondary treatment	16	16	6,376	1.4	0.3
Any system receiving soil treatment	153	170	63,052	5.7	2.6
Multiple OSDS types • 26 cesspools • 26 septic systems • 1 aerobic unit • 41 soil treatment systems	30	94	12,360	2.6	0.7
TOTAL:	**928**	**1,015**	**395,686**	**111.3**	**25.7**



Kaiaka Bay Watershed-Based Plan

FIGURE 27. ON-SITE SEWAGE DISPOSAL SYSTEM TYPES & LOCATIONS

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: July 2016

7.2.9.1 Implications

Very few studies have been conducted to date to evaluate the extent and impacts of wastewater contamination in the Kaiaka Bay Watersheds. However, the fact that there are hundreds of aging cesspools along the shoreline and near streams gives reason for concern.

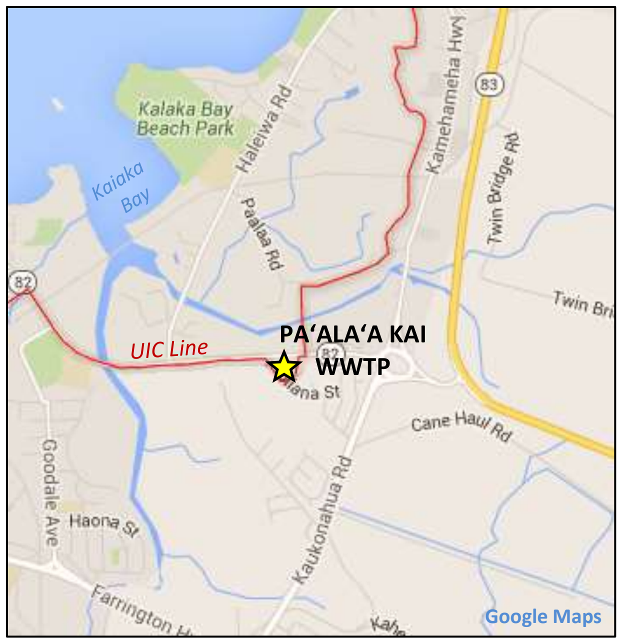
The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Education and outreach programs should be promoted to teach community members about wastewater treatment systems and the impacts on their environment and well-being.
- Encourage qualified cesspool owners to apply for the tax credit to upgrade their cesspools to better system.

7.2.10 Wastewater Injection Wells

There are numerous wastewater injection wells located in the Kaiaka Bay Watersheds. According to a 2017 report to the legislature, there are 14 different wastewater injection wells in the Waialua area (DOH, 2017).

One injection well in the area is the Paʻalaʻa Kai WWTP. Operated by the City and County of Honolulu, the Paʻalaʻa Kai WWTP was built in 1980 and serves over 300 homes in the community of Paʻalaʻa Kai, located in the Paukauila Watershed in the town of Waialua. The effluent receives secondary treatment and is disposed of via injection wells located on site. The average daily flow is approximately 90,900 gallons.



The Paʻalaʻa Kai WWTP is located in Waialua (indicated with a star), just makai of the UIC Line

The City's "North Shore Wastewater Alternatives Plan" (2012) recommends that the Paʻalaʻa Kai WWTP be upgraded to provide tertiary treatment to produce an R-1 quality effluent, which will facilitate reuse of the wastewater. It also recommends that the WWTP should be slightly expanded to allow a few adjacent parcels to connect to the collection system.

DOH's Underground Injection Control (UIC) program specifies where injection wells can be located and operated to reduce the risk that injected fluids could pollute underground sources of drinking water. The boundary between exempted aquifers and underground sources of drinking water is generally referred to as the "UIC Line." Restrictions on injection wells differ, depending on whether the area is mauka or makai of the UIC line. The WWTP operates under an UIC permit (# UO-1258).

The impacts of wastewater injection wells on surface water quality are unknown, but presumed to be minimal since the effluent is injected underground. However, it is known that seepage occurs two-ways: from surface waters into groundwater and from groundwater back into surface waters. Consequently, it is possible that the injected effluent may be a source of pollutants in the Kaiaka Bay Watersheds and in Kaiaka Bay. For example, injection wells near Lahaina on the island of Maui have been associated with algae blooms in the nearshore environment, harming the coral reef ecosystem. As a result of a settlement reached in a federal lawsuit over Clean Water Act violations, Maui County may be required to pay $2.5 million for projects to divert and reuse wastewater from Lahaina injection wells. The potential impact that wastewater injection wells have on the environment should not be ignored.

Algae-covered coral offshore of Kahekili Beach, Maui, 2004

7.2.10.1 IMPLICATIONS

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- The recommendations of the North Shore Wastewater Alternatives Plan should be considered.

7.2.11 URBAN CHEMICAL USE

A variety of chemicals are commonly used in urban and residential areas on O'ahu, including chemicals related to the use of pesticides, fertilizers, household cleaners, paints, solvents, oil, grease, fuels, pharmaceutical products, and caffeine. Commonly used pesticides include insecticides, herbicides, fungicides, acaricides, mulluscicides, fungicides, rodenticides, and fumigants. Pesticides are commonly applied on lawns and gardens, inside homes, and on pets, and may be used in liquid, aerosol, bait, powder, and granule formulations. Various types of pesticides and fertilizers are also likely used by the City, the State, and Federal agencies to maintain parks, landscaped areas, gardens, cemeteries, roadsides and other areas under their jurisdiction (Oki and Brasher, 2003).

Chemicals used in urban environments can be washed into waterbodies via stormwater runoff. They can also infiltrate groundwater which can then contaminate surface waterbodies. The issue is compounded when people purposefully or inadvertently improperly use or dispose of products or waste. For example, people may improperly dispose of pool or hot tub water that has been treated with chlorine and other chemicals by directly discharging into stormwater systems. The careless disposal of wash water from cleaning vehicles or other objects can also pollute waterbodies. People may improperly dispose of many other types household chemicals by discharging directly into stormwater systems. Additionally, many people do not follow labels and overuse herbicides and fertilizers on their lawns, causing an excess of chemicals that can make their way to streams or the ocean.

While the risk of misuse and improper disposal of urban chemicals poses a threat to water quality in the Kaiaka Bay Watersheds, Hunt (2004) points out that many of the commonly used herbicides in urban environments (post-emergent) have less leaching potential than many of the herbicides commonly used for agriculture (pre-emergent). The use of fertilizers in urban areas may also be less of a threat to water quality than in agricultural areas, since large percentages of urban land are taken up by impervious surfaces (i.e. there is less acreage to be treated than in agricultural lands).

7.2.11.1 Implications

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Education and outreach programs should be promoted to teach community members about the importance of proper use, storage, and disposal of household chemicals.

7.2.12 Urban Stormwater Runoff

Urban stormwater can pick up and transport a wide variety of pollutants as it travels along impervious surfaces such as streets, gutters, ditches, or pipes. Contaminants on impervious surfaces come from both human activity and natural sources. Common pollutants include oil/grease/fluids from automobiles, pesticides, bacteria and other pathogens, polycyclic aromatic hydrocarbons, household chemicals, and metals such as lead, cadmium, copper, and zinc. Stormwater can also transport carelessly discarded trash, such as cigarette butts, paper wrappers, and plastic bottles.

Hoover (2002) found that water samples taken from storm runoff in urban areas had the highest concentrations of dissolved nutrients compared to agricultural and conservation lands on Oʻahu.

Polluted stormwater is often collected in MS4 systems in urban areas and discharged into nearby waterways. It can also flow directly into waterbodies. On bridges, for example, stormwater runoff flows directly into the water body below.

Most bridge stormwater runoff discharges directly to the water bodies below, as seen at this bridge over Kiʻikiʻi Stream near Waialua

7.2.12.1 Implications

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Education and outreach programs should be promoted to teach community members about stormwater, how it impacts their environment and well-being, and what they can do to prevent polluted runoff.
- Management practices that reduce the risk of polluted runoff should be promoted (e.g. street sweeping).

7.2.13 Superfund Sites & Other Hazardous Waste Sites

A superfund site any land in the United States that has been contaminated by hazardous waste and identified by the EPA as a candidate for cleanup because it poses a risk to human health and/or the environment. These sites are placed on the National Priorities List. In the Kaiaka Bay Watersheds, there are two Superfund sites: one is located at Schofield Barracks (Army) and the other is located at the JBPHH-Wahiawā Annex (Navy).

The Superfund site at the Army's Schofield Barracks pertains to the detection of contaminated drinking water in 1985. In April of that year, DOH detected trichloroethylene (TCE) at concentrations that exceeded the EPA's maximum contaminant levels in one of the four on-site wells that supplied drinking water to 25,000 people at Schofield. After this discovery, the Army suspended use of the wells and drinking water was supplied from off-site wells in Wahiawā. A remedial investigation characterized the extent of groundwater contamination and revealed other environmental contamination, including soils, sediments, and surface waters. Potential contaminants included volatile organic compounds, semivolatile organic compounds, pesticides, PCBs, and inorganic chemicals. In 1986, the Army began removing the contaminants from the water using an air stripper treatment system. The site was delisted from the National Priorities List in 2000 after the Army completed all work necessary to protect human health and the environment. Five-year reviews of the site have found that the cleanup remedies are functioning properly and that the potential for exposure to contamination has been sufficiently reduced. Water from the Schofield wells continues to be treated at the wellhead by air stripper technology and is the source of drinking water for the installation. Drinking water supply wells are monitored to ensure federal drinking water standards are met, and a system of monitoring wells throughout Schofield and nearby communities is routinely monitored to ensure that contamination is detected and drinking water supplies are protected.

The Navy's JBPHH-Wahiawā Annex Superfund sites are primarily land disposal areas that are no longer in use and PCB transformer sites. Soil contamination depends on the site but generally the chemicals of concern are PCBs, volatile organics, semi-volatile organics and metals. Removal actions were necessary at the transformer sites to protect human health and the environment from PCBs in soil. Multiple areas at JBPHH-Wahiawā Annex also have mandated land use controls that restrict current and future land use to activities compatible with low-occupancy use as the final remedy to ensure protection of human health. This final remedy allows residual PCB concentrations in soil and concrete to remain on site at concentrations above levels that allow for unlimited use and unrestricted exposure. It is important to note that samples of water and sediments that are downstream and pass through the contaminated sites at JBPHH-Wahiawa Annex have been analyzed for all contaminants of concern and are below either background or action levels. The Navy and EPA have concluded that no further action is necessary to protect public health or welfare or the environment, however, five-year reviews are conducted to ensure standards are met.

In addition to the two superfund sites, there are two sites that are recorded as "Toxic Release Inventory Sites" by the EPA: one in Wahiawā and one in Waialua. The EPA also has record of a number of sites with reported hazardous waste activity near Wahiawā and Waialua.

7.2.13.1 Implications

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- Water quality testing for contaminants in surface waters would be valuable to better understand how much of concern these hazardous waste sites are today.

7.2.14 MILITARY TRAINING EXERCISES

The Army uses their land in the Kaukonahua Watershed for training activities, including live-fire training in Schofield Barracks West Range (see section 3.2.5 for more information about military training). Erosion resulting from prescribed burns and training activities in West Range may be a source of sediments in Kaukonahua Stream. Schofield Barracks East Range prohibits live-fire exercise, but according to the TMDL study for Upper Kaukonahua (DOH, 2009), there is a potential for petroleum hydrocarbon fuels or lubricants spills from vehicles and for legacy toxic pollutants from past range activities that have been forgotten or ignored. These chemicals could bind strongly to the fine silty clays of the East Range and become mobilized and transported via suspended sediments in streams. Water quality data from streams and soils in the East Range could be used to more definitively ascertain the Army legacy as a possible upstream source of toxic contaminants.

The Army also conducts “jungle training” in the forests located in East Range (Kaukonahua and Poamoho Watersheds). The training course, known as the Jungle Operations Training Center, has been in use since 2013. Jungle training involves learning how to navigate and work in thick vegetation and challenging terrain. No live-fire training is involved and there is little vehicular access. The majority of the impact to the watershed likely occurs as a result of foot traffic and related on-the-ground training activities. Jungle training likely accelerates erosion in some places due to the combination of steep slopes, easily erodible soils (Helemano series), and damage or modification to land cover and/or surface drainage due to maneuver training and road construction.

Soldiers participating in “jungle training” in the Kaukonahua Watershed

Drum Road is a paved road used by the Army that starts at Helemano Military Reservation and heads in a northerly direction across the Helemano and ʻŌpaeʻula watersheds (and beyond). It was paved primarily for the training needs of the Stryker Brigade, however, the majority of the Strykers have now left Hawaiʻi. There may be some stormwater runoff and erosion associated with this road and the use of the road by the Army.

A Stryker has eight wheels and weighs 19 tons; most Strykers have now left Hawaiʻi

The Stryker Brigade also trained in the forested areas in East Range (Upper Kaukonahua). According to the final Stryker Brigade Environmental Impact Statement (Tetra Tech, 2004), training with Strykers was expected to increase erosion and suspended sediments in adjacent streams. Land conditions were projected to decline from “moderate” under existing conditions to “severe” due to the heavier weights and intensive use of Strykers in a small area both within and immediately downstream of the South Fork Kaukonahua Stream sub-basin.

The Army has numerous helicopter landing zones located in remote, mauka areas of the Kaukonahua Watershed and the Poamoho Watershed (Army-leased land). These areas can become eroded over time and can also be a hotspot for invasive plants, since they can be easily transported in the aircraft or on the boots and gear of military personnel. The Oʻahu Army Natural Resources Program inspects all Army helicopter landing zones for the presence of incipient invasive species on a regular basis.

The Integrated Training Area Management (ITAM) program at Schofield Barracks is currently identifying and classifying erosion hot spots in order to support the selection and implementation of management practices in priority areas.

7.2.14.1 Implications

While the Kaiaka Bay WBP cannot make recommendations about the types of military training that are conducted in the watersheds, the WBP should recommend management practices based on the following considerations:

- Excessive erosion should be prevented through implementing management practices to stabilize soils along roads and other high-use areas.
- Care should be taken to avoid the spread of invasive species (e.g. wash tactical vehicles in designated areas and clean boots/gear before entering new areas).
- Water quality monitoring could help determine the historic effects of Army training on surface waters downstream.

