CENTRAL O'AHU WATERSHED STUDY

FINAL REPORT

May 2007

Prepared For:
Honolulu Board of Water Supply
U.S. Army Corps of Engineers
City and County of Honolulu Department of Environmental Services

Prepared By:
Oceanit
Townscape, Inc.
Eugene Dashiell

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TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

LIST OF ACRONYMS

AFB	Air Force Base
ARPZ	Aquifer Recharge Protection Zone
BARS	Branched Aquifer Recharge System
BMP	Best Management Practices
BOD	Biological Oxygen Demand
BPNAS	Barber's Point Naval Air Station
BWS	Board of Water Supply (City and County of Honolulu)
CERCLA	Comprehensive Environmental Response, Cleanup, and Liability Act
CFS	Cubic Feet per Second
CGG	Coastal Geology Group (University of Hawai'i, School of Ocean and Earth Science and Technology)
CIP	Capital Improvement Program
CLP	Coastal Lands Program (State of Hawai'i, Department of Land and Natural Resources)
COE	Corps of Engineers (United States Army)
CPR	Condominium Property Regime
CRC	Coastal Resource Coordinator (United States Department of Commerce, National Oceanic & Atmospheric Administration)
CRS	Community Rating System
CTAHR	College of Tropical Agriculture and Human Resources (University of Hawai'i)
CWA	Clean Water Act
CWRM	Commission on Water Resource Management (State of Hawai'i, Department of Land and Natural Resources)
CZM	Coastal Zone Management (United States Department of Commerce, National Oceanic & Atmospheric Administration)
DAR	DLNR Division of Aquatic Resources
DBCP	Dibromochloropropane
DBEDT	Department of Business, Economic Development & Tourism (State of Hawai'i)
DDC	Department of Design and Construction (City and County of Honolulu)

LIST OF ACRONYMS (CONTINUED)

DDT	Dichlorodiphenyltrichloroethane
DFM	Department of Facility Maintenance (City and County of Honolulu)
DHHL	Department of Hawaiian Home Lands (State of Hawai'i)
DLNR	Department of Land and Natural Resources (State of Hawai'i)
DMC	Del Monte Corporation
DOA	Department of Agriculture (State of Hawai'i)
DOFAW	Division of Forestry and Wildlife (State of Hawai'i, Department of Land and Natural Resources)
DOH	Department of Health (State of Hawai'i)
DOQQ	Digital Orthographic Quarter Quads
DOT	Department of Transportation (State of Hawai'i)
DP	Development Plan (City and County of Honolulu)
DPP	Department of Planning and Permitting (City and County of Honolulu)
EDB	Ethylene Dibromide
ENV	Environmental Services Department (City and County of Honolulu)
EPA	Environmental Protection Agency (United States)
EZ	Enterprise Zone
FEMA	Federal Emergency Management Agency (United States)
FHWA	Federal Highway Administration (United States Department of Transportation)
FIRM	Flood Insurance Rate Map
GAC	Granular Activated Carbon
GPD	Gallons per Day
HAR	Hawai'i Administrative Rules
HARC	Hawai'i Agriculture Research Center
HCDA	Hawai'i Community Development Authority
HCDCH	Housing and Community Development Corporation of Hawai'i
HECO	Hawaiian Electric Company, Inc.
HFD	Honolulu Fire Department (City and County of Honolulu)

LIST OF ACRONYMS (CONTINUED)

HIARNG	Hawaii Army National Guard
HISWAP	Hawai'i Source Water Assessment Program
HNC	Hawai'i Nature Center
HNHP	Hawai'i Natural Heritage Program
HSA	Hawai'i Stream Assessment (1990)
HSPF	Hydrologic Simulation Program - FORTRAN
HWEA	Hawai'i Water Environment Association
HWRF	Honouliuli Water Recycling Facility
ID	Infantry Division
KMWP	Ko'olau Mountains Watershed Partnership
LA	Load Allocation
LID	Low Impact Development
LLC	Limited Liability Corporation
MBR	Membrane Bioreactor
MCL	Maximum Contaminant Level
MG	Million Gallons
MGD	Millions of Gallons per Day
MGY	Millions of Gallons per Year
MOU	Memorandum of Understanding
NAVFAC	Naval Facilities Engineering Command
NB	Neighborhood Board
NFIP	National Flood Insurance Program
NOAA	National Oceanic & Atmospheric Administration (United States Department of Commerce)
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service (United States Department of Agriculture)
NRS	Natural Resource Staff (UH Pacific Cooperative Studies Unit)
NWR	National Wildlife Refuge
O&M	Operations and Maintenance

LIST OF ACRONYMS (CONTINUED)

OHA	Office of Hawaiian Affairs (State of Hawai'i)
OISC	O'ahu Invasive Species Committee
OP	Office of Planning (State of Hawai'i)
OR&L	O'ahu Rail and Land Company
OTEC	Ocean Thermal Energy Conversion
PACAF	Pacific Air Forces
PAH	Polycyclic Aromatic Hydrocarbon
PCA	Potential Contaminating Activity
PCB	Polychlorinated Biphenyls
PHMWG	Pearl Harbor Monitoring Working Group
PHNC	Pearl Harbor Naval Complex
PLACER	Point Location and Calculation of Error
PSD	Department of Public Safety (State of Hawai'i)
PTF	Pre-Treatment Facility
PUC	Primary Urban Center
RAM	Robust Analytical Model
RBZ	Riparian Buffer Zone
RC&D	Resource Conservation and Development (United States Department of Agriculture, National Resources Conservation Administration)
RO	Reverse Osmosis
SCP	Sustainable Communities Plan (City and County of Honolulu)
SDWA	Safe Drinking Water Act
SHPD	State Historic Preservation Division (State of Hawai'i, Department of Land and Natural Resources)
SMZ	Streamside Management Zone
SOEST	School of Ocean and Earth Science and Technology (University of Hawai'i)
SS	Suspended Solids
SSA	Sole Source Aquifer
SY	Sustainable Yield
TCE	Trichloroethylene

LIST OF ACRONYMS (CONTINUED)

TCP	Trichloropropane
TES	Threatened and Endangered Species
TMDL	Total Maximum Daily Load
TNCH	The Nature Conservancy of Hawai'i
UCB	Urban Community Boundary
UH	University of Hawai'i
UHM	University of Hawai'i at Mānoa
UIC	Underground Injection Control
US	United States
USAF	United States Air Force
USAG-HI	United States Army Garrison Hawai'i
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAAF	Wheeler Army Airfield
WLA	Waste Load Allocation
WMA	Water Management Area
WRRC	Water Resources Research Center (University of Hawai'i at Mānoa)
WWTP	Waste Water Treatment Plant
YMCA	Young Men's Christian Association

EXECUTIVE SUMMARY

The Central O'ahu Watershed Study is an overview of watershed information pertinent to the area and will be used by the Honolulu Board of Water Supply (BWS) to develop Watershed Management Plans for the Central O'ahu and 'Ewa Development Plan areas, and parts of the Primary Urban Center. Using this overview, resource problems and issues were identified. Potential projects and programs to remediate these issues were then investigated and outlined. **Chapter 1** of the Study provides a short introduction explaining the purpose and objectives of the report, and the methodology used. **Chapter 2** is the Watershed Profile, providing information on the study area's climate, soils, hydro geology, ground water, surface water, flooding and drainage, near shore waters, terrestrial ecosystems, traditional and customary rights and practices, settlement history, socioeconomics, land use, stakeholder consultation, and implications for watershed planning. **Chapter 3**, Water Use, provides a separate section specifically for water infrastructure. This chapter provides an inventory of this infrastructure; types of uses; condition of water facilities; water withdrawal, transmission, and use; preliminary forecasts of water demand; and ways of meeting future demand. **Chapter 4** then presents Projects and Programs suggested to address these watershed issues.

The study area encompasses all of the streams and their related land areas that drain into Pearl Harbor, as well as lands of the 'Ewa District to the boundary of the Wai'anae District. This area includes the Pearl Harbor Aquifer Sector, the Honolulu Board of Water Supply's largest source of potable water, providing approximately 98 million gallons of water per day (mgd) to Central O'ahu, 'Ewa, Wai'anae, and parts of the Primary Urban Center. Envisioned as the Second City of O'ahu, Kapolei in the 'Ewa district and its environs are the designated urban growth areas for O'ahu, and are among the fastest-growing districts on the island. The Central O'ahu Watershed is challenged with issues associated with a growing population and a finite supply of potable water. How can economic development and environmental sustainability be balanced? Specific issues for the area have been grouped into the following categories: water quantity and quality; sedimentation; terrestrial, stream, and near shore degradation; and flooding.

Combined, the 'Ewa and Central O'ahu districts are expected to have an increase in population of approximately 160,000 people, or 73% between the years 2000 and 2030. During this same time, BWS expects the study area's urban potable water demand to increase by 33.6 mgd. Though it is expected that the water demand in the next 25 years will be met, ground water withdrawals will also inevitably near sustainable yield estimates. To address the issues associated with ground water supply, it will be necessary to promote actions to sustain ground water supplies such as ground water infiltration and water conservation, maintaining regular updates and refinements of sustainable yield and permitted use, and investigating and implementing alternative water sources.

Ground water quality is also a concern for the area. Inactive landfills and dumping of urban trash at various locations could pose a threat to potable ground water quality. Broken or leaky sewer lines can cause nutrient, viral, and chemical contamination. Water quality has also been compromised due to solvent spills and historical pesticide use in the area. Wells with elevated levels of contaminants are treated with Granular Activated Carbon filters, but are expensive. To improve ground water quality, potable ground water resources need to be protected from contamination by land use activities, and current ground water and soil remediation practices should be continued.

Urban contaminants such as metals and sediment are being discharged into storm drain systems, streams, and the receiving waters of Pearl Harbor and fringing wetlands. Several chemicals in stream water and bottom sediment exceeded guidelines established to protect the health of stream animals and fish-eating wildlife. Stream protection is necessary and can be accomplished through restoration measures, vegetated buffers, identification of pollutant sources, and an inventory and assessment of the impacts of impervious surfaces, including a road and highways storm water runoff study. To effectively reduce sedimentation of surface water and near shore environments, sediment sources on land and within streams need to be identified and prioritized for management, and increased incentives and enforcement of best management practices in all related fields are needed. Sedimentation reduction can further be enhanced by controlling terrestrial degradation through increased wildfire prevention and response and protection of undeveloped lands.

The near shore environment is also feeling the effects of urbanization in the area. The beach is eroding at a rapid rate, and the amount of limu growing off the coast of ʻEwa .Beach has declined over the past 30 years. Improving the conditions of the near shore environment will require developing an overall Pearl Harbor Management Plan and associated activities, protecting existing wetlands at Pouhala and Pearl Harbor National Wildlife Refuge, restoration of Hawaiian fishponds within Pearl Harbor for cultural and watershed education purposes, and erosion mitigation of the ʻEwa Shoreline.

Finally, flooding continues to be a problem in low-lying parts of ʻEwa, Waipahu, and the lower reaches of Waiawa Stream, and will only increase from the pressures of proposed housing developments. Flood management is necessary and will require a hydrologic analysis, drainage improvements at chronic flooding sites, and restriction of development within floodways and gulches.

To remediate many of these issues, effective watershed management is necessary, requiring the continued cooperation and information sharing of City, State, and Federal government; communities; landowners; and businesses. The Honolulu BWS will be the principal implementing agency for meeting future water demand, but even then, collaboration between BWS and other City and State agencies is needed to ensure timely and efficient action.

1 CENTRAL O'AHU WATERSHED STUDY OVERVIEW

1.1 INTRODUCTION

The Central O'ahu Watershed Study area encompasses all of the streams and their related land areas that drain into the Pearl Harbor estuary, as well as lands of the 'Ewa District to the boundary of the Wai'anae District (Figure 1-1: Central O'ahu Watershed Study Location). This area is the Honolulu Board of Water Supply's largest source of potable water, providing approximately 98 million gallons of water per day (mgd). The project area includes Kapolei in the 'Ewa district, which is the designated urban growth area, and the envisioned "Second City," of O'ahu. This watershed study is being conducted to inventory and address water-related issues associated with development and other land uses, in order to protect and restore critical environmental resources.

1.1.1 PURPOSE

This Study will provide an overview of water-related information for what is denoted in this report as the Central O'ahu Watershed: 'Ewa, Central O'ahu, and the western portion of the Primary Urban Center (PUC) from Hālawa to Pearl City. This data will be used to identify resource problems and develop potential solutions to improve watershed health. The Honolulu Board of Water Supply (BWS), in cooperation with the U.S. Army Corps of Engineers (COE), initiated this study pursuant to Section 22 of the 1*974 Water Resources Development Act*, as amended. The Act authorizes COE to assist states and tribes in the preparation of comprehensive plans for the development, utilization, and conservation of water and related land resources.

1.1.2 OBJECTIVES

The objectives of this study were to provide an overview and analysis of Central O'ahu water-related resources. Available data was collected and reviewed, and problems and issues were identified. Using this information, potential projects and programs were conceptualized and described to help address these watershed needs. This information will be used by BWS as a basis to develop the Watershed Management Plans for the Central O'ahu, 'Ewa, PUC, and East Honolulu Districts. Further and more in-depth analysis of pertinent issues will take place in the Watershed Management Plans.

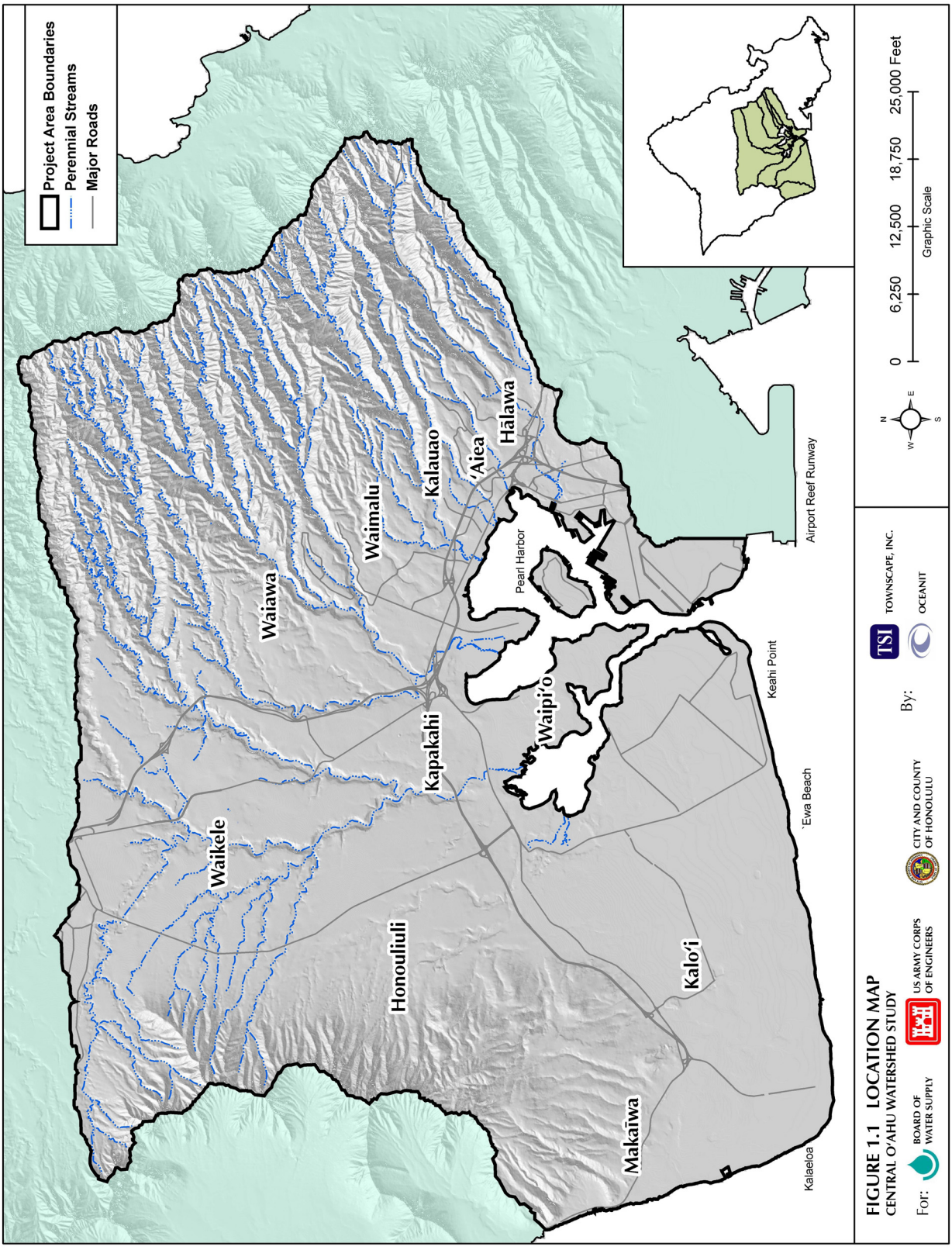
Project Area Boundaries
Perennial Streams
Major Roads
Waiawa
Waimalu
Kalauao
'Aiea
Hālawa
Waikele
Kapakahi
Waipi'o
Honouliuli
Kalo'i
Makaiwa
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
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FIGURE 1.1 LOCATION MAP
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI TOWNSCAPE, INC.
OCEANIT

1.2 METHODOLOGY

The project began with an inventory of existing data. The most pertinent data and reports were gathered, reviewed, and evaluated with a focus on water resources information and related concerns within the Watershed. After a basic understanding of the project area was gained through these sources, interviews were conducted with a limited number of stakeholders within the project area, including Federal, State, and City agencies; military planners; large landowners and lessees; large water users; developers; neighborhood board chairs; and active interest groups. Please see Section 2.14 for a detailed list of these stakeholders and further description of the outcomes of this process. These interviews and consultations were held between March 2005 and January 2007.

A meeting held in November 2005 brought together researchers and agencies specifically doing work within the study area. This group was asked to review stakeholder and researched issues to date, and provide a more detailed understanding of theses issues. Also, attendees identified additional problems and issues that may have been missed in the reviewed literature and interviews.

A "windshield survey" was conducted to provide a visual understanding of the landscape and the problems identified through the research. The general route driven was north on Kamehameha Highway and returning south on Kunia Road. Stops made during the survey included: Waipi'o Sports Complex, Waikele Stream, Central O'ahu Regional Park, various points along Waikakalaua Stream, Kunia Village, and Hawai'i Country Club.

Once the background research and information from stakeholders was compiled, critical problems, issues, and needs relating to man-made and natural water systems were identified. Projects and programs to address these water issues were then conceptualized and described. Additional research and interviews were conducted, as needed, to adequately articulate each project or program.

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2 CENTRAL O'AHU WATERSHED PROFILE

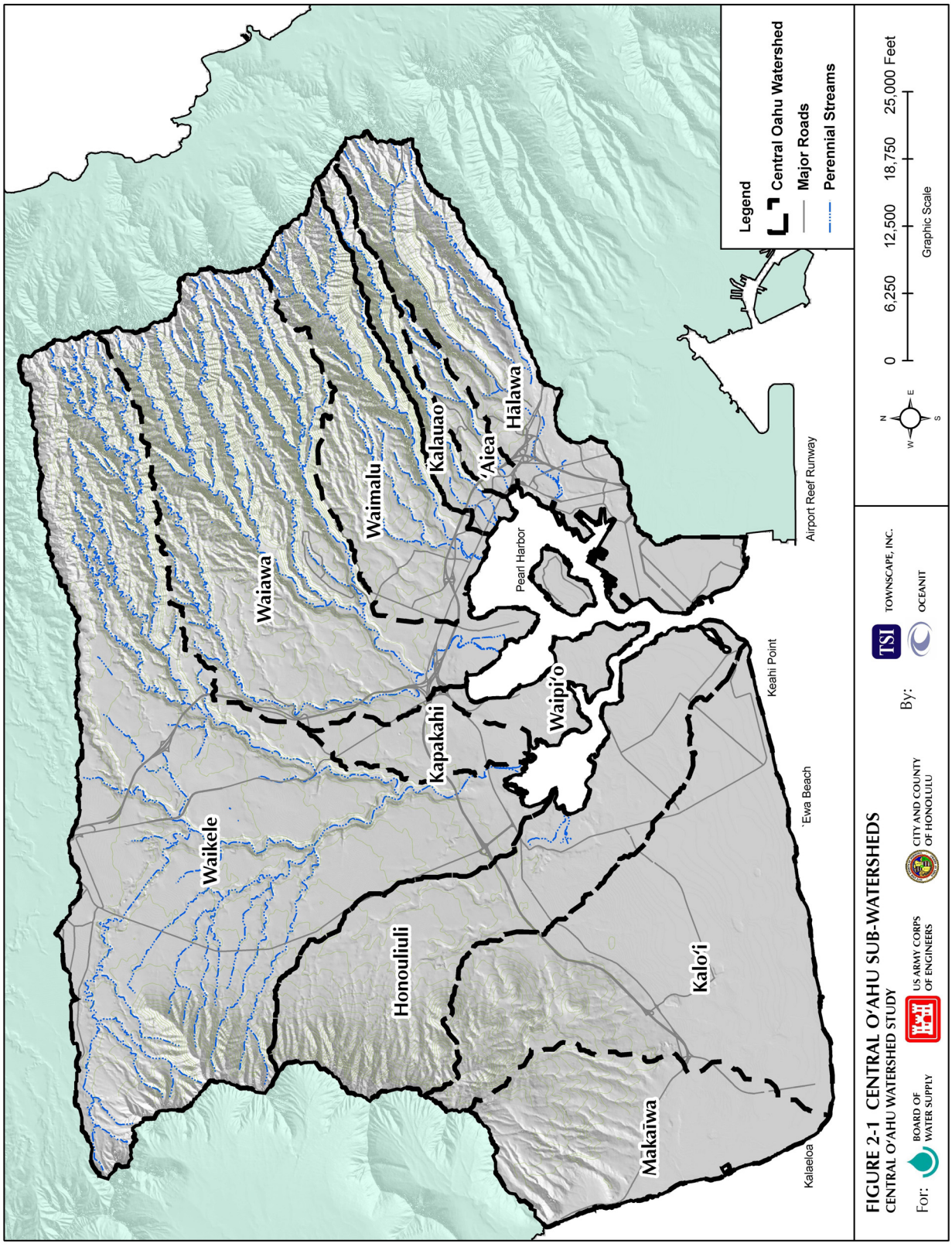
2.1 STUDY AREA

The Central O'ahu Watershed Study area is bounded by the Ko'olau and Wai'anae mountain ranges, spanning from Hālawa to 'Ewa, continuing north to Wahiawā. This area includes those sub-watersheds that drain into Pearl Harbor: Hālawa, 'Aiea, Kalauao, Waimalu, Waiawa, Kapakahi, Waipi'o, Waikele, and Honouliuli; and the 'Ewa District sub-watersheds of Kalo'i and Makaīwa, which drain the 2,400-foot tall Pu'u Manawahua into the Pacific Ocean on the southwestern shoreline of O'ahu (Figure 2-1: Central O'ahu Watershed). The Central O'ahu Watershed area encompasses approximately 110,250 acres (172 square miles), and is home to approximately 287,900 people. At 29% of Oahu's land mass (approximately 384,000 acres, or 600 square miles), the Central O'ahu Watershed accounts for almost a third of the island.

2.2 CLIMATE

The Central O'ahu Watershed area has a mild, subtropical climate. Temperatures in the area typically range from 69°F to 91°F. The warmest average monthly temperature is 80.7°F and the coolest monthly average temperature is 72.3°F.[1] The southwestern sections of the study area, including Makaīwa, Kalo'i, and Honouliuli, have the lowest average annual rainfall with approximately 20 inches per year. Further north and along the Wai'anae mountain range, rainfall increases to approximately 40 inches per year. The eastern sub-watersheds bordering the Ko'olau Mountains experience heavier rainfall, with approximately 30 inches per year along the West Loch coastline, gradually increasing to approximately 240 inches per year at the northeastern-most peak of Pu'u Ka'aumakua (2,681-foot elevation). This rainfall pattern occurs because the northeasterly trade winds move clouds over the Ko'olau Mountains, causing rainfall in the *mauka* areas. As the clouds continue to move over the Central plain, rainfall decreases (Figure 2-2: Average Annual Rainfall).

An additional form of precipitation occurs where water drips to the ground from trees, bushes, or other objects that have collected moisture from fog. Fog drip can be a very important source for ground water recharge and stream flow, and as a moisture source during rainless periods. Fog drip can be used for human consumption; for example, the small village of Chungungo in Chile has increased water availability by 35% by capturing fog drip.[2] A study on Maui (USGS, 2004)[3] measured fog drip on both the windward and leeward sides of the island to gain an understanding of the role of fog in forest hydrology, and to learn what factors are most important in restoration of the forests in these areas. The windward site indicated that fog drip contributes substantially to stream flow, and at the leeward site, most of the intercepted fog drip evaporated before reaching the ground. The contribution of fog drip to the Central O'ahu Watershed is unknown at this time.


Legend
Central Oahu Watershed
Major Roads
Perennial Streams
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
N
W
E
S
Waiawa
Waimalu
Kalauao
'Aiea
Hālawa
Waikele
Kapakahi
Waipi'o
Honouliuli
Kalo'i
Makaiwa
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
FIGURE 2-1 CENTRAL O'AHU SUB-WATERSHEDS
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
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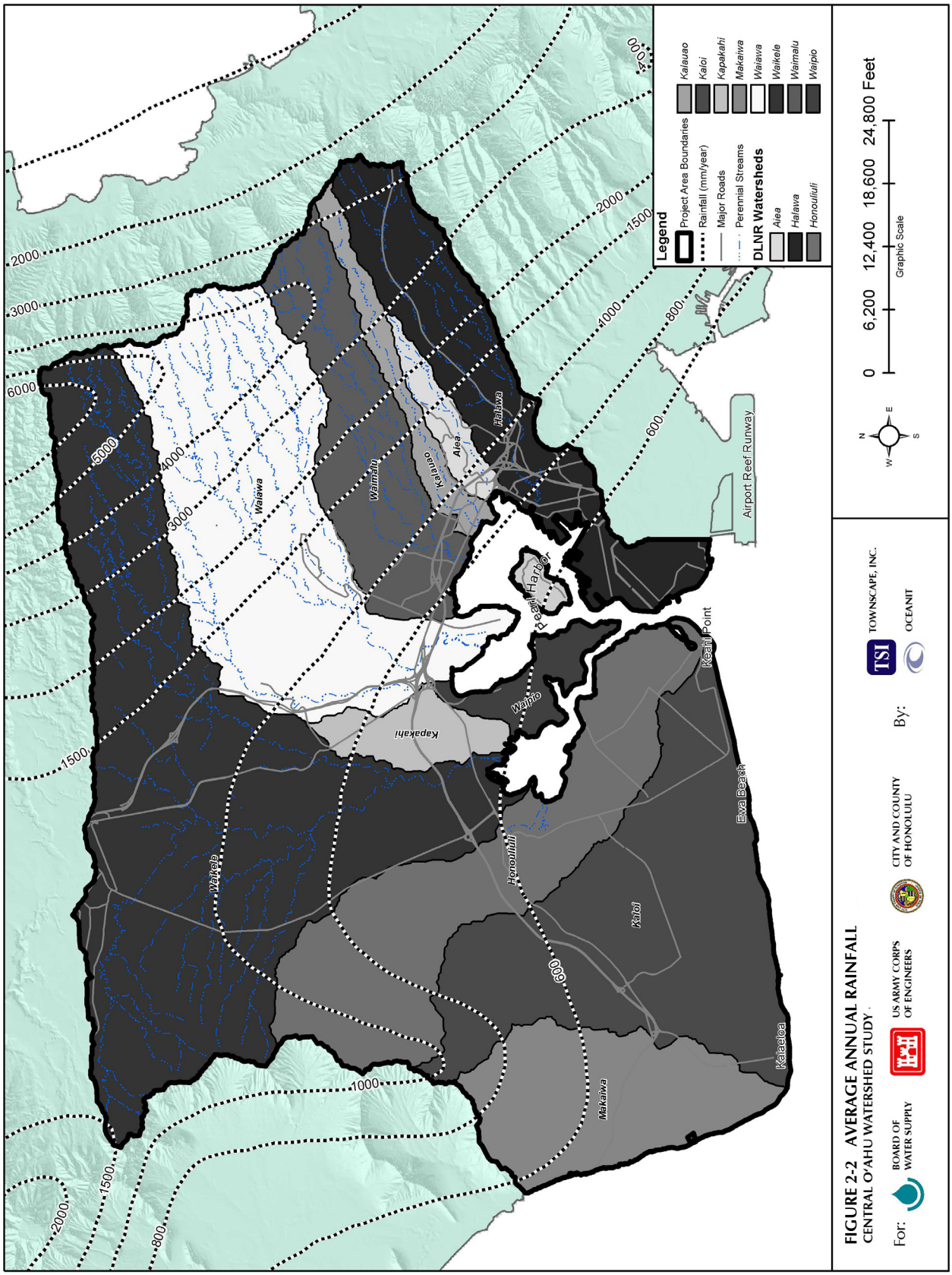
Legend
Project Area Boundaries
Rainfall (mm/year)
Major Roads
Perennial Streams
DLNR Watersheds
Kalauao
Kaloi
Kapakahi
Makaiwa
Waiawa
Waikele
Waimalu
Waipio
Aiea
Halawa
Honouliuli
0 6,200 12,400 18,600 24,800 Feet
Graphic Scale
N E S W
Airport Reef Runway
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Keahi Point
Ewa Beach
Kalaeloa
Waiawa
Waimalu
Kalauao
Aiea
Halawa
Waipio
Kapakahi
Waikele
Honouliuli
Kaloi
Makaiwa
FIGURE 2-2 AVERAGE ANNUAL RAINFALL
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
OCEANIT

Evapotranspiration, the loss of water to the atmosphere, is a major component of the hydrologic budget.[4] Water loss is due to a combination of transpiration by plants and direct evaporation from plants, land, and water surfaces. The main measurement used to evaluate evapotranspiration is pan evaporation. Pan evaporation is a measured water loss from the surface of the water in an evaporation pan, which is a cylindrical container of a specified volume fabricated from a rust-resistant metal. For O'ahu, pan evaporation is the lowest at the highest elevations of the Ko'olau and Wai'anae Ranges (mean annual pan evaporation of 20 inches), where clouds reduce sunlight intensity, humidity is high, and temperatures are low. Positive heat advection causes the pan evaporation rate to climb to 80 inches within the Central O'ahu basin and 90 inches along the 'Ewa coast. Evaporation rates are highest with maximum sunlight and trade-wind flow, especially during the drier summer months.

2.3 SOILS

A majority of the soils in the Central O'ahu plain are characterized as oxisols, which are found on old, geomorphically stable surfaces and are resistant to physical deterioration under intensive mechanized agriculture. Mollisols, occurring throughout the 'Ewa plain, possess high fertility, and are normally well-drained, relatively young soils that developed on coral, lava, or alluvium.

Vertisols are found in the East Kapolei / Honouliuli / 'Ewa Villages area, which are dry areas where expandable clays may become dominant in the soil. Construction on vertisols is problematic because of the tendency of these soils to shrink and swell with wetting and drying. However, most of the soil in this area is generally considered low to moderately expansive.[5] Moderately expansive soils could require special procedures for house foundation design, such as deep footings, subgrade saturation, or capping with non-expansive soils.[6]

2.4 HYDROGEOLOGY

2.4.1 O'AHU HYDROGEOLOGY

The western half of O'ahu was formed by the Wai'anae Volcano series about three million years ago. The eastern portion of the island was formed when the Ko'olau series erupted, about two million years ago, pouring lava against the slope of the Wai'anae Range to the west and forming the Schofield Plateau. This central saddle of land, which constitutes much of the Central O'ahu study area, is the result of overlapping flows from the Ko'olau volcano overlain by weathered sediments and incised by stream channels. Today, remnants of these lava flows comprise the long, narrow-ridged Wai'anae and Ko'olau Mountain Ranges.

Subsequently, O'ahu underwent a series of submergences and emergences resulting from changes in the ocean level during glacial and interglacial phases. The island has also substantially subsided about 6,000 feet during the past two-million years. Stream erosion carved a series of valleys into the Ko'olau shield. On the upper high rainfall portions of the mountain, the many valleys are separated by steep narrow ridges that represent the original surface of the volcanic shield in a few locations. In the Schofield Plateau between the Ko'olau and Wai'anae mountains, the many streams and sharp valleys coalesce into only a few larger streams. These larger streams tend to form deep erosional valleys through the relatively flat plateau. Alluvium, which is clay, silt, sand, and gravel deposited by running water, accumulated in valley floors and coral reefs and extended over low-lying coastal areas during higher stands of the ocean. Along the coast, deposits of interbedded terrestrial and marine sediments formed a relatively impermeable wedge of sedimentary material known as caprock.

Oahu's geology, climate and water cycle all influence the storage and movement of ground water. The volcanic rock and the residual soils have a great capacity to absorb and percolate water, and consequently, when soils are unmodified, the amount of rainfall that recharges the ground water is greater than the amount of overland runoff and stream flow running over the surface to the sea. This infiltration creates the large ground water bodies of Central O'ahu on which O'ahu depends for much of its water supply.

2.4.2 STUDY AREA HYDROGEOLOGY

The hydrogeology of the Central O'ahu study area primarily consists of the Pearl Harbor area and upland areas in the central corridor between the Ko'olau and Wai'anae Ranges. The study area is bounded on the northeast by the crest of the Ko'olau Range, on the southeast by South Hālawa Valley dividing the Honolulu Aquifer Sector Area, on the south by the coast, on the west by the crest of the Wai'anae Range, and on the north by the approximate southern boundary of the Schofield ground water area. The Schofield ground water area is separated from the Pearl Harbor Aquifer Sector Area by the southern Schofield ground water divide, which is a natural feature of undetermined structural origin. A small portion of the Schofield ground water area is within the study area.

The study area is defined as a freshwater lens system, as described by Ghyben-Herzberg principles, with the freshwater lens forming due to the density difference between freshwater and underlying saltwater. Within this lens, freshwater generally flows from inland areas to coastal discharge areas, including Pearl Harbor. A saltwater circulating system exists beneath the freshwater lens. A brackish water transition zone exists between the freshwater lens and saltwater circulating system. In the dike-free volcanic rocks of the Pearl Harbor area, mixing of freshwater with underlying saltwater creates a brackish-water transition zone that may be hundreds of feet thick. A schematic chart showing the

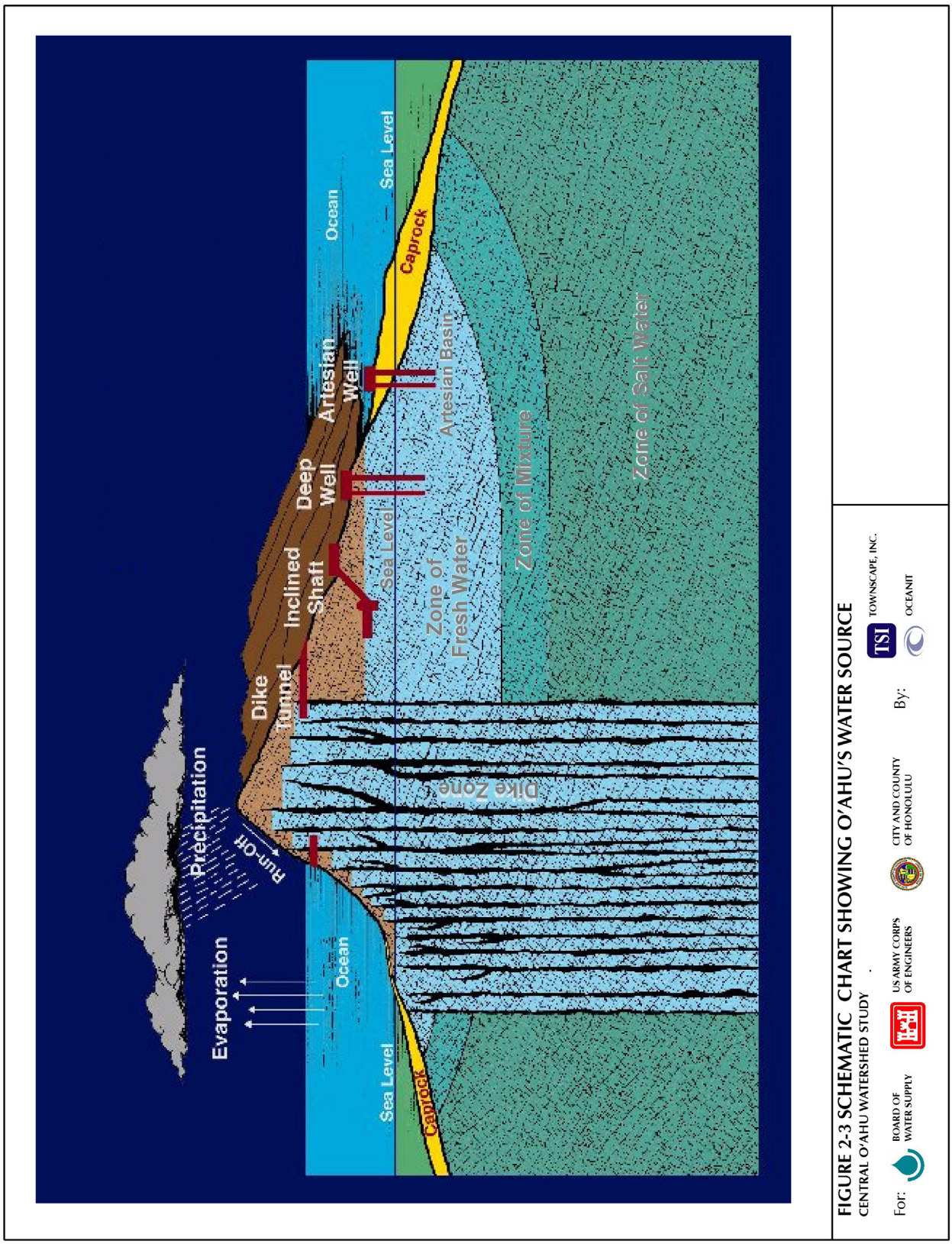


FIGURE 2-3 SCHEMATIC CHART SHOWING O'AHU'S WATER SOURCE
CENTRAL O'AHU WATERSHED STUDY

For: BOARD OF WATER SUPPLY; US ARMY CORPS OF ENGINEERS; CITY AND COUNTY OF HONOLULU

By: TSI TOWNSCAPE, INC.; OCEANIT

freshwater lens in relation to the brackish water transition zone and underlying saltwater zone is given in Figure 2-3.

The 'Ewa caprock layer is located toward the west end of the southern coastal plain, in an area where deposits of porous reef limestone predominate in the uppermost sedimentary levels. Below these sedimentary levels, low-permeability coastal caprock consisting of interbedded marine and terrestrial deposits impedes the discharge of fresh ground water from the aquifer, thus allowing fresh water to build up in large quantities. This caprock extends offshore, beyond the seaward extent of the freshwater lens and eastward, contiguous with the Honolulu coastal plain.

Recharge to the freshwater lens system in the Pearl Harbor area is from infiltration of rainfall and discharge from upgradient ground water bodies, including dike-confined water, in the Ko'olau and Wai'anae ranges. With the decline of the sugar industry, recharge from irrigation has been significantly reduced. Recharge amounts as of 1996 were less than 10 inches per year for areas of the 'Ewa plain to 25 to 50 inches for the Ko'olau upslope areas within the study area.[7]

2.5 GROUND WATER

Ground water provides essentially all municipal, military, and diversified agricultural uses in Central O'ahu. Although the Hawaiian Islands are surrounded by seawater, their aquifers are overlain by large lenses of fresh ground water. Orographic rainfall mainly concentrates water at the center of the island's Ko'olau Range where it soaks into the ground and builds up within confining dikes and unconfined ground water bodies. A combination of caprock impoundment and the lower density of freshwater over saltwater causes a substantial lens of fresh water to build up.

Ground waters can be either confined or unconfined. Confined is where the aquifer is bounded by impermeable or poorly permeable formations where water will rise above the overlaying impermeable boundary in a well. The top of the saturated aquifer is below the potentiometric surface of the underlying confined ground water. This surface is a measure of an aquifer's water pressure, as reflected by the height to which its water will climb when tapped by a well.

2.5.1 TYPES OF GROUND WATER IN THE STUDY AREA

The Central O'ahu ground water area is bounded on the southeast by the Honolulu Aquifer Sector Area and the Ko'olau dike-confined water zones, on the north by the Schofield high-level ground water barrier, on the west by the Wai'anae rift zone, and on the south by the sea and Pearl Harbor. The area has been divided into smaller ground water management areas (see Section 2.5.3) or hydrologic units by the State, mostly by valley-fill type hydrologic barriers. Each of the hydrologic units contains a basal

freshwater lens confined by the coastal plain. The 'Ewa area on the west is underlain by the Wai'anae Volcanics and originally was identified as a separate major ground water area based on differences in ground water levels with the adjacent Pearl Harbor area. The Pearl Harbor area is underlain by Ko'olau Basalt and is separated by valley-fill barriers,[8] as shown in Figure 2-4.

The Central O'ahu ground water system includes the northern and southern boundaries of two ground water divides, as shown in Figure 2-5. Ground water flow from the Schofield High-Level Water Body is mostly to the south across the ground water divide into the Pearl Harbor Aquifer but also to the north across to the Waialua Aquifer.

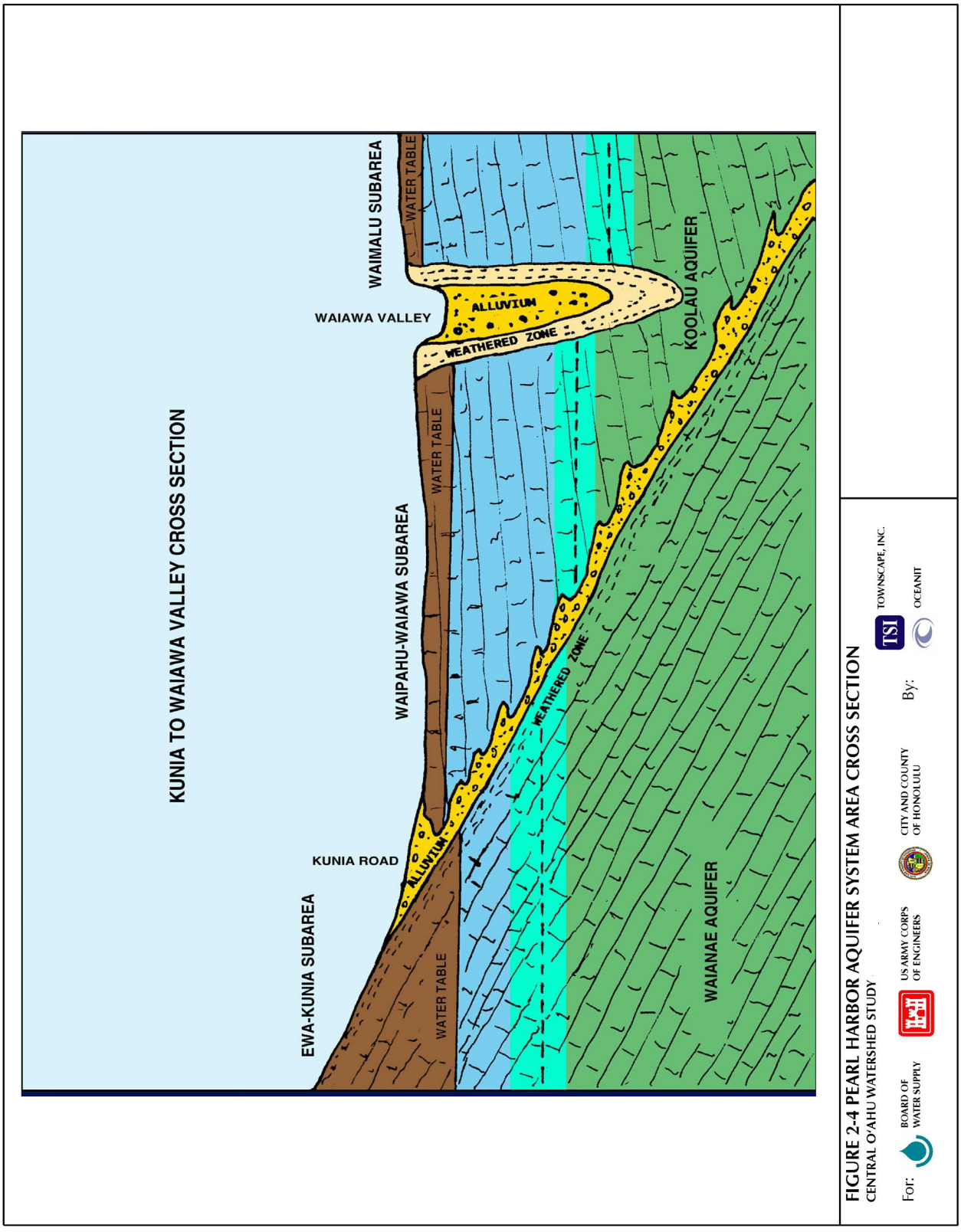
Most of the water in Central O'ahu is derived from extensive volcanic aquifers of thin-bedded basalts in central and southern O'ahu. Although the depth to water is as great as 600 to 1,000 feet in the island's interior, the aquifers are unconfined and are commonly within a few hundred feet of ground surface.

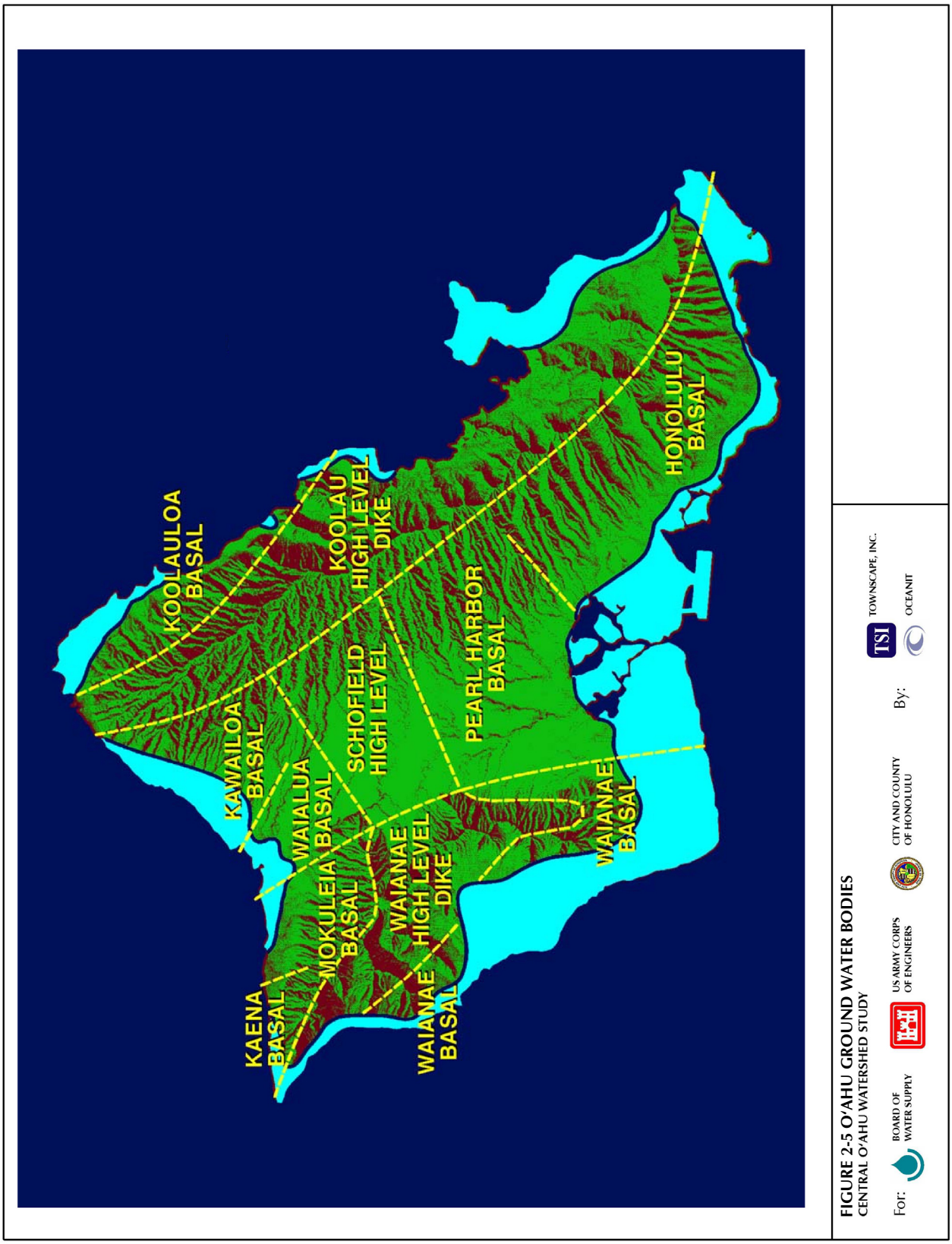
2.5.1.1 Basal Freshwater Lens

There are several types of ground water bodies in Central O'ahu. The primary and most extensive is the "basal fresh water lens" that floats on seawater under much of Central O'ahu. Water from the inland basaltic aquifers is relatively fresh (less than one percent saline), but as it moves from Schofield towards Pearl Harbor and the ocean, it mixes with seawater forming a brackish transition zone. The immense basal water bodies of Central O'ahu, which are artesian where they underlie the coastal plain, exist because of the difference in density between fresh water and seawater. Fresh water floats on the heavier seawater, both of which permeate the subsurface rock. The density ratio between fresh water and salt water is such that, theoretically, for each foot that the fresh water lens stands above sea level (i.e., for each foot of "head"), the lens extends 40 feet below sea level to a midpoint where salinity is half that of sea water. A zone of mixture ("transition zone") grades upward to fresh water and downward to seawater.

2.5.1.2 Caprock Water

The majority of the Central O'ahu study area is underlain by an unconfined basal aquifer. However, on the coastal plain between Kalaeloa and Pearl Harbor, there is a relatively impermeable sedimentary sequence commonly called "caprock." This caprock barrier tends to restrict the seaward flow of freshwater and causes the thickness of the freshwater lens to be greater than it would be if the caprock were absent. Caprock water is derived from local rainfall, return irrigation water, and leakage of basal water bodies. Ground water in the upper layers of the caprock flow system is unconfined, but water in the lower caprock layers and in the underlying basalt near the coast is confined or semi-confined by the overlying caprock. The caprock or basal ground water found near the shore at Kalaeloa is brackish, and is in direct hydraulic connection with the Pacific Ocean.


KUNIA TO WAIAWA VALLEY CROSS SECTION
EWA-KUNIA SUBAREA
KUNIA ROAD
WAIPAHU-WAIAWA SUBAREA
WAIMALU SUBAREA
WAIAWA VALLEY
WATER TABLE
ALLUVIUM
WEATHERED ZONE
WAIANAE AQUIFER
KOOLAU AQUIFER
FIGURE 2-4 PEARL HARBOR AQUIFER SYSTEM AREA CROSS SECTION
CENTRAL O'AHU WATERSHED STUDY
For:
BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI
TOWNSCAPE, INC.
OCEANIT


KOOLAULOA BASAL
KOOLAU HIGH LEVEL DIKE
HONOLULU BASAL
KAWAILOA BASAL
WAIALUA BASAL
SCHOFIELD HIGH LEVEL
PEARL HARBOR BASAL
MOKULEIA BASAL
WAIANAE HIGH LEVEL DIKE
WAIANAE BASAL
KAENA BASAL
WAIANAE BASAL
FIGURE 2-5 O'AHU GROUND WATER BODIES
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
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Water occurring in the 'Ewa caprock, the basal water transition zone, and basal springs comprise a significant resource. This brackish water is used at 'Ewa golf courses and at various developments, such as 'Ewa by Gentry, Kapolei Villages, Ko Olina, and Kapolei Business Park, in the Central O'ahu Watershed. Brackish water from Kalauao Spring is used to irrigate commercial crops at Sumida Farms and Lau Farms. Chlorides range from just above recommended drinking water limits to that of seawater. Fresh and salt water merge to form a brackish zone of mixture. The movement of this transition zone, both horizontally inland from the seacoast and vertically upward in response to pumping, presents a constant potential danger of saline contamination to the fresh water portion of the system.

2.5.2 AQUIFERS

The State Commission on Water Resource Management (CWRM) divides the island's ground water into aquifer sector areas and aquifer system areas which are management tools; they do not imply non-communication or separate independent aquifer bodies. CWRM also designates water management areas that coincide with individual hydrologic unit areas or aquifer sector areas. Water management areas are discussed further in Section 2.5.3. Aquifer sector areas generally define large geological boundaries, such as rift zones, unconformities, or valley fills that separate areas of different water levels. They reflect broad hydrogeological similarities and are generally bounded by geologic structures, which incorporate topographic divides. Aquifer system areas are more specifically defined by ground water hydraulic continuity. O'ahu is divided into six aquifer sector areas. The Central O'ahu Watershed study area encompasses the entire Pearl Harbor Aquifer Sector Area and a small portion of the Central Aquifer Sector Area (Wahiawā), as shown in Figure 2-6. The Pearl Harbor Aquifer Sector Area is comprised of the Waimalu, Waipahu-Waiawa, and 'Ewa-Kunia Aquifer System Areas.

CWRM determines sustainable yield numbers, which are the maximum levels of withdrawal permissible for each aquifer system. Sustainable yield (SY) is defined by the Hawai'i Administrative Rules as "the maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source as determined by the commission."[9] Sustainable yield is a theoretical withdrawal rate of ground water and depends on optimal well spacing and balanced withdrawal rates. Other estimates exist regarding likely recoverable or developable yields which are lower than the SY amounts.[a] The recoverable yield is an estimate of the amount of ground water that could feasibly be developed for an aquifer area. The recoverable yield estimate is less than the CWRM SY. Various factors affect the ability to develop sources, such as the availability of land, regional salinity levels, water lost to the brackish water transition zone, and terrain (which may have cost and environmental impacts). The Honolulu Board of Water Supply estimates recoverable yields by taking into account the above factors and

[a] Note: withdrawals affecting streams require amendments to interim instream flow standards.

possible impacts on stream flow. Due to land limitations and distribution system constraints, BWS installed wells where feasible and as optimally as possible.

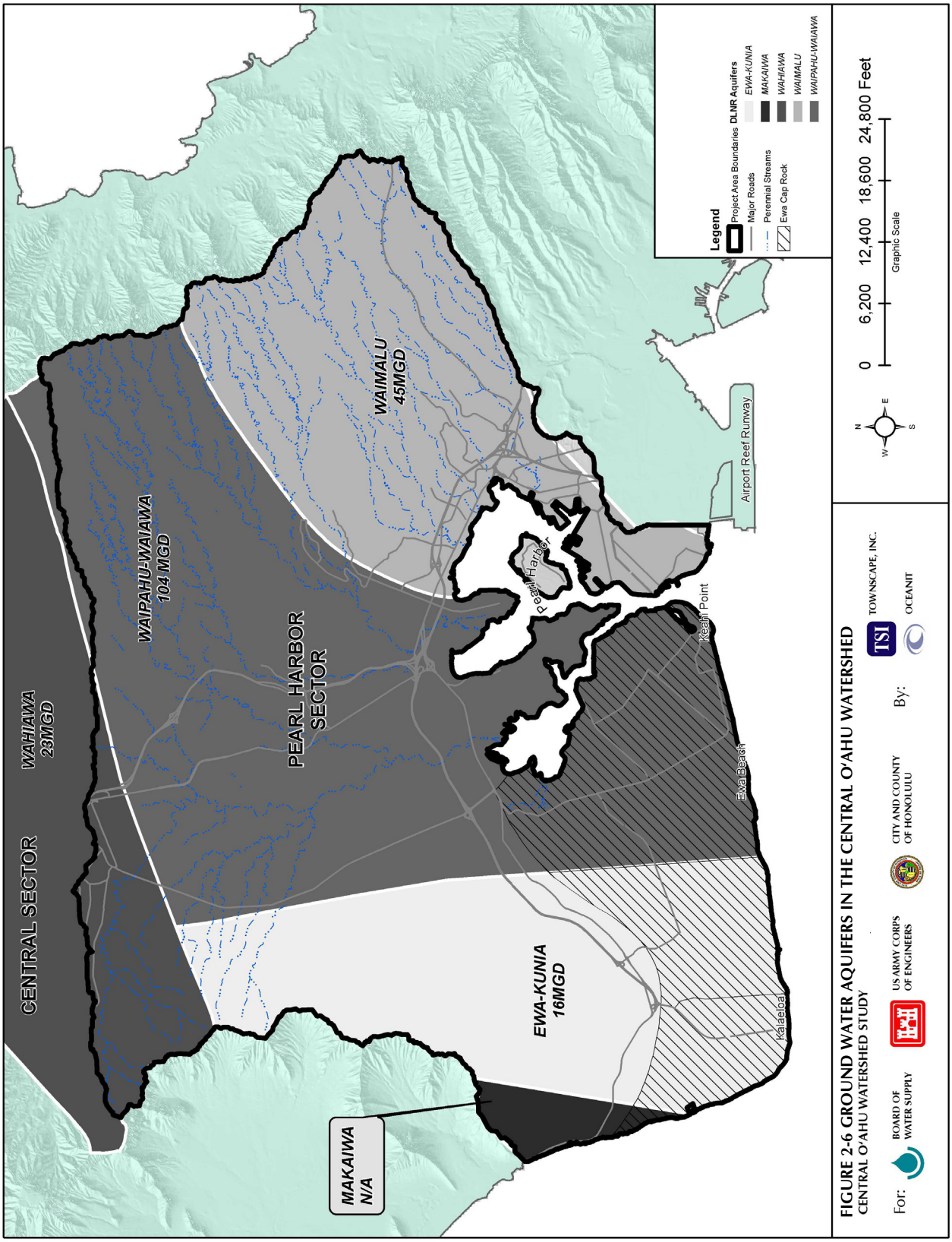
To establish and periodically update SY estimates, a number of ground water models have been developed over the years. A simple robust analytical model (RAM) was originally developed by Mink (1981) for the determination of the Pearl Harbor Aquifer Sector Area sustainable yield. The RAM model, as the most popular ground water management tool in the state, has been used to estimate the SY of the Pearl Harbor Aquifer Sector Area and many other basal aquifers in the state. CWRM, working with UH, is reviewing the SY of certain aquifers statewide using a modified RAM model calibrated to new deep monitoring wells. A three-dimensional flow and solute transport simulation of the Pearl Harbor Aquifer Sector Area has been evaluated by the Hawai'i District of the U.S. Geological Survey Water Resources Division and was co-funded by BWS[10]. Three-dimensional solute transport ground water models are used to verify locations and yields of new wells and assess impacts to existing downgradient wells. In addition, three-dimensional solute transport models are used to determine how much of the theoretical sustainable yield can be developed.

Using current official CWRM criteria, the Pearl Harbor Aquifer Sector Area:

- has a total sustainable yield of 165 million gallons per day (mgd);
- contains three aquifer system areas (Waimalu, Waipahu-Waiawa, and 'Ewa-Kunia), which are basal ground water bodies;
- contains a brackish aquifer ('Ewa caprock); and
- provides the largest amount of potable water on O'ahu.[11]

The Waimalu and Waipahu-Waiawa Aquifer System Areas contain a basal lens in the Ko'olau volcanic series. In the 'Ewa-Kunia System, the basal lens is in the Wai'anae volcanic series. A thick, effective caprock of sediments causes high ground water head.

The 'Ewa caprock aquifer is comprised of three smaller aquifers: Malakole, Kapolei, and Pu'uloa. Unlike the sustainable yield of the basal aquifer systems, the sustainable yield of the 'Ewa caprock aquifer is set by a chloride limit of 1,000 milligrams per liter (mg/L).


CENTRAL SECTOR
WAHIAWA
23MGD
WAIPAHU-WAIAWA
104 MGD
PEARL HARBOR
SECTOR
WAIMALU
45MGD
EWA-KUNIA
16MGD
MAKAIWA
N/A
Pearl Harbor
Airport Reef Runway
Keahi Point
Ewa Beach
Kalaeloa
Legend
Project Area Boundaries
Major Roads
Perennial Streams
Ewa Cap Rock
DLNR Aquifers
EWA-KUNIA
MAKAIWA
WAHIAWA
WAIMALU
WAIPAHU-WAIAWA
0 6,200 12,400 18,600 24,800 Feet
Graphic Scale
N
E
S
W
FIGURE 2-6 GROUND WATER AQUIFERS IN THE CENTRAL O'AHU WATERSHED
CENTRAL O'AHU WATERSHED STUDY
For:
BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
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The current sustainable yields established by CWRM for the Waimalu, Waipahu-Waiawa, and 'Ewa-Kunia Aquifer System Areas are listed in Table 2-1.

TABLE 2-1
PEARL HARBOR AQUIFER SYSTEM AREAS

AQUIFER SYSTEM AREA	CURRENT SUSTAINABLE YIELD (MGD)
Waimalu	45
Waipahu-Waiawa	104
'Ewa-Kunia	16
Total	**165**

With the decline of the sugar industry in Central O'ahu, large volumes of irrigation water no longer enter this system and recharge the aquifer. Without supplemental irrigation below the 50 inches-per-year rainfall isohyet, the evaporation exceeds rainfall, and ground water recharge from agricultural irrigation is assumed to be zero.

The implementation of the sustainable yields for the Waipahu-Waiawa and 'Ewa-Kunia Aquifer System Areas are tied to milestones set by the Pearl Harbor Monitoring Working Group (PHMWG). The PHMWG is comprised of the Honolulu Board of Water Supply, U.S. Geological Survey, and CWRM. The milestones include allocation and pumpage values for the two aquifer system areas and a three-phase monitoring plan. The allocation and pumpage milestones for the Waipahu-Waiawa and 'Ewa-Kunia Aquifer Systems are listed in Table 2-2[12].

TABLE 2-2
ALLOCATION AND PUMPAGE MILESTONES
FOR WAIPAHU-WAIAWA AND 'EWA-KUNIA AQUIFER SYSTEM AREAS

MILESTONE	'EWA-KUNIA (MGD)	WAIPAHU-WAIAWA (MGD)
ALLOCATION	16	82
PUMPAGE	14	62

Phase I of the monitoring plan involves the development of a deep well and observation monitoring plan.[13]

Phase II of the monitoring plan involves multiple tasks[14]:

- Set resource management criteria or triggers to ensure resource protection and encourage that pumpage is optimized throughout the Pearl Harbor Aquifer Sector Area;
- Develop an infrastructure optimization plan;
- Initiate the development of an overall water shortage plan for the Pearl Harbor and Honolulu Aquifer Sector Areas;
- Initiate the re-assessment of the sustainable yields for the Waipahu-Waiawa and 'Ewa-Kunia Aquifer System Areas.

The initiation of the overall water shortage plan is triggered when the allocation milestone is reached.[15] The overall water shortage plan should be completed within four years after the allocation milestone is reached.[16] The initiation of the re-assessment of sustainable yields is triggered when the pumpage milestone is reached.[17] The re-assessment should be completed within five years after the pumpage milestone is reached.[18]

Phase III of the monitoring plan involves the completion of the deep well and observation well monitoring plan started in Phase I and the implementation of the infrastructure optimization plan started in Phase II.[19] The well monitoring plan should be completed within four years after the pumpage milestone is reached.[20] The infrastructure optimization plan should be implemented within 10 years after the pumpage milestone is reached.[21]

2.5.3 GROUND WATER MANAGEMENT AREAS (WMA)

In September of 1979, the first designation of a Ground Water Control Area, now called a Ground Water Management Area, was made when the Board of Land and Natural Resources designated the 'Ewa-Pearl Harbor Aquifer in the Central O'ahu study area. The Pearl Harbor WMA includes the 'Ewa-Kunia, Waipahu-Waiawa, and Waimalu Aquifer Management Systems defined by CWRM. The management areas defined by CWRM do not necessarily coincide with aquifer or watershed boundaries.[22]

A water management area is defined by the State Water Code as "a geographic area which has been designated…as requiring management of the ground or surface water resource, or both." Under such designation, any "withdrawal, diversion, impoundment, or consumptive use of water,"[23] with the exception of domestic consumption of water by individual users and catchment systems must first be permitted by CWRM. In order to obtain a water use permit, applicants must show that the proposed use of water "(1) Can be accommodated with the available water source; (2) Is a reasonable-beneficial use, (3) Will not interfere with any existing legal use of water; (4) Is consistent with the public interest; (5) Is consistent with the state and county general plans and land use designations; (6) Is consistent with county land use plans and policies, and (7) Will not

interfere with the rights of the Department of Hawaiian Home Lands as provided in section 221 of the Hawaiian Home Commission Act."[24]

The State Water Code authorizes CWRM to designate water management areas, a process that may be initiated upon recommendation by the CWRM Chairperson or by written petition. The criteria for designation by the commissioners are set forth in HAR 13-171-7 and 13-171-8. The entire island of O'ahu, with the exception of the Wai'anae Aquifer Sector Area, is designated as a ground water management area.

In both designated and non-designated areas, CWRM regulates the construction, development, and abandonment of new ground and surface water sources through a permitting system. In addition, any proposal for a new or expanded diversion that will result in further amounts of water being diverted offstream must be supported by a successful petition to amend the interim instream flow standard for the affected stream(s). Permits are also required for the alteration of stream channels. CWRM sends a copy of all permit applications and petitions to numerous State and County agencies for review and comment. CWRM also publishes a bulletin of all new applications that is updated monthly on its website and sent to any interested party who requests to receive the monthly bulletin.

2.5.3.1 EPA Sole Source Aquifer Designation

The Environmental Protection Agency's (EPA) Sole Source Aquifer (SSA) Program was established under Section 1424(e) of the Safe Drinking Water Act (SDWA). Since 1977, it has been used by communities to help prevent contamination of ground water from Federally funded projects and has increased public awareness of the vulnerability of ground water resources. The SSA program allows for EPA environmental review of any project that is financially assisted by Federal grants or Federal loan guarantees. These projects are evaluated to determine whether they have the potential to contaminate a sole source aquifer. To be a sole source, the aquifer must supply more than 50% of a community's drinking water. The O'ahu Sole Source Aquifer encompasses the entire Central O'ahu study area.

2.5.4 GROUND WATER QUALITY

Ground water that accumulates in high rainfall regions in higher elevations of the Central O'ahu study area is superb in quality and needs no treatment before being used as drinking water. The quality of ground water as it reaches urbanized areas is affected by the introduction of dissolved matter generated by surface activities and the intrusion of salt water into basal lenses due to fresh water withdrawal. Historically, the infiltration of rainfall and irrigation return water replenished ground water reserves, but brought with it the additional fertilizers, salts, pesticides, and residues resistant to breakdown in the soil column.

Since the end of sugar production on O'ahu in 1995, recharge of ground water from irrigation has subsided, resulting in less fertilizers leaching into the ground water from this source. In areas once fed primarily by irrigation, such as areas above the 'Ewa caprock Aquifer System Area, the lost input of fresh water has contributed to reduced sustainable yield and increased saltwater intrusion.

The City and State both take measures to protect ground water in Hawai'i. BWS defined a "pass/no pass line" in the 1970s to regulate ground disposal of wastewater and other sources of contamination. The map in Figure 2-7 indicates "pass" zones, where sedimentary caprock would be thick enough to prevent contaminants from leaching into the underlying basalt, and "no pass" zones, where waste disposal facilities are restricted.

The State Department of Health (DOH) also has Underground Injection Control (UIC) regulations that are intended to protect the quality of underground drinking water sources by restricting the injection of fluids to those areas where drinking water aquifers will not be affected. The UIC line identifies aquifers *makai* of the UIC line as exempt from "underground sources of drinking water" status. If aquifers are *mauka* of the UIC line, they are considered underground sources of drinking water.[25] Injection wells are generally restricted *mauka* of the UIC line to protect underground sources of drinking water from chemical, physical, radioactive, and biological contamination.[26] The UIC line was drawn in the 1970s by committees of various Federal and State agencies, and generally follows the 500 ppm isochlor,[27] but in some places, was drawn to follow a road or other significant landmark for regulatory convenience.

2.5.4.1 Source Water Assessment Program

The 1996 SDWA Amendments established new requirements for source water quality assessments. This section required each state to submit a source water assessment program to the EPA for approval.

Hawai'i was required to:

- delineate the boundaries of areas providing source waters for public water systems; and
- identify the origins of regulated and unregulated contaminants in the delineated area to determine the susceptibility of public water systems to such contaminants.

Hawaii's Source Water Assessment Program (HISWAP) study was completed by the Hawai'i DOH and was approved by EPA in November 1999. The reports associated with the study were completed in 2004. DOH intends to update the HISWAP approximately every five years. The study recommends a combination of voluntary non-regulatory protection strategies, public education and outreach, incentive-based results, and coordination with existing regulatory agencies.

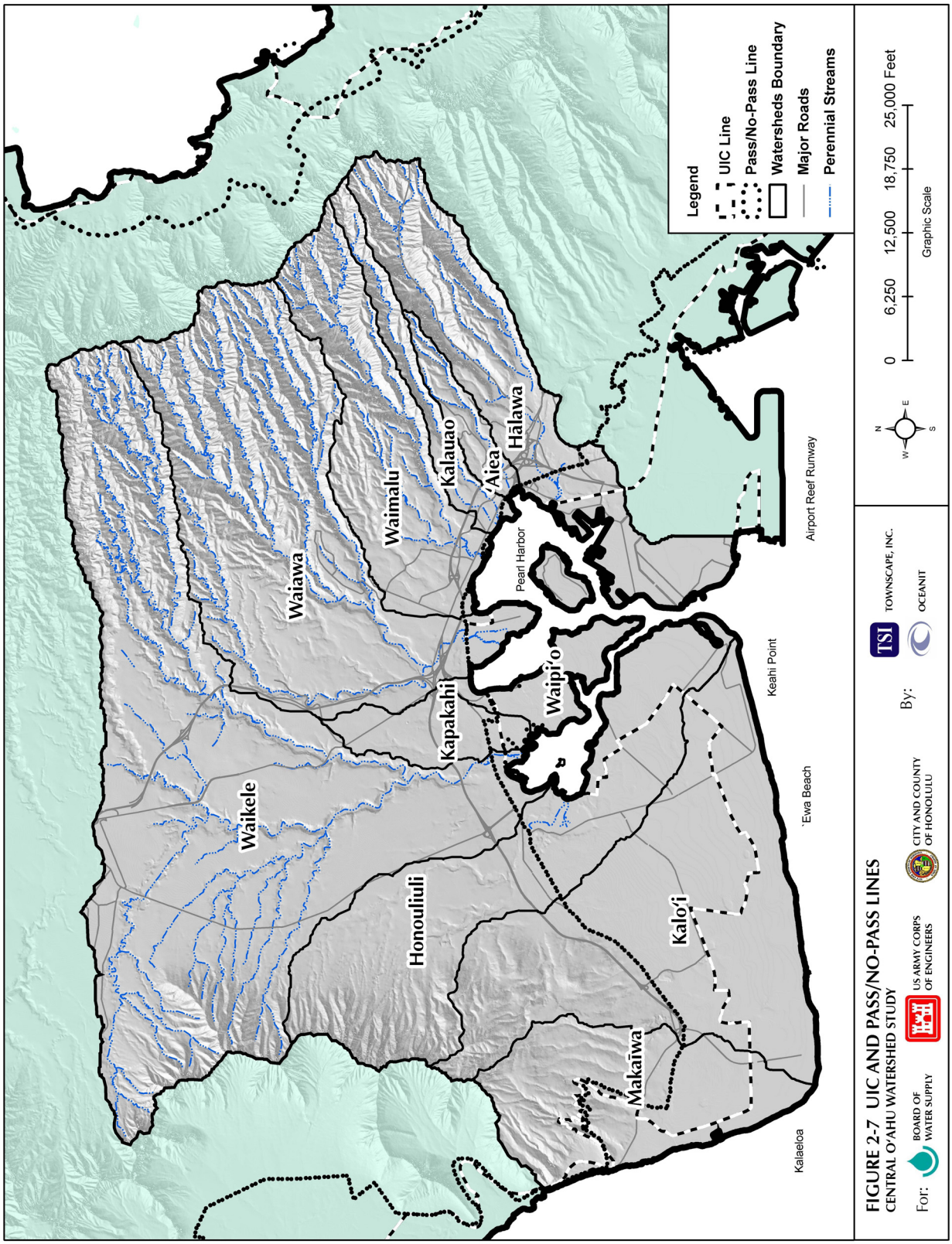
On a scale of Very High, High, Medium, and Low for potential contaminating activities in the HISWAP, those that ranked as Very High for the Central O'ahu Watershed study area include: RCRA (Resource Conservation and Recovery Act) sites, CERCLA (Comprehensive Environmental Response, Compensation and Liability Act) sites, gas stations, historic landfills and dumps, cesspools, wastewater treatment plants, military installations, leaking underground storage tanks, pineapple cultivation, and power plants. Golf courses ranked High for potential contaminating activities in the HISWAP. There are fifteen golf courses in the study area, and an additional four planned for construction.

The HISWAP study for Central O'ahu lists the status of various wells based on type of activity and proximity to the well. This formula produces a Potential Contaminating Activity score. The lowest (best) scores were located at wells in 'Ewa and Mililani. Wells in 'Aiea, some wells in Waipi'o, Waipahu, and Kunia had mostly higher (worse) scores while wells closest to Pearl Harbor, including Waiau and Pearl City, scored the highest.

2.5.4.2 Threats to Ground Water

Vulnerability of ground water to contamination has been confirmed by the widespread detection of pollutants in potable aquifers. Pesticides and herbicides have been detected in the aquifers beneath agricultural fields in Central O'ahu (Kunia, Mililani, Waikele, Waipahu, Waipi'o, and Waiawa). Solvents have been detected beneath sites of known use or spillage, such as Kunia Village and Pearl Harbor Naval Complex (PHNC).

