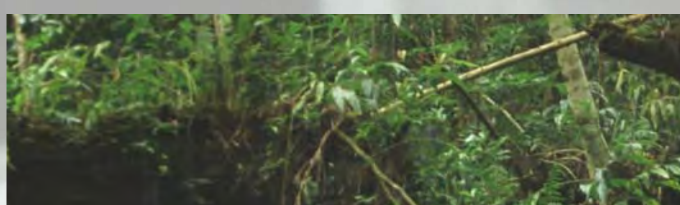
Hawaii Water Plan

Water Resource Protection Plan

JUNE 2008

Prepared for:

State of Hawaii
Commission on
Water Resource Management



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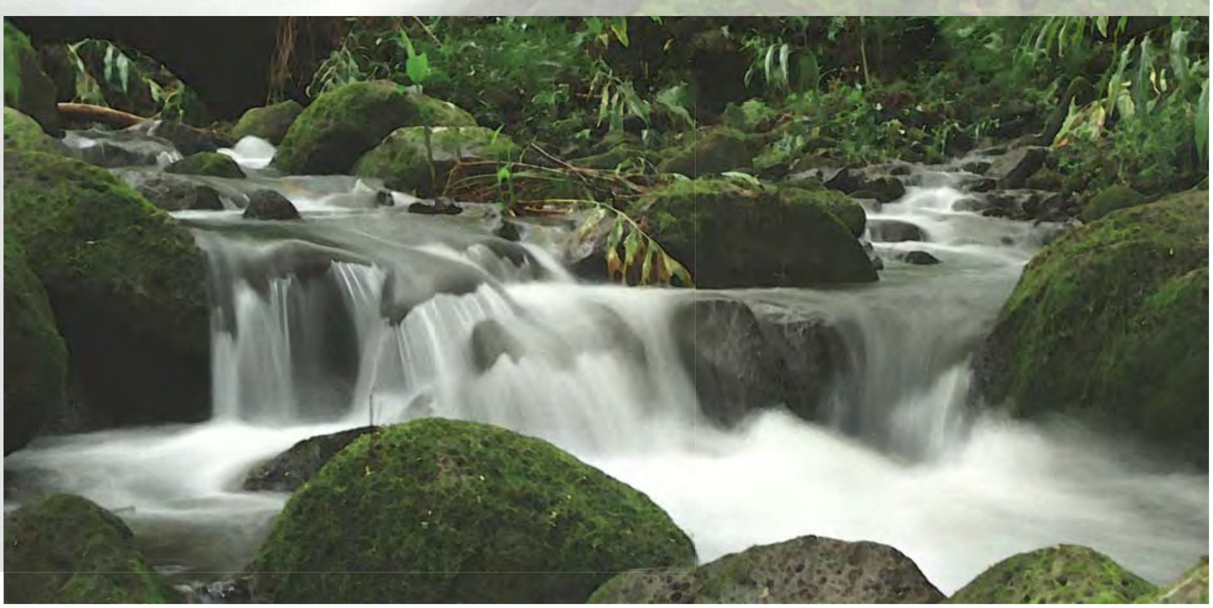

Hawaii Water Plan

WATER RESOURCE PROTECTION PLAN

Prepared for:

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COMMISSION ON WATER RESOURCE MANAGEMENT
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JUNE 2008

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LIST OF ABBREVIATIONS

%	percent
12-MAV	12-month moving average
AHR	American Heritage River
AWUDP	Agricultural Water Use and Development Plan
AWWA	Ala Wai Watershed Association
BFI	base-flow index
BLNR	Board of Land and Natural Resources
CLDC(s)	County/Local Drought Committee(s)
County WUDPs	County Water Use and Development Plans
CPC	National Weather Service Climate Prediction Center
CSTRs	completely stirred tank reactors
CTAHR	College of Tropical Agriculture and Human Resources, University of Hawaii
CWRM	Commission on Water Resource Management
CZARA	Coastal Zone Reauthorization Amendments of 1990
CZM Program	Coastal Zone Management Program
DAR	DLNR Division of Aquatic Resources
DBCP	dibromochloropropane
DBEDT	Department of Business, Economic Development and Tourism
DHHL	Department of Hawaiian Home Lands
DOA	Department of Agriculture
DOFAW	DLNR Division of Forestry and Wildlife
DOH	Department of Health
DOWALD	DLNR Division of Water and Land Development
DLNR	Department of Land and Natural Resources
EDR	electrodialysis reversal
EIS	Environmental Impact Statement
ENSO	El Niño/Southern Oscillation
EPA	U.S. Environmental Protection Agency
EPO	DOH Environmental Protection Office
FEMA	Federal Emergency Management Agency
Framework	Statewide Framework for Updating the Hawaii Water Plan
FY	Fiscal Year
GAP	Gap Analysis Program
GCM	General circulation models
GIS	Geographic Information Systems
gpd	gallons per day
gpd/ac	gallons per day per acre
gpm	gallons per minute
GPS	global positioning satellite
GWPP	Groundwater Protection Program
HAR	Hawaii Administrative Rules
Hawaii DWS	Hawaii Department of Water Supply
HAWP	Hawaii Association of Watershed Partnerships
HDP	Hawaii Drought Plan

LIST OF ABBREVIATIONS (continued)

HECO	Hawaiian Electric Company
Honolulu BWS	Honolulu Board of Water Supply
HRS	Hawaii Revised Statutes
HSA	*Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources*
HWCPIS	Hawaii Well Construction and Pump Installation Standards
HWH	Hanalei Watershed Hui
HWP	Hawaii Water Plan
IFS	Instream Flow Standard(s)
in/yr	inches per year
interim IFS	interim Instream Flow Standard(s)
Kauai DOW	Kauai Department of Water
LEED standards	Leadership in Energy and Environmental Design standards
Legislature	Hawaii State Legislature
LUC	DBEDT Land Use Commission
Maui DWS	Maui Department of Water Supply
mi^2	square mile(s)
mgd	million gallon(s) per day
mg/L	milligrams per liter
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPTZ	midpoint of the transition zone
NAPP	Natural Area Partnership Program
NARS	Natural Area Reserves System
NCDC	National Climatic Data Center
NDMC	National Drought Mitigation Center
NGS	National Geodectic Survey
NOAA	National Oceanic & Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
OCCL	DLNR Office of Conservation and Coastal Lands
Office of Water	U.S. Environmental Protection Agency Office of Water
ORMP	Hawaii Ocean Resources Management Plan
OWMP	Oahu Water Management Plan
PDO	Pacific decadal oscillation
PHGMP	Pearl Harbor Ground Water Monitoring Plan
PHMWG	Pearl Harbor Monitoring Working Group
ppm	parts per million
R-O water	Reverse-osmosis-treated recycled water
R-1 water	tertiary-treated recycled water
R-2 water	disinfected secondary-treated recycled water
R-3 water	undisinfected secondary-treated recycled water
RAM	robust analytical model
RAM2	modified robust analytical model