7.2.15 Impacts of Climate Change

The effects of global climate change have already been detected in Hawaiʻi (see section 2.4), and they are predicted to increase over the coming decades. Increasing temperatures and decreasing rainfall will lead to an increased frequency of droughts and increased evapotranspiration rates, which will reduce the amount of water going into streams and groundwater recharge. During droughts, soil moisture may be completely depleted in un-irrigated, fallow fields, causing dust storms and loss of top soils from wind erosion. The frequency of forest fires will also increase, further contributing to erosion and the degradation of native ecosystems. With declining forest health, erosion and runoff will increase, causing more sediments to be washed into streams and receiving water bodies. Climate change is also expected to cause more severe storm events, which will further contribute to erosion. Rising sea levels, higher sea-surface temperatures, increased coastal flooding, and increased sediment load deposition on coral reefs will have detrimental effects on aquatic and marine ecosystems.

7.2.15.1 Implications

The Climate Change Task Force within the State Office of Planning has identified 15 areas of planning that are likely to be affected by climate change, including the potential impacts climate change may have on water supply, coastal zone management, storm and wastewater management, agriculture, natural resources/environmental protection, and flood control. These impacts should be considered in watershed planning efforts.

The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- A precautionary approach to adaptation and mitigating impacts is to: 1) identify the most critical vulnerabilities; 2) suggest how climate variability and extremes might aggravate those vulnerabilities, and 3) design a range of solutions covering the climate uncertainty (G70, 2016).
- The protection and management of the mauka, forested areas in the watersheds should be a priority in order to protect the watersheds' ability to retain soil and moisture (and prevent erosion and runoff).
  - Forests also reduce the impacts of climate change by absorbing greenhouse gases.

7.2.16 Other Natural Sources of Pollutants

Nutrients in stream water in the Kaiaka Bay Watersheds can be derived from various natural sources. For example, nitrogen can be derived from rainfall or by fixation of atmospheric nitrogen by certain plants and by bacteria in soil (azofication). Organic nitrates (alkyl nitrates) in the atmosphere may be derived from the ocean, and may represent a natural source of nitrogen in stream water. Phosphate in streams can be derived from the weathering of certain types of volcanic rocks or from Asian dust. Chloride in stream water may be from rain or groundwater discharge. Bicarbonate in streams may be a result of dissolution of calcareous rock material in streams or from decaying vegetation in the soil. Volcanic rocks and soil can also be a source of heavy metals in stream water (Oki and Brasher, 2003).

Fecal indicator bacteria, including enterococci, total coliform, fecal coliform, *E. coli*, and fecal streptococci, are commonly found in the soil in Hawaiʻi. Because soil is commonly transported to streams during periods of rainfall, the soil represents a natural source of fecal indicator bacteria in streams. Studies have found that forested headwaters serve as sources of fecal indicator bacteria to downstream ecosystems.

Additionally, pollutants that are present in groundwater can potentially be discharged into surface waters, whether they are derived from natural or anthropogenic sources. Studies have shown that groundwater contributes nutrients and herbicides to streams (Anthony et al., 2004).

7.2.16.1 Implications

While very little can be done to control natural sources of pollutants in waterbodies, the Kaiaka Bay WBP should recommend management practices based on the following considerations:

- More research on the role of natural pollutant sources in water quality would help guide other planning and management decisions.
  - For example, it would be helpful to understand how much fecal indicator bacteria in water is derived from natural sources versus from OSDS.

7.2.17 Future Sources of Pollution

As discussed in section 3.3 (Future Land Use Plans), there are a number of planned projects that could contribute pollutants to the Kaiaka Bay Watersheds, including:

- The sale of thousands of acres of Dole land in the Kaiaka Bay Watersheds.

- A plan to revitalize agriculture by the State (the Whitmore Project) by purchasing and leasing land to farmers, upgrading the Wahiawā WWTP to produce R-1 quality effluent to be used for agriculture, and creating pumped-storage hydropower using the Wahiawā Reservoir dam.
- Possible expanded Army “Jungle Training” operations.
- Possible creation of an area for motorized recreational activities (see section 7.2.8).
- A number of proposed development projects in the Waialua/Haleʻiwa area (some of which involve zoning changes).

In addition, climate change will also be a future source of pollution.

7.2.17.1 Implications

While the actual impacts of the possible future land use changes are unknown, it is important to evaluate the possible impacts and scenarios in order to develop a robust watershed plan. The Kaiaka Bay WBP should recommend management practices based on the following considerations:

- An evaluation of the possible scenarios that could result from the sale of Dole lands should be conducted.
- With respect to the Whitmore Project’s objective to revitalize agriculture in the watersheds, it would be valuable to assess the impacts if a significant portion of fallow or minimally-used agricultural lands become actively farmed (diversified agriculture).
- Assess possible impacts if the Army expanded Jungle Training in Schofield Barracks East Range (Kaukonahua Watershed) and started training in Army-leased land in the Poamoho Watershed (increased foot-traffic).
- It can be assumed that the proposed development projects will result in increased stormwater runoff due to an increase in impervious surface, therefore, the pollutants that are commonly associated with urban stormwater runoff will also increase (see section 7.2.12).
- Some of the impacts of climate change may be able to be assessed through modeling (e.g. reduced rainfall/streamflow, increased frequency of wildfires, or less forest cover).

7.3 MODELING NONPOINT SOURCE POLLUTION

OpenNSPECT was used to model nonpoint source pollution (sediments and nutrients) in the Kaiaka Bay Watersheds. OpenNSPECT is an open-source version of the Nonpoint Source Pollution and Erosion Comparison Tool designed by NOAA that examines the relationship between land cover, nonpoint source pollution, and erosion. As with any model, there are a few key assumptions and limitations of OpenNSPECT that are important to understand when assessing the model outputs. One key limitation of OpenNSPECT is that it does not model stream channel erosion caused by instream flows; it only models rill and sheet erosion. It also does not account for stormwater drainage systems, stream diversions, and other man-made hydrological alterations. The potential impacts of cesspools and other OSDS to surface water quality are not considered by the model. Additionally, the land cover classes that are a key data input in the model are not customized for Hawaiʻi's habitat types, crop-types, or other Hawaiʻi-specific land uses, therefore, scenarios that involve specific land use changes or management strategies can be difficult to incorporate into the model.

7.3.1 MODELING METHODOLOGY

The outputs of the model show where nonpoint source pollutants (sediments, nitrogen, and phosphorus) originate and estimate the accumulated pollutant loads that are transported in streams and to Kaiaka Bay. OpenNSPECT uses NOAA's C-CAP land cover dataset and known pollutant coefficients that correspond to each landcover type (along with other data inputs) to determine the resulting pollutant loads.

The results of the model can then be assessed in a variety of ways to determine trends in pollutant loads originating in different watersheds, landcover classes, and land use types. In this WBP, the modeling results were assessed by individual watershed, C-CAP land cover type, as well as by four general land use types defined for this WBP. Dividing the project area in to four main land use types is helpful to provide a general context for understanding "big picture" on how land use is related to specific pollutants and where management recommendations should be focused for each pollutant type. The four general land use types include Forest Lands, Agricultural Lands, Developed Areas, and Army Training Areas (Figure 28). These four land use types are summarized in tables 42 and 43, depicted in Figure 28, and further described in the following text.

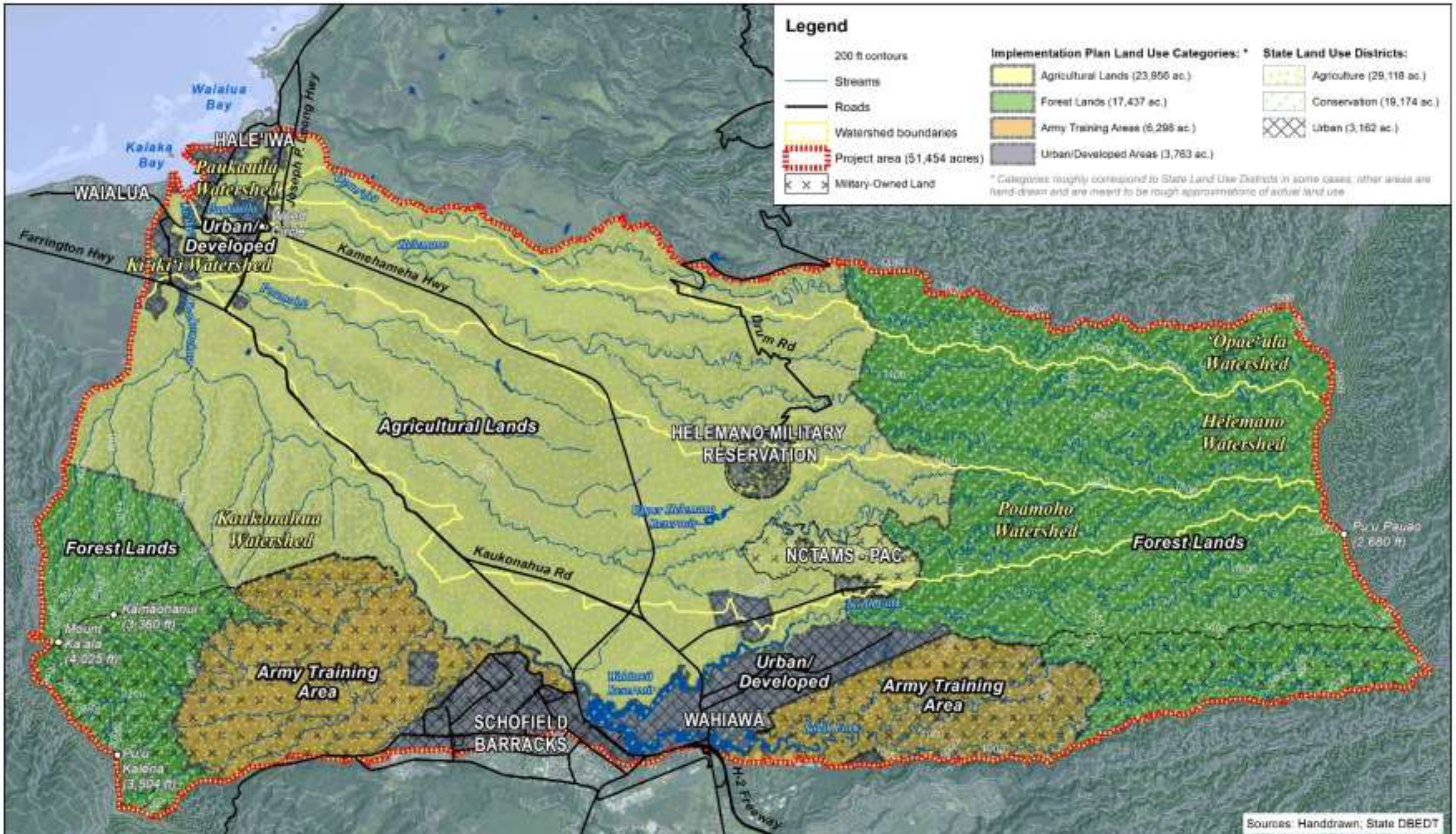
TABLE 42. DESCRIPTIONS OF THE FOUR GENERAL LAND USE TYPES

LAND USE TYPE	DESCRIPTION
FOREST LANDS	• Forested areas of the Koʻolau range & Waiʻanae range (Mt. Kaʻala) • Part of State Conservation District • Largely State-owned • Mixed native-nonnative forest (higher elevations are more native-dominated) • Includes multiple State reserves • Several fenced ungulate-free exclosures; on-going management in some areas
AGRICULTURAL LANDS	• Agricultural areas primarily used for crops, fallow fields, and grazing • Part of State Agricultural District • Dole Food, Co. and the State ADC are two of the major landowners • Dominated by nonnative vegetation (scrubland/grassland)
DEVELOPED AREAS	• Includes the developed areas of Haleʻiwa, Waialua, Schofield Barracks, Wahiawā, JBPHH-Wahiawā Annex, Helemano Military Reservation, and the area immediately around the Dole Visitors' Center; also includes paved roadways (Drum Road, Kaukonahua Road, Kamehameha Highway) • Includes areas in the State Urban District and in the Agricultural District • The major landowners include the City and County of Honolulu and the Federal Government • Primarily consists of nonnative vegetation (scrubland/grassland) and impervious surfaces
ARMY TRAINING AREAS	• Includes the areas used by the Army primarily for training activities, namely Schofield Barracks East Range and Schofield Barracks West Range • Includes areas in the State Conservation District and in the Agricultural District • Owned by the Federal Government (Army) • Mixed native-nonnative forest (East Range) and nonnative scrubland/ grassland (West Range)

The geographic coverage for each the four land use types in the Kaiaka Bay Watersheds is depicted in Figure 28 (next page), however, the boundaries of the land use types should be regarded as rough approximations of actual land uses. Table 43 below shows the approximate number of acres in the Kaiaka Bay Watersheds for each of the four land use types.