Most sugarcane cultivation ceased in the 1990s and has been replaced by residential development, coffee and corn farms, and diversified agriculture. The recent announcement of the closure of the Del Monte pineapple facilities in Central O'ahu may result in further changes to the agriculture and development of the area. Residual agricultural chemicals from sugarcane and pineapple cultivation, such as TCP and DBCP, are still detected in many of the wells in the Central O'ahu Watershed. In addition, the Schofield Shaft is contaminated with the solvent TCE.


Legend
UIC Line
Pass/No-Pass Line
Watersheds Boundary
Major Roads
Perennial Streams
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
N
E
S
W
Waikele
Honouliuli
Kapakahi
Waiawa
Waimalu
Kalauao
Aiea
Halawa
Waipi'o
Kalo'i
Makaiwa
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
FIGURE 2-7 UIC AND PASS/NO-PASS LINES
CENTRAL O'AHU WATERSHED STUDY
For:
BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
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Urban development is anticipated to continue to expand onto lands once used for farming on the 'Ewa Plain and Central O'ahu areas. This change in land use brings a change in threats to ground water quality. To quote from a recent survey of ground water quality of the United States Geological Survey (USGS): [28]

> "For the most part, organic and nutrient contaminations appear to reflect decades-old releases and former land use. Most ground-water ages were decades old, with recharge dates ranging from pre-1940 to the present, and with most dates falling within the 1950s to 1980s time span. Several widely detected compounds were discontinued as long ago as the 1970s but have yet to be flushed from the ground-water system. Although large tracts of land in Central O'ahu have been converted from agriculture to residential urban use since the 1950s, water quality in the converted areas still more closely reflects the former agricultural land. It appears to be too early to detect a distinct water-quality signature characteristic of the newer urban use, although several urban turf grass herbicides in use for just 10 years or so were detected in monitoring wells and may represent early arrivals of urban contaminants at the water table."

Potential sources of ground water contamination associated with urban development include:

- Nutrient, viral, and chemical contamination from broken or leaky sewer lines
- Petroleum hydrocarbon contamination from the increased quantity of fuel tanks in urban settings
- Turfgrass and garden pesticides, herbicides, and fertilizers
- Previous ground termite treatment with dieldrin and chlordane in older urban areas, such as Hālawa and 'Aiea
- Fuel lines and fuel storage tanks at military installations, such as those in Kīpapa Gulch and Waikakalaua Gulch
- Military landfills

As urban land uses increase within the Watershed, the potential impact on ground water quality will increase.

In response to the concerns of the impacts of urban and agricultural development on its primary ground water supplies, the Navy has established a Hydrologic Zone of Contribution directly above its Waiawa Shaft tunnel. Most of this zone is in the conservation district, which allows very limited development to prevent or inhibit the potential for chemicals leaching to the ground water shaft.

2.5.4.3 Contaminated Wells in Central O'ahu

O'ahu ranked first in the nation in the percentage of wells in which fumigants were detected.[29] Fumigants have long been applied to pineapple fields to combat nematodes (rootworms). In 1999, the Honolulu BWS filed a lawsuit against chemical manufacturers, distributors, and plantations for contaminating the ground water on O'ahu with pesticides.[30] The lawsuit was settled in 2002 for $19.9 million.[31]

Most contaminated wells on O'ahu are located in the Central O'ahu study area and contain contaminants from years of pesticide use on sugarcane and pineapple fields. Nine wells within the Central O'ahu area exceeded the state maximum contaminant level (MCL) for the fumigant dibromochloropropane (DBCP). Twelve wells exceeded the state MCL for trichloropropane (TCP), which is a trace contaminant found in certain fumigants. Where standards were exceeded, the wells were taken out of service or are receiving treatment to remove the contaminants.[32] Within the Central O'ahu Watershed, the Honolulu BWS has installed 102 granular activated carbon (GAC) treatment units across 11 source stations since 1986 to remove pesticides in the drinking water. The total construction cost of these GAC treatment units is over $46 million, or about $451,000 per unit.[33]

During the spring of 1980, DOH began a program designed to determine whether the fumigants used in pineapple agriculture had contaminated drinking water wells in Central O'ahu. As part of this program, the Del Monte Kunia well was sampled. Analyses detected two fumigants, ethylene dibromide (EDB) and DBCP. On April 25, 1980, DOH ordered the Del Monte Kunia well removed from service. Del Monte voluntarily disconnected the Kunia Well from the non-crop irrigation system in September 1994, and is working with the EPA to develop and implement alternative treatment technologies and a ground water monitoring program. This site was recently partially removed from the EPA's National Priorities List (Superfund).

Superfund site near Kunia Village.

Solvents (among them, trichloroethylene [TCE]) from a 1985 spill at Schofield Army Barracks seeped into the Pearl Harbor Aquifer Sector Area. Now delisted, the 1990 National Priorities List site also had a separate plume of TCE contamination in the ground water emanating from the former Schofield Barracks Landfill. The ground water contaminant plume appears to be confined by a system of dike impoundments and natural attenuation. Solvents that have contaminated ground water at Schofield Barracks are continually being monitored at supply and monitoring wells both on and off site. Air

stripper technology was installed at drinking water supply wells, and the former landfill was recapped and revegetated. Migration of contaminated ground water will be tracked, and if necessary, corrective measures taken to ensure safety of the area's drinking water.[34] The plume has been modeled up to the Mililani Wells but the existing GAC treatment systems will remove the TCE.

The former Barbers Point Naval Air Station (BPNAS), now called Kalaeloa, is located in the study area, 13 miles west of Honolulu, Hawai'i. As part of the 1999 closure, an environmental investigation was completed. The primary contaminants of concern, affecting soil, include the chemical additive Polychlorinated Biphenyls (PCB), heavy metals, petroleum products, pesticides and solvents. Due to the presence of highly permeable limestone bedrock and thin, poorly developed soils at BPNAS, any leachates or liquid wastes in the ground may readily migrate to the caprock water table. Current operations include pollution prevention measures to prevent further contamination. There are no drinking water wells in Kalaeloa because the caprock aquifer is brackish.

Residual fuel contamination from a former Air Force fuel pipeline that runs along Kamehameha Highway was detected in the monitoring wells at Pearl City Junction, the present location of a Home Depot store. In addition, during the removal action of abandoned aviation and diesel fuel lines at the Hālawa Landing area, a break in the fuel pipeline was discovered. It is undetermined at this time whether a fuel release occurred there, but an investigation is being planned. Two rounds of monitoring have been completed for the former Mānana and Pearl City Junction areas, and a final regional ground water assessment report has been prepared. No drinking water wells are down gradient of these areas.

Other areas of contamination in Central O'ahu include industrial uses at military installations and oil refinery areas in 'Ewa. Fuel lines, USTs, leaking sewer lines over the aquifer, cesspools, old unlined landfills, and old injection wells located in the Central O'ahu study area all have the potential for contamination of ground water sources.

2.5.4.4 Seawater Intrusion

Finally, seawater intrusion has been and is an increasing problem in the Waimalu Aquifer System Area. It affects both quality and quantity of fresh water. Saltwater intrusion is induced mostly by stresses accompanying the extraction of ground water by pumping, especially with high capacity pumps and from deep wells. Since ground water development started nearly a century ago, the fresh water levels have contracted and saltwater intrusion has advanced inland. For example, long-term pumping of the Waiawa and Hālawa Shafts has created an expanded transition zone within a several mile radius. Saltwater intrusion is controllable when proper ground water extraction practices are employed. In many instances, the effects of saline water intrusion are reversible after

improper extraction techniques are corrected or the volume of ground water removed from the lens is held consistent with the hydrologic balance.

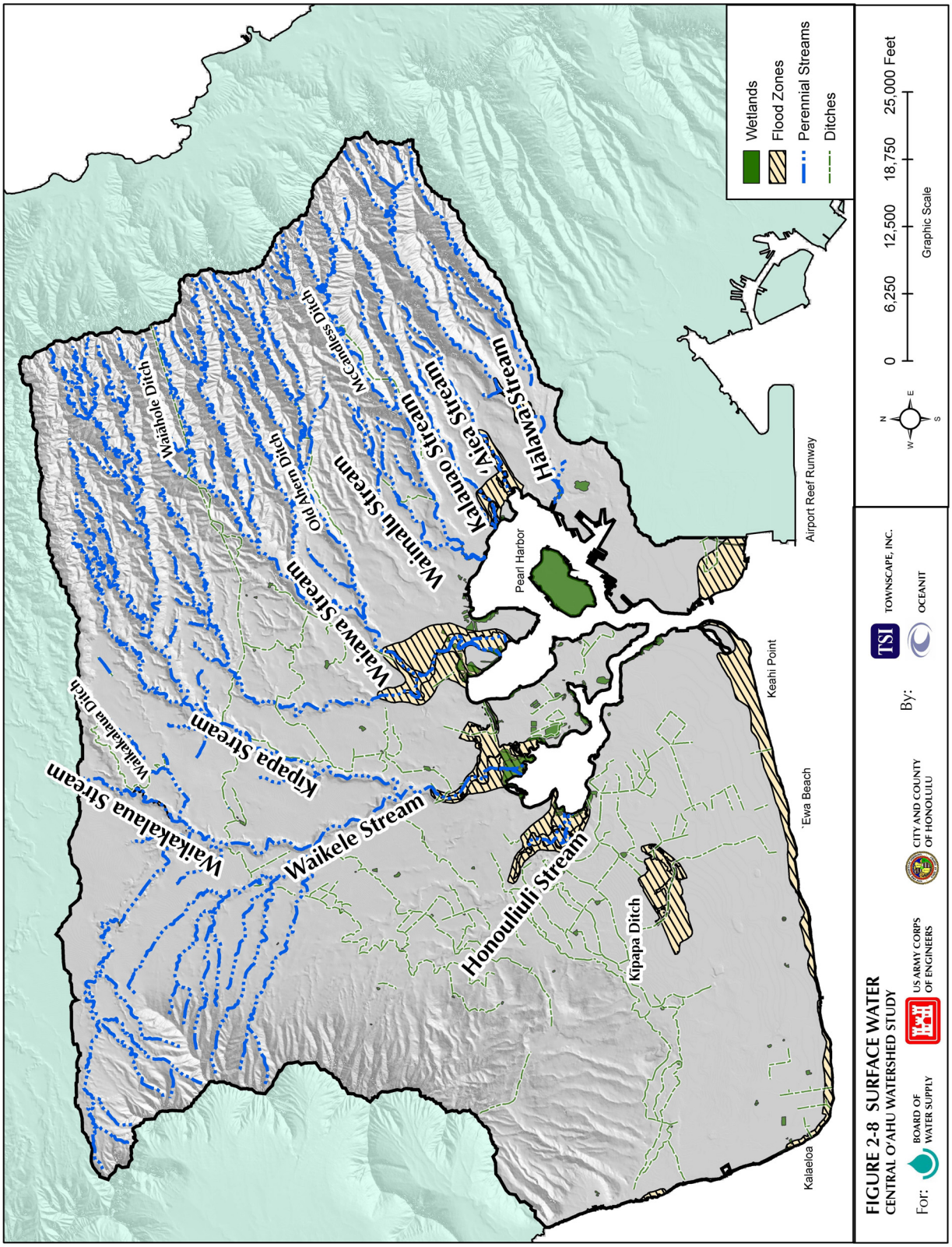
BWS is working with CWRM to monitor salinity with deep monitoring wells, and using 3D modeling to observe how the aquifer responds to different pumping schemes. This will help to develop better sustainable yield figures, as pumping closer to sustainable yield affects salinity. The deep monitoring wells show a chloride lag time of 6 months to a year from the midpoint of the aquifer to respond to high rainfall and associated recharge and lower pumping rates. This aquifer recovery will change in response to periods of high rainfall and drought. Reduced pumping from the aquifers, high rainfall, and increased recharge will reduce chloride levels and thicken the freshwater lens. Drought and increased pumping will increase chloride levels and reduce the thickness of the freshwater lens.

2.5.5 THREATS TO GROUND WATER QUANTITY

With the decline of agriculture in Central O'ahu, water use and irrigation have declined. Reduced flow in the Waiāhole Ditch from 27 mgd to the current 12.57-mgd allocation and pumping of ground water for irrigation translates into a loss in potential water for recharge. Recharge may be further reduced by the urbanization and accompanying reduced permeability of prime recharge areas. The decrease in area of the forests and possibly a deterioration of forest health will also result in less ground water recharge and more runoff. Increasing expansion of military bases, development in the dry 'Ewa area, pollution and increasing community resistance to any continued conveyance of water from the windward to the leeward side of the island, all pose threats to the quantity of water that will be available to satisfy Central Oahu's needs.

2.6 SURFACE WATER

Surface water within the Central O'ahu Watershed exists in agricultural ditches and ponds, natural streams, wetlands, and in the shallow surface soils and vegetative mass. The shallow surface soils and vegetative mass are the major source of water evaporation back to the atmosphere.


Wetlands
Flood Zones
Perennial Streams
Ditches
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
N
W
E
S
Hālawa Stream
'Aiea Stream
Kalauao Stream
Waimalu Stream
Waiawa Stream
Waiahole Ditch
McCandless Ditch
Old Aiwa Ditch
Waikakalaua Stream
Kipapa Stream
Waikakalaua Ditch
Waikele Stream
Honouliuli Stream
Kipapa Ditch
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
FIGURE 2-8 SURFACE WATER
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSM TOWNSCAPE, INC.
OCEANIT

2.6.1 AGRICULTURAL WATERWAYS

The large number and complexity of agricultural ditches in Central O'ahu is linked to the historical importance of agriculture in the Watershed. The National Wetland Database lists 26 miles of aqueducts, flumes, and siphons, and 107 miles of water ditches within the Watershed. The Waikakalaua Ditch historically diverted water from Waikakalaua Stream above Mililani to supply agriculture in the central Mililani area above the 600-foot elevation. This area is now almost exclusively urban and there are no current flow records for this ditch. The McCandless Ditch, also known as the Waimalu Ditch was constructed on the south side of Waimalu Valley by the McCandless Ranch when the valley was used for cattle ranching. The Old Ahern Ditch was constructed on the north side of Waiawa Valley parallel to the Waiāhole Ditch tunnel, and drew water from the upper Waiawa Stream. The Kīpapa Ditch was constructed on the 'Ewa plain to draw water from wells and/or the Waiāhole Ditch from Honouliuli across the lower 'Ewa plain.

Waiāhole Ditch North Portal main tunnel. Source: Starbulletin.com, April 25, 1997, Rough Waters Ahead, by Pat Omandam.

Approximately 27 mgd (USGS 2002 to 2003 measurement = 37 cubic feet per second [cfs]) of water was historically derived from outside the Central O'ahu Watershed, principally from the windward Ko'olau Poko district through the Waiāhole Ditch. During past years (1951 to 1969), flow through this ditch averaged 42 cfs.[35] This system, completed in 1916, draws ground water from about 5 miles of tunnels dug into the face of the Ko'olau Mountains at an elevation of about 800 feet above the Kahana, Waikāne, and Waiāhole Valleys. About 37 cfs of water formerly was transported through the Ko'olau Mountains in another 6 miles of tunnel at Adit 8 to emerge above Waipi'o at an elevation just over 700 feet. From this point, the ditch traverses through Waiawa, Waipi'o, and Mililani and to various agriculture uses as it proceeds across the valley in a series of siphons across the Kīpapa and Waikele gulches. Along the eastern foot of the Wai'anae Mountains, the ditch feeds a series of reservoirs and side channels leading to agricultural fields in Kunia, and terminates near Makakilo at an elevation of about 600 feet. Flow from windward O'ahu is now limited to 12 mgd.

For additional information on Waiāhole Ditch, see Section 3.4.3.1.

2.6.2 WETLANDS

Wetlands within the Central O'ahu Watershed include coastal marshes, mangrove swamps, and upland freshwater bogs. A COE wetland survey[36] lists vegetation found in 16 wetlands within the Watershed. The National Wetlands Inventory[37] and the Directory of Wetlands in Oceania[38] list 22 wetlands within the Central O'ahu Watershed totaling 380 acres. The National Database is, however, quite old (1971) and is presently being updated. Many of the wetlands in the database are located on the 'Ewa plain, possibly associated with agricultural irrigation features, in areas now under dense urban development. The database does not include known riparian wetland areas in the upper Watershed, some of which are associated with abandoned taro lo'i. Results from a 2003 study of vegetation patterns before human contact by the Hawai'i Natural Heritage Program determined that approximately 95% more wetland acreage was present in the Pearl Harbor region during pre-human times as compared to today.[39]

A series of biologically valuable fresh and brackish water wetlands encircle the Pearl Harbor shoreline. The United States Fish and Wildlife Service (USFWS) and State DLNR Division of Forestry and Wildlife (DOFAW) established the Pearl Harbor National Wildlife Refuges to provide habitat and protection for endangered Hawaiian waterfowl. These species of endangered waterfowl include:

- The Hawaiian Duck, *Anas wyvilliana*
- Hawaiian Coot, *Fulica alai*
- Hawaiian Gallinule, *Gallinula chloropus sandvicensis*, and
- Hawaiian Stilt, *Himantopus mexicanus knudseni*

The Pearl Harbor National Wildlife Refuge was created in 1976 to mitigate loss of wetlands brought about by construction of the Honolulu Airport Reef Runway. This refuge is composed of two units, the 37-acre Honouliuli Unit that borders West Loch and the 25-acre Waiawa Unit bordering Middle Loch of Pearl Harbor. These wetlands were recovered by clearing mangrove and rubbish from existing historic Hawaiian fishponds and adjacent lands. Work is presently underway to clear mangrove from additional adjoining areas to increase water bird habitat.

Honouliuli, also a fresh water wetland, is extensively managed for a variety of water birds, including endangered and migrant waterfowl. It serves as the site of the Hawai'i Nature Center's Third Grade Wetlands Education Program. During the fall semester of each school year, thousands of students learn about the recovery of Hawaii's water birds and the value of wetlands.

Waiawa is composed of two ponds, one of which is primarily managed for the endangered Hawaiian stilt (ae'o). However, its estuarine environment is ideal for

establishing a host of food resources for all four endangered water bird species: Hawaiian coot ('alae ke'oke'o), moorhen ('alae 'ula), and duck (koloa maoli). Fresh water is pumped into the refuge from a nearby stream and empties into Pearl Harbor.

Other wetlands include:

- Fort Kamehameha
- Pearl Harbor East Loch
- Pouhala
- Waiawa National Wildlife Refuge
- Waikele
- Waipahu Peninsula
- Waipi'o Basins
- Walker's Bay

Honouliuli Wetland. Source: Starbulletin.com, Nov. 11, 2001: Gung-ho for Green by Jim Borg.

2.6.3 STREAMS

A stream is defined as a natural watercourse with a permanent bed and bank readily distinguishable from the surrounding higher terrain. Stream flow may be defined as all waters which accumulate and travel in a stream channel, including direct surface runoff, ground water seepage and bank storage. Direct surface runoff is the component of rainfall that moves overland on the surface and through a shallow layer of soil and debris before joining a stream. Ground water is infiltration which accumulates in a saturated aquifer after passing through the unsaturated (vadose) zone. Stream flow is highly variable and the statistics of flow are dominated by direct runoff from rainfall.

Natural streams in Hawai'i are typically short and steep with limited watershed areas. This physical aspect combined with intermittent and often intense rainfall patterns tend to make the streams very flash-flood prone. Streams in Hawai'i exceed their average flow only about 10% of the time.

Streams are classified as ephemeral, intermittent, or perennial. Ditches, swales, rills, and gullies are, therefore, not classified as streams but may be precursors to streams. An ephemeral stream usually has flow only during or shortly following active rainfall. These streams are sometimes referred to as dry streams. Intermittent streams are often fed by dike-confined water in the upper reach and basal water near the ocean and will typically go dry during the summer, or at least once on an annual basis. Perennial streams flow year-round through the entire reach or length and therefore will support a more robust population of aquatic flora and fauna.

In Hawai'i, two additional stream descriptions are often used: non-perennial and perennial interrupted. The term "non-perennial" is often used for a stream that is almost perennial but may dry up for several days during the year. Because of the often porous

nature of Hawaiian soils, perennial streams that constantly flow in the mountains often "go to ground" or dry up in their middle reaches only to re-appear downstream where they intersect the basal ground water lens near the ocean. These streams are termed perennial interrupted.

Native Hawaiian stream fauna in perennial interrupted streams rely on the flash flood nature of the flows to migrate up and down the stream for spawning purposes. In the Central O'ahu Watershed, only the streams with headwaters in the Ko'olau Range or fed by basal springs are perennial. The National Wetland Database lists 12.3 miles of intermittent, 5 miles of non-perennial, and 10.5 miles of perennial streams in the Watershed. Six perennial (Waikele, Waiawa, Waiau, Waimalu, Kalauao, Hālawa) and two intermittent (Honouliuli, 'Aiea) streams flow into Pearl Harbor and drain about two thirds of the Watershed area.

Ground water flow into Pearl Harbor occurs as seeps and boils in the estuary, and springs along the shore. A series of large springs (Kalauao, Waiau, Waimano, Waiawa, and Waikele) along the upper loch shorelines, collectively known as the Pearl Harbor Springs, input additional fresh water into the system.[40] Ground water flow is estimated at between 31 and 340 cfs at the springs. A decrease in the average daily flow of the springs has been documented by Nichols, et al., (1996), as shown in Table 2-3.

TABLE 2-3
ESTIMATED DISCHARGE OF PEARL HARBOR SPRINGS

PEARL HARBOR SPRINGS	1911–1920 DISCHARGE (MGD)	1971–1980 DISCHARGE (MGD)
Kalauao	25.0	12.4
Waiau-Waimano	39.6	25.0
Waiawa	18.0	9.2
Waikele	45.1	14.8
Total	**127.7**	**61.4**

While flow from the Pearl Harbor Springs has decreased, the chloride concentration in two of the springs has increased. Data from 2001 to 2005 shows that the chloride concentration in Kalauao and Waiawa Springs has increased. The chloride data are in Appendix D.

TABLE 2-4
PHYSICAL CLASSIFICATION OF NAMED SURFACE WATERS IN THE CENTRAL O'AHU WATERSHED

Shoreline	Watershed	Spring	Perennial Stream	Perennial Tributary	Non-Perennial Stream	Dry Stream or Gulch
West Beach	Makaīwa					Pili o Kahe
						Limaloa
						Keone'ō'io
						Waimanalo
						Makaīwa
					Barbers Point Canal	
						Palailai
						Awanui
	Kalo'i					Kalo'i
						Hunehune
						Makalapa
						Makakilo
						Awanui
						Palalai
West Loch	Honouliuli				Honouliuli	Honouliuli
						Ka'aikukui
						Pālāwai
	Waikele	Waikele	Waikele		Waikele	
						'Ēkahanui
						Poliwai
						Huliwai
					Waikakalaua	
					Mililani	
				Kīpapa	Waipi'o	Manuwaiahu
					Kapakahi	
Middle Loch	Kapakahi	Kapakahi			Kapakahi	
	Waipi'o	Loko E'o	Waipahu Canal		Wailani	
		Waipahu				
	Waiawa	Waiawa	Waiawa		Mānana	
					Waimanao	Pānakauahi
East Loch	Waimalu				Waimalu	Waimalu
						Punanani
		Pu'ukape				
		Kalua'o'opu				
		Waiau				
			Waimano Channel		Waiau	
	Kalauao	Kalauao			Kalauao	
	'Aiea					
	Hālawa				N. Hālawa	
					S. Hālawa	
Airport Shoreline					Hickam Drive Canal	
					Honolulu Airport Canal	

Note: Streams listed generally from west to east, clockwise around the Watershed.

2.6.3.1 Stream Flows and Standards

The USGS monitors the flows on many, but not all streams and springs in the Watershed and publishes the updated and historical flow data annually[41] and also as a database on the internet.[42] The average flows from several of the major streams and springs are noted in Table 2-5.

Instream flow standards may be established on a stream-by-stream basis to protect the public interest. The State is to establish "a quantity or flow of water or depth of water which is required to be present at a specific location in a stream system at certain specified times of the year to protect aquatic life, wildlife, recreational, aesthetic, scenic and other beneficial instream uses" as defined under Chapter 13-169 of the Hawai'i Administrative Rules (effective May 27, 1988). Interim instream flow standards were set for Leeward O'ahu streams in 1988 based on the amount of water flowing in each stream at that time. A methodology for establishing measurable instream flow standards, based upon available information, is being developed by CWRM.

TABLE 2-5
HISTORICAL FLOW CHARACTERISTICS OF GAUGED STREAMS

Stream Name	Watershed Area mi^2 Above Monitor	Monitor Elevation (Feet)	Average Flow (CFS) *	USGS Gauge Number
Kalo'i	1.7	260	Peak flow only	16212450
Honouliuli	11	65		16212500
Waikele	45.7	1.3	27	1621300
Waikakalaua	6.9	540	Peak flow only	16212700
Kīpapa	13.8	90	10.5	16212900
Kapakahi Spring	not applicable	***	1.6	212317158003701
Waipahu Spring	not applicable	***	2.7 **	212332158003701
Waiawa	26.4	1.8	33.52	16216000
Waimano	2.63	50	Peak flow only	16216500 / 5400
Waimalu	5.97	10	8.26	16223000
Pu'ukape Spring	not applicable	***	3	21232615758xxxx
Kalua'o'opu Spring	not applicable	***	7.6	212331157570101
Waiau Spring	not applicable	***	5.3	212331157574101
Kalauao	2.59	11.7	2.93	16227000
Kalauao Spring	not applicable	***	2 * *	16224000/500/550
Hālawa	8.78	16.5	8.88	16227000
North Hālawa	4.01	160	4.82	16226200

Notes: * All data represents average flow as reported by USGS from longest period available from on-line database (http://waterdata.usgs.gov/hi/nwis/sw).

* * Accounts for flows from multiple springs in same area.

* * * All springs are around border of Pearl Harbor just above sea level.

2.6.4 DESCRIPTIONS OF PRIMARY STREAMS

2.6.4.1 Honouliuli Stream

Honouliuli Stream (State Identification No. 3-4-11) drains an area of about 11.5 square miles of the 'Ewa plain and Wai'anae Mountains. None of the drainage contains native forest areas. The stream is normally dry above Fort Weaver Road, with ground water input providing flow below this point.[43] In 2000, USGS testing of 105 sediment samples from Pearl Harbor (including offshore from the Honouliuli Stream) indicated that 148 of 252 chemicals of concern were present. Significant portions of these appear to originate from the Watershed as agriculture or termiticide chemicals.

The estuary serves as habitat for endangered waterfowl in the 70-acre Pouhala Marsh managed wetland preserve. A primary threat to wetland species here is the proliferation of mangrove.

2.6.4.2 Waikakalaua Stream

Waikakalaua Stream (State Stream Identification No. 3-4-10.02) flows from the top of the Ko'olau Mountains through conservation land, but is highly developed with urban use from an elevation of about 740 feet down to Kamehameha Highway and the H-2 Freeway. The Waikakalaua flume that once took water from just above the 750-foot elevation is no longer operational. Waikakalaua is joined by a major tributary draining Mililani after crossing Kamehameha Highway and is then joined by the smaller Waikele Stream as it passes through the lower section of Wheeler Air Force Base.

Waikakalaua Stream along new homes in Launani Valley.

2.6.4.3 Kīpapa

The Kīpapa Tributary (State Stream Identification No. 3-4-10.01) is similar in size and runs parallel to Waikakalaua Stream from the top of the Ko'olau Mountains. Unlike Waikakalaua, Kīpapa Valley is not highly developed for urban use and has historically had only minor water diversions for agriculture on the valley floor. Also similar to Waikakalaua, flow in this stream is largely a function of rainfall in the upper Ko'olau Mountains. Down slope at its junction with Waikele Stream, where average rainfall is very low, rapid increases in stream height can occur without warning due to storms in the distant mountaintops. While this stream is known to go dry during summer above its confluence with Waikele (likely as a partial result of agriculture withdrawals), it is likely that flow in the mountains continues unabated from ground water sources.

2.6.4.4 Waikele Stream

Waikele (State Stream Identification No. 3-4-10) is the largest stream on O'ahu and includes the tributaries of Waikakalaua and Kīpapa Streams. The Waikele Stream sub-watershed covers 45.7 percent of the Central O'ahu project area. Most of Waikele and its tributary streams flow in their natural beds, although they have been altered in some places by bridges, culverts, water withdrawals for irrigation, and in response to changes in flow regimes. The only portions of the Waikele system deemed to drain native forests lie within the upper reaches of the Waikakalaua and Kīpapa drainages. The upper course of Waikele is ephemeral and receives flow from several un-named dry tributaries as it begins at the peak of the Wai'anae Mountains at an elevation of about 2,900 feet and passes down through Wheeler and Schofield military bases. Its juncture with Waikakalaua is indistinct as it loses its bed and spills into a grassland that may act as a seasonal wetland. The Waikele Stream is only perennial below its junction with the larger Waikakalaua Stream as it falls into this deeper gulch. From this juncture, the combined stream flows begin to cut downward through the volcanic soils to form the steep-sided Waikele Gulch. The Waikele Gulch, just above its junction with Kīpapa Gulch, is 1,600 feet across, with nearly vertical sides dropping 240 feet to the relatively flat valley floor. At this depth, the stream is likely to receive shallow ground water input as well as inflow from the dry stream gulches draining the Wai'anae mountain range at low ground elevations.

Just below its intersection with Kīpapa Stream, at an elevation of about 90 feet, Waikele Stream begins to emerge from the gulch and flow over alluvial sediments. At this point, the combined stream flows often go to ground, only to emerge further downstream as partial flow to the Waikele springs at an elevation of 10 to 20 feet. Water from these springs has been found to have high nutrient content, a likely result of agriculture activities in the Central O'ahu Watershed areas.

Waikele Stream at Farrington Highway.

Waikele Stream passes through Waipahu, under the Farrington Highway just below the USGS stream gauge and enters West Loch through a thick forest of mangroves. Aerial photographs from 1951[44] show no mangroves over the stream delta, whereas today this mangrove forest covers several hundred acres.

2.6.4.5 Kapakahi Stream

Kapakahi Stream (no State Identification No.) arises from a 0.5 mgd[45] spring and from a watercress well just north of Farrington Highway. USGS gives this spring a higher average flow rate of 1.6 cfs (approximately 1.0 mgd). The stream is channelized, primarily for flood control, but is not continuously lined with concrete. The mouth of the stream enters

West Loch through the same forest of mangrove as Waikele Stream. Much of the short length of this stream is challenged by urban trash and potential industrial pollutants from adjacent light industrial uses.

2.6.4.6 E'o Stream

This stream enters Middle Loch through the Makalena Golf Course, the construction of which filled the fishpond Loko E'o, from which the stream derives its name. The stream banks are lined with mangroves up to the top of the golf course where an artificial concrete embankment prevents any plant growth. Upstream of the golf course, the stream is generally referred to as the Waipahu drainage canal, and then as Wailani Stream as it flows under the H-1 Freeway and through urban neighborhoods. Flow is intermittent and natural resources are limited by an almost complete lack of natural riparian areas.

2.6.4.7 Waiawa Stream

Waiawa Stream (State Identification No. 3-4-06) enters Middle Loch of Pearl Harbor across the Pearl City peninsula adjacent to an abandoned wastewater treatment plant. As with other streams in the West and Middle Lochs of Pearl Harbor, the stream mouth is dominated by a dense growth of mangrove. The Waiawa Stream bifurcates around the Waiawa plateau. Much of this area is fallow agriculture lands planned for urban development in the near future. The western stream branch, Pānakauahi Gulch, does not reach to the summit of the Ko'olau Mountains and therefore does not normally flow unless there is active rainfall in the immediate area. The main branch of Waiawa Stream courses up through Pearl City and receives flow from both Waimano (Identification No. 3-4-6.01) and Mānana (Identification No. 3-4-6.02) Streams on either side of Pacific Palisades. The upper reaches of Waiawa Stream parallel the path of the Waiāhole Ditch Tunnel bringing water from Windward O'ahu. As of 1990,[46] some of the upper tributaries of Waiawa Stream fed into the Waiāhole Ditch system, as much as 24 mgd (32 cfs). Current water allocations between these systems are unknown.

2.6.4.8 Waimalu Stream

Waimalu (State Identification No. 3-4-05) is a continuous perennial stream entering Pearl Harbor in the central portion of East Loch through Blaisdell Park and about one mile east of the Waiau Hawaiian Electric Power Plant. While mangrove dominates the growth on the stream bank, the growth of this alien plant is nowhere near as extensive as in either the West or Middle Lochs. Some of the intertidal areas are void of mangroves, allowing growth of pickleweed and providing habitat for waterfowl. The stream is bound by a concrete channel upstream of Kamehameha Highway. The upper sub-watershed is about 10% native forest, confined primarily to steep canyons.

2.6.4.9 Kalauao Stream

Kalauao Stream (State Identification No. 3-4-04) enters East Loch to the east of the Pearl City Shopping Center and receives flow both from springs in the area as well as base flow

from elevations up to 2000 feet in the Koʻolau Mountains. The stream has no major tributaries and flows in a relatively narrow sub-watershed up into the Koʻolau Mountains with about 10-percent native forest cover. Kalauao Spring, in the middle of the Pearl City Shopping Center, also receives drainage from an unnamed intermittent stream draining the Pearl Country Club and flows to Pearl Harbor 137 meters to the west of the Kalauao Stream.

2.6.4.10 ʻAiea Stream

According to the Hawaii Stream Assessment (1990), flow from ʻAiea Stream (State Identification No. 3-4-03) is often interrupted. There are no major tributaries and no native forests in the upper sub-watershed, which is impacted by pigs. The lower sub-watershed is channelized, primarily marine in nature except during storm flows, and supports scattered growth of mangroves.

ʻAiea Stream at Moanalua Road.

A Total Maximum Daily Load (TMDL) study is presently being conducted through the State DOH. ʻAiea Stream is on the State's list of impaired waters due to excessive turbidity and trash.

2.6.4.11 Hālawa Stream

Hālawa Stream (State Identification No. 3-4-02) drains the southeastern most valleys in the Central Oʻahu Watershed. The upper portions of the valleys served by the North and South branches contain some native forests from which this perennial continuous stream gains most of its flow from rainfall and ground water in the upper dike system. The stream is on the State's list of impaired waters for excessive nutrients and turbidity. Associated with the construction of the H-3 Freeway through this valley, the USGS has collected water quality samples in Hālawa Stream since the mid-1990s.

Aquatic resources are limited, particularly in the lower portion of the sub-watershed where habitats have been impacted by excessive silt. The stream enters Pearl Harbor near the USS Arizona Memorial Visitor Center, but is essentially estuarine in nature and supporting mangrove along the shorelines up to and above Kamehameha Highway. Above the tidal influence, the banks are often overgrown by hau or California grass.

2.6.5 STREAM BIOTA

Oʻahu streams are important habitats for endemic fish, mollusks, crustaceans, and insects. Although the diversity of native species is low, most of these species are endemic, found nowhere else on earth. With the exception of a damselfly species and one species of freshwater snail found only on Kauai, none of Hawaii's stream species are listed as

endangered or threatened. Native stream fauna present in Central O'ahu Streams, not including insects, consist of the following thirteen species:

Fish

- 'O'opu nākea *Awaous stamineus* (goby)
- 'O'opu alamo`o *Lentipes concolor* (goby)
- 'O'opu nōpili *Sicyopterus stimpsone* (goby)
- 'O'opu naniha *Stenobobius genivittatus* (goby)
- 'O'opu akupa *Eleotris sandwicensis* (eleotrid)
- 'Ama`ama *Mugil cephalus* (mullet)
- Āholehole *Kuhlia sandvicensis* (kuhliid)

Mollusks

- Hihiwai *Neritina granosa* (snail)
- Hapawai *Theodoxus vespertinus* (snail)
- Pipiwai *Theodoxus cariosus* (snail)

Crustaceans

- 'Ōpae kalaole *Atyoida bisulcata* (shrimp)
- 'Ōpae oeha'a *Macrobrachium grandimanus* (prawn)
- 'Ōpae ula *Halocaridina rubra* (shrimp)

Native Hawaiian insect species specialized to stream or wetland habitats have displayed adaptive evolution similar to their non-aquatic cousins. Many species of insects adapted to specific aquatic habitats have been identified. Recent surveys by the Bishop Museum[47] identified three abundant species of introduced damselflies, and two native and two introduced species of dragonflies.

More than 50 species of exotic non-native fishes, invertebrates, frogs, turtles, and algae are established in the streams and reservoirs of Central O'ahu. Some, such as mosquito fish, game fish (bass), tilapia, and prawns have been intentionally introduced, but others have become established by multiple introductions from aquarium or aquaculture releases. These introduced species can have highly adverse impacts to native fauna. Populations of non-native fish and invertebrates in the streams of Central O'ahu heavily outnumber native species.

The short, steep streams with small drainage areas produce flashy stream flow. The short duration flows, termed "freshets," are critical in the life cycle of many of Hawaii's native stream animals. The native stream fauna evolved from marine ancestors and still maintain a strong dependence on the ocean. The adult fish live and breed in the stream, some

moving down to the estuaries to lay their eggs. Eggs or larvae are washed out to sea where they live as plankton for several months before finding a fresh water stream to inhabit. The freshets provide the clues for both the spawning migrations and provide the link allowing juveniles to migrate back up intermittent stream sections to the perennial headwaters. Water withdrawals from streams that decrease or eliminate water flow will have detrimental impacts on native stream fauna.

Primary threats to fresh water habitats within Central O'ahu[48] are:

- Stream channelization
- Water pollution
- Reduced stream flow from water withdrawals
- Exotic, non-native species.

2.6.6 STREAM WATER QUALITY

Several chemicals in stream water and bottom sediment exceeded guidelines established to protect the health of stream animals and fish-eating wildlife. Sediment concentrations of the pesticides dieldrin, chlordane, and Dichlorodiphenyltrichloroethane (DDT) were in the highest 5% of streams sampled nationally by USGS, and similarly high concentrations were present in fish tissue. Dieldrin and chlordane were highest in urban areas where they were used to kill termites, and DDT was highest where it had been used for agriculture as discussed in the USGS National Water Quality Assessment Program of 1998.

2.7 FLOODING AND DRAINAGE

Floods can cause considerable damage to agricultural lands, public property, homes, and human and animal life. Besides the peripheral mountain areas, much of the Central O'ahu Watershed consists of flatter terrain with broad floodway areas draining mostly to Pearl Harbor. While flooding does occur in these low-lying areas and interior valleys, they are usually not the flash flooding episodes commonly found on the windward side of the island.

Wailani (E'o), Kapakahi, and Waikele Streams form a floodplain where they enter the West and Middle Lochs. Waiawa, Honouliuli, 'Aiea, and Kalauao Streams all have floodplains associated with them as they enter the Pearl Harbor area. Additional floodplains occur at the mouth of Pearl Harbor, along much of the Leeward Coast, and along Hālawa Stream near Moanalua Highway. Floodplains are also associated with Kalo'i Gulch, near Kapolei Parkway.

2.7.1 PREVIOUS FLOOD DAMAGE

Flooding on Renton Road.
Source: Starbulletin.com, November 6, 1996.
Deluge Floods Roads, Cuts Power.

On November 5, 1996, 12.5 inches fell in seven hours on the 'Ewa plain, flooding this poor draining, low coastal plain. On New Year's Day 1988, a series of slow-moving storms with prolonged rains saturated the soils of south-central O'ahu, culminating in severe runoff, hillside erosion, and damage to stream flood mitigation channels, homes, and roads. Other recent severe events in Central O'ahu include an October 1981 flooding of Waiawa Stream after heavy rains that led to $786,000 in damage and a January 1968 flooding in Pearl City, which caused $1.2 million damage. The most recent flooding events were during the month of March 2006. A review of records dating back to 1879 reveals flooding mostly occurs along the Waiawa and Kīpapa Streams.[49]

2.7.2 FLOODING THREATS

Flooding has been more prevalent in the Central O'ahu lowlands, around lower reaches of Waiawa Stream. The flooding problem and property loss and damage have increased as these flood plain and wetland areas have been developed. In the past, when much of the Central O'ahu study area was used for agriculture, the threat of flooding and the need for engineered drainage facilities was minimal. As the area became more urbanized and development continued to occur in flood-prone areas, such as around Pearl Harbor and in the 'Ewa plain, the threat from flooding became more severe. Areas not in flood plains added to higher flood flows by contributing higher runoff volumes from increased non-porous surfaces, such as buildings and pavement.

Low-lying parts of the 'Ewa plain are subject to flooding during intense rainstorms. The relatively flat topography of the area has resulted in difficulty in draining large quantities of rainwater. With increased development, drainage problems have intensified through an increase in impermeable surfaces, channelization resulting in high velocity drainage ways, and alteration of natural water flow patterns. As an alternative to channelization, both the *Central O'ahu Sustainable Communities Plan* and the *'Ewa Development Plan* have developed policies for the preservation of gulches and drainage ways in their natural state to assist in flood control.

Tsunami inundation is a threat to much of Hawai'i and poses an increased risk in the Central O'ahu Watershed, especially around the low-lying Pearl Harbor and 'Ewa plain areas.

2.7.3 EXISTING FLOOD MITIGATION

Flood control means the minimizing of flood damage by appropriate protective, preventive, and corrective measures. DLNR has been designated the State agency overseeing all flood control and floodwater conservation activities. These activities include all flood disaster operations.

Flood control has typically been provided for urbanized areas through the development of concrete-lined channels to convey storm water to the ocean. However, discharge of floodwaters to the ocean is a major source of non-point source pollution of near shore waters, negatively affecting coral growth, fish populations, and use of the shoreline for swimming, surfing, and other types of ocean recreation.

The most common type of flood control in the Central O'ahu area is channelization of streams, especially in the lower reaches and urbanized areas, and the use of culverts and ditches to divert excess water flow. For Central O'ahu, there are already existing flood management programs for Kalauao, Waimano, Waikele, and Honouliuli Streams. Flood control measures for these streams include: (1) the regulation of land use through buffer zones, zoning ordinances, building codes, and urban renewal projects; (2) an efficient evacuation system for flood plains; and (3) the confinement of floods through the construction of levees and dikes, decreasing flood runoff, and improving channel capacity.

2.7.3.1 Detention Basins

Detention basins in the Central O'ahu study area are being used for two purposes: flood control and water quality. Detention basins are reservoirs designed to reduce or slow the rate of flow in an open drainage facility. These basins provide temporary storage of excess storm water, and allow some percolation into the ground water.

Many detention basins used for flood control are integrated into golf courses, including West Loch, 'Ewa Villages, the Villages of Kapolei, and Coral Creek. There are also large detention basins in residential developments, such as 'Ewa by Gentry, Royal Kunia, and Ocean Pointe in the 'Ewa/Kapolei area. Smaller detention basins are located in the Mililani Mauka area. Non-residential facilities using detention basins include commercial areas in Pearl City and the industrial park near the old Waipahu Sugar Mill. These areas also potentially contribute to contamination of the aquifer by collecting water containing urban contaminants and allowing it to infiltrate into the ground.

2.7.3.2 Swales

Grassed swales are typically shallow, vegetated, man-made ditches designed to allow runoff to infiltrate into ground water. The vegetation or turf prevents erosion, filters sediment, and provides some nutrient uptake. Grassed swales can also serve as conveyance systems for urban runoff and provide similar benefits. Vegetated swales are

used at the Waipi'o Soccer Complex, Central O'ahu Park, and some commercial businesses in the Central O'ahu area. These areas also potentially contribute to contamination of the aquifer from urban runoff.

2.7.4 PLANNED FLOOD MITIGATION

For proposed projects, the 1983 *General Flood Control Plan for Hawaii* and the 1994 *Statewide Capital Improvement Program* recommend the following projects, with the Waikele Berm Enhancement as a priority project: For the Kalauao, Waimano, Honouliuli, Kalo'i, and Waimalu Streams, projects include flood plain zoning and channel improvements, and closer to the shore, a tsunami warning and evacuation system. For Waikele Stream, recommendations include flood plain zoning, stream improvements, soil conservation measures, and the aforementioned enhancement of existing berms to 100-year level protection. Hālawa and Waiawa recommendations include dredging, stream maintenance, and bank protection, and construction of an earthen dam upstream as well as organizing a flood fighting unit.

2.7.4.1 'Ewa Development Plan

The *'Ewa Development Plan* stipulates the preservation of natural gulches for drainage and flood control, but with an emphasis on the recreational benefits of peripheral trails along the gulches.

Continuing drainage problems combined with increasing development on the 'Ewa plain have resulted in the *'Ewa Development Plan* recommending the following drainage improvements:

- *A major new system to drain Makaīwa Hills, Kapolei Business Park, and the industrial areas closest to the Kalaeloa Deep Draft Harbor.* The Makaīwa Hills system proposes detention basins *mauka* of the H-1 Freeway with a concrete-lined channel conveying storm waters to the ocean near Barbers Point.

- *Expansion of the channel at the western edge of Kalaeloa to provide additional capacity for the City of Kapolei.*

- *A system to drain the West Loch Drainage Basin, serving 'Ewa by Gentry and development in East Kapolei.* Drainage improvements in the West Loch Drainage Basin would be constructed to handle storm water runoff from existing and proposed projects located in the basin. The new 'Ewa by Gentry development will have a grass-lined drainage channel terminating near the Honouliuli National Wildlife Refuge.

- *A system to drain the Kalo'i Gulch Drainage Basin.* This basin is one of the larger drainage basins in the region encompassing approximately 7,140 acres. Flow through this basin has historically been constrained by the barrier created by the O'ahu

Railroad elevated right-of-way. The impeded water backs up into nearby residential communities. Improvements are planned for Kaloʻi Gulch to enlarge the existing drainageway to provide flood control for up to the 100-year flood for the communities within the Kaloʻi Gulch sub-watershed.

- The ʻEwa Beach 5-year Plan (January 2004) proposes to leave existing gulches and drainageways in their natural state to maintain their drainage function.

For Kīpapa Gulch, the City has passed a resolution stipulating that subdivisions designate a separate landscaped lot in this area and that the Gulch shall be preserved in its natural state.

The Barbers Point Redevelopment Commission Plan stipulates that major natural gulches should be retained as flood plains and open space resources and that disturbance of, or development in, the gulches should be avoided. Other proposed urban development projects in the basin, including the University of Hawaiʻi West Oʻahu Campus and the ʻEwa Marina project have not yet received City approval for their drainage master plans.

2.7.4.2 Central Oʻahu Sustainable Communities Plan

The *Central Oʻahu Sustainable Communities Plan* is similar to the *ʻEwa Development Plan* in that it directs drainage systems to integrate with the regional open space network, emphasizing retention basins and recreational access. This includes retaining natural gulches as flood plains. Other existing flood plains should be left intact and urban development restricted, except where necessary, to protect existing urban development from flooding. Channelization of streams is also discouraged.

2.8 NEAR SHORE WATERS

Near shore waters associated with the Watershed are divided into three segments: (1) the ʻEwa plain and Kahe shoreline east of Pearl Harbor, (2) Pearl Harbor, and (3) waters bordering Hickam Air Force Base (AFB) immediately east of Pearl Harbor.

Fisheries resources in the near shore area off Central Oʻahu may be estimated by examining the recreational and commercial fisheries statistics collected by the DLNR Division of Aquatic Resources (DAR). Fisheries zones in Hawaiʻi are demarcated radially around the islands and divided into "near shore" and "offshore" areas. The two near shore zones off of the Central Oʻahu Watershed are Zone 401 from the Honolulu Airport to Barbers Point, and Zone 402 from Barbers Point north to Māʻili Point. While Zone 401 overlaps almost completely with the Central Oʻahu shoreline, only about half of Zone 402 is within the Watershed. Commercial fishermen are asked to designate the zone within which their catch was made, the type of fishing method used, and total weight of fish. The information for the two zones off the Central Oʻahu Watershed is summarized in the table below for the most recent four-year period. The average annual commercial fish

catch from near shore waters in these two zones is about 157,000 pounds, or 78 tons per year.

TABLE 2-6
COMMERCIAL FISHING STATISTICS

4-Year ('02–'05) Average
Area 401—Honolulu Airport to Barbers Point
Commercial Fishing Statistics

Method	No. fishers	Trips	Lbs. Caught
Bottom handline	21.8	271	20,516
Casting, jigging	4.0	102	714
Hand (limu)	11.8	173	515
Netting	10.0	82	42,243
Other	2.5	13	1,009
Spearing	9.3	70	4,075
Trolling	27.5	86	2,116

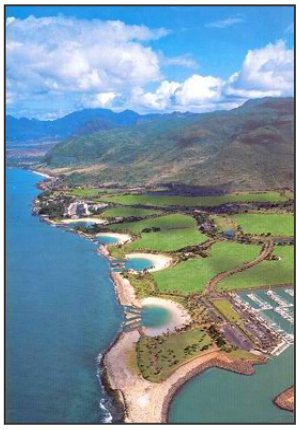
4-Year ('02–'05) Average
Area 402—Barbers Point to Maile Point
Commercial Fishing Statistics

Method	No. fishers	Trips	Lbs. Caught
Bottom handline	28.8	330	32,535
Casting, jigging	3.7	43	2,403
Hand (limu)	0.0	0	0
Netting	7.0	62	34,065
Other	4.0	19	3,612
Spearing	4.8	30	2,399
Trolling	45.8	216	10,590

The ʻEwa and Kahe shorelines extend about 12 miles from the mouth of Pearl Harbor west to Barbers Point and north to Kahe Point. Recreational fishing vessels access this coastline primarily through Pearl Harbor and from the private marina and boat ramp adjacent to Barbers Point Harbor.

The near shore waters off the southern ʻEwa plain increase in depth very gradually and much of the shore is protected by a series of narrow sand beaches. Much of the benthic substrate is relatively flat pavement heavily colonized by macroalgae. Although individual coral colonies are interspersed across this wide shallow plain, nowhere do they approach concentrations sufficient to be termed a true reef. This shallow shoreline was once prized for its abundance of native edible seaweed or *ogo*. A decrease in the abundance of *ogo* is likely a combined effect from decreased near shore nutrients

following the demise of sugar agriculture, increased harvesting, and increased competition from non-edible, non-indigenous algae species.



Ko Olina lagoons and harbor.

North of Barbers Point, the width of the shallow near shore zone is greatly decreased and the shoreline typically consists of an abrupt ledge of consolidated limestone. A mile-long channel dredged through the shallow sea floor allows deep draft ships to enter Kalaeloa (Barbers Point) Harbor and the adjacent, private Ko Olina Marina. Although tidally influenced, the near shore currents are predominantly to the south and have fostered greater coral growth on the north side of the channel cut. North of the harbor, four artificial lagoons have been carved out of coastal lands to create swimming beaches for the Ko Olina Resort complex.

Pearl Harbor is the state's largest estuary. It consists of a system of drowned river valleys that have successively been flooded and emerged to dry land in response to glacier melting cycles. This cyclical sea level has left the floor of the harbor with successive layers of mud, limestone, oyster beds, stream alluvium, and marine clays above the volcanic basalt. The harbor mouth and active areas of the harbor have been subject to dredging intermittently since the early 1900s and the bottom substrate is primarily mud. Corals and invertebrate habitats are typically located on vertical or near vertical surfaces not subject to heavy sediment loads.

The harbor is surrounded by the U.S. Navy installation with its associated shipyard, maintenance supply center, public works center, ammunition depot, 12 miles of docks, and four dry docks. The harbor consists of East Loch, Middle Loch, West Loch, Southeast Loch, and Ford Island, and has a water surface area of about 8 square miles. The U.S. Air Force's Hickam AFB borders a small portion of the East Loch shoreline.

The State identifies the entire harbor, out to a depth of 30 feet and extending up into the mouths of perennial streams, as a Water Quality Limited Segment (see Figure 2-9). The pollutants determined to have exceeded State Standards by numeric assessment include total nitrogen, chlorophyll-a, turbidity, and total phosphorous. Nitrogen and phosphorous have been shown to enter the harbor through ground water and stream flow. Levels of nitrogen and phosphorous in ground water are high, presumably because of agriculture fertilization in the Watershed. Chlorophyll-a is a measure of phytoplankton growth and requires both high nutrient levels and a high residence time. High turbidity may arise either from high plankton concentrations or high concentrations of silt. The harbor acts as an effective sink for all urban and agriculturally derived pollutants entering with stream waters. Approximately 96,000 tons of sediment is estimated to enter the harbor annually from streams.[50] The Navy[51] estimates that it removes 75,000 cubic yards of sediment per

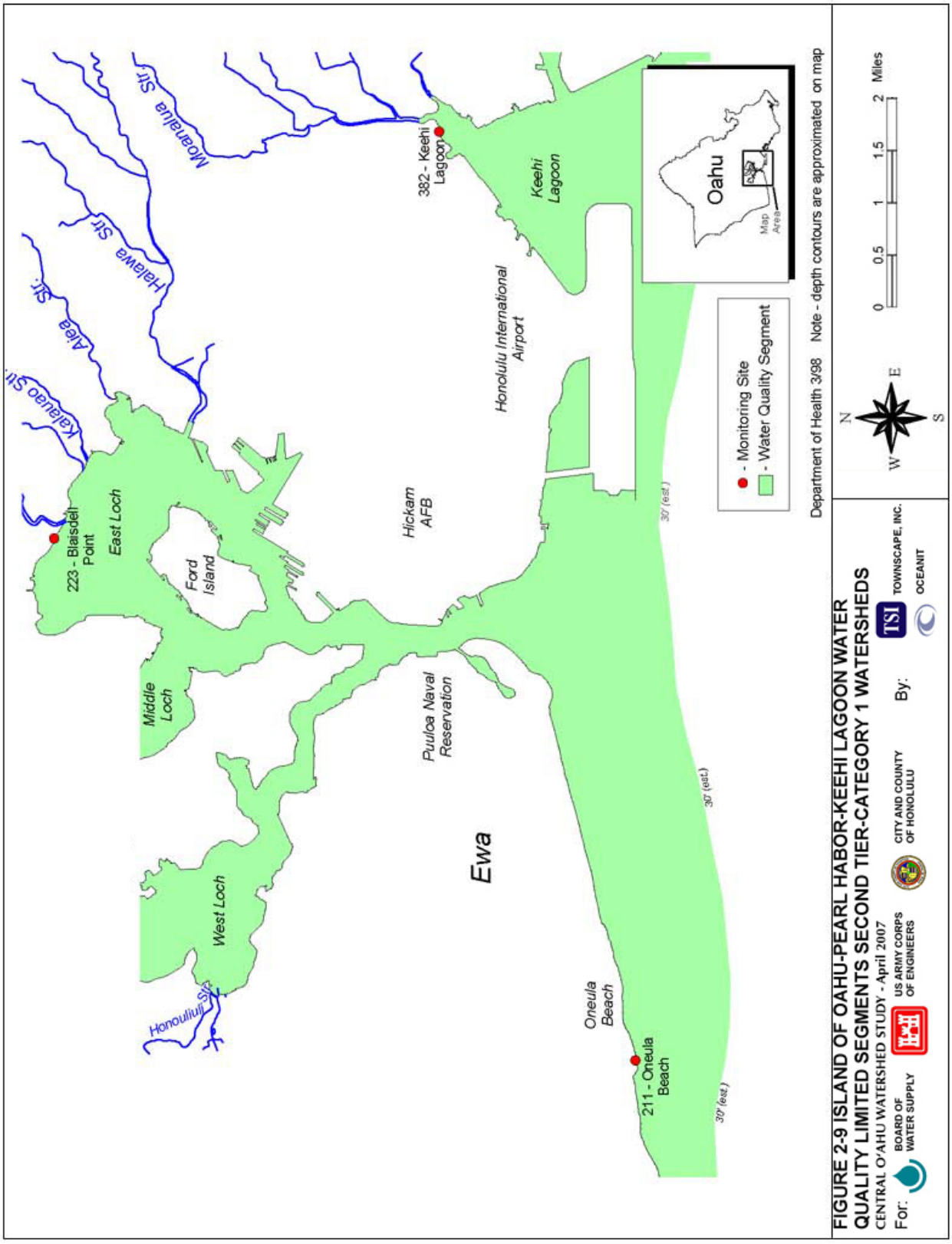
year from harbor operational areas, and 200,000 cubic yards of sediment per year from the main channels. These dredging operations typically occur every five years. A series of studies conducted by the Naval Ocean Systems Center in the 1970s and 1980s[52] documented the high level of pollutants in Pearl Harbor sediments, and the impact of these sediments and poor water quality on marine communities in the harbor. One-hundred five sediment samples were analyzed for 252 chemicals determined to have the potential to be present in harbor sediments based on past land use. One-hundred forty-eight of the 252 chemicals of concern were present in Pearl Harbor.

Even prior to designation of portions of the Harbor as a Superfund site by the EPA in 1992, controls on pollutant sources and clean-up of existing pollutants were being instituted. Control on the use and application of tri-butyl-tin bottom paints was instituted, selective dredging of contaminated sediments was conducted, and 40,000 cubic yards of PCB-contaminated sediments were removed and cleaned. Pearl Harbor Superfund site clean-up actions are still underway and may be monitored through the EPA web site.[53] Ongoing dredging operations within the harbor are attempting to deal with a variety of pollutant types and concentrations at different locations within the harbor.[54]

Satellite view of Pearl Harbor.
Source: http://en.wikipedia.org/wiki/Image:PearlHarbor_Sm.jpg

In the 1960s, there were seven major sewer outfalls into Pearl Harbor (City and County at Waipahu, Pearl City, and Mililani; Navy raw sewage discharge at Fort Kamehameha and Iroquois Point; and Army at Schofield) and at least one major source of sugar mill waste to the harbor. Today, only the Fort Kamehameha outfall still exists and this outfall has both a higher treatment standard and is piped out to a deep ocean outfall where it no longer affects the Harbor.

Even though it is known that many areas (particularly West Loch) remain with contaminated sediments, a series of studies in the 1990s documented the occurrence of invertebrate species (including corals) not seen previously in the harbor.[55] More recent surveys by the Navy's Natural Resource Management Environmental Department continue to document the apparent recovery of benthic ecosystems within the Harbor.[56]


Moanalua Str.
Halawa Str.
Aiea Str.
Kalauao Str.
382 - Keehi Lagoon
Keehi Lagoon
Honolulu International Airport
Hickam AFB
223 - Blaisdell Point
East Loch
Ford Island
Middle Loch
Puuloa Naval Reservation
Ewa
West Loch
Honouliuli Stm.
Oneula Beach
211 - Oneula Beach
30' (est.)
30' (est.)
30' (est.)
Oahu
Map Area
- Monitoring Site
- Water Quality Segment
Department of Health 3/98 Note - depth contours are approximated on map
N
W
E
S
0 0.5 1 1.5 2 Miles
FIGURE 2-9 ISLAND OF OAHU-PEARL HABOR-KEEHI LAGOON WATER QUALITY LIMITED SEGMENTS SECOND TIER-CATEGORY 1 WATERSHEDS
CENTRAL O'AHU WATERSHED STUDY - April 2007
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
OCEANIT

Commercial fishing in Pearl Harbor ceased in 2001 when the final baitfishing permit was revoked following the September 11, 2001 terrorists attacks. Marine resources are managed by the Navy Natural Resources Management Environmental Department and there is officially no recreational fishing allowed within the harbor, although casual observations would suggest that these regulations are at best selectively enforced.

The Hickam and Airport shorelines have been completely modified by man. The Hickam shoreline consists of small docks, a marina, and a military beach fronted by a relatively shallow (10 to 20 feet) dredged area covered with sand. The Airport Reef Runway was constructed by filling over the inner lagoon of the active fringing reef. While this area is technically outside of the Central O'ahu Watershed shoreline boundary, this structure has significant impact on currents and water quality that affect the Watershed shoreline. Landing strip construction created an enclosed estuary between the runway and the shoreline which receives runoff from the airport drainage canal. This water then drains through the eastern causeway to the dredged area fronting Hickam. Fishery resources within this half-square-mile pond are purported to be significant and a concern for airport safety as it attracts birds. The reef fronting the reef runway is considered to be an excellent site for recreational fishing, diving, and surfing.

2.9 TERRESTRIAL ECOSYSTEMS

The Hawai'i Natural Heritage Program (HNHP) compiled a likely picture of the natural ecosystem types that existed on O'ahu before human contact.[b] Results from the study of these vegetation patterns show that before human contact, dry shrubland and grassland were likely found in the 'Ewa plain, and dry forest and shrubland were found throughout the Central Plateau, dominated by one or more trees, such as *wiliwili* (*Erythrina spp.*), *lama* (*Diospyros spp.*), and *manele* (*Sapindus spp.*). Mesic forest and shrubland, found up to the 590-foot elevation, consisted of many potential dominant taxa, had increased plant diversity over the lower elevations, and had the highest tree diversity of the ecosystem types at the time.[57] An understanding of natural ecosystem patterns can help shape management and restoration decisions. For example, restoring non-native ecosystems to the previously present and naturally-occurring vegetation mixes could restore structure and function to an ecosystem. According to HNHP data, the only native vegetation remaining in the Central O'ahu Watershed Study area is found in the upper reaches of the Wai'anae and Ko'olau Mountains, and a few areas around Pearl Harbor.

2.9.1 ECOSYSTEM TYPES

Currently, 80% of the Central O'ahu Watershed ecosystem is dominated by non-native vegetation. Remaining native ecosystems are mostly found at the peaks of the Ko'olau and Wai'anae mountain ranges (Figure 2-10). Of the 20% remaining native vegetation,

[b] HNHP recreated undisturbed native ecosystem ranges by expanding the current vegetation patterns into those areas devoid of native ecosystems, using clues from historical records. When there were no such sources, current rainfall patterns were overlaid on the island, and general moisture and presumed physical characteristics of the vegetation were assigned within the elevation and moisture zones.

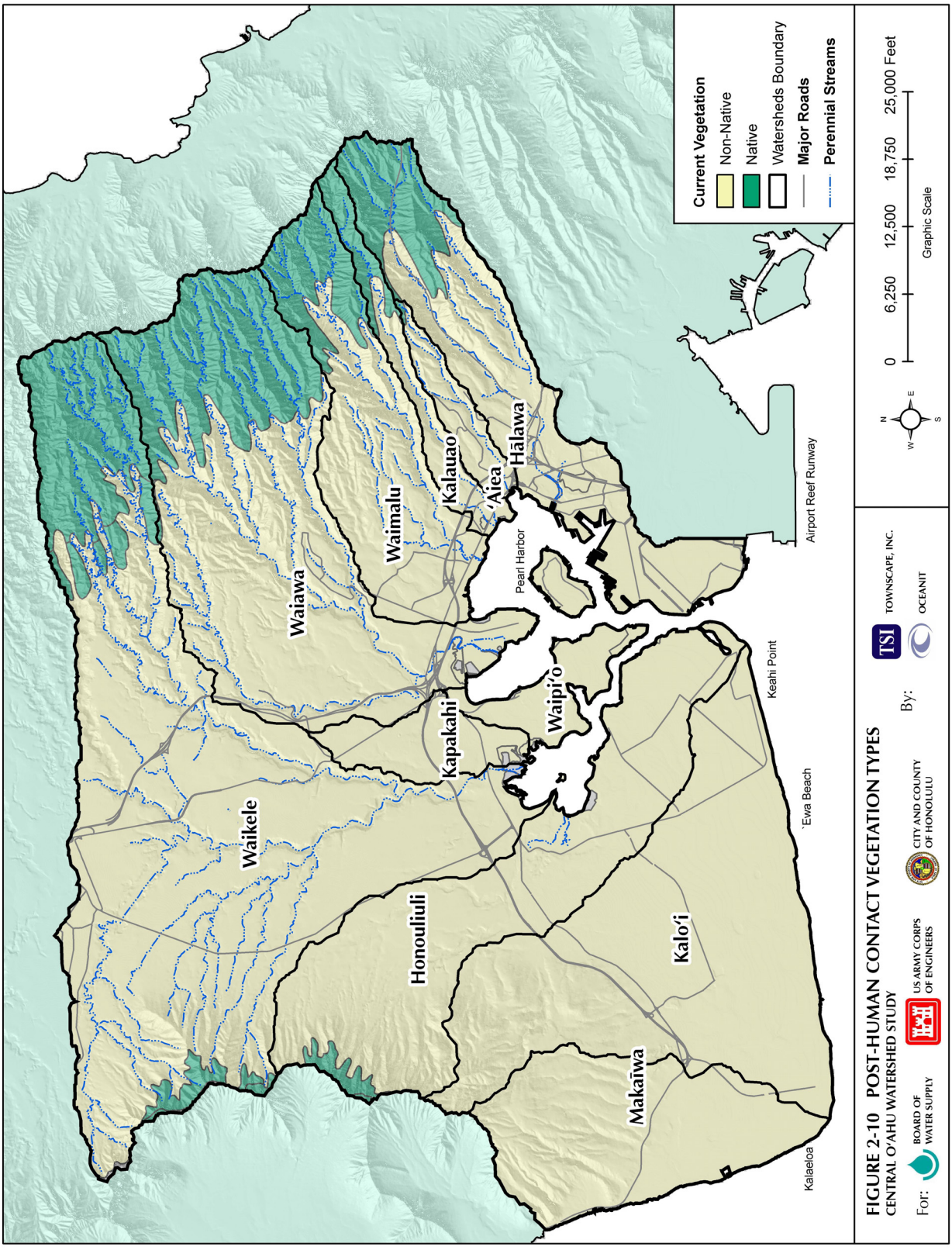
approximately 83% is characterized as Lowland Wet Forest / Shrubland, which typically occurs below the 2,200-foot elevation in moderate to steep slopes on the Ko'olau Mountains. It is dominated by *'ōhi'a* (*Metrosideros spp.*), with a variety of codominant taxa; good plant diversity; and understory taxa, such as *ha'iwale* (*Cyrtandra spp.*), lobeliads, and ferns. This ecosystem has persisted since before human settlement, but its extent has been reduced. Approximately 11% of the native vegetation is Wet Cliff, 3% Lowland Mesic (moderately moist) Forest / Shrubland, and 2% Dry Cliff. The remainder is made up of Wetland and Lowland Dry Shrubland / Grassland. Wet Cliff is characterized as having waterfalls and seeps, and is typically marked by near vertical, wind-swept, wet slopes covered with shrubs and ferns. Lowland Dry Forest / Shrubland no longer exist in the area.

TABLE 2-7
TYPES OF NATIVE VEGETATION CURRENTLY FOUND

Native Vegetation Type	% Native Coverage
Lowland Wet Forest / Shrubland	83%
Wet Cliff	11%
Lowland Mesic Forest / Shrubland	3%
Dry Cliff	2%
Wetland, Lowland Dry Shrubland / Grassland	1%

Sinkhole at Kalaeloa.

An interesting ecosystem to note within the 'Ewa Plain is a network of karsts (pit caves, or sinkholes). They could also be termed phreatic caves, which develop below the water table. The 'Ewa Karst is the largest of several karsts on O'ahu, but possibly the least studied. There are approximately 12,000 acres of exposed reef from Kahe Point to Pu'uloa, preserving the remains of ancient plants and animals, particularly shells, extinct birds, and two bats, of which one is new to science.[58] The U.S. Geological Survey 'Ewa Quadrangle shows numerous sinking streams and closed depressions within the karst, some manmade. Most of the land surface of the karst has been developed.


Current Vegetation
Non-Native
Native
Watersheds Boundary
Major Roads
Perennial Streams
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
N
W
E
S
Waikele
Honouliuli
Kapakahi
Waipi'o
Waiawa
Waimalu
'Aiea
Kalauao
Hālawa
Makaīwa
Kalo'i
Pearl Harbor
Keahi Point
'Ewa Beach
Kalaeloa
Airport Reef Runway
FIGURE 2-10 POST-HUMAN CONTACT VEGETATION TYPES
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI TOWNSCAPE, INC.
OCEANIT

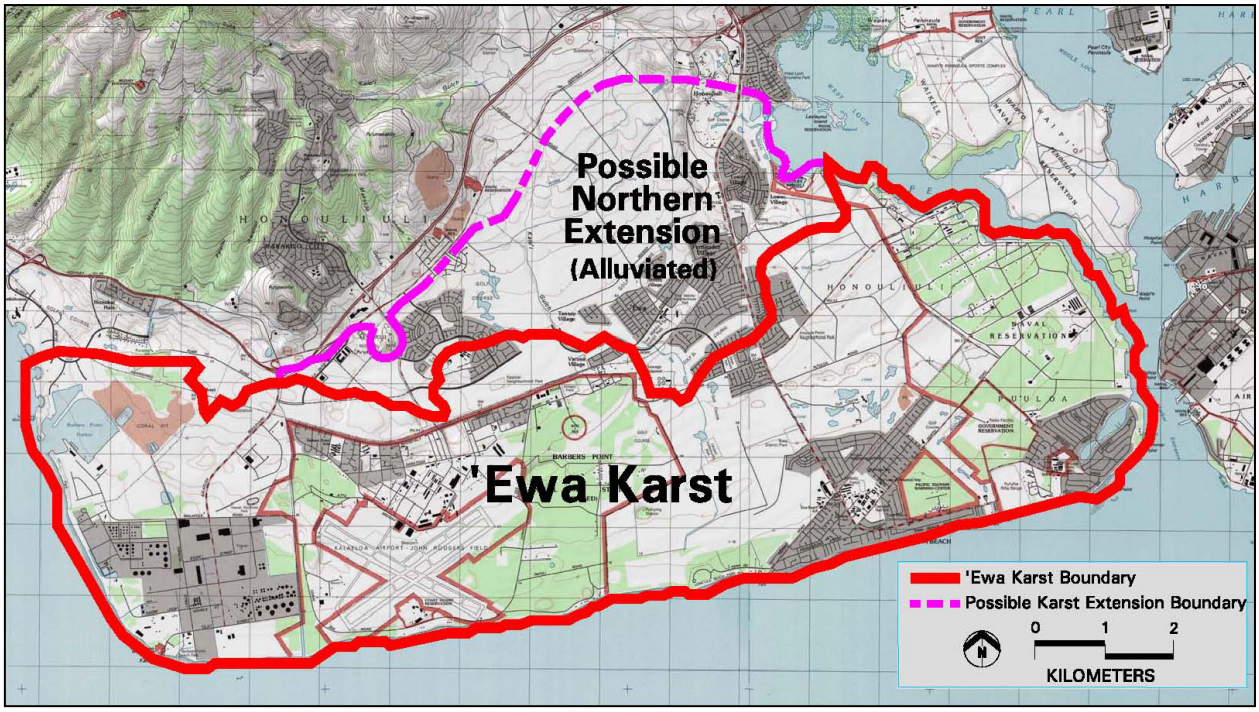
Some remaining sinkholes of the 'Ewa Karst are home for *'ōpae 'ula* (*Halocaridina rubra*), tiny brackish water shrimp. A natural sinkhole with these shrimp is found near Chevron's Rowland's Pond preserve. Two to three artificial ponds were dug by the Division of Aquatic Resources (DAR), two of which filled back up with water. DAR is waiting to see if this will provide the habitat that *'ōpae 'ula* need.

2.9.2 FLORA AND FAUNA OF SIGNIFICANCE

There are a variety of native, threatened and endangered flora and fauna found within the Central O'ahu Watershed. Many types of native forest birds, including the O'ahu *'elepaio* (*Chasiempis sandwichensis ibidus*), *pueo* (*Asio flammeus sandwichensis*), *'i'iwi* (*Vestiaria coccinea*), *'apapane* (*Himatione sanguinea*), and *'amakihi* (*Hemignathus chloris*) can be found in the Honouliuli Preserve in the Wai'anae Mountains and the O'ahu Forest National Wildlife Refuge (NWR) in the Ko'olau Mountains.[59]

The Pearl Harbor NWR, Kalaeloa Unit, is home to two endangered plants, including the largest population of *'akoko* (*Chamaesyce spp.*) on O'ahu, and the second largest population of endangered *'Ewa hinahina* (*Achyranthes splendens var. rotundata*). Other

FIGURE 2-11 'EWA KARST



Map of 'Ewa Karst. Source: http://www.caves.org/section/ccms/wrh/index.htm. Modified by Townscape, Inc.

native plants in the Kalaeloa Unit include the night blooming *maiapilo* (*Capparis spp.*) and *naio* (*Myoporum spp.*), or false sandalwood.[60] The Honouliuli Forest Reserve has some very rare and endangered species, including *Abutilon spp.*, rare mint plants, a lobelia plant (*pānaunau*, or *Lobelia yuccoides*),[61] and the largest known population of the endangered plant *haha* (*Cyanea grimesiana ssp. obatae*).[62] The O'ahu Forest NWR is also home to 15 endangered plant species.[63]

2.9.3 CRITICAL HABITAT DESIGNATIONS

Critical habitat is defined as those areas "with the physical and biological features essential to the 'conservation' of a threatened or endangered species, and that may require special management considerations or protection."[64] There are two USFWS-designated critical habitat areas on O'ahu that overlap portions of the Central O'ahu Watershed Study area. In December of 2001, the USFWS designated five units, 65,879 acres, of critical habitat for the O'ahu *'elepaio*.[65] Two of the five units of *'elepaio* critical habitat overlap the study area: one on the western slopes of the Wai'anae Mountains and one on the eastern slopes of the Ko'olau Mountains.

Endangered O'ahu 'elepaio. Source: www.angelfire.com/hi/ecosystem2/

In June of 2003, 304 units, 55,040 acres, were designated critical habitat for 99 plant species. Critical habitat boundaries within the study area are in areas similar areas as the *'elepaio* units, on the slopes of the Wai'anae and Ko'olau mountains.