LIST OF ABBREVIATIONS (continued)

RASA	Regional Aquifer-System Analysis
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RFD	Request for Determination
SCAP	Stream Channel Alteration Permit(s)
SCO	University of Hawaii - State Climate Office
SDWP	Stream Diversion Works Permits
SMA	Special Management Area
SMURRF	Santa Monica Urban Runoff Recycling Facility
SPAM Branch	CWRM's Stream Protection and Management Branch
State Constitution	Constitution of the State of Hawaii
State Water Code	Chapter 174C, Hawaii Revised Statutes
SWAP Program	Source Water Assessment and Protection Program
SWCD(s)	Soil and Water Conservation District(s)
SWIM System	Surface Water Information Management System
SWPP	State Water Projects Plan
SY	Sustainable Yield
The Court	Hawaii Supreme Court
TMDL	Total Maximum Daily Load
UIC Program	Underground Injection Control Program
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USNPS	U.S. National Park Service
Waihole Water Case	Waiahole Ditch Contested Case, Docket No. CCH-OA95-1
WCFSP	Water Conservation Field Services Program
WMA(s)	Water Management Area(s)
WQP	Water Quality Plan
WRF	Water Recycling Facility
WRPP	Water Resource Protection Plan
WRRC	Water Resource Research Center
WUDP	Water Use and Development Plan
WWRF	Wastewater Reclamation Facility
WWTP	Wastewater Treatment Plant

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Section 1

Introduction

1. INTRODUCTION

The Water Resource Protection Plan (WRPP) is one of five major plans that comprise the Hawaii Water Plan (HWP), established pursuant to Chapter 174C, Hawaii Revised Statutes (HRS §174-C) (State Water Code). The Water Resource Protection Plan, together with the Water Quality Plan (WQP), State Water Projects Plan (SWPP), Agricultural Water Use and Development Plan (AWUDP), and the County Water Use and Development Plans (WUDPs), provides the overall guidance and direction for managing Hawaii's water resources (see Figure 1-1). Article XI, Section 7, of the Constitution of the State of Hawaii (State Constitution) establishes the State as trustee of water resources, with the constitutionally mandated responsibility to set policy, establish regulatory procedure, and establish and protect water use priorities while assuring water rights. Initially prepared in 1990, the WRPP update reflects the latest efforts in water resource planning as part of the State's mandate to protect and sustain the water resources for the benefit of the citizens of the state of Hawaii.

The plan is organized into the following sections:

Section 1 **Introduction:** This section gives an overview of the State Water Code and the HWP, including background information on both the initial 1990 WRPP and the organization of this update.

Section 2 **General Water Resource Management Principles and Policies:** The State Constitution, the State Water Code, and the Hawaii Administrative Rules set forth water management principles and policies for the State. The Commission on Water Resource Management (CWRM) applies these principles and policies when implementing the State Water Code. This section summarizes water management principles and policies, and presents CWRM's goals and objectives for executing the agency's mandated responsibilities.

Section 3 **Inventory and Assessment of Resources:** The State Water Code mandates that the HWP provide an inventory of water resources statewide. This section provides the resource inventory, as well as supporting information and a discussion of issues that contribute to resource assessment and management.

Section 4 **Monitoring of Water Resources:** Careful program planning and interagency cooperation is necessary for effective implementation of statewide-resource monitoring programs. This section of the WRPP describes Hawaii's existing ground water, surface water, and climate monitoring and assessment programs, and provides recommendations for future actions, program expansion, and agency coordination.

Section 5 **CWRM Regulatory Programs:** CWRM uses regulatory controls to implement policies for ground and surface water development and water use. Regulations are employed to protect the resource, optimize its availability, and obtain maximum and reasonable-beneficial use of water, CWRM relies on a permit system to enforce these regulations. This section summarizes CWRM's regulatory programs and recommendations.

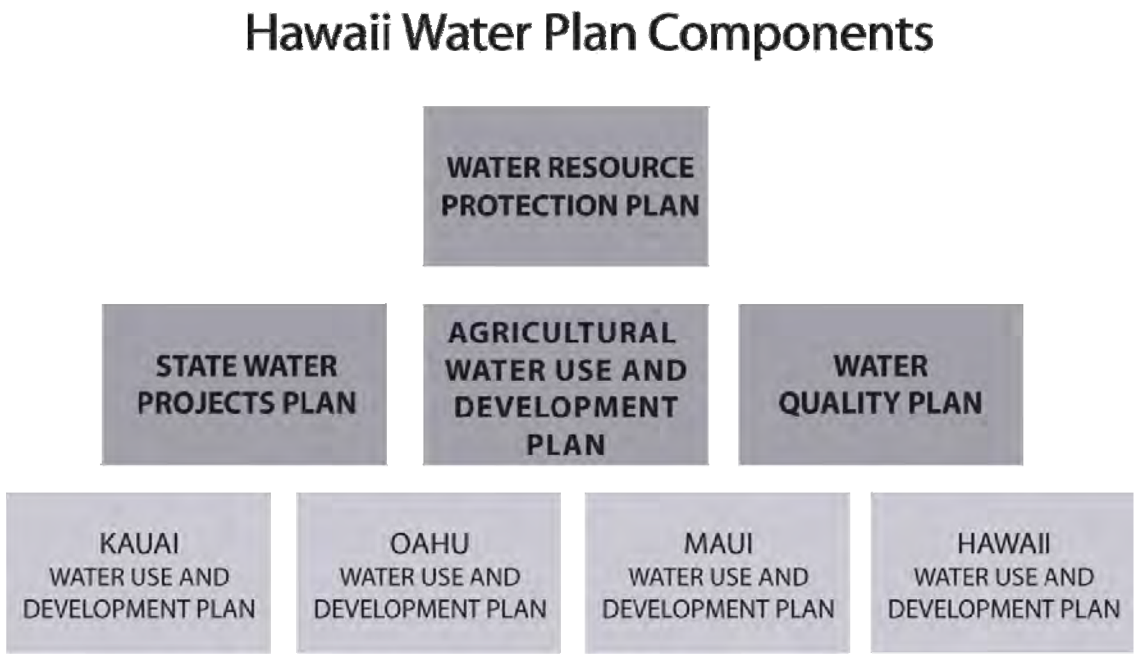

Figure 1-1. Hawaii Water Plan Components

Section 6 **Existing and Future Demands:** This section focuses on data available about existing and future water demands statewide, as well as the issues that are associated with quantifying water use and projecting water demand. Available data on existing ground water use and surface water use are presented, followed by a summary of water demand projections through 2030, as prepared by each county. The section concludes with a discussion of county-level water planning and the status of each county's planning efforts.