TABLE 43. FOUR GENERAL LAND USE TYPES BY WATERSHED

		Forest Lands		**Agricultural Lands**		**Developed Areas**		**Army Training Areas**		
	Watershed	**Acres**	***% of Watershed***	**Acres**	**% of Watershed**	**Acres**	***% of Watershed***	**Acres**	***% of Watershed***	**Total Acres**
Kiʻikiʻi System	Kiʻikiʻi	0	*0%*	344	*58%*	248	*42%*	0	*0%*	**592**
	Kaukonahua	9,217	*37%*	6,841	*27%*	2,803	*11%*	6,298	*25%*	**25,159**
	Poamoho	2,016	*17%*	9,328	*80%*	331	*3%*	0	*0%*	**11,675**
Paukauila System	Paukauila	0	*0%*	531	*61%*	334	*39%*	0	*0%*	**865**
	Helemano	4,088	*44%*	5,225	*56%*	40	*0%*	0	*0%*	**9,353**
	ʻŌpaeʻula	2,116	*56%*	1,687	*44%*	7	*0%*	0	*0%*	**3,810**
	Total Acres	**17,437**	*n/a*	**23,956**	*n/a*	**3,763**	*n/a*	**6,298**	*n/a*	**51,454**
	% of Project Area	**34%**	*n/a*	**47%**	*n/a*	**7%**	*n/a*	**12%**	*n/a*	**100%**



Kaiaka Bay Watershed-Based Plan

FIGURE 28. FOUR GENERAL LAND USE TYPES

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: October 2016

Forest Lands

For the purposes of the Kaiaka Bay Watershed-Based Plan, Forest Lands include all forested and natural areas in the higher elevations of the watersheds. This includes the slopes of the Waiʻanae range that lead to Mt. Kaʻala to the west and the network of ridges and gulches that give rise to the summit of the Koʻolau range to the east. These lands are categorized as part of the Conservation District by the State of Hawaiʻi and are zoned as Preservation by the City and County of Honolulu. Note that some areas of the State Conservation District are not included in this land use category (e.g. primary Army training areas or the Wahiawā Reservoir). The highest elevation forests are actively managed by a number of entities (e.g. ungulate control, fenced exclosures, weed control, etc.) to project the watersheds and their natural resources.

Forest Lands are largely owned by the government (State and Federal), however, a portion of the ʻŌpaeʻula Watershed is owned by Kamehameha Schools (refer to section 3.2.4 for details on land ownership). The highest elevations of the Upper Kaukonahua subwatershed in the Koʻolau mountains are Army-owned and can be used for training purposes; however, they are categorized as Forest Lands in this WBP since most of the Army's training activities in the Koʻolau forests occurs in the lower elevations of Upper Kaukonahua. Therefore, the issues and management recommendations for higher elevations of the Upper Kaukonahua subwatershed are presumed to be essentially the same as the Koʻolau summit area in the other Kaiaka Bay Watersheds.

The Forest Lands land-use type accounts for approximately 34% of the total area in the Kaiaka Bay Watersheds. Kaukonahua Watershed has the largest amount of Forest Lands (9,217 acres), followed by Helemano, Poamoho, and ʻŌpaeʻula watersheds (Table 43). Kiʻikiʻi and Paukauila watersheds do not have any land that is classified as Forest Lands.

Per the USGS GAP analysis, nearly half of the area categorized as Forest Lands is dominated by native species, such as ʻōhiʻa, koa, and uluhe (8,585 acres). The native-dominated habitats are located at the highest elevations, near the summit of the Koʻolau range and along the slopes of Mt. Kaʻala. The remaining area consists primarily of nonnative-dominated forest or mixed native-nonnative forest.

Agricultural Lands

Agricultural Lands in the Kaiaka Bay WBP include areas used for growing crops, fallow fields, and pasturelands. These areas are primarily located in the central portion of the project area (Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula watersheds), however, Kiʻikiʻi and Paukauila watersheds also have Agricultural Lands. These lands are categorized as part of the Agriculture District by the State of Hawaiʻi and are zoned as Agriculture by the City and County of Honolulu. Note that some areas of the State Agriculture District are not included in this land use category (primarily Army training areas).

This land-use type accounts for approximately 47% of the total area in the Kaiaka Bay Watersheds (Table 43). Each of the six Kaiaka Bay Watersheds has some Agricultural Lands, however, Kaukonahua Watershed has more than twice as many acres as any other watershed (25,159 acres).

The Agricultural Lands are largely owned by Dole Food Company, Inc. (refer to section 3.2.4). However, in recent years Dole has listed thousands of acres of land for sale. Many parcels have already been sold or are under negotiations, while other have yet to be sold. The Agribusiness Development Corporation (a branch of the State Department of Agriculture) has purchased a number of parcels that were formerly owned by Dole. DuPont Pioneer is another large landowner of Agricultural Lands.

These agricultural areas are some of the most productive lands in all of Hawaiʻi. As of 2015, approximately 3,262 acres of agricultural land in the Kaiaka Bay Watersheds are used for pineapple, 2,751 acres are used for pastureland, 1,480 acres are for diversified crops, and 1,094 acres are used for seed production. Other crops include coffee, papaya, fruits, forestry products, and flowers.

Developed Areas

Developed Areas, as classified in this WBP, include areas near Kaiaka Bay (Haleʻiwa and Waialua) and in the "saddle" between the Waiʻanae and Koʻolau mountain ranges (Wahiawā and Schofield). Developed Areas also include areas that have high densities of impervious surfaces, as identified in using the C-CAP landcover analysis (see section 2.6). Using this approach, portions of the JBPHH-Wahiawā Annex, the Helemano Military Reservation, and the area immediately around the Dole Visitors' Center are classified as part of this land-use type. Paved roads that traverse various land use types, including Kaukonahua Road, Kamehameha Highway, and the Army's Drum Road, are also applicable to the management measures and practices for Developed Areas. In the year 2010, there were approximately 48,730 people living in the Kaiaka Bay Watersheds in Developed Areas.

These lands are largely categorized as part of the Urban District by the State of Hawaiʻi and are zoned as Residential, Business, or Industrial by the City and County of Honolulu. Note that some areas of the State Agriculture District are were also included in this land use category when high densities of impervious surfaces were observed (e.g. JBPHH-Wahiawā Annex and Helemano Military Reservation). Developed Areas are owned largely by the City and County of Honolulu and the Federal government (refer to section 3.2.4).

While Developed Areas account for a relatively small proportion of the total area in the Kaiaka Bay Watersheds (approximately 7% of the total; Table 43), these areas can have considerable impacts on water quality. Each of the six Kaiaka Bay Watersheds has some land in this land-use type, however, Kaukonahua Watershed has more than twice as many acres as any other watershed (25,159 acres). Kiʻikiʻi and Paukauila watersheds have the highest percent of their total area classified as Developed Areas, at 42% and 39%, respectively.

Army Training Areas

Army Training Areas include the U.S. Army's Schofield Barracks West Range and East Range in the Kaukonahua Watershed. These areas are used for live fire and maneuver training to accomplish the Army's training objectives. Army Training Areas, as classified in this WBP, are categorized as part of two different State Land Use Districts: The Agriculture District and the Conservation District. They are primarily zoned as Military and Federal by the City and County of Honolulu; however, a portion is zoned as Preservation (the area that is in the State Conservation District). The Federal Government (U.S. Army) owns all land in this land-use type.

Army Training Areas account for approximately 12% of the total area in the Kaiaka Bay Watersheds (Table 43). Kaukonahua Watershed is the only watershed with this land use type (6,298 acres).

7.3.2 Modeling Results

This section presents the results of the modeling for each of the three main pollutant types: sediments, nitrogen, and phosphorus. The modeling results were analyzed by individual watersheds as well as by C-CAP landcover type and the four general land use types. Results for sediments are presented in U.S. standard units of measurement (pounds), while results for the nutrients are presented in the metric system (milligrams or kilograms) to be consistent with the units used in Hawaiʻi's Water Quality Standards. Key findings from the analyses are presented as bullet points and will be summarized in section 7.3.3.

7.3.2.1 Sediments

OpenNSPECT estimates areas where erosion is likely to occur and result in sediment transport as a result of landcover type, soil characteristics, topography, and rainfall. A visual assessment of the results reveals that the majority of the sediments in the Kaiaka Bay Watersheds are generated in the central portion of the project area, primarily in the Poamoho Watershed (Figure 29). However, there are a number of other small areas that seem to be erosion "hotspots."

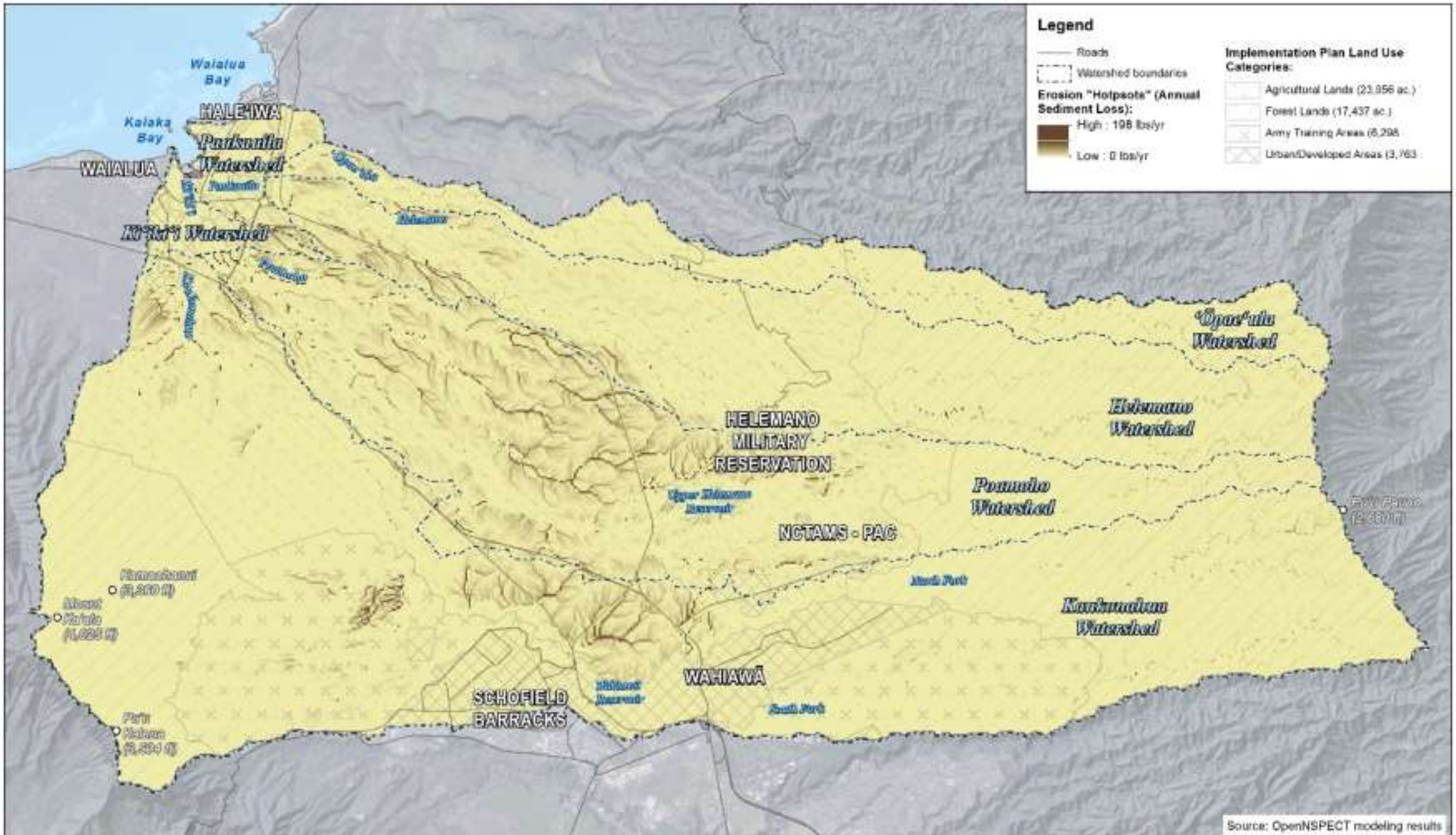
Analysis of these results indicate that the Kiʻikiʻi Stream System generates three times as many sediments that flow into Kaiaka Bay than the Paukauila Stream System, however, the former is nearly three times larger than the latter, making the difference in sediment production not as significant (Kiʻikiʻi Stream System generates 0.9 lbs/acre and Paukauila Stream System generates 0.7 lbs/acre).

Assessing the modeling results by individual watershed shows that Poamoho Watershed generates the most sediments out of the six watersheds (45% of the total sediments for the entire project area) followed by Kaukonahua Watershed (32%; Table 44). However, when examining sediment generation by pounds per acre, Paukauila Watershed produces the most (3.1 lbs/acre), followed by Poamoho Watershed (1.6 lbs/acre) and Kiʻikiʻi Watershed (1.0 lbs/acre). It is likely that the reason these three watersheds produce the most sediments per acres is that they have the highest proportion of their total area classified as "Cultivated Lands," as determined by the C-CAP landcover data input for the model. "Cultivated Lands" is associated with high rates of erosion. Refer to Table 45 for the analysis of the C-CAP landcover types.

- ***Key Finding: Poamoho, Paukauila, and Kiʻikiʻi watersheds should all be priorities for implementing management measures to reduce sediments.***

TABLE 44. SEDIMENTS ORIGINATING IN EACH WATERSHED

Stream System	Watershed	Percent of Total Sediment Coming from Each Watershed	Pounds per Acre
Kiʻikiʻi	Kiʻikiʻi	1%	1.0
	Kaukonahua	32%	0.5
	Poamoho	45%	1.6
Paukauila	Paukauila	6%	3.1
	Helemano	13%	0.6
	ʻŌpaeʻula	3%	0.4
	Total:	**100%**	*n/a*



Kaiaka Bay Watershed-Based Plan

FIGURE 29. MODELING RESULTS – SEDIMENT SOURCES

The results of the model can be assessed by the default C-CAP landcover classes that are used by the model to determine trends in pollutant loads originating in the different landcover types. Of all the different C-CAP landcover types, areas classified as “bare ground” produce the most sediments per acre. For example, “bare ground” areas produce 11 times more sediments than areas classified as “grasslands” and 28 times more than areas classified as “scrub/shrub” (Table 45). However, areas classified as “bare ground” account for less than one percent of the total land area in the Kaiaka Bay Watersheds (195 acres) and only 4% of the total sediment. Kaukonahua Watershed has the most area classified as “bare ground” (172 acres), followed by Poamoho Watershed (17 acres). The other watersheds have comparatively little to no bare ground.

- ***Key Finding: Areas with bare ground should be a top priority for implementing management measures to reduce sediments, especially in Kaukonahua and Poamoho watersheds.***

Areas classified as “cultivated lands” produce the second most sediments per acre (nearly four times more than “grasslands” and ten times more than “scrub/shrub” areas; Table 45). Cultivated lands cover 18% of total project area and produce the largest proportion of total sediments than any other C-CAP landcover type (63% of total sediments). Poamoho Watershed has the most area classified as “cultivated lands” (5,132 acres or 44% of total watershed), followed by Kaukonahua Watershed (2,015 acres or 8% of total watershed) and Helemano Watershed (1,184 acres or 13% of total watershed).