2.9.4 ECOSYSTEM THREATS

The primary threats to terrestrial ecosystems in Central O'ahu include alien species and habitat loss. The O'ahu Invasive Species Committee (OISC) is a voluntary partnership that aims to prevent the spreading of invasive species on O'ahu as well as the introduction of new invasive species. The Caribbean (or Coqui) frog (*Eleutherodactylus spp.*) is targeted by OISC as one of the most important invasive species found in the Central O'ahu Watershed. Although they are found in only limited locations on O'ahu, they are highly invasive and prey upon native invertebrates, which could in turn reduce food sources for native forest birds such as the *'elepaio*. Additionally, their loud calls have created a nuisance to nearby residences and could potentially reduce property values.[66]

The OISC targets three plant species in the Central O'ahu Watershed: fountain grass, fire tree, and Bush Beardgrass. Fountain grass and fire tree are also designated as a noxious weed by the Hawai'i Department of Agriculture (DOA), and DLNR DOFAW designated

fountain grass as one of Hawaii's most invasive horticultural plants.[67] The grasses provide fuels for wildfire and Beardgrass readily colonizes burned areas.[68] The fire tree out-competes native species and alters soils by increasing nitrogen levels.[69]

TABLE 2-8
SPECIES TARGETED BY THE OISC IN THE
CENTRAL O'AHU WATERSHED STUDY AREA

Common Name	Scientific Name	Threat
Carribbean Frog	*Eleutherodactylus spp.*	Prey upon native invertebrates
Fountain Grass	*Pennisetum setaceum*	Fuel source for fire
Fire Tree	*Morella faya (previously Myrica faya)*	Increases nitrogen levels in soils, outcompetes native spp.
Bush Beardgrass	*Schizachyrium condensatum*	Fire-promoter, post-fire colonizer

In addition to those species targeted by the OISC, plant aggressors include *Clidemia*, *Lantana*, Christmas berry, guava, and passion vine, while animal threats come from goats, pigs, rats, feral cats, mongoose, alien birds, carnivorous snails, and pest insects. Introduced plants compete for space, light, water, and nutrients. Nonnative birds eat food and occupy nesting areas needed by native bird species. Rats eat the fruit and bark of native plants, prey on birds, their eggs and nestlings, and are, along with carnivorous snails, major predators of endangered tree snails. Ungulates add to habitat destruction in their search for food, and other animals compete with natives for food and space. Mosquitoes and other nonnative insects serve as vectors for lethal bird diseases, such as avian malaria (*Plasmodium relictum*) and poxvirus (*Poxvirus avium*). The State is continually taking efforts to prevent other diseases, such as West Nile Virus (*Favivirus spp.*) brought by the southern house mosquito (*Culex quinquefasciatus*), from entering Hawai'i in the future.[70]

Ecosystem threats also result from human activities in and around the Watershed. Activities such as hiking can increase the spread of invasive plants, and motorized vehicle recreation can cause erosion, sedimentation in streams, and facilitate the colonization of weeds by exposing bare soil.[71] Wildfire is a concern to the native habitat in the Wai'anae Mountains not only from careless individuals, but also from impact areas for live-fire training on adjacent military lands.[72] Increased urban development decreases permeable surfaces and infiltration of water into the aquifers and increases the potential for erosion. Encroachment into previously undeveloped areas reduces habitat for native species and fragments existing habitat. While City zoning and State land use designations currently

protect conservation areas, easements or changes in designations could allow for development in the future.[73]

2.9.5 MANAGEMENT ACTIVITIES

Management of forests is essential to the water supply of the Watershed. Both the Wai'anae and Ko'olau Mountain Ranges have management programs for the restoration of native forest habitat and protection of unique rare and endangered species. This requires controlling alien plant and animal species, locating and protecting populations of native species, re-introducing native species, conducting research, and public education.

2.9.5.1 State Reserves and Parks

The **'Ewa Forest Reserve** is managed by the State of Hawai'i DLNR DOFAW and is located in the *mauka* Conservation District of the Waipi'o sub-watershed. The reserve is divided into three sections: Mānana, Waimano, and Poamoho. Management plans for this area are out-of-date; however, in partnership with the Ko'olau Mountains Watershed Partnership, the 'Ewa Forest Reserve is a priority location to conduct biological surveys to identify rare plant and animal species, and invasive weed locations of most concern.

The State maintains a public hunting area in a portion of the **'Ewa Forest Reserve Waimano Section**. Removal of wild pigs and goats is allowed within this hunting unit year-round, which helps to control feral ungulate populations.[74]

State Parks are managed for outdoor recreation and heritage opportunities. **Keaīwa Heiau State Recreation Area** is a 384.5-acre park located in 'Aiea and is maintained for picnicking, camping, hiking, and preserving the remains of a *heiau ho'ola*, a temple of healing.

2.9.5.2 National Wildlife Refuges

National Wildlife Refuges are managed by the USFWS to protect native plants and animals and their habitats. Two of the three refuges that make up the **O'ahu National Wildlife Refuge (NWR) Complex** lie within the Central O'ahu Watershed boundaries: O'ahu Forest NWR and Pearl Harbor NWR. The **O'ahu Forest NWR** is located on the upper slopes of the northern Ko'olau Mountains, and contains some of the last remaining intact native forests on O'ahu. This 4,525-acre refuge was established in December of 2000 on land formerly owned by Castle and Cooke. The *NWR Conceptual Management Plan* focuses on the management of native natural communities; protection and recovery of endangered, threatened, and rare wildlife; public use for awareness and appreciation; and the protection and management of significant cultural and historic resources.

The **Pearl Harbor NWR** was originally made up of two wetland units, Honouliuli and Waiawa, which protect endangered waterfowl. The Kalaeloa Unit, once a part of the former Barbers Point Naval Air Station (now referred to as Kalaeloa), was added to the

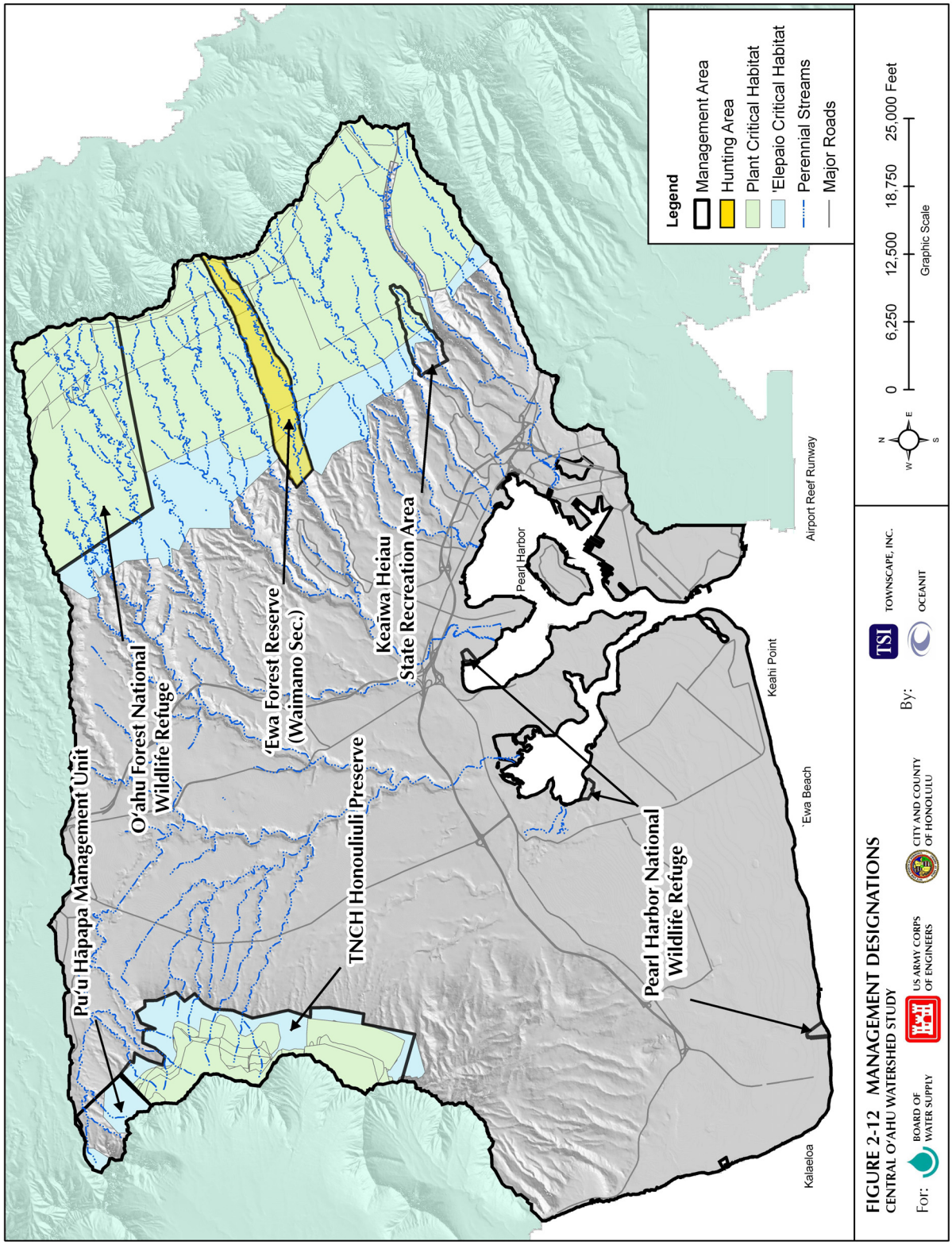
Pearl Harbor NWR to protect the last remaining, ancient, coastal dry land, plant communities once widespread throughout the 'Ewa plain. USFWS manages this area under a cooperative agreement with the U.S. Navy.

2.9.5.3 U.S. Military Installations Integrated Natural Resource Management Plans

The U.S. Army developed *Integrated Natural Resource Management Plans* to document previous management actions for rare plants, animals, and ecosystems on Army training areas, and to recommend future management efforts. The O'ahu Integrated Natural Resource Management Plan identifies management activities for the **Pu'u Hāpapa Management Unit** in the Schofield Barracks Military Reservation on the South Range. This management unit is approximately nine acres in size and is located at the top of Pu'u Hāpapa in the Wai'anae Mountains, the first peak south of Kolekole Pass. It is the only native forest patch deemed worthy of intensive ecosystem management in the South Range.[75]

The Army contracts the Natural Resource Staff (NRS), employed by the University of Hawai'i Pacific Cooperative Studies Unit, to manage the Unit. A rat control program is currently maintained to protect O'ahu Tree Snails (*Achatinella spp*) and terrestrial snails (*Laminella sanguinea* and *Amastra micans*). Fencing was also constructed to protect snail habitat from predators. Other snail protection activities involve surveying to identify new populations, monitoring known populations, and prioritizing and managing known sites. NRS also regularly monitors critical rare plant populations as well as conducts threat control, propagation, and reintroduction of rare plant species.[76]

The **Pearl Harbor Naval Complex** *Integrated Natural Resource Management Plan* **c**overs most of the U.S. Navy installation areas at Pearl Harbor, with a focus on Pearl Harbor's waters from the intertidal zone into Māmala Bay.


Pu'u Hāpapa Management Unit
O'ahu Forest National Wildlife Refuge
'Ewa Forest Reserve (Waimano Sec.)
TNCH Honouliuli Preserve
Keaīwa Heiau State Recreation Area
Pearl Harbor National Wildlife Refuge
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
Legend
Management Area
Hunting Area
Plant Critical Habitat
'Elepaio Critical Habitat
Perennial Streams
Major Roads
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
FIGURE 2-12 MANAGEMENT DESIGNATIONS
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
OCEANIT

2.9.5.4 TNCH Honouliuli Preserve

The Nature Conservancy of Hawai'i (TNCH) leases approximately 3,600 acres from Campbell Estate, which it manages as the **Honouliuli Preserve**. Located between the 1,200 and 3,100-foot elevations on the eastern slopes of the Wai'anae Mountains, the Preserve contains more than 70 different rare and endangered plants and animals. It specifically protects six native natural communities where 66 rare plants have been recorded, 20 of which had not been seen for 15 or more years, and 40 of which are listed as endangered.[77, 78]

The *Honouliuli Preserve Master Plan* of 2000-2005 focuses on five key natural resource management strategies: threat control, habitat restoration, rare species, research, and safety and preserve maintenance. TNCH manages the Honouliuli Preserve for research and education, community service, cultural preservation, and enjoyment of open spaces. Community partnerships and citizen volunteers assist in removing alien plants and animals, re-introducing native species, and educating the public on the importance of preservation. Creating firebreaks in rare plant and *'elepaio* habitats protects these species and also improves hunter access. Other activities include seedling propagation and planting, weed and predator control, and trail construction. TNCH is currently looking for a partner to take over management of the Preserve, in order to focus more on the group's mission of managing more intact native ecological systems.

2.9.5.5 Watershed Partnerships

The Ko'olau Mountains Watershed Partnership (KMWP) was formed to protect the forested areas within the Ko'olau Mountain Range. KMWP is working to improve water and environmental quality by working with landowners to implement watershed management projects, while maintaining ecosystem integrity and protecting the economic, socio-cultural, and ecological resources of the Ko'olau Mountains. Partners of KMWP are Kamehameha Schools, BWS, DLNR, Bishop Museum, State Department of Hawaiian Home Lands, Agribusiness Development Corporation, U.S. Army, The Queen Emma Foundation, Mānana Valley Farm, Tiana Partners, Dole Food Company, Inc, USFWS, Hawaii Reserves, Inc., Kualoa Ranch, Inc., and O'ahu Country Club. Additionally, there are six non-voting associate partners that support the KMWP but do not own land within the partnership boundaries. Activities include an invasive weed survey, fencing, ungulate management plan, and directed hunts. Long-range goals include expanding the partnership to cover *makai* regions, as well as including communities in their protection and restoration efforts.

State Watershed Protection and Management Program Act 152: Relating to Watershed Protection (2000) identified the Wai'anae Mountains as a potential watershed partnership area due to its agricultural and domestic water sources, native species ecosystems, hunting, hiking, offshore waters, and cultural resources.[79] A study done by TNCH for DLNR on the feasibility of forming a Wai'anae Mountains Watershed Partnership

concluded that such a partnership is possible and needed. Unique challenges regarding partnership structure, leadership, funding, and community and landowner interests will need to be overcome during the planning process. DLNR will now decide on whether to move forward with forming such a partnership.

2.9.5.6 Conservation Partnerships Program

The USFWS Conservation Partnerships Program facilitates restoration of native habitats by providing cost-share funding, biological expertise, and technical assistance to landowners, non-profit organizations, and community groups.[80] USFWS has sponsored two projects with The Nature Conservancy: the Honouliuli Preserve Hunter & Firefighter Access program and the North Puali'i Gulch Ungulate Exclosure. The Queen Emma Foundation is teaming up with USFWS in their South Hālawa Valley Restoration Project.

2.9.5.7 Mānana Valley Watershed Protection and Habitat Restoration Project

This Federally funded project, through the City and County of Honolulu, is an acquisition and restoration project of Mānana Valley. This multi-species conservation effort includes critical habitat for 15 listed plants and O'ahu *'elepaio*, as well as essential habitat for the O'ahu tree snail. This parcel contains five distinct forest types, including wet and mesic forest types and four miles of stream, and is adjacent to the 'Ewa Forest Reserve.

2.9.5.8 Na Kupuna a me Na Kako'o O Hālawa

A native Hawaiian grassroots organization called Na Kupuna a me Na Kako'o O Hālawa (The Elders and Helpers of Hālawa) is working to care for and protect the land in Hālawa Valley. This area is considered the sacred site of Papahanaumoku, Mother Earth, who gave birth to the Hawaiian Islands. The group is focusing their efforts on protecting two sacred sites in the Valley, native plants, and other cultural resources.[81]

2.9.5.9 Karst Protection

In 2001, the Estate of James Campbell erected a substantial chain-link fence to protect eight acres of karst with at least 100 sinkholes from destruction by nearby quarry operations. Some other areas, "B6-137" and "B6-22" have been fenced due to efforts by former Bishop Museum vertebrate zoologist Alan Zeigler.

2.10 TRADITIONAL AND CUSTOMARY RIGHTS AND PRACTICES

Traditional and customary Native Hawaiian practices are dependent upon access to natural and cultural resources and the ability to use and care for the water, land, and air. These natural elements form the basis of subsistence, cultural and religious beliefs, customs, and practices. The following sections describe some important cultural places within the Central O'ahu Watershed Study area and their associated traditional Hawaiian practices. Understanding the significance of these places helps to gain insight when

making land and water management decisions. Most of these are referenced from *Sites of O'ahu* (Sterling and Summers, 1978), unless otherwise noted.

2.10.1 WAHI PANA

Wahi Pana include sacred sites, significant places such as *heiau*, shrines, churches, observation points, prominent pōhaku or stones, burial caves, geographic features, and natural features and phenomena associated with deities or significant events.[82] *Wahi Pana* in Central O'ahu include:

- Waimalu burial cave.
- Lei Lono, an opening for mankind to enter eternal night, was located on the northern side of Red Hill, at the boundary of Kona and 'Ewa, in line with the burial hill of Āliamanu. The hole was about two feet wide in the pāhoehoe lava, and a breadfruit tree was found here.
- Limestone caves or pits (*ana*) in the uplifted coral reef that makes up the 'Ewa Plain in Kalaeloa were marked by Hawaiian legends as the location where the hairless human beings (*'olohe*) lived when they first landed on O'ahu.[83]
- Hale O Papa *heiau* in Hālawa Valley.
- Keaīwa Heiau in 'Aiea is a healing or life-giving *heiau*. Medicinal herbs were grown beyond the *heiau* walls. The young were taken there to be trained as *kahuna lapa'au*.
- Kapolei was one of three places in the island chain where Hawaiians would go to identify Hokule'a, which is one of three stars that led to and from Tahiti.[84]
- Large *pōhaku* were markers for canoe travel, located at Barbers Point and the airport side of Pearl Harbor. Stone markers also were used to locate artesian wells.[85]
- Ka'ahupahau, a guardian shark chiefess who guarded the entrance to Pearl Harbor, lived in an underwater cave in Honouliuli Lagoon (West Loch), and her brother Kahi'uka lived in an underwater cave off Moku'ume'ume (Ford Island) near Keanapua'a Point at the entrance of East Loch.[86]
- Puhikani in Waiau and Ma'ipuhi in Waimano were bathing places of Ka'ahupahau.

2.10.2 STREAMS, SPRINGS AND PONDS

Surface waters support habitat for native species of marine life, taro and other cultivation, domestic use, conducting cultural and spiritual customs, and recreation.

- Kahuawai, a small waterfall on Kalauao Stream was once a favorite resting place exclusively for chiefs.
- Kauwamoa (in Hālawa), also a favorite resting and diving place.
- Waikakalaua swimming hole.
- Taro was found at the water of Ka'aimalu, 'Ewa.
- Kūnana Pond, at the base of Hālawa Stream, once connected with Kūāhua Island (now Kūāhua Peninsula).

- All streams of the area, including Honouliuli, Waikele, Kapakahi, Waiawa, Waimalu, Kalauao, 'Aiea, and Hālawa Streams.

2.10.3 SHORELINES, REEFS, FISHPONDS, AND NEAR SHORE AREAS

Coastal areas were important for gathering food and medicine, practicing cultural and spiritual customs, and recreation.

- Loko Pa'aiau ('Aiea, McGrew Point), Loko Laulaunui (Laulaunui Island), Loko 'Oki'okiolepe (near Iroquois Point), and Loko Pa'akea (Waimalu).
- Fishponds at Waiawa. Mullet at Kuhia *loko* (fishpond), fine seaweeds at Kuhia waho, salt at Ninauele.
- Fishponds in Waipahu.[87]
- Limu (seaweed) at 'Ewa Beach - Limu was gathered here for food and medicinal purposes.

Loko E'o, 1930 - This fishpond has since been filled. Source: Biodiversity of Freshwater and Estuarine Communities in Lower Pearl Harbor, Oahu, Hawaii with Observations on Introduced Species, February 2000.

2.10.4 FORESTS

Forests are where activities take place, such as hunting pigs and animals; gathering plants used for medicine, food, *hula*/ceremonial adornments, and offerings; and where cultural and spiritual customs are practiced.

- The greenish-yellow flowers or seed from *'aiea*, or *hālena* (*Nothocestrum*), a plant of 'Aiea, can be used to make lei.
- Forests of Halemano and Honouliuli.[88]

2.10.5 ARCHAEOLOGICAL AND HISTORIC SITES

Man-made structures may include temples, shrines, agricultural sites, and sites for food production such as *lo'i*, terraced slopes, *'auwai*, and fish ponds; sites with special functions may include trails, salt pans, *hōlua* slides, quarries, petroglyphs, gaming sites, and canoe landings.

- Kīpapa Gulch archaeological sites.
- Waikele Gulch archaeological sites.
- Waikakalaua Gulch archaeological sites.
- Barbers Point archaeological district.
- One'ula archaeological district.
- Hawaiian Petroglyphs in Waipahu.

- A *maika* field was located in Waiau. *Maika* was an ancient Hawaiian game similar to bowling. Two other *maika* fields were near the stream of Kukehi in Waiawa.

2.10.6 AREAS OF CULTIVATION

Cultivated areas can be described as a system with interrelated elements, such as fields, streams, and *'auwai*. Other areas may include cultivation of plants used for food, medicine, adornment, ornament, implements, cooking, fuel, mulching, and ceremony.

- 'Ewa was an extensive and fertile plain, the whole of which was in the highest state of cultivation. Every stream was carefully embanked, to supply water for the taro beds. Where there was no water, the land was under crops of yams and sweet potatoes.[89]
- Kalelealuaka's father described to him the site of his former plantation at Keahumoe (or Keahumoa). This land is located in the general vicinity of Honouliuli / Waipahu. As Kalelealuaka and his father journeyed inland from Wai'anae (through Pōhākea, or Kolekole Pass), they reached a plain of soft, whitish rock, where they refreshed themselves with food. Then they kept on ascending, until Keahumoe lay before them, dripping with moisture from the mist of the mountain. There they found bananas, upland *kalo*, sugar cane, and sweet potatoes.
- *Sites of O'ahu* indicates that there was coconut at Hapenui and taro at the water of Ka'aimalu, to remove the bitterness of the *awa* at Kalahikuola.
- Historically, terraces for taro extended up the flats along the lower courses of Kamananui and Kamanaiki streams which join to form Hālawa. Four and five miles inland, dry taro was planted on the banks of gulches. Taro was also found in 'Aiea, the lowlands of Kalauao, Waimalu, Waiau, and 'Ewa. Taro of 'Ewa was kai-kea, kai-koi, haokea, lehua, and kai ele'ele.

2.10.7 CIRCULATION NETWORKS INCLUDING TRAILS AND DIRT ROADS

On land, these include trails and roads for lateral access and for *mauka* and *makai* access. Along the shore, these networks include landings, harbors, and piers.

- The 'Ewa Trail: A historical trail throughout the Central O'ahu Watershed. The 'Ewa Trail began at the lowland of Hālawa, and followed streams and taro patches through 'Aiea, Kalauao, Waiau, Waimano, Mānana, and Waiawa, to the stream of Kukehi. Here the trail branched, one towards Waialua and the other to Honouliuli. At Honouliuli, the trail again branched into three trails, by Pu'u-o-Kapolei, Pōhākea, and Kolekole. The trail from Pu'u o Kapolei went by the sandy stretch to meet with the trail that led along the beach from Pu'uloa to Waimanalo. The trail at Pōhākea went up through Kunia and Honouliuli to meet up with a trail from Wahiawā and Waialua. The Kolekole trail passed over the Wai'anae Range through Kalena (currently Schofield Barracks).
- 'Aiea Hiking Trail.
- Pearl Harbor Historic Trail.

- Palikea Trail.
- Kalua'a Loop Trail.
- Waikakalaua Trail.
- Poamoho Access Road and Trail.
- Mānana Trail.
- Waimano Trails.

2.11 SETTLEMENT HISTORY

From fishing village to diversified agriculture, and master-planned communities to possibly the Technology Center of O'ahu, the Central O'ahu Watershed has had a varied history, and will perhaps have an equally colorful future. In ancient times, Hawaiians lived near the shore and streams to tend to fishing and taro *lo'i*. Much can be learned about water management techniques for the Central O'ahu Watershed by understanding traditional Hawaiian water management, and the how and why of settlement history in the area.

2.11.1 SETTLEMENT JUST PRIOR TO WESTERN CONTACT

Hawaiians used the *ahupua'a* system for land management and political boundaries before the Great Mahele of 1848. *Moku* (islands) were first divided into *mokuoloko* (districts), and within each *mokuoloko* were *ahupua'a*. On the *moku* of O'ahu, the 'Ewa *mokuoloko* was divided into the *ahupua'a* of Hālawa, 'Aiea, Kalauao, Waimalu, Waiau, Mānana, Waimano, Waiawa, Waipi'o, Waikele, Hō'ae'ae, and Honouliuli.

Furthermore, the *ahupua'a* were generally, but not always, subdivided into *'ili* (land sections). As was recognized by the decision of the Supreme Court in the Kāne'ohe case in 1877, there were two types of *'ili*.[90] One class of *'ili* was merely a subdivision of the *ahupua'a* for the convenience of the chief, who received revenues from his *konohiki* (agent). The other class was *'ili kūpono* or *kū* where each *'ohana* (family) would be responsible for its care. In such situations, it was common to attach separate supplementary mountain and ocean resource areas called *'ili lele*,[91] providing the *'ohana* access to resources both in the mountain areas and seaward zones (from *mauka* to *makai*). The right to continue to use and cultivate these areas stayed with the *'ohana* living on them regardless of any transfer of title to the *ahupua'a*. In some cases, these *'ili* absorbed the greater part of the *ahupua'a* in which they were situated, such as the *ahupua'a* of Waikele. While some districts are regularly divided up into *ahupua'a* averaging only a quarter of a mile in width and several miles in length, other *ahupua'a,* like Honouliuli, encompassed over forty thousand acres.[92]

Although many *ahupua'a* extended from the mountaintops to the near shore reef, *ahupua'a* boundaries are somewhat different when compared to current sub-watershed boundaries (see Figure 2-13 Ahupua'a). *Ahupua'a* were defined to allow access to the

resources necessary to sustain the Hawaiian way of life.[93] Each *ahupua'a* contained the resources that were necessary to provide food for the *'ohana* living there and tending the *kuleana* (land allotment).[94] By comparison, watershed boundaries delineate drainage areas, and are not defined by the other types of resources they provide.

In ancient times, the Central O'ahu Watershed was an area known for its abundance of water and agriculture. Most of the *ahupua'a* names are indicative of water: Kalauao (multitude of clouds), Waimalu (shaded water), Waiau (water to swim in, or swirling water), Waimano (many waters), Waiawa (bitter water), Waipi'o (curved, winding water), Waikele (muddy water), and Honouliuli (blue harbor).[95] Honouliuli also means dark harbor, for the dark fertile lands that stretch from the waters of Pearl Harbor to the summit of the Wai'anae Mountains.[96]

The abundance of water in this area led Native Hawaiians to establish densely populated villages in what is now called the Waipahu (gushing waters) region of Pearl Harbor.[97] The coastline of coral outcroppings, mud flats, and shallow waters was ideal for fishing, and made the construction of 30 or more fishponds possible. Springs provided ample water for agriculture and taro was grown in surrounding wetlands. As was typical of settlement throughout Hawai'i, eventually a shift from the sea to the land took place. As the population grew, this would have provided a more efficient means of subsistence than total reliance on fishing.[98] Taro was grown along all of the streams, and dryland taro was planted along the banks of gulches that were not too steep. With the abundant food supply, the area around Pearl Harbor had the second highest density in population after Honolulu in ancient Hawai'i.[99]

2.11.2 POST-CONTACT SETTLEMENT

Western development in Central O'ahu began in the late 1800s[100] after the establishment of the Constitution of the Kingdom of Hawai'i in 1840. The *ahupua'a* of Waipi'o, Waikele, and Hō'ae'ae were conveyed to William Jarrett, a high-ranking official in the Hawaiian government. Pearl City and Waipahu were settled by independent farmers and fishermen, changing the areas from fishing village to wetland farming communities.[101] Fishponds and taro lands were converted to other wetland crops, such as rice, watercress, asparagus, and lotus. Some settlers made their living by growing pineapple and sugar cane on the hillsides, while others harvested fish and crabs.

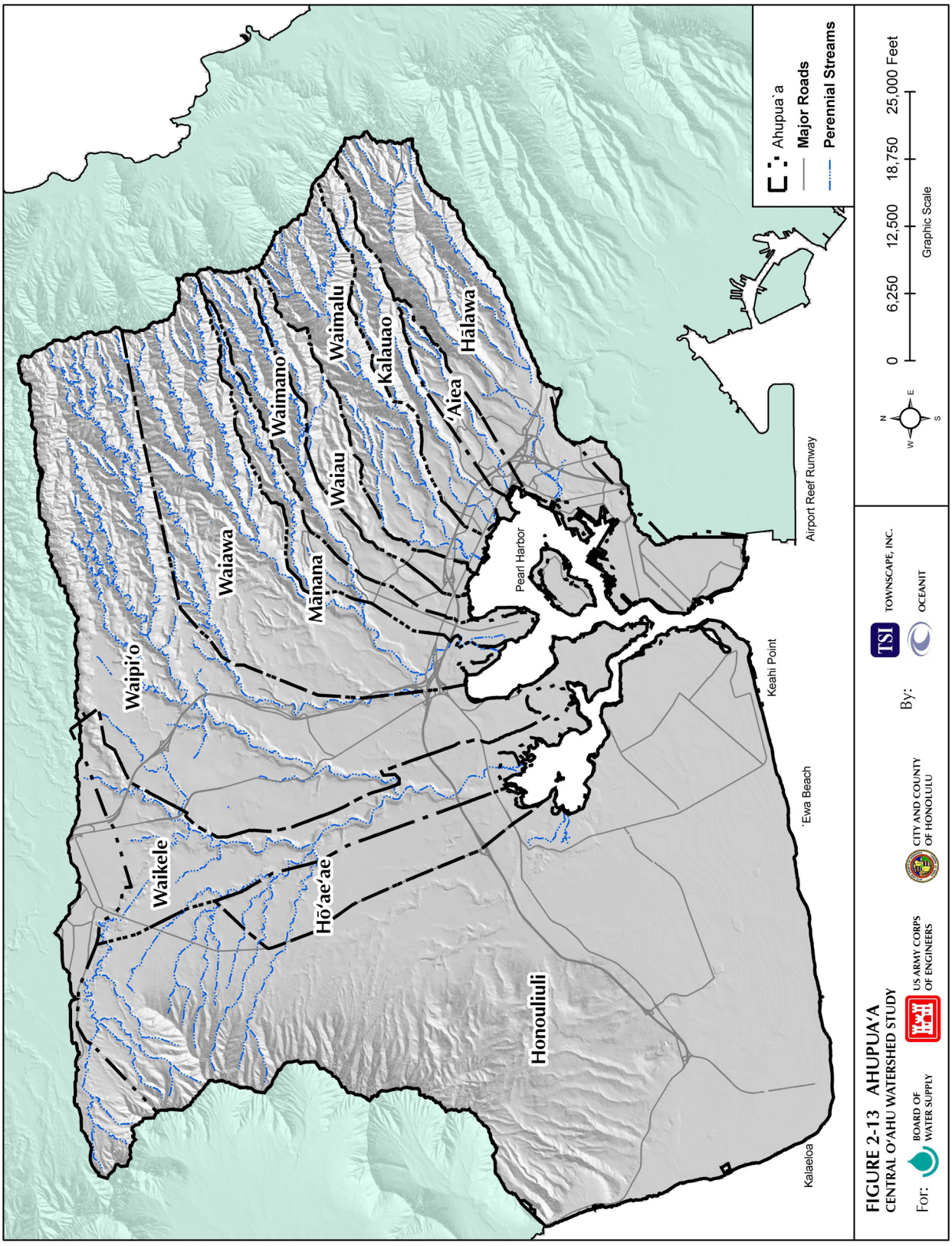

Waipi'o
Waikele
Hō'ae'ae
Waiawa
Mānana
Waiau
Waimano
Waimalu
Kalauao
'Aiea
Hālawa
Honouliuli
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FIGURE 2-13 AHUPUA'A
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
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Pearl City got its name from the oysters containing pearls that were discovered in Pearl River.[102] Early Pacific voyages also mention Pearl River as Pearl Lochs and Wai-Momi, translated as Water of the Pearl or Pearl Water. Peter Corney, one of the earliest settlers of European ancestry on O'ahu, reported in 1818 that the depth of the water in Pearl River was "not more than 15 feet of water on the bar or reef at high water and inside from 6 to 18 fathoms mud and sand."[103] Andrew Bloxom, part of an expedition party in 1825, often described the hazards of navigating the narrow entrance through the coral reefs of the Pearl Lochs. He stated that if it were not for the treacherous approach "it would form a most excellent harbor as inside there is plenty of water to float the largest ship and room enough for the entire Navy of England."[104]

Lands other than those distributed to William Jarrett in the Central O'ahu Watershed area were distributed to State and private interests. Waimalu Valley was owned and developed by the McCandless family. One of the many development activities of the McCandless Cattle Company was the construction of a ditch system in Waimalu Valley, where they grazed cattle.[105] When James Campbell purchased the land in 1877, he drove about 30,000 head of cattle out of the area now known as Honouliuli Preserve.[106] Cattle grazing in the uplands stripped the land of its vegetation, washing soil into the Pearl River lagoons, wiping out the oyster population. In 1904, the narrow coral reef entrance to Pearl River was dredged to form Pearl Harbor, allowing the gunboat USS Petrel to proceed to the upper part of Main Loch in January 1905.

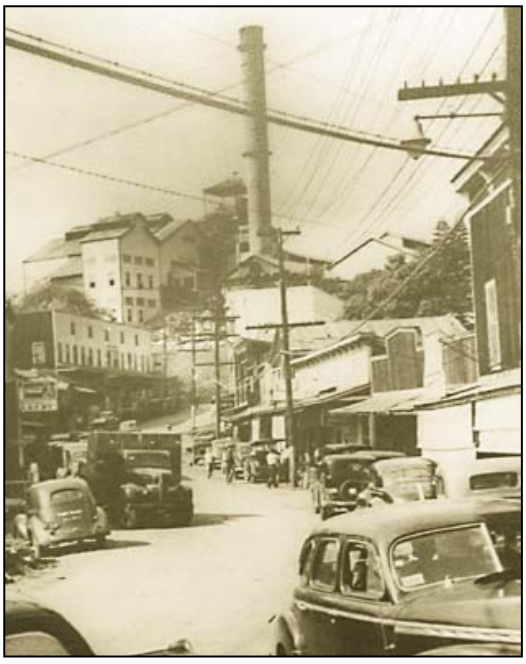
The introduction of the O'ahu Rail and Land Company (OR&L) Railroad in 1889 by Benjamin Franklin Dillingham linked Leeward O'ahu with Honolulu. These trains carried freight and passengers, providing more people with access to the leeward coast. With the help of hydraulic engineers, Dillingham found an abundance of quality artesian water in 'Ewa for irrigating planned sugar plantations. O'ahu Sugar Company (OSCo) incorporated in 1897, harvested the first commercial crop of sugar in 1899. The OR&L Railroad brought raw sugar to the docks to be loaded onto the ships and then taken to other parts of the world.

The Waiāhole Ditch System, a network of tunnels and ditches, carries water from Windward O'ahu to the island's central plain. Waiāhole Water Company, Ltd., a subsidiary of OSCo, built the main bore and smaller tunnels from 1913 to 1916 to subsidize water needs for expanding crops. Waipahu became a sugar plantation town and new towns such as 'Aiea started to spring up to support the sugar industry.

In the 1930s, 1.5 million non-native trees were planted to halt erosion in the forests, and the Civilian Conservation Corps built roads and trails in the Honouliuli Preserve area.[107]

Between 1939 and 1944, about 3,000 acres of sugar cane lands on the coastal plain were converted to military use. Previously, Pearl Peninsula was where wealthy people built elaborate mansions, and enjoyed parties and yacht races in Pearl Harbor. However, the

bombing of Pearl Harbor on December 7, 1941 in World War II, changed the face of the area, and Pearl Peninsula and its surrounding areas became the property of the military.[108] Military development of Pearl Harbor, Schofield Barracks, and Barbers Point Naval Air Station occurred during this time.



Old Depot Road in Waipahu during the Sugar Era. Source: Honolulu Star Bulletin. "Waipahu residents strive to build community after being divided by a freeway." 9/28/03.

The social fabric of the sugar plantation towns changed quickly after World War II (1941 to 1945), and Hawaii's admission to statehood in 1959. Between 1949 and 1964, about 2,000 acres of sugar cane lands were converted to urban use, and between 1950 and 1955, another 2,000 acres of sugar cane lands were converted to unirrigated pineapple fields. The accumulated impact of the increase in population and household income, extension of major highways, availability of motor vehicles, and improved access to other parts of the island subsequently led to a change in the lifestyle of the once rural close-knit communities.

The population of southwest O'ahu nearly tripled during the 1960s. Growth in tourism and supporting businesses expanded at this time, and included such developments as the commercial strip along Farrington Highway. The opening of Campbell Industrial Park in 1963 brought thousands of new job opportunities to the area with the opening of two petroleum refineries, a steel fabricating plant, cement plant, and many other industrial enterprises. With more jobs came more homes.

Faced with a shrinking demand for the pineapple and sugar grown in the 1960s, Central O'ahu began to play a role as a major area for housing development. At that time, Castle & Cooke began development of Mililani Town, a 3,500-acre planned, low-density, suburban community that offered affordable single-family housing to first-time buyers.

Subsequently, additional housing was developed above Waipahu and the H-1 Freeway in Village Park, Gentry Waipi'o, Waikele, Royal Kunia, and other development projects.[109] In 1970, the 'Ewa plantation merged with OSCo. Sugar cane fields gradually receded with the expansion of residential subdivisions, ending the sugar mill era for surrounding towns. "Mom and Pop" stores closed due to competition from chain and large-scale retailers, which were able to sell goods profitably at costs significantly lower than those of local stores.

In 1983 when production was no longer economically feasible, the cane fields were fallowed and subleased for ranching and pasture purposes.[110] Since 1985, 3,000 acres of land in Central O'ahu have been taken out of agricultural production.[111] With the closure of OSCo in 1995, future use and allocation of water between Leeward and Windward O'ahu have become an issue. A large portion of the water that was used for sugar cane irrigation was diverted from the Windward to the Leeward side via the Waiāhole Ditch. Residents on the Windward side would like to see all of the water that was diverted for sugar production returned back to Windward streams. However, those on the Leeward side are still dependent on this water, as most of the former sugar cane lands of OSCo are currently used for diversified agriculture, and some for golf courses and a cemetery.

2.12 SOCIOECONOMICS

The Central O'ahu Watershed Study area accounts for a significant percentage of Oahu's future growth as projected in the City and County's *General Plan*. Statistical data used for this section is generally no older than the year 2000, but when available, more recent data is used.

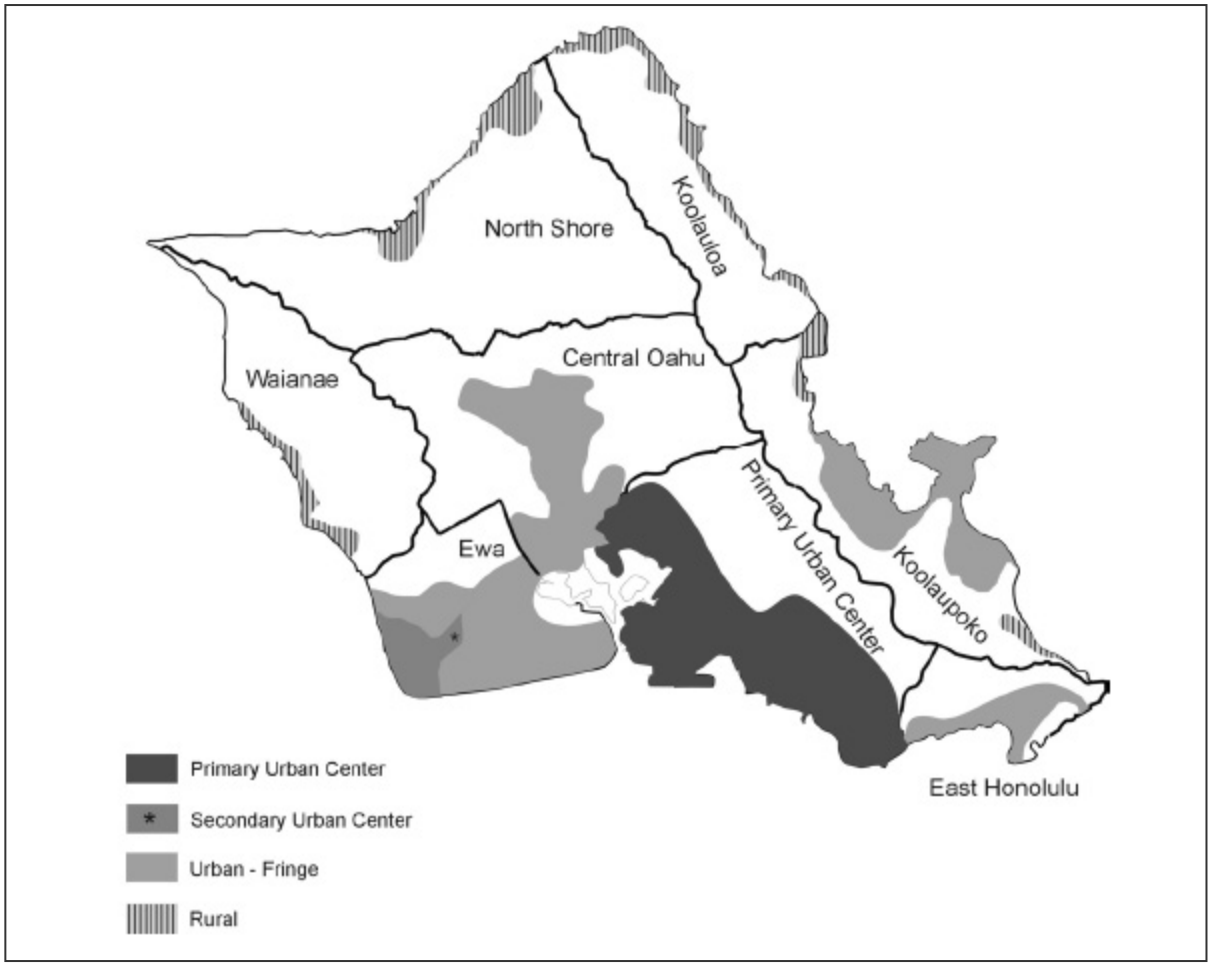
2.12.1 POPULATION CHARACTERISTICS

Based on the U.S. Census tract data from the year 2000, there are 287,899 people, 83,480 households, and 68,326 families residing in the Central O'ahu Watershed area. The population density is approximately 1,671 people per square mile. Half (50%) of the population is Asian, 21% has a mix of two or more races, and 18% is White. The remaining 11% of the population is made up of Native Hawaiians or other Pacific Islanders, African Americans, or those of other races. The majority of people living in this area speak English, with 33% primarily speaking Asian or Pacific Island languages.[112]

In the Central O'ahu Watershed area, 63% of the population is within the 18 to 64-year old age group. Twenty-seven percent of the remaining population is under the age of 18, and 10% is 65 years of age or older. The median age is 34 years old. There are 83,480 households, of which 82% are considered family households. Of these family households, 81% are married couples living together, and 51% have children under the age of 18 living with them.

According to the City and County of Honolulu's *General Plan,* concentrated growth will be directed to the Primary Urban Center (PUC), of which the Hālawa, 'Aiea, Kalauao, and Waimalu sub-watersheds, and Pearl City of the Waiawa sub-watershed are located. The Second Urban Center is located in the Kalo'i sub-watershed extending into the Makaīwa sub-watershed of the 'Ewa District, and will proportionately have the greatest amount of growth in residential population and jobs. Some growth is also projected for the remaining sub-watersheds, identified as the Urban Fringe (See Figure 2-14).

FIGURE 2-14 GENERAL PLAN DEVELOPMENT PATTERN



General Plan Development Pattern.
Source: Oahu General Plan, 1992.

According to The City and County of Honolulu Department of Planning and Permitting's (DPP) *Fiscal Year 2005 Annual Report on the Status of Land Use on O'ahu*, the population in the *'Ewa Development Plan* (DP) area will increase by 139% between the years 2000 to 2025 (See Table 2-9). This is an increase of 95,440 people. The *Central O'ahu Sustainable Communities Plan* (SCP) area is expected to increase in population by 22%, or 32,479 people over the same period. The projected trend anticipated that the population of O'ahu will shift from the PUC to the 'Ewa DP area. Note that PUC figures are for the entire PUC, which extends east of the Central O'ahu study area. The population of the PUC DP area made up 47.9% of Oahu's total population in 2000, and is projected to drop slightly to 44.4% in 2025. The Central O'ahu SCP area accounted for 16.9% of the county-wide population in 2000, and that percentage is projected to remain relatively

stable at 16.8% by 2025. However the 'Ewa DP area, accounting for 7.8% of the population in 2000, is projected to account for almost double that percentage (15.2%) by 2025. Military personnel, excluding their families, are included in these projections. These projected figures will remain constant each year until 2025: 12,300 military personnel for Central O'ahu and 350 for 'Ewa.

Projections for the year 2025 show that the 'Ewa DP area will exceed its allotted share of Oahu's population as outlined by the General Plan by 2.2%, or roughly 23,750 people. Population projections for the PUC DP area and Central O'ahu SCP area indicate that these areas will match the *General Plan*'s policies for growth.

TABLE 2-9
2005 POPULATION[c] TRENDS VS. GENERAL PLAN POLICY[d]

DEVELOPMENT PLAN AREA	% OF ACTUAL POPULATION FOR 2000	% OF PROJECTED POPULATION			GENERAL PLAN PERCENTAGE FOR 2025
		2010	2020	2025	
Primary Urban Center[e]	47.9%	46.4%	45.1%	44.4%	46.0%
'Ewa	7.8%	10.1%	13.6%	15.2%	13.0%
Central O'ahu	16.9%	16.9%	16.6%	16.8%	17.0%
Remaining O'ahu	27.4%	26.6%	24.7%	23.6%	24.0%
Total	100%	100%	100%	100%	100%

	ACTUAL POPULATION FOR 2000	PROJECTED POPULATION			
		2010	2020	2025	2030
Primary Urban Center	419,422	442,018	468,025	478,430	489,389
'Ewa	68,696	95,769	141,417	164,136	184,612
Central O'ahu	148,208	160,338	172,103	180,687	189,599
Remaining O'ahu	239,830	254,525	255,705	254,797	253,700
Total	876,156	952,650	1,037,250	1,078,050	1,117,300

[c] Residential population.
[d] Information for this table is extracted from the Annual Report on the Status of Land Use on Oahu, Fiscal Year 2005, City and County of Honolulu, Department of Planning and Permitting.
[e] Figures represent entire PUC, not just the portions of the PUC that are within the study area.

2.12.2 HOUSING

Newer homes in Central O'ahu. Source: http://www.hawaiiremodeling.com/hr42001/default.php?urlarticleid=0006

There is a variety of housing in the Central O'ahu Watershed area, from affordable units and starter homes to mid-size single-family and multi-family units. The area is generally characterized by the various master-planned and bedroom communities that began springing up as the sugar cane industry in the area declined in the 1960s. Mililani is known as Oahu's first master-planned community, and is made up of single-family homes, townhouses, and apartments. Some of the older communities that started out as sugar mill towns include Waipahu, 'Aiea, and Pearl City. 'Ewa homes in the Tenney, Renton, and Varona villages, built in the 1920s, were once home to OSCo workers and their families. They have since been renovated. Makakilo also has older homes, combined with brand-new residences, townhouses, and condominiums. Waikele and Waipi'o are communities of homes, townhouses, and condominiums in lower to middle price ranges, with available rentals.

The 2000 Census shows 88,481 housing units in the area at an average density of 513.5 units per square mile. The average household size is 3.22 persons and the average family size is 3.68 persons. The median housing prices for the Central O'ahu Watershed area ranged from $520,000 to $620,000 as of the fourth quarter of 2006 (See Table 2-10). The median condominium prices ranged from $284,000 to $315,000.

TABLE 2-10
MEDIAN SALES PRICE FOR HOUSING, FOURTH QUARTER, 2006[f]

GEOGRAPHIC AREA	HOMES	CONDOS
Entire Island	$620,000	$315,000
Central O'ahu	$587,000	$310,000
'Ewa Plain	$520,000	$284,300
Makakilo	$591,000	$314,000
Waipahu	$585,500	$285,000
Pearl City	$605,000	$305,000

The General Plan encourages development within the Second Urban Center at Kapolei and the 'Ewa and Central O'ahu urban-fringe areas to meet housing needs not readily

[f] As reported by the Honolulu Board of Realtors.

provided for in the Primary Urban Center. The 'Ewa DP allows for nearly 28,000 new housing units to be built in a series of master-planned communities by the year 2020. These communities include the City of Kapolei, East Kapolei, 'Ewa by Gentry, 'Ewa Marina, 'Ewa Villages, Ko Olina, Laulani, Makaīwa Hills, Makakilo, and the Villages of Kapolei. The Central O'ahu SCP allows for the eventual development of up to 25,000 new homes in master-planned residential developments at Mililani Mauka, Koa Ridge Makai, Waiawa, Royal Kunia, and the now-completed Waikele.

2.12.3 ECONOMICS

For 1999, the median household income for the Central O'ahu Watershed Study area was approximately $59,464,[113] and 0.6% of the population was below the poverty line. Employment statistics show that the region surrounding Waikele, including Pearl Harbor/Hickam and 'Ewa, accounts for 15% of the employment for all of O'ahu.

Of two major job centers in the PUC, one is the Pearl Harbor area, reaching from Āliamanu (just outside the Central O'ahu Watershed) to Pearl City. This area includes the various military bases and functions centered on and around Pearl Harbor and Hickam AFB. It also includes Aloha Stadium, the regional commercial activities centered on Kamehameha Highway, and industrial areas at Waiawa, Waiau, Bougainville, and Hālawa.[114]

An Enterprise Zone (EZ) is a joint State-County effort to stimulate job creation and economic diversification in areas where they are most appropriate or needed. The program offers State and County tax reduction and other benefits for up to seven years for businesses that satisfy EZ hiring and other requirements.[115] Of the five EZs in the City and County of Honolulu, the Central O'ahu Watershed area has two. The first zone encompasses Mililani Technology Park and parts of Wahiawā. The second zone is a conglomerate made up of Mill Town Business Center in Waipahu, Pearl City (Mānana parcel), Gentry Business Park in Waipi'o, and Waiawa; all of Kapolei, most of Campbell Industrial Park, 'Ewa, and Kunia.

2.12.3.1 Employment

Employment sectors within the Central O'ahu Watershed include services, retail, resort, government, agriculture, industrial, construction, technology-intensive industries, finance / insurance / real estate and trade.[116] The City's 2025 projections (made in 2002) show the number of PUC jobs increasing by 20%. By comparison, jobs in 'Ewa are projected to increase by over 200%.[117] By 2020, it is projected that the City of Kapolei will provide office and retail opportunities for 25,000 private jobs and 5,000 City and State jobs.[118]

The continuation of high-level military-related employment in the Hickam-Pearl Harbor, Wahiawā, and 'Ewa area is encouraged in the General Plan. This includes Hickam AFB, Pearl Harbor Naval Base, Wheeler AFB, and Schofield Barracks.

There is a variety of current and planned commercial opportunities for the Central O'ahu Watershed area. The *General Plan* directs major economic activity and government services to the Primary Urban Center and the Second Urban Center at Kapolei, and permits the moderate growth of business centers in the urban-fringe areas. Many State and City and County offices have moved their headquarters from Honolulu to Kapolei, shifting to the Second Urban Center as the "Second Civic Center,"[119] dominated by government buildings. In maintaining the viability of Oahu's visitor industry, the *General Plan* also permits the development of secondary resort areas in West Beach, namely the resort of Ko Olina.

2.12.4 INDUSTRIAL CENTERS

Spread across 1,367 acres, Campbell Industrial Park is the state's largest industrial park, with tenants representing the industries of manufacturing, recycling, import/export, power generation, fuel storage, construction, warehouse and distribution. Tesoro and Chevron are two oil companies with refineries in the park. Facilities include Tesoro's 95,000 barrel-per-day oil refinery complex, which includes the main processing units, storage tanks with a capacity of 5.2 million barrels of crude oil and refined products and administrative and utility buildings.[120] The industrial park is served by the adjacent Kalaeloa Barbers Point Deep Draft Harbor, the state's second busiest commercial harbor.[121] The Campbell Industrial Park / Kalaeloa Barbers Point complex generates over 7,000 jobs.

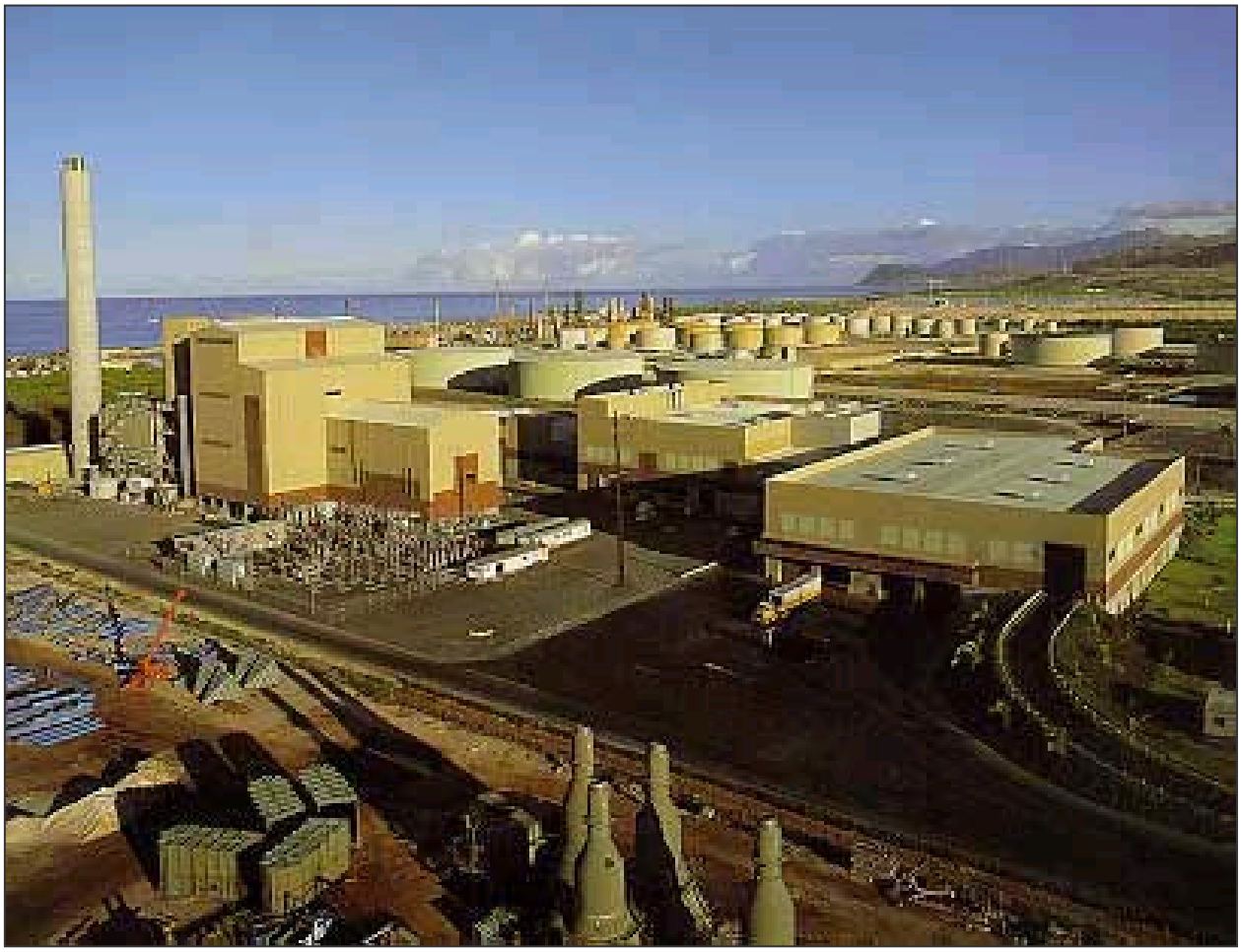
The 103 acres of Mililani Technology Park is used for various offices and some emerging technology-intensive industries such as electronics firms, computer software developers, and biotechnology firms and their support services.[122] Phase II (135 acres) will have a commercial / industrial emphasis. The park has been designated as a Free Trade Zone by the U.S. Department of Commerce, providing tenants with significant savings by avoiding U.S. customs duties and taxes. Qualified companies can benefit from various State and City incentives.[123]

Gentry Business Park in Waipi'o is comprised of 127 acres of which 101 acres have already been developed. The park is currently home to many companies specializing in warehousing, distribution, restaurants, moving, and storage.[124]

The Hālawa Valley Central Park Industrial Area sits on 122 acres and has 2,300,655 square feet of space for commercial and light industrial activities. The park is located at the interchange of the H-1 and H-3 Freeways. Zoned I-2 Intensive Industrial, the complex is home to Pepsi, Anheuser-Busch, Frito Lay, Crazy Shirts, AT&T, and other local and national companies. Hālawa Quarry, operated by Hawaiian Cement, is also located in the industrial area.

The 94-acre Waipahu Industrial area (1,615,866 square feet of space), located *makai* of Farrington Highway, includes the Waipahu Industrial Park Complex. Within the Complex is the Waipahu Industrial Center on Leoole Street, which has four buildings on 3.9 acres of land, and Waipahu Industrial Court.

Bougainville Industrial Park in Waipahu has 749,414 square feet of space. This area previously housed the Costco Wholesale Store.



H-Power Plant at Campbell Industrial Park.
http://www.iolani.honolulu.hi.us/Academics/UpperSchool/Science-Upper_School/Chemistry/ChemCom/VFT/HPOWERplant.html

The Waiawa Pearl City Industrial Park (676,299 square feet of space) is located in the valley of Waiawa on Waihona Street, full of small businesses and light industry. Complexes within the park include Waihona Industrial and the 5.1-acre Hawaii Business Park.

2.12.5 REGIONAL COMMERCIAL CENTERS

A regional commercial center is over 50 acres in size with more than 500,000 square feet of floor area, fronting a major arterial highway, with access from a freeway interchange. There are five regional commercial centers in the Central O'ahu Watershed Study area.

Mill Town Business Center located in Waipahu is two million square feet of commercial/ industrial floor area. The park was the center of O'ahu Sugar Company operations. Zoned I-1, the park's current occupants include light industrial, warehouse / distribution and restaurants.[125] Lots are still available for future development.

At 1.3 million square feet, Pearlridge Center is the largest enclosed shopping center in the state of Hawai'i. In addition to the monorail, Pearlridge is home to more than 170 stores, two food courts, 12 full-service restaurants, a miniature golf course, two arcades, 16 theaters, an emergency clinic, and an 8-story office complex.[126]

Waikele Premium Outlets offers 730,000 square feet of 50 discount outlet stores, shops, and restaurants. Low-cost warehouse stores in the Central O'ahu Watershed Study area include Sam's Club, Home Depot, and Costco. Discount stores include K-Mart and Wal-Mart.

The town of Waipahu and the City of Kapolei can be considered regional commercial centers, as they were intended to provide for regional shopping needs. However, they differ in that they are not managed as a unit with shared parking and center management.

2.13 LAND USE

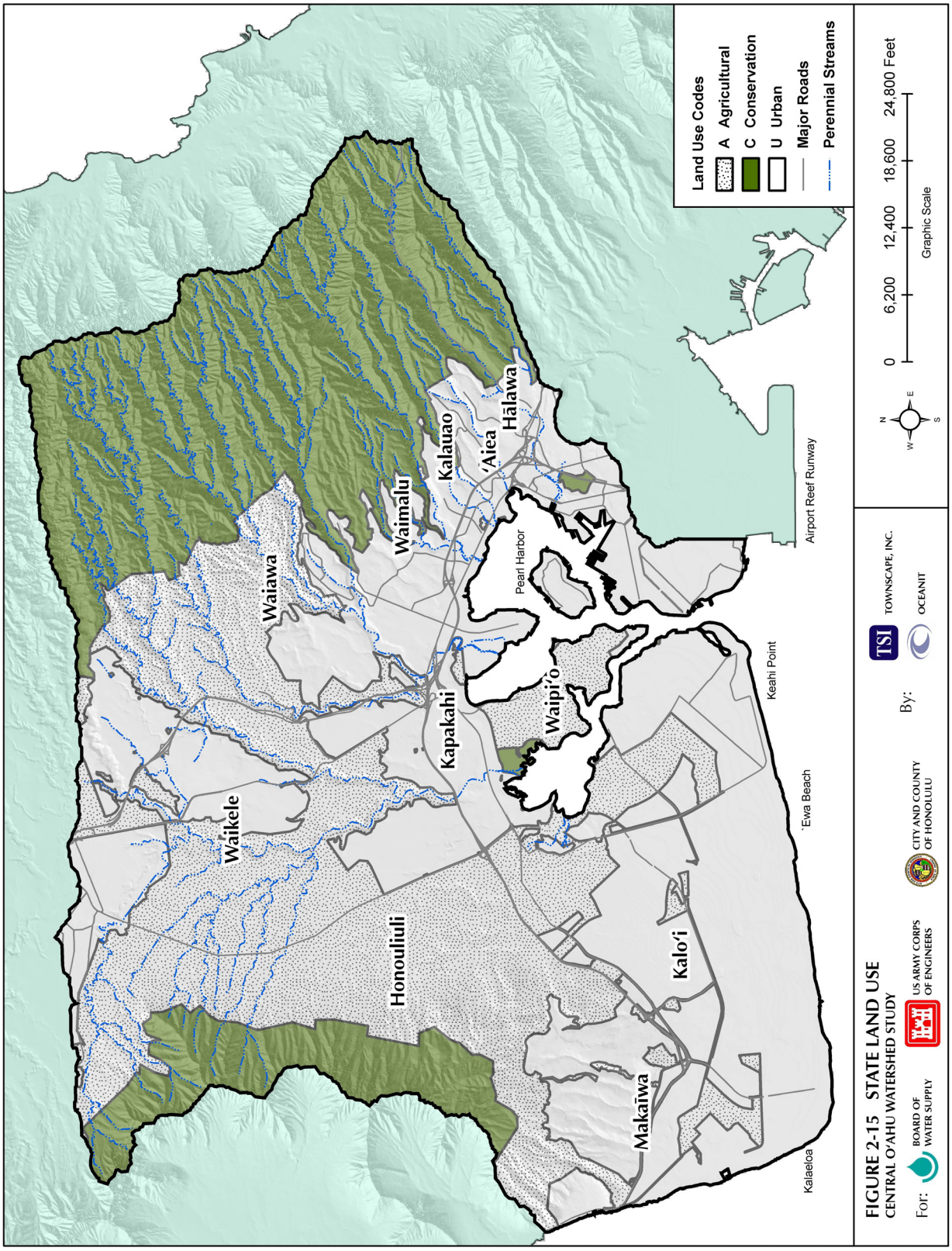
2.13.1 STATE LAND USE DISTRICTS

The State Land Use Commission designates land into one of four classifications: Conservation, Agricultural, Rural, and Urban. Urban lands make up 40% of the Central O'ahu Watershed Study land area, with the remaining land divided somewhat equally into the Conservation and Agricultural districts; there are no lands designated Rural in the Study area (Figure 2-15).

TABLE 2-11
STATE LAND USE DISTRICTS[g]

Land Use Districts	Acreage	Percentage
Conservation	31,150	28%
Agricultural	34,850	32%
Urban	44,250	40%
Total	110,250	100%

[g] Information compiled from State of Hawaii, Office of Planning GIS data for February, 2004.


Land Use Codes
A Agricultural
C Conservation
U Urban
Major Roads
Perennial Streams
0 6,200 12,400 18,600 24,800 Feet
Graphic Scale
N
W
E
S
Waikele
Waiawa
Waimalu
Kalauao
'Aiea
Hālawa
Kapakahi
Waipi'o
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Honouliuli
Kalo'i
Makaīwa
Kalaeloa
FIGURE 2-15 STATE LAND USE
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By: TSI TOWNSCAPE, INC.
OCEANIT

2.13.2 ZONING

Land use is further dictated by City zoning designations. The City and County GIS zoning maps of 2001 show the study area as roughly a third of the land designated P-1 Restricted Preservation, a third designated Ag-1 Restricted Agriculture, and the remaining third made up of F-1 Military and Federal lands, R-5 Residential, P-2 General Preservation, and I-2 Intensive Industrial.

The P-1 Restricted Preservation Zone is located along the ridge of the Waiʻanae Mountains, and encompasses large areas of the sub-watersheds bounded by the Koʻolau Mountains. The Ag-1 Restricted Agricultural areas sweep across the ʻEwa plain up through Honouliuli and Kunia, across Waikele and into Waiawa. F-1 Military and Federal Lands are primarily located at Barber's Point / Kalaeloa, the Pearl Harbor area, and up through the center of Waikele sub-watershed. Military training areas, located in the northeastern portion of Waikele sub-watershed at Schofield Barracks South, and a firing range located in the Honouliuli sub-watershed where the Puʻuloa Rifle Range is located, are also included in the F-1 designation. Until July 1999 when it was formally closed, the 3,700-acre Barbers Point Naval Air Station was an active military field and a major staging area during every war since the Japanese attack on Pearl Harbor in 1941. As a part of the closure, the Navy retained control of 1,007 acres, 548 housing units, and a golf course, but the rest of the Kalaeloa property was turned over to the State. Much of the old Navy base is not currently utilized, except for a State of Hawaiʻi homeless shelter, the relocation of major elements of the Hawaiʻi Army and Air National Guard, a Coast Guard aerial operation,[127] and the State Department of Transportation use of the airfield for general aviation purposes.

A majority of the R-5 Residential zoning, which includes housing and schools, is clustered around the H-1 Freeway and Farrington Highway from Hālawa to Kunia Road in Waikele. The stretch along H-1 after Kunia Road is Ag-1 Restricted and once again becomes Residential at Kapolei and Makakilo. More R-5 Residential zoning is found along Fort Weaver Road to ʻEwa Beach, and includes beach parks. P-2 General Preservation includes recreation such as parks and golf courses, spread throughout the study area. I-2 Intensive Industrial is largely located along the south and western coast of the Makaīwa sub-watershed.

2.13.3 URBAN BOUNDARY

As part of the City's Development Plan/Sustainable Communities Plans, an Urban Boundary (UB) was drawn for the ʻEwa, Central Oʻahu, and PUC areas to contain growth and protect open space, including prime agricultural land. The boundary is further named Urban Community Boundary (UCB) for the Central Oʻahu and PUC areas, and Urban Growth Boundary (UGB) for the ʻEwa area. This boundary gives long-range protection from urbanization for 10,350 acres of prime and unique agricultural lands and open space for the Central Oʻahu SCP area, and protection of 3,000 acres for the ʻEwa DP area. Lands

outside of the UB are generally not intended to be converted from Agriculture or Conservation to Urban land use.

2.13.4 "ACTUAL" LAND USE

The following section discusses land use that is actually occurring, regardless of zoning, and other designations. Land use in the Central O'ahu Watershed has shifted from primarily agricultural (including sugar cane, pineapple, taro, and watercress farming) to commercial, industrial, and residential. A marked increase in urban development in Leeward O'ahu is reflected by recent extensive housing development in the Pearlridge, Waimalu, and Waiawa areas of Pearl City since 1970. Waipahu and 'Ewa Beach regions have experienced greatly increased residential growth in the past few years. Commercial or light industrial complexes have also accompanied this growth.

2.13.4.1 Preservation/Conservation Land Use

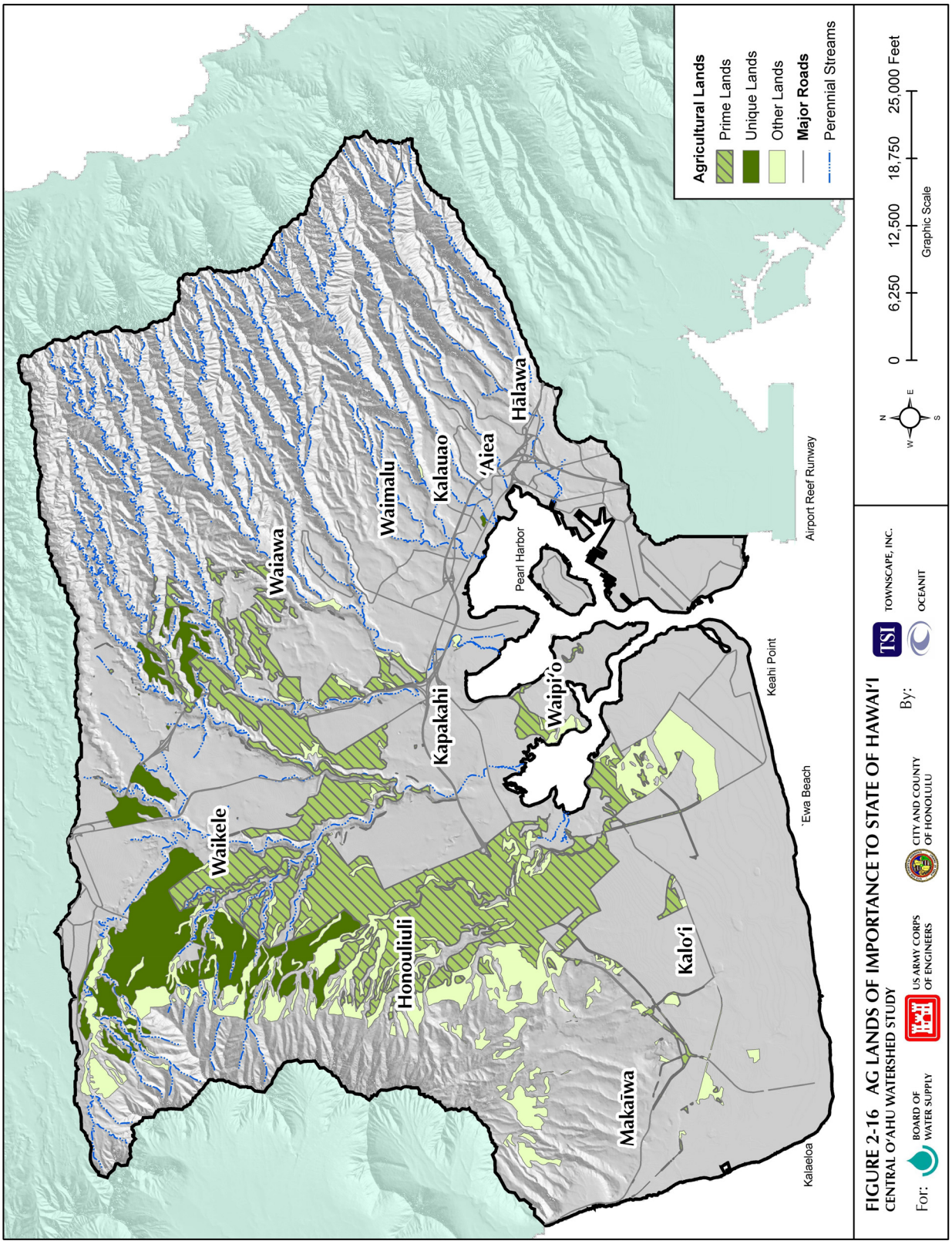
Preservation and conservation lands for the Central O'ahu Watershed total 31,140 acres. These conservation lands are distributed throughout the mountains and wetland areas. Preservation areas in the Wai'anae Mountains include the Wai'anae Range Conservation District Lands, Honouliuli National Wildlife Refuge, and Schofield Barracks Forest Reserve, South Range.

The Ko'olau Mountains host the Ko'olau Range Conservation District Lands, the O'ahu Forest National Wildlife Refuge, 'Ewa Forest Reserve, Keaīwa Heiau Forest Reserve, and part of the Honolulu Forest Reserve. Wetlands in the Central O'ahu Watershed area include Apokaa Ponds, the Batis Salt Marsh at 'Ewa Marina, Pouhala Marsh, and Pearl Harbor National Wildlife Refuge, made up of the 37-acre Honouliuli unit bordering West Loch and the 25-acre Waiawa unit bordering Middle Loch.

2.13.4.2 Agricultural Land Use

The lands within the Central O'ahu Watershed area are noted as potentially the most productive diversified agricultural lands in the state.[128] About 26% of Oahu's 122,565 acres of agricultural lands are located in the Central O'ahu Watershed Study area. These 31,600 acres are designated as Agricultural Lands of Importance to the State of Hawai'i (ALISH) (Figure 2-16). Approximately 18,900 acres of the Central O'ahu Watershed are considered "Prime Agricultural Land," which is best suited for the production of food, feed, forage, and fiber crops. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops when managed with modern farming methods.

Approximately 4,560 acres of land in the study area are considered "Unique Agricultural Land." This is land other than "Prime Agricultural Land" and is used for the production of specific high-value food crops. Some examples of such crops are coffee, taro, rice,


Agricultural Lands
Prime Lands
Unique Lands
Other Lands
Major Roads
Perennial Streams
0 6,250 12,500 18,750 25,000 Feet
Graphic Scale
N
W
E
S
Waikele
Honouliuli
Makaīwa
Kalo'i
Kapakahi
Waipi'o
Waimalu
Waiawa
Kalauao
'Aiea
Hālawa
Pearl Harbor
Airport Reef Runway
Keahi Point
'Ewa Beach
Kalaeloa
FIGURE 2-16 AG LANDS OF IMPORTANCE TO STATE OF HAWAI'I
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI TOWNSCAPE, INC.
OCEANIT

watercress, and non-irrigated pineapple. Unique lands have the special combination of soil quality, growing season, temperature, humidity, sunlight, air, drainage, elevation, aspect, moisture supply, or other conditions, such as nearness to market, that favor the production of a specific crop of high quality and/or high yield when the land is treated and managed according to modern farming methods.

Approximately 8,140 more acres of land are classified as "Other Important Agricultural Land" because they are also important for agricultural production, but limiting factors exclude them from being classified as "Prime" or "Unique Agricultural Land." Examples of limiting factors include seasonal wetness, erodibility, limited rooting zone, slope, flooding, or droughtiness. Two examples are lands that do not have an adequate moisture supply to qualify as "Prime Agricultural Land," and lands that have similar characteristics and properties as "Unique Agricultural Land," except that the land is not currently in use for the production of a "unique" crop. These lands can be farmed satisfactorily by applying greater inputs of fertilizer and other soil amendments, drainage improvement, erosion control practices, or flood protection, and they produce fair to good crop yields when managed properly.