Section 7 **Resource Conservation and Augmentation:** To protect and conserve the State's water resources, the CWRM encourages water conservation and the use of alternative resources wherever feasible. This section reviews existing water conservation and augmentation activities in Hawaii and establishes goals and priorities for statewide planning programs. Climate change and its impacts to Hawaii's water resources are also discussed. Recommendations provide State leadership and guidance for the establishment, development, and implementation of such programs.

Section 8 **Drought Planning:** Droughts have affected the islands throughout Hawaii's recorded history, with the most severe events occurring in the past 15 years being associated with the El Ñino phenomenon. Direct and indirect impacts due to drought, manifest themselves as changes in the environment, economy, public health, and available water supplies. This section reviews and assesses drought-mitigation planning efforts undertaken in the state of Hawaii.

Section 9 **Watershed Protection:** For the most part, modern watershed protection and management programs have sprung from the Clean Water Act of 1977 and subsequent supporting legislation. This section describes watershed protection programs currently being implemented at the federal, State, and county levels, and summarizes community efforts and partnership projects that have achieved success in Hawaii. The section concludes with recommendations that encourage more integrated watershed management, by building upon existing programs linking mountain and shoreline area activities.

Section 10 **Water Quality:** The State Water Code provides that the Department of Health (DOH) shall have primary jurisdiction and responsibility for administration of the State's water quality control programs. This section provides information on the purpose and function of the WQP, reports the status of efforts to update the WQP, and describes current DOH programs that will contribute to the WQP plan update.

Section 11 **Priority Recommendations and Implementation Plan:** Recommendations are provided throughout the WRPP. This section organizes recommendations into an implementation plan providing for short and long-term actions. For planning purposes, cost implications and budget estimates are included as appropriate.

This plan update is ambitious in content and is comprehensive in its treatment of resource protection. It reflects CWRM's acknowledgement and understanding of the numerous issues that must be addressed in the preservation and stewardship of our state's limited water resources.

1.1. Overview of Statewide Water Resource Planning

It is generally recognized that the Hawaii's water resources need judicious management and regulation to assure availability and quality. In 1978, the State Constitutional Convention mandated the Legislature with formulating a statutory plan to address these concerns. Accordingly, in 1987, the Fourteenth Legislature enacted the State Water Code to "protect, control, and regulate the use of Hawaii's water resources for the benefit of its people" (HRS §174-C).

CWRM administers the State Water Code. CWRM's general mission is to protect and enhance the water resources of the state of Hawaii through wise and responsible management. HRS §174C-2(c) specifies the following:

> *The state water code shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes such as domestic uses, aquaculture uses, irrigation and other agricultural uses, power development, and commercial and industrial uses. However, adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper*

ecological balance and scenic beauty, and the preservation and enhancement of waters of the State for municipal uses, public recreation, public water supply, agriculture, and navigation. Such objectives are declared to be in the public interest.

A major responsibility of CWRM is to assemble the eight-part HWP, which consists of the following components:

- WRPP, prepared by CWRM;
- WQP, prepared by the DOH;
- SWPP, prepared by the Department of Land and Natural Resources (DLNR);
- AWUDP, prepared by the Department of Agriculture (DOA), and the
- WUDPs, prepared by each county.

The State Water Code provides that each HWP plan component, with the exception of the WQP, must be *adopted* by CWRM. The DOH's Water Quality Plan is *accepted* and incorporated by CWRM into the HWP. CWRM will integrate the plan components from various agencies into a cohesive tool for managing, protecting, and studying water resources statewide.

The State Water Code imposed a December 31, 1989 deadline for the completion and adoption of the HWP. While it may be argued that the HWP, adopted by CWRM in 1990, falls short of achieving the intended objectives, the existing plan establishes sufficient provisions and appreciable guidance to manage and protect the state's water resources.

Specific plan recommendations that emanated from the 1990 HWP clearly identified the need for further studies, assessments and follow-up actions that should be undertaken by government agencies. In 1992, the State and each county prepared draft updates to their respective HWP components, but CWRM's adoption of the 1992 draft HWP update was deferred, pending refinement of the individual plan components and availability of additional information.

As agencies struggled to complete the 1992 draft HWP update, a consensus arose among State and county entities that a comprehensive water resource planning process was needed to guide the development of various HWP components and integrate components into a comprehensive planning document. Under the authority of HRS §174C-31, which provides that CWRM may add to the HWP any information, directions, or objectives it feels are necessary or desirable for the guidance of the counties in the administration and enforcement of State Water Code provisions, CWRM developed a document to guide the updating process. In 2000, CWRM adopted the *Statewide Framework for Updating the Hawaii Water Plan* (Framework) (see Figure 1-2). The Framework is intended to provide focus and additional guidance to each agency responsible for updating specific components of the plan.