- ***Key Finding: Agricultural areas should be a top priority for implementing management measures to reduce sediments, especially in Poamoho and Kaukonahua watersheds.***

TABLE 45. SEDIMENTS PRODUCED IN EACH C-CAP LANDCOVER TYPE

C-CAP Landcover Class	Pounds per Acre	Percent of Total Sediment Coming from Each Class
Developed, High Intensity	0.1	0.2%
Developed, Medium Intensity	0.3	0.8%
Developed, Low Intensity	0.6	4%
Open Spaces Developed	1.0	2%
Cultivated Land	2.9	63%
Grassland	0.8	8%
Evergreen Forest	0.2	15%
Scrub/Shrub	0.3	3%
Palustrine Forested Wetland	0.0	0.0%
Palustrine Scrub/Shrub Wetland	0.2	0.0%
Palustrine Emergent Wetland	0.2	0.03%
Estuarine Forested Wetland	1.3	0.01%
Unconsolidated Shore	0.0	0.0%
Bare Land	8.6	4%
Water	0.0	0.03%
Total (rounded):	**n/a**	**100 %**

The final analysis of the modeling results for sediments presented in this WBP examines differences between the four customized land use types in each watershed. The four general land use types include: Forest Lands, Agricultural Lands, Developed Areas, and Army Training Areas (refer to Table 43 and Figure 28 in section 7.3.1). The results of this assessment indicate that 85% of all sediment originates from areas classified in this WBP as Agricultural Lands (Table 46). The Poamoho Watershed alone produces 44% of the total sediments coming from areas classified as Agricultural Lands. Areas classified as Agricultural Lands are the main contributor of sediments in all six watersheds. The analysis also indicates that Forest Lands and Army Training Areas each contribute 7% of the total sediments, while Developed Areas only contribute 1%. Refer to Figure 30, "Percent of total Sediments Each Land Use Type Contributes by Watershed," for a visual representation of the data portrayed in Table 46.

- ***Key Finding: Agricultural Lands should be a top priority for implementing management measures to reduce sediments, especially in Poamoho Watershed.***

TABLE 46. PERCENT OF TOTAL SEDIMENT ORIGINATING IN THE FOUR LAND USE TYPES BY WATERSHED

General Land Use Type	Ki'iki'i	Kaukonahua	Poamoho	Paukauila	Helemano	'Ōpae'ula	Total
Forest Lands	0%	3%	1%	0%	2%	1%	**7%**
Agricultural Lands	1%	21%	44%	6%	10%	2%	**85%**
Army Training Areas	0%	7%	0%	0%	0%	0%	**7%**
Developed Areas	0%	1%	0%	0%	0%	0%	**1%**
TOTAL (rounded):	**1%**	**32%**	**45%**	**6%**	**13%**	**3%**	**100%**

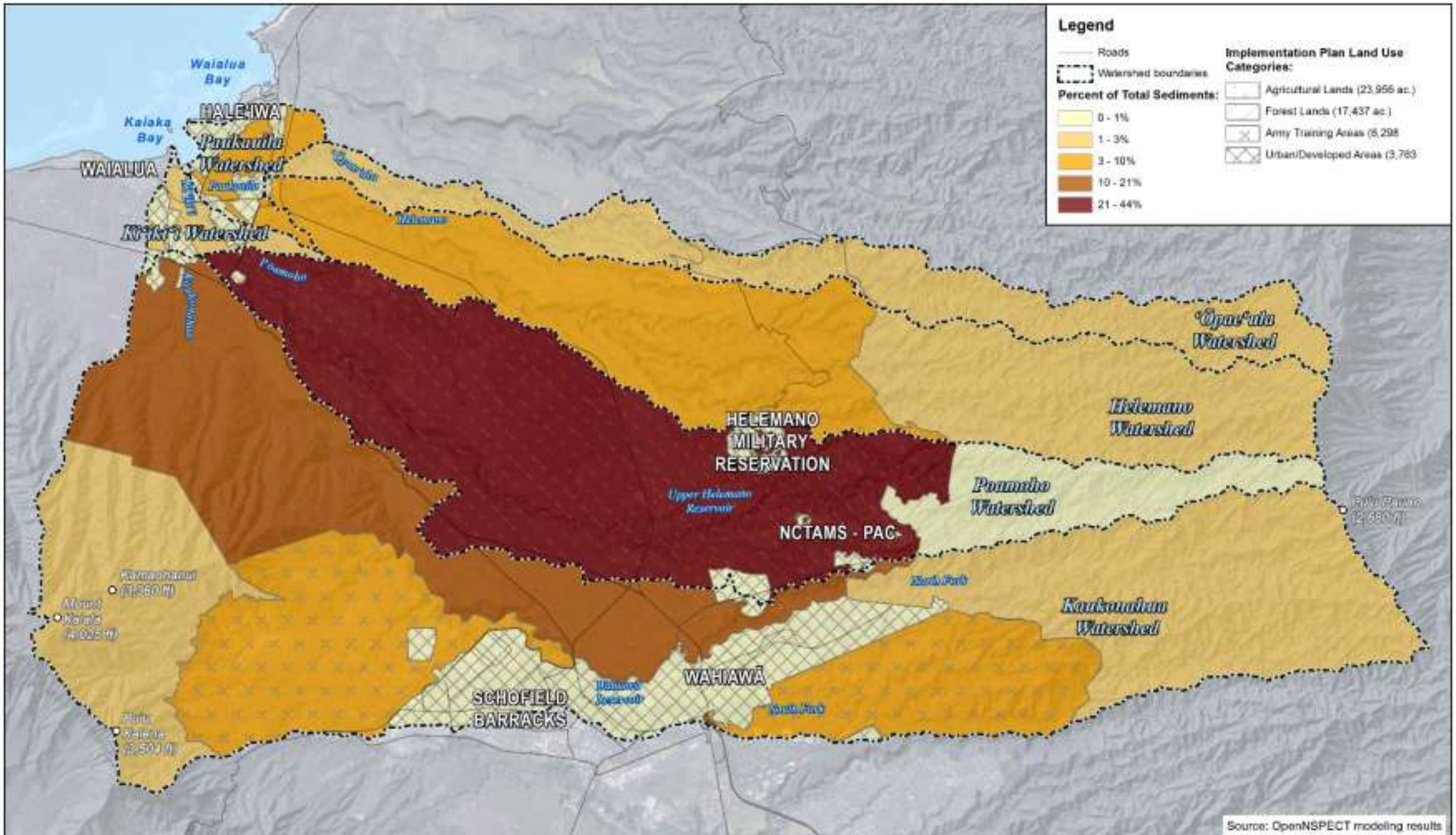
When looking at pounds of sediments produced per acre in each of the four land use types, the modeling results indicate that across all watersheds, areas classified as Agricultural Lands produce approximately 14 times more sediments per acre on average than Developed Areas, ten times more sediments per acre than Forest Lands, and four times more sediments per acre than Army Training Areas (derived from Table 47).

Agricultural Lands in the Paukauila Watershed produce more than twice as many pounds of sediments per acre than any other watershed (5.0 pounds per acre; Table 47). Agricultural Lands in the Poamoho Watershed have the second highest sediment generation per acre (2.0 pounds per acre). Refer to Figure 31 (Sediments Per Acre by Land Use Type in Each Watershed) for a visual representation of the data portrayed in Table 47.

- ***Key Finding: Agricultural Lands in Paukauila and Poamoho should be a priority for implementing management measures to reduce sediments.***

TABLE 47. SEDIMENT SOURCES BY LAND USE TYPE AND WATERSHED (POUNDS PER ACRE)

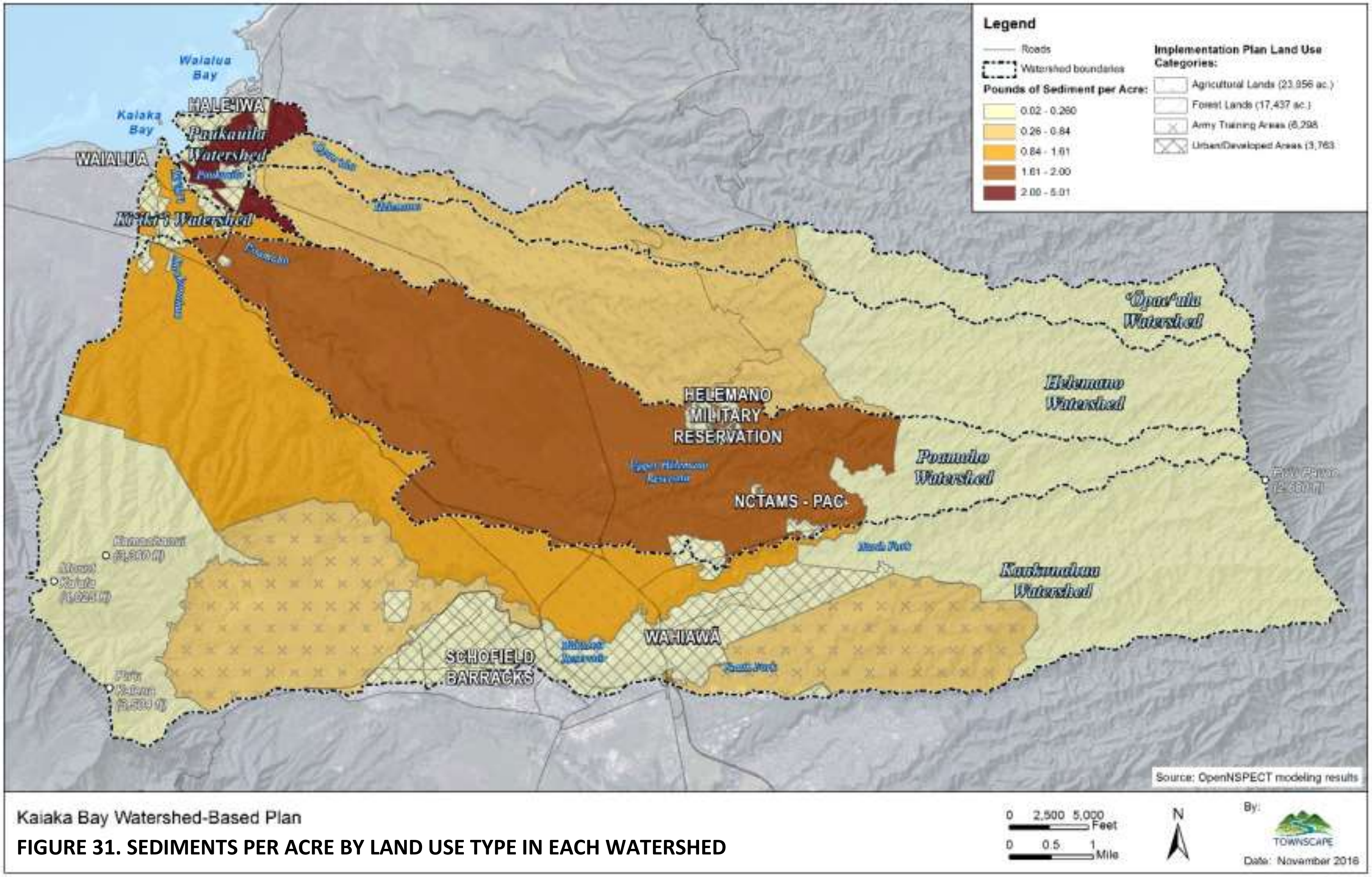
General Land Use Type	Ki'iki'i	Kaukonahua	Poamoho	Paukauila	Helemano	'Ōpae'ula
Forest Lands	*n/a*	0.1	0.1	*n/a*	0.2	0.3
Agricultural Lands	1.6	1.3	2.0	5.0	0.8	0.5
Army Training Areas	*n/a*	0.5	*n/a*	*n/a*	*n/a*	*n/a*
Developed Areas	0.2	0.1	0.1	0.2	0.2	0.0



Kaiaka Bay Watershed-Based Plan

FIGURE 30. PERCENT OF TOTAL SEDIMENTS EACH LAND USE TYPE CONTRIBUTES BY WATERSHED

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: November 2016



Kaiaka Bay Watershed-Based Plan

FIGURE 31. SEDIMENTS PER ACRE BY LAND USE TYPE IN EACH WATERSHED

7.3.2.2 NITROGEN

OpenNSPECT models nonpoint sources of pollutants such as nitrogen and phosphorus by assessing factors such as rainfall and landcover type. The results of the modeling for nitrogen indicate that the vast majority of the nitrogen that is generated in the Kaiaka Bay Watersheds comes from the forested areas in the Koʻolau range (Figure 32). The results also show that small amounts of nitrogen are produced in some of the developed areas in the central portions of the Poamoho and Kaukonahua watersheds.

Analysis of the modeling results indicate that Kiʻikiʻi Stream System generates over twice as much nitrogen that accumulates and flows into Kaiaka Bay than the Paukauila Stream System, however, the former is nearly three times larger than the latter, making the difference in nitrogen production per acre negligible (Kiʻikiʻi Stream System generates 0.10 kg/acre and Paukauila Stream System generates 0.12 kg/acre).