Most of the agricultural lands are located *mauka* of H-1 and on the Waiʻanae side of Kunia Road.[129] Small and medium sized farms make up Kalaeloa Agricultural Park, which is composed of 10 acres subdivided into two lots, as well as agricultural lands in the Naval Magazine Lualualei West Loch Branch[130] and Waipiʻo Peninsula.

Diversified agriculture on Oʻahu. Source: http://www.hawaii.gov/dlnr/cwrm/regulate.htm

The *Central Oʻahu Sustainable Communities Plan* and *ʻEwa Development Plan* promote diversified agriculture and pineapple on 13,350 acres of prime and unique agricultural lands along Kunia Road, surrounding Mililani, on the Waipiʻo Peninsula, and surrounding the West Loch Naval Magazine. This is in accordance with the General Plan policies to support agricultural diversification in all agricultural areas and to encourage continuation of a viable pineapple industry.[131] However, with the recent closure of Del Monte farms in 2006, the trend from pineapple towards diversified agriculture will continue. Remaining major farms include Larry Jefts Farms and Aloun Farms. Crops are irrigated from private wells and supplemented by the Waiāhole Ditch System. Crops include bell peppers, spinach, watermelon,[132] green onions, radish, zucchini, won bok, apple banana, romaine and leaf lettuces, herbs, and specialty vegetables.[133] The floodplain adjacent to Pearl Harbor consists mainly of farms with small

acreages raising livestock, fruit, watercress, wetland taro and a variety of vegetable produce. The Hawai'i Agriculture Research Center (HARC), formerly Hawaiian Sugar Planters' Association, has a 78-acre experiment station in Kunia. HARC researchers oversee plots of chili peppers, watermelon, asparagus, dwarf elephant grass, dry-land taro, spring barley, coffee trees, neem trees, haole koa, banagrass, and assorted other plants in different stages of varietal and disease testing. Mainland companies often hire HARC to do the testing, since Hawai'i also offers the benefit of no real winter season.

With the introduction of drip irrigation technology in the early 1970s to replace furrow irrigation of sugar cane, irrigation water requirements were reduced. To protect from droughts, the 2003 *Hawai'i State Agricultural Water Use and Development Plan* (AWUDP) recommends that the agricultural industry maintain the original capacities of the agricultural water systems.[134] By 1994, all irrigation to 'Ewa sugar cane fields had ceased and almost all 'Ewa Caprock wells stopped pumping, reducing pumpage from the caprock aquifer in the Pu'uloa area from 17 mgd to 3 mgd. The loss of irrigation recharge has shrunk the caprock aquifer and led to an increase in aquifer chlorides. Besides major changes such as caprock pumpage and loss of irrigation, other reasons for chloride increase are due to a change in acreage being irrigated and quality of applied basal water.

2.13.4.3 Residential Land Use

All types of housing are available, including single- and multi-family homes, resort homes, townhouses, condominiums, and apartments. Housing prices in the Central O'ahu Watershed area are generally lower than the median price for the entire island of O'ahu. Early housing developments for the area include Waipahu, 'Aiea, and Pearl City. Most of the homes built after the 1960s are within bedroom or master-planned communities. These housing developments include Mililani, Waikele, 'Ewa Villages, Kapolei, and Makakilo. For more detailed information on these and other communities, see Section 2.13.6.

2.13.4.4 Commercial/Industrial Land Use

Commercial areas within the Central O'ahu Watershed Study area range from "Mom and Pop" stores to "Power" shopping centers. Power centers are shopping centers with few tenants, most of them anchor tenants. Generally, a power center's anchor tenants are the dominant retailer in the market they serve. Waikele Power Center, for instance (located across the street from Waikele Premium Outlets), is considered a "destination retail center." Anchor tenants at this center include Lowe's, K-mart, CompUSA, and Borders Books. Smaller town centers are neighborhood-oriented commercial centers that are generally located along main corridors, such as Kunia Road, Kamehameha and Farrington Highways, and H-1 Freeway. Some examples include Hālawa Town Center, 'Aiea Town Center, Pearl Harbor Regional Town Center (Pearlridge), Waimalu Town Center, and Pearl City Town Center. Campbell Industrial Park in 'Ewa is known as a "regional industrial" center. Other business and industrial parks include Mililani Technology Park, Kapolei

Business Park, Mill Town Business Center, Gentry Business Park, and Hālawa Business Park.

Two of the three power generating stations on O'ahu are located within the Central O'ahu Watershed. These include Hawaiian Electric Company's (HECO) Waiau and Kahe Generating Stations. Waiau is capable of producing 499 MW (megawatts) and Kahe 651 MW, 70% of HECO's total firm generating capacity.

2.13.4.5 Resort Land Use

The only resort within the Watershed is Ko Olina Resort, located in the Makaīwa sub-watershed, on the southeastern coast of O'ahu. The 640-acre resort and spa has a hotel, restaurant, golf course and clubhouse, 43-acre marina with 270 full service slips, four lagoons, a chapel, and private housing.

2.13.4.6 Educational Land Use

The Central O'ahu Watershed area has 35 public elementary schools, seven public intermediate schools, seven public high schools, and eight private schools. Colleges include: University of Hawai'i West O'ahu Campus, Leeward Community College, two University of Phoenix campuses, Wayland Baptist University Hawai'i, and Embry-Riddle Aeronautical University.

2.13.4.7 Military Land Use

Schofield Barracks is the Headquarters for the 25th Infantry Division (ID) (Light), and provides U.S. Pacific Command trained and ready forces in support of security operations. The Kunia Facility, south of Schofield Barracks, provides subsurface access to 62 acres. This tunnel complex is used by the National Security Agency.[135]

Wheeler Army Airfield (WAAF) supports Schofield Barracks with activities of the Defense Communications Agency, the Air Force's Aerospace Defense Group, and an Army aviation brigade. Ammunition storage facilities at WAAF support the firing ranges at Schofield Barracks and mobilization requirements of the 25th ID(L), which requires a brigade in ready status at all times. The Kīpapa Ammunition Storage Site consists of two parcels, upper and lower. Upper Kīpapa was used to store ammunition and is occasionally used as a training area by 25th ID(L). Lower Kīpapa is unused.

Another former Army ordnance storage area is located at the Waikakalaua Ammunition Storage Site. The Hickam Petroleum Storage Annex, south of WAAF, is capable of underground storage of more than 630,000 barrels. Although no longer used and empty of fuel, the installation has fuel lines running to Barbers Point Naval Air Station (now Kalaeloa), Hickam Air Force Base, and Pearl City Fuel Annex.

Naval Magazine Lualualei HQ, West Loch, and Waikele Branches are the major ammunition storage area for all branches of the military in Hawai'i. The headquarters and main storage areas are at the Lualualei branch, the West Loch branch occupies the south shore of West Loch and Waipi'o Peninsula, and the Waikele branch is located in a gulch with tunnels that have been cut into the sides of the valley walls. The Waikele branch was declared in excess of ordnance storage needs in 1993 and remains empty. These tunnels are now being converted for commercial storage.

Pearl Harbor National Historic Landmark.

The Pearl Harbor Naval Complex (PHNC) consists of these major facilities: Naval Shipyard, Naval Supply Center, Naval Station, Submarine Base, Public Works Center, Inactive Ships, and Navy Magazine Lualualei (West Loch Branch and Waipi'o Peninsula). Land use within PHNC is primarily limited to operational and industrial activities, housing, and related administrative, training, and support facilities.[136]

West Loch Branch of Naval Magazine Lualualei serves as a shipping and receiving facility and is bounded on the north and northwest by waters of the West Loch of Pearl Harbor and on the west by the communities of 'Ewa, 'Ewa Beach, and Kapolei. West Loch covers approximately 3,970 acres and has 118 above-ground magazines with a storage capacity of 20,830 short tons. Pu'uloa Rifle Range is located here.

Naval Station Pearl Harbor (Waipi'o Peninsula) lies within the Explosives Safety Zone at West Loch Naval Magazine. Certain types of land uses such as agriculture, open-air recreation, or other uses that do not involve the construction of inhabited buildings or structures may be permitted within the outer 40 % of the hazard zone.[137] The Waipi'o Soccer Complex lies in the northernmost part of the Peninsula. The Naval Base has first-line responsibility for implementing Regionalization and Claimant Consolidation for the Navy in Hawai'i. Both initiatives are closely linked together and are necessary for the Navy to gain service improvements in Shore Installation Management, including food service, supply, building maintenance, firefighting, public affairs, and data processing support.[138]

Ford Island lies at the center of the Pearl Harbor National Historic Landmark District, and is adjacent to Battleship Row, now home to the USS Missouri Memorial.

Marine Corps Base Hawaii's Camp Smith is located atop Hālawa Heights. The Camp serves as the home for the headquarters of U.S. Commander in Chief Pacific, U.S. Marine

Forces Pacific, Joint Task Force - Full Accounting, and Special Operations Command Pacific.[139]

A portion of the Red Hill Naval Reservation is within the Central O'ahu Watershed. Red Hill consists of 20 underground tanks that store bulk fuel, a water pumping station, and small arms range.

Hickam Air Force Base serves as the primary strategic Air Force base in the mid-Pacific. It is home to the 15th Airlift Wing and 140 tenant and associate units including, Pacific Air Forces Headquarters and the Hawai'i Air National Guard. The 15th Airlift Wing flies worldwide missions in support of the commander, Pacific Command and commander, Pacific Air Forces. The wing is growing into a Pacific Mobility Hub as it prepares for the arrival of the C-17 Globemaster III and the stand-up of the 535th Airlift Squadron.

Marine Corps Base Hawaii, Pu'uloa Training Facility provides an individual weapons training area for Marine, Navy, and Coast Guard personnel. The facility consists of one active 600-yard rifle range and another inactive 1,000-yard rifle range, two pistol ranges, and a small arms range.

The Coast Guard Air Station Barbers Point serves as the "Guardian of the Pacific" in their support of the Fourteenth Coast Guard District, the largest of all Coast Guard operating areas, protecting 14.2 million square miles of open ocean, atolls, and island nations. Air Station Barbers Point has long-range patrol and logistical support capabilities, as well as quick and versatile search and rescue response.

The Hawai'i Army National Guard (HIARNG) Facility is located in Waiawa Gulch in Pearl City. HIARNG uses this area for operation of a mobilization and training equipment site, equipment and material storage, and classroom training. The 103rd Troop Command is located at this facility, and their mission is to serve as a command and control headquarters for separate units of the HIARNG.

Additional information regarding military water systems can be found in section 3.1.1.3.

2.13.4.8 Recreational / Cultural Land Use

The Central O'ahu Watershed area has many recreational and cultural areas. There are six district parks, Kapolei Regional Park, West Loch Shoreline Park, and visitor-drawing Paradise Cove and Lanikuhonua Hawaiian Cultural Park. Locals enjoy Hawaiian Waters Adventure Park in Kapolei, skate parks in Mānana, Mililani, and 'Ewa Beach, and attend college football games and other events, including the Swap Meet, at the Aloha Stadium. Waipi'o Peninsula Soccer Complex and Central O'ahu Regional Park in Waipahu are two of the island's busiest sports parks. Gardens include the Hālawa Xeriscape Garden and the Waipahu Cultural Garden.

Ko Olina Hole 18. Source: http://www.spiritofaloha.com/golf/0901/golf.html

Fifteen golf courses are located in the Central O'ahu Watershed. Two courses are military, three are municipal, and ten are public / semi-private. West Loch, 'Ewa Villages, and Coral Creek serve as flood retention basins. Detention basins are also located in 'Ewa by Gentry, Royal Kunia, Ocean Point, and Mililani Mauka.

There are a variety of trails, including the 'Aiea hiking trail, Palikea trail, Kalua'a Loop trail, and the historic OR&L Railway / Bikeway Corridor.

2.13.4.9 Natural Gulches and Drainageways

Within the Urban Community Boundary of the *Central O'ahu Sustainable Communities Plan* (SCP), the major gulches are indicated for preservation, except for the portion of Waikakalaua Gulch that had been previously designated for urban use. The Central O'ahu SCP states that major natural gulches within the Urban Community Boundary, including Waiawa, Pānakauahi, Kīpapa, Waikele, and Waikakalaua, should be preserved as part of the Open Space Network. The SCP also recommends trails leading from Central O'ahu Regional Park to Waikele Gulch, and connecting to a trail system throughout Central Oahu's gulches, to provide an important public recreational asset. Where appropriate, new development projects are encouraged to provide public access to trail heads from the streets extending toward the mountain slopes or approaching the edges of the gulches. In addition, the City should support other efforts to expand access to mountain and gulch trails in areas where urban development will not occur. The *'Ewa Development Plan* also stipulates that the natural gulches on the slopes of the Wai'anae Range foothills are within the Urban Growth Boundary, and should be preserved as part of the Open Space Network.

This trail network could become very important in preserving and educating the public about Native Hawaiian cultural and archaeological sites. Kīpapa Gulch, Waikele Gulch, Waikakalaua Gulch, Barbers Point, and One'ula all have cultural and archaeological sites of significant value.

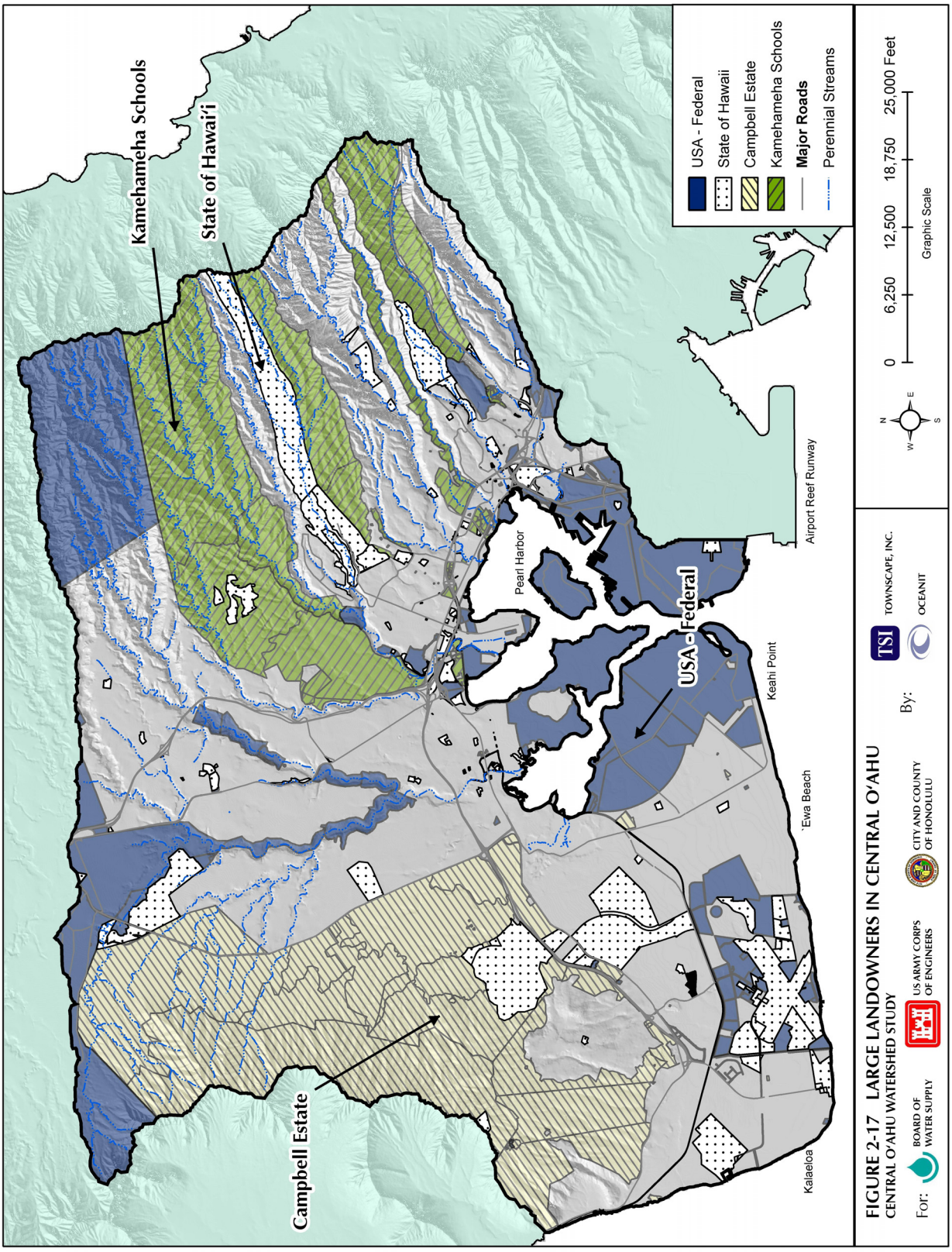
2.13.5 LARGE LANDOWNERS

The top five landowners within the Central O'ahu Watershed include the United States of America, James Campbell Trust Estate, Kamehameha Schools, State of Hawai'i, and Castle & Cooke. Together, these five landowners own approximately 60% of the land in the

TABLE 2-12
CENTRAL O'AHU LANDOWNERS OVER 1,000 ACRES

MAJOR LANDOWNER	ACREAGE*	SQUARE MILES	PERCENTAGE
United States of America	28,334	44	25.7%
James Campbell Co., LLC	14,088	22	12.8%
Kamehameha Schools	9,702	15	8.8%
State of Hawai'i	7,387	12	6.7%
Castle & Cooke	4,631	7	4.2%
U.S. Naval Reservation	3,969	6	3.6%
City and County of Honolulu	3,749	6	3.4%
Unknown	2,650	4	2.4%
Dept. of Transportation Airports Division	2,642	4	2.4%
D.R. Horton, Inc. / Schuler Division	2,000	3	1.8%
The Queen Emma Foundation	1,764	3	1.6%
Elizabeth M. Stack	1,720	3	1.6%
Austin Income Trust	1,363	2	1.2%
Robinson Trust Estate	1,322	2	1.2%
Mānana Valley Farm, LLC	1,290	2	1.2%
Others (under 1,000 acres)	23,639	37	21.4%
Totals	**110,250**	**172**	**100.0%**

*The land area is a calculated approximation based on 2004 City and County of Honolulu GIS parcel data, with changes to James Campbell Co. land holdings via sales to HRPT (2005) and D.R. Horton (2006).


Kamehameha Schools
State of Hawai'i
Campbell Estate
USA - Federal
Pearl Harbor
Keahi Point
`Ewa Beach
Kalaeloa
Airport Reef Runway
USA - Federal
State of Hawaii
Campbell Estate
Kamehameha Schools
Major Roads
Perennial Streams
0
6,250
12,500
18,750
25,000 Feet
Graphic Scale
N
E
S
W
FIGURE 2-17 LARGE LANDOWNERS IN CENTRAL O'AHU
CENTRAL O'AHU WATERSHED STUDY
For:
BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI
TOWNSCAPE, INC.
OCEANIT

project area. (See Table 2-12). The land owned by the United States is primarily used for military purposes and a National Wildlife Refuge. Campbell lands are primarily used for agriculture, as well as for protecting conservation lands in the Wai'anae Mountains and for developments in Kapolei. Kamehameha Schools owns land primarily in conservation, as well as some agricultural and urban lands. The State of Hawai'i owns conservation lands known as the 'Ewa Forest Reserve and Keaīwa Heiau State Recreation Area, as well as agricultural and urban lands. The lands owned by Castle & Cooke are a compilation of various properties under the Castle & Cooke name, and include undeveloped lands in Waipi'o, Mililani Technology Park, Mililani Mauka home and commercial properties, Koa Ridge, a portion of Waiawa, and a portion of Makakilo.

2.13.6 CENTRAL O'AHU COMMUNITIES

Land uses in the Central O'ahu Watershed Study area include prime agricultural lands, military installations, and major residential communities. Over the last two decades, the land use focus of Central O'ahu has been residential development. The major neighborhood communities within the study area are described below, from the Hālawa to the Makaīwa sub-watersheds.

2.13.6.1 Hālawa

Hālawa is one of the older neighborhoods in the area, with 69 houses built by 1939. Post-contact settlers came to Hālawa while working on sugar cane plantations. Parks in Hālawa include: Makalapa Park, Hālawa District Park, Hālawa Xeriscape Garden, and Aloha Stadium. Aloha Stadium was built in 1975, with 50,000 seats, costing $32 million. Aloha Stadium was once a place of housing for low- and moderate-income families. Displaced families were moved to Makalapa Manor and Puuwai Momi, just a few blocks away. The stadium also displaced an open-air theater, piggery, saimin stand, cane field,

Hālawa Xeriscape Garden.

watercress patch, and stream. Today, this area hosts UH football games, swap meets, and concerts at the stadium. Hālawa is also home to an interchange connecting the H-1, H-3, and Moanalua Freeways. The H-3 Freeway was opened in 1997. Construction of the freeway revealed many archaeological sites in the area, showing that up to 30 individual housing sites in the upland regions of the valley existed by 1500 A.D. Hālawa is also home to the Animal Quarantine Station and Hālawa Correctional Facility.

2.13.6.2 'Aiea

'Aiea was named for the *Nothocestrum* tree, which has greenish-yellow flowers and seeds that can be used to make lei. Some species are now listed as endangered. 'Aiea is located near the East Loch of Pearl Harbor, and is believed to be the only city in the United States whose name is made up entirely of vowels. The *'okina* (glottal stop) is technically considered a consonant in the Hawaiian language, but when people outside of Hawai'i speak of 'Aiea, they usually do not include the *'okina*.

A culturally significant place in 'Aiea is the Keaīwa Heiau, located near the 'Aiea Loop Trail. It is a Hawaiian temple with life-giving powers believed to be a center where the *kahuna la'au lapa'au*, or herb doctors, practiced the art of healing.

'Aiea became a plantation town at the end of the 19th century, after a sugar cane plantation was opened in the district by the Honolulu Plantation Company. After World War II, the plantation shut down and the mill was converted into a sugar refinery. Just two years after statehood, the quiet sugar cane town experienced incredible growth. Developers started extending housing and business developments into the surrounding former sugar cane fields. Many current residents work at nearby military installations, and there are varied manufacturing operations located in the area. 'Aiea is also home to Pearlridge Shopping Center, the second largest shopping center in Hawai'i.

The town's sugar history came to a close in 1996, when C&H Sugar closed its refinery. In 1998, the 99-year old sugar mill was torn down by the owners, amid protests from town residents and the City government. Currently, the community would like to preserve the 'Aiea Sugar Mill site to promote a sense of place by restoring the heritage of 'Aiea.

2.13.6.3 Pearl City

Pearl City is located along the north shore of Pearl Harbor, with a population of almost 31,000 people in the year 2000. Early settlement was below Kamehameha Highway, and began spreading to the highlands in the early 1950s with the subdivision of Pearl City Heights. Additional housing developments spread throughout the area to the 1970s, replacing sugar cane and pineapple fields. These developments include Pearl City Uplands, Momilani, Twin View Terrace, Holiday City, Mānana, Waiau, and Pacific Palisades. The Pearl City Shopping Center opened in the late 1950s, and as the population grew, additional facilities were developed, such as a library, police and fire stations, courthouse, and Leeward Community College and West O'ahu College.

Kamehameha Highway now sustains a high concentration of strip malls, freestanding stores and fast food outlets.

2.13.6.4 Waipahu

The abundance of water in this area led Native Hawaiians to establish densely populated villages in what is now Waipahu, establishing the area as one of Central Oahu's oldest communities. As the sugar industry moved into the area, plantation villages were built around the Waipahu Sugar Mill in the 1890s. As the population grew after World War II, Waipahu transformed into an area of suburban and commercial land uses. The northern part of Waipahu is now predominantly single-family residential land use, and the southern portion along Farrington Highway supports mixed-use commercial, light industrial, and apartment land uses. The commercial uses consist of strip malls and car dealerships along the highway. Waipiʻo Peninsula is the site of the Waipiʻo Soccer Complex, providing playing fields for over 23,000 youth. The Waipahu Community Association is working hard to fulfill Waipahu's vision to become revitalized both socially and economically.

2.13.6.5 Waipiʻo

Waipiʻo is a relatively new master-planned suburban community by Gentry Homes Hawaiʻi of 3,500 single-family residences and low-density townhouses, bounded by the H-2 Freeway and Kamehameha Highway. The population according to the 2000 Census was just over 11,500 people. Gentry Business Park includes Costco and the Tony Group Autoplex, and the Gentry Waipiʻo shopping center has Foodland and other tenants, such as Outback Steakhouse, L&L Drive-Inn, Blockbuster, and Big City Diner.

2.13.6.6 Mililani

Mililani is Hawaii's first master-planned community, built in 1968 by Castle & Cooke. It includes all types of housing, from condominium townhouses to luxury single-family homes. The area is bounded by the two large gulches of Waikele and Kīpapa. With a population of about 50,000 residents, Mililani is a complete community with schools, churches, shopping centers, parks, recreation centers, a golf course, and a public library. Mililani Technology Park is home to high-tech companies and other services. Mililani received an "All-America City Award" in 1986; no other community in Hawaiʻi has received this recognition. Mililani even has its own trolley service. The older portion of Mililani to the west of the H-2 Freeway is known as Mililani Town. The newer portion of Mililani to the east of the H-2 Freeway is known as Mililani Mauka. The first homes at Mililani Mauka were occupied in 1990. Almost all of Mililani's commercial and retail centers are in Mililani Town.

2.13.6.7 Launani Valley

Launani Valley, a master-planned condominium community located at the base of Waikakalaua Gulch in Central Oʻahu, broke ground in 1992. It is located near shopping,

dining, entertainment, golf courses, medical facilities, and freeway access. Surrounded by 150 acres of pristine preservation land, Launani Valley is comprised of six separate multi- and single-family developments that were created to provide a neighborhood feeling within a larger community. In addition to individual community amenities that include pools, spas, and party rooms, residents enjoy Launani's private park with tennis courts, volleyball / basketball court, a jogging trail with exercise stations, picnic areas, and children's play areas.

2.13.6.8 Kunia Village

The small village of Kunia is located on the Del Monte pineapple plantation and is the residence for 65% of Del Monte's full-time employees. More than 500 residents live at Kunia, a quiet, rural, vibrant community where people know each other, raise each other's children, and doors are left unlocked. A post office, store, gym, church, and The Nature Conservancy share the area with residents. Unfortunately, Del Monte's closure in 2006 leaves the future of the area uncertain. Efforts to preserve this historic plantation village are being pursued in the Legislature and are outlined in the *Central O'ahu Sustainable Communities Plan*.

2.13.6.9 Royal Kunia

Royal Kunia is a relatively new master-planned community of single-family homes and condominiums, and has been dubbed West Oahu's fastest growing new community. The elevated location overlooks the 'Ewa plain and gives ocean and mountain views. Development of a 12-acre community recreation center and nine-acre community park is underway, in addition to the existing golf course. Royal Kunia shopping facilities includes Times Supermarket and Wal-Mart, and will provide other services through its commercial office facilities.

2.13.6.10 Waikele

The 15-year-old master-planned Waikele community, home to approximately 6,000 residents, completed its last subdivision in 2002. Waikele offers golf course homes, townhouses, and garden condominiums. Shopping, in particular, has put Waikele on the map. Waikele Premium Outlets has stores such as Banana Republic, Kenneth Cole, and Saks Fifth Avenue Outlet-Off 5th, and Waikele Shopping Center is home to Lowe's, Borders Books and Music, and K-Mart, among others. Waikele offers landscaped boulevards with bike paths, parks, a new recreation center and pool complex, a site for a future elementary school, and an 18-hole golf course designed by renowned golf course architect Ted Robinson.

West Loch

The master-planned West Loch Fairways and West Loch Estates communities include single- and multi-family housing units, a golf course, clubhouse, shoreline park, district park, and elderly housing. West Loch Estates won a design excellence award from the American Institute of Architects in 1989, and named "Project of the Year" by the City and County of Honolulu.

West Loch Estates and Fairways. Source: http://www.rmtowill.com

2.13.6.11 Iroquois Point / Pu'uloa Housing

Located at the entrance to Pearl Harbor, this Navy housing consists of 1,463 single-family and duplex housing units occupied by Navy personnel and dependents. An adjoining saltwater inlet contains a small marina for recreational boats. Information from the *2002 Ford Island Development Final Programmatic Environmental Impact Statement* states that water consumption is approximately 2.0 mgd, based on Navy Public Works Center metering records. Potable water is supplied by the Navy's Pearl Harbor area distribution system.

2.13.6.12 'Ewa Villages

In the late 1800s to early 1900s, 'Ewa was one of the large population centers on O'ahu, with industry focused around sugar cane production. The 'Ewa Mill was a major employer that set up residential villages within 'Ewa. The oldest community in the 'Ewa region is 'Ewa Villages, a plantation town which was built in the 1890s. It consisted of eight villages housing immigrant plantation workers from Japan, China, and the Philippines, segregated by national origin. Remaining villages from the historic core include Tenney, Varona, and Renton villages. These homes have undergone redevelopment to preserve the history of the area, and the 'Ewa Plantation Villages Revitalization Project was selected for the 1995 to 1996 Historic Preservation Honor Award by the Historic Hawai'i Foundation. Fernandez Village, a plantation camp constructed in the 1950s, was subdivided in the 1980s and sold to the plantation workers with minimal design control over rebuilding and renovation work by the new homeowners. Ten years later, Fernandez Village showed little evidence of its origin as a plantation camp.

The 'Ewa Villages Master plan expands from the historic core to provide newer housing and commercial uses. The total land area for the master plan is approximately 630 acres. The New Villages consist of Areas A (Lokahi Greens), B (Laulima), E (Lincoln), G (St. Francis), and Areas H and 1 (Affordable Rentals). The Commercial Area is bounded by Renton Road, Park Row Extension, and a childcare center. Public Facilities include the Mahiko District Park and the 'Ewa Villages Golf Course.

2.13.6.13 'Ewa by Gentry

The 'Ewa by Gentry subdivision began development in 1988 and will eventually have a total of 8,000 units of single- and multi-family projects. Neighborhoods include the single-family homes of Ali'i Cove, Ali'i Court, Las Brisas, Soda Creek, Sun Terra, Tiburon, Tuscany, and Montecito, and the townhouses of Palm Villa, Palm Court, and the Arbors. Each large group of townhouses includes a recreation center with a swimming pool. Condominiums can be found at The Lofts and Sunrise. The 'Ewa by Gentry community also has a neighborhood shopping center, several parks, an elementary school and an 18-hole golf course. The latest developments include Terrazza and CorteBella. Other amenities planned for the area include an intermediate school, two parks, a 30-acre commercial park, and a portion of the Kapolei Parkway. 'Ewa by Gentry was honored in 2004 as a recipient of the Outdoor Circle's prestigious "Beautification Award," using native Hawaiian plants whenever possible.

2.13.6.14 Ocean Pointe

Ocean Pointe is the newest development in 'Ewa. This 1,100-acre master-planned community includes both single-family homes and townhouses. About 1,800 of its planned 4,850 homes have been completed since groundbreaking in 1998. A new golf course is scheduled for completion at the end of 2007. When the total development is completed, it will contain commercial buildings, retail and office space, neighborhood parks, and a marina that will be the largest in the state.

2.13.6.15 The City of Kapolei

Kapolei golf course and housing developments.

The City of Kapolei, located in the western portion of the 'Ewa Planning Area, is a master-planned urban center being developed as the "second city" of O'ahu. Existing land uses include a community shopping center, a 16-screen movie theater complex, a 73-acre regional park, an office complex, a bank office building, and a State office building. A State Public Library, a City and County Civic Center, and a police station were recently opened. The Kapolei region encompasses the state's largest industrial park and second-busiest commercial harbor, a new business park and vacation resort area, residential developments, and telecommunications infrastructure. The area also offers the Hawaiian Waters Adventure Park, six public

schools, two private schools (one pre-school to elementary and the other pre-school through high school), and hospital.

2.13.6.16 Villages of Kapolei

Upon completion, the Villages of Kapolei will consist of eight privately developed residential villages, three schools, a senior housing center, a golf course, neighborhood parks, two recreation centers, and two retail centers on 888 acres of land. Seven of the villages have been built. The completed villages are Kumu Iki, A'eloa, Malanai, Kekuilani, Iwalani / Kulalani, Malu'ohai, and Kapolei Kai. The community features affordable and market-priced single-family homes, condominiums, and rental apartments. Soon to be constructed is the eighth Village, Kaupe'a, which will have 326 homes. Additional infill projects are also yet to be constructed. Approximately 5,000 units are planned at build-out.

2.13.6.17 Kapolei Knolls

Kapolei Knolls, started in 1997, consists of 79 acres of land located in Kapolei, located close to schools and shopping centers. Kapolei Knolls features its own landscaped park for residents with a walkway on the perimeter and a number of picnic and barbecue stations. This development offers semi-custom homes from 12 different model styles. The project includes 425 single-family homes, many with views of the ocean.

2.13.6.18 Makakilo

The residential community of Makakilo began in the early 1960s and today has more than 3,500 single-family homes and townhouses located on the lower slopes of the Wai'anae Range. An estimated 1,500 units continue to be developed on the upper slopes of Makakilo. Among the newer subdivisions are Royal Ridge (single-family) and Westview at Makakilo Heights (townhouse). The residents of this hillside community enjoy panoramic views of the ocean extending to Diamond Head.

2.13.6.19 Honokai Hale / Nanakai Gardens

Adjacent and to the south of Farrington Highway lays the bedroom community of Honokai Hale / Nanakai Gardens. This is an older residential community with 500 moderately priced housing units. About thirty years ago, Makakilo, Honokai Hale, and Nanakai Gardens were the only communities that existed among the fields of sugar cane and a little stretch of road, and are now relatively isolated from the greater Kapolei community. This insular quality is more in tune with a village, rather than feeling cut off from outside influences, even though entertainment centers and shopping malls do not exist close enough to reach on foot. Residents of this older neighborhood have a sense of family, community, and belonging.

2.13.6.20 Ko Olina

Groundbreaking for the planned 640-acre Ko Olina residential / resort community took place on December 2, 1986. Land and infrastructure development began in March 1987 with completion anticipated for mid-1989. First phase development plans called for 5,200 housing units. Of these units, 3,700 are designated as high-rise apartment / condominium units. The remaining 1,500 units are planned for low-rise, lower density attached units located around the golf course. Another 4,000 visitor units, consisting of hotel rooms and resort condominiums, are also planned.[140]

2.13.6.21 Military Housing

Military Housing includes Hickam Village, Pearl Harbor Naval Complex (Hospital Point, Marine Barracks, Hale Ali'i, Hale Moku, Hokulani, Little Makalapa and Makalapa), Hālawa, Camp Smith, McGrew Point, Camp Stover, Mānana, Pearl City Peninsula, Ford Island, Iroquois Pt. / Pu'uloa, Naval Computer and Telecommunications Area Master Station Pacific Housing, and Barbers Point. Revitalization of many of the housing developments have been taking place over the last five years, due to private acquisition and management of military housing properties in response to the Military Housing Privatization Initiative.

2.13.7 CURRENT / PLANNED PROJECTS

Most of the new developments are master-planned communities, and will be responsible for providing their own water source, storage, and transmission. New facilities are typically designed to BWS specifications, and are turned over to BWS for management and operation.

Projects that are near completion at the time of publication of this document include 'Ewa by Gentry, 'Ewa Villages, Kau'olu Properties, Makakilo properties, Mililani Mauka, Villages of Kapolei, and Waipi'o Point.

According to the *Annual Report on the Status of Land Use on Oahu* for 2005, it is estimated that approximately 57,000 housing units will be built between 2000 and 2030 for the 'Ewa and Central O'ahu DP areas. At least 15,000 housing units are planned to be built in the next 10 years.[h] It is possible that between 2015 and 2030, an additional 33,675 housing units will have been completed.

BWS is currently conducting a water rate study that forecasts an additional need of 10 to 11 mgd for 'Ewa and 3 mgd for the Central District by 2025. BWS has purchased the abandoned 'Ewa Shaft from Campbell Estate, which is currently under construction and needs to accommodate GAC (granular activated carbon) treatment. BWS will construct a 6 million gallon reservoir. The 'Ewa Shaft capacity is 10 mgd, which could accommodate

[h] Calculated remaining number of housing units to be built by 2015 using Table 2-13, Status of Housing Projects as of June 30, 2005.

the projected growth demand for 'Ewa. Waipahu Wells III and IV are being completed and will provide water to the Primary Urban Center.

2.13.7.1 Housing Projects

Most of the following housing projects can be found in Table 2-13.

City of Kapolei: Remaining housing projects for the City of Kapolei include a retirement community, planned residential community, mixed-use area, and apartments. The site for the Kapolei Senior Village (formerly known as Luana Koa Retirement Community) is just *makai* of Kapolei Regional Park in the City of Kapolei. At an estimated 704 units, this will be the largest community in the state to offer comprehensive care for seniors with various mental and physical conditions. The preliminary design for the Kapolei project calls for a group of townhouse-style garden apartments, with basic amenities, such as a post office, hair salon, and sundry store. The planned Mehana community will have 1,150 single- and multi-family homes within nine neighborhoods, parks, recreational facilities, commercial space, and a new elementary school. Houses are expected to be on the market in 2008. Mixed Use zoning for Kapolei was approved in 2004, allowing Phase II of Kapolei development to proceed for additional commercial, retail, and other mixed uses. Although on the books, the Palailai Apartments in Kapolei Mauka currently have no activity.

East Kapolei I: This area is being developed by the State Department of Hawaiian Home Lands (DHHL), with 402 single-family homes to be built on 64 acres. A new DHHL office and a community center will be part of the East Kapolei I development, adjacent to the proposed University of Hawaii's West O'ahu campus. This project will bear the majority of infrastructure costs for the area by bringing down water from the mountains and sewer lines from the coast.[141]

'Ewa Makai by Gentry: The final increment of Gentry Homes Hawaii's master plan, 'Ewa Makai will provide 550 single-family, 640 multi-family, and 675 cluster housing units. In addition, the project will provide commercial space, industrial-commercial mixed use, a community center, churches, and a park.

Ho'opili: D.H. Horton-Schuler Homes' planned Ho'opili (literally "to bring together") subdivision is a master-planned community that will connect 'Ewa Beach, Waipahu, Makakilo, and Kapolei. Ho'opili is currently in the planning stage, and will feature a mix of approximately 10,000 affordable and market rate homes on 1,600 acres. The community will also offer schools, commercial centers, and other community amenities.

Kapolei West (Ko Olina, Phase II): Kapolei West is a master-planned residential and golf community proposed by the Aina Nui Corporation, an affiliate of Campbell Estate. The Kapolei West project area is located between the City of Kapolei and Ko Olina Resort and

is currently vacant. The first home sales are projected in 2008 (with total build-out estimated at 2018).

Kau'olu Properties: Kau'olu is a master-planned community by the Housing and Community Development Corporation of Hawai'i (HCDCH). Most of the 23 acres were developed from 1993 to 2003, and include the Waipahu Civic Center, Waipahu Library, Kamalu and Ho'olulu elderly housing projects, the Hale Kuhao assisted-living facility, and a health and childcare facility. Remaining development on six acres of land is planned for 165 affordable housing units in two mid-rise buildings. Additional amenities would include a park, picnic area, vegetable garden, "tot lot," and recreation / meeting room.[142] Community concern regarding the height of the buildings, which would be the second tallest structure after the Waipahu Sugar Mill smokestack, as well as a possible increase in traffic problems, may delay the project[143].

Koa Ridge Makai and Waiawa: In a court challenge by the Sierra Club, the Supreme Court upheld a 2003 Circuit Court decision overturning the State Land Use Commission's 2002 reclassification of 750 acres of Castle & Cooke land from agricultural to urban use for the project. Castle & Cooke will have to produce an environmental impact statement for its Koa Ridge Makai and Waiawa developments and resubmit its application to the State Land Use Commission. If it again gets approval, the earliest that homes would be available at Koa Ridge Makai would be 2010, a year later than the company had hoped. Plans are to build 3,000 to 3,500 homes on 750 acres, including some affordable homes and some town homes or condominiums.

Koa Ridge Mauka: Castle & Cooke's Koa Ridge Mauka plans also must go before the Land Use Commission and City Council. The company will not seek approval this year for a Koa Ridge Mauka parcel that was refused reclassification by the Commission in 2002.

Makaīwa Hills: This planned residential development by the Estate of James Campbell will include 2,706 single-family residences, 1,404 apartment units, a commercial area, parks, roads, and preservation land. The 1,781 acres of land are currently vacant.

Makakilo: The Schuler Homes developments are almost complete for Anuhea and HighPointe. Single-family townhouses in two projects became available by lottery in May 2006. Another development, Kai Nani, features 72 units, and Ocean Ridge features 68 units.

Wai Kalo'i: Formerly known as Pālehua East B in Makakilo, this is a 275-unit single-family home subdivision project by Castle & Cooke. It is scheduled for completion by the end of 2007.

TABLE 2-13
STATUS OF HOUSING PROJECTS
AS OF JUNE 30, 2005[i]

PROJECT	% BUILT	TOTAL UNITS	ACREAGE	YEAR OF COMPLETION	SUMMARY OF LATEST PROGRESS
City of Kapolei, including:	**0%**	**2,850**	**228**	?	Parts of the city center finished; SLUC allowed housing in '95.
Kapolei Senior Village	0%	650	43	2009	Site is just *makai* of Kapolei Regional Park in the City of Kapolei.
Mehana at City of Kapolei	0%	1,150	115	2015	Groundbreaking in 2007.
Kapolei Mixed Use	0%	300	n/a	2009	Project proposals being sought.
Kapolei Mauka (Palailai Apartments)	0%	750	70	?	Site is between the H-1 Freeway and the bottom of Makakilo.
East Kapolei I (State DHHL)	0%	402	65	2008	Infrastructure construction to start in early 2006.
'Ewa by Gentry	86%	7,163	720	2010	Over three-fourths done; construction is ongoing.
'Ewa Makai by Gentry	0%	1,865	189	2011	The Laulani/Fairways project areas, just *makai* of 'Ewa by Gentry.
'Ewa Villages (City DCS)	55%	1,385	620[j]	?	Approximately 770 units have been completed as of 2004.
Ho'opili	0%	10,000	1,600[k]	?	(DR Horton / Schuler)
Kapolei West (Ko Olina, Phase II)	0%	2,370	163	2018	In EIS stage; zoning & SLU changes.
Kau'olu Properties (State HCDCH)	50%	490	23[l]	2007	
Ko Olina Resort	19%	4,450	189	2015	Construction has resumed; multiple housing projects under way.
Koa Ridge Makai and Waiawa	0%	3,000-4,500	763	?	EA and LUC application resubmittal needed. [m]
Koa Ridge Mauka	0%	3,000	486[n]	?	LUC Reclassification is needed.
Makaīwa Hills	0%	4,100	306	2020	New plan for 4,100 units proposed.

[i] (Information from this table is extracted from the Annual Report on the Status of Land Use on Oahu, Fiscal Year 2005, City and County of Honolulu, Department of Planning and Permitting, unless otherwise noted). Note: This table describes the current status of projects containing 25 housing units or more. Percent of total units reflects those that have been completed as of June 20, 2005.

[j] 'Ewa Development Plan (City and County of Honolulu; 2000).

[k] Nina Wu, "Suburbs no longer," June 23, 2006 <http://starbulletin.com/2006/06/23/business/ story02.html>.

[l] Andrew Gomes, "Affordable Condos Planned in Waipahu," March 9, 2006 <http:// the.honoluluadvertiser.com/article/2006/Mar/09/bz/FP603090321.html>.

[m] Castle & Cooke Homes Hawaii, Inc., 2002, "Koa Ridge - In the News" <http://www.castle-cooke.com/KoaRidge/06_21_02.aspx>

[n] Castle & Cooke Homes Hawaii, Inc., 2002, "Koa Ridge - In the News" <http://www.castle-cooke.com/KoaRidge/06_21_02.aspx>

TABLE 2-13
STATUS OF HOUSING PROJECTS
AS OF JUNE 30, 2005 (CONTINUED)

Project	% Built	Total Units	Acreage	Year of Completion	Summary of Latest Progress
Makakilo since 1984, including:	**70%**	**3,791**		?	Two-thirds done; construction is ongoing.
Already completed phases	100%	2,320		2005	
Current Schuler projects	0%	500		?	Includes Kahiwelo at Makakilo
Future Schuler projects	0%	300[o]	115	?	
Makakilo Heights Projects by lot owners	83%	396		?	The 4 projects are complete except for some remaining house lots.
Wai Kaloʻi (Palehua East B)	0%	275		2008	
Mililani Mauka	86%	6,486	864	2008	Over three-fourths done; construction is ongoing.
Ocean Pointe	32%	4,850	500	2013	One-third done; construction is ongoing.
Royal Kunia, Phase II	0%	2,000	327	?	Developer has declared bankruptcy; project's future is unknown.
Villages of Kapolei (HCDCH/DHHL)	68%	4,280		2011	
Waiawa by Gentry, increments I & II	0%	5,540	546	2016	Delayed; still in the permit phase.
Waipiʻo Point (Waipahu)		66	13	2006	Active; park 2005, infrastructure pending.
Total	**-**	**69,588**	**-**	**-**	

[o] Robert Bruhl, Vice President, Oahu Development Group, D.R. Horton Schuler Division, personal communication (December 13, 2006).

Waiawa by Gentry, Increments I & II: Currently, Waiawa by Gentry is the largest master-planned effort in the State of Hawai'i. The 2,000-acre master-planned community will be built over the next 25 years, and will include approximately 12,000 residential units, two golf courses, and commercial and industrial facilities. Groundbreaking for Phase I (5,000 units over 10 years) of the project may begin at the end of 2008 or early 2009. Water resources sufficient to serve most of Phase I needs have been identified and approved by BWS, and the City has approved a Wastewater Master Plan that connects to the Pearl City pump station[144].

Waipi'o Point: This project by Castle & Cooke is bringing new development to an established neighborhood in Waipahu. Sixty-six single-family homes are planned for the 13.2-acre site next to Waipahu High School.

Kalaeloa: After the closure of Barbers Point Naval Air Station in 1999, various plans for the redevelopment of the area have been underway. The Hawai'i Community Development Authority is planning to build a village of offices, shops, industrial workplaces, and 6,000 housing units on 3,700 acres by 2025.[145]

2.13.7.2 Golf Course Developments

Kapolei West: This 18-hole championship golf course is proposed as part of the planned residential and golf community just east of the Ko Olina Resort. The course will provide a natural drainage system for the homes.

Ocean Pointe: Designed by PGA Tour champion Ernie Els, this golf course will be the first new golf course built on O'ahu in more than a decade ('Ewa Villages Golf Course was built in 1996). The course will be a private club as part of the planned Hoakalei Resort, but will initially be open to the public.

Waiawa #1 and #2: In 2005, the State Commission on Water Resource Management approved the pumping of about 1 mgd of potable water a day to irrigate these two golf courses envisioned as part of a 3,700-acre residential complex. The use of potable water to irrigate golf courses has caused public concern.[146] There also are plans for a wastewater recycling plant near Wahiawā to provide non-potable water for Central O'ahu irrigation purposes, such as for the twin golf courses. Once this is in place, the use of potable water for irrigating the courses is planned for conversion to the recycled water.

TABLE 2-14
CONSTRUCTION SCHEDULE FOR GOLF COURSE DEVELOPMENTS[147]

PROJECT	ACREAGE	YEAR OF GOLF COURSE COMPLETION	YEAR OF CLUBHOUSE COMPLETION
Kapolei West Golf Course	200	?	?
Ocean Pointe Golf Course	250	2007	2007
Waiawa Golf Course #1	209	2008	2009
Waiawa Golf Course #2	173	2010	2011
Total	**832**	-	-

2.13.7.3 University Projects

UH-West O'ahu has 862 multi-family residential units proposed for 169 of the 500 acres next to the proposed North-South Road and the Kapolei Golf Course. The design work is being paid for through an $8 million appropriation from the Legislature. The University is negotiating with a development team that will get development rights in exchange for building the first phase of the new campus. The University is willing to sell or lease the 169 acres, help the developer obtain proper zoning, and prepare design and construction drawings for phase one of the campus. In exchange, the developer would build sewer, water, electrical infrastructure, and roads to the campus. The developer would also build a central plaza and pedestrian malls, parking areas, an administration and student services building, a campus center, library, and central air conditioning plant. Groundbreaking is expected to begin in 2007, and classes to start in 2009.

2.13.7.4 Resort Projects

Hoakalei Resort: Haseko's planned Hoakalei resort is master-planned for a hotel, marina, commercial complex, and vacation homes next to Ocean Pointe. The hotel, permitted for 950 units, could include time-share use. The hotel is projected for completion in 2008 along with the marina, which is about halfway excavated.

Ko Olina Resort: This resort has a variety of projects planned. The most recent project broke ground in 2005 and is a planned 247-unit Beach Villas beachfront condo by Centex Destination Properties.

The **Crescent Heights** development firm plans to develop a 16-story condotel with 400 to 500 units on eight acres fronting Lagoon No. 3, next to the Marriott Ko Olina Beach Club time-share. The firm is in discussions with Donald Trump to operate the hotel under the Trump name. Construction is scheduled for completion in 2008.

Other planned Ko Olina Resort Projects include a marine science building, yacht club building, ocean residences, beach hotel, Grand Ko Olina, hotel and timeshare, shopping center (inland from small lagoons), and preschool.

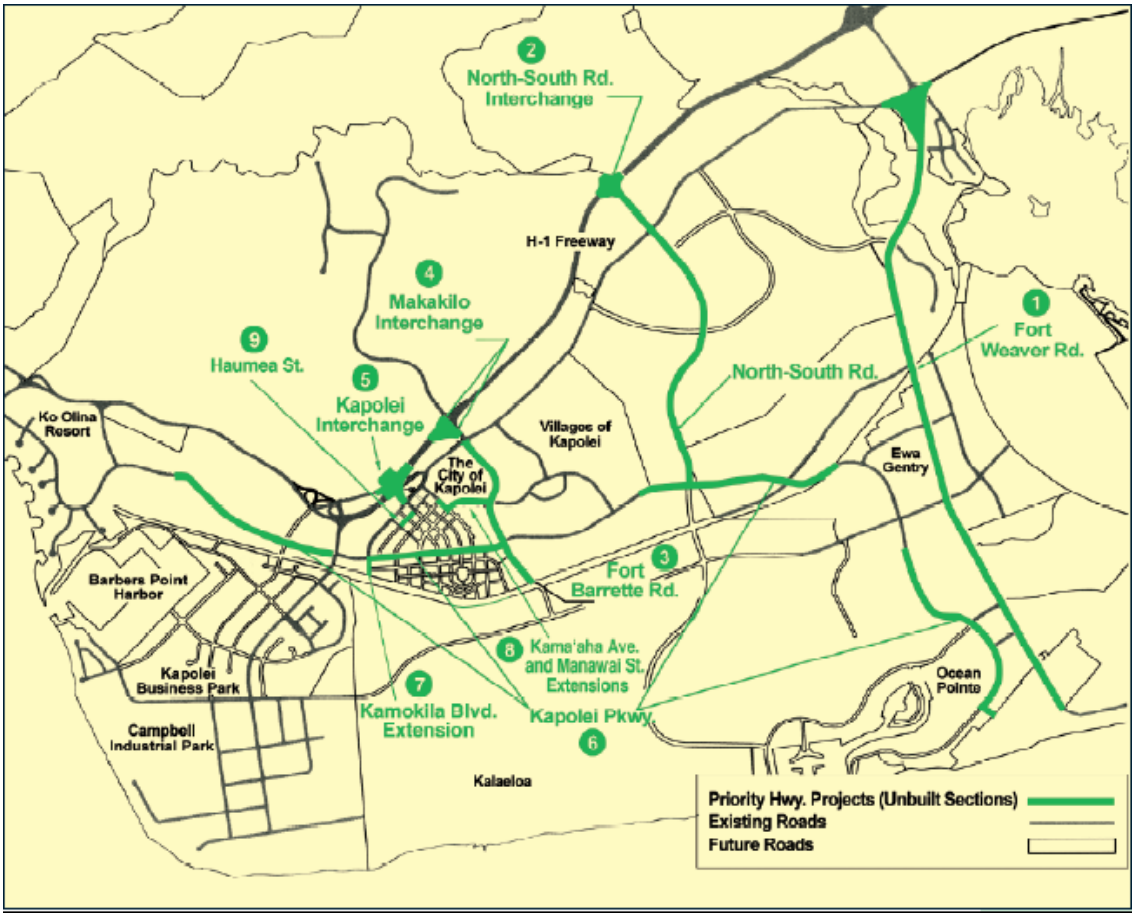
2.13.7.5 Commercial Development

Considerable commercial and industrial development is planned to accompany residential and resort development in the region. State and City capital improvement budgets are focused on the new growth areas in the state, including development of new facilities in Kapolei.[148] Much of the commercial development will locate at Kapolei. Ongoing developments in the 890-acre town center include shopping centers, a new power center (which includes factory outlets), entertainment centers, office complexes, government offices and facilities, medical clinics and offices, private schools, daycare centers, and others. Industry is also expected to expand at the Campbell Industrial Park, the Kapolei Business / Industrial Park, Kenai Industrial Park, and other areas near the Kalaeloa Barbers Point Deep Draft Harbor (such as the Kapolei Harborside Center). Civilian reuse of Barbers Point Naval Air Station, now known as Kalaeloa, is estimated to provide almost 6,000 jobs. Additional commercial and/or industrial development will locate in Waipahu, Mililani, Royal Kunia, Honouliuli, Waiawa, 'Ewa Marina, and elsewhere in the region,[149] including Pearl City near Pearl Highlands Center where a Wal-Mart opened in 2006.[150]

2.13.7.6 Transportation Projects

Impervious surfaces, including roads, parking lots, driveways, and rooftops add to the increased non-point source pollution of an area. Roads, highways, and bridges are a source of significant contributions of pollutants to water bodies. Research conducted in Wisconsin by Roger Bannerman, et al., of the Wisconsin Department of Natural Resources identified streets as the type of surface that creates the highest pollutant load, contributing 54% of all runoff volume in residential neighborhoods and 31% of runoff in commercial neighborhoods (streets and parking lots combined to contribute 80% of runoff in commercial neighborhoods).

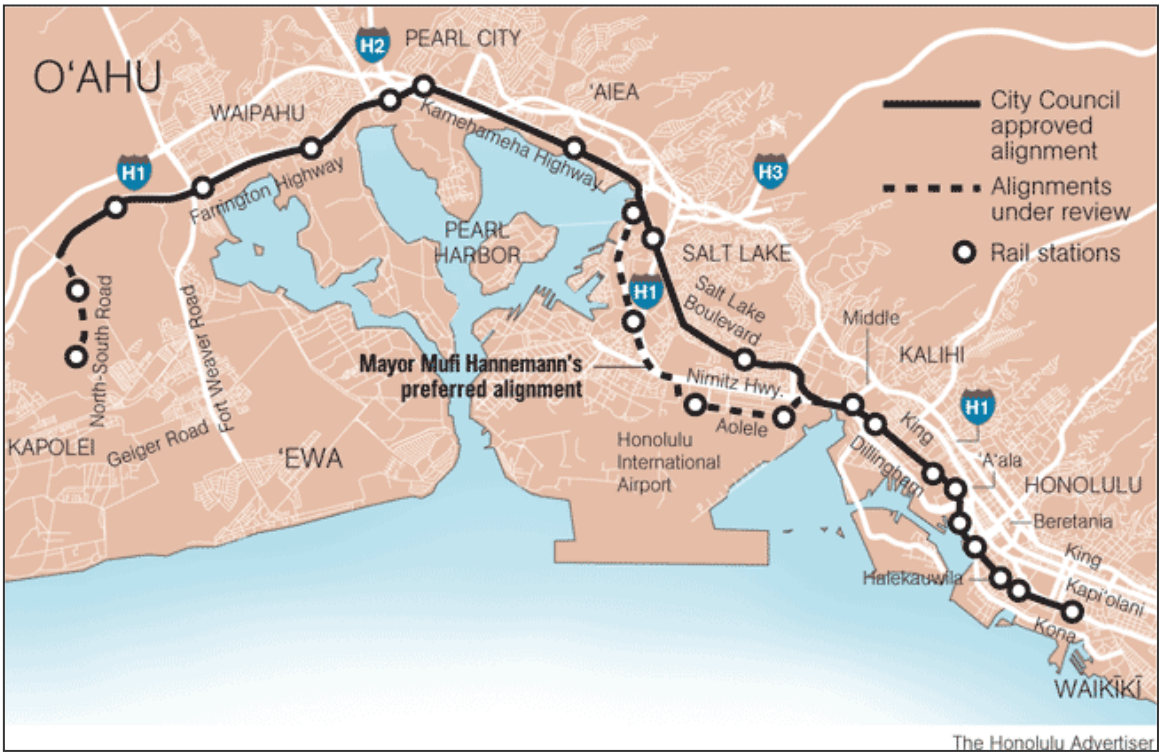
Contaminants from vehicles and activities associated with road and highway construction and maintenance are washed from roads during rains and carried as runoff to streams, harbors, and the ocean through storm drains. These contaminants include heavy metals, suspended solids, oil, grease, rubber particles, nutrients, sediment, chemicals, fertilizers, debris from wearing parts, litter, and petroleum-related organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, and xylene. Many of these pollutants, in particular PAHs, are toxic to aquatic life and several are suspected carcinogens.



Road projects planned or under construction. From "Kapolei FYI," September 2005.

Infrastructure, specifically roads and highways, will need to be built or supplemented to support the planned developments for the area. The construction of North-South Road began in 2005, with the first phase scheduled for completion in 2008. This road is designed to alleviate rush-hour congestion in the 'Ewa-Kapolei area, but will not solve larger regional needs. [151] Additional North-South corridors are recommended in the *Central O'ahu Sustainable Communities Plan*, along with East-West corridors and a second Waipi'o interchange. The *'Ewa Development Plan* calls for roadway extensions, which include widening Farrington Highway from the H-1 terminus to Nānākuli, creating a High-Occupancy Vehicle median lane from Makakilo to the Waiawa Interchange, and creating an interchange at Makaīwa Hills.

Larger regional needs are planned to be alleviated through a mass transit rail system. An increase in the general excise tax in 2007 will be used to fund the project. The completed system is expected to be more than 30 miles long, with estimated construction costs of at least $5 billion. Earliest construction would begin in 2009, with the first phase of rail completed in 2012. A final route has not been approved yet. Possible routes and extensions include Kapolei, University of Hawai'i West O'ahu Campus, Salt Lake, the Honolulu Airport, Waikiki, and University of Hawai'i at Mānoa.



Proposed mass transit routes. From "Council alters portion of mass transit route" The Honolulu Advertiser. February 22, 2007.

Highway runoff can have adverse effects if no measures are taken for the removal of excessive contaminants before the runoff reaches the receiving water. If handled properly, it need not be a serious problem. Given that a large number of preventive and corrective measures can and are being taken to suppress the potential of any disturbing effects of highway runoff on nearby receiving waters, it is important to recognize that highway runoff need not be and most often is not a serious problem. See Project 21 (Roads and Highways Runoff Study) for additional information on what HDOT and the City are doing to remediate this problem.

2.14 STAKEHOLDER CONSULTATION

2.14.1 PURPOSE OF STAKEHOLDER CONSULTATIONS

Stakeholder consultations were held to gain a general understanding of those Watershed issues of most concern. Information elicited included data, concepts, plans, programs, problems, issues, and needs. Stakeholders are those organizations and individuals who have an interest or "stake" in the water resources of the Central O'ahu Watershed. This includes both public and private sectors. For the purposes of this report, the list of stakeholders is broad, but does not include a representation of all community members.

2.14.2 OBJECTIVES

The Stakeholder Consultation process emphasized a fact-finding approach through discussion and consultation with Federal, State, and City agencies; military planners; large landowners and lessees; large water users; developers; neighborhood board chairs; and active interest groups. Interested and active public and private stakeholders provided valuable insight during the course of the study regarding:

- Defining and prioritizing key issues, problems and needs
- Conceptualizing actions and strategies in response to issues.

2.14.3 METHODOLOGY

The Stakeholder Consultation process involved email, telephone, and one-on-one interviews. A water fact sheet was developed to describe the project at a glance and used as a basis for discussion (see Appendix C). Once issues were identified, stakeholders were consulted by email for review, prioritization, and input of remaining issues that might have been missed. An agency-researcher meeting was held to gather information from researchers and others who are doing on-the-ground work in the project area. Specific stakeholders were again contacted for additional information to support projects and programs devised to mitigate the Watershed issues.

2.14.4 STAKEHOLDER CONSULTATION PROCESS

2.14.4.1 Stakeholder Identification

Stakeholders represented a range of organizations and public agencies that are interested in, are affected by, or could affect activities related to water resources in the Central O'ahu Watershed. Three resources were used to identify potential stakeholders: (1) Neighborhood Board chairpersons within the area, (2) Government Agencies, and (3) references from the above. A compiled database outlined community-based organizations, neighborhood boards, community leaders, large water users, large landowners, and developers having activities within the Central O'ahu Watershed area.

2.14.4.2 Process for Preliminary Consultations

Federal agencies helped to define and evaluate the critical issues, problems, and needs for the project. The preliminary consultation strategy involved initial one-on-one dialogues and telephone interviews. The purpose of these dialogues was to identify watershed activities that might have an impact on water resources in the Central O'ahu and 'Ewa areas, and any concerns regarding water, including man-made and natural water systems, such as water use, water systems, water quality and supply, forests, and streams. A total of 34 "dialogues" were held with 51 individuals who represented the Neighborhood Boards within the area, active interest groups, large land owners / users, developers, large water users, and public agencies.

Due to the scope and timeframe of this project, there were stakeholders who were not interviewed. Further study of this area should consider contacting the following groups, in addition to those already interviewed.

- 'Ahahui Siwila Hawai'i o Kapolei Hawaiian Civic Club
- 'Aiea Community Association
- Agribusiness Development Corporation
- City (City and County of Honolulu) Department of Design and Construction (DDC)
- City Council Members
- City Department of Facility Maintenance (DFM)
- 'Ewa Beach Community Association
- 'Ewa by Gentry Community Association
- Friends of Honouliuli
- Haseko Construction, Inc.
- Hawaiian Civic Club of 'Ewa
- Hawai'i Nature Center
- Hawai'i State Department of Business, Economic Development and Tourism (DBEDT)
- Hawai'i State Department of Hawaiian Home Lands (DHHL)
- Hawai'i State Department of Health (DOH) Environmental Management Division (EMD) Clean Water Branch
- Hawai'i State Department of Land and Natural Resources (DLNR) Division Of Boating and Ocean Recreation (DOBOR)
- Hawai'i State Department of Transportation (DOT)
- Hawai'i State DLNR Division of State Parks
- Hawai'i State DLNR Land Division
- Hawai'i State DLNR Office of Conservation and Coastal Lands (OCCL)
- Hawai'i State DLNR State Historic Preservation Division (SHPD)
- Hawai'i State DOH Office of Environmental Quality Control (OEQC)
- Hawai'i State DOH Solid and Hazardous Waste Branch
- Hawai'i State DOH Wastewater Branch
- Hawai'i State Hawai'i Community Development Authority (HCDA)

- Hawai'i State Legislature Members
- Hawai'i State Office of Hawaiian Affairs (OHA)
- Hawai'i State Office of the Governor
- Hawai'i State Office of the Lieutenant Governor
- Hawai'i Water Environment Association (HWEA)
- Health of the Land
- Honokai Hale / Nanakai Gardens Community Association
- Kamehameha Schools - Waiawa
- Kapolei Rotary Club
- King Kamehameha Hawaiian Civic Club
- Makakilo Community Association
- Mānana Valley Farm LLC
- Mililani Town Association
- Pālehua Community Association
- Pearl Harbor Area Restoration Advisory Board
- Pearl Harbor Hawaiian Civic Club
- Robinson Estate
- Soil and Water Conservation Society
- South O'ahu Soil and Water Conservation Districts
- The Queen Emma Foundation
- U.S. Air Force
- Villages of Kapolei Association
- Waipahu Community Association
- West Loch Estate Homeowners Association
- West Loch Fairways Association
- West O'ahu Current / Leeward Current / Ka Nupepa
- West O'ahu Soil and Water Conservation District
- Additional Community Members

2.14.5 AGENCY AND RESEARCHER MEETING

2.14.5.1 Attendee Identification

A small group of researchers and government agency staff were selected for a brainstorming session to discuss water resources issues and solutions with regard to their on-the-ground experience within the study area. The attendee list was compiled based on authors of literature pertinent to this study, as well as from the knowledge of the study team of actively involved persons. The size of the group was kept small to allow for maximum discussion from each individual.

Groups and agencies represented include:

- AECOS, Inc.
- City Board of Water Supply

- City Department of Environmental Services
- Environmental Planning Services
- Hawai'i Nature Center
- Hawai'i State Department of Health (DOH) Polluted Runoff Control Program (PRC)
- Hawai'i State DLNR Commission on Water Resources Management
- Hawai'i State DLNR Division of Aquatic Resources (DAR)
- Hawai'i State DLNR Division of Forestry and Wildlife (DOFAW)
- Hawai'i State DOH Safe Drinking Water Branch (SDWB)
- Hawai'i State Office of Planning
- Leeward Community College
- University of Hawai'i at Mānoa (UHM) Center for Conservation Research & Training (CCRT), Pacific Biomedical Research Center (PBRC)
- UHM Department of Economics
- UHM Department of Natural Resources & Environmental Management (NREM)
- UHM Water Resources Research Center (WRRC)
- U.S. Department of Agriculture/Natural Resources Conservation Service (USDA/NRCS)
- U.S. Geological Survey (USGS)
- U.S. Navy

2.14.5.2 Meeting Process

The purpose of the meeting was to:

- inform researchers with an interest in the study area about the preliminary findings regarding watershed issues and proposed projects,
- clarify current findings and gather information from researchers on watershed issues,
- help prioritize issues for the study area, and
- collectively identify current and proposed projects to address these issues.

Invitees to the meeting were sent a pre-meeting packet that included the same water fact sheet stakeholders were sent to help familiarize them with the geographic area and overall plan process, a potential projects list and matrix for review and comment, and a questionnaire on issues, projects, and references that pertain to the study area.

The three-hour meeting included a power point presentation of this study process, issues identified, and potential projects for their mitigation. The remainder of the time was divided into discussion pertaining to elaboration of previously noted issues and new ones identified; and discussion of potential solutions. Meeting notes were distributed for review and clarification, and some attendees were contacted again for further information.

2.14.6 PROFILES OF SELECTED STAKEHOLDERS

The following table lists the stakeholders interviewed. The remainder of the chapter gives profile descriptions for each stakeholder, discussing their role within the Watershed.

TABLE 2-15
STAKEHOLDERS INTERVIEWED

Federal Agencies
United States Army
United States Department of Agriculture, Natural Resources Conservation Service
United States Environmental Protection Agency
United States Fish and Wildlife Service
United States Geological Survey
United States Navy, Naval Facilities Engineering Command (NAVFAC)
State of Hawai'i
Hawai'i Coastal Zone Management
Department of Agriculture
Department of Health (DOH) Environmental Planning Office
DOH, NPDES Enforcement Division
Department of Land and Natural Resources (DLNR) Division of Aquatic Resources
DLNR, Division of Forestry and Wildlife
DLNR, Commission on Water Resource Management
City and County of Honolulu
Department of Environmental Service, Division of Environmental Quality, Storm Water Quality Branch
Department of Planning and Permitting
Neighborhood Boards
'Aiea
'Ewa
Foster Village
Makakilo / Kapolei / Honokai Hale
Mililani / Waipi'o / Melemanu
Mililani Mauka / Launani Valley
Pearl City
Wahiawā
Waipahu
Large Land Owners / Users
Aloun Farms, Inc.
Castle & Cooke Homes Hawai'i Inc.
Del Monte Fresh Produce Hawai'i Inc.
Gentry Homes Hawai'i
The Estate of James Campbell
Larry Jefts Farms
Largest Water Users
Chevron Hawai'i
Hawaiian Electric Company
The Resort Group (Ko Olina)
Active Interest Groups
Hawai'i Agriculture Research Center (HARC)
Ko'olau Mountains Watershed Partnership
The Nature Conservancy, Hawai'i Chapter
Resource Conservation and Development

2.14.6.1 Federal Agencies

United States Army

Environmental Division, Directorate of Public Works, Schofield Barracks, U.S. Army Garrison, Hawaii (USAG-HI)

The vision of the USAG-HI is to establish itself as a leader in ecosystem management. The ecosystem management program on O'ahu complies with applicable laws and regulations to preserve, protect, and enhance the natural and cultural resources of Hawai'i, while improving the Army's capability to conduct training and maintain military readiness.

The Army manages six major training sub-installations on the Island of O'ahu and one on Hawai'i Island, totaling over 150,000 acres of training lands in Hawai'i. The Army manages the Pu'u Hāpapa Management Unit of Schofield Barracks Military Reservation within the Central O'ahu Watershed. Maintaining functioning ecosystems ultimately supports training since degraded ecosystems lead to a loss of training realism.

A high priority is placed on management of threatened and endangered species (TES) on Army lands, including 58 plants, 10 endangered O'ahu tree snails, a bat, and two birds. TES management on Army lands is by the Conservation/Restoration Branch of the Environmental Division, Directorate of Public Works. Major threats to TES and native ecosystems are fire, human land use, introduced plants and animals, and disease. The Army's natural resources staff implements various management actions to counter these threats, such as fuels reduction around TES populations, fencing to exclude feral animals, and other control of alien species and disease.[152]

United States Department of Agriculture, Natural Resources Conservation Service (NRCS)

NRCS is an agency of the U.S. Department of Agriculture and is committed to assisting in responsible conservation, management, and use of Hawaii's natural resources. NRCS works closely with Soil and Water Conservation Districts, other Federal, State, and county agencies, private landowners, managers, and their lessees to conserve, sustain, and improve natural resources on private and other non-Federal lands in Hawai'i. Much of NRCS's work involves providing technical assistance to private land users. NRCS has no regulatory or enforcement responsibilities. They encourage those who manage private lands to practice a variety of measures designed to conserve or improve natural resources. Programs within NRCS include: Conservation Standards, Conservation Planning, Plant Materials Center, Watershed Program, Soil Survey, Resource Conservation and Development, and Farm Bill Programs.

United States Environmental Protection Agency (EPA)

The EPA provides Federal leadership in environmental science, research, education, and assessment efforts. Working closely with other Federal agencies, as well as State and local governments, the EPA develops and enforces regulations under existing environmental

laws. The EPA is also responsible for researching and setting national standards for a variety of environmental programs and delegates the responsibility for issuing permits, monitoring, and enforcing compliance to individual states. Where national standards are not met, sanctions may be issued and/or steps might be taken to assist states in reaching the desired levels of environmental quality. The EPA also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

The EPA Office of Water is responsible for the Agency's water quality activities, including the development of national programs, technical policies, and regulations relating to drinking water, water quality, ground water, pollution source standards, and the protection of wetland, marine, and estuarine areas.

United States Fish and Wildlife Service (USFWS)

The USFWS is the main Federal agency dedicated to protecting wildlife and their habitat from the harmful effects of pollution, helping to create a healthy world for all living things. The USFWS coordinates and participates in numerous programs, partnerships, and grants. USFWS is also involved in Superfund sites by providing data and guidance to the EPA. The Endangered Species Branch designates "critical habitats" for listed species, which regulates Federal-related activities within these designations.

United States Geological Survey (USGS)

The United States Congress created the USGS in 1879 as a bureau of the Federal Department of the Interior. The primary role of the USGS is to provide data and information to government decision-makers whose responsibilities are then to make recommendations and policies for action. The USGS in Honolulu has been actively studying streams in Central O'ahu, and many other locations in Hawai'i, for several decades. The USGS focuses its efforts in five primary areas of study: (1) ground water availability, (2) quantity and availability of stream water flows, (3) water quality in streams and the subsurface aquifer as it relates to land use, (4) Erosion and sediment transport, and (5) Long term changes in climate.

United States Navy

Naval Facilities Engineering Command (NAVFAC)

NAVFAC Hawaii is a new command that was established in 2005, compiling employees from Navy Public Works Center, Pearl Harbor; Resident Officer in Charge of Construction, Pearl Harbor and Kaneohe; Navy Region Hawaii Facilities and Environmental Departments; and Naval Facilities Engineering Command, Pacific's Integrated Product Team Hawaii.

This command provides a single touch-point for engineering, public works, and acquisition services in Hawai'i to Navy, Marine Corps, Department of Defense, and other Federal agency clients. NAVFAC Hawaii is a large employer of local trade and

white-collar expertise that can maintain, repair, and demolish facilities; provide utilities services (electricity, water, steam, air, and wastewater treatment); lease and maintain a vehicle pool of cars, trucks, and heavy equipment; and provide engineering expertise, contracting capabilities, environmental assistance, and lab services.[153]

2.14.6.2 State Agencies

Hawai'i Coastal Zone Management (CZM)

The Federal CZM Program was created through passage of the Coastal Zone Management Act of 1972. Since approval of Hawaii's program in 1977 (Chapter 205A, Hawai'i Revised Statutes), remarkable results have been achieved. This unique Federal-State partnership provides a proven basis for protecting, restoring, and responsibly developing the nation's important and diverse coastal communities and resources.

Unlike single-purpose programs, the CZM Program focuses its work on the complex resource management problems of coastal areas, the part of the state that is under the highest stress. Within a framework of cooperation among Federal, State and local levels, the Hawai'i CZM Program employs a wide variety of regulatory and non-regulatory techniques to address coastal issues and uphold environmental law. Among them are stewardship, planning, permitting, education and outreach, technical assistance to local governments and permit applicants, policy development and implementation, and identification of emerging issues and exploration of solutions.[154]

Hawai'i Department of Agriculture (DOA)

The State Department of Agriculture is charged with preserving Hawaii's important land and water resources to ensure the viability of Hawaii's diversified agricultural industry. Through its Agricultural Resource Management Division, the Department operates the State's Agricultural Park Program. The major objective of this program is to assist people who are interested in leasing land for farming ventures by providing irrigation water, reasonably priced farmland with infrastructure, and facilities to encourage competition within the industry.