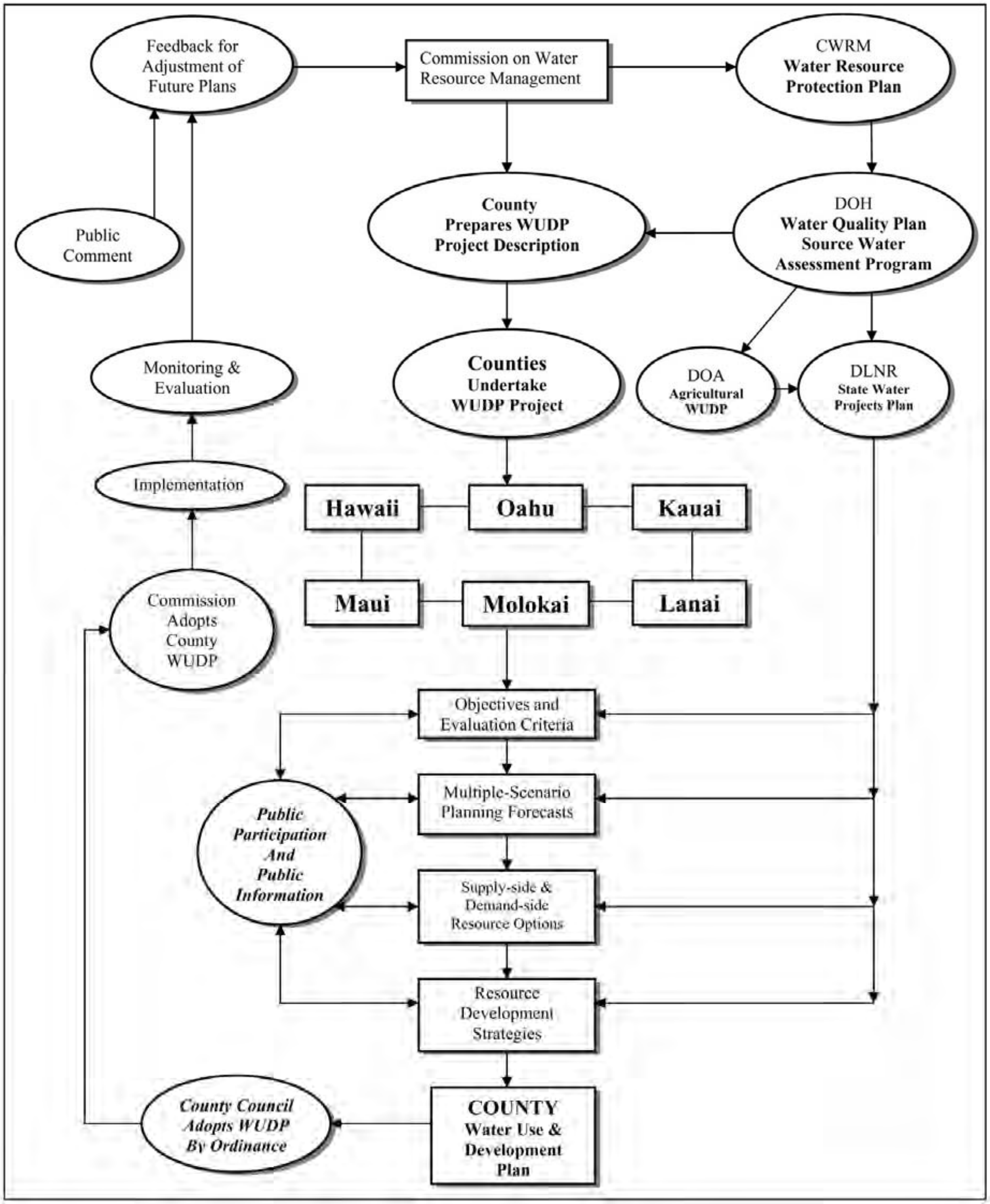

Figure 1-2. Framework for the Hawaii Water Plan

The Framework incorporates techniques to address the current complexities associated with planning activities regulation and management of water resources. It should be viewed as part of a long-term vision to prepare a "living document," which over several iterations will result in a truly comprehensive water resource plan. The dynamic process delineated in the Framework directs current State and county efforts to update the HWP components.

1.2. Water Resource Protection Plan Objectives

The WRPP is the key component of the HWP. CWRM is responsible for the preparation, implementation, and updating of the WRPP.

The scope of the WRPP, as provided by the State Water Code in HRS §174C-31, is as follows:

(1) Study and inventory the existing water resources of the State and the means and methods of conserving and augmenting such water resources;
(2) Review existing and contemplated needs and uses of water including State and County land use plans and policies and study their effect on the environment, procreation of fish and wildlife, and water quality;
(3) Study the quantity and quality of water needed for existing and contemplated uses, including irrigation, power development, geothermal power, and municipal uses;
(4) Identify rivers or streams, or a portion of a river or stream, which appropriately may be placed within a wild and scenic rivers system, to be preserved and protected as part of the public trust. For the purposes of this paragraph, the term "wild and scenic rivers" means rivers or streams, or a portion of a river or stream of high natural quality or that possess significant scenic value, including but not limited to, rivers or streams which are within the natural area reserves system. The commission shall report its findings to the legislature twenty days prior to the convening of each regular legislative session; and
(5) Study such other related matters as drainage, reclamation, flood hazards, flood plan zoning, dam safety, and selection of reservoir sites, as they relate to the protection, conservation, quantity and quality of water.

§174C-31, HRS further provides that:

The Water Resource Protection Plan shall include, but not be limited to:

(1) Nature and occurrence of water resources in the State;
(2) Hydrologic units and their characteristics, including the quantity and quality of available resource, requirements for beneficial instream uses and environmental protection, desirable uses worthy of preservation by permit, and undesirable uses for which permits may be denied;
(3) Existing and contemplated uses of water, as identified in the water use and development plans of the State and the counties, their impact on the resources, and their consistency with objectives and policies established in the water resource protection quality plan;
(4) Programs to conserve, augment, and protect the water resource; and
(5) Other elements necessary or desirable for inclusion in the plan.

Thereafter, the commission, in coordination with the counties and the department of health, shall formulate an integrated, coordinated program for the protection, conservation and management of the waters in each county based on the above studies. This program, with such amendments, supplements, and additions as may be necessary, shall be known as the water resource protection and quality plan.

1.3. Current Update of the Water Resource Protection Plan

The initial WRPP was completed and adopted by CWRM in 1990. As new and better information becomes available (e.g., hydrologic information and land use changes), CWRM must periodically update the WRPP. The 1990 WRPP provided the means by which to address many issues, including but not limited to estimates of sustainable ground water yields by island, description of aquifer sectors and aquifer systems, and an initial evaluation of current and projected water needs for the State and the counties.

This current update to the WRPP includes policies, program directives, resource inventories, and recommendations across a broad spectrum of resource management issues. Efforts supporting this update focused on the following tasks:

- Declaration of CWRM policies, goals, and objectives;
- Update of ground water hydrologic units and sustainable yields;
- Establishment of surface water hydrologic units and a stream coding system, and the development of a surface water diversion database;
- Explanation and description of CWRM's surface water management program and implementation plan;
- Development of statewide ground and surface water monitoring program priorities;
- Examination of water conservation and augmentation alternatives, drought preparedness and mitigation actions, and watershed protection programs; and
- Development of recommendations for future actions and funding requirements.

This update of the WRPP is intended to provide for more successful coordination and integration of State and county efforts related to sustainable water resource development and to enable CWRM to more effectively implement the statutory objectives of the State Water Code. Regularly updating this and other components of the HWP will facilitate the counties' integration of updated information into their respective WUDPs. Preparation and revision of HWP components through a "living document" approach provides county and State decision makers with well-formulated options and strategies for addressing future water resource management and development issues.