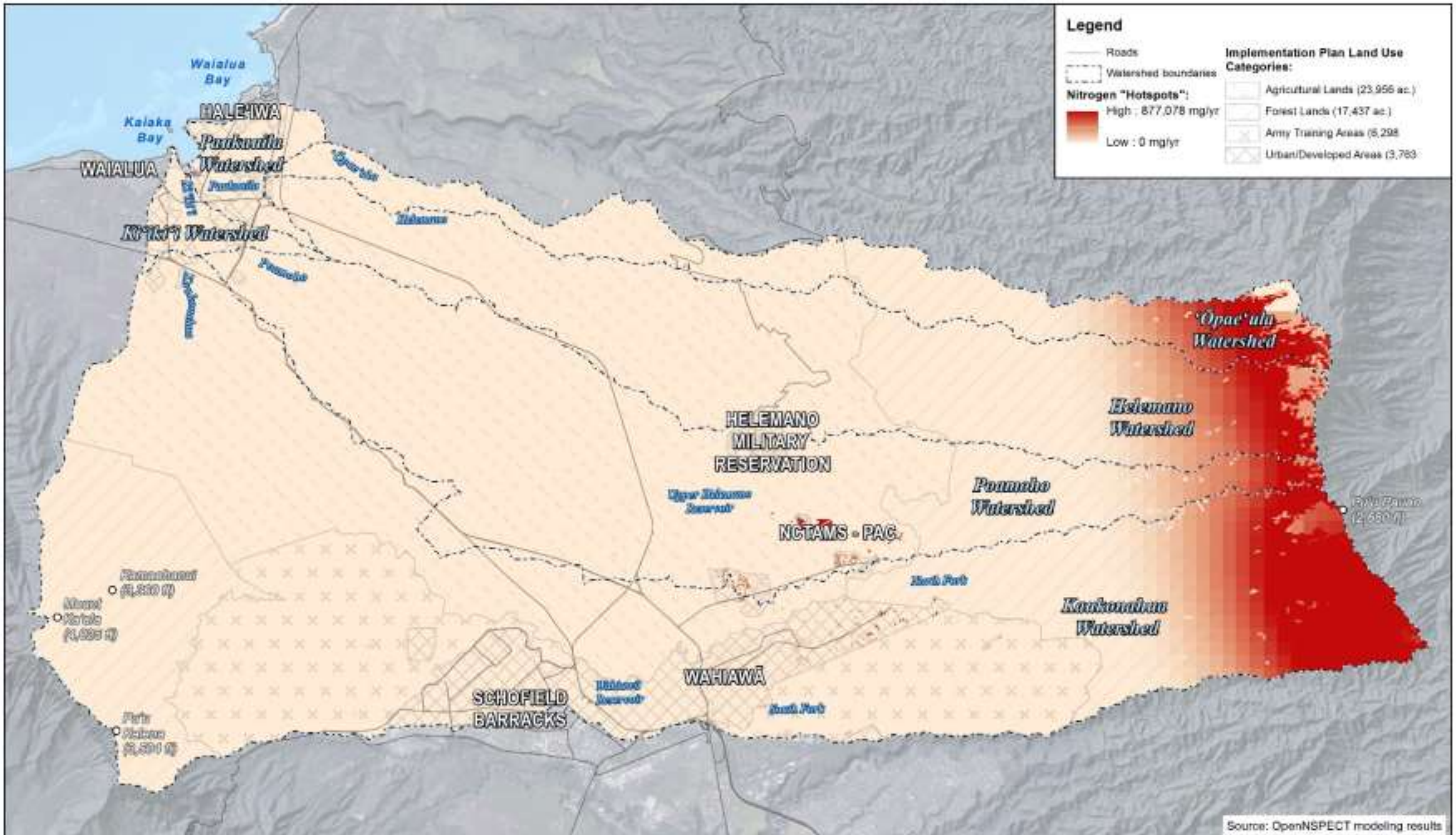
Assessing the modeling results by individual watershed shows that Kaukonahua Watershed generates the most nitrogen out of the six watersheds (64% of the total nitrogen for the entire project area; Table 48). The data indicate that Kaukonahua Watershed produces nearly four times more nitrogen than Helemano Watershed (which produces the second most nitrogen out of the six watersheds), and significantly more than the other watersheds. The reason Kaukonahua Watershed produces the most nitrogen is likely because it has the highest proportion of its total area classified in the C-CAP landcover dataset as “Evergreen Forest” (61% of the total watershed), which is associated with relatively high rates of nitrogen production, especially in areas of high rainfall (such as the Koʻolau summit). Refer to Table 49 for the analysis of the C-CAP landcover types.

When examining nitrogen sources by milligrams per acre, ʻŌpaeʻula Watershed produces the most nitrogen per acre (189,913 mg/acre), followed by Kaukonahua Watershed (144,777 mg/acre; Table 48). The reason ʻŌpaeʻula and Kaukonahua watersheds produce the most nitrogen per acre is likely that they have the highest proportion of their total area as classified as “Evergreen Forests,” as determined by the C-CAP landcover data.

- ***Key Finding: Kaukonahua, Helemano, and ʻŌpaeʻula watersheds should all be priorities for implementing management measures to reduce nitrogen.***

TABLE 48. NITROGEN ORIGINATING IN EACH WATERSHED

Stream System	Watershed	Percent of Total Nitrogen Coming from Each Watershed	Mg per Acre
Kiʻikiʻi	Kiʻikiʻi	0.004%	392
	Kaukonahua	63.9%	144,777
	Poamoho	6.2%	30,476
Paukauila	Paukauila	0.001%	89
	Helemano	17.2%	104,690
	ʻŌpaeʻula	12.7%	189,913
	Total:	**100%**	*n/a*



Kaiaka Bay Watershed-Based Plan

FIGURE 32. MODELING RESULTS – NITROGEN SOURCES

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: November 2016

The results of the model can be assessed by the default C-CAP landcover classes that are used by the model to determine trends in pollutant loads originating in the different landcover types. Areas classified with landcover type called “Evergreen Forest” produce 94% of all nitrogen in the Kaiaka Bay Watersheds (Table 49), however, it is very important to note that while “Evergreen Forest” can be found in both the Waiʻanae range and the Koʻolau range, all or almost all nitrogen originates on the Koʻolau side likely because of high rainfall and increased runoff (refer to Figure 32 on previous page). The “Evergreen Forest” landcover type also produces the most nitrogen per acre (Table 49).

Land classified as “Evergreen Forest” covers 53% of the total project area (27,406 acres). Kaukonahua Watershed has by far the most area classified as “Evergreen Forest” (15,236 acres or 61% of the watershed). Poamoho, Helemano, and ʻŌpaeʻula watersheds have considerably less acreage, but still have a large percentage of their total area classified as “Evergreen Forest” (30%, 62%, and 73%, respectively). Kiʻikiʻi and Paukauila watersheds have comparatively very little “Evergreen Forest.”

Areas classified with the C-CAP landcover type “Scrub/Shrub” produce 5% of all nitrogen in the project area. This landcover type covers 9% of the total project area, however, it is again very important note that all or almost all nitrogen originates in the Koʻolau range and not the Waiʻanae range (refer to Figure 32 on previous page).

The three types of developed areas in the C-CAP dataset produce a combined 1% of all nitrogen. High, medium, and low intensity developed areas cover 8% of the total project area (4,251 acres). Kaukonahua Watershed has the most developed land (2,722 acres or 11% of total watershed), however, Kiʻikiʻi and Paukauila watersheds have the largest percentage of their total areas classified as developed (37% and 34%, respectively).

- ***Key Finding: The protection and management of the forests of the Koʻolau range should be a priority to prevent increased nitrogen-rich runoff (applicable watersheds include Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula).***

TABLE 49. NITROGEN PRODUCED IN EACH C-CAP LANDCOVER TYPE

C-CAP Landcover Class	Mg per Acre	Percent of Total Nitrogen Coming from Each Class
Developed, High Intensity	36,467	0.4%
Developed, Medium Intensity	15,528	0.3%
Developed, Low Intensity	4,585	0.2%
Open Spaces Developed	4,741	0.1%
Cultivated Land	9	0.001%
Grassland	143	0.01%
Evergreen Forest	194,741	93.6%
Scrub/Shrub	65,899	5.4%
Palustrine Forested Wetland	0	0%
Palustrine Scrub/Shrub Wetland	0	0%
Palustrine Emergent Wetland	0	0%
Estuarine Forested Wetland	0	0%
Unconsolidated Shore	0	0%
Bare Land	387	0.001%
Water	294	0.001%
Total (rounded):	**n/a**	**100 %**

In examining differences in sources of nitrogen between the four general land use types defined for this WBP (Forest Lands, Agricultural Lands, Developed Areas, and Army Training; refer to Table 43 and Figure 28 in section 7.3.1), the results of the model indicate that 99% of all nitrogen in the Kaiaka Bay Watersheds originates from Forest Lands (Table 50). Forest Lands in the Kaukonahua Watershed alone produce 63% of all nitrogen; Forest Lands in all watersheds are the main source of nitrogen. Again, it should be noted that while "Forest Lands" occur in both the Waiʻanae range and the Koʻolau range, all or almost all nitrogen originates on the Koʻolau side (refer to Figure 32).

The analysis also indicates that Developed Areas contribute 1% of the total nitrogen and the other two land use types contribute a negligible amount. Unlike the sediments analysis, no additional maps are necessary to show sources of nitrogen since the original data (presented in Figure 32) is clear and easy to interpret.

- ***Key Finding: Forest Lands in the Koʻolau range should be a top priority for implementing management measures to reduce nitrogen, especially in Kaukonahua Watershed.***

TABLE 50. PERCENT OF TOTAL NITROGEN ORIGINATING IN THE FOUR LAND USE TYPES BY WATERSHED

General Land Use Type	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula	Total
Forest Lands	0%	63.4%	5.7%	0%	17.2%	12.7%	**99%**
Agricultural Lands	0.0004%	0.01%	0.3%	0.0005%	0.005%	0.0005%	**0%**
Army Training Areas	0%	0.07%	0%	0%	0%	0%	**0%**
Developed Areas	0.004%	0.4%	0.3%	0.0008%	0.004%	0.00003%	**1%**
TOTAL (rounded):	**0%**	**64%**	**6%**	**0%**	**17%**	**13%**	**100%**

When looking at the quantity of nitrogen produced per acre in each of the four land use types, the modeling results indicate that across all watersheds, areas classified as Forest Lands produce exponentially more nitrogen per acre than the other three land use types (Table 51). Forest Lands in Kaukonahua Watershed produce the most nitrogen per acre out of the six watersheds (392,448 mg/acre). Forest Lands in ʻŌpaeʻula Watershed have second highest nitrogen production rate (341,938 mg/acre), followed by Forest Lands in the Helemano and Poamoho Watersheds. Developed Areas in the Poamoho Watershed have the highest nitrogen production rate among Developed Areas in the other watersheds; these areas include the Helemano Military Reservation, JBPHH-Wahiawā Annex, and the area around the Dole Visitors' Center.

Again, no additional map is presented for this analysis since the original data (presented in Figure 32) is clear and easily interpreted.

- ***Key Finding – Same as Previous: Forest Lands in the Koʻolau range should be a top priority for implementing management measures to reduce nitrogen, especially in Kaukonahua Watershed.***

- ***Key Finding: Developed Areas should also be considered a source of nitrogen, with a priority on developed areas in the Poamoho Watershed.***

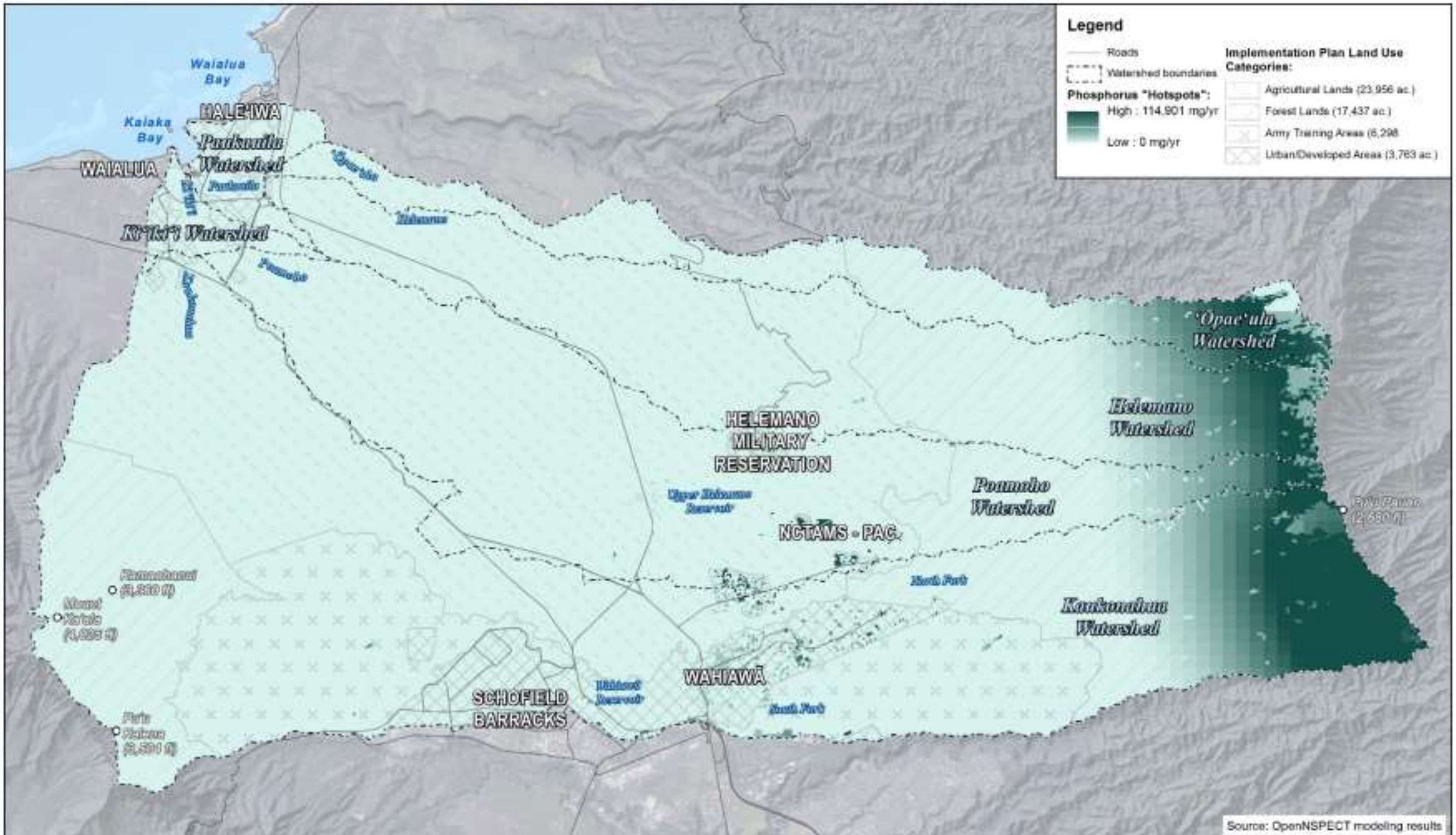
TABLE 51. NITROGEN SOURCES BY LAND USE TYPE AND WATERSHED (MILLIGRAMS PER ACRE)

General Land Use Type	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula
Forest Lands	*n/a*	392,448	160,736	*n/a*	239,401	341,937
Agricultural Lands	59	95	1,563	58	50	17
Army Training Areas	*n/a*	624	*n/a*	*n/a*	*n/a*	*n/a*
Developed Areas	854	7,370	51,915	140	5,841	230

7.3.2.3 PHOSPHORUS

OpenNSPECT models nonpoint sources of phosphorus by assessing factors such as rainfall and landcover type. The results of the modeling for phosphorus are very similar to the results for nitrogen: the clear majority of the phosphorus in the watersheds originates in the forested areas in the Koʻolau range (Figure 33). The results also show that small amounts of phosphorus are produced in some of the developed areas in the central portions of the Poamoho and Kaukonahua watersheds.