The program is composed of three separate sub-programs: Agricultural Parks, Irrigation Systems, and Agricultural Produce Processing and Marshalling Facilities. Agricultural parks are areas set aside specifically for agricultural activities to encourage continuation or initiation of such operations. The State's Agricultural Park Program makes land available to small farmers at reasonable cost with long-term tenure. Within Central O'ahu, the Department operates the Kalaeloa Ag Park, composed of 10 acres subdivided into two lots.

DOA manages five irrigation systems across the state; however, none of these are located within the study area. Five agricultural produce processing and marshalling facilities are

located throughout the islands, and on O'ahu, the Kalaeloa Slaughterhouse is currently under development.

Hawai'i State Department of Health, Environmental Planning Office (EPO)
EPO provides strategic planning services for all programs under the Deputy Director for Environmental Health. These services include program evaluation and planning, land use review, legislative coordination, and information management. EPO is also responsible for data collection and analysis, and the development of scientifically based environmental standards. The Water Quality Management Program employs a watershed-based approach to water quality management. Responsibilities include setting the State's water quality standards, assessing and listing impaired water bodies, and being involved in the TMDL process and long-range planning for surface water quality improvement and protection. Most of this work is Federally funded, must meet Federal Clean Water Act requirements, and obtain U.S. Environmental Protection Agency (EPA) approval. EPO works to strengthen the connection between these efforts and linking them with other government functions and private actions.[155]

Hawai'i State Department of Health, Clean Water Branch, NPDES Enforcement Division
The mission of the Clean Water Branch is to protect the public health of residents and tourists, who recreate in and on Hawaii's coastal and inland water resources, and to also protect and restore inland and coastal waters for marine life and wildlife. The mission is to be accomplished through statewide coastal water surveillance and watershed-based environmental management through a combination of permit issuance, monitoring, enforcement, sponsorship of polluted runoff control projects, and public education. The Enforcement Section analyzes water quality and operational data to determine the degree of non-compliance. Compliance with permit conditions is determined via site inspection, source testing, and special studies; and corrective measures are carried out through administrative or court actions.[156]

Department of Land and Natural Resources, Division of Aquatic Resources (DAR)
The mission of DAR is to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations. DAR manages the state's aquatic resources and ecosystems through programs in commercial fisheries and resource enhancement; aquatic resources protection, habitat enhancement and education; and recreational fisheries. Major program areas include projects to manage or enhance fisheries for long-term sustainability of the resources, protect and restore the aquatic environment, protect native and resident aquatic species and their habitat, and provide facilities and opportunities for recreational fishing.[157]

Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW)
DOFAW administers five programs: Watershed Protection, Natural Resources Protection, Outdoor Recreation Resources, Forest Products Resources, and Public Information and Education. The priority of DOFAW is to balance desired levels of human use on DOFAW

managed land. Initial emphasis is on three program areas with conflicting resource demands: Outdoor Recreation, Forest Products, and Game Management and Hunting.

Department of Land and Natural Resources, Commission on Water Resource Management (CWRM)

CWRM administers the State Water Code, which was created by the 1987 Hawaii State Legislature. The Water Commission's general mission is to protect and enhance the water resources of the State of Hawaii through wise and responsible management. The Commission's primary responsibilities include basic data collection and resource assessment, water resource planning, regulation of water development and use, enforcement and technical support services, and protection of instream uses.

2.14.6.3 City and County of Honolulu Agencies

Department of Environmental Services (ENV), Division of Environmental Quality, Storm Water Quality Branch

ENV administers the Clean Water Program. This effort ensures that the City must conform to a set of Federal rules called the National Pollutant Discharge Elimination System (NPDES) regulations. These rules, part of the Federal Clean Water Act, are aimed at keeping Oahu's ground and surface water clean and apply to anyone residing or doing business on the island. The NPDES Phase 1 regulations mandate cities with more than 100,000 residents to keep their municipal storm drains and sewer systems as free of pollution as possible. They also require the City to educate the public about the law's requirements.[158]

Department of Planning and Permitting (DPP)

DPP provides services and information on building permits, development projects, and planning activities for the City and County of Honolulu. They are responsible for processing applications for land use approvals, zoning and land use permits, construction and building permits and engineering and subdivision permits. The Planning Division also helps establish, promote, and implement long-range planning programs for Honolulu that reflect the community's values, priorities, and visions for the future, such as the O'ahu General Plan, regional Development/Sustainable Communities Plans, Development Plan Land Use Annual and Biennial Reports, and Special Area and Neighborhood Master Plans. The Planning Division also provides Research and Statistical Information related to Oahu's population, land use, and employment.[159]

2.14.6.4 Neighborhood Boards (NB)

The Neighborhood Boards (with District number) for the Central O'ahu Watershed Study area are:

- Foster Village (18)
- 'Aiea (20)

- Pearl City (21)
- Waipahu (22)
- 'Ewa (23)
- Mililani/ Waipi'o/ Melemanu (25)
- Wahiawā (26)
- Makakilo/ Kapolei/ Honokai Hale (34)
- Mililani Mauka/Launani Valley (35)

The NBs provide an avenue for citizen participation in government so that the City and County can properly serve and advance the aspirations of its citizens. The system applies the concept of participatory democracy, involving communities in the decisions affecting them. It establishes an island-wide network of elected neighborhood boards as communication channels, expanding and facilitating opportunities for community and government interaction.[160]

2.14.6.5 Large Landowners / Users

Aloun Farms

Aloun Farms was incorporated in late 1995 and finalized its first land lease of 880 acres of former sugar-cane fields of 'Ewa and Kunia. The farm quickly grew from an 18-acre-family farm to a commercial operation consisting of 1,200 acres by summer of 1996. Currently, Aloun Farms provides full-time employment to 180 people and has expanded production to approximately 3,000 acres. The company's goal is to provide Hawai'i consumers with "the highest quality of fresh island grown produce." Together, with the communities of 'Ewa and Central O'ahu, Aloun Farms is a strong supporter of community out reach through educational tours and collaboration with the Future Farmers of America (FFA) program. School-to-work programs, educational farm visits, and practical training for FFA high school students have been implemented in order to sustain the support for Hawaii's agriculture industry.[161]

Del Monte Fresh Produce Hawai'i Inc.

The Del Monte O'ahu Plantation occupies 6,000 acres in Kunia, with a small village located on the plantation that is the residence for 65% of Del Monte's full-time employees. Pineapple has been cultivated on the plantation since the 1940s. The plantation receives its water from the Waiāhole Ditch and two wells on the property. Water is recycled from the village to a reservoir and then used for irrigation.[162]

Castle & Cooke Homes Hawai'i Inc. / Castle & Cooke Inc.

Castle & Cooke Hawaii, a division of Castle & Cooke, Inc., was founded in 1851 and is one of the nation's oldest developers. It built itself around three guiding principles: investing in Hawai'i, creating communities, and delivering dreams. Castle & Cooke, Inc. was incorporated in Hawai'i on October 10, 1995, to be the successor to the real estate and resort business of Dole Food Company, Inc. The Company is engaged in three

principal businesses: residential real estate, commercial real estate, and resorts. Its residential real estate operations in Hawai'i are headed by Castle & Cooke Homes Hawaii, Inc., the premier developer of master-planned communities and builder of quality, fee simple homes. Current real estate developments include Mililani, Castle & Cooke's flagship master-planned community, as well as the communities of Wai Kalo'i at Makakilo, Waipi'o Point, and the future community of Koa Ridge. Castle & Cooke also develops and manages commercial offices and retail and industrial properties in Hawai'i. The development of the Mililani Technology Park complements the residential real estate operations of Castle & Cooke Homes Hawaii.[163]

Gentry Homes Hawai'i

Gentry Homes Hawai'i has built about 15,000 single-family and condominium homes in exclusive master planned communities, and commercial and industrial projects, since 1968, including Waipi'o by Gentry and 'Ewa by Gentry. When the entire 'Ewa by Gentry community is finished, likely around 2010, it will contain almost 10,000 homes. The Waiawa project, in the works since the mid-1980s on 3,700 acres of Kamehameha Schools land, is envisioned for 10,000 to 12,000 homes, two golf courses, parks, a commercial center, schools and other community facilities. The first homes are expected to be finished in 2009.

James Campbell Trust Estate

The Estate of James Campbell was established in 1900 as the legacy of one of Hawaii's foremost business pioneers, and has played a pivotal role in Hawaii's history from the growth of Hawaii's sugar plantations to today's growing City of Kapolei. Today, the Estate of James Campbell is one of Hawaii's largest private landowners and administers the assets under the will of James Campbell for his heirs. The Estate's major undertakings include the development of the City of Kapolei and the ownership of office, retail, and industrial properties both in Hawai'i and on the mainland. The James Campbell Company is the successor to the Estate of James Campbell, which ends in 2007 as specified by James Campbell's will. The transition to the James Campbell Company ensures that the ongoing business of the Estate will continue beyond 2007. In Hawai'i, the Estate owns 57,607 acres of land – 24,994 on O'ahu, 28,676 on the island of Hawai'i, and 3,937 acres on Maui.

Larry Jefts Farms

Larry Jefts manages several thousand acres of agricultural land throughout Central O'ahu and the North Shore, growing vegetables and melons. With over 25 years of farming in Hawaii, Larry Jefts is considered by many to be Hawaii's largest diversified agricultural farmer. Where Hawai'i once imported 75% of the tomatoes it consumed, Jefts Farms now provides most of the 85 to 90% locally grown crop. His farms use water from wells, State water systems, and private systems. Larry Jefts is an economist by training, a farmer by heritage. He understands the importance of science to farming, but he is motivated more by what sells at the marketplace, and what makes it there with the least resistance. Jefts is

keenly aware of the importance of weather and climate on his business. He maintains his own network of weather stations, from which he has determined microclimatic variations over the relatively small area of his Kunia farm.

2.14.6.6 Large Water Users

Chevron Hawai'i

Chevron, the state's largest oil refinery, is located on 252 acres at Campbell Industrial Park. The refinery receives crude oil from the Far East and Alaska. Typically, it is transported aboard one of Chevron's fleet of tankers. The tankers anchor at a mooring almost two miles off Barbers Point and pump their oil to the refinery via a submerged pipeline. Chevron refines propane, gasoline, jet fuel, diesel, fuel oil, and asphalt from the crude oil. These refining processes use large amounts of water, especially for using water in the cooling towers. Currently, freshwater is used for this process, along with general uses at the refinery. RO water is used for steam generation.

Hawaiian Electric Company (HECO)

HECO generates and maintains power for the island of O'ahu. Two of three power plants are located within the Central O'ahu Watershed (the Kahe and Waiau Generating Stations). Waiau is capable of producing 499 MW and Kahe 651 MW, 70% of HECO's total firm generating capacity. Waters used at these plants include potable, ocean water, and for the Kahe plant, fresh water from a nearby stream and pond. HECO is currently in discussions with BWS for use of alternative water sources for the Kahe Generating Station. HECO promotes energy conservation via radio spots, print ads, press releases, and Consumer Lines articles that include energy saving tips such as taking shorter showers and installing low-flow showerheads.

The Resort Group, LLC (Ko Olina)

The Resort Group is an integrated, multi-disciplinary development firm focused exclusively on the acquisition, development, redevelopment, and marketing of resort real estate projects in domestic and international markets. Ko Olina Resort is one of its projects. The Ko Olina Resort has 640 total acres, of which the Resort Group owns 620 acres and Campbell owns 20 acres. The Resort Group sells land to developers to build on and therefore leaves management practices up to the buyers' discretion.

2.14.6.7 Active Interest Groups

Hawai'i Agriculture Research Corporation (HARC)

Founded in 1895, the Hawaiian Sugar Planters' Association (HSPA), dedicated to improving the sugar industry in Hawaii, has become an internationally recognized research center. Its name change in 1996 to Hawaii Agriculture Research Center (HARC) reflects its expanding scope to encompass research in forestry, coffee, forage, vegetable crops, tropical fruits, and many other diversified crops in addition to sugarcane. HARC is a private, non-profit 501(c)5 organization. HARC specializes in horticultural crop

research including agronomy and plant nutrition, plant physiology, breeding, genetic engineering and tissue culture, and control of diseases and pests through integrated pest management. HARC also performs pesticide registration work; training in areas such as pesticide application and environmental compliance; ground water monitoring; and technical literature searches. In addition to serving Hawaii's agricultural industries through research and immediate response teams to solve problems, HARC helps other local, national, and international organizations meet their research, on-site consulting, and training needs.

Koʻolau Mountains Watershed Partnership (KMWP)
KMWP is a consortium of landowners and interested parties who have banded together to protect the watershed areas of the Koʻolau Mountains on Oʻahu. KMWP was formed in 1999 to address the array of environmental and social issues facing the various watersheds in that mountain range. It seeks to balance the varied interests represented by each of the partnership's unique members, with the goal of protecting the forested watershed areas within the Koʻolau Range.

The Nature Conservancy, Hawaiʻi Chapter (TNCH)
On Oʻahu, TNCH is focused on protecting and managing native landscapes and their associated native and rare species in the Koʻolau and Waiʻanae Mountains. Their intent is to be a catalyst to increase conservation actions in native landscapes on all islands. By utilizing best management practices at Honouliuli Preserve, TNCH's primary strategy is to develop and demonstrate a strong volunteer-based resource management and community outreach program for replication by partners on Oʻahu and elsewhere.[164]

Resource Conservation and Development (RC&D)
Oʻahu RC&D is a 501(c) 3 organization, with about 3 or 4 years of Natural Resources Conservation Service (NRCS) support. For 7 to 8 years, they were purely a non-profit organization. RC&D assists partners in finding resources (technical and financial) to improve watersheds, assist with community development (especially in rural areas or in limited resource areas), land conservation, and management. This assistance can include acquiring funds, project visualization, technical help (especially help in using NRCS and U.S. Department of Agriculture [USDA] technical and financial assistance), or 319 grants. RC&D helps create watershed partnerships, and can be a partner or assist with an aspect of another group in accomplishing their goals. The Oʻahu RC&D typically is involved at the project level versus policy or advocacy.

2.14.7 SUMMARY OF STAKEHOLDER ISSUES

This section is a summary of the issues raised by stakeholders, and is anecdotal and not necessarily supported by scientific studies. Stakeholders interviewed were asked to identify concerns regarding water, including man-made and natural water systems, such

as water use, water infrastructure, water quality and supply, forests, streams, and near shore waters for the Central O'ahu Watershed.

In general, residents are concerned about where the water will come from to meet the demands of new housing developments. The quality of water is of concern due to pesticides and other hazardous materials that have contaminated ground water for the last twenty years. Water users are willing to use recycled water, but water infrastructure has not been able to keep up with demand in older neighborhoods.[165]

Stream banks are washing out due to drainage and runoff from increased development. This adds to a sedimentation problem that all NPDES permit holders are concerned about. This sediment flows to Pearl Harbor and the ocean, causing sediment build-up, and affecting near-shore biota. Increased development also brings other problems associated with it, such as decreased water infiltration to the aquifer, flooding, sewage spills, and illegal dumping.

2.14.7.1 Watershed-related Problems and Constraints with Current Solutions or Alternatives

(1) Land use development and potential contamination of ground water:

Problems

- Conversion of agricultural lands to urban: The community is concerned about the future of agricultural lands.[166]
- Water quality: The community feels they have been drinking water for the past 14 years that has been polluted by agricultural pesticides.[167] They are concerned about the quality of water for future developments.[168]

Application of agrochemicals.

Current Initiatives

- Both the *Central O'ahu Sustainable Communities Plan* and the *'Ewa Development Plan* support an Urban Growth Boundary, of which agricultural lands outside of this boundary are protected from development.
- Contaminated wells are treated with a GAC filter, and any wells exceeding fumigant standards were taken out of service or treated to remove the contaminants.[169]
- Hawai'i Wellhead Protection Program
  - In conjunction with the HISWAP, DOH has been working with Neighbor Island Planning Offices to delineate certain areas near potable underground drinking water supplies in order to develop plans for preventing ground water contamination. DOH has scheduled to meet with the City Department of Planning and Permitting (DPP) Office after working with neighbor island planning offices.

- The Navy has implemented this program and designated a Hydrologic Zone of Contribution around Waiawa shaft, which restricts the type of development allowed in this area.

(2) Potable and recycled water demand:

Problems

- Quantity of water: Residents are wondering if there will be enough water to accommodate planned future development. There are concerns associated with the future development of 20,000 homes in Central O'ahu, including the planned Koa Ridge Mauka.[170]
- Increasing legal costs passed on to Waiāhole Ditch water consumers may force ditch users to look for a water source elsewhere.
- Farmers are interested in using R-1 water but costs are too high. According to Larry Jefts Farms, past discussions with BWS regarding R-1 water rates would be more than ten times the currently incurred cost of potable water for the acreage than can be reached by R-1 water.

Current Initiatives

- The projected future potable water demands for the area will be primarily met by new BWS sources, including Waipahu Wells II, III, and IV; 'Ewa Shaft; and Kalaeloa Desalination Facility. The Deep Ocean Water Application Facility (DOWAF) / Ocean Thermal Energy Conversion (OTEC) feasibility analysis will evaluate another potential potable water source. Expansion of the Honouliuli Recycling Facility would provide for future non-potable demand.[171]
- BWS is evaluating use of R-1 recycled water from the City's Wahiawā WWTP for transmission to Central O'ahu Regional Park and other potential customers within similar proximity.

(3) Sedimentation of streams and near-shore waters:

Problems

- According to personnel at ENV, sediment will discharge into storm drain systems and receiving waters.[172]
- Pearl Harbor receives large quantities of sediment from streams and runoff. Silt can be re-suspended, clogging boat engines, degrading water quality and affecting sedentary marine life.

Current Initiatives

- Street sweeping to remove metals and other urban contaminants before they can contaminate runoff is conducted by State Department of Transportation (DOT) or the City, depending on road ownership.

- To relieve Pearl Harbor sedimentation, maintenance dredging is performed and dredge spoil is disposed of in the EPA/COE approved ocean disposal site. The Navy also has some land disposal capacity at Waimalu Peninsula.

(4) Polluted runoff adversely impacts Pearl Harbor and tributary streams:

Problems
- Non-point source water pollution is evident in all streams.
- Runoff: From Āliamanu Crater into Foster Village during heavy rains.[173]

Current Initiatives
- The 'Aiea Community Association regularly holds 'Aiea and Hālawa Stream clean-ups.
- Kapakahi Stream Restoration through O'ahu Resource Conservation and Development involves removing trash, clearing mangrove and other non-native vegetation, and fill removal.
- A large retention basin in the Āliamanu Military Reservation may be reducing the silt and other runoff from the crater.[174]

(5) Sewage spills:

Problems
- Heavy rains have caused sewage backflow in Foster Village. This problem is common in older urban areas, where ground water and runoff enters cracks in old sewer pipes, and is called infiltration inflow. Sewage spills pose a health threat, can cause property damage, and can result in fines up to $25 thousand per spill for the City. Located in valleys, the City and County Āliamanu Pump Stations 1 and 2 both overflow in heavy rains.[175]

Current Initiatives
- ENV recognizes the low capacity problems at the Āliamanu 1 and 2 stations. Funds will be requested to increase capacity once designs are complete in 2008. ENV also has a 17-year plan to upgrade leaky sewer pipes.[176]
- Under consent decree, the City has until 2019 to complete capital improvement projects that would mitigate deficiencies within its collection system to minimize overflows. This 20-year program deals with replacement, rehabilitation, and expansion of existing facilities, and will cost the City approximately $1.7 billion.

(6) Shoreline concerns:

Problems
- The amount of limu growing off the coast of 'Ewa Beach has declined over the past 30 years. Residents feel that this decline is due to development, the construction of the reef runway causing a change in currents, and over harvesting.

- Fishpond restoration.
- Beach erosion.

Current Initiatives
- The 'Ewa Beach Limu Project meets once a month to tend limu and educate the public about ocean resources.
- On June 26, 2006 Governor Lingle signed into law Act 293, which establishes an 'Ewa limu management area, where taking of limu is prohibited.
- The 'Oki'okiolepe Fishpond, located along the shoreline at the confluence of West Loch and East Loch at Naval Magazine Lualualei, is listed on the National Register of Historic Places.
- The Coastal Zone Management (CZM) Program funded a coastal erosion project under the direction of Dr. Chip Fletcher, University of Hawai'i, School of Earth Technology and Science. An analysis of aerial photographs from 1950 to 1997 was used to develop a histogram of the erosion and accretion movement of the Lanikai, Sunset Beach, and 'Ewa Beach shorelines.

(7) Privatization of military water management:

Problem
- There is community concern as to how this conversion will work.[177]

Current Initiative
- The Board of Water Supply (BWS) and other private water companies have submitted proposals to own and operate military water systems on O'ahu. These actions are in response to Department of Defense initiatives to privatize military water and wastewater systems nationwide. BWS began discussions with military representatives in 2004.[178] BWS is still negotiating management of Army water systems; the Navy and Air Force have terminated discussions to privatize their water systems.

(8) Increasing demand on resources:

Problem
- Infrastructure for schools, sewers, roads, parks, and jobs is not keeping up with development.[179]

Current Initiatives
- In 2005, Governor Linda Lingle released funds for the addition of six classrooms to 'Ewa Beach Elementary School, and for the design and construction of a new Ocean Pointe Elementary School. Classes are scheduled to start in January 2007. Another middle school is planned in the next few years in 'Ewa Makai.
- Seagull Schools began construction of a preschool in March 2006 to serve the 'Ewa Beach area. The school was planned for opening in December 2006.

- An additional 13 elementary, 4 intermediate, and 3 high schools are planned within the *'Ewa Development Plan* and *Central O'ahu Sustainable Communities Plan*.
- Construction of a new UH-West O'ahu is projected to start in late 2007, with the campus open by 2009. Legislators believe that building the new campus will help relieve traffic in West O'ahu and overcrowding at UH-Mānoa.[180]
- In Waipahu, installation of a new sewer line and CIPP (cured in place pipe) installation along Kahuanani Street was estimated to be completed by April 2006. The estimated completion date for the Fort Weaver Road Reconstructed Sewer – Pohakupuna Road project was September 2006.
- The construction of North-South Road began in 2005, with the first phase scheduled for completion in 2008. Phase 1 will create the first three lanes from Kapolei Parkway to the H-1 Freeway. Phase II will complete the North-South Road to its final six-lane configuration. The six-lane North-South Road will be located between the Kapolei and 'Ewa communities and connect Kapolei Parkway with Farrington Highway and the H-1 Freeway. This road is designed to alleviate rush-hour congestion in the 'Ewa-Kapolei area, but will not solve larger regional needs. [181]
- The *Central O'ahu Sustainable Communities Plan* recommends additional North-South corridors, East-West corridors, and a second Waipi'o interchange. These and other projects will support the planned Transit Corridor connecting Waipahu with both Kapolei and the PUC.
- Planned roadway extensions in the *'Ewa Development Plan* include widening Farrington Highway from the H-1 terminus to Nānākuli, creating an HOV median lane from Makakilo to Waiawa Interchange, and creating an interchange at Makaīwa Hills.
- Larger regional needs are planned to be alleviated through a mass transit rail system. The first phase of rail is expected to be completed in 2012.
- The *'Ewa Development Plan* calls for a continuous shoreline park along the 'Ewa coastline and a major regional park and recreation complex at Kalaeloa. Other planned parks include East Kapolei District Park, Pu'u Palailai Regional Park, and Makaīwa District Park.
- Developing job centers include the City of Kapolei, Ko Olina, Campbell Industrial Park, the Deep Draft Harbor, Kapolei Business Park, Kalaeloa, and the UH-West O'ahu.

(9) Total Maximum Daily Loads (TMDLs):

Problems

- There is concern that the TMDL waste load allocation may not be a statistically valid number, given the limited 1 to 2 year period for data collection. Storm events bring stream load, and if there is no storm event within the study period, the data will not be representative of stream loads, therefore giving false readings for levels of pollutants that should be expected in streams.
- TMDLs are designed to pinpoint where runoff is coming from, but this is dependent on various factors. The timing of a storm event and the land uses at the time will affect

the source point. Examples include if the timing of a storm event happens after agricultural lands have just been tilled, which will show more sediment than usual, or if it is the end of winter and plants have grown, there will be less sediment.

Current Initiatives

- The Environmental Planning Office states that the target for storm events in the Central Watershed TMDL studies was met. There may be different ways for doing it to get an accurate reading, but the sampling plan is accurate.

(10) Dumping:

Problem

- There are concerns for dumping and urban trash, possibly from commercial trucking companies. Dumping locations include One'ula Beach Park in 'Ewa, on the side of the road next to the convenience center in Pearl City when the center is closed, and areas in Waipahu, such as the lower reaches of Kapakahi Stream. Some stakeholders feel that proper enforcement is lacking.

Dumping at One'ula Beach Park.

Current Initiatives

- Regularly scheduled bulky item pick-up is not currently in effect in Kapolei and 'Ewa, but after initial expansion on the Wai'anae coast, equipment and resource needs will need to be evaluated before the service is expanded in Kapolei and 'Ewa. It is hoped that this initiative will help curb illegal dumping.
- The City is leading a collaborative effort with the Department of Health, local EPA officials, the Office of the State Attorney General, the Honolulu Police Department, and individual communities to address the problem.
- The City's Environmental Concern Line operates as a clearinghouse for reporting illegal dumping. City staff works with callers to identify dumpsites, coordinate the appropriate agencies, work with offenders (if identified), and manage clean-ups.
- Crimestoppers has gotten involved with trying to deter dumping at One'ula Beach Park, and will pay a cash reward of up to a thousand dollars for information that leads to the arrest of the illegal dumper.

(11) Safety of water holdings:

Problem
- Community members are not sure if water tanks are regularly inspected.

Current Initiative
- In the wake of the September 11, 2001, terrorist attacks, all BWS facilities have been equipped with intrusion alarms. If there were any break-ins, BWS officials along with HPD would respond immediately.[182]

2.15 IMPLICATIONS FOR WATERSHED PLANNING

The issues identified through the watershed research and stakeholder and agency consultation were analyzed to identify their implications. The following is a list of how the identified issues might affect water resource planning in the Central O'ahu Watershed.

2.15.1 GROUND WATER QUANTITY

- **Regular updates and refinements of sustainable yield and permitted use are necessary** in order to manage current and future ground water uses and ensure available water exists before new development is approved. Various land use changes have likely affected the sustainable yields in the Central O'ahu Watershed Study area.

- **Ground water infiltration should be maximized** to sustain ground water supplies. Encroachment into the high recharge areas or degradation of watershed health (forests) may reduce ground water quantities and sustainable yields.

- **Water conservation is needed** at every level to defer the need to develop new ground water sources and construct expensive new alternative technologies. Demand is expected to near BWS existing Pearl Harbor Aquifer source capacity in the next ten to fifteen years.

- **New technologies to supplement ground water will be necessary** in the future. The 'Ewa and Central O'ahu districts are expected to have a 73% increase in population between the years 2000 and 2030. While the Pearl Harbor Aquifer is the largest on the island, sustainable yield uncertainties are best addressed by diversifying water supplies with recycled water and desalination.

2.15.2 GROUND WATER QUALITY

- **Potable ground water resources need to be protected from contamination** by land use activities. The HISWAP and the O'ahu Inactive Landfills Relative Risk Evaluation identified some potential contaminating activities and landfills of concern near potable sources.

- **The potential for ground water contamination from storm water runoff through detention and infiltration basins needs to be quantified**. Although risks are likely minimal, basins could potentially concentrate contaminants that infiltrate into the ground.

- **Active irrigation wells, injection wells, and abandoned wells need safeguards** to prevent them from being direct conduits for contamination to the underlying potable aquifer.

- **Illegal dumping of household and commercial wastes needs to be mitigated and prevented** to reduce potential contamination of ground and surface water. Dumping hotspots include lower Kapakahi Stream, Waipahu Canal, parts of Mililani, Onipaa Ranch, and One'ula Beach Park.

- **Contaminants from Superfund sites should continue to be treated or contained** to prevent contamination of ground water. Pesticides from the Kunia Superfund site have already been detected in ground water.

- **Pesticides, herbicides, and fertilizer nutrients should be approved for application over the potable aquifer and applied according to directions so as to minimize their impact on ground water**. These contaminants have been detected in significant quantities in the ground water.

- **Potential contamination from fuel and sewer line breaks and backflows should be minimized**. Previous fuel line breaks have occurred, but the current status of fuel lines is unclear. Cracks in sewer lines are suspected of allowing inflow and rupturing during heavy rains and flows.

2.15.3 SEDIMENTATION

- **Sediment sources need to be identified** in order to effectively target reduction efforts. Currently, non-point source programs target urban land uses although it is generally believed that most of the sediment is generated from the conservation and agricultural districts.

- **Stream erosion needs to be reduced** to maintain stream habitat and minimize sedimentation in lower stream reaches and near shore waters. There are several streams and stream reaches that have been identified as having excessive erosion problems.

- **Incentives to increase the use of best management practices are needed**. BMPs are mostly optional, but even those that are required are not fully enforced. Oftentimes,

penalties are not enough to compel use of BMPs. Continued surface water pollution suggests that BMPs are either ineffective or are not being exercised.

- **Sediment volumes should be reduced** to minimize impacts to lower stream reaches and Pearl Harbor. The City and the Navy must periodically dredge stream mouths and Pearl Harbor in order to maintain channel and harbor capacity.

2.15.4 STREAM DEGRADATION

- **Restoration of stream habitat is necessary** to maintain native aquatic species populations. Native freshwater habitat has been degraded or eliminated by a variety of human-induced factors, such as pollution, introduced species, and channelization.

- **Vegetated buffers are needed around streams** to protect and enhance aquatic habitat. Riparian areas have been degraded or eliminated in much of the study area, eliminating habitat, altering stream hydrology, and reducing natural filtration of pollutants from surface water.

- **Pollutant sources need to be identified** in order to manage their input and effect on surface water.

- **The amount of impervious surfaces in the Watershed should be inventoried and assessed** to provide indications of overall watershed and stream health. Impervious cover has been linked to lowering water quality and other aquatic resource health. An understanding of the impervious cover in this developing area will help make future management decisions.

- **The impact of storm water runoff from roads and highways needs to be assessed**. There is a wide range of vehicle contaminants that are carried from roads and highways into the storm drain system. The impact of these contaminants on surface and ground water is unknown.

2.15.5 FLOOD MANAGEMENT

- **Drainage improvements are needed** to protect development in low-lying areas throughout the Watershed. Parts of 'Ewa, Waipahu, and Waiawa Stream have chronic flooding problems.

- **A hydrologic analysis is necessary** to provide data for input into other water management models. Hydrologic analysis will allow for more accurate modeling and better management of water resources.

- **Development should be restricted to areas outside of floodways and gulches** to reduce the potential for flooding. Some existing development, such as that in Waikakalaua Gulch, experiences frequent flooding.

2.15.6 TERRESTRIAL DEGRADATION

- **Wildfire prevention and response should be increased** to protect life, property, and natural resources. Wildfires threaten hundreds of acres of forest, native species, and critical habitat every year.

- **Undeveloped lands need protection** to maintain permeability, reduce soil compaction, and preserve existing vegetation and potential habitat.

2.15.7 NEAR SHORE DEGRADATION

- **Existing wetlands at Pouhala and Pearl Harbor National Wildlife Refuge need protection** from a variety of threats, such as invasive non-native species, poor water quality, and human disturbances.

- **Hawaiian fishponds within Pearl Harbor should be restored** for cultural and watershed education purposes. A few of the dozens of fishponds previously constructed and later destroyed by infill, runoff, and mangroves could still be restored.

- **Erosion of the 'Ewa shoreline needs to be mitigated** to protect property and coastal recreation. The 'Ewa coast is experiencing a high rate of erosion, possibly from reef degradation, reduced sediment supply, and coastal development and shoreline hardening.

- **The ecological health of Pearl Harbor should be improved** to allow for aquatic habitat, fishpond and fishery restoration, recreational opportunities, and human health and safety.

2.15.8 OTHER

- **Watershed education is necessary** to continue to build awareness for resource stewardship.

- **Partnerships and information sharing is needed** to improve natural resource management by increasing efficiency, reducing duplication of efforts, and pooling resources and funding.

3 WATER USE

The types, uses, and condition of water infrastructure affect the extent of residential, commercial, and military development within the Central O'ahu Watershed. As development in the Central O'ahu Watershed has increased over the years, the impetus to use different types of water sources and conserve water resources has also grown. Because of the sheer size of the Central O'ahu Watershed, the water infrastructure in the watershed is extensive and is a varied combination of different types. This section provides an overview of the different types of water infrastructure, current uses, potable water demand, and measures to meet future water demand in the Central O'ahu Watershed.

3.1 INVENTORY OF WATER INFRASTRUCTURE

In the broadest sense, water infrastructure includes any facility, system, or equipment that conveys, treats, or processes potable water and non-potable water. Non-potable water includes recycled water, wastewater, spring water, stream water, brackish water, seawater, and storm water. The sources of the different types of water may be wells, shafts, tunnels, springs, rainfall, streams, or human activities.

The various types of water infrastructure can be classified in terms of the fluid that the infrastructure conveys, treats, or processes. This section provides a brief overview of the components of the various types of water infrastructure.

3.1.1 WATER SYSTEMS

Potable water infrastructure typically consists of the following components:

- Sources
- Reservoirs
- Pipelines (transmission mains and laterals)
- Booster stations
- Treatment systems
- Control valves
- Fire hydrants
- Water meters

Sources can include wells, shafts, or tunnels. Water from sources is pumped directly to transmission mains or reservoirs. Reservoirs or storage tanks are typically constructed of reinforced concrete. The elevations of the reservoirs set the pressure in the water distribution pipelines. The network of transmission mains and laterals conveys the potable water throughout a particular water system. Booster pump stations are used at selected locations in a particular water system to maintain the system pressure, move water from one area to another, such as from Honolulu to Hawaii Kai, and move water to higher

elevations, such as up to Makakilo. For the Honolulu BWS, water treatment systems in the Central O'ahu Watershed consist of disinfection and granular activated carbon (GAC) at selected sources as required. GAC units are used to remove pesticides and herbicides from ground water. A microfiltration water treatment plant owned by the State is used to provide potable water at the Waiawa Correctional Facility. Control valves are used to maintain pressure or flow in a particular section of the water distribution system, redirect flow, or prevent backflow. Fire hydrants provide fire protection for the various land uses. Water meters are used to derive revenues to recover operation and maintenance costs. Water meters also help to monitor water loss. In the Central O'ahu Watershed, potable water infrastructure includes wells, a tunnel, shafts, reservoirs, control valves, booster stations, fire hydrants, water meters, and treatment at selected sources.

3.1.1.1 Honolulu Board of Water Supply Systems

BWS owns, operates, and maintains the largest potable water system in the State. In the Central O'ahu Watershed, it system includes 34 active potable well stations, one non-potable well station, one non-potable spring, two shafts, 56 potable reservoirs, and two non-potable reservoirs. BWS also pumps potable water from the Waiau Tunnel owned by *HECO*. Three additional well stations, Kaonohi Wells II, Waimalu Wells I, and Waimalu Wells II, are currently inactive. Two more well stations, Waipahu Wells III and IV, are planned or in construction but have not been placed on-line yet. One additional shaft ('Ewa Shaft) is planned and has not been placed on-line yet. Granular activated carbon systems are installed at nine active source stations. A total of 84 individual GAC vessels are installed across the nine active source stations. Granular activated carbon systems will be installed at Waipahu Wells III and IV. After Waipahu Wells III and IV are on-line, a total of 102 GAC vessels will be owned and operated by BWS within the Central O'ahu Watershed. BWS also operates and maintains 16 monitoring wells in the Central O'ahu Watershed.

3.1.1.2 State of Hawai'i Systems

The State of Hawai'i owns several wells, a ditch diversion system, and water systems within the Central O'ahu Watershed. According to the *State Water Projects Plan,* the State owns 15 wells in the Central O'ahu Watershed. Four wells are currently unused. Five wells are used for observation or monitoring of aquifers. Two wells are used for irrigation, and another two wells are used to supply potable water to the Waimano Training School and Hospital.

The State owns four water systems within the Central O'ahu Watershed. These systems include the Waiāhole Ditch System, Keaīwa Heiau State Recreation Area Water System, Waiawa Correctional Facility Water System, and Waimano Training School and Hospital Water System. Details on these water systems are given below.

The State also owns a project that diverts water from the Waiāhole Ditch System. This diversion is operated by the State Department of Public Safety (DPS) and feeds the Waiawa Correctional Facility Water System via a pump station.

Waiāhole Ditch System

From 1913 to 1916, the Waiāhole Water Company constructed the Waiāhole Ditch System to harvest impounded dike stream water above Kahana, Waikane, and Waiāhole Valleys for irrigation on leeward O'ahu. Initially, the Waiāhole Ditch System consisted of a 14,339-foot main tunnel through the Ko'olau Mountains and a network of ditches, gates, flumes, siphons, and tunnels on the leeward side of the Ko'olau Mountains.[183] The Waiāhole Ditch System was expanded between 1925 and 1931 with the construction of four additional tunnels (Kahana, Waikane #1, Waikane #2, and Uwau) to a total length of about 25 miles. For about seventy years, the Waiāhole Ditch System supplied about 28 to 33 mgd for irrigation in leeward O'ahu.[184]

The ownership of the Waiāhole Ditch System has changed a few times over the years. Originally, the Waiāhole Ditch System was owned by the Waiāhole Water Company, which was later renamed Waiāhole Irrigation Company. The Waiāhole Water Company was a commercial venture of O'ahu Sugar Company.[185] American Factors (Amfac) purchased Waiāhole Irrigation Company and O'ahu Sugar Company. In 1999, control of the Waiāhole Ditch System was transferred to the State of Hawai'i.[186] The Waiāhole Ditch System is operated by the Agribusiness Development Corporation (ADC) under the State DOA.

The allocation of water via the Waiāhole Ditch System has been hotly debated over the years between windward and leeward interests. The Waiāhole contested case started in 1994 and culminated in a landmark decision by the State of Hawai'i Supreme Court six years later in 2000 and continues to be appealed. The Supreme Court's decision returned 12.0 mgd of unused water to four Windward streams resulting in revised interim instream flow standards for these streams and a lower allocation of water to leeward users. The current allocation to the leeward side is 12.57 mgd, with 9.25 mgd allocated for leeward farms and 3.32 mgd allocated for Waiawa Correction Facility, Mililani Memorial Park, Mililani Golf Course, and Pu'u Makakilo Golf Course and to account for system losses.[187]

The Commission has also set interim instream flow standards for Waiāhole, Waianu, Waikāne, and Kahana Streams. These flow standards are summarized below.[188]

TABLE 3-1
INTERIM INSTREAM FLOW STANDARDS FOR WINDWARD STREAMS

Stream	Interim Instream Flow Standard (mgd)
Waiāhole	8.7
Waianu	3.5
Waikāne	3.5
Kahana	13.3

The Waiāhole Ditch System has been seen as a critical part of the agricultural development on leeward O'ahu. Currently, the Waiāhole Ditch System supplies water to 4,809 acres of diversified agriculture.[189] The Waiāhole Ditch System provides inexpensive, high quality irrigation and drinking water to leeward farms and other users and higher flows to windward streams.

Waiawa Correctional Facility Water System
The Waiawa Correctional Facility Water System is owned and operated by the State DPS. Originally, the Waiawa Correctional Facility was a U.S. Army radio station. In 1985, the State acquired the facility and converted the facility to a prison. The Waiawa Correctional Facility Water System is a water diversion fed from the Waiāhole Ditch System through two intake water lines. The water from the Waiāhole Ditch System is treated with microfiltration membrane systems to potable quality. The Waiawa Correctional Facility Water System consists of the water treatment facility, a 0.33-million gallon (MG) reservoir, booster pump stations, and pipelines.

In addition to the potable water system, the State DPS owns and operates a secondary treated recycled water system at the Waiawa Correctional Facility as a wastewater disposal solution. The non-potable water system provides irrigation water for small-scale farming at the correctional facility. The system consists of a 0.092-MG reservoir and irrigation piping.

Keaīwa Heiau State Recreation Area Water System
The Keaīwa Heiau State Recreation Area Water System in 'Aiea is owned and operated by the State DLNR, Division of State Parks. The park's water system is fed from the BWS water system and consists of a booster station, 0.02-MG reservoir, and distribution pipelines.

Waimano Training School and Hospital Water System
The Waimano Training School and Hospital Water System is owned and operated by the State DOH. The water system is fed by two ground water wells. The system consists of the two ground water wells, chlorination for disinfection, a 0.10-MG concrete reservoir, a

0.60-MG steel reservoir, a 0.10-MG steel reservoir, a booster pump station, and distribution pipelines.

3.1.1.3 Federal Systems

The main Federal facility in the Central O'ahu Watershed is Pearl Harbor, operated by the U.S. Navy. The Navy pumps ground water from the Waiawa, Hālawa, Red Hill, and Barbers Point Shafts. These sources are all potable. In addition, the Navy sells water to Hickam Air Force Base (AFB). The Pearl Harbor Water system serves about 52,326 people.[190] The Navy also has five observation wells within the Central O'ahu Watershed.

The majority of the Navy's water is supplied by Waiawa Shaft. Because of the importance of Waiawa Shaft, the Navy restricts development above the shaft to prevent contamination of its potable water supply.

In addition to the Pearl Harbor water system, the Navy owns three other water systems in the Central O'ahu Watershed: Camp Stover, Naval Magazine Pearl Harbor Waikele Branch, and Barbers Point. Camp Stover is a military housing community located in Central O'ahu south of Wheeler Army Airfield (WAAF). The Camp Stover water system serves about 595 people.[191] From 1942 to 1993, Naval Magazine Pearl Harbor Waikele Branch was used as a weapons storage facility. This facility was decommissioned in 1993, and the water system at the site is inactive. When the water system at Naval Magazine Pearl Harbor Waikele Branch was in use, it served about 25 people.[192] Barbers Point Naval Air Station closed in 1999 and almost 60 percent of the former federal lands was transferred to the State of Hawaii and City and County of Honolulu. The Navy still owns the Barbers Point water system, which serves about 5,256 people.[193]

Another federal facility within the Central O'ahu Watershed is Hickam AFB. The U.S. Air Force (USAF) owns the water system that serves the base. The Hickam AFB water system serves about 7,632 people with water it buys from the Navy's Pearl Harbor water system.[194] The USAF also has 13 observation wells and four unused or sealed wells within the Central O'ahu Watershed.

A portion of Schofield Barracks is in the Central O'ahu Watershed. Schofield Barracks pumps ground water from the Schofield Shaft. The shaft also supplies potable water to WAAF and the Naval Computer and Telecommunications Area Master Station Pacific (NTCAMS PAC) above Whitmore Village. The Schofield Barracks water system serves about 28,057 people.[195] The Army also has five observation wells in the Central O'ahu Watershed.

Other Federal agencies that maintain wells in the Central O'ahu Watershed include the National Oceanographic and Atmospheric Administration (NOAA), U.S. Fish and Wildlife (USFW), U.S. Geological Service (USGS), and U.S. State Department. NOAA has four

observation wells. USFW has one well. USGS has three observation wells and one unused well. The U.S. State Department has one well.

3.1.1.4 Private Systems

The CWRM maintains a database of wells constructed on O'ahu and throughout the state. This well database was reviewed to determine the number of private wells and their uses within the Central O'ahu Watershed.

The Commission's database classifies well use as domestic, industrial, and irrigation. According to the Commission's database, 31 private domestic wells are in the Central O'ahu Watershed. Another 29 private wells are used for industrial purposes. Still another 117 wells are used for irrigation. The Commission's database does not differentiate between agricultural irrigation wells and non-agricultural irrigation wells.

In addition to the various private wells, four private water systems are in the Central O'ahu Watershed. These private water systems are owned and operated by Del Monte Corporation (DMC), Mililani Memorial Park, Kipapa Acres Condominium Property Regime (C.P.R.), and Hawaii Country Club.

The DMC water system serves a population of about 650 people.[196] The system is fed by ground water. DMC uses the water for potable uses, processing, and irrigation. In addition, DMC sells water to farmers and cattle ranchers.

The Mililani Memorial Park system serves a population of about 100 people.[197] The system is fed by surface water from the Waiāhole Ditch. The ditch water is treated by a sand filter before entering a storage tank. After the storage tank, the water is treated by microfiltration and disinfection before entering the memorial park's distribution system. The water is primarily used for landscape irrigation. A small portion of the water is used for potable consumption by the memorial park's employees and funeral guests in the memorial park's dining area.

The Kipapa Acres C.P.R. water system serves a population of about 43 people. [198] The system is fed by a single well. Chlorine is added to the well discharge. The well pumps the water to a 50,000-gallon steel storage tank. A portion of the water from the storage tank is treated by an activated carbon block before entering residences. The carbon block removes contaminants in the well water. The remaining water is delivered to farms, a plant nursery, a chicken ranch, and contractors for irrigation.

The Hawaii Country Club water system serves about 400 people. [199] The system is fed by a single well. The Hawaii Country Club is a golf course in Wahiawā, and water from the well is used primarily for irrigation.

3.1.2 WASTEWATER AND RECYCLED WATER INFRASTRUCTURE

Wastewater generated by human activities is collected by pipelines. The collection pipelines convey the wastewater to treatment plants, where the wastewater is treated to meet Federal and State regulations prior to final disposal. Most wastewater is conveyed to treatment plants by gravity. At selected locations, pump stations are used to transport wastewater in the wastewater collection system. Manholes throughout the wastewater collection system allow for changes in direction of pipelines, flow from multiple pipelines to be combined into a single pipeline, and access to the pipelines for maintenance or repair. Manholes can also be potential locations of spills during storm events or due to clogged lines. In the Central O'ahu Watershed, collection pipelines, manholes, and pump stations are used to convey wastewater to treatment plants.

Most of the Central O'ahu Watershed is sewered and wastewater is collected in pipelines and conveyed to treatment plants. However, the North Road-'Ewa area and Campbell Industrial Park are not sewered. Wastewater in these areas is treated by cesspools and septic tanks.

Wastewater treatment plants (WWTPs) employ multiple levels of treatment prior to discharging treated wastewater effluent to the environment. The different levels of treatment are referred to as pretreatment, primary treatment, secondary treatment, and tertiary treatment. The objective of the different levels of treatment is to reduce the amount of waste (as measured by specific parameters such as suspended solids [SS] and biochemical oxygen demand [BOD]) in the wastewater before discharge to the environment. The different levels of treatment are additive and sequential. Secondary treatment plants will also include pretreatment and primary treatment. Tertiary treatment plants will also include pretreatment, primary treatment, and secondary treatment. Pretreatment removes large solids, such as rags, trash, and grit, and may also be used to condition raw wastewater before primary treatment. Primary treatment removes a portion of the SS and BOD in the wastewater and is typically a mechanical process, namely gravity sedimentation. Scum, oil, and grease are also removed in primary treatment. Secondary treatment removes additional SS and BOD and is usually a biological process, such as activated sludge oxidation or trickling filter. Tertiary treatment further reduces SS and BOD and also reduces nutrients in the wastewater by chemical processes (such as chemical precipitation), mechanical processes (such as sand or membrane filtration), biological processes (such as nitrogen removal), or a combination of these processes. Tertiary treatment is usually associated with the removal of nutrients. Tertiary treatment for the removal of nutrients is not used in the Central O'ahu Watershed. Secondary treatment is used in the Central O'ahu Watershed.

Wastewater and recycled water infrastructure are very similar. Recycled water, also referred to as reuse water, is wastewater that has been treated to a level that allows the use of the water for specific beneficial uses, such as agricultural or landscape irrigation. The

uses, level of treatment, and required treatment processes for recycled water are governed by the State of Hawai'i Department of Health in accordance with HAR 11-62 and the reuse guidelines published by the Wastewater Branch. Recycled water facilities are usually added downstream of secondary treatment plants and can consist of multiple processes, such as coagulation, flocculation, sedimentation, filtration, and disinfection. In the Central O'ahu Watershed, coagulation, flocculation, filtration, and disinfection are used to reclaim wastewater. Storage tanks are used to hold recycled water at the reclamation facility and points of use and pumps and pipelines are used to deliver recycled water to points of use.

3.1.2.1 Honolulu Board of Water Supply

BWS owns the largest recycled water facility in the State. The Honouliuli Water Recycling Facility (HWRF) is located in 'Ewa adjacent to the City's Honouliuli WWTP. BWS contracts a private operations firm to operate and maintain the HWRF.

The HWRF is the result of a 309 consent decree signed by the U.S. EPA, State DOH, and City and County of Honolulu in 1995.[200] The 309 consent decree required the City to develop a recycled water system that would recycle 10 mgd of wastewater by July 2001.[201] Construction on the HWRF was completed in summer 2000.[202] BWS purchased the HWRF from USFilter Operating Services in July 2000, one month prior to the plant's official dedication.[203]

The HWRF treats up to 13 million gallons per day (mgd) of secondary effluent from the Honouliuli WWTP. The HWRF generates two types of recycled water—R-1 water and RO water. The R-1 water is produced by treating secondary effluent with coagulation, flocculation, filtration, and disinfection to meet the R-1 water standards set the State DOH. The RO water is demineralized, high quality water and is produced by treating secondary effluent with microfiltration followed by reverse osmosis (RO) to meet industrial standards. The HWRF can produce up to 10 mgd of R-1 water and 2 mgd of RO water. The R-1 water is used for landscape irrigation at various golf courses, parks, schools, and roadways in the 'Ewa area. The RO water is used by businesses in Campbell Industrial Park for industrial purposes, such as boiler feed water, cooling tower make-up water, and oil refinery process water.

BWS is also evaluating the use of R-1 recycled water from the City's Wahiawā WWTP. The R-1 recycled water is planned to be delivered to the Central O'ahu Regional Park and Waiawa golf courses for irrigation and other potential customers along the Kamehameha Highway pipeline route.[204]

3.1.2.2 City and County of Honolulu

The City's Department of Environmental Services (ENV) owns, operates, and maintains the second largest WWTP on O'ahu. The Honouliuli WWTP is a primary treatment facility

with partial secondary treatment. The secondary treatment facilities were constructed as part of a consent order signed by the State DOH and City in 1993.[205] With secondary treatment in place, the secondary effluent could be recycled. Starting in 1998, about 2 mgd of recycled water was used for in-plant purposes.[206]

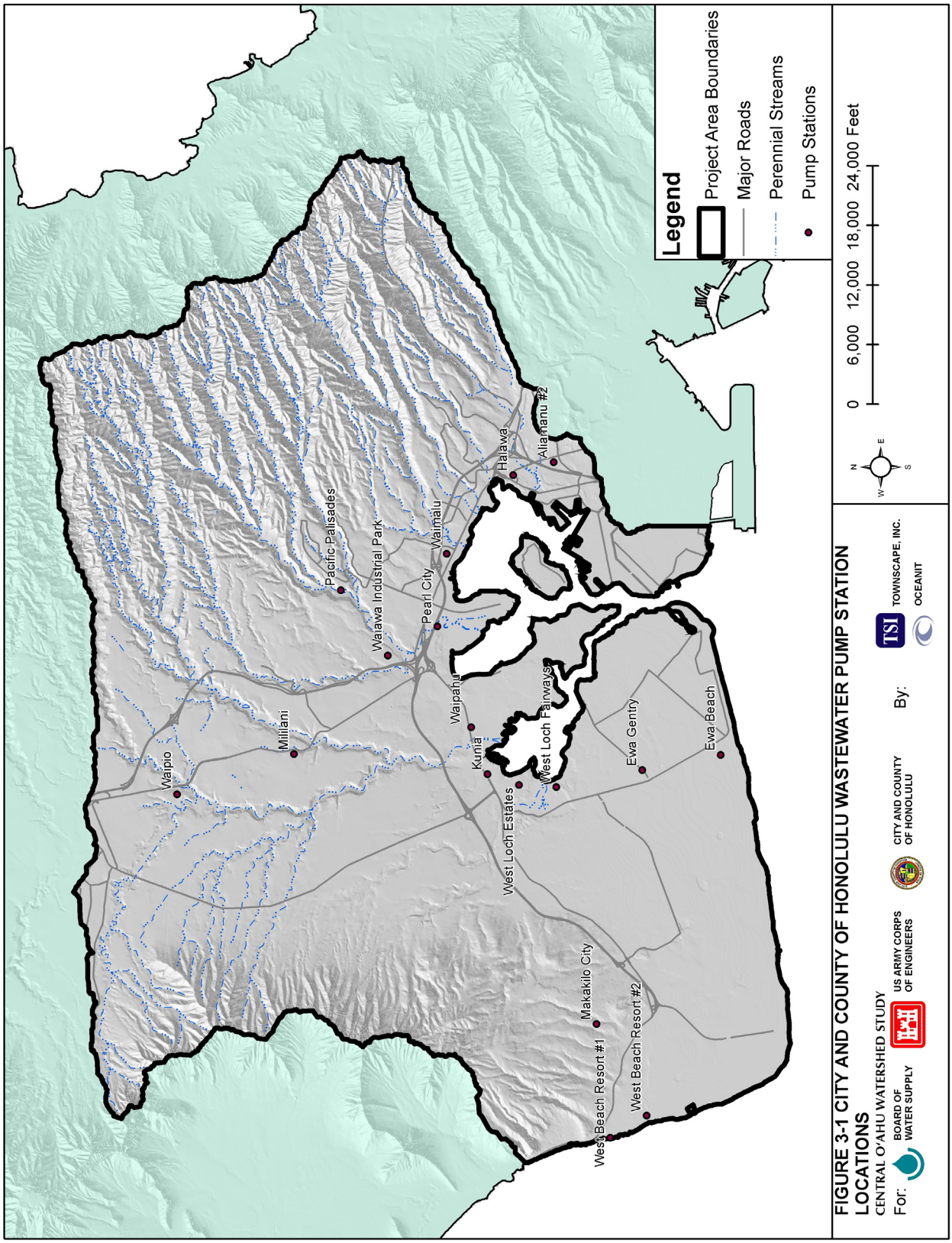
The current capacity of the Honouliuli WWTP is 38 mgd, with 13 mgd treated to the secondary level. The ultimate capacity of the Honouliuli WWTP with future expansion is 51 mgd. The secondary effluent is further processed by the HWRF to generate R-1 water and RO water. The Honouliuli WWTP discharges the remaining effluent (about 20 mgd) to the Barbers Point Ocean Outfall in West Māmala Bay.

The Barbers Point Ocean Outfall was completed in 1979. The outfall discharges effluent about 1.7 miles offshore at a depth of 200 feet. The outfall diffuser is 1,777 feet long located at the end of the outfall pipe. Effluent exits at multiple points along the diffuser, increasing the mixing between the effluent and surrounding ocean water. Ambient currents and the density difference between the effluent and ocean water also contribute to the mixing. This mixing mitigates impacts of the effluent on the discharge area.

The Honouliuli WWTP service area is about 76,000 acres and ranges from "Red Hill along its eastern boundary up to Mililani on its northern boundary and extends to Makakilo City [sic], Honokai Hale, and Ko Olina on its western boundary."[207] The Honouliuli WWTP serves all residential, commercial, and agricultural areas within these boundaries except for Pearl Harbor, Campbell Industrial Park, and small pockets served by cesspools or septic tanks.[208]

In addition to the Honouliuli WWTP, the former Mililani WWTP was another City treatment plant in the Central O'ahu Watershed. The plant discharged secondary effluent to Kipapa Stream. In 1990, the plant was taken out of service to eliminate discharges to Kipapa Stream, and the plant was converted into a pretreatment facility (PTF). A grinder at the Mililani PTF pre-treats the wastewater, which then flows to the Waipahu Wastewater Pump Station and eventually to the Honouliuli WWTP for treatment.

The City ENV also owns, operates, and maintains 17 wastewater pump stations in the Central O'ahu Watershed (see Figure 3-1). The pump stations are equipped with emergency generators in case of a power outage. If the flow into the pump station exceeds the pumping rate, the wastewater will back up in the collection system. Some of the City's pump stations also have holding tanks that can store wastewater for a short period in case the flow into the station exceeds the pumping rate.


Legend
Project Area Boundaries
Major Roads
Perennial Streams
Pump Stations
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Pearl City
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Waipahu
Kunia
West Loch Estates
West Loch Fairways
Halawa
Aliamanu #2
Ewa Gentry
Ewa Beach
Makakilo City
West Beach Resort #1
West Beach Resort #2
FIGURE 3-1 CITY AND COUNTY OF HONOLULU WASTEWATER PUMP STATION LOCATIONS
CENTRAL O'AHU WATERSHED STUDY
For: BOARD OF WATER SUPPLY
US ARMY CORPS OF ENGINEERS
CITY AND COUNTY OF HONOLULU
By:
TSI TOWNSCAPE, INC.
OCEANIT

3.1.2.3 Federal

There are two federal WWTPs are in the Central O'ahu Watershed: the Fort Kamehameha WWTP and the Schofield Barracks WWTP. The U.S. Navy owns, operates, and maintains the Fort Kamehameha WWTP. This plant is located on Navy land adjacent to the Hickam AFB near the entrance to Pearl Harbor. The Fort Kamehameha WWTP is an advanced secondary treatment facility that uses clarifiers, activated sludge tanks, sand filters, and ultraviolet disinfection prior to discharging the effluent to a deep ocean outfall. The plant treats domestic and industrial wastewater. The current capacity of the Fort Kamehameha WWTP is 13 mgd, which is sufficient for all planned developments (Air Force and Navy).[209] Fort Kamehameha WWTP's deep ocean outfall was placed on-line in January 2005. The outfall discharges effluent a quarter mile offshore at a depth of 150 feet.

The Fort Kamehameha WWTP service area includes Camp Smith, McGrew Point housing, and housing up to Peltier Avenue. Radford and Halsey Terrace are not included in the plant's service area. Hickam AFB, Ford Island, Pearl Harbor, and other various Navy activities within the service area boundary contribute wastewater to the plant.

Recycled water is used at the Fort Kamehameha WWTP for in-plant uses, the dissolved air flotation thickener system, and washdown purposes. The high chloride concentration of the recycled water limits its use on-site.[210]

The U.S. Army owns the Schofield Barracks WWTP, but contracts a private firm to operate and maintain the Schofield Barracks WWTP. This plant is located in the southwest corner of WAAF, off of Airdrome Road. The Schofield Barracks WWTP is a recycled water facility that uses equalization basins, screens, clarifiers, membrane bioreactors, and ultraviolet disinfection prior to discharging the effluent to an open ditch that is part of the Dole Foods irrigation system. The Schofield Barracks WWTP NPDES permit allows for bypassing of the effluent to Kahekuna Stream in cases of emergency. The bypass period is restricted to 37 days. The plant treats domestic and industrial wastewater. The current capacity of the plant is 4.2 mgd. The treatment plant's service area includes WAAF and Schofield Barracks.

3.1.3 SPRING WATER

Four springs are in the Central O'ahu Watershed. From East to West, these springs are Kalauao, Waiau, Waiawa, and Waikele. The water from Kalauao Springs is used by BWS and at H-1, Aloha Stadium, and the Honolulu International Airport.[211] Waiau Springs water is used by the Hawaiian Electric Company (HECO) Waiau power plant.[212] The water from Waiawa Springs is used by private farms.[213] Waikele Springs water is used at the Waipi'o Soccer Complex and Makalena Golf Course.[214]

3.1.4 STREAM WATER

Water is diverted from streams for beneficial uses, such as irrigation. The diversion structure usually consists of an intake connected to a channel, ditch, or pump station. According to the records of the Commission on Water Resource Management, twenty-one stream diversions are located in the Central O'ahu Watershed. All the stream diversions are private. The Commission includes diversions from springs, unnamed streams, and an unnamed drainage canal in its records for stream diversions.

The following streams have diversions: Hālawa, Waiawa, Kapakahi, Waikakalaua, Waikele, and Kīpapa. In addition, Waiau Springs has a diversion. Two unnamed streams, an unnamed spring, an unnamed drainage canal, and an unnamed tributary to Punalu'u Stream also have diversions.

3.1.5 BRACKISH WATER

Brackish ground water is available under the 'Ewa plain in the 'Ewa Caprock and withdrawal is permitted through the State CWRM. Brackish water infrastructure usually consists of wells, pumps, and pipelines to convey the water. In the Central O'ahu Watershed, brackish water wells have historically been used for industrial and agricultural purposes.

3.1.6 SEAWATER

Seawater infrastructure is currently used within the Central O'ahu Watershed. The Hawaiian Electric Company (HECO) uses seawater at its Kahe and Waiau plants for condenser cooling.[215] In addition, the Honolulu BWS is designing a seawater desalination plant in Kalaeloa and deep seawater wells in Ko Olina for district cooling.

3.1.7 STORM WATER

The runoff generated from storm events is collected in a network of channels, pipelines, culverts, catch basins, and manholes. In the Central O'ahu Watershed, this infrastructure conveys storm water to streams, gullies, and gulches, which then convey storm water to the ocean.

The major owners and operators of storm drainage systems within the Central O'ahu Watershed are the City ENV and State Department of Transportation (DOT), Highways Division. The City maintains public storm drainage systems within the Central O'ahu watersheds. The vast storm drainage systems are associated with private, State, and Federal lands. Both agencies regulate non-point and point source discharges to their drainage systems, including discharges from construction activities. Streams and near shore waters have benefited from the efforts of the State and City to curtail illicit discharges and connections to their storm drainage systems.

3.2 TYPES OF USES

The uses of the various types of water are diverse. Potable water is used for human consumption, landscape and agricultural irrigation, washing, and cleaning. Potable water is also used in certain industrial processes. Raw wastewater is not used as a resource. However, R-1 recycled water is used primarily for landscape irrigation and RO recycled water is used for industrial processes, such as boiler water or cooling water. A 309 consent decree requires the City to use 10 mgd of recycled water.[216] Stream water is used primarily for irrigation. Brackish water is also used for irrigation. Seawater is used for condenser cooling, and BWS is planning to desalinate seawater for potable use and to use seawater for district cooling. Storm water is not currently used as a resource.

3.3 CONDITION OF WATER FACILITIES

The condition of water facilities depends on several factors, including age of the system components, soil characteristics, high system pressure, corrosion, and an effective preventative maintenance program. With an effective preventative maintenance program consisting of corrosion protection, leak detection, and pipeline repair and replacement, the deterioration of system components can be alleviated; and the useful lifespan of the components can be extended.

BWS expends about $10 million per year to repair and replace pipes.[217] This maintenance program has resulted in a stable number of main breaks of less than 400 per year for 2,000 miles of pipe and an average water loss in the BWS distribution system of about 13%.[218] The national average for pipe system water loss is 10%.[219] The BWS goal for pipe system water loss is to match or be lower than the national average.[220]

The condition of water facilities is also periodically evaluated via sanitary surveys. A sanitary survey is a physical and administrative inspection of a public water system's facilities and operations. Periodic sanitary surveys of public water systems of certain sizes are mandated by Federal regulation. A sanitary survey of some of the BWS facilities in the Central O'ahu Watershed was conducted between 2004 and 2005. A separate sanitary survey that covers additional facilities in the Central O'ahu Watershed was completed in 2006. Because of security concerns, the results of the surveys are restricted to BWS and State DOH.

3.4 WATER WITHDRAWAL, TRANSMISSION, AND USE

The Central O'ahu Watershed Study Area has diverse and significant water demands due its large geographic area and population. The Watershed comprises one-third of Oahu's land mass and about one-third of Oahu's total population. The largest Aquifer Sector Area in terms of sustainable yield, Pearl Harbor, and the largest military installation on O'ahu, Pearl Harbor Naval Shipyard, is within the Watershed boundaries. The water needs in the

Central O'ahu Watershed include domestic, industrial, and irrigation (agricultural and non-agricultural) uses.

3.4.1 EXISTING WATER SUPPLY

Water use permit data and historical withdrawal data were analyzed to determine the available water allocations and consumption within the Central O'ahu Watershed. CWRM's permit index dated October 20, 2005, was used to analyze the permitted use according to aquifer system and type of ownership. Allocations to the Waiāhole Ditch System are addressed in Section 3.4.3.1. Withdrawal data provided by CWRM and BWS was used to estimate consumption.

Water use permits have been issued for a total of about 178 mgd within the Central O'ahu Watershed. This amount includes water use permits for withdrawals from the 'Ewa caprock and sources in the Wahiawā Aquifer System Area that are within the Watershed boundary. Only a portion of the Wahiawā Aquifer System Area is within the Watershed boundary.

The primary source of water in the Central O'ahu Watershed is the Waipahu-Waiawa Aquifer System Area. As shown in Figure 3-2, roughly half of all water use permits in the Central O'ahu Watershed have been issued for this Aquifer System Area. A little over a quarter of the water use permits in the Watershed have been issued for the Waimalu Aquifer System Area. The 'Ewa-Kunia Aquifer System Area has almost 9% of the water use permits in the Watershed. Almost 6% of the water use permits in the Watershed have been issued for the Wahiawā Aquifer System Area. The 'Ewa Caprock Aquifer System Areas (Kapolei, Malakole, and Pu'uloa) have over one-tenth of the water use permits in the Watershed.

The average annual pumpage within the Central O'ahu Watershed is significantly less than the total permitted use and the sustainable yield. For calendar year 2004, the average pumpage within the Watershed was a little over 113 mgd, including pumpage from the 'Ewa Caprock Aquifer System Areas. This average pumpage was about 64 mgd less than the current total permitted use. Without the 'Ewa Caprock pumpage, the average annual pumpage in 2004 was 82 mgd less than the current sustainable yield. A comparison of the average pumpage, permitted use, and sustainable yield is shown in Table 3-2.

FIGURE 3-2
PERMITTED USE BY AQUIFER SYSTEM AREA

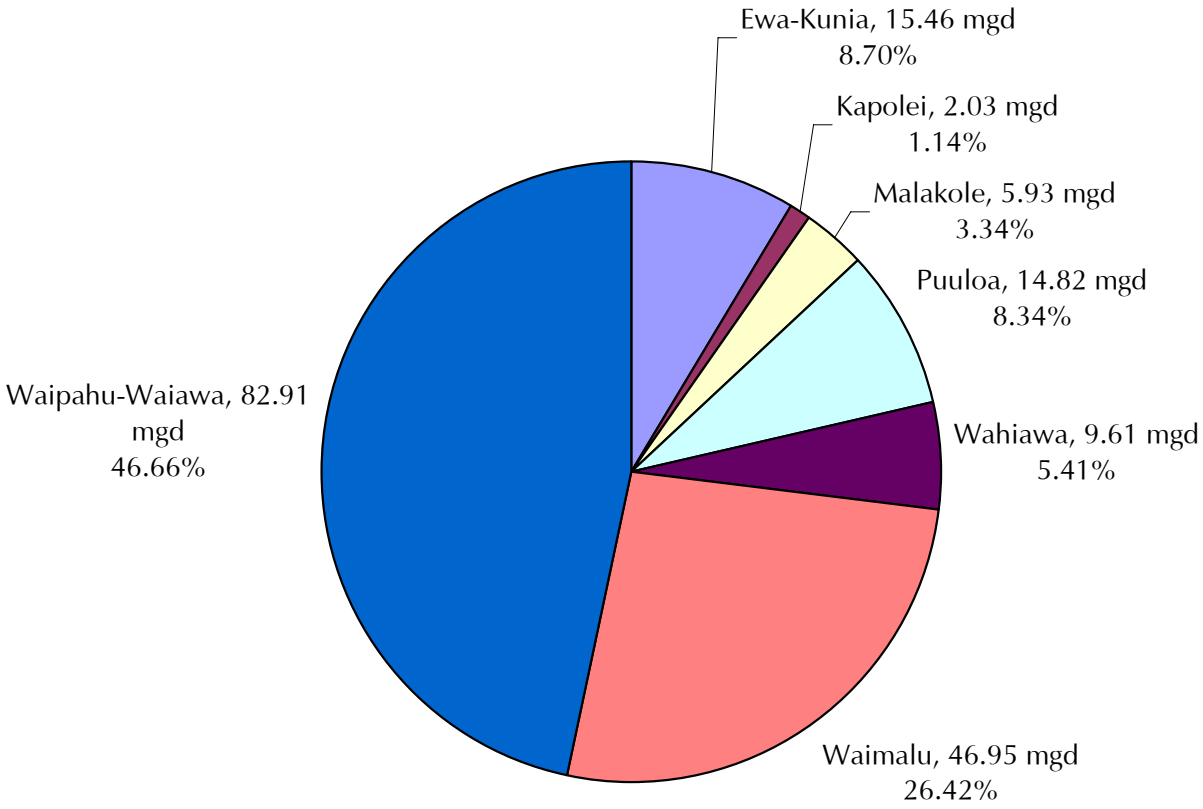


TABLE 3-2
ESTIMATED PUMPAGE VS. PERMITTED USE AND SUSTAINABLE YIELD

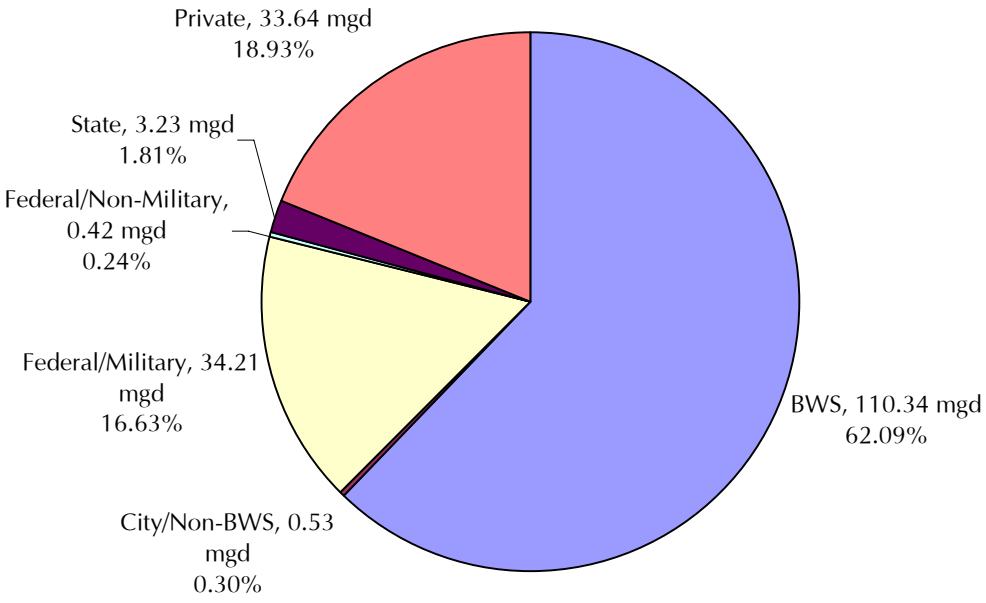
Aquifer System Area	2004 Pumpage (mgd)[p]	Permitted Use (mgd)	Sustainable Yield (mgd)
ʻEwa-Kunia	10.61	15.46	16
Kapolei	0.34	2.03	N/A
Malakole	3.61	5.93	N/A
Puʻuloa	3.43	14.82	N/A
Wahiawā	5.71	9.61	23[q]
Waimalu	43.14	46.95	45
Waipahu-Waiawa	46.53	82.91	104
Total	**113.37**	**177.71**	**188**

[p] Pumpage estimated from BWS and CWRM records.

[q] Total SY shown. Only a portion of the Wahiawā aquifer system area is within the watershed. 10.78 mgd of water use permits are not within the watershed.

In terms of permitted use, the Honolulu BWS is the single largest entity within the Central O'ahu Watershed. Slightly over 60% of the permitted use in the Central O'ahu Watershed has been allocated to BWS, as shown in Figure 3-3. Private systems comprise the second largest permitted use with almost 19% of the total permitted use. The military has the next largest permitted use allocation at just under 17%. City (non-BWS), non-military Federal systems, and State systems round out the remaining permitted use allocations in the Central O'ahu Watershed.

FIGURE 3-3
PERMITTED USE BY TYPE OF OWNER



The permitted use allocations are all less than the sustainable yields for the corresponding Aquifer System Areas in the Central O'ahu Watershed, except for the permitted use allocations for the Waimalu Aquifer System Area. The total permitted use allocations for the Waimalu Aquifer System Area exceed the sustainable yield by 1.951 mgd (see Table 3-3).

TABLE 3-3
PERMITTED USE WITHOUT WAIĀHOLE DITCH ALLOCATIONS

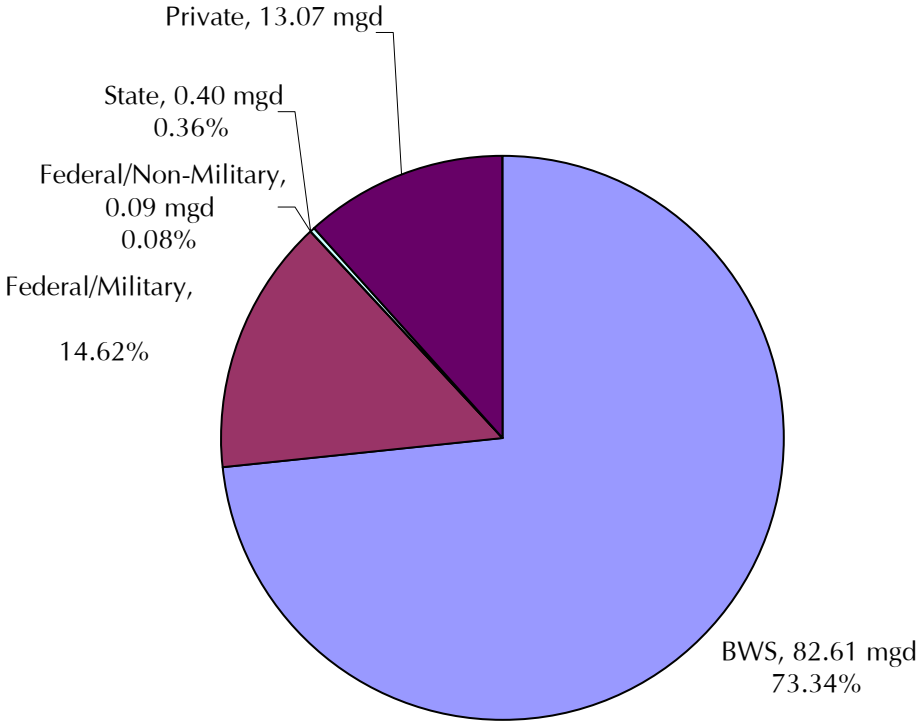
Aquifer System Area	BWS (mgd)	City/ Non-BWS (mgd)	Federal/ Military (mgd)	Federal/ Non-Military (mgd)	State (mgd)	Private (mgd)	Total (mgd)	SY (mgd)	Available Allocation (mgd)
'Ewa-Kunia	9.72	0.00	2.34	0.00	0.50	2.90	15.46	16	0.543
Kapolei	0.00	0.00	0.00	0.00	0.73	1.30	2.03	N/A[r]	N/A
Malakole	0.00	0.00	0.00	0.00	0.50	5.43	5.93	N/A	N/A
Pu'uloa	0.00	0.53	5.89	0.24	0.00	8.16	14.82	N/A	N/A
Wahiawā	0.00	0.00	5.65	0.00	0.00	3.96	9.61	23	N/A[s]
Waimalu	45.53	0.00	0.70	0.00	0.14	0.59	46.95	45	-1.951
Waipahu-Waiawa	55.09	0.00	14.98	0.18	1.36	11.30	82.91	104	21.091
Total	**110.34**	**0.53**	**29.56**	**0.42**	**3.23**	**33.64**	**177.71**	**188**	**46.416**

In terms of pumpage, the Honolulu BWS is the single largest entity within the Central O'ahu Watershed. For 2004, BWS pumped about 74% of the total withdrawals within the Watershed, as shown in Figure 3-4. The military had the next largest withdrawals at just under 15%. Private systems pumped about 12% of the total withdrawals. Non-military Federal systems and State systems round out the remaining pumpage in the Central O'ahu Watershed.