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Section 2

General Water Resource Management Principles and Policies

2. GENERAL WATER RESOURCE MANAGEMENT PRINCIPLES AND POLICIES

This section of the WRPP summarizes the water management principles and policies set forth in the State Constitution, the State Water Code, and the Hawaii Administrative Rules. The CWRM applies these principles and policies when implementing the State Water Code. Also presented are CWRM's goals and objectives for executing the agency's mandated responsibilities.

Following the summary of policies in Sections 2.1 and 2.2, Section 2.3 presents CWRM's goals and objectives for executing the agency's mandated responsibilities.

2.1. General Policies

This section relates general policies enumerated in the State Constitution and the State Water Code. Also included is a discussion of the Public Trust Doctrine, the Precautionary Principle, and legal provisions for water rights in Hawaii. This information is presented to encourage a broader understanding of the water management issues and implications of case law upon the administration of the State Water Code.

2.1.1. State Constitution

Under Article XI, Section 7, of the State Constitution, "The State has an obligation to protect, control, and regulate the use of Hawaii's water resources for the benefit of its people." With this statement, the Public Trust Doctrine was written into the State Constitution.

The Public Trust Doctrine is a concept relating to the ownership, protection and use of natural resources, where common resources such as water are to be held in trust by the State for the use and enjoyment of the general public. In Hawaii, the application of the Public Trust Doctrine in resource management considers both the public's right to use and enjoy trust resources, and the private property rights that may exist in the use and possession of trust resources; however, any balancing between public and private interests begins with a presumption in favor of public use, access, and enjoyment.

2.1.2. State Water Code

The Hawaii State Legislature (Legislature) incorporated the Public Trust Doctrine into the State Water Code. This section presents broad declarations of water resource protection and management policy that are embedded in the State Water Code and are employed by CWRM in program administration.

The State Water Code Declaration of Policy is as follows:

- *It is recognized that the waters of the State are held for the benefit of the citizens of the State. It is declared that the people of the State are beneficiaries and have a right to have the waters protected for their use.* (HRS §174C-2)

- *There is a need for a program of comprehensive water resources planning to address the problems of supply and conservation of water. The Hawaii water plan, with such future amendments, supplements, and additions as may be* *necessary, is accepted as the guide for developing and implementing this policy.* (HRS §174C-2)

- *The state water code shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes such as domestic uses, aquaculture uses, irrigation and other agricultural uses, power development, and commercial and industrial uses. However, adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance and scenic beauty, and the preservation and enhancement of waters of the State for municipal uses, public recreation, public water supply, agriculture, and navigation. Such objectives are declared to be in the public interest.* (HRS §174C-2)

- *The state water code shall be liberally interpreted to protect and improve the quality of waters of the State and to provide that no substance be discharged into such waters without first receiving the necessary treatment or other corrective action. The people of Hawaii have a substantial interest in the prevention, abatement, and control of both new and existing water pollution and in the maintenance of high standards of water quality.* (HRS §174C-2)

- *The state water code shall be liberally interpreted and applied in a manner which conforms with intentions and plans of the counties in terms of land use planning.* (HRS §174C-2)

2.1.3. The Public Trust Doctrine, the Precautionary Principle, and Water Rights in Hawaii[1]

Hawaii is one of several states that have included the Public Trust Doctrine into the State Constitution. As stated earlier in Section 2.1.2, the Legislature incorporated the Public Trust Doctrine into the State Water Code as follows:

> *It is recognized that the waters of the State are held for the benefit of the citizens of the State. It is declared that the people of the State are beneficiaries and have a right to have the waters protected for their use.* (HRS §174C-2)

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Hawaii's constitutional, statutory, and administrative rule provisions for protecting public interests was reinforced by the Hawaii Supreme Court (the Court) decisions in the Waiahole Ditch Contested Case (Waihole Water Case) proceedings (Docket No. CCH-OA95-1) during the late 1990s and early 2000s. The Court's decisions emphasize the Public Trust Doctrine and the associated Precautionary Principle as essential to the application and administration of the State Water Code, and have further helped to define current water rights in Hawaii.

Hawaii's water law is an amalgamation of the ancient and historical Native Hawaiian water management system, surviving Kingdom law, and modern constitutional and statutory mandates. Water rights, therefore, exist in several forms and carry different obligations under the State Water Code and under common law. In light of the above, the following sections provide further discussion and insight as to the relationship between the Public Trust Doctrine, the State Water Code, and legal provisions for water rights.

2.1.3.1. The Public Trust Doctrine

In its review of the Waiahole Water Case, the Court held that:

- Title to the water resources is held in trust by the State for the benefit of its people;
- Article XI, sections one and seven of the State Constitution adopted the public trust doctrine as a fundamental principle of constitutional law in Hawaii;
- The Legislature incorporated public trust principles into the State Water Code; and
- Nevertheless, the State Water Code did not supplant the protections of the Public Trust Doctrine, which the Court would continue to use to inform the Court's interpretation of the State Water Code, define its outer limits, and justify its existence.[2]

The Court has identified four trust purposes, three in the Waiahole Water Case, and a fourth in its 2004 decision, *In the Matter of the Contested Case Hearing on Water Use, Well Construction, and Pump Installation Permit Applications, Filed by Waiola o Molokai, Inc. and Molokai Ranch, Limited*. These purposes are listed below and are equally protected under the law:

- Maintenance of waters in their natural state;
- Domestic water use of the general public, particularly drinking water;
- The exercise of Native Hawaiian and traditional and customary rights, including appurtenant rights; and

[2] 94 Haw. 97, at 130-133; 9 P3d 409, at 443-445.

- Reservations of water for Hawaiian Home Land allotments.

The Court also identified the following principles for the water resources trust[3]:

- The State has both the authority and duty to preserve the rights of present and future generations in the waters of the State;
- This authority empowers the State to revisit prior diversions and allocations, even those made with due consideration of their effect on the public trust;
- The State also bears the affirmative duty to take the public trust into account in the planning and allocation of water resources and to protect public trust uses whenever feasible;
- Competing public and private water uses must be weighed on a case-by-case basis, and any balancing between public and private purposes begins with a presumption in favor of public use, access, and enjoyment;
- There is a higher level of scrutiny for private commercial uses, with the burden ultimately lying with those seeking or approving such uses to justify them in light of the purposes protected by the trust; and
- Reason and necessity dictate that the public trust may have to accommodate uses inconsistent with the mandate of protection, to the unavoidable impairment of public instream uses and values; offstream use is not precluded but requires that all uses, offstream or instream, public or private, promote the best economic and social interests of the people of the State.