Analysis of the modeling results indicate that Kiʻikiʻi Stream System generates two and a half times as much phosphorus that accumulates and flows into Kaiaka Bay than the Paukauila Stream System, however, the former is nearly three times larger than the latter, making the difference in phosphorus production per acre negligible (Kiʻikiʻi Stream System generates 0.004 kg/acre and Paukauila Stream System generates 0.005 kg/acre).



Kaiaka Bay Watershed-Based Plan

FIGURE 33. MODELING RESULTS – PHOSPHORUS SOURCES

0 2,500 5,000 Feet
0 0.5 1 Mile
N
By: TOWNSCAPE
Date: November 2016

Assessing the modeling results by individual watershed shows that Kaukonahua Watershed generates the most phosphorus out of the six watersheds (63% of the total phosphorus for the entire project area; Table 52). The data indicate that Kaukonahua Watershed produces nearly four times more phosphorus than Helemano Watershed (which produces the second most phosphorus out of the six watersheds), and significantly more than the other watersheds. The reason Kaukonahua Watershed produces the most phosphorus is likely because it has the highest proportion of its total area classified in the C-CAP landcover dataset as “Evergreen Forest” (61% of the total watershed), which is associated with relatively high rates of phosphorus production, especially in areas of high rainfall (such as the Koʻolau summit). Refer to Table 53 for the analysis of the C-CAP landcover types.

When examining phosphorus sources by milligrams per acre, ʻŌpaeʻula Watershed produces the most phosphorus per acre (7,620 mg/acre), followed by Kaukonahua Watershed (5,961 mg/acre; Table 52). The reason ʻŌpaeʻula and Kaukonahua watersheds produce the most phosphorus per acre is likely that they have the highest proportion of their total area as classified as “Evergreen Forests,” as determined by the C-CAP landcover data.

- ***Key Finding: Kaukonahua, Helemano, and ʻŌpaeʻula watersheds should all be priorities for implementing management measures to reduce phosphorus.***

TABLE 52. PHOSPHORUS ORIGINATING IN EACH WATERSHED

Stream System	Watershed	Percent of Total Phosphorus Coming from Each Watershed	Mg per Acre
Kiʻikiʻi	Kiʻikiʻi	0.02%	83
	Kaukonahua	63.0%	5,961
	Poamoho	8.3%	1,683
Paukauila	Paukauila	0.01%	19
	Helemano	16.5%	4,195
	ʻŌpaeʻula	12.2%	7,620
	Total:	**100%**	*n/a*

The results of the model can be assessed by the default C-CAP landcover classes that are used by the model to determine trends in pollutant loads originating in the different landcover types. Areas classified with landcover type called “Evergreen Forest” produce 90% of all phosphorus in the Kaiaka Bay Watersheds (Table 53), however, it is very important to note that while “Evergreen Forest” can be found in both the Waiʻanae range and the Koʻolau range, all or almost all phosphorus originates on the Koʻolau side, likely because of high rainfall and increased runoff (refer to Figure 33 on previous page). The “Evergreen Forest” landcover type also produces the most phosphorus per acre (Table 53).

Land classified as “Evergreen Forest” covers 53% of the total project area (27,406 acres). Kaukonahua Watershed has by far the most area classified as “Evergreen Forest” (15,236 acres or 61% of the watershed). Poamoho, Helemano, and ʻŌpaeʻula watersheds have considerably less acreage, but still have a large percentage of their total area classified as “Evergreen Forest” (30%, 62%, and 73%, respectively). Kiʻikiʻi and Paukauila watersheds have comparatively very little “Evergreen Forest.”

Areas classified with the C-CAP landcover type “Scrub/Shrub” produce 5% of all phosphorus in the project area. This landcover type covers 9% of the total project area, however, it is again very important note that all or almost all phosphorus originates in the Koʻolau range and not the Waiʻanae range (refer to Figure 33).

The three types of developed areas in the C-CAP dataset produce a combined 5% of all phosphorus. High, medium, and low intensity developed areas cover 8% of the total project area (4,251 acres). Kaukonahua Watershed has the most developed land (2,722 acres or 11% of total watershed), however, Kiʻikiʻi and Paukauila watersheds have the largest percentage of their total areas classified as developed (37% and 34%, respectively).

- ***Key Finding: The protection and management of the forests of the Koʻolau range should be a priority to prevent increased phosphorus-rich runoff (applicable watersheds include Kaukonahua, Poamoho, Helemano, and ʻŌpaeʻula).***

- ***Key Finding: Developed areas should also be considered a source of phosphorus.***

TABLE 53. PHOSPHORUS PRODUCED IN EACH C-CAP LANDCOVER TYPE

C-CAP Landcover Class	Mg per Acre	Percent of Total Phosphorus Coming from Each Class
Developed, High Intensity	7,705	1.9%
Developed, Medium Intensity	3,268	1.7%
Developed, Low Intensity	950	1.0%
Open Spaces Developed	990	0.3%
Cultivated Land	2	0.01%
Grassland	30	0.1%
Evergreen Forest	7,799	89.8%
Scrub/Shrub	2,657	5.2%
Palustrine Forested Wetland	0	0%
Palustrine Scrub/Shrub Wetland	0	0%
Palustrine Emergent Wetland	0	0%
Estuarine Forested Wetland	0	0%
Unconsolidated Shore	0	0%
Bare Land	52	0.004%
Water	38	0.005%
Total (rounded):	**n/a**	**100%**

In examining differences in sources of phosphorus between the four general land use types defined for this WBP (Forest Lands, Agricultural Lands, Developed Areas, and Army Training; refer to Table 43 and Figure 28 in section 7.3.1), the results of the model indicate that 95% of all phosphorus in the Kaiaka Bay Watersheds originates from Forest Lands (Table 54). Forest Lands in the Kaukonahua Watershed alone produce 61% of all phosphorus; Forest Lands in all watersheds are the main source of phosphorus. Again, it should be noted that while "Forest Lands" occur in both the Waiʻanae range and the Koʻolau range, all or almost all nitrogen originates on the Koʻolau side (refer to Figure 33).

The analysis also indicates that Developed Areas contribute 3% of the total phosphorus, Agricultural Lands contribute 1%, and Army Training Areas contribute a negligible amount. Like the nitrogen analysis, no additional maps are necessary to show sources of phosphorus since the original data (presented in Figure 33) is clear and easy to interpret.

- ***Key Finding: Forest Lands in the Koʻolau range should be a top priority for implementing management measures to reduce phosphorus, especially in Kaukonahua Watershed.***

TABLE 54. PERCENT OF TOTAL PHOSPHORUS ORIGINATING IN THE FOUR LAND USE TYPES BY WATERSHED

General Land Use Type	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula	Total
Forest Lands	0%	60.8%	5.5%	0%	16.5%	12.2%	**95%**
Agricultural Lands	0.002%	0.1%	1.3%	0.003%	0.02%	0.003%	**1%**
Army Training Areas	0%	0.3%	0%	0%	0%	0%	**0%**
Developed Areas	0.02%	1.8%	1.5%	0.004%	0.02%	0%	**3%**
TOTAL (rounded):	**0%**	**63%**	**8%**	**0%**	**16%**	**12%**	**100%**

When looking at the quantity of phosphorus produced per acre in each of the four land use types, the modeling results indicate that across all watersheds, areas classified as Forest Lands produce exponentially more phosphorus per acre than the other three land use types (Table 55). Forest Lands in Kaukonahua Watershed produce the most phosphorus per acre out of the six watersheds (15,706 mg/acre). Forest Lands in ʻŌpaeʻula Watershed have second highest phosphorus production rate (13,717 mg/acre). Developed Areas in the Poamoho Watershed have the third highest phosphorus production rate (10,986 mg/acre); these areas include the Helemano Military Reservation, JBPHH-Wahiawā Annex, and the area around the Dole Visitors' Center.

Again, no additional map is presented for this analysis since the original data (presented in Figure 33) is clear and easily interpreted.

- ***Key Finding – Same as Previous: Forest Lands in the Koʻolau range should be a top priority for implementing management measures to reduce phosphorus, especially in Kaukonahua Watershed.***

- ***Key Finding: Developed Areas should also be considered a source of phosphorus, with a priority on developed areas in the Poamoho Watershed.***

TABLE 55. PHOSPHORUS SOURCES BY LAND USE TYPE AND WATERSHED (MILLIGRAMS PER ACRE)

General Land Use Type	Kiʻikiʻi	Kaukonahua	Poamoho	Paukauila	Helemano	ʻŌpaeʻula
Forest Lands	*n/a*	15,706	6,440	*n/a*	9,576	13,717
Agricultural Lands	12	20	325	12	8	4
Army Training Areas	*n/a*	113	*n/a*	*n/a*	*n/a*	*n/a*
Developed Areas	180	1,557	10,986	30	1,237	49

7.3.3 Summary of Key Findings from Modeling

The "Key Findings" from the results of the modeling that were presented in the previous section are synthesized and summarized below. These summaries of the modeling results will be used in the following sections help to prioritize watersheds and areas with specific watersheds for management measures to reduce specific pollutants.

7.3.3.1 Erosion & Sediments

There were five "Key Findings" for the assessment of the modeling results for sediments (Section 7.3.2.1). These findings are summarized as follows:

- Areas with bare ground should be a top priority for implementing management measures to reduce sediments, especially in Kaukonahua and Poamoho watersheds.
- Agricultural areas should be a top priority for implementing management measures to reduce sediments, especially in Poamoho, Kaukonahua, Paukauila, and Kiʻikiʻi watersheds (in approximate order of priority).

7.3.3.2 Nutrients – Nitrogen & Phosphorus

There were five "Key Findings" for the assessment of the modeling results for nitrogen (Section 7.3.2.2) and six "Key Findings" for the assessment of the modeling results for phosphorus (Section 7.3.2.3). Since these findings showed similar trends and the sources of both nutrients are essentially the same, the findings for both nitrogen and phosphorus are summarized as follows:

- Kaukonahua, Helemano, and ʻŌpaeʻula watersheds should all be priorities for implementing management measures to reduce nitrogen and phosphorus.
- The protection and management of the forests of the Koʻolau range should be a priority to prevent increased nutrient-rich runoff (applicable watersheds include Kaukonahua [top priority], Poamoho, Helemano, and ʻŌpaeʻula).
- Developed Areas should also be considered a source of nutrients, with a priority on developed areas in the Poamoho Watershed.

7.4 Pollutant Source Assessment

The pollutant source assessment presented in this section is a synthesis of the data and information presented in previous sections of this document. On the next page, a synthesis of the known pollutants (discussed in Chapter 5) and the known or suspected sources of those pollutants (discussed in sections 7.1 and 7.2) for each watershed is presented (Table 56). This information, along with the insight gained from the stakeholder outreach process (Chapter 6), the Geomorphic Assessment of Poamoho Stream (AECOM, 2016; Appendix A), and the results of the modeling (Section 7.3), provide a framework for understanding the major water quality issues in each watershed.

The goal of this section is to assess the information to present a summary of management priorities by watershed. This prioritization is utilized in *Volume 2: Implementation Plan* for identifying implementation strategies to most effectively reduce overall pollutant-loading and ultimately improve water quality in Kaiaka Bay.

TABLE 56. SUMMARY OF POLLUTANTS AND POLLUTANT SOURCES BY WATERSHED

Stream System	Watershed	Known Pollutants	Primary Pollutant Sources – Point Source (PS) and Nonpoint Source (NPS) PS (Known)	NPS (Known or Suspected)
Ki'iki'i	**Ki'iki'i**	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• City MS4*	• Natural erosion processes • Agriculture (soil loss and nutrient/chemical application) • Cesspools and other on-site sewage disposal systems (OSDS) • Urban chemical use • Urban stormwater runoff • Impacts of climate change
	Kaukonahua	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Trash • Chemical contaminants	• Wahiawā WWTP** • City MS4* • Army MS4* • Navy MS4* • State Dept. of Transportation (DOT) MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Cesspools and other OSDS • Urban chemical use • Urban stormwater runoff • Superfund sites and other hazardous waste • Army training • Impacts of climate change
	Poamoho	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• Army MS4* • State DOT MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Soil loss from wildfires • Motorized recreational activities • Superfund sites and other hazardous waste • Impacts of climate change

- Table continued on next page -

TABLE 56. SUMMARY OF POLLUTANTS AND POLLUTANT SOURCES BY WATERSHED (CONTINUED)

Stream System	Watershed	Known Pollutants	Primary Pollutant Sources – Point Source (PS) and Nonpoint Source (NPS)	
			PS (Known)	NPS (Known or Suspected)
Paukauila	**Paukauila**	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Chemical contaminants	• City MS4* • State DOT MS4*	• Natural erosion processes • Agriculture (soil loss and nutrient/chemical application) • Cesspools and other OSDS • Pa'ala'a Kai Wastewater Treatment Plant (injection well) • Urban chemical use • Urban stormwater runoff • Impacts of climate change
	Helemano	• Nutrients • Sediments (turbidity) • Fecal indicator bacteria • Possible chemical contaminants	• Army MS4* • State DOT MS4*	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Motorized recreational activities • Impacts of climate change
	ʻŌpaeʻula	• Nutrients • Sediments (turbidity)	• N/A	• Natural erosion processes • Nonnative & invasive plants and feral ungulates • Agriculture (soil loss and nutrient/chemical application) • Grazing • Soil loss from wildfires • Impacts of climate change

** MS4 = Municipal Separate Storm Sewer System*

*** WWTP = Wastewater Treatment Plant*

7.4.1 Prioritization of Watersheds for Pollutant Load Reduction

While all pollutant sources can contribute to the degradation of water quality, prioritizing the Kaiaka Bay Watersheds for management actions by key pollutant types is helpful to identify the best strategies to most effectively reduce the overall pollutant source contributions and ultimately improve water quality in Kaiaka Bay. The prioritization for pollutant load reductions in specific watersheds should not prohibit the procurement of funding to implement projects in watersheds that were not deemed "priority," since implementing a project in any applicable watershed will have positive effects on water quality.