[r] Kapolei, Malakole, and Pu'uloa aquifer system areas comprise the 'Ewa caprock aquifer, which does not have a sustainable yield.

[s] Available allocation not shown. Only a portion of the Wahiawā aquifer system area is within the watershed. 10.78 mgd of water use permits are not within the watershed.

FIGURE 3-4
2004 ESTIMATED PUMPAGE BY TYPE OF OWNER

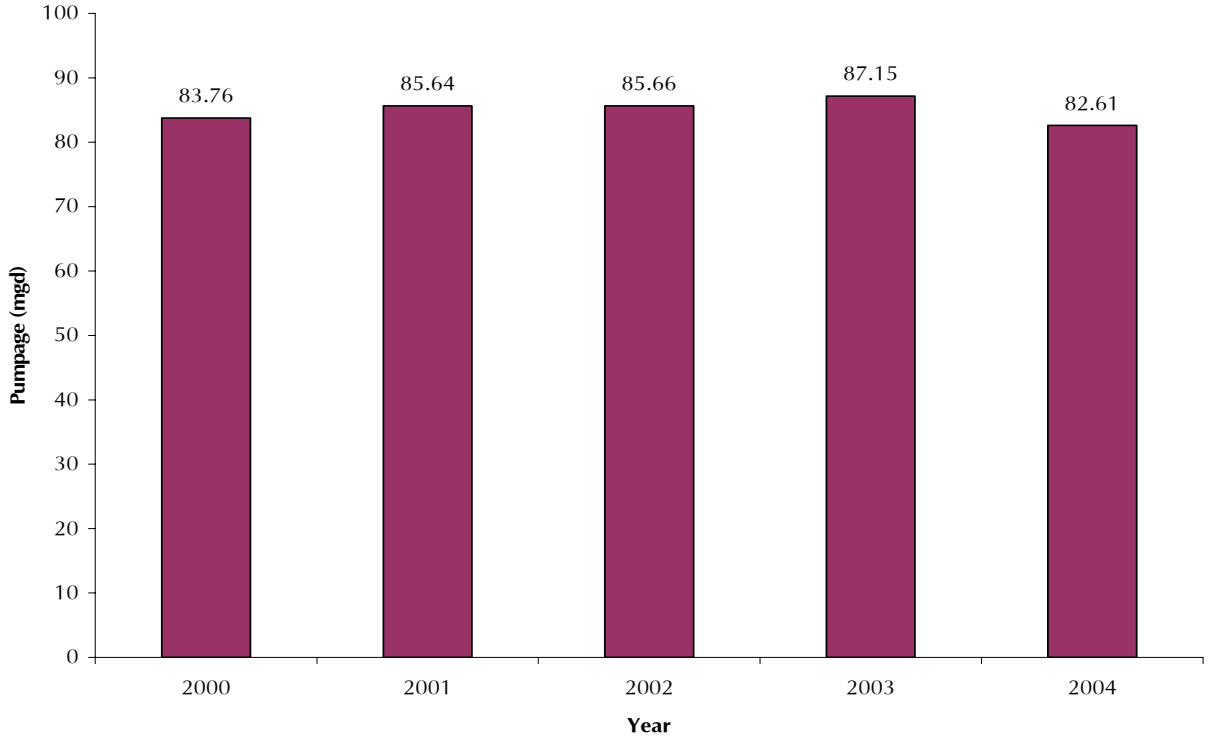


3.4.2 HONOLULU BOARD OF WATER SUPPLY SYSTEMS

BWS provided data on the daily average pumpage from 36 sources, including 34 well stations and two shafts, within the Central O'ahu Watershed. The data spanned the years 2000 to 2004.

The daily average pumpage of the sources were combined to obtain the total daily average pumpage for a particular year. Based on BWS data, the daily average pumpage for all sources in 2000 was 83.76 mgd. The total daily average pumpage rose 1.88 mgd (about 2%) in 2001 up to 85.64 mgd. In 2002, the total daily average pumpage increased marginally (less than 1%), up to 85.66 mgd. The total daily average pumpage increased again (almost 2%) in 2003 to 87.15 mgd. In 2004, the total daily average pumpage decreased 4.54 mgd (slightly over 5%) to 82.61 mgd. A chart showing the total daily average pumpage for years 2000 to 2004 is given in Figure 3-5.

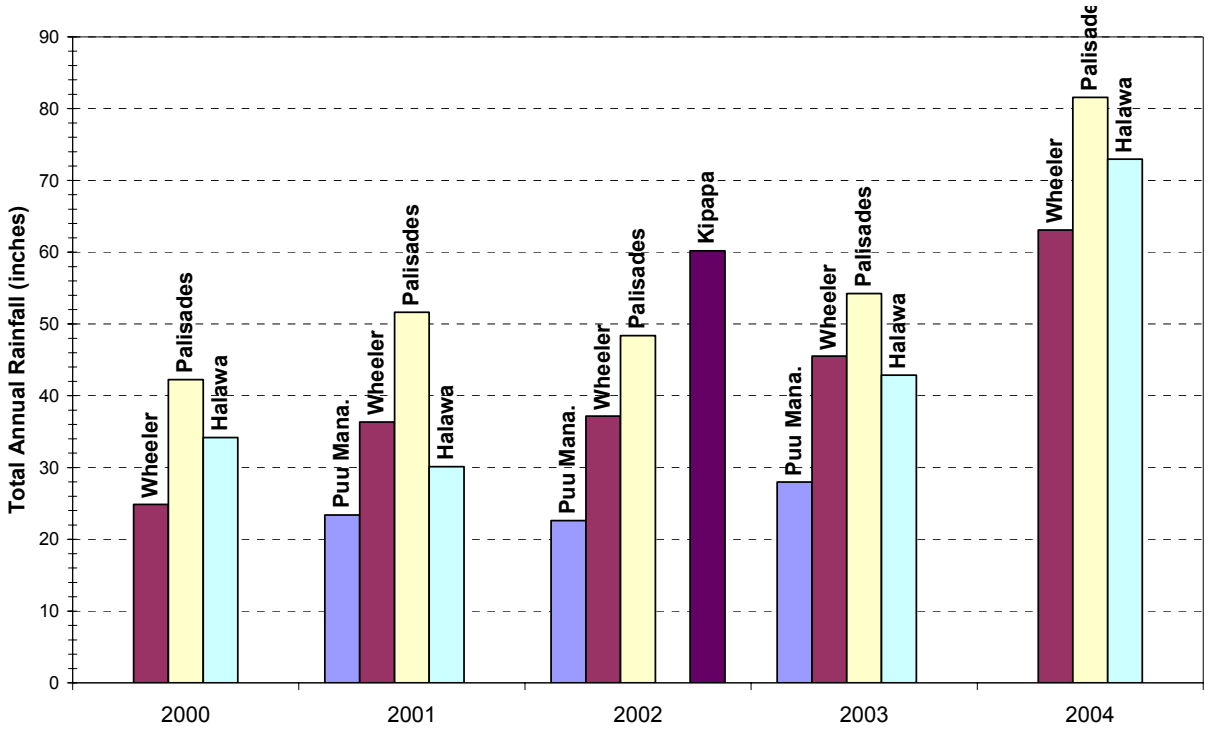
FIGURE 3-5
CENTRAL O'AHU WATERSHED
BWS DAILY AVERAGE PUMPAGE
(SOURCE: HONOLULU BOARD OF WATER SUPPLY)



The decrease in the 2004 pumpage can be attributed to increased rainfall, as shown in Figure 3-6. The total rainfall data for five active rain gage stations in the Central O'ahu Watershed were analyzed from 2000 to 2004. The rainfall data were obtained from the National Weather Service (NWS). If data are not shown in Figure 3-6 for a rainfall gage during a particular year, the data were unavailable from NWS. In addition, rainfall data were unavailable in the 'Ewa/Kapolei area for the listed time periods. 'Ewa golf courses may have rain gages but that data were unavailable from NWS. As shown in Figure 3-6, the years 2000 to 2003 were significantly drier than the year 2004.

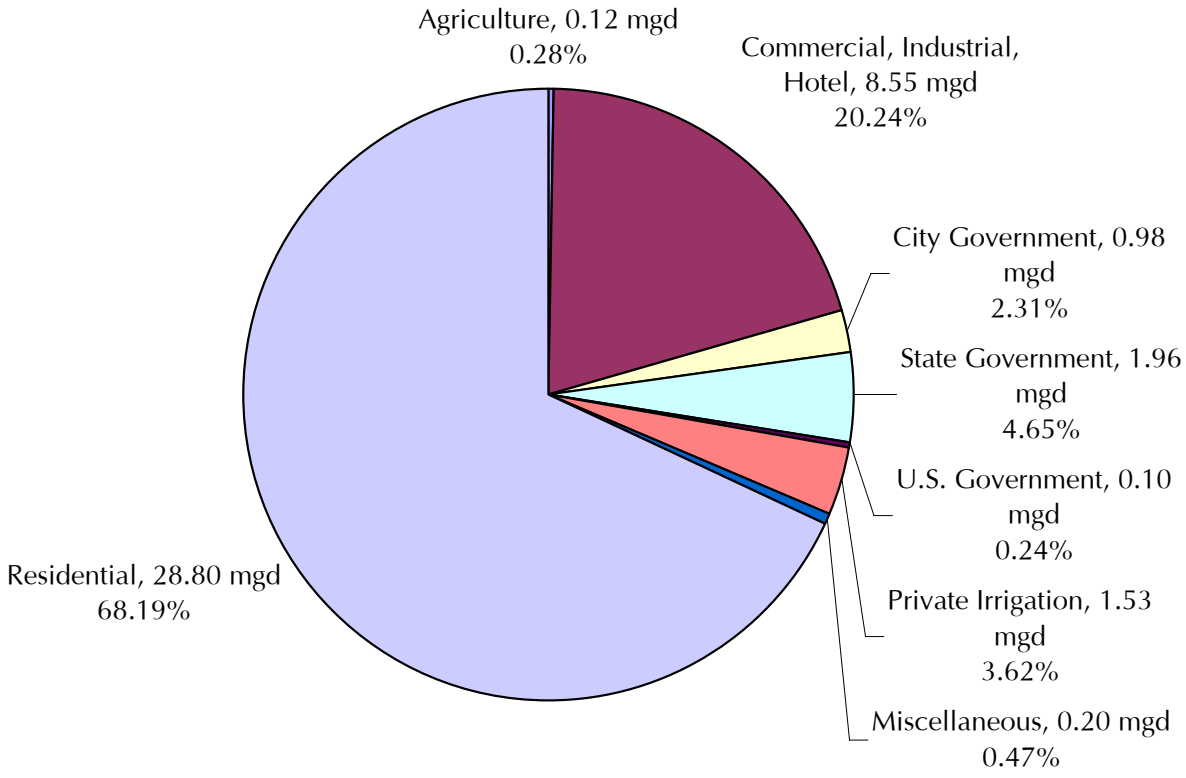
The Pearl Harbor Aquifer Sector provides water as far east as Hawai'i Kai (about 39 mgd) and westward to Wai'anae (5 mgd). Trends in deep monitoring well data show that pumping levels in Nu'uanu, Kalihi, and Waimalu need to be reduced. Therefore, BWS plans to redirect new sources in the Waipahu-Waiawa Aquifer System Area eastward. A significant portion of new sources will not be directed toward new growth, but to replace existing demands to accommodate newly determined sustainable pumping levels.

FIGURE 3-6
ANNUAL RAINFALL IN THE CENTRAL O'AHU WATERSHED



In addition to the pumpage data, BWS provided consumption data according to sector or type of land use, such as residential, commercial, and agriculture uses, based on water meter records. For 2004, the largest sector was residential use, with 28.8 mgd or almost 70% of the total consumption in the Watershed (see Figure 3-7). Commercial and industrial users plus hotels are the next largest water users, comprising slightly over 20% of the total consumption. The other land uses comprise less than 12% of the total consumption.

FIGURE 3-7
CY2004 CONSUMPTION BY SECTOR



According to data provided by BWS, the top 10 users of potable water in the Central O'ahu Watershed include seven private users and three government users. The seven private users include Chevron USA, Inc., Hawaiian Electric Company (HECO)—Waiau, Inc., Ko Olina Community Association, Marriott Ihilani Resort and Spa, Crosspointe Community Association, Honolulu Resource Recovery Venture (HRRV/H-Power), and HECO—Kahe. The three government users include the City's Department of Parks and Recreation, the State Hālawa Correctional Medium Facility, and the Office of Business Services, which is an office in the State Department of Education. The following Table 3-4 ranks the top 10 potable water users according to daily average consumption.

TABLE 3-4
BWS TOP 10 POTABLE WATER USERS (2004)

Rank	Business Name	Daily Average Consumption (mgd)
1	Chevron USA, Inc	1.29
2	Hawaiian Electric Company, Inc.—Waiau	0.46
3	Ko Olina Community Association	0.34
4	Honolulu Department of Parks and Recreation	0.33
5	Hālawa Correctional Medium Facility	0.31
6	Marriott Ihilani Resort and Spa	0.31
7	Crosspointe Community Association (CCA)	0.30
8	Honolulu Resource Recovery Venture (HRRV/H-Power)	0.28
9	Office Business Services	0.24
10	Hawaiian Electric Company–Kahe	0.23

The top three potable water users were contacted to determine their potable water use. Chevron uses potable water for domestic purposes, including drinking and sanitation; for cooling of equipment; and for backup fire suppression.[221] Chevron also uses about 350,000 gpd of RO recycled water from the HWRF. HECO uses potable water at the Waiau power plant for drinking and sanitation.[222] HECO is currently designing infrastructure at its Kahe power plant to use RO water instead of potable water. The Ko Olina Community Association uses potable water for its beach restrooms and showers and for a temporary office facility.[223] Ko Olina already has a brackish non-potable water system for irrigation.

3.4.3 STATE SYSTEMS

3.4.3.1 Waiāhole Ditch System

The Waiāhole Ditch System receives water from the Kahana tunnel, Waikane #1 tunnel, Waikane #2 tunnel, Uwau tunnel, North Portal tunnel, and Main Tunnel in Waiawa Valley. The Kahana Tunnel and intakes formerly produced 4 mgd.[224] Some intakes have become plugged with stream sediment.[225] According to the 2003 *State Water Projects Plan*, the capacities of the tunnels were estimated to be 1.1 mgd for the Kahana tunnel, 4.2 mgd for the Waikane #1 tunnel, 1.1 mgd for the Waikane #2 tunnel, 13.5 mgd for the Uwau tunnel, 1.3 mgd for the tunnel to the North Portal, and the 3.7 mgd for the Main tunnel.[226] The 2003 *State Water Projects Plan* estimated the flow of the Waiāhole Ditch System at 27 mgd.[227] The current allocation as of July 2006 to the leeward side of O'ahu is 12.57 mgd.[228] The system provides 9.25 mgd for agricultural irrigation in leeward O'ahu.[229] The system also provides water to the Waiawa Correctional Facility (0.15 mgd) for potable and non-potable uses and irrigation to the Mililani Memorial Park (0.14 mgd),

Mililani Golf Course (0.25 mgd), and Pu'u Makakilo Golf Course (0.75 mgd).[230] In addition, 2.03 mgd has been allocated to the Agribusiness Development Corporation to account for system losses.[231]

3.4.3.2 Keaīwa Heiau State Recreation Area Water System

The Keaīwa Heiau State Recreation Area Water System provides potable water to various park facilities. The system is metered. In 2003, the metered consumption was about 0.002 mgd.[232]

3.4.3.3 Waiawa Correctional Facility Water System

The Waiāhole Ditch System provides potable water to the Waiawa Correctional Facility. The diversion system at the correctional facility has a design capacity of 0.05 mgd, but the permitted allocation from the ditch system is 0.15 mgd.[233] In 2003, the existing inmate population was 134 inmates, which resulted in an average daily demand and a maximum daily demand of about 0.02 mgd and 0.03 mgd, respectively.[234] Since then, the prison population has increased to its maximum of 334 inmates.[235] This increase in the prison population is expected to increase the average daily demand and maximum daily demand to 0.075 mgd and 0.11 mgd, respectively.[236]

3.4.3.4 Waimano Training School and Hospital Water System

The water system currently provides potable water to the Waimano Training School and Hospital, DOH laboratory facilities, Pearl City Cultural Center Training Academy, Waiawa Correctional Facility, and private users. The two well pumps that feed the water system each have a pumping capacity of 0.58 mgd.[237] According to the 2003 *State Water Projects Plan*, the safe source capacity for the wells is 0.39 mgd; but the wells have a combined permitted allocation of 0.136 mgd.[238] In 2003, the pumpage estimated consumption for the water system was 0.133 mgd.[239] Historical pumpage data were only available for one of the wells. In 2004, the pumpage from one of the wells was about 0.08 mgd. An additional facility is planned for the water system. This additional facility is expected to increase the maximum daily demand of the water system to 0.207 mgd.[240]

3.4.4 FEDERAL SYSTEMS

In the Central O'ahu Watershed, Federal agencies that either consume water or have been allocated a permitted use include the Navy, Army, USAF, USFW, and NOAA. The largest Federal potable water user is the Navy. The Navy's total permitted water use allocation is 23.90 mgd. As of 2004, the Navy's pumpage reported to CWRM was 12.65 mgd. The Navy also sells potable water to Hickam AFB, which uses an average of about 2.2 mgd.[241] The second largest Federal potable water user is the Army. The Army's total permitted use is 5.68 mgd from the Schofield Shaft. However, the Army's actual pumpage in 2004 was about 3.82 mgd. The USFWS owns two wells in the Central O'ahu Watershed Study area that have a combined permitted use of 0.396 mgd. Limited or no pumpage data were

available for these wells. NOAA owns a single well with a permitted use of 0.023 mgd. NOAA's well is classified as irrigation by CWRM. No pumpage data were available for NOAA's well.

3.4.5 PRIVATE SYSTEMS

Data on private wells and stream diversions were obtained from CWRM. Data on private water systems were obtained from CWRM and the water system owners. The permitted uses for a particular type of well had to be estimated. Only partial information was available on the stream diversions. The private water systems included: DMC, Mililani Memorial Park, Kīpapa Acres C.P.R., and Hawai'i Country Club.

Various permitted use volumes for private wells in the Central O'ahu Watershed was estimated based on the well use classification in the CWRM well database, the well owner's name, and well name. The data showed that the predominant permitted use for private wells is agricultural irrigation. About 15.77 mgd or 46.88% of the total private permitted use is likely allocated to agricultural irrigation. The next largest permitted use is for golf course irrigation (7.37 mgd or 21.91%). Industrial wells have a total permitted use of 5.60 mgd (16.64%). Landscape irrigation (other than for golf courses) comprises 4.77 mgd (14.17%) of the total private permitted use. The remaining 0.14 mgd (0.40%) of the total permitted use is allocated to domestic purposes.

The DMC water system is fed by wells. Pumpage data for the DMC water system was obtained from CWRM. In 2004, the average pumpage for the DMC water system was about 1.9 mgd, almost half of the permitted use.

The Mililani Memorial Park water system is fed by the Waiāhole Ditch System. A portion of the ditch water is treated for potable use at the park; the remaining ditch water is used for irrigation. The average potable consumption is 3,500 to 5,000 gpd.[242] In the winter, the average irrigation consumption is about 70,000 gpd.[243] In the summer, the average irrigation consumption ranges from 135,000 to 140,000 gpd.[244] The park's allocation from the Waiāhole Ditch System is limited to 0.14 mgd.

The Kīpapa Acres C.P.R. water system is fed by a well. A portion of the well water is treated for potable use by residences; the remaining well water is used for irrigation. The average potable consumption is about 4,000 gpd, and the average irrigation consumption is about 30,000 gpd.[245] The consumption for this water system is significantly less than its permitted use of 0.1 mgd.

The Hawaii County Club water system is also fed by a well. A portion of the well water is treated for potable use; the remaining well water is used for irrigation. In 2004, the average pumpage for the water system was 0.25 mgd. Typically, about 75% of the well

water is used for irrigation.[246] The pumpage for this water system is about 62% of its permitted use of 0.4 mgd.

There are twenty-one stream diversions are in the Central O'ahu Watershed, all of which are private. The Commission on Water Resource Management has information on the declared water use for only some of the diversions. The declared water use, in million gallons per year (mgy) for the diversions is summarized below.

TABLE 3-5
DECLARED WATER USE FOR DIVERSIONS

Diversion	Declared Water Use (mgy)
Waiawa	7.2
Kapakahi	26.28
Unnamed Drainage Channel	80.3
Waikakalaua	0.5
Waikele	1,716.08
Kīpapa	7.2
Kipapa East Branch	0.144

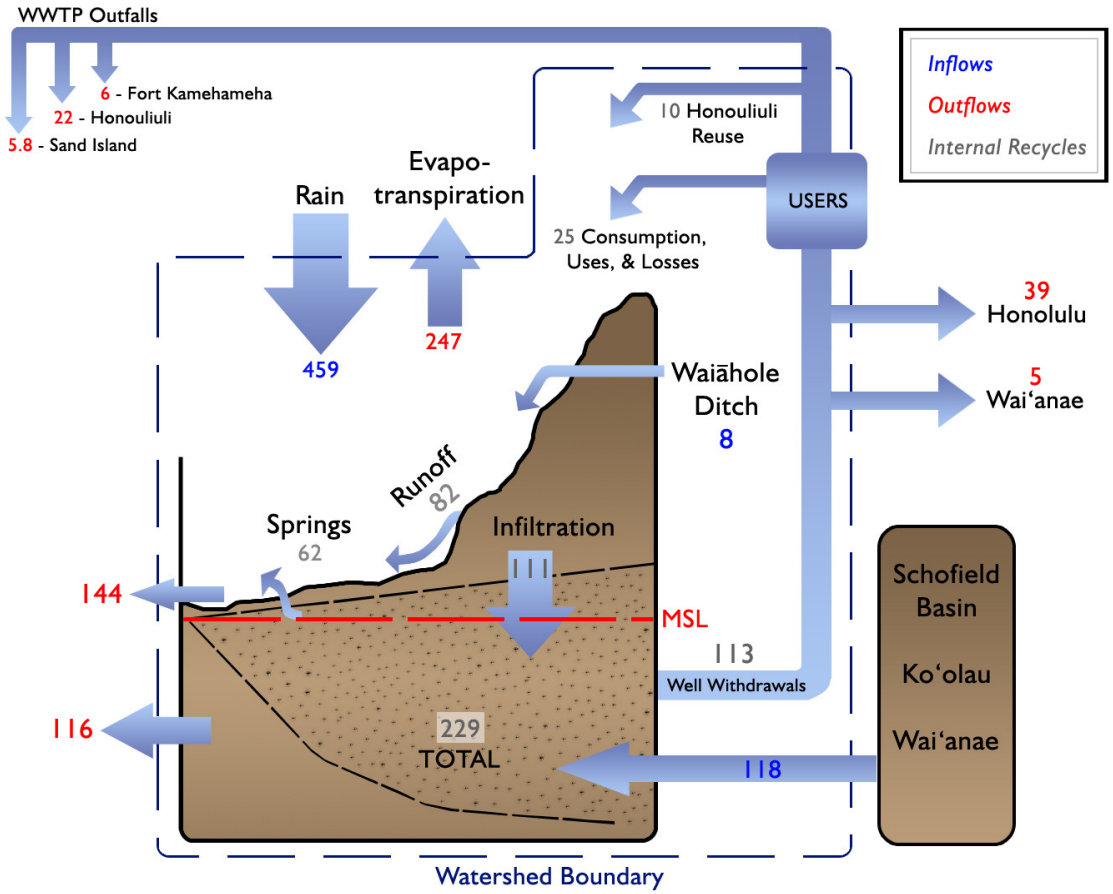
3.4.6 BALANCED WATER BUDGET

The value of a water budget is that it provides a simplified view of the inputs to, internal recycles, and outputs from the system enabling a better understanding of the operation as a whole. The balanced water budget shown in Figure 3-8 treats the Central O'ahu Watershed as if it existed in a sealed box and as if all flows that enter and leave the box and flows from one place to another within the box can be measured. The water budget assumes that ground water storage neither increased nor decreased, with the balance of the unaccounted flow entering the ocean as ground water. The water budget assumes that the total inflows and outflows are equal over the long term. However, at any given moment, the inflows and outflows are not in balance. In addition, the inflows and outflows change over time due to variability in climate, geography, and consumption behaviors. One of the very real challenges of ground water resource managers is to understand and interpret these variations to ensure that withdrawals do not exceed the capacity of the watershed to replenish itself. The sources for the values in Figure 3-8 are listed in Table 3-6. The sources and probable ranges for the values given in Figure 3-8 are described in the paragraphs below.

The values given in this section should not be considered fixed. These values are estimates based on averages, and hence, should not be used for short-term or long-term planning for water use. For example, rainfall is not constant in intensity or coverage, and

runoff is not fully measured. The actual values are variable and affected by a number of factors and will change seasonally, geographically, and temporally.

FIGURE 3-8
CENTRAL O'AHU WATERSHED WATER BUDGET



ALL Numbers are estimated flows in MGD.

3.4.6.1 Inflows to the Central O'ahu Watershed

Rainfall estimates are derived from USGS average rainfall isohyets figures initially developed by Giambelluca[247]. Using a GIS map database, the watershed was divided into sub-watershed basins. The area was computed within each sub-basin covered by an area of equal annual rainfall and multiplied by the rainfall in that area and divided by 365 days per year to yield the total flow in million gallons per day in each sub-basin. Totaling all of the sub-basins yielded 459 mgd in average daily rainfall. Daily variation in this figure can obviously range from zero (on any day with no rain) to several hundred times this average value during intense storms. On an annual basis, it is not unusual for rainfall to vary by more than 20% from this mean.

Honouliuli R-1 reuse or recycled water is an internal recycling of water that results from diversion and advanced treatment of typically 7 to 12 mgd[248] of Honouliuli WWTP influent for water reuse primarily on 'Ewa Plain golf courses. Demand, and therefore production, of this water varies inversely with rainfall on a daily to weekly basis but maintains a fairly constant annual average of 10 mgd[249]. If this water were not reused and recycled to the system it would add to the 22 mgd[250] effluent to the ocean through the Honouliuli WWTP ocean outfall.

TABLE 3-6
CENTRAL O'AHU WATERSHED GROSS WATER BALANCE

	Inflow (mgd)	Outflows (mgd)	Source
Rainfall	459		State isohyet data (Giambelluca, et al 1986)
Evapotranspiration		247	Interpolated evaporation data (Ekern and Chang 1985)
Runoff		82	Calculated based on Shade & Nichols 1996
Springs		62	Calculated based on Oki 2005
Groundwater from Schofield Basin, Ko'olau, Wai'anae	118		Oki 2005
Well Withdrawals (113 MGD)			BWS and CWRM pumpage records CY2004
Fort Kamehameha WWTP		6	WWTP flow records (Iha 2006 and 2007)
Honouliuli WWTP		22	WWTP flow records (Armas 2006 and 2007)
Sand Island WWTP		5.8	Pump station flow records (Piepgrass 2006 and 2007)
Consumption, Uses, & Losses	25	25	Calculated
BWS export to Honolulu		39	BWS pump records (Lao 2006)
BWS export to Wai'anae		5	BWS pump records (Lao 2006)
Honouliuli R-1 Reuse	10	10	WWTP flow records (Armas 2006 and 2007)
Waiāhole Ditch	8		CWRM records 2003
Groundwater to Ocean		116	Calculated
Total	**620**	**620**	Calculated

The flow from the Waiāhole Ditch presently averages about 8 mgd[251], down from two to three times this quantity when sugarcane was in full production. This input should remain fairly constant on a daily basis with long-term variation likely to be more a function of social and political considerations.

The Central O'ahu Watershed boundary overlaps the subsurface aquifers and thereby necessitates contributory flows from the Schofield Basin, Ko'olau, and Wai'anae aquifers to the aquifers within Central O'ahu Watershed. The quantity of subsurface water inflow from adjacent groundwater aquifers is a function of the artificial boundary alignment

between the aquifers, between watersheds, and between calculations from different hydrologists. Shade and Nichols estimated total inflows from the Schofield Basin, Ko'olau, and Wai'anae aquifers at 128 mgd[252]. More recently, Oki estimated these flows to total only 118 mgd[253]. The balanced water budget uses the more recent estimate of 118 mgd. The magnitude of the total contributory flow from these aquifers cannot be directly measured and the estimate is a function of the elevations of and withdrawals from the aquifers as well as the calculation methods and assumptions made by the hydrologists. The quantity of water actually used in the watershed and put back into the ground as a result of consumption, system losses (leaks), and other uses is an estimate based upon the total pumpage minus known outflows (wastewater flows and BWS flows to adjacent watersheds). Of the 113 mgd in well withdrawals, only 69 mgd is used within the watershed. Of this 69 mgd, 44 mgd is accounted for in flows to the three WWTPs listed in Table 3-6. This leaves a total of 25 mgd for system losses; State, City, and residential irrigation; consumption; and other uses withdrawn from taps and recycled to the watershed surface. This quantity will be heavily impacted by seasonal irrigation uses which can double to triple during summer months. Water losses within the BWS distribution system average about 13%. Losses within other private or federally owned systems within the watershed are not known but are generally considered to be much higher than 13%.

3.4.6.2 Outflows from the Central O'ahu Watershed

Evapotranspiration from the watershed is likely the largest, most capricious temporal and spatial variable, and one of the most difficult variables to accurately measure. Evapotranspiration is the total of all free water evaporated from the surface plus water vapor lost by plants and animals during respiration. Evaporation rates (as measured from an open pan of water) have been measured across the watershed and are known to be high over warm sunny coastal lands and lower at higher elevations where clouds and cooler temperatures prevail. At lower elevations, evaporation is limited because of the dry barren land and evaporation resistant plants. At moderate elevations, particularly in well irrigated agricultural areas, respiratory water loss from plants can greatly exceed pan evaporation rates. At higher elevations, evaporation is limited by cooler air and prevalence of cloud cover.

To calculate the average total evaporation over the entire watershed, evapotranspiration in the lower dry areas is limited to 80% of rainfall. Average evaporation over the ocean in Hawai'i is about 1651 millimeters (mm) or 65 inches per year. At the base of foothills, evapotranspiration is assumed to be 80% of pan evaporation. This value is decreased in a stepwise fashion up the watershed to 45% of pan evaporation at the highest elevations. These calculations result in a gross annual estimate of 247 mgd water lost from the watershed surface due to evapotranspiration. The evapotranspiration per square mile estimate by Shade and Nichols for all of Southern O'ahu (257 mi^2; 356 mgd = 1.40 mgd/mi^2)[254] is slightly lower than the evapotranspiration per square mile estimate (167 mi^2; 247 mgd = 1.48 mgd/mi^2) of the balanced water budget because of the different distribution of caprock and non-caprock areas.

Wastewater flows from WWTPs are direct outflows to the ocean and out of the Central O'ahu Watershed. The effluent flows for Honouliuli WWTP (22 mgd[255]) and Fort Kamehameha WWTP (6 mgd[256]) are measured by flow meters. The flow to Sand Island WWTP (5.8 mgd[257]) is taken from data for the Kamehameha Highway wastewater pump station. The wastewater flows for Honouliuli WWTP, Fort Kamehameha WWTP, and Sand Island WWTP vary significantly on a daily cycle and with rainfall due to infiltration and inflow into the wastewater collection system. Long-term averages of these wastewater flows are likely among the best flow estimates in the entire watershed.
Many permanent surface water flows have been gauged by the USGS; therefore, there are good long-term estimates for average stream flow of gauged streams at about 40 mgd. The USGS stream flow record does not account for any flows from the ungauged streams and dry gulches in the watershed. Shade and Nichols reached a conclusion that the total of all surface flows (gauged and ungauged streams plus direct sheet flow) to the ocean in the entire Southern O'ahu watershed was equal to 0.178 of precipitation[258]. Applying this percent to the Central O'ahu Watershed with 459 mgd of rainfall yields 82 mgd of runoff, or about double the runoff actually measured by the USGS in gauged streams. This quantity could be much higher during years that have a high frequency of large storms that typically produce higher runoff values and much lower in years when precipitation is light and infiltration is higher.

The USGS long-term estimate for spring flow directly to Pearl Harbor is about 56 mgd. In a recent report by Oki[259], equations were developed that relate spring discharge to water level elevation. Assuming an elevation of 16 feet, the calculated total spring flow is 62 mgd, only about 10% above the measured USGS value.

Subsurface groundwater flows to the ocean can be estimated but not measured because of their diffuse nature. Estimates on the order of 3–5 mgd per mile of coastline would indicate that 45–60 mgd flow to the ocean along the 15-mile perimeter (not including Pearl Harbor) of the Central O'ahu Watershed. The Shade and Nichols study estimates the subsurface flow to the ocean for this region as about 270 mgd[260], but this value included significant inputs from agricultural irrigation that are no longer present. In this balanced water budget, the subsurface groundwater flow to the ocean is calculated assuming that groundwater is in a steady state and accounting for all other flows to and from the system. This calculation results in a groundwater flow to the ocean of about 116 mgd to balance inputs to and other known outflows from the watershed.

3.4.6.3 Well Withdrawals and Infiltration

The present average well withdrawal of 113 mgd is taken directly from BWS and CWRM records for wells in the Central O'ahu Watershed. BWS withdrawals for CY2000 to CY2004 have remained relatively stable between about 82 and 87 mgd per year. CWRM reported withdrawals in CY2004 account for the difference up to the 113 mgd per year total. Well withdrawals can vary significantly depending on rainfall and land use. For example, when the Central O'ahu Watershed was under heavy agricultural use between

the mid-1960s to the early 1980s, well withdrawal figures often exceeded 200 mgd[261], with some of this water recharging the underlying aquifers.

The quantity of water that actually infiltrates from surface soils to deep groundwater cannot be directly measured. Infiltration is calculated as the sum of the total surface inflows (rainfall; reuse; consumption, losses, and other uses; and ditch water inflow) minus known and calculated outflows (springs, runoff, and evapotranspiration). Shade and Nichols estimate for infiltration is about 142 mgd[262], which is slightly less than the infiltration (111 mgd) plus the spring flow (62 mgd) in the balanced water budget. Infiltration varies seasonally and geographically and is dependent upon annual cycles of rainfall and evapotranspiration and the type of surface ground cover.

3.5 PRELIMINARY FORECASTS OF WATER DEMAND

Preliminary water demand forecasts for the Central O'ahu Watershed were obtained from BWS and the State. The BWS projections are for 2030 and do not include non-potable demand. The State projections were taken from the 2003 *State Water Projects Plan* and include non-potable and potable demand. In addition, the State projections are for 2018.

3.5.1 BWS WATER DEMAND PROJECTIONS

The BWS water demand projections are based on DPP population projections through the year 2030 and use a *per capita* method. Projections are arranged by City land use districts: 'Ewa, Central, and the Primary Urban Center (PUC). These districts are shown in Figure 2-14. The Central District includes Kunia, Waipahu, Waikele, Waipi'o, Waiawa, Mililani, and Schofield-Wheeler. The PUC includes Pearl Harbor. The demand projections are summarized in Table 3-7.

TABLE 3-7
BWS PROJECTED WATER DEMAND (2030)
IN CENTRAL O'AHU WATERSHED

City Land Use District	Population 2030	Water Demand 2000 (mgd)	Water Demand 2030 (mgd)	Increase (mgd)
'Ewa	184,612	15.302	42.503	27.201
Central	160,582	15.941	22.186	6.245
PUC	96,144	10.476	10.619	0.143
Total	**441,338**	**41.719**	**75.308**	**33.589**

The water demand in the Central O'ahu Watershed is expected to increase to 75.308 mgd in 2030, which is about an 80% increase from the demand in 2000. The total current permitted use for BWS in the Central O'ahu Watershed is 110.338 mgd. The 2030

projected water demand is 35.03 mgd less than the BWS current permitted use. If the Waiāhole Ditch System is excluded, the 2030 projected water demand is 130.692 mgd less than the total sustainable yield for the entire Watershed.

3.5.2 WATER DEMAND PROJECTIONS FOR STATE PROJECTS

The water demand for proposed State projects is arranged by Aquifer System Area. The State projections include non-potable and potable water demand, even if the aquifer system is non-potable. Some State projects will be located above non-potable aquifers but will require potable water. The water demand projections were based on land use types for the projects listed in the 2003 *State Water Projects Plan*. The demand projections are summarized in the following table (Table 3-8).

TABLE 3-8
PROJECTED WATER DEMAND (2018) FOR STATE PROJECTS
WITHIN CENTRAL O'AHU WATERSHED

Aquifer System Area	Total Permitted Use 2005 (mgd)	Sustainable Yield (mgd)	Non-potable Demand 2018 (mgd)	Potable Demand 2018 (mgd)	Total Demand 2018 (mgd)
'Ewa-Kunia	15.457	16	0.000	0.155	0.155
Kapolei	2.033	N/A	0.863	6.657	7.520
Malakole	5.928	N/A	1.210	0.663	1.873
Pu'uloa	14.817	N/A	0.000	0.011	0.011
Wahiawā[t]	9.608	23	0.014	0.027	0.042
Waimalu	46.951	45	0.190	0.049	0.239
Waipahu-Waiawa	82.909	104	6.286	0.770	7.056
Total	**177.703**	**188**	**8.563**	**8.332**	**16.896**

The non-potable and potable demands are for a variety of State facilities and projects. The following table (Table 3-9) summarizes the various types of State projects and facilities requiring potable or non-potable water.

[t] The total permitted use is only for the sources within the Central O'ahu Watershed. The sustainable yield is for the entire aquifer system.

TABLE 3-9
TYPES OF STATE PROJECTS/FACILITIES
REQUIRING POTABLE OR NON-POTABLE WATER

Type of Project/Facility	Non-potable Demand	Potable Demand
Civic center	X	X
Heiau	X	X
Sports recreational complex	X	X
Public library	X	X
Training facility/armory	X	X
Roadway landscaping	X	
University or community college	X	X
Community Development District	X	X
Barracks	X	X
State park	X	X
State marine recreation area		X
Garden center	X	
Agricultural park	X	X
Subdivision	X	X
Harbor		X
School		X
Aircraft hanger		X
Veterans center		X

The non-potable water demand is a little over half the total projected demand. About 73% of the non-potable demand is expected to come from State facilities that will overlay the Waipahu-Waiawa Aquifer System Area. Almost 80% of the potable demand is expected to come from State facilities that will overlay the Kapolei Aquifer System Area. Although the Kapolei aquifer is non-potable, many proposed State facilities and projects requiring potable water will be located above the aquifer.

The current State permitted use in the Central O'ahu Watershed is insufficient to meet the 2018 projected demand for the proposed State projects. If the Waiāhole Ditch System allocations are excluded, the State's current permitted use is 3.225 mgd, which is 13.671 mgd less than the projected demand. In order to meet the projected demand, non-State water resources will need to be tapped.

3.6 MEETING FUTURE DEMAND

Future water demand in the Central O'ahu Watershed can be fulfilled by employing a multitude of water resource strategies. These water resource strategies include developing conventional ground water supplies, developing alternative water supplies, and promoting conservation.

Three more conventional ground water sources are planned for the Central O'ahu Watershed. The 'Ewa Shaft, Waipahu Wells III, and Waipahu Wells IV will eventually increase the capacity of BWS to deliver potable water to its customers.

Alternative water supplies include recycled water, brackish water, desalination, deep ocean water, and surface water treatment. Recycled water and brackish water are already used in the Central O'ahu Watershed while desalination, deep ocean water, and widespread surface water treatment have yet to be implemented.

The BWS-owned Honouliuli Reclamation Facility can currently produce up to 12 mgd of recycled water. The capacity of the Honouliuli Reclamation Facility is limited by the capacity of the Honouliuli WWTP. Until the capacity of the Honouliuli WWTP secondary treatment system is expanded, the maximum capacity of the reclamation facility is limited to 12 mgd.

Possible candidate sites for implementation of recycled water facilities include the Navy's Fort Kamehameha WWTP and satellite treatment centers at points of use throughout the wastewater collection system. The high chloride concentration of Fort Kamehameha WWTP's effluent restricts the practical use of recycled water from the treatment plant. Additional treatment, such as reverse osmosis or nanofiltration, may be necessary in order to reduce the chloride concentration of the effluent before it can be used for irrigation or industrial purposes. Satellite treatment centers use packaged treatment plants with membrane bioreactors (MBRs) to treat raw wastewater to meet recycled water quality guidelines. The concept of satellite treatment centers for point-of-use wastewater recycling is relatively new and is not currently used on O'ahu.

Other impediments to the expansion of recycled water use in the Central O'ahu Watershed are the cost of the infrastructure to deliver the water to customers and the cyclical demand for recycled water. Recycled water requires separate infrastructure (pipes, valves, storage, etc.) to deliver the water to customers. This infrastructure must be constructed and can be quite expensive. Sometimes existing infrastructure, such as freeways, may conflict with the recycled water infrastructure, essentially blocking the route to potential customers. Recycled water demand is highest during the summer months because of the lack of rainfall. During winter, recycled water demand decreases as less water is needed for irrigation. Additional storage is needed during winter months or production of recycled water needs to be reduced to match the lower demand.

Existing and future brackish water sources can be used to supplement recycled water capacity. The 'Ewa Caprock is the main source of brackish water in the Central O'ahu Watershed. Several golf courses and industrial facilities in the Watershed use brackish water. New developments, such as the East and West Kapolei communities and the Kapolei Business Park, use brackish water. BWS can provide non-potable water to its customers in the Campbell Industrial Park area via the Barbers Point 215' non-potable reservoir. BWS also supplies brackish water from the Kalauao Springs Non-potable System to users from 'Aiea to the Honolulu International Airport.

Large-scale desalination for potable use is not used in the Central O'ahu Watershed. However, BWS conducted a multi-year planning study in the 1990s that outlined recommendations for a large-scale desalination facility in Kalaeloa. The design of the Kalaeloa Desalination Plant started in 2001 and a pilot study of the unit processes was conducted in 2003. The project has since ceased due to concerns about funding the construction of the plant. BWS purchased the former State Demonstration Desalting Plant in Campbell Industrial Park. This plant produced potable water from a brackish water source. The demonstration plant is currently inactive. Nevertheless, desalination remains a component of BWS' long-term strategy to deliver potable water to the population of the Central O'ahu Watershed.

Another alternative water resource that can be used to meet future water demand is deep ocean water. Applications for deep ocean water include district cooling, ocean to thermal energy conversion, and desalination. BWS is designing deep seawater wells in Ko Olina for district cooling. A district cooling system is in operation at the University of Hawai'i Medical School in Kaka'ako.

Still another alternative water resource that can be used to meet future demand is surface water. The high cost of treating surface water and the lack of surface water reservoirs limits the use of surface water as an alternative resource in the Central O'ahu Watershed. However, surface water from the Waiāhole Ditch system is currently treated at the Waiawa Correctional Facility to provide potable water to inmates and staff.

In addition to developing ground water and alternative water resources, conservation of water can help to meet future demand. Conservation measures are primarily voluntary and are applied generally throughout O'ahu. The State and City have separate programs and plans for water conservation. The U.S. Navy at Pearl Harbor also promotes water conservation. The following sections provide some details on the State, City, and Navy (Pearl Harbor) conservation programs.

3.6.1 STATE CONSERVATION PROGRAM

The 2005 update of the *Hawai'i Drought Plan* states that "water conservation should be promoted statewide and practiced within all water sectors."[263] A prototype conservation plan for the State DLNR is under development.[264] The State DOA has some power to enforce water conservation practices on its own irrigation systems.[265]

The 2005 update of the *Hawai'i Drought Plan* identified specific short-term and long-term statewide strategies to foster the implementation of water conservation practices. The short-term strategies included obtaining additional funds for the DLNR prototype conservation plan and initiating specific conservation plans for each State agency.[266] Long-term strategies included a comprehensive water conservation plan for the entire State, provisions and policies for regional water shortages, and completing agency-specific conservation plans.[267]

3.6.2 CITY CONSERVATION PROGRAM

On O'ahu, the City's potable water conservation program is administered by BWS. The BWS conservation program consists of five components:

- Public education and outreach
- Leak detection, repair, and maintenance
- Large water users programs
- Regulation
- Alternative source development, recycling, and conservation alternatives

3.6.2.1 Public Education and Outreach

The primary objective of BWS' public education and outreach programs is to influence consumer water use habits. A variety of programs target homes, schools, and businesses. These programs include public service announcements, poster contests, newspaper articles, water saving tips on the Internet, xeriscape demonstrations, detect-a-leak week, educational booths, and a water waste hotline.

3.6.2.2 Leak Detection, Repair, and Maintenance

BWS has a program to identify and fix system water losses. The goal of this program is to reduce the water lost between sources and customers. Some of the water loss is caused by leaking pipes, while other causes are flushing of pipes, reservoirs, and hydrants; illegal unmetered water taps; and meters that need calibration. The national average for pipe system water loss is 10%. The BWS goal for pipe system water loss is to match or be lower than the national average.

3.6.2.3 Large Water Users Programs

BWS' large water users programs target organizations and businesses with high consumption. Large water users often have the capacity to facilitate change in water consumption from within the organization. Existing agreements between City and State agencies target parks, schools, golf courses, roadway landscaping, and other government facilities to be more efficient with water use.

3.6.2.4 Regulation

BWS regulations and rules promote water conservation by

- establishing a drought plan
- requiring non-potable water master plans for new developments
- requiring low flow fixtures in all new developments

BWS developed a Low Groundwater Plan or drought plan that provides hydrologic monitoring triggers for increasingly restrictive conservation measures. These measures would result in reduced consumption to protect water resources and maintain high water quality during drought.

The amount of non-potable water needed for large landscape irrigation places a higher burden on new developments to reduce new demands on potable water supplies. BWS requires new large developments to submit non-potable water master plans to ensure that dual systems are installed—one for drinking and fire protection and the other for irrigation.

One of the existing and highly successful BWS initiatives has been the low flush toilet ordinance. City building codes were drafted to require the installation of low flow fixtures in all new developments.

3.6.2.5 Alternative Source Development, Recycling, and Conservation Alternatives

Realizing that Oahu's natural resources are limited, BWS is diversifying its water supplies to develop alternative sources, including recycled water, brackish water, seawater desalination, and encourage higher levels of water conservation. BWS currently operates the following non-potable water systems:

- Kalauao Springs Non-potable System
- Barbers Point–West Beach Non-potable System
- Honouliuli Recycled Water Facility
- District cooling system at the University of Hawai'i Medical School in Kaka'ako

BWS is designing deep seawater wells in Ko Olina for district cooling.

BWS continues to evaluate and plan for a seawater desalination plant in Kalaeloa. The desalination plant would provide additional water supply that is not susceptible to drought.

One way that BWS encourages higher levels of water conservation is through its toilet rebate program. BWS offers a rebate for the installation of low flow toilet fixtures. From 1995 to 2000, BWS issued about $7 million in rebates for the replacement of 72,850 toilets with low flush toilets. BWS plans to end the toilet rebate program in 2008 because it expects that most toilets on O'ahu will have been retrofitted by then.

3.6.3 U.S. NAVY (PEARL HARBOR) CONSERVATION PROGRAM

The U.S. Navy at Pearl Harbor has policies to limit irrigation to three days a week only between sundown and sunup. The Navy encourages residents and workers to report leaking or broken water systems or water waste. The Navy also encourages the use of the carwash located at Pearl Harbor base because the carwash uses on-site recycled water.

In the early 2000s, the Navy completed a comprehensive water audit on Navy lands and found a significant, undetected water pipe leak at Pearl Harbor. This leak was eventually fixed, resulting in a billion gallon a year water savings for the Navy. Continuous monitoring of the water system is designed to detect and fix other leaks in the system.

The Navy is also looking at expanded use of recycled water. However, recycling water at its Ft. Kamehameha WWTP would be difficult because many Navy base sewer pipes are below the water table and have suffered seawater intrusion through corrosion. The seawater intrusion has resulted in high chloride levels in potential recycled water. To address this issue, the Navy is currently implementing a project to re-line its sewer collection system for the purpose of reducing corrosion.

The Navy currently does not have a gray water system but continues to investigate the potential of this use. Previously, a gray water system connecting Barbers Point with the Honouliuli WWTP was investigated, but this project was not implemented. Long-term plans for the Navy include placement of individual water meters or area-wide meters to better track water use and replacement of all water fixtures with low flow fixtures and no-water urinals.

3.7 CONCLUSIONS

The Central O'ahu Watershed faces the serious issue of increased water demand over the next couple of decades. Increased development and population will only add to the already existing pressures to provide safe drinkable water to the public. The potable water demand in the Watershed is expected to increase by almost 34 mgd over the next 23 years.

The Honolulu BWS is at the forefront of meeting the water needs in the Watershed. The Honolulu BWS is the largest supplier of potable and recycled water in the Watershed. The next largest provider of potable water is the U.S. Navy. Private systems, the U.S. Army, State systems, and other federal agencies satisfy the remaining demand in the Watershed.

Historically, the water needs within the Watershed have been met primarily by ground water. The groundwater aquifers in the Watershed are fed primarily by rainfall, which infiltrates underground. Conservation areas are needed to ensure adequate infiltration area and maintain adequate aquifer storage.

The anticipated demand in the Watershed will provide an impetus to use alternative water sources and encourage conservation. Two alternative water sources that are currently used in the Watershed include recycled water and brackish water. Other alternative sources of water are surface water and desalination of brackish water or seawater. Targeted use of alternative water sources will free up traditional ground water supplies for potable consumption. Conservation will help to extend the useful supply of existing potable groundwater sources.

4 PROJECTS AND PROGRAMS

Research and stakeholder consultations identified various issues and problems in the Central O'ahu Watershed Study area. For organizational purposes, these problems were categorized by the following issue groups: Ground Water Quantity, Ground Water Quality, Sedimentation, Stream Degradation, Flood Management, Terrestrial Degradation, Near Shore Degradation, and Other. The Issues/Problems/Projects Matrix on the following pages illustrates how the proposed projects relate to the identified issues and problems. Problems were then researched to get a clearer understanding of their severity and extent, and to find out what actions, if any, are currently in place to address the situation.

4.1 ELIMINATED PROJECTS

The study did not develop a project for every problem identified. Those problems that currently have some action in place to address it were eliminated from further action by this study. Projects were not developed for the following problems: (1) ground water contamination from Superfund sites, (2) upstream flooding, particularly in gulches, (3) urbanization of undeveloped lands, and (4) the need for partnerships and information sharing in the management of natural resources. Below is an explanation of current initiatives that are already addressing these problems.

4.1.1 SUPERFUND SITES

Ground water contaminated by from activities at Schofield Barracks, Kunia, and the Pearl Harbor Naval Complex is undergoing treatment, or treatment has already taken place and monitoring is in effect. DOH and BWS use monitoring wells, an abandoned well sealing program, and 3-D ground water models to help to manage resources. Well water is also tested by BWS to ensure compliance in accordance with DOH/EPA standards, and any contaminated wells are treated with GAC (Granular Activated Carbon) filters.

4.1.2 GULCH DEVELOPMENT

There are gulches within the Central O'ahu Watershed with some urban and agricultural uses, such as a chicken farm in Kīpapa, military reservations in Kīpapa and Waikele, and a housing development in Waikakalaua. Restricting damage-susceptible development on the floodplain proper would minimize destruction during flood-related events. Both the Central O'ahu SCP and 'Ewa DP favor preserving the gulches as natural drainage ways, stating that further development of residential, commercial, or industrial uses within the gulches should be avoided. The major gulches are designated for preservation, except for the portion of Waikakalaua Gulch that was previously designated for urban use. The plans support efforts to expand access to mountain and gulch trails as part of the open space network.

4.1.3 URBANIZATION OF UNDEVELOPED LANDS

The Central O'ahu SCP and 'Ewa DP both also address the concern for forest, agricultural and open lands protection for aquifer recharge and view plane preservation. The 'Ewa DP protects agricultural land and open space by not allowing development outside of the Urban Growth Boundary, with the goal of retaining 27% open space inside the boundary by the year 2020. Central O'ahu SCP also does not allow development outside of its Urban Community Boundary, and has the goal of keeping 24% of the area within the boundary as open lands beyond 2025. Both plans create an open space and greenways network, and support the preservation of natural gulches and drainage ways, wildlife sanctuaries, and significant views and vistas. Even with the scheduled departure of Del Monte pineapple operations from Kunia lands, future plans for the area suggest that it will most likely be replanted in diversified agriculture.[268] Other programs in place that could be used to preserve open space include the Forest Legacy Program, American Farmland Trust, O'ahu Land Trust, and Legacy Lands Act.

4.1.4 NEED FOR PARTNERSHIPS

Watershed management involves many diverse disciplines and jurisdictions, making information sharing critical in order to make the best land and water management decisions. An interagency watershed council was suggested to promote collaboration, but there a similar groups already in place, such as the Ko'olau Mountains Watershed Partnership and Pearl Harbor Ground Water Monitoring Working Group. There have also been discussions about forming a possible Wai'anae Mountains Watershed Partnership. Within this report, there are additional partnerships suggested, such as the Pearl Harbor Fishpond Restoration Partnership (Project 27) and a partnership for Pearl Harbor ecological restoration (Project 29).

4.2 PROJECT DESCRIPTIONS

Projects were proposed to help mitigate those issues and problems within the Central O'ahu Watershed Study area that are not already being addressed by a government or private entity. Concepts were derived either from recommendations made in the literature, through stakeholder consultations, or by the study group.

Each project is described in a two-page format that includes a project number, action title, problem statement, general background, preliminary scope, suggested participating agencies, estimated cost, time frame, and references that may be helpful in developing the project. Rough cost estimates were developed through research on existing watershed initiatives, information provided by experts and agencies, and best professional judgment. These estimates were categorized within the following ranges:

- **$50,000 - $100,000**
- **$100,000 - $250,000**

- **$250,000 - $500,000**
- **$500,000 – $1,000,000**
- **$1,000,000 - $3,000,000**
- **$3,000,000+**

Specific costs were listed, if provided by a source. Most cost estimates are for planning and programming, and do not necessarily include costs for construction. Costs will be actualized during the scoping phase of these projects, if pursued. Project descriptions are grouped according to the issue they most affect, although many projects may mitigate problems from more than one issue group, as is the nature of watershed management.

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CENTRAL O'AHU WATERSHED STUDY
ISSUES / PROBLEMS / PROJECTS MATRIX

	Issues	Groundwater Supply								Groundwater Quality					Sedimentation				Stream Degradation				Flood Management		Terrestrial Degradation	Near Shore Degradation						Other
		1 Pearl Harbor Ground Water Modeling	2 Low Impact Development (LID)	3 Water Use Inventory	4 Aquifer Recharge Protection	5 Watershed Infiltration Enhancement	6 Water Conservation Program	7 Recycled Water Resource Development	8 Desalination Project	9 Source Water Protection Program	10 Inactive Landfill Mitigation	11 Detention / Infiltration Basins Study	12 Abandoned Well Inventory, Sealing, and Monitoring	13 Chemical Contamination Mitigation	14 Sedimentation Source Study and Analysis	15 Stream Erosion and Sediment Control Program	16 Increased BMP Incentives and Enforcement	17 Wasteload Allocation Modeling	18 Stream Habitat Restoration	19 Riparian Buffer Zones	20 Impermeable Surface Inventory and Analysis	21 Roads and Highways Runoff Study	22 Drainage Improvement Implementation	23 Hydrologic Analysis	24 Wildfire Protection Program	25 Wastewater Contamination Mitigation	26 Wetland Habitat Protection	27 Pearl Harbor Fishpond Restoration Partnership	28 'Ewa Beach Erosion Control Program	29 Pearl Harbor Ecological Restoration	30 Central Oahu Watersheds Public Education Program
1	**Groundwater Quantity**																															
1a	Sustainable Yield (SY) numbers need to be agreed upon and established.	●		●																				●								
1b	Adequate data is not available for private well and diversion locations, current use and pumpage.			●									●											●								
1c	The capacity for aquifer recharge will be reduced due to forest degradation and an increase in impervious surfaces from continued development.		●		●	●																		●								
1d	Water infiltration may be inhibited by "plow pan," a compacted area a few feet underground in areas that were planted in sugarcane.		●		●	●								●																		
1e	Increased urbanization will lead to an increase in potable water demand, possibly exceeding groundwater supplies in the future.		●	●		●	●		●															●								
1f	Alternative water sources are needed to minimize the demand on potable water and keep potable water sources healthy.		●				●	●	●																							
1g	Increasing Waiahole Ditch water costs may require users to look for cheaper alternatives.							●																								
2	**Groundwater Quality**																															
2a	Many Potential Contaminating Activities (PCAs) ranked as "very high" exist in the study area.									●	●		●	●																		
2b	Concerns regarding the pumpage and water quality monitoring of irrigation wells and possible backflow from pesticide mixing may affect potable water supplies.												●	●																		
2c	Possible contamination of groundwater sources via concentration of runoff into detention basins.											●		●										●								
2d	Urban contaminants such as lead, mercury, and chromium are starting to emerge in the groundwater in addition to herbicides and pesticides from agricultural use.		●							●		●	●	●								●		●								●
2e	Additional threats to water quality: termiticides from residential use, unsewered areas, injection wells, fertilizers, and unsealed wells.											●	●	●								●		●		●						●
2f	Illegal dumping of household and commercial waste possibly contaminating water sources.													●										●								●
2g	Initial studies of closed dumps in the area show a need for continued investigation to protect against contamination of groundwater sources and potable wells.										●			●										●								

CENTRAL O'AHU WATERSHED STUDY
ISSUES / PROBLEMS / PROJECTS MATRIX

		Groundwater Supply								Groundwater Quality					Sedimentation				Stream Degradation				Flood Manage-ment		Terrestrial Degradation	Near Shore Degradation					Other
	Issues	1 Pearl Harbor Ground Water Modeling	2 Low Impact Development (LID)	3 Water Use Inventory	4 Aquifer Recharge Protection	5 Watershed Infiltration Enhancement	6 Water Conservation Program	7 Recycled Water Resource Development	8 Desalination Project	9 Source Water Protection Program	10 Inactive Landfill Mitigation	11 Detention / Infiltration Basins Study	12 Abandoned Well Inventory, Sealing, and Monitoring	13 Chemical Contamination Mitigation	14 Sedimentation Source Study and Analysis	15 Stream Erosion and Sediment Control Program	16 Increased BMP Incentives and Enforcement	17 Wasteload Allocation Modeling	18 Stream Habitat Restoration	19 Riparian Buffer Zones	20 Impermeable Surface Inventory and Analysis	21 Roads and Highways Runoff Study	22 Drainage Improvement Implementation	23 Hydrologic Analysis	24 Wildfire Protection Program	25 Wastewater Contamination Mitigation	26 Wetland Habitat Protection	27 Pearl Harbor Fishpond Restoration Partnership	28 'Ewa Beach Erosion Control Program	29 Pearl Harbor Ecological Restoration	30 Central Oahu Watersheds Public Education Program
3	**Sedimentation**																														
3a	Contaminated sediment can include pesticides and other toxins, bacteria, heavy metals, excess nutrients, and pathogens.		●									●			●	●	●	●		●		●									●
3b	Sedimentation into Pearl Harbor from Waiawa and other streams has been identified as a major non-point source of contamination of harbor waters, impeding and restricting use of Pearl Harbor by the Navy.		●									●			●	●	●	●											●		●
3c	Surface runoff related sedimentation continues to be a problem in West Loch		●									●			●	●	●	●													
3d	Sediment accumulates at stream mouths		●												●	●	●	●													
3e	Exact point sources and percentage of sediment polluting streams/Pearl Harbor are unknown		●												●	●		●						●							
3f	Inability to monitor sediment sources and hold all sources accountable		●												●	●	●	●													
3g	Lack of compliance and enforcement of BMPs		●														●	●													●
3h	Intermittent dredging by both Navy and City and County is expensive.		●												●	●	●	●													
4	**Stream Degradation**																														
4a	Degradation, decrease or absence of stream riparian zones																		●	●	●										●
4b	Eroding streambanks and siltation from aquatic invasive species and increased runoff from development.																		●	●	●	●									●
4c	Stream dredging is expensive															●		●	●	●								●			
4d	All eight perennial streams were designated on the 2004 List of Impaired Waters in Hawaii.																	●	●	●	●					●					●
4e	Degraded native habitat from water pollution and invasive species introduction																●	●	●	●		●						●			●
4f	Increased run-off and velocity of storm water from channelization resulting in flooding and habitat loss																		●		●							●			

CENTRAL O'AHU WATERSHED STUDY
ISSUES / PROBLEMS / PROJECTS MATRIX

		Groundwater Supply								Groundwater Quality					Sedimentation				Stream Degradation				Flood Management		Terrestrial Degradation	Near Shore Degradation					Other
	Issues	1 Pearl Harbor Ground Water Modeling	2 Low Impact Development (LID)	3 Water Use Inventory	4 Aquifer Recharge Protection	5 Watershed Infiltration Enhancement	6 Water Conservation Program	7 Recycled Water Resource Development	8 Desalination Project	9 Source Water Protection Program	10 Inactive Landfill Mitigation	11 Detention / Infiltration Basins Study	12 Irrigation Well Monitoring	13 Chemical Contamination Mitigation	14 Sedimentation Source Study and Analysis	15 Stream Erosion and Sediment Control Program	16 Increased BMP Incentives and Enforcement	17 Wasteload Allocation Modeling	18 Stream Habitat Restoration	19 Riparian Buffer Zones	20 Impermeable Surface Inventory and Analysis	21 Roads and Highways Runoff Study	22 Drainage Improvement Implementation	23 Hydrologic Analysis	24 Wildfire Protection Program	25 Wastewater Contamination Mitigation	26 Wetland Habitat Protection	27 Pearl Harbor Fishpond Restoration Partnership	28 'Ewa Beach Erosion Control Program	29 Pearl Harbor Ecological Restoration	30 Central Oahu Watersheds Public Education Program
5	**Flood Management**																														
5a	Upland flooding in Waikakalaua Gulch		●																●	●			●	●							
5b	Flooding in lowland areas near stream mouths in Waipahu around Waikele Stream, and in Waiawa around the lower reaches of Waiawa Stream that have been developed.		●																	●			●	●							
5c	Prevalent flooding in low-lying portions of Ewa plain (including Tenney and Verona Villages)		●																				●	●							
5d	Floodwater discharge is a major contributor of non-point source pollution to nearshore waters		●														●		●	●			●	●							●
6	**Terrestrial Degradation**																														
6a	Reduced numbers of native plant and animal species																		●						●						●
6b	Native terrestrial ecosystems have been reduced to only 20% of their previous pre-human contact extents.																								●		●				●
6c	Wildfires are a recurring annual problem.																								●						●
6d	Runoff and erosion in terrestrial areas due to wildfire, invasive plants and animals, offroading by motorized vehicles, and increased development needs to be addressed.		●									●			●			●		●											●
7	**Near Shore Degradation**																														
7a	Pearl Harbor and Ewa Beach Park were listed in the 2004 List of Impaired Waters in Hawaii.																										●	●		●	●
7b	Wetlands have been reduced by 95%, or approximately 3,600 aces, since human contact																										●				●
7c	Any remaining fishponds are not fit for use due to contaminated sediment and/or broken walls.																											●			●
7d	Ewa Beach is experiencing significant beach erosion and shoreline retreat.																												●		●
7e	Continued trend of decreasing percentages of native species in Pearl Harbor.																										●	●		●	●
7f	Mangrove invasions cause elimination of native flora, encroachment into wetland habitat, and overgrowth of some Hawaiian fishponds within Pearl Harbor.																										●	●		●	●

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Note: The proposed strategies and projects within this plan are the result of a preliminary watershed analysis and stakeholder consultation process. The strategies and projects may involve various governmental agencies and non-governmental organizations, and the implementation and funding of these strategies and projects are not the sole responsibility of BWS, City and County of Honolulu, or State of Hawai'i. This plan is intended to guide agencies and organizations in implementing the most important initiatives for the Central O'ahu Watershed and water resources; however, implementation will likely depend on budgetary priorities, grant availability and partnering efforts over the long term.

CENTRAL O'AHU WATERSHED STUDY PROJECTS AND PROGRAMS

Ground Water Quantity
01 Pearl Harbor Ground Water Modeling
02 Low Impact Development (LID)
03 Water Use Inventory
04 Aquifer Recharge Protection
05 Watershed Infiltration Enhancement
06 Water Conservation Program
07 Recycled Water Resource Development
08 Desalination Project

Ground Water Quality
09 Source Water Protection Program
10 Inactive Landfill Mitigation
11 Detention / Infiltration Basins Study
12 Abandoned Well Inventory, Sealing, and Monitoring
13 Chemical Contamination Mitigation

Sedimentation
14 Sediment Source Study and Analysis
15 Stream Erosion and Sediment Control Program
16 Increased BMP Incentives and Enforcement
17 Waste Load Allocation Modeling

Stream Degradation
18 Stream Habitat Restoration
19 Riparian Buffer Zones
20 Impermeable Surface Inventory and Analysis
21 Roads and Highways Runoff Study

Flood Management
22 Drainage Improvement Implementation
23 Hydrologic Analysis

Terrestrial Degradation
24 Wildfire Protection Program

Near Shore Degradation
25 Wastewater Contamination Mitigation
26 Wetland Habitat Protection
27 Pearl Harbor Fishpond Restoration Partnership
28 'Ewa Beach Erosion Control Program
29 Pearl Harbor Ecological Restoration

Other
30 Central O'ahu Watershed Public Education Program

PROJECT 01: PEARL HARBOR GROUND WATER MODELING

PROBLEM STATEMENT

Improved ground water modeling of the Pearl Harbor Aquifer is needed to optimize use of the largest source of fresh water on O'ahu.

GENERAL BACKGROUND

The Pearl Harbor Aquifer Sector is the largest on the island of O'ahu, with a total estimated sustainable yield (SY) of 165 mgd; 'Ewa-Kunia, 16 mgd; Waipahu-Waiawa, 104 mgd; and Waimalu, 45 mgd. Currently, 145 mgd is permitted for use. The robust analytical model (RAM) was developed by Mink in 1980-81 to quantify the Pearl Harbor Aquifer Sector SY.

CWRM utilized three models to update SY numbers in the 1990s: RAM, Regional Aquifer System Analysis (RASA), and Central Corridor (CenCor). New SYs were adopted, but due to the wide range of results produced by the three models, CWRM also adopted a milestone approach, where specific actions were tied to allocation and pumpage milestones. Some milestone actions include: developing a monitoring plan that optimizes resources, sets management criteria, and implements actions; developing a plan to optimize water infrastructure; initiating development of an overall water shortage plan; and initiating re-assessment of SYs.

The Pearl Harbor Monitoring Working Group (PHMWG) was convened in March 2002 to facilitate actions associated with the SY milestones. Participants include CWRM, BWS, U.S. Navy, USGS, and non-government members with expertise in hydrogeology. PHMWG, as a part of its Memorandum of Agreement, agreed to "identify data needs and collect appropriate data to encourage the construction of numerical 3-D models to further our understanding of the resource and aid in resource assessment and the optimization of pumpage."

Currently, a monitoring plan is under review, although CWRM and BWS have already constructed additional deep water monitoring wells to improve understanding of the freshwater lens and the brackish transition zone in response to pumping. The deep monitor wells will be used to record trends in aquifer health and for calibrating 30-year model simulations.

BWS has completed modeling the Honolulu Aquifer Sector and funded the USGS-constructed 3D SUTRA model for the Pearl Harbor Aquifer Sector to complete their study on the effects of low permeability valley fill barriers. Both models provide the basis for developing a sustainable pumpage plan for their respective areas. The PHMWG is interested in conducting more simulations of the Pearl Harbor Aquifer Sector for the well optimization component of the CWRM milestone plan. This plan would include BWS water summit sustainable pumping goals at existing wells to minimize upward movement of the transition zone, protect ground water quality, and operate the integrated water system as efficiently as possible within the ground water parameters. Additionally, the plan would identify optimal locations for siting new BWS and private wells, when they become necessary.

Because Pearl Harbor provides the majority of the municipal water supply, CWRM contracted the UH WRRC to conduct an analysis of ground water flow using a modified RAM model. Results of that study estimate SY at slightly higher levels than those currently adopted. Eventually, as ground water withdrawals near current SY, more sophisticated modeling should be conducted to improve the distribution of pumping and permitted uses within the sustainable yield. A revision of the SY estimates may be necessary.

PROJECT 01: PEARL HARBOR GROUND WATER MODELING

PRELIMINARY SCOPE

This project should improve understanding and protection of the Pearl Harbor Aquifer Sector via improved modeling, information sharing, and optimized usage.

- Find opportunities to share funding.
- Complete and implement the ground water monitoring plan.
  - Improve access to existing data collected by various agencies.
  - Identify needed monitoring wells.
  - Establish criteria to monitor the resource, optimize withdrawals, and establish additional safeguards.
- Develop a process for stakeholder agencies to agree on an appropriate 3-D model to estimate SY.
  - Identify data needed for more refined modeling
  - Develop a protocol for evaluating various ground water models, i.e., cost-benefit analysis, etc.
  - Identify a preferred model.
  - Incorporate data on land use changes, e.g., increased impermeable surfaces and changes in agricultural irrigation.
  - Include comparison of future water demand estimates and SY.
- Develop an optimization plan for existing and future water infrastructure that may be impacted by a rise in the transition zone.
  - Fund and construct an appropriate model, calibrated to deep water monitor data.
  - Use model results to optimize pumping and water system operation.
- Optimize pumping and water system operation.
- Evaluate the availability of supply.
- Site new wells to minimize impacts to downgradient wells.
- Plan for various scenarios.
- Implement CWRM's remaining actions in accordance with the milestone approach.

PARTICIPATING AGENCIES

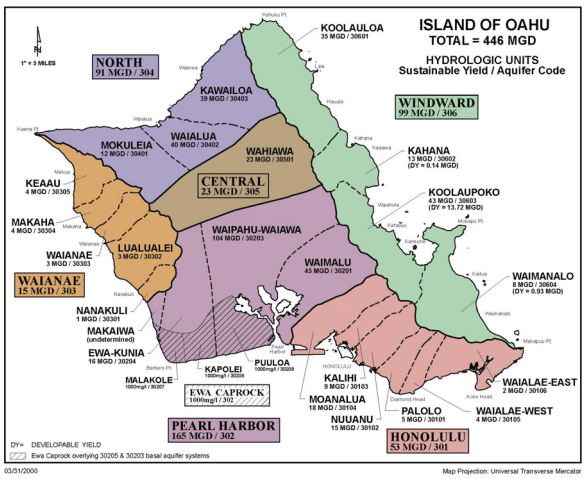
Lead Agencies: CWRM, BWS, USGS
Participating Agencies: UH WRRC, Navy, Private developers and landowners

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

2-3 years



REFERENCES

George L. Yuen and Associates, Inc. *Review and Re-evaluation of Groundwater Conditions in the Pearl Harbor Groundwater Control Area: Report R-78* (Commission on Water Resource Management, Department of Land and Natural Resources).

George L. Yuen and Associates, Inc. *Water Resources Protection Plan, Volumes I & II* (Commission on Water Resource Management, Department of Land and Natural Resources, June 1990),

Clarke C.K. Liu, Analytical Groundwater Flow and Transport Modeling For the Estimation of the Sustainable Yield of Pearl Harbor Aquifer, Project Completion Report to the Commission on Water Resources Management (UH Water Resources Research Center, 2006).

Memorandum of Agreement Pearl Harbor Monitoring Working Group

Delwyn S. Oki, Numerical Simulation of the Effects of Low-Permeability Valley-Fill Barriers and the Redistribution of Ground-Water Withdrawals in the Pearl Harbor Area (O'ahu, Hawai'i, Department of the Interior, USGS, 2005).

PROJECT 02: LOW IMPACT DEVELOPMENT (LID)

PROBLEM STATEMENT

The increase in impervious surfaces, due to development in Central O'ahu over the next 25 years, will reduce aquifer recharge and increase runoff, erosion and pollution. Development in the region is inevitable, but "low impact" standards should be established for the design of man-made structures so that their impact on water resources and natural functions is minimal.

GENERAL BACKGROUND

Low Impact Development (LID) encourages a set of drainage designs focused on capturing and infiltrating storm water into the soil as close as possible to the point at which it hits the ground, to ensure that a site's post-development hydrologic functions (such as ground water recharge, infiltration, and frequency and volume of discharges) mimic those in its pre-development state. It differs from conventional storm water management approaches, which typically aim to move water away from a site as quickly as possible to a central waterway. Besides reducing storm water volumes and peak storm water runoff rates, LID also provides storm water pollutant removal.