2.1.3.2. The Precautionary Principle

When scientific evidence is preliminary and not conclusive regarding the management of the water resources trust, it is prudent to adopt “precautionary principles.” The Court’s interpretation as explained in the Waiahole Water Case is as follows:

- As with any general principle, its meaning must vary according to the situation and can only develop over time. At a minimum, the absence of firm scientific proof should not tie the Water Commission’s hands in adopting reasonable measures designed to further the public interest.
- The precautionary principle simply restates the commission’s duties under the State Constitution and the State Code. The lack of full scientific certainty does not extinguish the presumption in favor of public trust purposes or vitiates the Water Commission’s affirmative duty to protect such purposes wherever feasible. Nor does its present inability to fulfill the instream use

[3] Note that, while these principles are directed at surface water resources, they apply equally to ground water resources.

> protection framework render the statute's directives any less mandatory. In requiring the Water Commission to establish instream flow standards at an early planning stage, the State Water Code contemplates the designation of the standards based not only on scientifically proven facts, but also on future predictions, generalized assumptions, and policy judgments. Neither the State Constitution nor the State Water Code constrains the Water Commission to wait for full scientific certainty in fulfilling its duty toward the public interest in minimum instream flows.

The Court's linking of the Public Trust Doctrine to the precautionary principle offers significant guidance to water resource management. The tenets of the precautionary principle state that:

- There is a duty to take anticipatory action to prevent harm to public resources;
- There is an obligation to examine the full range of alternatives before starting a new activity and in using new technologies, processes, and chemicals; and
- Decisions should be open, informed, and democratic and include affected parties.

In this regard, "precautionary actions" may include:

- Anticipatory and preventive actions;
- Actions that increase rather than decrease options;
- Actions that can be monitored and reversed;
- Actions that increase resilience, health, and the integrity of the whole system; and
- Actions that enhance diversity.

The Public Trust Doctrine establishes a general duty to take precautionary actions and thus shifts the burden of proof to non-trust purposes and requires preventive action in the face of uncertainty.

2.1.3.3. Water Rights and Uses in Hawaii

Water rights and uses in Hawaii are governed by the State Water Code[4] and the common law. The State Water Code preserved appurtenant rights but not correlative and riparian rights in designated water management areas. Thus, when a ground water management area is designated, existing correlative uses within that area can be issued water use permits under the existing use provisions of the

[4] HRS 174C, §§ 174C-1 to 174C-101.

State Water Code, but unexercised correlative rights are extinguished. Similarly, when a surface water management area is designated, existing riparian uses within that area are eligible for water use permits as existing uses, but unexercised riparian rights are extinguished. Furthermore, the Hawaii Supreme Court has ruled that when there is an undisputed, direct interrelationship between the surface and ground waters, designation of a ground water management area subjects both ground and surface water diversions from the designated area to the statutory permit requirement.[5] Presumably, permits would also be required for ground and surface water diversions when the interrelationship occurs in a surface water management area.

While water use permits are required only in designated water management areas and the common law on water rights and uses continue to apply in non-designated areas, other provisions of the State Water Code apply throughout the state. Thus, for example, well construction and pump installation permits are required for any new or modified ground water use, and stream diversion and stream alteration permits are required for any new or modified surface water diversions. If the proposed stream diversion will affect the existing instream flow standard, a successful petition to amend the interim instream flow standard is also required.

2.1.3.4. Correlative Rights

Under the common law, owners of land overlying a ground water source have the right to use that water on the overlying land, as long as the use is reasonable and does not injure the rights of other overlying landholders.[6] When the amount of water is insufficient for all, each is limited to a reasonable share of the ground water. Overlying landowners who have not exercised their correlative rights cannot prevent other landowners from using the water on the theory that they are using more than their reasonable share. They must suffer actual, not potential, harm. Only when landowners try to exercise their correlative rights and the remaining water is insufficient to meet their needs, can they take action to require existing users to reduce their uses.

2.1.3.5. Riparian Rights

Riparian rights are rights of land adjoining natural watercourses and are the surface water equivalent of correlative rights to ground waters; i.e., the use has to be on the riparian lands, the use has to be reasonable, and the exercise of those rights cannot actually harm the reasonable use of those waters by other riparian landowners. The Court had originally stated that the right was to the natural flow of the stream without substantial diminution and in the shape and size given it by nature[7], but later concluded that the right should evolve in accordance with changing needs and circumstances. Thus, in order to maintain an action against a diversion which diminishes the quantity or flow of a natural watercourse, riparian

[5] *In re Water Use Permit Applications*, 94 Haw. 97, at 173; 9 P3d 409, at 485 (2000).
[6] *City Mill Co. v Hon. S. & W. Com.*, 30 Haw. 912 (1929).
[7] *McBryde v Robinson*, 54 Haw. 174, at 198; 504 P.2d 1330, at 1344 (1973); *aff'd on rehearing*, 55 Haw. 260; 517 P.2d 26 (1973); *appeal dismissed for want of jurisdiction and cert. denied*, 417 U.S. 962 (1974).

owners must demonstrate actual harm to their own reasonable use of those waters.[8]

2.1.3.6. Appurtenant Rights

Appurtenant water rights are rights to the use of water utilized by parcels of land at the time of their original conversion into fee simple lands i.e., when land allotted by the 1848 Mahele was confirmed to the awardee by the Land Commission and/or when the Royal Patent was issued based on such award, the conveyance of the parcel of land carried with it the appurtenant right to water.[9] The amount of water under an appurtenant right is the amount that was being used at the time of the Land Commission award and is established by cultivation methods that approximate the methods utilized at the time of the Mahele, for example, growing wetland taro.[10] Once established, future uses are not limited to the cultivation of traditional products approximating those utilized at the time of the Mahele[11], as long as those uses are reasonable, and if in a water management area, meets the State Water Code's test of reasonable and beneficial use ("the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the State and county land use plans and the public interest"). As mentioned earlier, appurtenant rights are preserved under the State Water Code, so even in designated water management areas, an unexercised appurtenant right is not extinguished and must be issued a water use permit when applied for, as long as the water use permit requirements are met (see Figure 2-1).

2.1.3.7. Extinguishing Riparian or Appurtenant Rights

Unlike appurtenant rights, which are based in the common law, the Court has interpreted riparian rights as originating in an 1850 statute.[12] This has led to a curious inconsistency in that, while unexercised appurtenant rights are preserved and unexercised riparian rights are extinguished in designated water management areas, actions by private individuals can extinguish appurtenant but not riparian rights. Both appurtenant and riparian rights cannot be severed from the lands they are attached to, and such rights pass with the title to the land whether or not the rights are expressly mentioned in the deed. If the transferor of the land attempts to reserve the riparian right in the deed, the reservation is not valid and the right nevertheless belongs to the transferee as the new owner of the land.