Measurably reducing sediments, erosion, and nutrients is an important goal of this WBP (refer to section 1.2). In addition, other types of pollutants (e.g. pesticides, hydrocarbons, pathogens, metals, etc.) should be addressed as opportunities arise or as future needs indicate necessary. Accordingly, the prioritization of specific watersheds for each of these key pollutant types is broken down into the four main land use types (Forest Lands, Agricultural Lands, Developed Areas, and Army Training Areas) to provide a framework for recommending implementation strategies (presented in *Volume 2: Implementation Plan*). Under each land use type, specific hotspots that are known or suspected to generate that pollutant are described. A "hotspot" for pollution is essentially an area that is known or suspected to generate/ transport pollutants. Since determining the locations of all hotspots in the Kaiaka Bay Watersheds is not feasible in this project, the hotspots are described in terms of physical characteristics that can be used to assess individual locations on a case-by-case basis. The list of hotspots for each land use type should not be considered exhaustive; there are undoubtedly other pollution source hotspots that are not listed below.

7.4.1.1 Sediments & Turbidity

The modeling results indicate that Poamoho Watershed contributes the most sediments overall compared to the other watersheds, while Paukauila Watershed produces the most sediments per acre, followed by Kiʻikiʻi Watershed (Section 7.3.2.1). However, when examining the data as they pertain to different land use types within the project area, priorities can be established at a finer scale.

Forest Lands

Factors that contribute to erosion and sedimentation in Forest Lands include feral ungulate activity, wildfires, ecosystem degradation due to nonnative and invasive plants, and natural erosion processes (which are exacerbated when there is high rainfall, steep slopes, and/or highly erodible soil types). Natural erosion processes in the mountainous Forest Lands are known to be a significant source of sediments and turbidity in streams as well as areas that are degraded by invasive flora and fauna (see section 7.2). The geomorphology report concluded that natural erosion processes that occur in streambeds in Forest Lands are a significant source of sediments (AECOM, 2016; Appendix A). However, the modeling results indicated that the area classified as Forest Lands in this WBP only produces 7% of the total sediments in the project area, however, the selected model (OpenNSPECT) does not model erosion caused by instream flow. Taken together, this information indicates that Forest Lands should not be overlooked as a significant source of sediments in the Kaiaka Bay Watersheds.

Hotspots for erosion and sedimentation in Forest Lands include one or more of the following characteristics:

- Areas with little to no ground cover (exposed soils) as a direct result of human or feral pig activity;
- Degraded ecosystems that are especially susceptible to erosion and/or wildfire (e.g. areas that are dominated by nonnative species and experience high rainfall, have highly erodible soils, or steep slopes);
- Stream channels subject to natural erosion (note that it may be difficult to implement practices to prevent to reduce erosion in these locations); or
- Access roads and hiking trails.

Areas with exposed soil in steep, forested areas can be upstream sources of erosion and sediments in watersheds (Forest Lands of the Poamoho Watershed pictured)

The highest priority hotspots within Forest Lands are areas where the soils have been exposed because of human activity, animal activity, or natural causes and are therefore more prone to erosion during a rainfall event. The model showed that areas classified as "bare ground" produce 28 times more sediments than areas classified as "scrub/shrub" and 43 times more than areas classified as "evergreen forest." It is also well understood that ecosystems that are dominated by nonnative flora and fauna are generally degraded and are more prone to erosion than areas that are native-dominated.

Note that in addition to implementing practices in the hotspots described above, it is it is perhaps equally important to protect the most native-dominated ecosystems from further degradation and erosion. These "healthy" areas of the watersheds include the native-dominated high elevation forests in the Koʻolau range (the entire summit area) and the Mt. Kaʻala in the Waiʻanae range.

Priority watersheds for controlling sediments in Forest Lands include all four of the applicable watersheds, since each watershed presents opportunities for implementing important management practices to address erosion/sedimentation. Therefore, the priority watersheds include:

- Kaukonahua Watershed;
- Poamoho Watershed;
- Helemano Watershed; and
- ʻŌpaeʻula Watershed.

Agricultural Lands

Agricultural areas have been found to be a major source of suspended sediments in watersheds on Oʻahu, including in the Kaiaka Bay Watersheds (see sections 7.2.1.3 and 7.2.4). The results of the modeling also indicated that Agricultural Lands are the main source of sediments in the Kaiaka Bay Watersheds, producing 85% of the total sediments and significantly more sediments per acre than the other land use types. Therefore, reducing erosion and preventing sedimentation in agricultural areas is very important to improve overall water quality.

Nonpoint source pollution of sediments in Agricultural Lands likely results from agricultural practices including soil manipulation, poorly maintained field roads, grazing, wildfires, ecosystem degradation due to nonnative and invasive plants, and natural erosion processes (which are exacerbated when there are steep slopes and/or highly erodible soil types). Livestock grazing can also contribute to erosion, especially along waterways or in steeper areas. Point sources of sediments include the State DOT-HWYS MS4 outfalls that are located along the highways that run through the Agricultural Lands, however, discussions related to pollutants from MS4s are more applicable to Developed Areas since the MS4 collects stormwater from roadways.

Hotspots for erosion and sedimentation in Agricultural Lands include one or more of the following characteristics:

- Areas with a significant amount of bare/exposed soil (including fields and access roads);
- Areas without adequate practices to control erosion and runoff from fields and field access roads;
- Field access roads with steep topographical grades (may have a higher potential for rapid transport of sediments via runoff from an adjacent area);
- Field access roads that cross over or are adjacent to drainages;
- Field access roads with eroding shoulders;
- Areas that are dominated by nonnative species that are especially susceptible to wildfire (e.g. areas dominated by nonnative grasses);
- Areas that are dominated by nonnative species and have highly erodible soils or steep slopes;
- Areas located adjacent to or containing waterways/streams;
- Pasturelands located in areas with steeper topographical grades (more prone to erosion) or near stream channels;
- Stream channels subject to natural erosion processes; or
- MS4 outfalls that empty into stream channels and have evidence of extensive erosion.

The highest priority hotspots within Agricultural Lands are large areas with exposed soil, including field access roads and fields with recently disturbed soils. These hotspots are characterized by exposed soil with little to no ground cover to reduce erosion by wind and rain. The model showed that areas classified as “bare ground” produce three times more sediments per acre than areas classified as “cultivated land” and 11 times more than areas classified as “grasslands.” Poamoho Watershed had the most area classified as “bare ground” within the Agricultural Lands.

While all six watersheds have agricultural land, the analyses of the modeling results indicate that the priority watersheds for implementing management measures to reduce sediments in Agricultural Lands include:

- Poamoho Watershed;
- Kaukonahua Watershed;
- Paukauila Watershed; and
- Ki'iki'i Watershed.

DEVELOPED AREAS

Analysis of the modeling results for sediments shows that Developed Areas in the Kaiaka Bay Watersheds are not a major source of sediments (contributing 1% of the total sediments); however, it should be noted that OpenNSPECT only models rill and sheet erosion and therefore may overlook other significant sources of sediments in urban areas, such as stream channel erosion caused by instream flows or the effects of stormwater drainage systems, stream diversions, and other man-made hydrological alterations. It is well documented that stormwater runoff in urban areas can transport sediments from areas with exposed soils such as landscaping projects or constructions sites as well as from roadways and other impervious surfaces into nearby waterways. Point sources of sediments in the Developed Areas of the Kaiaka Bay Watersheds include the City MS4, State DOT-HWYS MS4, the Navy's MS4, and the Army's MS4. Additionally, the Wahiawā WWTP and, to a lesser degree, the Schofield WWTP are also potential point sources of sediments and turbidity (effluent from the latter does not typically enter a surface waterbody directly).

Hotspots for erosion and sedimentation in Developed Areas include one or more of the following characteristics:

- Unstabilized construction sites;
- Unstabilized landscaping projects;
- Unstabilized developed open spaces (e.g. beach park erosion);
- Other areas with bare/exposed soil;
- Areas with large amounts of impervious surfaces and no stormwater filtration system;
- Road crossings (i.e. bridges) over streams and waterways;
- Stream channels subject to natural erosion processes; or
- MS4 outfalls that empty into stream channels and have evidence of extensive erosion.

The highest pollutant priority hotspots within Developed Areas are locations with exposed soil that are actively eroding or have high erosion potential due to anthropogenic land alteration, activities, and land use. These areas are characterized by exposed soil with little to no ground cover to reduce erosion by wind and rain. The model showed that areas classified as "bare ground" produce on average 35 times more sediments per acre than areas classified as "developed" by the C-CAP dataset, however, there is not a lot of area classified as "bare ground" within the land classified as Developed Areas in this WBP.

Since the modeling results did not show any dramatic differences in sediment output from Developed Areas between the six watersheds, the priority watersheds for controlling sediments in Developed Areas are the watersheds that have the most land area in this land use class. Therefore, the priority watersheds for controlling sediments in Developed Areas include:

- Kaukonahua Watershed;
- Paukauila Watershed;
- Poamoho Watershed; and

- Kiʻikiʻi Watershed.

ARMY TRAINING AREAS

Analysis of the modeling results for sediments shows that areas classified in this WBP as Army Training Areas contributing 7% of the total sediments for the project area. A large portion of the sediments generated in Army Training Areas are likely coming from areas of exposed soil. An area classified as "bare ground" by the C-CAP dataset used in the model is located in Schofield Barracks West Range, in the Kaukonahua Watershed. The Kaukonahua Watershed has the most area classified as "bare ground" out of any other watershed, most of which located in the Army Training Area.

Hotspots for erosion and sedimentation in Army Training Areas include one or more of the following characteristics:

- Areas with little to no ground cover (exposed soils) as a result of prescribed burns or training activities;
- Unstabilized construction or training areas;
- Access roads and trails, especially those with steep topographical grades (may have a higher potential for rapid transport of sediments via runoff from an adjacent area);
- Helicopter landing zones with unstabilized soils;
- Road crossings (i.e. bridges) over streams and waterways;
- Areas that are dominated by nonnative species and are especially susceptible to wildfire (e.g. areas dominated by invasive grasses);
- Areas that are dominated by nonnative species and have highly erodible soils or steep slopes;
- Stream channels subject to natural erosion processes;
- Degraded ecosystems that are especially susceptible to erosion and/or wildfire (e.g. areas that are dominated by nonnative species and experience high rainfall, have highly erodible soils, or steep slopes); or
- Areas where Army training activities could cause a fire.

There is only one watershed with land that is classified in the Army Training Area land type, therefore, the priority watershed for reducing sediments in this land use type is Kaukonahua Watershed.

7.4.1.2 NUTRIENTS – NITROGEN & PHOSPHORUS

Nutrients can bind to soil particles be transported and deposited in new areas where they can accumulate (Oki and Brasher, 2003). For example, phosphorus is strongly adsorbed to silt and clay particles, so consequently, total phosphorus concentrations generally increase with increasing suspended-sediment concentrations in Hawaiʻi. Therefore, hotspots for erosion and sediment generation can sometimes be the same as hotspots for nutrient generation and transport.

Since the results of the modeling for nitrogen and phosphorus showed similar trends and indicated that the sources of the nutrients are essentially the same, the priorities for implementing management measures to reduce both nitrogen and phosphorus are described together.

The modeling results indicate that Kaukonahua Watershed contributes the most nitrogen and phosphorus overall (sections 7.3.2.2 and 7.3.2.3). However, this is likely related the fact the Kaukonahua Watershed is the largest and has the largest proportion of land classified as "evergreen forest" by the C-

CAP dataset, which is associated with relatively high rates of nitrogen production compared to other landcover classes, especially in areas of high rainfall (such as the Koʻolau summit).

As with sediments, priorities for implementing management measures to reduce nutrients can be established at a finer scale when examining the data as they pertain to different land use types within the project area.

FOREST LANDS

Sources of nutrients in Forest Lands can include natural sources that cannot be controlled (e.g. nitrogen fixation by certain plants and soil bacteria), as well as animal sources (e.g. the waste from feral pigs). In general, the factors that cause increased erosion and the transport of sediments into streams are can also increase the transport of nutrients into streams.

The modeling results indicate that Forest Lands in the Koʻolau range produce over 95% of all nitrogen and phosphorus in the project area

Analysis of the modeling results indicates that 99% of all nitrogen and 95% of all phosphorus in the Kaiaka Bay Watersheds originates from areas classified as Forest Lands in this WBP, however, it should be noted that while Forest Lands occur in both the Waiʻanae range and the Koʻolau range, all or almost all of these nutrients originate on the Koʻolau side (refer to Figures 32 and 33). Forest Lands in the Kaukonahua Watershed alone produces over 60% of all nitrogen and phosphorus.

Hotspots for nutrients in Forest Lands are found in the forests of the Koʻolau range and include one or more of the following characteristics:

- Areas with the highest amount of rainfall (i.e. near the summit of the Koʻolau range)
- Areas with little to no ground cover which can increase erosion and runoff rates;
- Degraded ecosystems that are especially susceptible to erosion and consequently increased runoff (e.g. areas that are dominated by nonnative species and experience high rainfall, have highly erodible soils, or steep slopes); or
- Areas with high densities of feral pigs and other invasive animals (animal feces are a source of nutrients).