LID still allows land to be developed, but in a manner that helps mitigate potential environmental impacts. Some techniques include bioretention areas, grass swales, rain gardens, permeable pavements and vegetated rooftops. Bioretention areas and grass swales are found to be effective in reducing runoff volume and removing metals and nutrients. Bioretention areas are shallow landscaped depressions, usually found in parking lot islands or median strips. During storms, the runoff ponds in the area, is filtered and collected in a perforated under-drain, and returned to the storm drain system.

Sometimes grass swales are used in conjunction with bioretention areas, slowing water movement and allowing for some pollutant removal before being conveyed to the bioretention site. Studies indicate that removal efficiencies are quite good in these techniques for both metals and nutrients. Other methods for reducing impervious surfaces include vegetated rooftops (more feasible for larger structures) and permeable pavements.

Proponents assert that some LID techniques can achieve sediment retention and pollutant removal goals at a lower initial cost than conventional systems, in part because they require less pipe and underground infrastructure. In some cases, up-front LID capital costs are higher than for traditional storm water alternatives, but LID is the least costly choice on a life-cycle basis.

The Hawai'i State Office of Planning (OP) is currently working on a Rural Policies and Best Practices Project, a watershed resources protection educational program for decision-makers, State agency personnel, and the counties about the relationship between land use planning, LID, and watershed resource protection. This project is designed to protect coastal and marine ecosystems and water quality.

The *Revised Ordinances of Honolulu,* Chapter 14, Article 12, Drainage, Flood and Pollution Control, are already generally in line with LID philosophies. Natural methods of drainage and soil infiltration, which absorb and slowly release runoff, are preferred methods of storm water management. The *'Ewa Development Plan* and *Central O'ahu Sustainable Communities Plan* support this school of thought as well, emphasizing control and minimization of non-point source pollution, and see storm water as a potential irregular source of water for recharge of the aquifer.

PROJECT 02: LOW IMPACT DEVELOPMENT

PRELIMINARY SCOPE

Integrating LID into new developments and redevelopments will help to improve water quality and reduce flooding.

- Continue LID public education, such as encouraging current homeowners to make LID improvements to their property via brochures sent to their homes.
- Encourage LID in addition to current City rules and standards.
  - Thoroughly review existing regulations, standards, and technical requirements for development in the public right-of-way for City and County of Honolulu (City) and Hawai'i State Department of Transportation (DOT).
  - Analyze which LID techniques are currently allowed and encouraged by City regulations and permitting processes.
  - Identify the potential hurdles for integrating LID into existing regulations.
  - Conduct meetings and workgroups with land developers, private engineering and design consultants, City officials, and plan reviewers to develop new details and regulations.
  - Develop strategies for implementation of the LID approach.
- Conduct an economic study of the LID life-cycle costs for upcoming development projects in the Central O'ahu Watershed.
- Develop an LID Design Manual suitable for local conditions.
  - Include methods and approaches to design a site.
  - Include detailed hydrological and hydraulic analyses for storm water management requirements, site analysis techniques, site detail selection, and BMP design.
  - Discuss erosion and sediment control requirements for LID.
  - Suggest potential public outreach activities.

PARTICIPATING AGENCIES

Lead Agency: DPP
Participating Agencies: ENV, DOT, BWS, OP

ESTIMATED COST

$0.25 - $40 per square foot depending on the LID structure

TIME FRAME

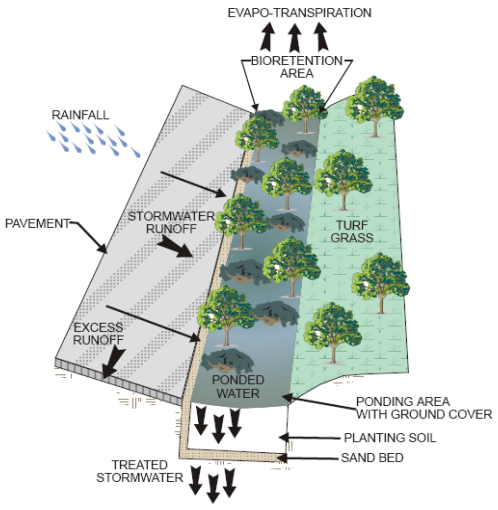
5-10 years

REFERENCES

City and County of Honolulu, Hawai'i, *Revised Ordinances of Honolulu Chapter 14 Article 12: Drainage, Flood and Pollution Control*, 1990, <http://www.honolulu.gov/refs/roh/14a10_19.htm> (January 11, 2006).

Department of Environmental Resources, Prince George's County, *Low Impact Development Design Strategies: An Integrated Design Approach* (Programs and Planning Division, Maryland, 1999).

United States Environmental Protection Agency, (2000). *Low Impact Development (LID): A Literature Review*, EPA-841-B-00-005 (Office of Water, 2000).



Example of bioretention design

PROJECT 03: WATER USE INVENTORY

PROBLEM STATEMENT

A more complete inventory of water use in Central O'ahu is needed in order to make appropriate future water use decisions.

GENERAL BACKGROUND

Surface water in Hawai'i is utilized in many ways; the *State Water Code* recognizes at least ten different stream water uses. Because there are many demands on surface water, proper management and allocation of resources are necessary to ensure fair and sustainable use. The State is currently in the process of developing measurable interim instream flow standards to protect and allow for multiple uses. However, basic data on many streams is limited, as is data on the volume of water required to sustain some recognized instream uses, such as habitat and ecosystem maintenance.

Ground water withdrawals will also inevitably near sustainable yield estimates. Pearl Harbor is the largest potable water aquifer on the island and has a sustainable yield of approximately 165 mgd, of which BWS has a permitted use of 110 mgd. However, Central O'ahu and 'Ewa are among the fastest-growing districts on the O'ahu, and are expected to increase their resident populations by 160,000 people by the year 2030. BWS expects the Central O'ahu Watershed Study area urban demand to increase by 33.6 mgd by the year 2030.

With increasing competition for a limited resource, it becomes more important to have reliable inventories of existing uses and estimates of available ground and surface water. CWRM maintains a state database of known wells and surface water diversions. However, this database was created via self-reporting and has not been fully verified for accuracy. The Department of Agriculture (DOA) has updated its *Agricultural Water Use and Development Plan* to include other large privately owned agricultural water systems in addition to the State-owned systems previously discussed, therefore helping CWRM to improve its water use database. BWS also maintains records of wells and water use, but water use categories do not always coincide with those of CWRM. This presents an issue that should be considered when working with multiple databases.

Due to the extensive history of agriculture in the Central O'ahu and 'Ewa areas, there are many private water systems that have been built over the years. Because the Pearl Harbor Aquifer is a Ground Water Management Area, average monthly ground water withdrawals over 100,000 gpd are required to be reported to CWRM.

In Surface Water Management Areas, a CWRM permit must be obtained for any withdrawal, diversion, impoundment, or other consumptive use of surface water, other than for individual domestic consumption. There are no designated Surface Water Management Areas in Hawai'i at this time, but consumptive uses of Waiāhole Ditch water, which is fed by both ground and surface water sources, now require permits and meters as a result of the Waiāhole contested case hearings. Additional records on surface water uses may be necessary when setting measurable interim instream flow standards for the Central O'ahu Watershed Study area. Surface water withdrawals may be as simple as digging a ditch or laying a pipe and may not be reported. The number of unreported water uses is unknown, but is becoming more important as water demands increase.

PROJECT 03: WATER USE INVENTORY

PRELIMINARY SCOPE

A water use inventory for the Central O'ahu and 'Ewa regions will provide a more accurate picture of water use in the areas and allow for better decision-making regarding future water allocations.

- Collect records of water use from CWRM, BWS, DOA, State Archives, and other potential sources, such as oral histories.
- Coordinate water use information, especially between CWRM, BWS, and DOA, to create a compatible database that can be cross-referenced. Reporting parameters, such as water use categories and units, should be integrated for consistency.
- Record historic accounts of surface and ground water, their use, and current status within the combined database.
- Verify the locations, uses, and volumes of recorded surface water systems.
  - Determine if historic ditches and flumes, such as the McCandless Ditch, are still in use. Identify current volumes or potential reuse possibilities.
  - Survey streams for undeclared diversions, starting with streams with historic records of diversions.
  - Train diversion owners to measure volumes and educate them on the importance of reporting any changes.
  - Identify abandoned reservoirs or other surface water sources that could be used for wild land fire fighting.
- Verify the locations, uses, and volumes of recorded wells and tunnels.
  - Research previously reported wells in order to record current use, identify potential future use, or identify potential candidates for sealing programs to prevent contamination.
- Maintain the database with new entries and updated information.
- Identify large water users that could be converted from potable to non-potable water. Investigate the potential for conversion.

PARTICIPATING AGENCIES

Lead Agency: CWRM
Participating Agencies: BWS, DOA, COE, USDA

ESTIMATED COST

$100,000 - $250,000

TIME FRAME

2 years

REFERENCES

Hawai'i Cooperative Park Service Unit, *Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources* (State of Hawai'i Commission on Water Resources Management, 1990).

Commission on Water Resource Management, Department of Land and Natural Resources, State of Hawai'i, *Declarations of Water Use Volume I: Declarations Summarized by File Reference, Circular C-123*.

Stream Protection and Management (SPAM) Task Force, *Stream Protection and Management in Hawaii: Recommendations and Suggestions* (State of Hawai'i Commission on Water Resource Management, Honolulu, Hawai'i, April 1994).

Siphons carrying Waiāhole Ditch water.

PROJECT 04: AQUIFER RECHARGE PROTECTION

PROBLEM STATEMENT

Urban growth in areas where ground water infiltration is at its highest could potentially impact recharge to Oahu's largest aquifer.

GENERAL BACKGROUND

"Recharge is an integral part of the hydrologic cycle and a significant factor in the determination of sustainable yield."[269] In order to provide water to the growing communities in Central O'ahu, 'Ewa, and the PUC, natural infiltration areas need to be protected to ensure potable ground water supplies are maximized.

The Central O'ahu SCP restricts urban zoning to within the Urban Community Boundary (UCB), but with the general intent to protect agricultural lands and open space, not increase recharge.[u] An aquifer recharge protection zone (ARPZ) should be identified to protect critical infiltration areas, and therefore ground water quantities, much like the existing UIC and Pass/No Pass lines protect the quality of the ground water.

The most productive ground water infiltration areas are located in the *mauka* areas of the Ko'olau Mountain Range. While State Conservation Districts were created in part to protect watersheds and water sources, much of the district was defined in 1957.[270] Since then, additional data has been acquired to better define what areas are critical for ground water infiltration. BWS currently estimates that the 50-inch isohyet is where average annual rainfall estimates exceed the evapo-transpiration rate, thus allowing for maximum ground water recharge. Therefore, lands above the 50-inch isohyet are the most critical for ground water infiltration. This and other inputs should be considered when defining criteria for ARPZ designation and identifying acceptable land uses within the protection zones.

For those areas that are currently designated as State Land Use Agriculture or Urban, but are within what is decided to be a critical aquifer recharge zone, recommendations may include reclassification from Urban to Conservation in order to protect water resources as intended by State Land Use law. City DP/SCP Urban Community Boundaries could also be aligned to protect identified ARPZs.

Another option would be to create development criteria for those areas that are currently both within a critical recharge zone and designated either Urban or Agriculture. Project Number 02, Low Impact Development, may provide some useful guidelines to apply to development. Some considerations include impacts on land owners with existing zoning that will need to be ether restricted or re-zoned, and amendments to City zoning codes.

Land use restrictions within an ARPZ should also consider impacts on water quality, as the intended uses for ground water include potable human consumption. Proper coordination and compliance with existing and developing ground water quality protection programs, such as the source water protection program, the Navy's hydrologic zone of influence around their Waiawa shaft, the DOH's UIC program, and the BWS Pass/No Pass line should occur.

[u] The Central O'ahu UCB generally follows the existing Conservation District boundary, except where it recognizes the lands proposed for addition to the Conservation District by the 1992 State Land Use District Boundary Review.

PROJECT 04: AQUIFER RECHARGE PROTECTION

PRELIMINARY SCOPE

Recharge of the ground water aquifers would be maximized by protecting the most beneficial infiltration areas.

- Form an agency working group to define the ARPZ, identify acceptable land uses and possible restrictions, and propose mechanisms for implementation.
  - Develop an MOA to work together and share information toward protecting critical infiltration areas.
  - Organize an advisory committee of land owners and other interests to provide input to the process.
  - Use established ground water models to evaluate land use impacts on aquifer SY and recharge area reduction on downgradient sources. If impacts are significant, use as a basis for establishing ARPZs.
  - Identify and collect data needed in order to improve decision-making, such as rainfall, existing land use, irrigation, potential evaporation, existing land cover, soil types, runoff, stream flow, etc.
- Define the ARPZ.
  - Identify criteria for definition.
  - Provide for ongoing updates as additional data is generated.
- Identify acceptable land uses and development criteria.
  - Consider private sector issues and concerns.
  - Coordinate and comply with existing and developing ground water protection programs.
  - Provide for ongoing updates.
- Propose and enact implementation strategies. Possibilities include:
  - Changes to City zoning and/or State land use district boundaries.
  - Modification and/or maintenance of DP/SCP UCBs.
  - Changes to City zoning requirements and allowed uses.
  - Policy adoptions by the State Land Use Commission, CWRM, BWS, and DPP.
  - Development criteria for areas within the protection zone, possibly including such requirements as low impact development.

PARTICIPATING AGENCIES

Lead Agency: DPP
Participating Agencies: USGS, DLNR, CWRM, BWS, UH WRRC, DOH, Navy

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

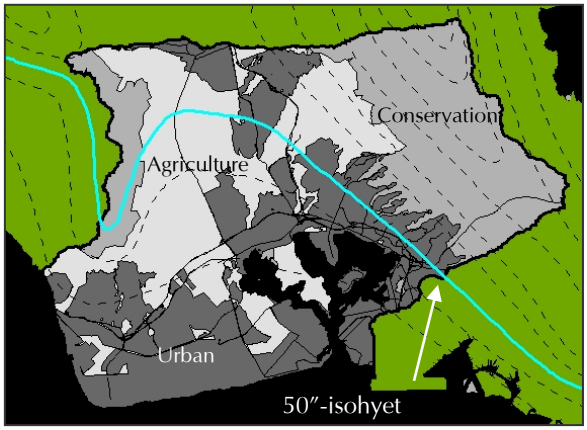
2 years

REFERENCES

Aly El-Kadi, Chittaranjan Ray, et. al., *Hawaii Source Water Assessment Program Report* (Water Resources Research Center UH Mānoa, prepared for State of Hawai'i Department of Health Safe Drinking Water Branch, November 2004).

George A.L Yuen & Associates, Inc., *State Water Resources Protection Plan* (Commission on Water Resources Management, Department of Land and Natural Resources, State of Hawai'i, March 1992),

Office of State Planning, *State Land Use District Boundary Review, Oahu* (1992).



There are currently urban, agricultural, and conservation lands above the 50-inch isohyet in the Central O'ahu area.

PROJECT 05: WATERSHED INFILTRATION ENHANCEMENT

PROBLEM STATEMENT

Reduced water infiltration has and will continue to reduce the sustainable yield (SY) of area aquifers, decreasing the amount of water available for human use.

GENERAL BACKGROUND

According to various CWRM reports, changing land and water use over the past 30 years has reduced ground water recharge in the Pearl Harbor Aquifer. Maintaining and increasing the current SY of Central O'ahu aquifers is dependent upon the capacity of the soil for optimal water infiltration. The types of soils found in the project area typically drain well to excessively well, but the structural condition of the soil has been altered by various land uses.

Undisturbed forests maintain soils' structural condition, allowing for optimal infiltration. Additionally, native, multi-tiered forests are thought to break the force of falling rain, slowing storm water runoff and increasing infiltration. However, native ecosystems in the Central O'ahu Watershed have been reduced to only 20% of their previous extents due largely to clearing for human development and agriculture. Disturbances such as off-roading or rooting by feral pigs have left portions of the forest vulnerable to invasive flora, which transform the multi-tiered forest into a one-tiered monocrop.

Agriculture has had a large impact on recharge rates over the decades. Early sugar plantations actually contributed to recharge via irrigation practices; however, closure of plantations and conversion from furrow to drip irrigation (a more efficient irrigation method) in the mid-1970s to early 1980s has reduced agriculture's contribution to ground water recharge. Conversely, agriculture also reduced infiltration by altering the soils, most notably by creating a "plow pan," a compacted area a few feet underground caused by tillage methods. Plow pans continue in areas that were sugar plantation agriculture and now abandoned or in small lessee use, and can reduce soil permeability by about 1 in/hr to 0.1 in/hr.

Infiltration rates are reduced even further under highly disturbed urban areas, where soil structure may be compacted due to development or by use of impervious surfaces, such as concrete and asphalt. A potentially significant decline in infiltration rates is possible in the Central O'ahu Watershed due to the approximately 16,000 housing units planned to be built within the next 10 years[v].

An alternative method for increasing aquifer recharge is via artificial means. Some of this is being accomplished via golf course retention sites that detain storm water and control flooding, although recharge is not the main objective. Storm water runoff from urban areas can be reclaimed for recharging the aquifer. One potential project suggested in the *Hawai'i Stormwater Reclamation Appraisal Report* lies near Iroquois Point Road in 'Ewa, which would capture storm water in a deep infiltration trench. There have also been suggestions to build a dam in Kīpapa Gulch to hold storm water for infiltration. Concerns with this project include construction and maintenance costs, liability, and quantification of benefits. Another potential artificial recharge project includes the use of excess recycled water. The City is considering a project that would use excess R-1 water to recharge the caprock aquifer via an existing 6-foot deep, 100-yard long trench near the Honouliuli Wastewater Treatment Plant (WWTP). DOH permits would be required for this project to proceed.

[v] Calculated remaining number of housing units to be built by 2015 using Table 2-13, Status of Housing Projects as of June 30, 2005.

PROJECT 05: WATERSHED INFILTRATION ENHANCEMENT

PRELIMINARY SCOPE

The objective of these projects is to enhance water infiltration for aquifer recharge.

Research

- Determine recharge rates for each aquifer system area within the Pearl Harbor Aquifer sector area.
- Map data on aquifer recharge areas using rainfall, land use, soils, surface water, and well water withdrawal.
- Investigate the use of a model such as Branched Aquifer Recharge System (BARS) using MODFLOW to engineer a hydrologic system to enhance natural recharge.

Lead Agencies: CWRM, BWS
Participating Agency: USGS

Reforestation and Soil Conservation Practices

- Map areas of monocrop forest to identify priority sites for additional plantings to increase infiltration.
- Conduct research to determine the best vegetation mix for maximum rainfall infiltration at proper elevations.
- Implement native plant rehabilitation and restoration.

Lead Agencies: DLNR, Army
Participating Agencies: UH Botany / WRRC / NREM, KMWP

- Increase funding for invasive plant species control and eradication.

Lead Agencies: USDA Animal and Plant Health Inspection Service (APHIS), DLNR
Participating Agency: KMWP

- Encourage soil conservation practices in agricultural areas such as mulch tillage, rotation of cover crops, and interim planting with deep-rooted perennials.

Lead Agency: NRCS.
Participating Agency: UH College of Tropical Agriculture and Human Resources (CTAHR)

Storm Water Reclamation/Artificial Recharge

- Research the effectiveness and cost of various artificial recharge methods as an aquifer recharge solution.
  - Conduct a feasibility study for a dam at Kīpapa Gulch
  - Implement the proposed storm water reclamation project near Iroquois Point Road in 'Ewa.
  - Identify additional storm water reclamation sites within the project area.

Lead Agencies: ENV, DOH
Participating Agencies: BWS, CWRM, UH WRRC, USGS

- Recycled Water Reuse / Disposal
- Obtain DOH approval for trench disposal near Honouliuli WWTP.
- Investigate other alternatives to recycled water reuse / disposal.

Lead Agencies: ENV, BWS
Participating Agency: DOH

ESTIMATED COST

$500,000 – $1,000,000

TIME FRAME

2-50 Years

REFERENCES

CWRM, *Interim Report of a Research Project on Analytical Groundwater Flow and Transport Modeling For the Estimation of the Sustainable Yield of Pearl Harbor Aquifer* (UH WRRC, 2005).

CWRM, *Final Report: Reevaluation of the Ground-Water Resources and Sustainable Yield of the Ewa Caprock Aquifer*, PR-1996-01 (1996).

U.S. Department of the Interior, *Hawaii Stormwater Reclamation Appraisal* (CH2MHill, 2005).

E. Vivoni, *Distributed Aquifer Recharge Enhancements in Arid Zones*, 2000, <http://web.mit.edu/vivoni/www/aridzone.html> (January 31, 2006).

PROJECT 06: WATER CONSERVATION PROGRAM

PROBLEM STATEMENT

Increased water consumption is putting a strain on existing resources and will force the development of new sources.

GENERAL BACKGROUND

Water consumption has been steadily increasing as Honolulu's population grows. Most of the potable water supply on O'ahu comes from ground water, which takes nature decades to replace. Since the 1950s, water conservation programs have been developed as a way to minimize water demand while reducing financial costs and mitigating environmental impacts.

Water conservation reduces overall consumption, thereby lowering the amount of water that must be pumped from the ground. This in turn, lowers operation costs by reducing the energy required for pumping, treatment, and disposal. Reduced demand also delays the need to construct new water supply facilities. This reduces costs and creates fewer social equity issues and environmental impacts related to the siting of new facilities. Long-term conservation measures are thought to be able to reduce consumption by 10 to 20% over 20 years.

The benefits to conserving water also come with some disadvantages that must be weighed and addressed. Lower demand will result in lower revenues to water purveyors, who require certain funding targets to be met. Effective conservation programs require dedicated staff and funding, which is often difficult to justify due to unreliable or non-existent estimates of water savings. Additionally, overly optimistic expectations may lead to water shortages if anticipated water savings do not materialize.

Despite these issues, conservation is still viewed as a viable, affordable, and resource-friendly option. BWS already engages in specific water conservation projects, which are implemented by their Communications, Customer Care, and Water Resources Divisions and Internal Conservation group. These efforts include: public education and outreach; leak detection, repair, and maintenance; large water user programs; regulation; and alternative source development, recycling, and conservation alternatives. The overall goal of the BWS program is to reduce water use by 10%.

At the State level, CWRM has developed a prototype water conservation plan for DLNR, which include low-flow fixtures and efficient irrigation systems, with the intent to establish policies and procedures for a statewide conservation program. The goals of this effort are to address both potable and non-potable water demands, identify practical water conservation measures, and develop implementation schedules and budgets for application of appropriate water conservation measures throughout the State government.

BWS also signed a Water Conservation Partnership MOU with UH Mānoa in 2003. The goals of the partnership are to develop water conservation programs and projects for the UH Mānoa campus; conduct economic analyses to meet the goals and objectives of the Partnership; consider general activities to increase community education and support for the Partnership; and develop and implement specific agreements, contracts, and working plans for individual projects.

Existing efforts that have proved somewhat successful include water-saving appliances, such as front-load washing machines, low-flush toilets, and low-flow showerheads, and irrigation-water saving devices, such as moisture/rain sensors and weather station-controlled automatic sprinkler systems, which reduce irrigation waste.

PROJECT 06: WATER CONSERVATION PROGRAM

PRELIMINARY SCOPE

A Water Conservation Program should aim to maximize water use efficiency for all users through a variety of facility improvements and behavioral changes.

- BWS Conservation Program.
  - Dedicate funding and staff toward coordinating a water conservation program.
  - Continue existing programs in the five designated program areas.
  - Continue MOU with UH Mānoa and use it as a model for partnerships with other large water users.
  - Monitor water use to track water savings associated with conservation programs, where possible.
  - Evaluate conservation measures.
- Water Conservation Program for State Agencies.
  - Monitor effectiveness of DLNR prototype plan and implementation.
  - Tailor conservation plan to fit additional State agencies, starting with those that use the most water, possibly DOA, DOT, and DHHL.
  - Develop and implement a statewide conservation plan.
- Water Conservation Program for City Agencies.
  - Develop a water conservation plan with the same intent as the DLNR pilot plan.
  - Focus on City agencies that consume the most water, possibly ENV, Department of Enterprise Services (municipal golf courses), and Department of Parks and Recreation.
  - Conversion to non-potable water for irrigation of large landscaped areas.
- Potential partnership between BWS and other City Agencies and/or State agencies.
  - Install moisture sensors as a means of conserving irrigation water.

PARTICIPATING AGENCIES

Lead Agency: BWS
Participating Agency: CWRM

ESTIMATED COST

$500,000 - $1,000,000

TIME FRAME

Ongoing

REFERENCES

Luisa F. Castro, *Water Issues in Hawaii: A Survey of Public Attitudes (WI-2)* (Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawai'i at Mānoa, August 2005).

Fukunaga and Associates, Inc., *Prototype Water Conservation Plan for the Department of Land and Natural Resources (DLNR)* (Commission on Water Resources Management, February 2005).

William O. Maddaus and Lisa A. Maddaus, *Advancing Water Conservation Concepts: Recommendations for Policy-Making, Planning, and Programme Design* (Economic and Social Commission for Asia and the Pacific, Ad Hoc Expert Group Meeting on Water Use Efficiency and Conservation, October 2001).

BWS spends approximately $8-10 million per year to replace aging waterlines and facilities, thereby reducing main breaks and water loss caused by leaks.

PROJECT 07: RECYCLED WATER RESOURCE DEVELOPMENT

PROBLEM STATEMENT

Alternative water sources are needed to minimize the demand on potable water and keep potable water sources healthy.

GENERAL BACKGROUND

The Central O'ahu Watershed Study area is expected to require approximately 33 mgd of increased potable demand by 2030. Withdrawals and water transfers between districts are limited, making recycled water an important component of the water supply picture.

BWS currently recycles water to R-1 (tertiary disinfected) and RO (reverse osmosis demineralized water) quality at its Honouliuli Water Recycling Facility (HWRF) in 'Ewa, with water supply obtained from the Honouliuli Wastewater Treatment Plant (WWTP). However, the Honouliuli WWTP secondary treatment facility is currently at capacity at 13 mgd, limiting the amount of R-1 water that can be produced. According to the 2006 City Capital Improvement Program (CIP), planning is underway for the expansion of the secondary treatment facility by 13 mgd, increasing capacity to 26 mgd. This would allow for expansion of the HWRF to provide for future non-potable demand. However, funding limitations will restrict expansion to the long term.

Currently, recycled water is used for golf course and landscape irrigation in 'Ewa, although it could also be used to irrigate certain crops. In drier months, consumption is high, sometimes leading to difficulties in meeting peak demands. During these peaks, recycled water is supplemented with non-potable brackish caprock water.

Recycled water use may expand outside of 'Ewa. Recycled water infrastructure, such as the Wahiawā/Central O'ahu Recycled Water System, is presently being evaluated to irrigate the City's Central O'ahu Regional Park and the future Waiawa golf courses. Various infrastructure options are being considered. The Wahiawā WWTP currently produces R-1 water based on "outdated" previous standards. The current level of treatment cannot be used on vegetable crops, but it could be used for turf irrigation.

A Soil Aquifer Test study was recently conducted by BWS to test the effects of recycled water on potable aquifers to expand potential application. The result of the testing showed that recycled water application is acceptable over the potable aquifer at appropriate rates based on the geology and vegetation of the site.

Membrane Bioreactors (MBRs) are being studied as a way to recycle wastewater on-site. MBRs eliminate several treatment steps and therefore require less space, while producing higher quality water than a typical treatment plant using secondary and tertiary treatment. This would allow for the placement of small treatment facilities where wastewater is being generated, thus saving the cost of transport to and from a centralized location. The WateReuse Foundation, ENV, and BWS have sponsored a pilot study on the feasibility of MBR use in Honolulu. If Satellite Treatment Centers are developed by BWS and ENV, the City could potentially operate and maintain them. BWS and the City are currently discussing the possibility of infrastructure projects at the Mililani WWTP and at the Central O'ahu Regional Park.

PROJECT 07: RECYCLED WATER RESOURCE DEVELOPMENT

PRELIMINARY SCOPE

The proactive development of recycled water resources is needed to match water quality with use to sustain the potable water resource.

- Continue to require dual water systems in new 'Ewa developments.
- Expand non-potable water master planning.
- Develop brackish ground water wells in Kapolei West and East Kapolei.
- Once non-potable water use is expanded in 'Ewa, begin feasibility study for expansion of Honouliuli Water Recycling Facility.
- Determine the best options for expanding recycled water facilities at Wahiawā WWTP. Options include:
  - Upgrade to R-1 standards, install emergency storage and continue lake discharge.
  - Convert plant to MBR, removing the need for storage.
  - Upgrade to R-1 standards, install effluent pipe and discharge into Dole Ditch.
  - Upgrade to R-1 standards, install effluent pipe and discharge to Waiāhole Ditch.
  - Transporting raw sewage to the Honouliuli WWTP via Kamehameha Highway.
- Investigate the feasibility of using MBRs to recycle water for non-potable uses at various points along existing wastewater mains.
  - Include feasibility of also using an MBR at the Mililani WWTP.
  - Identify potential users.
  - Investigate potential funding sources to supply up-front costs for MBR facilities.
- Begin feasibility study for additional locations for use of recycled and brackish water mixing.
- Evaluate, assess the feasibility of, and site recycled water storage facilities to help meet peak recycled water demand.
- Foster partnership between BWS and City ENV for improved production and distribution of recycled water.

PARTICIPATING AGENCIES

Lead Agencies: BWS, ENV
Participating Agency: CWRM

ESTIMATED COST

$500,000 - $1,000,000: Facility Plan, Feasibility Study
$15,000,000: Wahiawā/Central O'ahu Recycled Water System

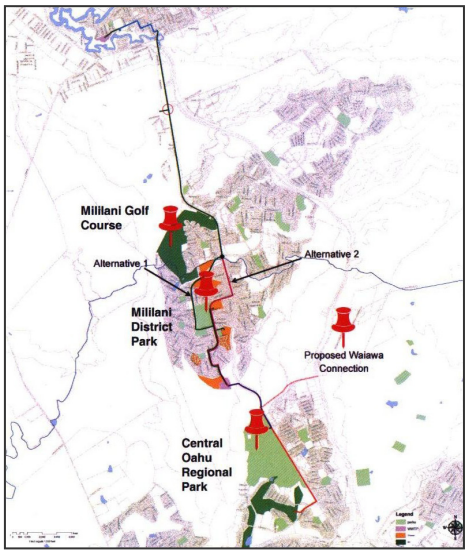
TIME FRAME

5-10 years

REFERENCES

Brown and Caldwell, *Assessment of Recycled Water in Central Oahu* (Honolulu Board of Water Supply, March 2005).

Department of Land and Natural Resources, Commission on Water Resource Management, *2004 Hawai'i Water Reuse Survey and Report*, (The Limtiaco Consulting Group, 2005).



Recycled water transmission line to the Central O'ahu Regional Park.

PROJECT 08: DESALINATION PROJECT

PROBLEM STATEMENT

New potable water source technologies need to be developed to prepare for when ground water sources are not able to meet Oahu's growing water demand.

GENERAL BACKGROUND

All potable water provided by BWS is supplied by ground water; approximately 88% of the Pearl Harbor Aquifer Sector Area sustainable yield estimate is permitted for use by BWS and other users. Potable water demand is eventually anticipated to exceed Pearl Harbor sustainable yields, thus triggering a need to reduce reliance on ground water sources. Diversification of water sources is also necessary to minimize increasing costs for the treatment of ground water contaminated by various land uses, effects of ground water withdrawal from dike formations on surface water, impacts from periodic drought occurrences, and the high cost of North Shore water development and transmission to 'Ewa.

To supplement ground water resources, BWS is investigating the feasibility of numerous alternative water sources, such as recycled water, Ocean Thermal Energy Conversion (OTEC), and desalination. Desalination is a process that removes dissolved minerals from seawater, brackish water, or treated wastewater. It is currently used in California, Florida, and over 100 countries to supply or supplement drinking water needs, and has proven to be an economically feasible and reliable source of fresh water. Various desalination technologies exist, including distillation, vapor compression, reverse osmosis, electrodialysis, vacuum freezing, membrane distillation, and solar dehumidification.

In a 2003 Draft EIS, BWS proposed a 5 mgd reverse osmosis facility at Kalaeloa. It is estimated that the average home uses 400 gallons per day (gpd); therefore, a 5 mgd desalination plant could supply up to 12,500 homes with potable water. Other water uses could also benefit from desalinated water.

The Navy has already provided BWS with 20 acres of land for a desalination plant at Kalaeloa as a part of a public benefit conveyance, off-setting some of the initial costs and providing enough area for future expansion tied to Ewa's growth.

As in any endeavor, the benefits of desalination should be weighed against its drawbacks. Disadvantages of desalination technology include high construction and operating costs, high electricity demand (approximately 5 MW for every 5 mgd), and environmental impacts associated with the disposal of waste brine. Operation and maintenance (O&M) costs run over $3 per thousand gallons of water, as opposed to less than $1 per thousand gallons in O&M costs for ground water. Problems identified in the EIS will need to be resolved in the next phase of development.

After a reassessment of their capital program priorities, long-range financial plan, available ground water sources, and infrastructure capacity, BWS has decided to defer immediate implementation of a desalination plant. Instead, other methods, such as conservation, will be used to meet demand; BWS currently has several water conservation programs (see Project Number 06). However, even with conservation, ground water supplies will still need to be supplemented in the future. Alternative water sources will still be necessary to provide a sustainable, renewable water system, thus making a desalination plant a critical and necessary component of the BWS water infrastructure.

PROJECT 08: DESALINATION PROJECT

PRELIMINARY SCOPE

This project would design and build a desalination plant to supplement existing potable water supplies.

- Complete and publish the Final EIS.
- Secure funding for the design and construction phase.
- Contract for design and construction. Contract scope could include:
  - Selection of an appropriate post-treatment method to eliminate corrosion of distribution lines.
  - Construct/upgrade distribution systems, as needed.
  - Implement mitigation measures recommended in the EIS, some of which may include installing a monitoring well to determine if waste water is behaving as theorized and if source water is being contaminated.
- Implement a pilot desalination plant to test the technology before full buildout.
- Support renewable energy projects, energy conservation, and projects that reduce conventional power generation costs equal to the power needs of the desalination facility, such as:
  - Evaluate the feasibility of an ocean wave generating facility off Kalaeloa to offset desalination's energy needs.
  - Apply photovoltaic technology at the desalination facility for lighting, etc.
  - Expand deep seawater well cooling for buildings as an energy and water conservation measure.
  - Demonstration/pilot radiant cooling using the desalination facility's cold seawater source wells.
  - Provide RO quality recycled water to the City's H-Power Plant and HECO's power plants to reduce the cost of demineralizing potable water.
  - On-site power generators to reduce HECO grid power during peak hours.
- Monitor distribution system to ensure water quality.
- Continue water conservation programs to delay the need for plant expansion.
- Evaluate the effect of capacity expansion on future water rates.

PARTICIPATING AGENCIES

Lead Agency: BWS
Participating Agencies: CWRM, HECO

ESTIMATED COST

Construction: $40-$45 million for a 5 mgd facility
O&M: $5.5-$6 million per year

TIME FRAME

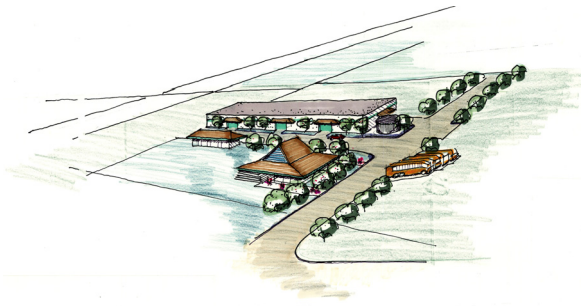
8-10 years

REFERENCES

Boyle Engineering Corporation, *Desalination for Urban Water Supply* (Prepared for California Urban Water Agencies, July 1991).

Oceanit, *Draft Environmental Impact Statement for the Proposes Kalaeloa Desalination Facility, Kalaeloa, Ewa, Oahu, Hawaii* (Honolulu Board of Water Supply, March 2003).

Susan E. Pantell, *Seawater Desalination in California*, October 1993, prepared for the California Coastal Commission, <http://www.coastal.ca.gov/desalrpt/dtitle.html#TOCDesalination> (February 15, 2006).



Proposed Kalaeloa Desalination Plant.
(BWS/Oceanit)

PROJECT 09: SOURCE WATER PROTECTION PROGRAM

PROBLEM STATEMENT

Growing populations and a mix of land uses in Central O'ahu pose threats to ground water quality and ultimately, municipal water supply for approximately 40% of Oahu's population.

GENERAL BACKGROUND

The 1996 reauthorization of the Safe Drinking Water Act required states to develop assessments of drinking water sources. In compliance with this mandate, the UH Water Resources Research Center developed the *Hawaii Source Water Assessment Program* (HISWAP) report for the State Department of Health in 2004. The four elements of the report included the delineation of the area around a drinking water source through which contaminants may travel to the supply; an inventory of activities that may lead to the release of microbiological or chemical contaminants within the delineated area; determination of the susceptibility of the drinking water source to become contaminated from surrounding potential contaminating activities (PCAs); and public disclosure and access to assessment information.

The HISWAP defined source water "susceptibility" as "the potential for a Public Water System to draw water contaminated by inventoried PCAs at concentrations that would pose concern." Relative susceptibility was determined using a numerical scoring system. Scores for ground water sources on O'ahu ranged from 0 to 2119, with higher scores indicating greater susceptibility.

Central O'ahu and 'Ewa water sources ranged in score from 5 to 1530, lower than other scores on O'ahu, but still indicating a relatively significant threat to drinking water quality in certain locations, particularly from agricultural chemicals. This is of concern for the Pearl Harbor Aquifer, which provides most of the potable drinking water on O'ahu.

Local drinking water purveyors were provided the HISWAP report in order to help them protect their sources. While local purveyors are responsible for source water protection, DOH is offering funding for planning and project implementation.

The U.S. Navy protects their potable water sources in Waiawa through a "Hydrologic Zone of Contribution" that delineates an area where land uses may affect the ground water supplying the source and restricts the type of development that is allowed to occur there. This might serve as a model for other water purveyors to protect their own sources

Water that contains pollutant levels higher than allowed by State and Federal standards require additional costs to install, operate, and maintain water treatment facilities, such as granular activated carbon (GAC) treatment facilities. Increased treatment may be necessary if ground water supplies become increasingly contaminated by land use activities. Additionally, new emerging contaminants may require new forms of treatment beyond the existing GAC treatment technology currently used. Thus, preventing contamination should be a priority.

Kunia Wells I treatment facilities.

PROJECT 09: SOURCE WATER PROTECTION PROGRAM

PRELIMINARY SCOPE

A Central O'ahu/'Ewa source water protection program should include the following actions to prevent contamination of the potable aquifer:

- Prioritize sources for protection. Consider susceptibility scores from the HISWAP report as well as current importance of a source to the potable water supply.
- Test sources with the highest susceptibility scores for likely contaminants as identified in the HISWAP report.
- For those sources that show contamination at or near threshold levels and/or a trend of increasing levels of contamination, determine the source of contaminants already present in ground water sources.
- Find ways to reduce or eliminate the impact of existing PCAs, particularly agricultural activities, within delineated capture zones.
    - Expand the design of agricultural BMPs to minimize effects of chemical application on ground water.
    - Identify the feasibility of phasing out recognized contaminating land uses from capture zones.
- Examine the overlap between delineated capture zones and land available for new urban development and agriculture.
- Convene a task force to identify appropriate measures to eliminate or reduce the conflict between land uses and capture zones. Include representatives from environmental groups, developers, farmers, residents, and others who would be directly impacted.
- Investigate preventive measures for restricting new PCAs within capture zones, particularly in Waiau, Newtown, and Pearl City, where susceptibility scores were the highest, or in Kalauao and Punanani, where well yields are relatively high. Restrictive methods to consider include zoning or permitting requirements, policies in DPs and SCPs, easements, land acquisition, and agreements with landowners.
- Develop education and outreach for homeowners and businesses.
- Conform with and feed into an island-wide source water protection program
- Develop appropriate draft land use regulations that would aid in the protection of critical ground water sectors.

PARTICIPATING AGENCIES

Lead Agencies: BWS, DPP
Participating Agencies: DOH, CWRM, Navy

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

3-4 years

REFERENCES

Aly El-Kadi, Chittaranjan Ray, et. al., *Hawaii Source Water Assessment Program Report* (Water Resources Research Center UH Mānoa, prepared for State of Hawai'i Department of Health Safe Drinking Water Branch, November 2004).

Charles D. Hunt, *Ground Water Quality and its Relation to Land Use on Oahu, Hawaii, 2000-01, Water-Resources Investigations Report 03-4305* (U.S. Geological Survey, 2004).

National Association of Counties, *Counties Protecting Drinking Water Through Partnering* (August 2000).

State of Hawai'i Department of Health, *Hawaii Ground Water Protection Strategy* (1990).

PROJECT 10: INACTIVE LANDFILL MITIGATION

PROBLEM STATEMENT

Inactive landfills could pose a threat to potable ground water quality.

GENERAL BACKGROUND

The Pearl Harbor Aquifer Sector underlies the City's 'Ewa, Central O'ahu, and a portion of the Primary Urban Center Development Plan Districts. This aquifer supplies most of the potable water withdrawn for municipal use and has an estimated sustainable yield of 165 mgd.

The *O'ahu Inactive Landfills Relative Risk Evaluation* was conducted for the BWS to evaluate risks to human health as a result of ground water contamination from inactive landfills. The risk evaluation identified 19 inactive landfills spread throughout the Central O'ahu and 'Ewa region. In terms of their potential effect on ground water quality, seven of the landfills are located within one mile of a municipal well. Sixteen landfills are located *mauka* of the BWS Pass/No Pass line and *mauka* of the DOH UIC line. The landfills were used primarily for agricultural wastes, but due to poor records and rotation of disposal fields and dumps, it is difficult to determine specific risks from agricultural landfills. Eight of the landfills are designated as Category 1, or high risk, i.e., over a potable aquifer and located within one mile of drinking water wells.

Category 1 Inactive Landfills in the Central O'ahu and 'Ewa Districts

- Oahu Sugar 1
- Oahu Sugar 2
- Oahu Sugar 3
- Oahu Sugar 4
- Oahu Sugar 5
- Oahu Sugar 6
- Puu Palailai
- Mililani Old

Characteristics of Inactive Landfills in the Central O'ahu and 'Ewa Districts

Usage	Number of Landfills
Agricultural	12
Municipal	2
Military	2
Private	3

Mauka of No Pass Line	16
Makai of No Pass Line	2
Unspecified	1

Capped	3
Uncapped/Unknown	16

Lined	0
Unlined/Unknown	19

Preliminary risk-modeling assessments indicate that none of the landfills have an Excess Cancer Risk Hazard Index that exceeds acceptable US EPA Comprehensive Environmental Response, Cleanup, and Liability Act (CERCLA) thresholds. No further calculation of risk was determined to be necessary at this time. If, however, further investigations were to be conducted, the current risk evaluation recommended Oahu Sugar Dumps 3, 5, and 6, within the Central O'ahu and 'Ewa Districts, for further studies. These three landfills are within one mile of BWS wells, are above vulnerable potable water sources, indicate no evidence that they are capped, and they are within the capture zones of BWS wells. Additional precautionary investigations are also suggested for the wells that lie within one mile of Category 1 landfills and have landfills within their capture zones.

PROJECT 10: INACTIVE LANDFILL MITIGATION

PRELIMINARY SCOPE

Monitoring of inactive landfills will ensure that proper steps will be taken to protect the public if potentially harmful substances leach into the potable aquifer.

- If further investigations are conducted, they should focus on Oahu Sugar Dumps 3, 5, and 6.
- Monitor Category 1 landfills and downgradient wells.
  - Monitor high-risk landfills for vertical or horizontal migration of contaminants.
  - Sample wells for typical landfill contaminants.
- Prepare a plan of action to be initiated if substances attributable to inactive landfills are detected in potable sources.
  - Sample for typical contaminants identified in the *Inactive Landfills Relative Risk Evaluation*
  - Develop trend analyses.
  - If target constituents are found at actionable levels, program best available technologies from the EPA before MCL is reached.
- Strengthen policies to restrict new landfills to areas downgradient of the potable aquifer.
  - Encourage the City ENV and State Land Use Commission to adopt the Pass/No Pass line, downgradient wells, and aquifer quality as considerations when selecting new landfill sites.
- Identify appropriate mitigative actions that could be applied to the most high-risk landfills to reduce threats to the potable water supply.
  - Explore availability of programs such as the EPA Brownfields for assistance.
  - Determine if risks are high enough to justify closure of a potentially affected well and replacement with another well.

PARTICIPATING AGENCIES

Lead Agencies: DOH, ENV
Participating Agencies: CWRM, USGS, UH WRRC, BWS

ESTIMATED COST

$250,000 - $500,000

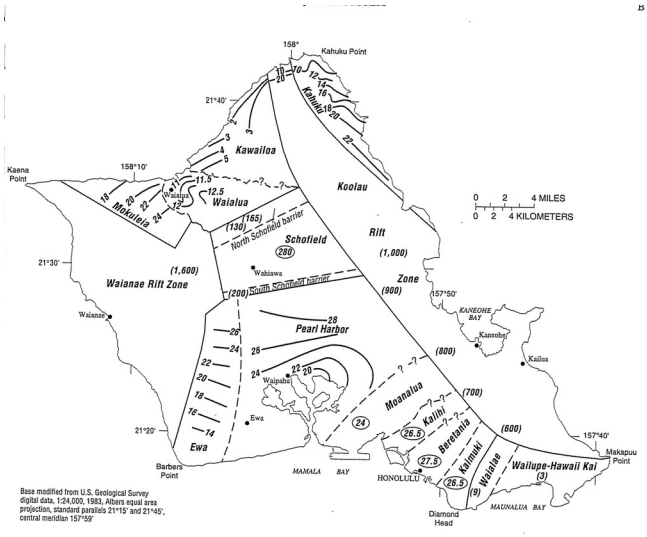
TIME FRAME

Ongoing

REFERENCES

Aly El-Kadi, Chittaranjan Ray, et. al., *Hawaii Source Water Assessment Program Report* (Water Resources Research Center UH Mānoa, prepared for State of Hawai'i Department of Health Safe Drinking Water Branch, November 2004).

URS, *Oahu Inactive Landfills Relative Risk Evaluation Draft* (Honolulu Board of Water Supply, March 2005).



Ground water flow influences how landfills affect wells.

PROJECT 11: DETENTION / INFILTRATION BASINS STUDY

PROBLEM STATEMENT

The impact that detention and infiltration basins have on ground water quality is not known and should be addressed.

GENERAL BACKGROUND

The *Revised Ordinances of Honolulu*, Chapter 14, Article 12, discuss Drainage, Flood and Pollution Control. The City finds that there is a growing need to protect the City's natural watercourses and other vital water resources from contamination and pollution, and every effort should be made to minimize flood damage potential. Natural methods of drainage and soil infiltration, which absorb and slowly release runoff, are preferred methods of storm water management.

Detention and infiltration basins are designed to reduce the impacts of increased runoff rates and remove pollutants contained in storm water runoff. Pollutants include excess sediments, trash, oil and grease, pesticides and fertilizers, harmful bacteria, viruses, and metals such as lead, cadmium and copper. Although they can be effective at removing some pollutants through settling, dry extended detention basins are less effective at removing soluble pollutants because of the absence of a permanent pool. As sediment within the basin accumulates, the concentration of metal and organic contaminants could exceed toxic levels, and must be periodically removed to allow for effectiveness and prevention from flushing into an adjoining stream. Infiltration basins can provide the highest pollutant removal effectiveness of all pond best management practices, and can provide for some ground water recharge if the soil conditions permit.

In the case of subdivisions, the City's chief engineer may require the construction of permanent detention or retention drainage structures to contain or divert storm water runoff. There are large detention basins in the 'Ewa by Gentry, Royal Kunia, and Ocean Pointe subdivisions, and a few smaller detention basins in Mililani Mauka. Many of the basins used for flood control were integrated into golf courses, including West Loch, 'Ewa Villages, and Coral Creek. Many of these are privately maintained. Other proposed projects that will need drainage facilities include the University of Hawai'i West O'ahu and the 'Ewa Marina project.

Although the construction of a detention basin may be required, the type of basin is left completely to the designer. Those detention basins required only for flood control do not have to undergo water quality tests. Other drainage facilities must adhere to the same rules related to storm drainage standards. DPP enforces water quality for those facilities that drain into City jurisdiction.

Although the infiltration of storm water is beneficial to surface receiving waters, there is the potential for ground water contamination. Previous research on the effects of incidental infiltration on ground water quality indicated that the risk of contamination is minimal, and that metals and pollutants contained in the infiltrated runoff are absorbed in the upper few inches of the soil and are considered permanently removed from the water. However, there is some documentation of ground water contamination from infiltration facilities. Wilde (1994) showed breakthrough of metals to ground water from storm water impoundment, and Pitt, et al. (1994) noted that previous studies did not thoroughly investigate the impact of soluble organics on the ground water. Additional study is needed into the potential ground water problems that may result from infiltration of storm water runoff.

PROJECT 11: DETENTION / INFILTRATION BASINS STUDY

PRELIMINARY SCOPE

Current operation and future design of storm water detention basins should consider water quality in addition to flood control.

- Compile and map data on soils, climate, proximity to drinking water wells, and location of ground water tables within the project area.
  - Overlay locations of current and potential detention basins and surrounding hotspot land uses (that produce highly contaminated runoff).
  - Rank the sites according to ground water contamination potential.
  - Determine if additional action is needed.
- Identify techniques that can be used in addition to current detention ponds for further storm water contamination removal.
- Evaluate various coagulants for their ability to enhance removal of sediment and metals.
- Evaluate the effects of an existing detention basin on ground and stream water quality.
  - Compare the water quality in samples from wells on the shore of the basin with that in the well upgradient from the basin.
  - Examine the time history of water quality in the wells on the shore of the basin.
- Prepare a Detention Basin Guidance Document with design recommendations to ensure that the soils and other factors on the site are appropriate for infiltration, and that designs minimize the potential for ground water contamination and long-term maintenance problems.

PARTICIPATING AGENCIES

Lead Agency: DPP
Participating Agencies: USGS, UH WRRC

ESTIMATED COST

$50,000 - $100,000

TIME FRAME

2 years

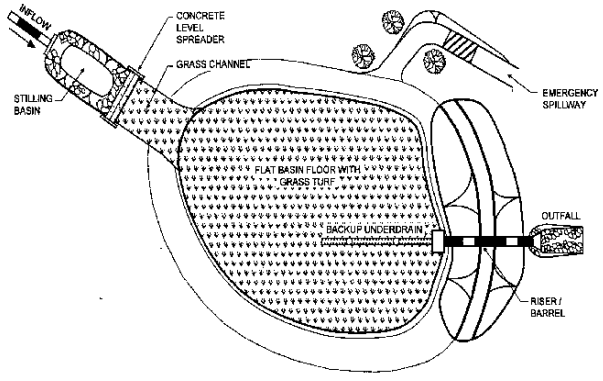
REFERENCES

Connecticut Department of Transportation, *ConnDOT Drainage Manual: Chapter 10.13 Infiltration Controls*, 2003, <http://www.ct.gov/dot/lib/dot/documents/ddrainage/10.13.pdf> (February 8, 2006).

Florida Department of Environmental Regulation, *The Florida Development Manual: A Guide to Sound Land and Water Management. Department of Environmental Regulation. Stormwater Management Practices*, (1988).

R. Pitt, et al. *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration*, (U. S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Office of Research and Development, Springfield, VA, 1994).

F. D. Wilde, *Geochemistry and Factors Affecting Ground-Water Quality at Three Storm-Water-Management Sites in Maryland: Report of Investigations No. 59*, (Department of Natural Resources, Maryland Geological Survey, Baltimore, Maryland, 1994).



Example of an infiltration Basin Design.

PROJECT 12: ABANDONED WELL INVENTORY, SEALING, AND MONITORING

PROBLEM STATEMENT

Existing agricultural wells could be a potential source of ground water contamination.

GENERAL BACKGROUND

Central O'ahu was extensively used for agricultural activities, for over 100 years. Many private water sources were developed to irrigate these plantations, and while most of the active wells are believed to be recorded in the CWRM's water use database, many abandoned wells may not be. Abandoned wells are identified as a potential contaminating activity (PCA) in the 2004 Hawai'i Source Water Assessment Program Report. These wells could provide a direct conduit for contamination of the aquifer either through accidental or malicious means.

The CWRM coordinates a program to seal abandoned wells, via the *Hawaii Well Construction and Pump Installation Standards* (January 1997, revised February 2004). These standards are meant to prevent "the pollution, contamination, and wasting of ground water and [minimize] saltwater intrusion into wells and ground water…in the course of: Construction of wells, Modification of wells, Abandonment and permanent sealing of wells and test borings, and Installation and repair of pumps."

Just as abandoned wells provide for potential ground water contamination, active agricultural wells may also pose potential hazards. "Chemigation, the direct addition of agrichemicals to irrigation water, potentially can pose special problems…If the backflow prevention device is defective or chemical handling is sloppy, accidental backflow into the irrigation well can occur and produce a pollutant point source."

CWRM's well Installation Standards provide guidance for protecting the aquifer from contamination via vertical movement of pollutants through or along wells. Any wells that supply water used in chemigation is required to install a backflow prevention device[w] acceptable to DOH requirements. The *Hawai'i Administrative Rules* §11-27-7(a)(4) states that "A reduced pressure principal backflow preventor or air gap separation shall be required before any piping network in which fertilizers, pesticides, and other chemicals or toxic contaminants are injected into the irrigation system."

Additionally, BWS has Rules and Regulations (Chapter III: Protection, Development and Conservation of Water Resources) that allow BWS to review applications and grant permits for drilling, modifying, recasing, or reusing wells. Specifications and requirements for each well are also outlined, including use, abandonment, and sealing.

These Standards, Rules, and Permits work toward preventing aquifer contamination via new and modified wells and pumps, but it does not address existing infrastructure that does not undergo modification. Wells that are no longer in use must be properly abandoned and sealed under CWRM and BWS permits and standards. Well owners and/or operators are responsible for proper sealing, but CWRM has the authority to determine a well abandoned and notify the owner/operator of their responsibility to properly "re-case, cement, plug back, cap, or otherwise repair the well or fill and seal the well."

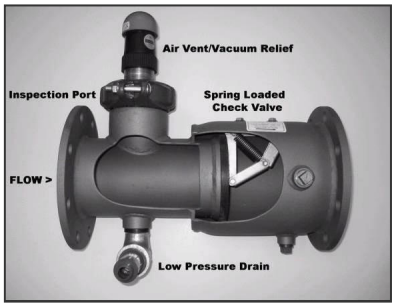
[w] A backflow preventor is a device to prevent backflow of water into a well or potable water system.

PROJECT 12: ABANDONED WELL INVENTORY, SEALING, AND MONITORING

PRELIMINARY SCOPE

An irrigation well program would inventory irrigation wells, monitor activity, initiate sealing of inactive wells, and

- Inventory all agricultural wells and systems. Mail out surveys to all agricultural well owners on the CWRM data base.
  - Verify active wells.
  - Identify inactive wells; determine if there is potential for re-activation.
- Initiate well-sealing program for those abandoned wells that are not properly sealed and are not slated for re-activation.
  - Secure funding for up-front costs of well-sealing until reimbursement is made by well owners/operators.
  - BWS building permit screening and enforcement.
- Identify chemigation activities in the Central O'ahu Watershed that utilize existing wells and may therefore have been exempt from backflow preventor requirements.
- Encourage entities that practice chemigation to utilize approved backflow prevention devices with subsidies and technical assistance.
- Monitor agricultural wells that are associated with chemigation, particularly those that do not have a backflow preventor.



Chemigation pump. Source: http://www.itrc.org/reports/chemigation/chemigationandfertigationforca1.htm

PARTICIPATING AGENCIES

Lead Agencies: CWRM, DOH, BWS
Participating Agencies: DOA, UH

ESTIMATED COST

$250,000 - $500,000 sealing cost

TIME FRAME

18 months

REFERENCES

Department of Land and Natural Resources Commission on Water Resources Management, *Hawaii Well Construction and Pump Installation Standards* (2004).

Charles D. Hunt, *Ground Water Quality and its Relation to Land Use on Oahu, Hawaii, 2000-01, Water-Resources Investigations Report 03-4305* (U.S. Geological Survey, 2004).

National Association of Counties, *Counties Protecting Drinking Water Through Partnerin*, (August 2000).

Aly El-Kadi, Chittaranjan Ray, et. al., *Hawaii Source Water Assessment Program Report* (Water Resources Research Center University of Hawai'i at Mānoa, prepared for State of Hawai'i Department of Health Safe Drinking Water Branch, November 2004).

State of Hawai'i Department of Health, *Hawaii Ground Water Protection Strategy* (1990).

Chemigation is the addition of fertilizers of pesticides directly to irrigation water. Source: http://groups.ucanr.org/kernag/Chemigation/

PROJECT 13: CHEMICAL CONTAMINATION MITIGATION

PROBLEM STATEMENT

Widespread detection of contaminants such as pesticides, herbicides, nutrients and solvents are present in Central O'ahu drinking water aquifers.

GENERAL BACKGROUND

Spills, improper applications, fuel and sewer line leaks and breaks, and other land uses have allowed chemical contaminants to travel through the soil and into the aquifer. Many chemicals used in the past and now banned from use are still lingering in the ground water. It would be expected that the concentration of these contaminants would be reduced over time. BWS data shows that the concentrations of some pesticides no longer in use (such as TCP and DBCP) are actually rising. Effects on ground water recharge such as rainfall, irrigation, soil compaction, and pumping may have influenced the concentration of these contaminants, causing concern for the quality of drinking water.

Ground water is continually tested and monitored for contamination by DOH and BWS. Wells that exceed standards are treated with a Granular Activated Carbon (GAC) filter. Nine of 34 active BWS well stations require 84 individual GAC vessels to remove pollutants from urban and agricultural activities. These filters are very expensive; approximately $500,000 per mgd treatment, for a total cost to date of $52 million. Additional wells in Waipi'o Heights and Hālawa will require GAC treatment for the discontinued pesticides TCP and dieldrin at an additional estimated $8 million. In addition to the cost of treatment, land space is necessary to build the treatment facilities. Not all wells have additional surrounding lands to build these facilities, so early detection of contaminants is necessary to make space or buy adjoining land to construct facilities.

Although GAC filtration is effective at removing a large number of known contaminants, there are chemicals currently in use or that will come up in the future that, if found in ground water, could require additional treatment facilities, at additional costs, to keep drinking water in compliance with State and Federal standards. For example, pharmaceuticals, a contaminant of wastewater, is currently not monitored for in drinking water at this time. GAC, if used properly, is effective at removing many pharmaceuticals, but ozonation treatment is also recommended for additional filtration. Other advanced techniques, such as membrane filtration and advanced oxidative processes using a combination of ozone and UV or ozone and hydrogen peroxide, should also remove pharmaceuticals. However, these treatment methods are expensive, and the rising costs of providing clean drinking water may ultimately be burdened by the consumer.

Mitigating chemical contamination of the aquifer is of top priority. Continued education of proper chemical application and alternatives to chemicals is a must. Creating an inventory of known chemicals, their location, and their concentrations in relation to groundwater availability could be used to determine pumping management decisions. This understanding could also be used to determine potential chemical reactions with one another, and provide information for public health risk assessment. DOH is currently working towards such a data management system. Creating scenarios using current chemical concentrations and future water demand will help to determine current land management decisions for future treatment of ground water. These and other steps are necessary for keeping the Pearl Harbor aquifer's drinking water contaminant-free.

PROJECT 13: CHEMICAL CONTAMINATION MITIGATION

PRELIMINARY SCOPE

To mitigate past and potential chemical contamination of drinking water wells.

Prevention

- Continue responsible chemical use education
- Promote low-impact alternatives to "indispensable" pesticides
  - Research the top most "indispensable" pesticides in use today
  - Identify alternatives
  - Evaluate alternatives based on effectiveness, affordability, and ease of application
  - Identify and offer financial and other incentives for the use of alternatives.

Monitoring

- Support DOH in creating a data management system to characterize type and quantity of chemicals and nutrients used, by whom, and where they are located
- Set up a monitoring grid to see if contamination is migrating toward drinking water sources
- Increase data sharing between agencies to determine what chemicals are being monitored and those that are not
- Continue to monitor EPA tracking of chemicals to see what chemicals might become regulated
- Begin testing production wells for low levels of the most currently used pesticides.[271]

Modeling

- Perform a trend analysis scenario of past contamination levels to speculated drinking water consumption rates to determine if future treatment facility expansion will be necessary.[6]
- Determine how chemical concentration is related to soil structure and water availability, including such factors as rainfall, thickness of lens, pumping.[6]

Other

- Do feasibility analysis for constructing a reverse osmosis plant for potable water[272]
  - Residents would use tap water for non-potable uses
  - Get potable water from the RO plant using refillable containers
  - Cost-Benefit analysis
  - This could open up restrictions on land use because ground water would not be used for drinking.

PARTICIPATING AGENCIES

Lead Agencies: BWS, DOH
Participating Agencies: EPA, Army, Navy, USGS, DOA, UH Mānoa CTAHR

ESTIMATED COST

$250,000 - $500,000 per project

TIME FRAME

On-going

REFERENCES

S.S. Anthony, et.al., *Water Quality on the Island of Oahu. Hawaii, 1999–2001* (U.S. Geological Survey Circular 1239), <http://pubs.usgs.gov/circ/2004/1239/pdf/circular1239.pdf> (September 13, 2006).

K.S. Betts, "Keeping Drugs Out of Drinking Water," *Environmental Science & Techonology*, v.36, n.1, 1 Oct 02 (2002).

State of Hawaii, Department of Health, *Draft 2006 Integrated Report of Assessed Waters in Hawai'i,* 305 (b) Report for 2004-2005, Section 3 (Groundwater Assessment. Environmental Planning Office; 2006).

PROJECT 14: SEDIMENT SOURCE STUDY AND ANALYSIS

PROBLEM STATEMENT

Locating the sources and volumes of sediment polluting Central O'ahu streams and Pearl Harbor will aid in making informed decisions on land management practices and sediment control, improving water quality.

GENERAL BACKGROUND

The amount of sediments in a watershed influences the availability and suitability of aquatic habitat, geomorphic characteristics of streams, and the long-term performance of receiving waters - in this case, Pearl Harbor. Pearl Harbor receives large quantities of sediment from streams and runoff, with more than 75 feet of silt sitting on the bottom of the harbor.[273] Silt can be re-suspended, clogging boat engines, degrading water quality and affecting sedentary marine life. This impedes and restricts use of Pearl Harbor by the Navy and recreational users. Pearl Harbor wetlands are home to threatened and endangered native bird species, and are at risk from sediment delivered to their habitat that includes pesticides and other toxins, bacteria, heavy metals, excess nutrients, and pathogens. Sediment also accumulates at stream mouths and continues to be a problem particularly in West Loch.

In 1993, an analysis by the Environmental Planning Office of sediment loads to Pearl Harbor indicated that they were almost entirely (74%) from streams and derived from upper watershed areas. The remainder mean annual non-point source loads (assumed suspended sediments) were estimated to be (1) urban (4%), (2) from construction activities, (5%), and (3) from agricultural activities (17%) of total sediment loads. Point sources and percentage of sediment polluting Central O'ahu streams and Pearl Harbor have not been analyzed since the 1993 study.

Maintenance dredging of Pearl Harbor and stream mouths is very expensive. The Navy estimates costs to range from $11 per cubic yard for dredging and ocean disposal to $53 per cubic yard for dredging and upland disposal. Currently, the City only routinely maintains the 'Ewa Line Channel off Aekai Place within the Central O'ahu Watershed. Other streams are dredged every 10 to 20 years.

It is important that legislators and other decision-makers who allocate budget spending have accurate information regarding watershed management, so that resources can be directed appropriately. Specifically, one concern expressed by City Department of Environmental Services (ENV) is that a large amount of money may be spent to control urban sediment when the problem could actually be coming from non-urban areas. A complete understanding of the flow patterns from specific land uses, and specific paths into streams needs to be evaluated so NPDES holders (such as ENV) know how to direct their efforts. USGS will soon begin sampling and testing sediment from Waikele Stream at the request of ENV to determine the land use source of the sediment and associated pesticides.

The Hawai'i Department of Health (DOH) is currently using the EPA-recommended Hydrologic Simulation Program - FORTRAN (HSPF) in their TMDL studies to evaluate (among other things) sediment load and transport within streams. TMDL studies for Central O'ahu streams are currently in progress.

PROJECT 14: SEDIMENT SOURCE STUDY AND ANALYSIS

PRELIMINARY SCOPE

A combination of observations, measurements, and modeling techniques should be used to gain a better understanding of both long-term and episodic transport of sediments, which can in turn be used to formulate projects with quantifiable effects.

- Identify sources of sediment.
- Assess existing watershed conditions by analyzing available data relating to sediment sources and transport.
- Review Navy records of constituents in Pearl Harbor dredge material, to help determine sources.
- Review of NPDES permits, conditions, and compliance from files at DOH to help determine locations of sediment deposition.
- Evaluate general reach-averaged sediment transport characteristics to identify potential problem areas.
- Perform field reconnaissance to verify these problems.
- Perform sediment transport modeling.
    - Measure and analyze stream sediment samples for data.
    - Use various scenarios for key stream reaches, such as increased development, changes to stream channels, etc.
    - Improve overall accuracy by applying empirical watershed sediment modeling using results from several models (i.e., USLE, RUSLE, MUSLE, PSIAC) used in combination with sediment source estimates previously performed.
    - Estimate the accumulation of sediments in the Harbor using a combination of hydrographic survey, geophysical survey (e.g., GEOPULSE or similar geophysical technology), sediment sampling, and historical mapping.
    - Estimate annual sediment loads for long-term average annual conditions.
- Identify sediment mitigation activities
    - Prepare a sediment study memorandum to serve as the information base for defining study priorities and tasks.
    - Identify linkages to other study areas.
    - Develop potential projects to reduce sediment.
    - Identify and quantify potential effects of sediment reduction activities on fresh water and marine communities.

PARTICIPATING AGENCIES

Lead Agency: ENV
Participating Agencies: USGS; UH WRRC; DLNR; COE; NRCS; Army; Navy.

ESTIMATED COST

$100,000-$250,000

TIME FRAME

5 Years

REFERENCES

Steven Anthony, *Hydrogeology and Water Related Issues in Hawaii and the Pacific. Power Point Presentation*,2003, <http://www.wrrc.hawaii.edu/publication/wrrc_conf_2003_01/wrrc_conf_jan03/Anthony_talk.pdf>" (January 2, 2006).

R. A. Englund, et al., *Biodiversity of Freshwater and Estuarine Communities in Lower Pearl Harbor, Oahu, Hawaii with Observations on Introduced Species: Final Report* (Prepared for the U.S. Navy. Bishop Museum technical report, ISSN1085-455X; no. 16, Bishop Museum, Honolulu, Hawai'i, 2000).

Environmental Planning Office, *Revised Total Maximum Daily Load Estimates for Six Water Quality Limited Segments, Island of O'ahu, Hawaii. Pacific Environmental Research* (1993).

Upper Yuba River Studies Program: Sediment Studies, 2000, <http://www.nasites.com/pam/yuba/docs/scopeofwork9_27_00sediment.PDF> (January 2, 2006).

PROJECT 15: STREAM EROSION AND SEDIMENT CONTROL PROGRAM

PROBLEM STATEMENT

Sedimentation into Pearl Harbor from attributing streams has been identified as a major non-point source of contamination of stream deltas and Harbor waters; a risk to aquatic life, fishermen catching bottom-feeding fish and crabs; cause of reduction in flood capacity; and impeding and restricting use of Pearl Harbor by the Navy.

GENERAL BACKGROUND

Of the ten streams discharging into Pearl Harbor, five are perennial (Hālawa, Kalauao, Waimalu, Waiawa, and Waikele) and five are intermittent ('Aiea, Waiau (Waimano), Kapakahi, E'o, and Honouliuli). All streams drain forested and agricultural lands and pass through urban areas, transporting sediment and contaminants to Pearl Harbor. In 1980, a Statewide Silt Basin Investigation by DLNR found excessive sediment discharge into the Harbor. It was found to be caused by accelerated erosion in the tributary regions used for agriculture and urban development, and was considered a major reason for the degradation of the estuarine ecosystem. In 1993, the DOH Environmental Planning Office assessed sediment loads to Pearl Harbor originating almost entirely from streams and derived from upper watershed areas.

All five perennial streams have either been periodically dredged or have had improvements made to mitigate further erosion. Dredging of Hālawa Stream occurred in 1976 and 1991 by the Navy and City, respectively, for a total 175,500 cubic yards of sediment. A total of $700,000 was budgeted in the FY 2004 and 2006 CIP projects for the planning and design of Hālawa Stream dredging. Dredging of Waimalu Stream occurring in 1988, 1990, and again in 2002 by the City totaled 146,400 cubic yards of sediment. In 2005, the City appropriated $3.5 million for additional Waimalu Stream dredging of approximately 46,000 cubic yards.

Stream improvements either are in progress or have been made to Kalauao, Waiawa, and Waikele Streams. In 2005, the City appropriated $260,000 for Kalauao Stream improvements to mitigate erosion. A containment system was built in 2000 for Waiawa Stream to minimize severe erosion sites. In 2000, constructing a rip-rap lining to Waikakalaua, a highly degraded tributary stream to Waikele, was proposed at Waihuna Village III to protect the bank from erosion from a drain outlet.

The accumulation of the above efforts has removed 321,900 cubic yards of sediment, with CIP projects totaling a projected $4.46 million. These figures do not include additional programs or other costs associated with dredging. Yet with all of these efforts, erosion and sediment have not been controlled.

According to the *Revised Ordinances of Honolulu*, Article 26, Section 41-26.3, private owners have the duty to maintain, dredge and clear their stream. If an owner permits, the stream can be cleaned by the City and charged to the owner for the cleaning. The frequency and impact of private stream maintenance is unknown.

To reduce the amount of contaminated silt and sediment that reach Pearl Harbor, every effort should be made to maintain an appropriate flood plain riparian buffer to slow the speed of floodwaters and limit streambed down-cutting that promotes erosion.

PROJECT 15: STREAM EROSION AND SEDIMENT CONTROL PROGRAM

PRELIMINARY SCOPE

Stream dredging is costly and is not addressing the cause of the sedimentation in Central O'ahu streams. Further analysis is needed to target erosion sites with appropriate measures.

- Review and assess existing stream conditions by reviewing available data relating to erosion and sedimentation.
- Evaluate general reach-averaged sediment transport characteristics to identify potential problem areas.
- Perform field reconnaissance to verify and map the problem areas.
- Perform stream sediment measurements.
  - Compute sediment volume for each stream.
- Investigate appropriate erosion control techniques, such as re-vegetation, gabions, and flow control check dams for their appropriate location and effectiveness.
- Prioritize eroded locations.
  - Determine the sediment load for each location, willingness of landowner involvement, accessibility, cost of mitigation, etc.
- Investigate the potential use of sediment basins on intermittent streams.
- Review the use of other catchments, velocity dissipators, channelization renovation, and "soft" stream channel sediment-dissipation projects.
- Provide recommendations for specific locations along all perennial and intermittent streams in the Central O'ahu Watershed to provide maximum erosion control.
- Provide a funding mechanism for long-term monitoring of new erosion control structures, sedimentation monitoring, and maintenance of these areas.

PARTICIPATING AGENCIES

Lead Agencies: DDC, Navy
Participating Agencies: DFM, COE, DLNR

ESTIMATED COST

$500,000 - $1,000,000

TIME FRAME

5 years

REFERENCES

T. L. Ashwood, et. al., *Sources and Areal Distribution of Trace Metals in Recent Sediments of Middle Loch, Pearl Harbor (Hawaii),* ORNL/TM-11135 (Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1989).

Department of Environment and Conservation, State of Tennessee, *Tennessee Erosion and Sediment Control Handbook,* <http://www.state.tn.us/environment/wpc/sed_ero_controlhandbook> (February 21, 2006).

USEPA, *Waimanalo Stream TMDL Implementation Plan* (State of Hawai'i DOH EPO, 2001).

Example of "coir" erosion control technique.

PROJECT 16: INCREASED BMP INCENTIVES AND ENFORCEMENT

PROBLEM STATEMENT

Best Management Practices (BMPs) are suggested to reduce erosion and storm water impacts on surface water quality, but current water quality assessments suggest that these BMPs are not being applied.

GENERAL BACKGROUND

BMPs generally fall under the categories of structural, vegetative, or management practices, and affect agriculture, silviculture, construction, and industrial and urban practices. There are various manuals and guidance documents on these practices, such as DLNR's *Best Management Practices for Maintaining Water Quality in Hawai'i* and CZM's *Hawaii's Coastal Nonpoint Pollution Control Program*. The overall goal in the development of BMPs is to assist landowners /users in managing their facilities more efficiently, while moving towards compliance with discharge regulations. A number of State and Federal programs have been developed that promote the use of storm water BMPs and assist in implementation. There are also some BMPs required by water pollution-control laws (such as the Storm Water Phase II Rule) and through the NPDES permitting system. The City & County of Honolulu (City) also requires BMPs in Drainage Ordinances and grubbing and grading permits.

Monitoring requirements on some installed BMPs have shown their efficiency to control various pollutants. However, Pearl Harbor is listed on the 2004 List of Impaired Water Bodies for Hawai'i. This suggests that the small number of BMPs being applied is insufficient to solve the problem. Where the State has a specific authority to address a potential non-point pollution source, the requirements of the enforceable policy and the process for implementing those requirements are usually clear. For example, the DOH Clean Water Branch Enforcement Section determines compliance with permit conditions, and issues corrective measures through administrative or court actions. However, it is more difficult for the State to enforce voluntary efforts needed for a general authority, such as State Water Quality Standards. The State does not have many enforceable policies, but relies on the voluntary BMPs implicated by the City.

Relatively low fines for water quality violations are probably not a disincentive to potential violators. The length of time required to process an NPDES permit can lead to higher project costs. Ensuring that contractors adequately deploy and maintain the BMPs is a logistic problem and current remedies (e.g., stop work, withheld payments, verbal warnings) are not necessarily effective or efficient.