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[8] *Reppun v Board of Water Supply*, 65 Haw. 531, at 553; 656 P.2d 57, at 72 (1982).
[9] 54 Haw. 174, at 188; 504 .2d 1330, at 1339.
[10] 65 Haw. 531, at 554; 656 P.2d 57, at 72.
[11] *Peck v Bailey*, 8 Haw. 658, at 665 (1867).
[12] 54 Haw. 174; 504 P.2d 1330.

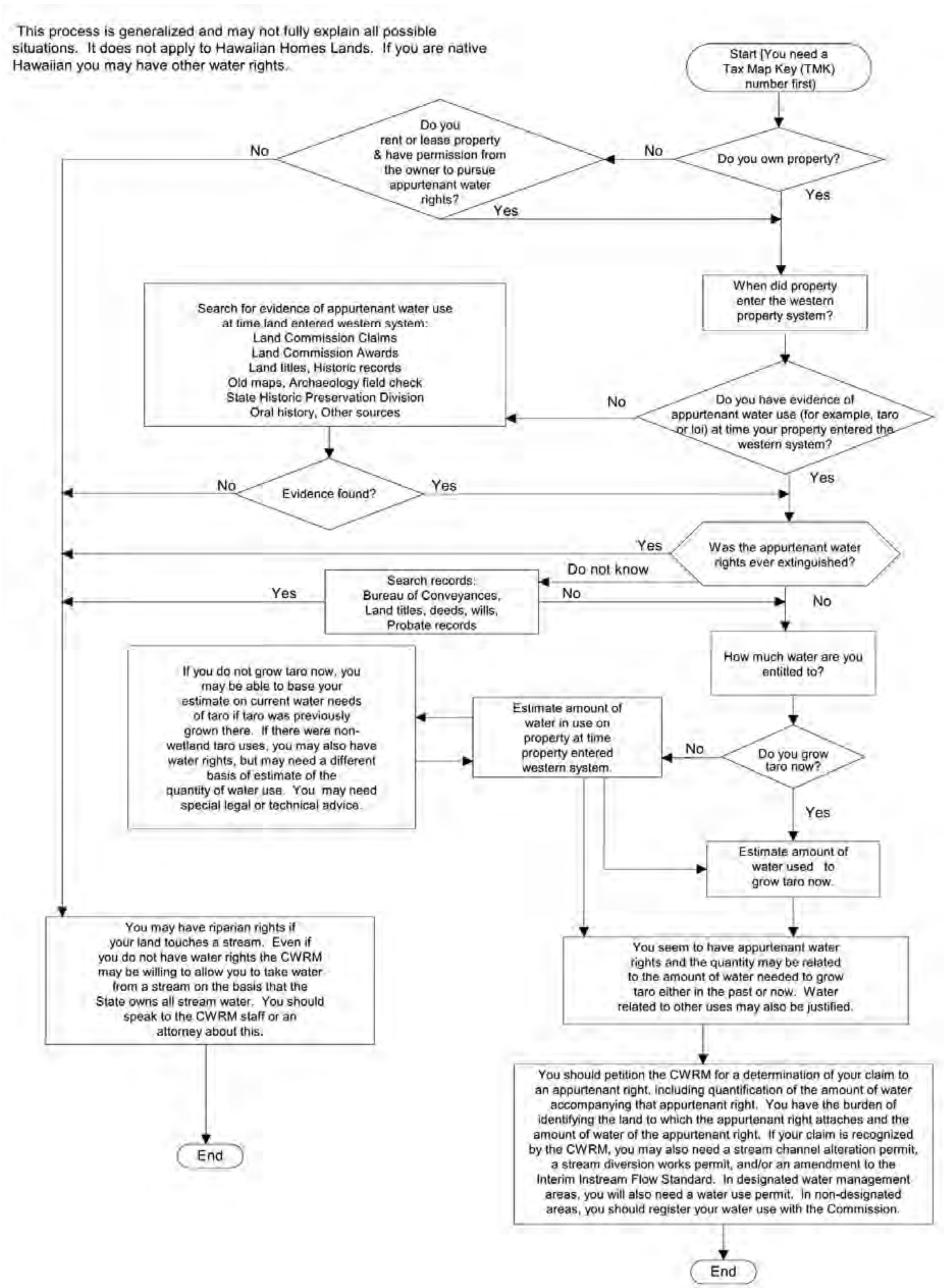

Figure 2-1. Generalized Process for Determining Appurtenant Water Rights

The law with regards to appurtenant rights is not clear. The Supreme Court in Reppun[13] held that where a landowner attempted to reserve an appurtenant right while selling the underlying land, the reservation is not valid and the attempt to reserve extinguishes the appurtenant right. In doing so, the Court reasoned that there is nothing to prevent a transferor from effectively providing that the benefit of the appurtenant right not be passed to the transferee.[14] This difference is due to the Court's interpretation that riparian rights had been created by the 1850 statute, so any attempt by the grantor to reserve riparian water rights in the deed when riparian lands are sold is invalid. Presumably, the inconsistency could be cured by legislation providing a statutory basis for appurtenant rights. In fact, the Court in the Waiahole Water Case cited to the State Water Code's recognition of appurtenant rights and legislative comment to the effect that "[a]ppurtenant rights may not be lost."[15] However, the Court did not explicitly discuss its prior Reppun decision, so it is unclear whether its Waiahole decision overruled Reppun.

2.1.3.8. Appropriated Uses

Appropriated uses are uses of surface or ground waters on non-riparian or non-overlying lands. In the case of ground water, "[P]arties transporting water to distant lands are deemed mere 'appropriators,' subordinate in right to overlying landowners …[T]he correlative rights rule grants overlying landowners a right only to such water as necessary for reasonable use. Until overlying landowners develop an actual need to use ground water, non-overlying parties may use any available 'surplus' (citations omitted)."[16] For surface waters, "the effect of permitting riparian owners to enjoin diversions beneficial to others in the absence of a demonstration of actual harm may occasionally lead to wasteful or even absurd results…The continuing use of the waters of the stream by the wrongful diversion should be contingent upon a demonstration that such use will not harm the established rights of others."[17] Thus, appropriated uses are not based on water rights but are allowed as long as they are reasonable and do not actually impinge on correlative and riparian rights. Note that appurtenant uses would be a type of appropriated uses if they were not based on appurtenant rights, and that in fact, the history of appurtenant uses in the Kingdom of Hawaii has led to their establishment as water rights superior to riparian rights. Also note that when a water management area is designated, appropriated uses become superior to unexercised water rights, because appropriated uses become existing uses and are eligible for water use permits, while unexercised correlative and riparian rights are extinguished.