The highest priority hotspots within Forest Lands are areas with exposed soils as a result of human activity, animal activity, or natural causes; these areas are more prone to nutrient runoff during rainfall events. It is also well understood that ecosystems that are dominated by nonnative flora and fauna are generally degraded and are more prone to erosion than areas that are native-dominated.

Note that in addition to implementing practices in the hotspots described above, it is it is perhaps equally important to protect the most native-dominated ecosystems from further degradation. These "healthy" areas of the watersheds include the native-dominated high elevation forests in the Koʻolau range (the entire summit area).

Priority watersheds for controlling nutrients in Forest Lands include all four of the applicable watersheds, since each watershed presents opportunities for implementing relevant management measures to address existing hotspots but also to protect native ecosystems and watershed functioning. Therefore, the priority watersheds include:

- Kaukonahua Watershed;
- Poamoho Watershed;
- Helemano Watershed; and
- ʻŌpaeʻula Watershed.

Agricultural Lands

Fertilizers (a source of nutrients including nitrogen and phosphorus) that are applied to crops can be washed off fields during rain events and flow into waterbodies. Fertilizers can also contaminate groundwater, which can then contaminate stream water since groundwater contributes to the base flow of streams. As discussed in section 7.2.5, streams in agricultural areas on Oʻahu have been found to have generally higher concentrations of dissolved nutrients than streams in undeveloped and urban areas, including total nitrogen, nitrate, and phosphorus. In addition, cattle and other livestock operations can be a source of nutrients (via their waste), especially if the livestock are continually brought to a single area for watering each day, concentrating the waste. Point sources of nutrients include the State DOT-HWYS MS4 outfalls that are located along the highways that run through the Agricultural Lands, however, discussions related to pollutants from MS4s are more applicable to Developed Areas since the MS4 collects stormwater from roadways. Despite these known sources of nutrients, the results of the modeling indicated that Agricultural Lands contributed very little nitrogen and phosphorus (less than one percent of the total). Taken together, this information indicates that Agricultural Lands should not be overlooked as a source of nutrients in the Kaiaka Bay Watersheds, especially since sedimentation is associated with nutrient transport and erosion is a significant natural resource issue in agricultural areas.

Nutrient hotspots in Agricultural Lands include one or more of the following characteristics:

- Fields where conventional agriculture is primarily utilized (i.e. heavy use of fertilizers);
- Areas with a significant amount of bare/exposed soil (including fields and access roads);
- Areas without adequate practices to control erosion and runoff from fields and field access roads;
- Field access roads with steep topographical grades (may have a higher potential for rapid transport of sediments via runoff from an adjacent area);
- Stream channels subject to natural erosion processes;
- Pasturelands located in areas with steeper topographical grades (more prone to erosion) or near stream channels; or
- MS4 outfalls that empty into stream channels.

While all six watersheds have agricultural land, the analyses of the modeling results indicate that Agricultural Lands in the Poamoho Watershed contribute far more nutrients per acre than Agricultural Lands in the other watersheds (see tables 51 and 55). Therefore, Poamoho Watershed is the priority watershed for implementing management measures to reduce nutrients in Agricultural Lands.

Developed Areas

Nonpoint sources of nutrients in Developed Areas in the Kaiaka Bay Watersheds can be generated from on-site sewage disposal systems (e.g. cesspools), use of fertilizers, improper disposal/containment of vegetative debris, landfills, and other waste sites. Areas with impervious surfaces can accelerate the transport of nutrients and other pollutants into nearby waterbodies. Point sources of nutrients in the Developed Areas include the Wahiawā WWTP and, to a lesser degree, the Schofield WWTP (effluent from the latter does not typically enter a surface waterbody directly). In addition, the City MS4, State DOT-HWYS MS4, the Navy's MS4, and the Army's MS4 also contribute PS pollution to Developed Areas.

The results of the model indicate that three types of developed areas classified in the C-CAP landcover dataset produce a combined 1% of all nitrogen and 5% of all phosphorus. Given that the model could not account for nutrient input from any wastewater system (including all OSDSs and WWTPs) nor could it account for nutrients transported and deposited in MS4s, Developed Areas should not be considered a negligible source of nutrients in the Kaiaka Bay Watersheds.

Hotspots for nutrient sources in Developed Areas include one or more of the following characteristics:

- Unstabilized landscaping projects;
- Unstabilized developed open spaces (e.g. beach park erosion);
- Unstabilized residential and commercial construction sites;
- Other areas with bare/exposed soil;
- Areas with regular application of fertilizers;
- Areas with high densities of cesspools, especially near waterbodies;
- Areas where there are regular introductions of wastewater into groundwater (e.g., OSDSs; Paʻalaʻa Kai WWTP);
- Areas where there are regular introductions of treated wastewater into surface waters (e.g. Wahiawā WWTP);
- Areas with large amounts of impervious surfaces and no stormwater filtration system;
- Stream channels subject to natural erosion and nutrient generation processes;
- Road crossings (i.e. bridges) over streams and waterways; or
- MS4 outfalls.

The highest pollutant priority hotspots within Developed Areas are areas where OSDS are located in close proximity to waterbodies as well as areas with extensive amounts of impervious surfaces.

The priority watersheds for controlling nutrients in Developed Areas are the watersheds that have the most land area or have the largest percentage of their total area in this land use class, as well as the watersheds with the most OSDSs. Additionally, the results of the model indicate that Developed Areas in the Poamoho Watershed contribute the most nutrients per acre out of any other watershed. Therefore, the priority watersheds to reduce many types of urban pollutants are:

Therefore, the priority watersheds for controlling nutrients in Developed Areas include:

- Kaukonahua Watershed;
- Ki'iki'i Watershed;
- Paukauila Watershed; and
- Poamoho Watershed.

ARMY TRAINING AREAS

Analysis of the modeling results for nutrients shows that areas classified in this WBP as Army Training Areas contributing less than 1% of the total nitrogen and less than 1% of the total phosphorus for the project area. A large portion of the nutrients generated in Army Training Areas are likely coming from areas with steeper slopes and higher rainfall, such as in Schofield Barracks East Range. Additionally, areas with exposed soil are likely sources of nutrients since erosion of soils is closely associated with the transport of nutrients.

Hotspots for nutrients in Army Training Areas are similar to hotspots for erosion. Accordingly, nutrient hotspots include one or more of the following characteristics:

- Areas with little to no ground cover (exposed soils or other unstabilized areas);
- Access roads and trails, especially those with steep topographical grades;
- Road crossings (i.e. bridges) over streams and waterways;
- Stream channels subject to natural erosion and nutrient generation processes; or
- Degraded ecosystems that are especially susceptible to erosion and/or wildfire (e.g. areas that are dominated by nonnative species and experience high rainfall, have highly erodible soils, or steep slopes).

There is only one watershed with land that is classified in the Army Training Area land type, therefore, the priority watershed for reducing nutrients in this land use type is the Kaukonahua Watershed.

7.4.1.3 OTHER POLLUTANTS

There are many other types of pollutants that can impact water quality and pose threats to both human and ecological health. Common pollutant types include bacteria and other pathogens, chemical contaminants, and trash. However, the goals of the WBP state that pollutants other than sediments and nutrients should be addressed opportunistically or as deemed necessary. This section discusses sources of other pollutants and presents priority watersheds for pollutants other than nutrients and sediments when deemed necessary in each of the four land use types.

FOREST LANDS

Feral pigs and other animals can introduce bacteria and other microbes to ecosystems through their feces. The extent of the impact these sources of pollutants make on water quality is not well-understood, however, addressing the bacteria contributed through animal droppings is not a major priority for this WBP, especially since feral pig management in Forest Lands will be addressed in the management measures to reduce sediments and nutrients coming from those areas. Natural sources of bacteria are described in section 7.2.16; these sources are also not a priority for management since little can be done to reduce them.

Therefore, none of the Kaiaka Bay Watersheds are identified as a priority for addressing other types of pollutants coming from Forest Lands.

Agricultural Lands

In addition to sediments and nutrients, there are a number of other pollutant types that can be generated on Agricultural Lands in the Kaiaka Bay Watersheds. Pesticides that are applied to manage crops can result in nonpoint source pollution when excessive amounts are applied or when rainfall occurs after application resulting in contaminated stormwater runoff. In addition, bacteria can be introduced via the droppings of cattle and other livestock that are grazed in pastures. In some agricultural areas, excessive salts can result from irrigating with brackish water or from the addition of soil amendments. The resulting salt residue can be washed off the surface during runoff events and pollute nearby and downstream waterbodies. Point sources of other types of pollutants include the State DOT-HWYS MS4 outfalls that are located along the highways that run through the Agricultural Lands, however, discussions related to pollutants from MS4s are more applicable to Developed Areas since the MS4 collects stormwater from roadways.

Of these pollutants, community concerns are mostly related to the excessive use of pesticides. Since the Poamoho Watershed has the most area classified as Agricultural Lands in this WBP (as well as the highest percentage of its total area at 80%), it is the priority watershed for implementing measures to reduce pesticides entering waterbodies.

Developed Areas

Developed and urban areas are significant sources of many types nonpoint source pollutants in watersheds, including oil and grease from automobiles and roadways, pesticides, bacteria and other pathogens, polycyclic aromatic hydrocarbons, metals, and other household chemicals. Stormwater runoff from parking lots and roadways can rapidly transport these pollutants along with carelessly discarded trash into waterbodies. Leaking cesspools and other OSDSs are a potential source of fecal indicator bacteria and other pathogens. Point sources of pollutants in the Developed Areas of the Kaiaka Bay Watersheds include the City MS4, State DOT-HWYS MS4, the Navy's MS4, the Army's MS4, the Wahiawā WWTP, and the Schofield WWTP (however, effluent from the latter does not typically enter a surface waterbody directly).

The priority watersheds for reducing most of these pollutant types are those with the highest percentages of impervious surfaces, since impervious surfaces facilitate the transport of pollutants into waterbodies. Additionally, the watersheds with the most OSDSs are also priorities. Therefore, the priority watersheds to reduce many types of urban pollutants are:

- Kaukonahua Watershed (Schofield Barracks and Wahiawā);
- Kiʻikiʻi Watershed (Waialua); and
- Paukauila Watershed (Haleʻiwa).

Army Training Areas

The Army Training Areas may be a source of pesticides and other chemical pollutants. Pesticides are applied occasionally in select areas for range management as a pre-treatment to prescribed burn areas to improve the effectiveness of the burn, however, pesticide-use in these areas is not considered a significant issue and therefore is not a priority to address in this plan. Other chemical pollutants could be generated from vehicles used for training purposes or from historic training or waste sites. It is not a focus of this plan to address specific training strategies or historic land uses, therefore, no watershed is identified as a priority in this WBP.

7.4.2 Summary of Priority Watersheds

Table 57 provides a summary of the primary sources of pollutants in each of the four general land use types and identifies the priority watersheds for management actions to address specific pollutants. Note that while nutrients and sediments are the primary pollutants of concern, other pollutants such as pesticides, bacteria, and pollutants associated with stormwater runoff are also considered. This prioritization guides the recommendations presented in the *Implementation Plan* (Volume 2).

TABLE 57. PRIORITY WATERSHEDS FOR MANAGING POLLUTANTS

General Land Use Type	Primary Factors That May Contribute Pollutants	Pollutants of Concern	Priority* Watersheds: Sediments	Priority* Watersheds: Nutrients	Priority* Watersheds: Other Pollutant Types**
Forest Lands	• Natural erosion processes • Feral ungulates • Nonnative & invasive plants • Forest fires	• Sediments and turbidity • Nutrients • Bacteria (from animals and natural sources)	• Kaukonahua • Poamoho • Helemano • ʻŌpaeʻula	• Kaukonahua† • Poamoho† • Helemano† • ʻŌpaeʻula† † *Primarily the forests of the Koʻolau range*	*None‡* ‡ *Not considered significant or feasible to address*
Agricultural Lands	• Natural erosion processes – Highly erodible soils – Steep slopes (gulches) • Grazing • Nonnative & invasive plants • Feral ungulates • Fires • Natural erosion processes • Agriculture practices	• Sediments and turbidity • Nutrients • Chemical contaminants (e.g. pesticides transported in runoff)	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Poamoho	• Poamoho *(pesticides)*
Developed Areas	• Wahiawā WWTP • Wastewater injection wells (Paʻalaʻa Kai WWTP) • MS4s (City, DOT, Army, Navy) • Cesspools and other OSDS • Urban/roadway stormwater runoff • Chemical use • Hazardous waste sites	• Sediments & turbidity • Nutrients • Bacteria & other pathogens • Chemical contaminants • Trash	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Kaukonahua • Poamoho • Paukauila • Kiʻikiʻi	• Kaukonahua • Paukauila • Kiʻikiʻi *(pollutants associated with urban stormwater runoff)*
Army Training	• Natural erosion processes • Feral ungulates • Nonnative & invasive plants • Army training activities • Forest fires • Controlled burns and other fires	• Sediments and turbidity • Nutrients • Bacteria (from animals and natural sources)	• Kaukonahua	• Kaukonahua	*None‡* ‡ *Not considered significant or feasible to address*

* *Watersheds are listed in no particular order.*
** *Other pollutants are considered secondary pollutants to sediments and nutrients. These pollutants are addressed opportunistically in the Implementation Plan (Volume 2).*

8 NEXT STEPS

Volume 1: Watersheds Characterization provides important baseline information about the six watersheds that drain into Kaiaka Bay. Data and information contained in this document represent the best available at the time of writing.

The second volume of the Kaiaka Bay Watershed-Based Plan, titled *Volume 2: Implementation Plan*, builds on *Volume 1* and outlines the priority management measures and projects necessary to improve water quality in the watersheds, as well as describes how to measure progress and improvements. Together *Volume 1* and *Volume 2* make up the complete Kaiaka Bay Watershed-Based Plan.

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