Farmlands are not subject to the NPDES requirements from which the impetus for BMPs arise. BMP equivalents for farm operations are mediated through the NRCS as soil conservation projects and are voluntary. If specific management techniques are mandated, the economic affect on Hawaii's farmers could be substantial and the viability of small farming may be jeopardized. It might not be worth the cost to comply if they only have month-to-month leases and the benefits are realized in the long-term. There is not always a good incentive for farmers to implement BMPs, since the benefits are generally off-site.

BMPs were drafted assuming that compliance would be voluntary. They will need to be redrafted if compliance is to be expected and enforced. This may require either some modification to the BMP manuals or some other enforcement mechanism.

PROJECT 16: INCREASED BMP INCENTIVES AND ENFORCEMENT

PRELIMINARY SCOPE

A combination of research, incentives, and enforcement for voluntary and regulatory BMPs must take place to increase compliance and improve water quality.

- Develop and implement a BMP Effectiveness Monitoring Program.
  - Analyze monitoring data required by DOH on specific BMPs.
  - Study several years of water quality data in comparison to the use of BMP practices to see if trends in water quality have improved.
  - Integrate BMP monitoring into current State and City programs, observing stream impairment and soil delivery to channels, and conduct water and biological sampling.
  - Research the most effective BMPs for different practices / situations.
  - Develop a system to track the location and maintenance of structural controls after they are installed.
  - Provide performance standards that must be fulfilled instead of specific measures.
  - Develop procedures to assess BMP performance/effectiveness.
- Research the economic impact of BMPs on various industries and suggest alternatives if needed.
- Institute BMPs within government.
- Educate key public land managers.
- Require BMP implementation as a condition of all State land leases.
- Require Federal BMP implementation through the Federal Consistency Review.
- Create incentives to comply with BMPs.
- Increase permitting efficiency.
- Identify funding programs and financial assistance available for voluntarily using BMPs.
- Identify additional enforcement mechanisms.
- Increase funding to hire more inspectors.
- Standardize and implement a BMP inspection form for inspectors.
- Increase the frequency of inspections.
- Develop an effective enforcement tool to encourage violators to implement BMPs in a timely manner.
- Improve follow-up on outstanding fines.
- Continue BMP education efforts.
- Offer on-site training.
- Require current BMP testing of land managers, contractors, and others that are up for licensing, certification, registration, and accreditation.
- Promote the formation of partnerships among water quality agencies and other organizations, to resolve jurisdictional issues and improve BMP development.

PARTICIPATING AGENCIES

Lead Agencies: DOH, DOA, DPP, ENV
Participating Agencies: UH CTAHR, DLNR, NRCS, CZM

ESTIMATED COST

$50,000 - $100,000

TIME FRAME

2 years

REFERENCES

W.E. Archery, *The National Association of State Foresters 2004 Progress Report State Water Resources Programs for Silviculture* (2004).

DOH, *Draft Program Evaluation Report: City and County of Honolulu Storm Water Management Program (Permit No. HI 0021229)* (Tetra Tech, 2003).

DOH, *Draft Program Evaluation Report: Hawaii Department of Transportation Storm Water Management Program (Permit No. HI 0021245)* (Tetra Tech, 2004).

PROJECT 17: WASTE LOAD ALLOCATION MODELING

PROBLEM STATEMENT

As Total Maximum Daily Load (TMDL) allocations are determined for the Central O'ahu Watershed, National Pollutant Discharge Elimination System (NPDES) permit holders will require efficient analytical tools to correctly identify and properly manage pollutant sources.

GENERAL BACKGROUND

Water quality management has become increasingly more complex, due to toxic contaminants, sediments, and nutrients that are produced by a variety of point and non-point sources. The TMDL process was established under the Clean Water Act (CWA) as the mechanism to address these problems in a comprehensive manner.

The State of Hawai'i Department of Health (DOH) is mandated by the Environmental Protection Agency (EPA) to list impaired and threatened waters and develop TMDLs. A TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards. It includes waste load allocations (WLA) from point sources, load allocations (LA) from non-point sources and natural background conditions, and a margin of safety with consideration for seasonal variations.

Once allowable loadings have been developed, pollutant limits are incorporated into NPDES permits. TMDL violations must be addressed by the NPDES permit holder, as discharges above the set allowable limits are typically attributed to the WLA component of a TMDL, and not to the LA component. For example, if agricultural runoff discharges into the storm water system of a nearby housing development, the NPDES permit holder, in this case the City, is responsible, not the farmer. The non-permit holder may be held liable if it is brought to the attention of NPDES regulators, but it is the responsibility of the permit holder to identify the source of pollution.

There is concern that current TMDL studies may not provide statistically valid WLA numbers given the limited 1 to 2 year period for the TMDL data collection. This may be too short of a time span to capture large storm events, thus setting WLAs at unrealistically low levels. However, DOH identifies targets of small, medium, and large storm events that must be experienced during the TMDL study period, which were met during the Central O'ahu Watershed TMDL study.

Beginning in 2007, a three-year study of Waikele Stream by USGS, initiated by the City, will determine suspended-sediment loads at land-use district boundaries. This may help to alleviate concerns for capturing waste load allocations from varying storm events, and provide data needed to recalculate the TMDL, if necessary. Analysis of suspended-sediment loads and yields for four land-use districts will help to determine the amount of load originating from agriculture, conservation, military, and urban land use.

Other similar long-term studies for the remaining streams in the area may also be necessary. Once specific point sources have been identified, best management practices (BMPs) by the landowner should be implemented. If these actions are already taking place, additional actions may be necessary, such as funding specially designed catch basins that can be used for collection of sediment and contaminants. Some units are designed to retrofit existing storm water inlets. Manufacturers include Vortechnic and Stormwater Management Co.

PROJECT 17: WASTE LOAD ALLOCATION MODELING

PRELIMINARY SCOPE

A long-term monitoring study is needed to determine point sources affecting pollutant loads at specific discharge locations, supply additional information for TMDL allocations, and help identify effective management techniques for waste load reduction and maintenance. A scope for this type of study would include the following:

- Review all available waste load allocation models to determine a combination most suitable for finding primary pollutant sources, such as FWLAM, QUAL2E, SWMM, HSPF, STORM, CREAMS, SWRRB, and others.
- Compile historical water quality data for all streams in the project area.
  - Analyze trends.
  - Compare pollutant loads with storm events.
- Analyze storm water runoff composition to determine potential sources.
  - Perform field studies to verify these findings.
- Provide data that will supplement the TMDL studies.
  - Identify funding sources to reinstate water quality gages that have been discontinued, and to install and maintain new gages at appropriate locations, such as land use boundaries.
- Agree upon the length of monitoring necessary or appropriate storm event occurrence to ensure accurate allocation levels.
- Map storm water systems and discharge locations with land use and topography to show possible influences to storm water runoff.
- Identify BMPs to reduce waste load from point sources.
- Encourage the formation of stakeholder partnerships along a drainage way to share costs of complying with TMDLs.
- Conduct a feasibility study for the cost and effectiveness of retrofitting manholes and select storm drain locations with catch basins for treating storm water.
- Revisit TMDL allocation standards annually to make appropriate adjustments.

PARTICIPATING AGENCIES

Lead Agency: ENV
Participating Agencies: Army, DLNR, DOH, NRCS, USGS

ESTIMATED COST

$100,000 - $250,000 per stream system

TIME FRAME

10 years

REFERENCES

A.S. Donigian, Jr. and W.C. Huber, *Modeling of Nonpoint Source Water Quality in Urban and Non-urban Areas* (USEPA Contract No. 68-03-3513, 1991).

USEPA, *Guidance for Water Quality-Based Decisions: The TMDL Process. Office of Water, Washington, DC*, 1991, <http://www.epa.gov/OWOW/tmdl/decisions> (January 4, 2005).

Non-point source pollution.

PROJECT 18: STREAM HABITAT RESTORATION

PROBLEM STATEMENT

Degraded native habitat from water pollution, invasive species introduction, channelization and other riparian zone modifications threaten native stream organisms.

GENERAL BACKGROUND

Quality of water has a direct correlation to the health of aquatic species. Eight streams ('Aiea, Hālawa, Kalauao, Kapakahi, Waiawa, Waikele, Waimalu, Waimano) were listed in the 2004 List of Impaired Waters in Hawai'i, with pollutants including turbidity, trash, nitrite/nitrate, total nitrogen, and nutrients. Water pollution degrades native habitat and threatens diadromous life cycles of native organisms. Restoration of water quality conditions to the level set by the DOH State Water Quality Standards is an important step in maintaining the populations of native species that do exist.

Over 50 species of non-native organisms are established in Central O'ahu streams, out-competing native species for resources and eroding stream banks. A few examples are the introduced armored catfish (*Hypostomus c.f. watwata*) and introduced bristlenose catfish (*Ancistrus c.f. temmincki*) found in Kīpapa, Waiawa, and Waikele Streams, which dig out nesting tunnels in stream banks, causing erosion.

Stream channelization has further negative impacts on native species by destroying habitat, increasing water temperatures, and degrading water quality by increasing the movement of pollutants and lowering dissolved oxygen. If a stream needs to be channelized, a suggestion is to keep a natural stream bottom, or modify it in a way so that vegetation can still be present and native aquatic species can pass through to upper reaches. Channelized streams include Waikele, Waipahu, Waiawa, and 'Aiea Streams. Instream channel alterations such as low flow channels and other stream modifications may need to be considered in the future to mitigate impacts of increased urbanization.

Hālawa Stream was named a candidate stream for protection in the 1990 *Hawaii Stream Assessment* (HSA) due to its cultural resources. Waikele Stream was listed as having outstanding riparian resources and Honouliuli Stream with substantial riparian resources. HSA recommends that a stream protection program should be established. The diversity of the resources identified for specific streams should be the focus for a range of management and planning activities, and management decisions should be based on natural resource conservation standards. Priority should be given to improving instream habitat values, and discouraging channelization and diversions that detract from natural habitat values. Where possible, a sufficient instream flow to support native aquatic life should be required.

Communities would also like to improve access to and along streams for their greater appreciation by creating greenway paths and features, such as a nature park, overlooks, and children's education centers. Stream trails and walkways are being developed and envisioned for all streams and gulches within the Central O'ahu Watershed. An example of a project by O'ahu Resource Conservation and Development includes the Kīpapa Gulch Pathway project (currently on hold), which is intended to provide for proper streamside maintenance and actions that promote public health, education, and safety in and around the waterways. Such trails and greenways need to consider stream restoration concepts that are in alignment with flood mitigation, water quality improvement, and ecological restoration goals.

PROJECT 18: STREAM HABITAT RESTORATION

PRELIMINARY SCOPE

Restoration opportunities should be identified on an individual stream basis in order to maximize habitat improvements for remaining native species.

- Research the characteristics of previous native stream habitat and the extent of current degradation.
- Conduct a resource survey of streams.
  - Compile and map existing information on water quality, locations of and source of pollutants and trash, stream flow, and diversions.
  - Map habitat types and describe plant and animal associations.
  - Prioritize restoration needs using the Hawaii Stream Visual Assessment Protocol and the Hawaii Stream Bioassessment Protocol.
- Form an advisory group for each stream, by community, consisting of private citizens, public interest groups, and public officials.
- Design a habitat improvement plan.
  - Quantify the desired results in terms of hydraulic changes, habitat improvement, and population increases.
  - Integrate selection and sizing of habitat improvement that will be reinforced by existing stream dynamics.
- Channelized stream modifications project:
  - Conduct a feasibility study for the modification of concrete channels to allow passage of native aquatic species to upper reaches.
  - Identify methods for softening existing channelized reaches while maintaining ease of stream maintenance.
  - Create a demonstration channelized stream modification project.
- Invasive aquatic fauna removal and education:
  - Remove alien aquatic fauna.
  - Collaborate with pet stores to educate customers on returning unwanted pets to the store and not releasing in streams.
  - Reintroduce native species.
  - Continue education on the importance of streams and the need to care for them.
- Identify funding sources.
- Implement planned measures.
- Monitor and evaluate results.
  - Conduct water sampling.
  - Arrange for periodic surveys of the habitat improvement project and determine if additional improvements are needed.

PARTICIPATING AGENCIES

Lead Agencies: DLNR, USFWS, Army, NOAA CRC

Participating Agencies: Hawai'i Nature Center, NRCS O'ahu RC&D, Ducks Unlimited, City and County of Honolulu, COE, Navy

ESTIMATED COST

$50,000 - $1,000,000 per stream ($205/ linear foot)

TIME FRAME

2-20 years

REFERENCES

CWRM and Hawai'i Cooperative Park Service Unit, *Hawaii Stream Assessment* (1990).

CWRM, *Stream Protection and Management in Hawaii: Recommendations and Suggestions* (Stream Protection and Management Task Force, 1994).

USDA NRCS, *Stream Corridor Restoration: Principles, Processes, and Practices* (The Federal Interagency Stream Restoration Working Group, 1998).

PROJECT 19: RIPARIAN BUFFER ZONES

PROBLEM STATEMENT

Many Central O'ahu streams have limited or no vegetated buffers, leaving the streams susceptible to increased sediment load, increased temperatures, decreased water quality and reduced flood control.

GENERAL BACKGROUND

A riparian buffer zone (RBZ) is the area on both sides of streams covered with vegetation or ground cover. The RBZ provides shade and functions as a buffer when fertilizers, pesticides, and other chemicals are applied to adjacent lands. This zone helps to reduce sediment load into the streams by stabilizing stream banks, and provides flood control by allowing floodwaters to expand over foliated slopes, reducing the velocity of floodwaters, and preserving the floodplain. Riparian areas also provide opportunities for recreation, the exercise of subsistence gathering and cultural rights of Native Hawaiians, wildlife habitat, aesthetic values, and other uses.

According to the City's Flood Hazard Ordinance, current setback lines for stream and flood areas are in accordance with Federal Flood Insurance Rate maps, and have construction limitations. Exemptions are made (due to low flood damage potential), in accordance with any underlying zoning, for recreational areas, agricultural uses, and drainage improvements. Infringements within the RBZ for walls, footings, and fill are common on many streams. However, riparian management of these areas is not outlined.

The creation and designation of buffers can be a very long, involved, multi-jurisdictional process, especially for urbanized, expensive O'ahu lands. The creation of these would require time, expertise, and money. One method would be to require stream setbacks for home development to allow for larger floodplains. In specific situations and critical riparian areas, an acquisition strategy can be appropriate for ensuring desired resource protection. In these situations, several tools are available to government and private groups – outright purchase, conservation easements, or transferred development rights.

Determining appropriate buffer widths could be complex. For practical purposes, an RBZ must be wide enough to protect water quality and stream characteristics. Ideally, RBZ widths would be designed on a case-by-case basis, and depend on the stream, soils, slopes, location in upper or lower watershed, adjacent land use, and other related factors. In practice, a more rigid approach may be easier to implement. DOFAW defines riparian buffer zones as a Streamside Management Zone (SMZ) in their best management practices for silviculture, and has suggested zone widths (see below).

DOFAW Recommended Widths for Streamside Management Zones

Soil Type	Percent Slope	SMZ Width (each side)
Slightly erodible	0-5 %	35 ft.
Slightly erodible	5-20 %	35-50 ft.
Slightly erodible	20%+	50-160 ft.
Erodible	0-5 %	35-50 ft.
Erodible	5-20 %	80 ft. minimum
Erodible	20%+	160 ft. minimum

The RBZ designation should require specific criteria that define operational restrictions and special management objectives. Use of buffers near agricultural lands is best understood. Few have done the necessary research to understand the effectiveness of buffers in more heterogeneous areas, especially with respect to slopes and ground cover.

PROJECT 19: RIPARIAN BUFFER ZONES

PRELIMINARY SCOPE

Riparian buffers should be implemented as a first line of defense against surface water pollution, stream bank erosion, and flooding.

- Prioritize the implementation of RBZs using designated criteria such as where:
  - Water quality is impaired and adjacent land use contributes to that degradation.
  - Good water quality exists and protection against potential future impairment is desired.
  - Stream bank erosion is a concern.
  - Wildlife habitat enhancement is desired.
- Develop a database to help determine the appropriate width of RBZs along all streams within the project area.
  - Database should include information such as: slope of land adjacent to stream, ground cover, soil erodibility, precipitation, seasonal high water table, the size and type of water body involved, perennial or intermittent status, knowledge of particular area, sensitivity of stream, etc.
- Evaluate feasibility of RBZ:
  - Perform a cost/benefit analysis to determine what level of protection is needed.
  - Investigate the need for land acquisition, and appropriate strategies for each.
  - Determine the effectiveness that RBZs would have using information from the above database in relation to the potential pollutants to be mitigated.
- Encourage government ability to implement RBZs through such actions as:
  - Instituting a riparian setback line much like the shoreline setback line.
  - Expanding coastal Special Management Areas to include riparian areas with permit requirements for specific activities.
  - Specifying riparian areas as sub-zones within Conservation Districts with special Conservation District Use Amendment conditions to address riparian area management.
- Design a manual to help guide stream modifications and riparian developments.
  - Include information about long-term management of these areas.

PARTICIPATING AGENCIES

Lead Agencies: DLNR, City and County of Honolulu
Participating Agencies: NRCS, DPP

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

6-15 years

REFERENCES

DLNR, *Best Management Practices for Maintaining Water Quality in Hawai'I*, <http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm>.

Maryland Cooperative Extension, *When a Landowner Adopts a Riparian Buffer – Benefits and Costs,* Fact Sheet 774, <http://www.riparianbuffers.umd.edu/PDFs/FS774.pdf>.

State of Hawai'i Office of State Planning, *Riparian Nonpoint Pollution Control in Hawai'i* (Bay Pacific Consulting, 1996).

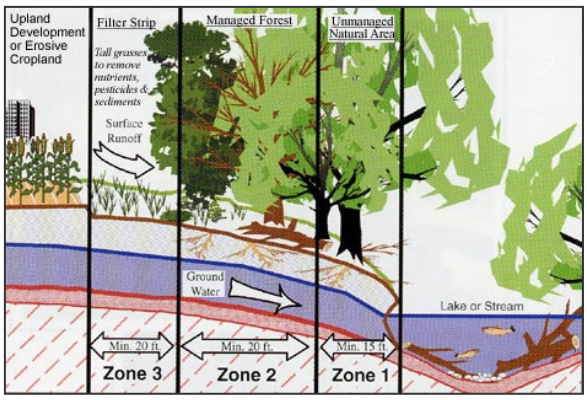


Diagram of a Riparian Buffer Zone.

PROJECT 20: IMPERMEABLE SURFACE INVENTORY AND ANALYSIS

PROBLEM STATEMENT

Increased impervious surfaces in the Central O'ahu Watershed may potentially degrade water quality and reduce ground water recharge.

GENERAL BACKGROUND

As of June 2005, housing construction plans for the Central O'ahu Watershed account for approximately 84% of all new home construction on O'ahu.[274] Along with commercial and industrial construction, this leads to an increase in water use and the amount of impermeable surfaces such as buildings, roads, and parking lots. Construction activity compacts soils in a way that areas that are not paved or built on have lower infiltration rates, which decreases the amount of ground water recharge. Some soil and rock types, such as clays (typical of Hawai'i), are naturally impervious. The increased runoff of water, nutrients, and other chemicals bypasses the natural filtering effect of the soil system and can cause pollution problems in surface water bodies such as streams and oceans.

The impacts of impervious areas include increased runoff rates, creating flash flooding; increased runoff volume, reducing infiltration and increasing erosion; and possible increased pollutant loadings due to channelization, causing temperature changes and loss of aquatic diversity. It is now a well-accepted scientific principle that the amount of impervious surface in a watershed is closely related to the degradation of water quality and other aquatic resources.

Stream research done by the Nonpoint Education for Municipal Officials (NEMO) program, University of Connecticut, generally indicates that at about 10% impervious cover, sensitive stream elements are lost from the system. Where an estimated 11 to 25% of a watershed is covered with impervious surfaces, streams are impacted and can be expected to experience some degradation with further development. Mitigation at this level may be achievable with effective best management practices. Central O'ahu ahupua'a were found to be in this range from a 2000 study done by Coastal Zone Management Hawai'i and National Oceanic and Atmospheric Administration Coastal Services Center (with the exception of Waiawa, at less than 10% cover). If more than 25% of the watershed is covered with impervious surfaces (which is expected to happen with continued development), streams will be degraded to the point where predevelopment stream form and health cannot be fully maintained, even when BMPs or retrofits are fully maintained. Conditions may improve in these sub-watersheds with restoration projects. These ranges are approximate and have been developed based on quantitative assessments conducted in the mainland U.S., and have not been quantitatively evaluated in Hawai'i.

Impervious cover serves not only as an indicator of urban stream quality but also as a valuable management tool in reducing the cumulative impacts of development within sub-watersheds. Calculating impermeable surfaces can help managers to make a determination about the impact current and future impervious surface coverage have on infiltration rates, runoff, water quality, stream degradation, and associated management measures and strategies. Impervious surface information can also be used for community outreach and education, water quality and land cover research, urban planning, and land use decisions.

PROJECT 20: IMPERMEABLE SURFACE INVENTORY AND ANALYSIS

PRELIMINARY SCOPE

The objective of this project is to determine the percentage of current and pending impervious surfaces in the Watershed and investigate alternatives to mitigate their detrimental effects.

- Revise outdated impervious surface percentages for Central O'ahu Watershed.
  - Gather topographic maps, GIS, high-resolution photography, and one-meter digital orthographic quarter quads (DOQQs) for each sub-watershed.
  - Use these to delineate impervious surface features for areas representative of high, medium, and low impervious surface coverage.
  - Overlay the most recent land cover data to generate coefficients for each land cover type.
  - Enter these coefficients into the Impervious Surface Analysis Tool to calculate the percentage of impervious surface coverage.
  - Use the above technique to determine possible future scenarios.
- Promote awareness of need and methods to reduce polluted surface water runoff.
  - Identify interested stakeholders from residential and commercial sectors.
  - Conduct design workshops to develop site specific BMPs.
  - Develop and promote non-site specific BMPs.
  - Implement, monitor, and document BMP applications and results.
- Institute meaningful growth control measures to protect coastal resource lands:
  - Limit impervious surfaces in sub-watersheds to less than 25% of total land area, 10% if possible.
  - Set residential densities at levels that can support transit and reduce vehicle trips per household.
- Limit the amount of impermeable surface in new developments by:
  - Placing limits on the amount of a site that can be covered by impermeable surfaces.
  - Encouraging the use of alternative parking lot surfaces and other low impact development practices.

PARTICIPATING AGENCIES

Lead Agencies: CZM, NOAA
Participating Agencies: City and County of Honolulu, DOH, EPA, USGS

ESTIMATED COST

$100,000 - $250,000

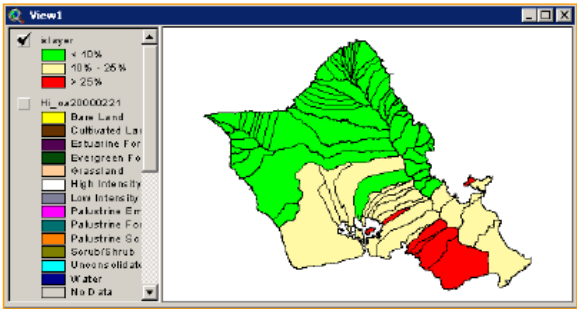
TIME FRAME

2-5 years

REFERENCES

CZM Hawai'i, *An Impervious Surfaces Model for Determining Water Quality within Watersheds,* Handout, 2000, <http://ilikai.soest.hawaii.edu/HILO/cald/megis/notices/ISAT_handout.pdf> (March 28, 2006).

Nonpoint Education for Municipal Officials, (n.d.) *Impervious Surfaces*, n.d., <http://nemo.uconn.edu/impervious_surfaces/index.htm> (March 28, 2006)



GIS can be used to identify the percentage of impervious surface cover within a watershed.

PROJECT 21: ROADS AND HIGHWAYS RUNOFF STUDY

PROBLEM STATEMENT

The impact of road and highway storm water runoff on ground and surface waters is unknown.

GENERAL BACKGROUND

Roads, highways, and bridges are significant sources of pollutants to water bodies. Contaminants from vehicles and activities associated with road and highway construction and maintenance are washed from roads during rains and carried as runoff to streams, harbors, and the ocean through storm drains. These contaminants include heavy metals, suspended solids, oil, grease, rubber particles, nutrients, sediment, chemicals, fertilizers, debris from wearing parts, litter, and petroleum-related organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, and xylene. Many of these pollutants, in particular PAHs, are toxic to aquatic life and several are suspected carcinogens.

Receiving surface and ground waters are both susceptible to contamination from these pollutants. Contaminants can reach ground water quickly through fractured rock formations or sinkholes in karst areas, such as that found in 'Ewa. Ground water is more sensitive to contamination in these areas because runoff may pass directly into the subsurface with little if any infiltration through the soil, a process that typically filters at least some pollutants.

Hawai'i Department of Transportation (DOT) is currently revising its storm water mitigation methods to meet national and State requirements. DOT has agreed to stabilize earthen slopes in 10 chronic problem areas on the H-2 Freeway, Kunia Road, and Kamehameha Highway; and increase the frequency of street sweeping on 60 miles of road to every five weeks instead of once every three months. A street sweeping study conducted in the Salt Lake neighborhood in 1999 by the City showed that street cleaning (once per week or two) is most effective in controlling debris and gravel buildup and moderately effective in controlling oil, grease, and heavy metals.[275] DOT is also addressing post-construction runoff during the design phase for projects that increase impervious surfaces by more than one acre.

DOT has contracted USGS to monitor storm water quality and quantity for a portion of the H-3 Freeway and North Hālawa Stream. In a USGS study of water quality before, during, and after construction of the H-3 Freeway (1983-1999), specific-conductance values (related to the dissolved-solids content in the water) increased throughout the study period, most likely due to highway construction. This increase may degrade water quality and increase water temperature. The Navy collects periodic storm water samples under its storm water management program at sites where contaminants may potentially enter Pearl Harbor.

DOT and the City are also revising storm water management practices for compliance with NPDES permits issued in 2006. Work is being done to develop, implement, and enforce a Storm Water Management Plan and an erosion control plan, and incorporate pollution prevention into operation and maintenance procedures to reduce pollutant loadings to surface runoff.
However, to determine the extent of road and highway runoff on water quality and determine appropriate best management practices to mitigate it, an extended study is necessary.

PROJECT 21: ROADS AND HIGHWAYS RUNOFF STUDY

PRELIMINARY SCOPE

Analysis of pollutants in storm water and the adjacent environment will help to determine the impact that road and highway runoff may be having on water quality, and allow for making effective mitigation decisions.

- Use the National Highway Runoff Water-Quality Data and Methodology Synthesis (developed by USGS and the Federal Highway Administration) to document highway runoff quality from Central O'ahu roads and highways, thus contributing to a national characterization of highway storm water runoff pollutant loadings and impacts.
- Complete the current inventory and digitize map locations of roads and highway storm water discharge to streams or aquifers.
- Spatially represent surface water quality data of those contaminants found in roads and highway runoff.
  - Determine if surface waters are receiving their contaminants from adjacent roads and highways.
- Compile additional data such as volume and intensity of precipitation and features of the drainage basin such as area, slope, infiltration capacity, channel roughness, and storage characteristics to represent temporal and spatial variability.
- Determine appropriate locations and fund monitoring stations for storm water flow at roadway sites throughout the Watershed.
  - Use of a program designed for point location and calculation of error (PLACER) may be helpful in deriving study-site locations.
  - Determine if additional precipitation monitoring stations are needed.
- Measure pollutant concentrations, including sediment, in runoff.
  - Examine the potential linkage between pollutant concentrations in runoff and aquatic organisms.
- Identify priority watershed pollutant reduction opportunities.
  - Establish schedules for implementing appropriate controls.
  - Make improvements to existing urban runoff control structures on roads, highways, and bridges adjacent to surface water bodies and with high pollutant concentrations.
- Plan, site, and develop road and highway drainage structures to remove pollutants from runoff before discharging it to water bodies.
- Explore alternatives to roadside spraying of pesticides.
- Continue monitoring water quality to determine mitigation effectiveness.

PARTICIPATING AGENCIES

Lead Agencies: ENV, DOT
Participating Agencies: EPA, USGS, NRCS, DOH, FHWA.

ESTIMATED COST

$1,000,000 - $3,000,000

TIME FRAME

10 years

REFERENCES

City and County of Honolulu, *NPDES Permit No. S000002*, <http://www.cleanwaterhonolulu.com/storm/NPDES_Permit.pdf> (April 3, 2006).

FHWA, *Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. FHWA-EP-00-002*, USDOT, 2000, <http://www.fhwa.dot.gov/environment/ultraurb/index.htm> (April 5, 2006).

USGS, *National Highway Runoff Water-Quality Data and Methodology Synthesis*, (n.d.), <http://ri.water.usgs.gov/fhwa/ndamsp1.htm> (April 3, 2006)..

PROJECT 22: DRAINAGE IMPROVEMENT IMPLEMENTATION

PROBLEM STATEMENT

Flooding continues to be a problem in low-lying parts of 'Ewa, Waipahu, and the lower reaches of Waiawa Stream, and will only increase from the pressures of proposed housing developments unless proper mitigation measures are implemented.

GENERAL BACKGROUND

Most recommendations from the 1983 *General Flood Control Plan for Hawai'i* and the 1994 Statewide Capital Improvement Program have been put into action. For the Hālawa, Kalauao, Waiawa, Waimano, Waikele, Honouliuli, Kalo'i, and Waimalu Streams, projects including flood plain zoning, drainage design and construction, stream and channel improvements and maintenance, bank protection, dredging, and a tsunami warning and evacuation system have either taken place or are within the 2006 City CIP budget.

For Waikele Stream, an additional recommendation included enhancement of existing berms near Waipahu Cultural Garden to the 100-year storm level of protection. The Waipahu Flood Study was produced to evaluate the feasibility of this berm, but the cost/benefit ratio was found too high to justify the enhancements. Additional 2003 and 2004 hydrologic data is being analyzed through O'ahu RC&D to determine if berm augmentation costs can be reduced. The 2006 City CIP budgeted $900,000 for the design and construction of a drainage system along Waipahu Street at August Ahrens Elementary School, but an additional flood control solution, through berm enhancement, stream widening or redirection, is still needed for Waipahu.

For Waiawa, additional recommendations include a Waiawa Stream Improvement Study, and organizing a flood-fighting unit. Studies conducted in 1971 and again in 1978 found that construction of an earthen dam in the upper reaches of Waiawa Stream to be economically unfeasible, and a COE 1989 study showed realignment of lower reaches is infeasible. More recently, studies on the effects of development on Waiawa flooding have been done, but to date, there is no comprehensive plan for improving drainage way carrying capacity. There are currently no flood-fighting units on O'ahu.

The drainage improvements recommended by the 2000 *'Ewa Development Plan* include the West Loch, Kalo'i Gulch, and Kapolei Drainage Basins. These projects, for the most part, have been implemented, or are in the drainage plans of planned developments in the area. However, a proposal to create a drainage system through Kalaeloa (former Barbers Point Naval Air Station lands) for the Villages of Kapolei and Kalo'i Gulch drainage basins has been put on hold.

In 1990, the National Flood Insurance Program (NFIP) instituted a voluntary Community Rating System (CRS) program for additional mitigation measures enacted over and above the minimum NFIP requirements. Credit is given for programs that provide increased protection to new development. These activities include mapping areas not shown on the FIRM, preserving open space, enforcing higher regulatory standards, and managing storm water. The credit is increased for growing communities. City participation in this program would provide a reduction in flood premiums and significantly reduce the risk of future flood losses. At this time, Maui County is the only county in Hawai'i that has joined the NFIP's CRS. The City may not have joined the CRS because of the additional effort required to commit to the development and implementation of a repetitive loss plan and other additional information needed.

PROJECT 22: DRAINAGE IMPROVEMENT IMPLEMENTATION

PRELIMINARY SCOPE

The objective of this project is to implement additional flood mitigation measures to control problem flood areas and prepare for additional drainage impacts from future development.

- Determine if an additional analysis is needed in order to find an economical solution to Waikele berm enhancements.
  - Suggest alternatives to the berm enhancements to alleviate flooding.
- Investigate alternatives for increasing carrying capacity of Waiawa Stream.
  - Review and analysis of previous dam and channel studies of Waiawa Stream.
  - Present recommendations for alternatives.
- Organize flood-fighting units for Hickam Air Force Base, 'Aiea, Pearl City, Waipahu, Honouliuli, and 'Ewa.
  - Develop a flood response plan to ensure that the response activities are appropriate for the expected flood threat.
  - Offer educational courses on Flood Fighting Operations and refresher drills and exercises between floods.
- Continue discussions with Hawai'i Community Development Authority for the development of a drainage system through Kalaeloa.
- Encourage the City and County of Honolulu to participate in the Federal Emergency Management Agency's (FEMA) Community Rating System program.

PARTICIPATING AGENCIES

Lead Agencies: DDC, O'ahu RC&D, DLNR
Participating Agencies: FEMA, COE, DFM

ESTIMATED COST

$100,000 - $250,000

TIME FRAME

15-25 years

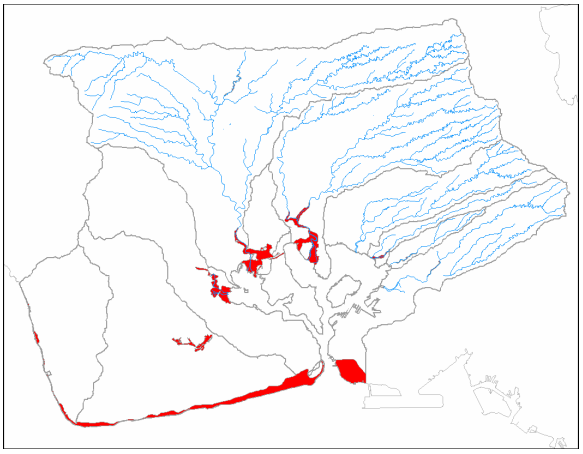
REFERENCES

City and County of Honolulu, *Multi-Hazard Pre-Disaster Mitigation Plan for the City and County of Honolulu, Hydrologic Hazards Chapter 10 Floods* (2003).

City and County of Honolulu, *Waipahu Flood Study* (Park Engineering, 2004).

Department of Land and Natural Resources, *General Flood Control Plan for Hawaii, Flood Control and Flood Water Conservation in Hawaii*, Volume II (Revised), Circular C93 (1983).

Department of Land and Natural Resources, *Statewide Capital Improvements Program Flood Control Projects* (Fukunaga & Associates, Inc., 1994).



Flood zones in the Central O'ahu Watershed Study area.

PROJECT 23: HYDROLOGIC ANALYSIS

PROBLEM STATEMENT

A hydrologic analysis that compiles site-specific information and completes data gaps is needed to improve watershed management strategies and gain a better understanding of the relationships among rainfall, stream flow, and ground water flows to and from the streams for the Central O'ahu Watershed.

GENERAL BACKGROUND

Some site-specific hydrologic studies have been performed for the Central O'ahu Watershed, including at the Pearl City Peninsula Burn Site (to evaluate risks due to waste disposal activities over the past 60 years), Hālawa Valley (to determine effects of H-3 highway construction), and the Waipi'o Peninsula (to determine potential ground water impacts related to the discharge of dredged material leachate). Total Maximum Daily Load (TMDL) studies are almost complete for all streams within the study area (excepting Honouliuli stream). These studies predict flow rate, sediment load, and nutrient and pesticide concentrations. Hydrologic information can also be found within environmental impact statements for proposed developments. Even though this site-specific information is available, it should be compiled and analyzed for a better understanding of watershed-wide processes.

A hydrologic analysis would be helpful in managing the following issues for the Watershed:

Water quality:

- Significant quantities of pesticides and herbicides are present in ground water, even in developed areas.
- Solvents (among them, trichloroethylene (TCE)) from a 1985 spill at Schofield Army Barracks) are moving towards Pearl Harbor through the aquifer. Now delisted, the 1990 National Priorities List site also had a separate plume of TCE contamination in the ground water emanating from a former landfill.
- Kunia and the Pearl Harbor Naval Complex have been designated as Superfund sites because of their contamination of soil and ground water.

Land use changes that will affect future hydrology:

- The substantial amount of planned future developments will increase impervious surfaces, increasing peak flood flows.
- Changes in agricultural irrigation from furrow to drip and the subsequent plantation closing have affected aquifer recharge rates.

Sustainable yield (SY) agreement among water agencies can be facilitated with accurate hydrologic information:

- Quantity and location of potable and non-potable ground water needs to be analyzed to plan for uncertainties in SY estimates.
- There are currently no estimates for recharge rates that are completely agreed upon for Central O'ahu.

Sediment sources:

- The amount of sediment coming from each source is unclear.
- Understanding sediment sources would help in targeting preventive or remediation actions.

Flood control:

- All flood control and drainage facilities from new developments should be inventoried for incorporation into models.

In-stream flow standards:

- Measurable interim in-stream flow standards have not been established for Central O'ahu streams.

PROJECT 23: HYDROLOGIC ANALYSIS

PRELIMINARY SCOPE

The following steps should be included in a hydrologic analysis, using appropriate models to evaluate important variables:

- Identify sources of all hydrologic data.
- Review and update existing hydrologic analyses (including TMDL studies) to produce flow-duration and flow-frequency estimates for key locations.
- Identify data not currently available that would be necessary for a better analysis.
- Prepare and carry out a monitoring plan that optimizes data gathering resources.
  - Perform remote sensing using aerial photography, satellite images and photogrammetry to estimate soil moisture, floodplain delineation, and floodway mapping.
  - Ground-truth channel sections through a field survey.
  - Produce detailed hydrographic surveys of the study area to update peak flow flood estimates.
- Determine flow routing conditions via hydraulic model (e.g., HEC-RAS Unsteady, FLO-2D, etc.) or simplistic flow routing methods utilized by rainfall-runoff computer programs.
  - Estimate flow-duration and flow-frequencies
  - Develop future (built-out) condition flow rates and floodplain information in addition to existing conditions.
- Perform a detailed sediment transport and geomorphic analysis to evaluate current and future environmental impacts of land use.
- Include a statistical analysis to quantify uncertainty in subsurface hydrology and a comparison with established flow rates for similar watersheds.
  - Determine pesticide (TCP, EDB, DBCP) and solvent (TCE) movement in surface and ground water flow.
  - Determine recharge rates for the area.
- Publish an interpretive report on hydrology, describing the surface and ground water hydrology and the response of these systems to stresses in both a historic and recent context.
- Make hydrologic data publicly available for increased data sharing and availability.

PARTICIPATING AGENCIES

Lead Agencies: BWS; CWRM.
Participating Agencies: UH WRRC; USGS; COE; DFM; DPP; Navy.

ESTIMATED COST

$1,000,000 - $3,000,000

TIME FRAME

5 years

REFERENCES

Colorado Water Board, *Appendix B Hydrologic Analysis*, 2005, <http://cwcb.state.co.us/Flood/pdfDocs/RulesRegsAppendixB.pdf> (December 12, 2005).

Environmental Planning Office, *Revised Total Maximum Daily Load Estimates for Six Water Quality Limited Segments, Island of O'ahu, Hawai'i* (Pacific Environmental Research, 1993).

Natural Resources Conservation Service, *National Engineering Handbook, Part 630 Hydrology, 210-VI-NEH*, 2001, <http://www.wcc.nrcs.usda.gov/hydro/hydro-techref-neh-630.html> (December 28, 2005).

PROJECT 24: WILDFIRE PROTECTION PROGRAM

PROBLEM STATEMENT

Wildfires cause widespread damage to native ecosystems, increasing erosion and destroying native plants and animals and their habitat.

GENERAL BACKGROUND

In 2004, the Honolulu Fire Department responded to 169 wildfires in the Central O'ahu-'Ewa region, or about 36 percent of the 465 wildfires on O'ahu that year. In 2005, there were 241 wildfires occurring in the Central O'ahu Watershed Study area, an increase of 15.5 percent.

Fires are generally fought by Honolulu Fire Department (HFD) personnel, although additional support may come from private land owners, such as the Military, State, and other private entities. Participation usually depends on the location of the fire and the resources threatened. DLNR has primary responsibility over fires in forests and natural area reserves. Their fire protection program and contingency budgets for fiscal year 2006 were both exhausted and officials are seeking more funds to cover any additional fires that may occur.

Wildfires often start in the accessible urban and agricultural zones and travel upslope to native forests. While some brushfires are caused by carelessness, accidents, or electrical malfunctions, many of them are believed to be intentionally set.

In forested areas, wildfires destroy these native, threatened, and endangered species and their habitats. Areas of bare soil exposed after fires are prone to erosion, due to the lack of protective vegetative cover whose roots also anchor the soil. Many native species are not adapted to frequent fires and are thus replaced by opportunistic alien plant species that quickly colonize a burn site. Alien species are undesirable for many reasons, some of which include their tendency to displace native species and disrupt the native ecosystem, and the hypothesis that alien plant species are not as effective as native species in reducing erosion and promoting infiltration of water into the aquifer.

Forested lands in the Central O'ahu Watershed study area are located on the eastern flank of the Wai'anae Mountains and on the southern flank of the Ko'olau Mountains. These forests are home to many species of native plants and animals, including dozens of threatened or endangered species, such as *Schiedea* and *Cyanea* species, and the Hawaiian hoary bat.

The Hawai'i Nature Conservancy manages the Honouliuli Forest Reserve in the Wai'anae Mountains, a reserve that provides habitat to approximately 60 species of native plants and animals. Like the May 2005 brush fire in Nānākuli that threatened the Honouliuli preserve, fires have historically threatened these resources. Sensitive species make for difficult decisions when helicopters are used for water drops on areas that are difficult to access on foot. If no fresh water dipping ponds are available for use, helicopters use ocean water. However, the sea water often damages the very plants that fire fighters are trying to protect.

Areas of concern are generally the conservation-urban and conservation-military interface. The Ko'olau forests are of concern due to their drier nature as compared to the wet windward side, their proximity to military training areas and other human uses, and for their relatively inaccessible terrain, which often requires the use of helicopters.

PROJECT 24: WILDFIRE PROTECTION PROGRAM

PRELIMINARY SCOPE

A wildfire protection program should identify the most sensitive areas for protection, engage in preventive actions, outline a protocol for action should a wildfire occur, and educate the community on the threats of fire, the importance of preventive care, and recommended actions once a fire has occurred.

- Review existing fire management plans and programs for the area.
- Develop and/or update coordinated operational plans among land owners, managers, and agencies.
- Determine fire susceptibility ratings that identify fire-prone areas.
- Conduct fire-wise campaigns in high-risk communities.
- Educate on the dangers of careless behavior.
- Fuel hazard reduction and other ways to reduce risks.
- Increase community awareness through known user groups: hunters, hikers, etc.
- Document and pre-plan existing fire management structures, such as fuel breaks, dipping ponds, fire caches, etc., and engineer additional facilities, as needed.
- Acquire needed equipment, training, and budget.
- Restore buffers between conservation and agriculture/urban/military zones.
- Manage vegetation to reduce fuels.
- Joint personnel training and mobilization.
- Enhance existing fire suppression capabilities.
- Integrate fire protection measures in all natural and cultural resource planning and management activities.
- Partner to engage in post-fire restoration activities such as erosion control and re-seeding with more desirable species.

PARTICIPATING AGENCIES

Lead Agencies: DLNR, HFD

Participating Agencies: Army, FedFire, TNCH, O'ahu Civil Defense, State Civil Defense.

ESTIMATED COST

$100,000 - $250,000

TIME FRAME

18 months

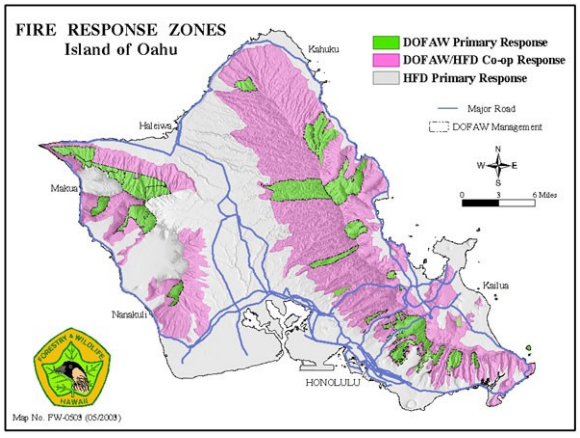
REFERENCES

National Wildland/Urban Interface Fire Program, *Firewise* <http://www.firewise.org/> (March 30, 2006).

Jason Sumiye, *Ko'olau Mountains Watershed Partnership Management Plan* (Ko'olau Mountains Watershed Partnership, 2002).

U.S Army, Hawaii and 25th Infantry Division (Light), *Wildland Fire Management Plan, Pohakuloa & Oahu Training Areas* (January 2000).

Charles K. Wakida, *Mauna Kea Ecosystem Wildland Fire Management Plan* (State of Hawai'i Department of Land and Natural Resources Division of Forestry and Wildlife, 1997).



DOFAW Fire Response Zones.

PROJECT 25: WASTEWATER CONTAMINATION MITIGATION

PROBLEM STATEMENT

Streams, near shore waters, and brackish irrigation wells are at risk of contamination from unsewered areas that still exist and spills from wet weather flows on over-taxed collection systems.

GENERAL BACKGROUND

Unsewered areas still exist in 'Ewa Beach along Ft. Weaver Road, and in Campbell Industrial Park *makai* of Malakole Street, including the State Deep Draft Harbor. The discharge of partially treated sewage into the caprock, although not impacting drinking water aquifers, can still leach into near shore waters and contaminate brackish irrigation wells in the vicinity or render the coastal brackish aquifer unusable for irrigation purposes.

The City Water Quality Management Plan (2001) recommends a centralized sewer system for James Campbell Industrial Park to serve the growing needs of the area, including the Barber's Point Deep Draft Harbor. The area is currently utilizing septic systems, as it is below the Pass/No Pass line and below the UIC line at Malakole Street. To date there are no plans for constructing a new major sewer system.

The City currently has a 20-year plan in place to address many wastewater concerns, some of which includes extension of service to unsewered areas. ENV is currently focusing on repair and replacement of existing infrastructure, with a lower priority for installing new sewer lines. However, ENV is always working on at least one or two Improvement District programs (new sewers) at any time.

Wet weather flows can over tax the collection system causing inadvertent spills that can contaminate streams and near shore waters. Roughly 50 percent of the excess water coming into the system comes in part from private property, through broken or missing lateral pipe cleanout caps, illegal connection of rain gutters and yard drains to the sewer system, or cracked or broken house-to-sewer laterals. Smoke testing is funded by ENV's operations budget to check for infiltration/inflow on private property. There is a process to notify noncompliant homeowners through letters and eventually fines. However, of the homes cited between May 2004 and May 2005, only two percent have made improvements. ENV hopes to improve compliance through one of their NPDES control measures, which consists of public education and outreach on storm water impacts.

During dry weather flows, tree roots penetrate collection pipes causing leaks or serving as a debris catcher for solids, and oil and grease buildup in pipes cause backup of wastewater into homes or manholes. ENV currently uses chemicals to either kill roots that have grown into pipes or cause them to retreat to the inside wall of the pipe, but this tends to be a reactive method. Grease disposal is addressed through public education and an ongoing grease trap interceptor program. The grease prevention program also contains enforcement capability.

ENV currently engages in several measures to prevent wastewater leaks and spills. In addition to constant monitoring of facilities and flow levels, backup pumps and bypass pipes and hoses are included in facility design. In the event that a leak occurs in a large main, ENV attempts to reduce the flow by pumping wastewater upstream of the leak site to pump trucks. For those large capacity mains where bypasses are difficult or impossible, parallel lines could be considered.

PROJECT 25: WASTEWATER CONTAMINATION MITIGATION

Preliminary Scope

Improvements to the sewer collection system are needed to minimize leaching and spills into coastal areas.

- Plan, conduct studies, and construct a centralized sewer system to serve Campbell Industrial Park and remaining unsewered areas that are currently not in the long-range plan.
- Install planned improvements to minimize inadvertent sewer spills.
- Reduce private property contributions to wet weather flows.
  - Continue smoke testing and follow up with homeowners for compliance
  - Continue to educate private property owners on their contribution to wet weather spills
  - Target large property owners
  - Investigate the feasibility of an ordinance that requires leaks and illegal connections be fixed before a property is sold or a new sewer connection is granted
  - Improve ENV inter-departmental communication between permitting and enforcement, not allowing wastewater permits until fines are paid and improvements are made
- Reduce the impacts of grease and tree roots on sewer lines.
  - Continue educating business owners regarding proper grease disposal and recycling
  - Encourage private industry efforts to recycle used oil and grease
  - Educate private property owners on proper plantings and vegetative management near utility lines
  - Continue investigation of alternative pipe materials or pipe wraps that can withstand or prevent tree root intrusion.
- Continue discussion of installing parallel force mains at specific locations where existing bypass methods cannot be used.
- To minimize the effects of spills, coordinate with BWS to trigger the water conservation plan asking consumers to delay water use to off-peak hours.

PARTICIPATING AGENCIES

Lead Agencies: ENV
Participating Agencies: DOH, BWS, Developers, Landowners

ESTIMATED COST

$500,000 - $1,000,000

TIME FRAME

On-going

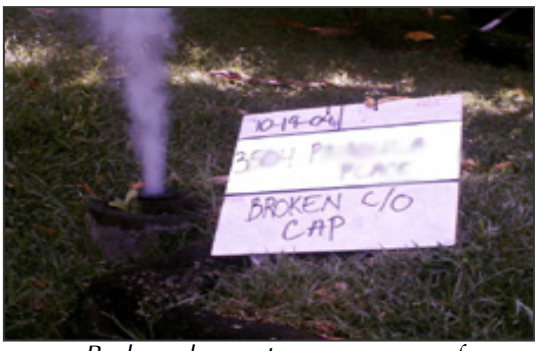
REFERENCES

CH2MHill, *Consulting Engineer's Study Wastewater System Revenue Bonds Series 2006* (City and County of Honolulu Department of Environmental Services; 2006), <http://www.honolulu.gov/budget/ww_2006_ series_abc.pdf> (October 11, 2006).

Department of Environmental Services, *West Mamala Bay Wastewater Facilities Plan* (Wilson Okamoto and Brown & Caldwell; 2001).

Department of Environmental Services, *Water Quality Management Plan for the City and County of Honolulu* (City and County of Honolulu and Hawaii State Department of Health; 2001).

Fukunaga and Associates, *Sewer Rehabilitation and Infiltration & Inflow Minimization Plan* (1999).



Broken cleanout cap, a source of infiltration / inflow.

PROJECT 26: WETLAND HABITAT PROTECTION

PROBLEM STATEMENT

Habitat loss, invasion of wetlands by non-native plants, environmental contaminants, and predation by alien species threaten endemic waterbirds and other native fauna and flora, and reduce the valuable functions that wetlands can offer.

GENERAL BACKGROUND

A series of biologically valuable fresh and brackish water wetlands encircle the Pearl Harbor shoreline. However, wetlands in the Central O'ahu Watershed are estimated to have been reduced by 95%, or approximately 3,600 acres, since first human contact. These wetlands were either impacted by sediment from terrestrial degradation, or filled for development. Alien plants and animals have also added to the depletion of the wetlands. Heavy littering and previous dumping are also a problem for Pearl Harbor wetlands.

Wetland restoration improves water quality, provides habitat for endangered birds, and gives the community an opportunity to engage in environmental stewardship and ownership. Wetlands are natural water pollution filters, breaking down pollutants and catching silt and sediment before they reach the Pearl Harbor estuary and coastal areas. Wetlands at higher elevations are also important in that they serve as flood control.

The wetlands that encircle the Pearl Harbor shoreline provide habitat for endangered waterfowl, including: koloa (Hawaiian Duck), 'alae ke'oke'o (Hawaiian Coot), 'alae 'ula (Hawaiian Gallinule), and ae'o (Hawaiian Stilt). Sufficient suitable habitat must be protected and managed in perpetuity such that these species no longer require protection under the Endangered Species Act. Wetlands are also important to native amphidromous species, such as 'anae-holo and 'ama'ama (mullet), 'o'opu (gobies), and 'ōpae (shrimp).

Pearl Harbor NWR was essentially "created" in exchange for the near-shore mudflat areas that were destroyed due to the building of the Honolulu Airport reef runway in 1972. Additional wetlands created here could be used as a "wetland bank" to mitigate loss of wetlands in other locations, both within and outside of this Watershed.

The USFWS *Waterbird Recovery Plan* lists Pearl Harbor NWR (USFWS) and Pouhala Marsh (DLNR) as Core Wetlands that must continue to be protected and managed for recovery of endangered wetland birds. Additional wetlands that are currently unprotected and considered worthy of management by USFWS include: Apoka'a Pond (West Loch Shoreline Park), Barber's Point Golf Course Ponds, Batis Salt Marshes (West Loch and 'Ewa Marina), Chevron Rowland Pond and Impounding Basin, Fort Kamehameha, Hawai'i Prince Golf Course Ponds, Hickam Air Force Base Wetlands Preserve, Honouliuli Golf Course Ponds, Kapolei Golf Course Ponds, Ko Olina Golf Course Ponds, Pearl Harbor East Loch, Sumida Watercress, Waikele Harbor Mudflat, Waipahu Landfill, Waipi'o Basins, Walker's Bay (Waipi'o Peninsula), and Waipi'o Soccer Fields Wetlands.

During the spring, Hawai'i Nature Center provides an education program to Pouhala Marsh, and in the fall, to the Honouliuli unit of Pearl Harbor National Wildlife Refuge. This is a popular program, but funding for HNC on this project runs out in June 2006. A co-sponsor for the program is needed because costs are prohibitive. Partnerships have been instrumental in achieving past conservation efforts and are essential to protect and manage existing wetlands.

PROJECT 26: WETLAND HABITAT PROTECTION

PRELIMINARY SCOPE

The objective of this project is to protect and manage wetland habitats in order to maximize productivity and survival of endangered waterbirds and other native species, as well as reclaim their natural water cleansing and protection abilities.

- Research information on previous native habitat and the extent of current wetland degradation.
- Conduct resource surveys of wetlands.
  - Compile and map information on water quality, locations and source of pollutants and trash, and any fencing that has taken place.
  - Document extent of non-native species and identify all species and their locations.
  - Prioritize restoration need according to hydrology, biotics, land ownership, and agency requirements (i.e., see NRCS Wetland Reserve Program Ranking Criteria).
  - Suggest appropriate restoration techniques.
  - Determine sites that would be appropriate for future "wetland banks."
- Develop wetland banking system.

Pouhala Marsh and Pearl Harbor National Wildlife Refuge:

- Develop or update management plans.
- Continue to maintain appropriate hydrological conditions (i.e., manage water levels).
- Manage vegetation.
  - Control invasive nonnative plants.
  - Encourage desirable plant species.
- Eliminate or reduce and monitor predator populations.
  - Finish remaining fencing.
- Minimize human disturbance.
- Remove any remaining fill.
- Monitor water quality.
- Investigate funding to hire additional staff for wetland management.
- Coordinate management of wetlands with other agencies and organizations.
- Build overlooks for community access.
- Investigate funding possibilities to continue education program to increase public awareness and support for wetlands.

PARTICIPATING AGENCIES

Lead Agencies: DLNR, USFWS, Ducks Unlimited

Participating Agencies: HNC, NRCS O'ahu RC&D, DOH, DFM, COE, Navy, NOAA CRC

ESTIMATED COST

$500,000 - $1,000,000

TIME FRAME

2-20 years

REFERENCES

The Wildlife Society. *Wetland Management in the Hawaiian Islands Workshop Proceedings, October 31, November 1, 2002*, 2002, <http://www.tws-west.org/2002ha_wetland_proceedings.pdf> (March 22, 2006).

U.S. EPA, *Wetlands*, 2006, <http://www.epa.gov/OWOW/wetlands/index.html> (March 22, 2006).

U.S. Fish and Wildlife Service, *Draft Revised Recovery Plan for Hawaiian Waterbirds, Second Draft of Second Revision*, 2005, U.S. Fish and Wildlife Service, Portland, Oregon <http://ecos.fws.gov/docs/recovery_plans/2005/050824.pdf> (March 20, 2006).

Honouliuli National Wildlife Refuge.

PROJECT 27: PEARL HARBOR FISHPOND RESTORATION PARTNERSHIP

PROBLEM STATEMENT

Any remaining fishponds within Pearl Harbor are not fit for use due to contaminated sediment and/or broken walls.

GENERAL BACKGROUND

Due to its sheltered location, Pearl Harbor was the ancient location of several Hawaiian fishponds. The Hawaiians knew Pearl Harbor by several names, for example, Ka-awa-lau-o-Pu'uloa, the many harbors of Pu'uloa, and Awaawa-lei, the garland of harbors. A map compiled from information available from 1873 to 1915 shows 30 fishponds along Pearl Harbor's shoreline, including the two largest, Loko Hanoloa and Loko 'Eo, on Waipi'o Peninsula. Over half remained after initial development of the Pearl Harbor Naval Base, but only four fishponds existed by 1974 ('Oki'okiolepe, Pa'aiau, Kaaku, and Laulaunui).

Since human contact, there has been a transformation of Hawaii's natural wetlands to cultural fishponds, to their subsequent degradation from erosion and run-off. Large areas of the Waipi'o Peninsula in West Loch were filled with dredged material. Because of this and other dredge and fill operations, most of the Hawaiian fishponds existing early in the century were destroyed. Mangrove overgrowth has also damaged a number of others.

Fishpond restoration is generally initiated for cultural and educational purposes. The ultimate goal of organizations involved in restoration is typically to restore its intended function and to produce edible fish. It is necessary to keep in mind that restoration of fishponds must take into consideration the land use and environment *mauka* of the pond, as runoff and pollutants from upland may impact the health of the pond downstream.

Senator Inouye established the Federal Legacy Resource Management Program in 1991 to identify, manage, and protect natural and historic treasures on military lands. One project funded from that program included a Native Hawaiian fishpond inventory at Pearl Harbor. This was a joint project between the U.S. Navy and the State of Hawai'i Historic Preservation Division, investigating traditional stone walled fishponds that were characteristic of Hawaiian fishing strategies. Located on the shores of Pearl Harbor are 18 buried and 3 extant fishponds.

In 1997, legislative resolution HR121 was adopted requesting the establishment of a community-based, cooperative Hawaiian Fishpond Restoration project to restore and maintain one or more of the remaining fishponds in Pearl Harbor. The two fishponds found most feasible for restoration were Pa'aiau and Laulaunui. However, the Pa'aiau project was unable to move forward due to lack of funds and security access issues onto Navy lands. The Navy was supportive of work at Laulaunui, but the Commander in favor of the project retired before any work could proceed.

Additional fishponds that may have restoration potential include 'Oki'okiolepe (listed on the National Register of Historic Places) and Pa'akea. Other fishponds have reverted from a cultural wetland back to a natural state of being a marsh or refuge, such as Opu in Kalauao, Kuhialoko in Waiawa, and Pouhala in Waipahu. These fishponds-turned-marsh could be used as interpretive sites.

PROJECT 27: PEARL HARBOR FISHPOND RESTORATION PARTNERSHIP

PRELIMINARY SCOPE

The objective of this project is to revitalize the Hawaiian Fishpond Restoration Partnership for Pearl Harbor to restore these significant archaeological, cultural, and historic sites.

- Update 1997 research to determine the extent of work necessary for remaining fishponds restoration.
- Gather water samples, depth measurements, determine footprint of pond walls, and make an overall assessment of the ponds.
- Research the history of fishpond construction in Pearl Harbor.
- Develop a Pearl Harbor fishponds restoration plan and identify feasible improvements. Partial restoration may be possible for some in conjunction with interpretive exhibits.
- Identify and secure participants in the partnership.
- Identify the jurisdictional authorities and resources that each partner brings to the table.
- Develop a relationship with the Navy that will survive past rotations in command.
- Secure funding through such avenues as EPA, Pacific American Foundation, Rails to Trails, and TEA-21.
- Seek Federal, State, and City permits.
- Develop volunteer base.
- Determine restoration schedule.
- Encourage public education in relation to the fishponds.
- Determine the eligibility of remaining fishponds for the National Register of Historic Places.
- Develop a long-range master plan that incorporates aquaculture production, economic sustainability, education, and research.

PARTICIPATING AGENCIES

Lead Agencies: Friends of Pearl Harbor Historic Trail, 'Aiea Community Association.
Participating Agencies: EPA, USFWS, DLNR, Navy, SHPD, National Park Service, OHA, landowners, Leeward Community College, DBEDT Aquaculture Program.

ESTIMATED COST

$50,000 - $100,000

TIME FRAME

2 – 10 years

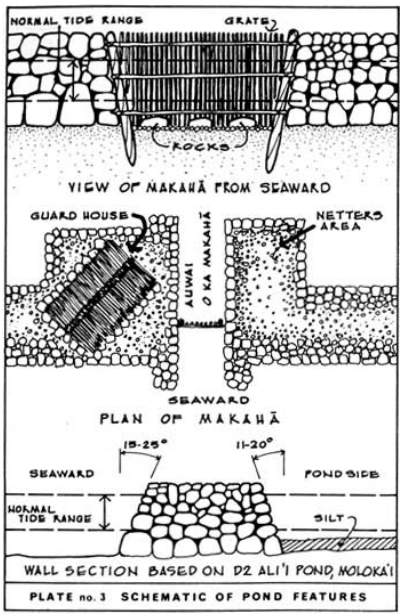
REFERENCES

City and County of Honolulu, *Aiea - Pearl City Livable Communities Plan* (Wilson Okamoto and Associates, 2004).

City and County of Honolulu, *Draft Pearl Harbor Historic Trail Master Plan* (Belt Collins Hawai'i, 2000).

EPA, *Resolving Water Quality and Permitting Issues for Native Hawaiian Fishponds. Project Loko I'a* (Pacific American Foundation, 2003).

C. Wyban, *Tide and Current – Fishponds of Hawaii* (University of Hawai'i Press, 1992).



Typical Fishpond features.

PROJECT 28: 'EWA BEACH EROSION CONTROL PROGRAM

PROBLEM STATEMENT

The 'Ewa beach coastline is experiencing significant beach erosion and shoreline retreat, a threat to both homeowners and the growing population that uses the coast as a recreational resource.

GENERAL BACKGROUND

The stretch of beach along the 'Ewa shore begins at Keahi (Iroquois) Point at the west side of the Pearl Harbor entrance, and includes 'Ewa and One'ula beaches. Iroquois Beach extends from the seawalls on the southern sandy point through a beach recreation area and picnic grounds open only to military personnel. 'Ewa Beach Park is a popular public picnic and swimming site. Both 'Ewa and One'ula Beach Parks are popular for fishing, gathering *limu*, and surfing.

The 'Ewa coastline is an eroding coastline, even though it sustains relatively low wave activity. The waves maintain a thin, narrow beach with considerable beachrock, reef and sand flats located along the base of the beach, and surf extending out across the reef flats. Possible causes of erosion include nearby concrete-lined channels, reduced sediment supply, channel dredging, reef degradation, long-term sea level rise, extensive coastal development, and ironically, construction of shoreline protection structures such as seawalls.

'Ewa Beach Park is currently experiencing low erosion rates because there are no seawalls fronting the beach, and the existing sand dunes are a source for natural sand replenishment. West of the park, however, houses, small jetties, groins, and seawalls front the beach, causing the beach to narrow to just a few meters in some places. At high tide, water meets the walls, indicating severe erosion, and a loss of the beach as a recreational and environmental amenity. The seawalls are so extensive here that there is a local surf site called Sea Walls located off the beachfront homes at the west end of Pūpū Street.

East of the park, the Iroquois Point Naval Housing area has also experienced chronic, severe erosion. The Navy has contracted Sea Engineering to design a 3,200-foot long beach restoration project with stabilization structures. The work includes hydrographic surveys, investigation of offshore and onshore sand sources, engineering design analysis including determination of oceanographic parameters, numerical modeling of beach response, evaluation of alternatives, and detailed design of a selected beach and stabilization plan.

The City and the University of Hawai'i Coastal Geology Group (UH-CGG) are currently performing a coastal erosion-mapping project. Detailed maps of the erosion patterns of O'ahu beaches will be created to help guide future development. This project will be nearing completion in early 2007.

The beaches of Hawai'i have historically been a poorly managed resource, which is somewhat surprising considering their link to the state's multi-billion dollar tourism industry. The 'Ewa coastline may not attract as many tourists as Waikiki Beach does; but the growing population of the area requires a recreational outlet. The environment is already degraded along this coastline. If not properly mitigated now, erosion of these beaches could have disastrous effects on property values and community well-being.

PROJECT 28: 'EWA BEACH EROSION CONTROL PROGRAM

PRELIMINARY SCOPE

Further study of 'Ewa coast beach erosion with recommendations for restorative action is necessary to help prevent property damage and protect the environment for the community and marine life.

- Review and analyze all studies of erosion history, coastal processes, beach profile fluctuations, long-term changes, and the reef record for the 'Ewa coastline.
  - Research bathymetric and condition surveys, dredging information, NOAA charts, SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) data, etc.
  - Study near shore circulation patterns to help determine environmental impacts of various drainage master plans.
- Document all shoreline structures and recommend any replacement alternatives.
- Develop a sediment budget that accounts for the sources and sinks of littoral material.
  - Run a sediment transport model to determine sediment loads and sources with various scenarios, such as increased development, changes to stream channels, marina development, etc.
- Conduct monthly beach profiling to understand seasonal sediment dynamics.
- Develop a cost/benefit analysis for guiding erosion management efforts.
- Provide recommendations for feasible 'Ewa coast beach erosion management strategies including:
  - Soft engineering: Restoration through coastal dune stabilization, beach nourishment, and vegetation restoration.
  - Hard engineering: Beach widening through groins that are filled with sand to create a scalloped shoreline.
- Predict future shoreline erosion with and without engineering options.
- Consider designating the 'Ewa coastline as a Beach Management District to ensure adequate resources are dedicated for coastal protection, research, recreation, and restoration.

PARTICIPATING AGENCIES

Lead Agencies: CZM, DLNR CLP, City and County of Honolulu, COE
Participating Agencies: UH CGG, USGS, UH Sea Grant, UH SOEST, NOAA

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

2 years

REFERENCES

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The 'Ewa coastline.

PROJECT 29: PEARL HARBOR ECOLOGICAL RESTORATION

PROBLEM STATEMENT

Upstream and in-harbor uses have degraded Pearl Harbor's ecological health.

GENERAL BACKGROUND

Pearl Harbor and the waters just outside its channel contain recreational and commercial fisheries, endangered species habitat, wetlands, and recreation areas. Heavy use by Hawaiians for fishing and other food gathering suggests that Pearl Harbor always supported a rich ecosystem. Recent surveys have identified hundreds of taxa despite many problems including poor water quality, contamination, high sedimentation rates, and introduced species.

Pearl Harbor was thought to have high water quality until major upstream land use changes increased runoff and sedimentation.[276] The State Department of Health (DOH) included Pearl Harbor and eight feeder streams in its 2004 List of Impaired Waters in Hawai'i for several pollutants. The harbor is a high priority for the development of Total Maximum Daily Loads (TMDLs), which are currently being developed for the listed streams.[277]

The Pearl Harbor Naval Complex was also listed on the National Priorities List in 1992.[278] The Navy and others have identified various chemicals that may present unacceptable risk to human health and the environment, and in 1998, the DOH issued a Fish and Shellfish Consumption Advisory.

Natural habitat in the harbor has been altered, with widening and deepening of the harbor mouth, likely creating more saline conditions and much of the shoreline converted to docks and other naval facilities. Dredging has deepened shallow areas and fishponds were filled with the dredge material. Water quality has decreased largely due to nutrification, increased sedimentation, and previous effluent discharges. In 1988, the Navy detected bis(2-ethylhexyl)phthalate in sediment samples from the National Wildlife Refuge, a habitat for four Federally endangered species.[279]

Both intentional and unintentional species introduction are occurring at a moderate rate, with introduced species already making up a substantial portion of the total biological community.[280] There is little data to verify water quality and habitat trends since the 1970s; however, subjective observations and abatement of many pollution sources suggest improvement. Organisms such as coral reefs that are sensitive to sedimentation, turbidity, and other pollution stresses, appear to be establishing themselves.

There are many entities with interests in the welfare of the harbor. Partnerships have been formed to address specific concerns, such as pollution runoff (Pearl Harbor Estuary Program Interagency Committee) and non-point source pollution (Pearl Harbor Watershed Environmental Restoration Projects), but there is no entity whose mission is to comprehensively improve ecological health in a manner that accommodates human uses.

PROJECT 29: PEARL HARBOR ECOLOGICAL RESTORATION

PRELIMINARY SCOPE

The *Pearl Harbor Ecological Restoration Plan* should bring government agencies and private and community groups together to restore ecological health and environmental safety to Pearl Harbor while accommodating Naval shipyard and other uses.

- Develop a partnership to restore the Pearl Harbor habitat and ecosystem. Work with prior and existing partnerships to see where they can be expanded, combined, or partnered with this effort.
- Develop an overall Pearl Harbor Management Plan.
  - Involve community early and often.
  - Understand the needs of all user groups and work to accommodate all uses, or as many as can be safely accommodated.
  - Review previous reports to gain a comprehensive understanding of the actions that are necessary to improve environmental health.
  - Design remedies to minimize short-term risks while achieving long-term protection.
- Conduct follow-up studies to identify ecological trends and evaluate actions.
  - Identify new, non-indigenous species since the last survey in1997.
  - Monitor the balance between introduced and native species.
- Determine the extent, severity, and cause of soil and water contamination and identify remedial actions to bring environmental health into compliance with health and safety requirements.
  - Complete TMDL studies.
  - Identify contaminants associated with unacceptable risks.
  - Control contaminant sources early.
  - Share harbor data and work plans for future sampling.
  - Ensure that cleanup levels are clearly tied to risk management goals.

PARTICIPATING AGENCIES

Lead Agencies: Navy
Participating Agencies: NOAA, USFWS, EPA, DLNR, DOH, DFM, ENV, Fishpond restoration organizations.

ESTIMATED COST

$250,000 - $500,000

TIME FRAME

3 years

REFERENCES

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Pearl Harbor has been heavily modified by shore facilities and dredging to support Naval and other shipping activities.

PROJECT 30: CENTRAL O'AHU WATERSHED PUBLIC EDUCATION PROGRAM

PROBLEM STATEMENT

Central O'ahu and 'Ewa residents no longer have a close affinity for the environment.

GENERAL BACKGROUND

Ignorance of the environment and watershed functions has led to degradation of native habitat by actions such as dumping and littering. While there is a plethora of environmental education materials available from various agencies, it is difficult to find Central O'ahu-specific information, which is more likely to influence a person as they can relate to areas around their home or place of business.

A watershed center, similar to the Hawai'i Nature Center in Makiki, would help to coordinate existing and future watershed-related activities for Central O'ahu and 'Ewa. Possible locations for such a center include the Honouliuli Reserve or the DLNR baseyard in Pearl City where the Ko'olau Mountains Watershed Partnership is based. Such a center could disseminate brochures and promote programs that are already available by various agencies and community groups. By being focused on just the Central O'ahu Watershed, this education program will be able to connect the public with watershed issues and opportunities in their own backyards.

A Central O'ahu Watershed website could provide a community calendar of watershed events and neighborhood cleanups of which volunteers can take a part, such as beach and stream cleanups, storm drain stenciling, and water quality monitoring. The website could also provide information such as public disclosure of known habitual stream polluters and public health notices to protect the health of those fishing and consuming aquatic organisms out of Pearl Harbor and associated streams. Other essential information that could be posted on the website include occurrences of rock falls, erosion, and wildfires. The website could also provide a venue for residents to report any problems that they have witnessed, such as dumping, alien species infestations, or pig damage, so the proper authorities may be contacted.

The education program would also develop a handbook that provides watershed contacts, whom to call for skill development, and outlines how community groups / organizations can get involved in improving their sub-watersheds. The program would also train volunteers to help manage and monitor resources and coordinate workshops with the community on such topics as composting, proper pesticide and fertilizer use, xeriscaping, conservation, etc.

Children who are environmentally conscious often maintain an environmentally friendly lifestyle throughout their lives. Therefore, environmental education should target youth as well as adults, and provide opportunities for kid-friendly learning, including educational "games" and mini watershed tours, and work days where children can get into the watershed and see how they can improve the ecosystem.

A Central O'ahu Watershed public education program would promote classroom and in-the-field learning, hands-on ecological investigations, networking, partnerships, stewardship, and community service in an effort to produce environmentally literate citizens.

PROJECT 30: CENTRAL O'AHU WATERSHED PUBLIC EDUCATION PROGRAM

PRELIMINARY SCOPE

Public watershed education is needed to encourage an appreciation of Central O'ahu Watershed and educate all stakeholders, including students, business owners, agencies/elected officials, military, visitors, and residents on their role in protecting and managing these natural resources.

- Identify a location for a watershed center. Some considerations when identifying a site include an accessible location in an area that allows access to outdoor programs such as watershed tours.
- Develop a steady funding source for one full-time and one half-time staff and office needs.
- Gather watershed education information from various agencies and compile a digital library.
- Create a database of all watershed organizations, schools, churches, housing associations, businesses, hula halau, scouts, service organizations, military groups, etc., located within the Central O'ahu Watershed.
- Develop a website that makes local watershed information available, such as a project / programs calendar, health advisories, and disclosure of dumpsites and offenders.
- Organize, publicize, and conduct environmental workshops.
- Develop a handbook with Central O'ahu-specific watershed information, similar to *Island Stewardship* or the *West Maui Watershed Owners Manual* (both by DOH).
- Attend fairs and public conferences to disperse information.
- Develop a presentation and visit schools and community groups.
- Develop a child-oriented educational program, including hands-on activities and take-home materials.
- Encourage the public to volunteer for environmental projects.
- Conduct watershed tours.

PARTICIPATING AGENCIES

Lead Agencies: DOH, DLNR
Participating Agencies: TNCH, YMCA, UH Sea Grant, NRCS, DBEDT

ESTIMATED COST

$50,000 - $100,000 per year

TIME FRAME

4-10 years or more, depending on funding

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