2.1.3.9. Obsolete Rights: Prescriptive and Konohiki Rights

Until 1973, surface waters were treated as private property and could be owned. Prescriptive water rights were the water equivalent of "adverse possession" in land ownership, where open and hostile occupation of another's private property for a specified number of years entitled the occupier to take legal ownership, because it

[13] 65 Haw. 531, at 552; 656 P.2d 57, at 71 (1982).
[14] 65 Haw. 531, at 552; 656 P.2d 57, at 71 (1982).
[15] 94 Haw. 97 at 179, 9 P.3d 409 at 491 (2000).
[16] 94 Haw. 97, at 178; 9 P3d 409, at 490 (2000).
[17] 65 Haw. 531, at 553-554; 656 P.2d 57, at 72 (1982).

raised the legal presumption of a grant. Prescriptive rights to water were exercisable only against the ownership of other private parties and not against the government. Thus, under prescriptive rights, appropriated uses could ripen into a prescriptive right superior to riparian rights. (Some early Court cases viewed appurtenant rights as a type of prescriptive right.) In 1973, the Court voided private ownership of water resources and prescriptive rights because of public ownership of all surface waters.[18] As for ground water, two early cases (1884[19] and 1896[20]) reflected the then prevailing law on surface waters that water could be private property, but those cases also concluded that prescriptive rights cannot be exercised against subterranean waters that have no known or defined course, i.e., you could not adversely possess what you could not see. In 1929, the Court adopted the correlative rights rule[21], in which the overlying landowners could not use the water as they pleased, because it was a shared resource.

Until 1973, "konohiki lands," or lands whose title had passed from persons documented as konohiki, owned the "normal daily surplus water" in excess of waters reserved by appurtenant and prescriptive rights. (Despite a number of earlier cases, in 1930 the Court had concluded that riparian rights had never been the law in Hawaii.[22] The 1973 Court, instead of overturning that decision, found a statutory basis for riparian rights in the 1850 statute.) In 1973, in addition to voiding any private property interest in water, the Court ruled that there can be no "normal daily surplus water," because the recognition of riparian rights entitled owners of riparian lands to have the flow of the watercourse in the shape and state given it by nature.[23]

2.1.3.10. Native Hawaiian Water Rights

The State Water Code, HRS §174C-101, contains the following provisions on native Hawaiian water rights:

- Provisions of this chapter shall not be construed to amend or modify rights or entitlements to water as provided for by the Hawaiian Homes Commission Act, 1920, as amended, and by chapters 167 and 168, relating to the Molokai irrigation system. Decisions of the commission on water resource management relating to the planning for regulation, management, and conservation of water resources in the State shall, to the extent applicable and consistent with other legal requirements and authority, incorporate and protect adequate reserves of water for current and foreseeable development and use of Hawaiian home lands as set forth in section 221 of the Hawaiian Homes Commission Act.

[18] 54 Haw. 174; 504 P.2d 1330 (1973);
[19] *Davis v Afong*, 5 Haw. 216 (1884).
[20] *Wong Leong v Irwin*, 10 Haw. 265 (1896).
[21] *City Mill Co. v Hon. S. & W. Com.*, 30 Haw. 912 (1929).
[22] *Territory v Gay*, 31 Haw. 376 (1930); *aff'd* 52 F.2d 356 (9th Cir. 1931); *cert. denied* 284 U.S. 677 (1931).
[23] 54 Haw. 174, at 198; 504 P.2d 1330, at 1344 (1973).

- No provision of this chapter shall diminish or extinguish trust revenues derived from existing water licenses unless compensation is made.

- Traditional and customary rights of ahupua`a tenants who are descendants of native Hawaiians who inhabited the Hawaiian Islands prior to 1778 shall not be abridged or denied by this chapter. Such traditional and customary rights shall include, but not be limited to, the cultivation or propagation of taro on one's own kuleana and the gathering of hihiwai, opae, o`opu, limu, thatch, ti leaf, aho cord, and medicinal plants for subsistence, cultural, and religious purposes.

- The appurtenant water rights of kuleana and taro lands, along with those traditional and customary rights assured by this section, shall not be diminished or extinguished by a failure to apply for or to receive a permit under this chapter. (The *exercise* of an appurtenant water right is still subject to the water use permit requirements of the Water Code, but there is no deadline to exercise that right without losing it, as is the case for correlative and riparian rights, which must have been exercised before designation of a water management area.)

2.2. Water Management Policies in the Hawaii Administrative Rules

The Hawaii Administrative Rules (HAR), Title 13, Department of Land and Natural Resources, Subtitle 7, Water Resources contains the rules and procedures adopted pursuant to the State Water Code for administering code provisions. The rules constitute *procedural policies* of CWRM that provide additional guidance for the implementation of the broad water management and use policies included in the State Water Code. The appropriate chapters from the HAR are briefly summarized below:

HAR Chapter 13-167: Rules of Practice and Procedure for the Commission on Water Resource Management

This chapter governs practice and procedure before CWRM under Chapter 91, HRS, the Constitution and water laws of the State, the Constitution and laws of the United States, and such other related acts as may now or hereinafter be administered by CWRM. The rules in this section are intended to secure the just, speedy, and inexpensive determination of every proceeding.

HAR Chapter 13-168: Water Use, Wells, and Stream Diversion Works

The primary purpose of this section is to carry out the intent of the State Water Code to assure maximum beneficial use of ground and surface waters of the State by establishing rules for reporting and gathering meaningful data on all water uses and sources. The rules in this section provide for the declaration and certification of all existing uses of surface and ground water; the registration of all existing wells and existing stream diversion works; the reporting of current uses of surface and ground water; the permitting of wells; the permitting of pump installations and repairs; and the permitting of stream diversion works. The *Hawaii Well Construction and Pump Installation Standards* (HWCPIS) were amended to the HAR in January 1997, allowing subsequent revision as necessary. The HWCPIS were subsequently revised in February 2004. The standards serve to ensure the safe and sanitary maintenance and operation of wells, to prevent waste, and to prevent contamination of ground water aquifers.

HAR Chapter 13-169: Protection of Instream Uses of Water

The purpose of this chapter is to provide for the establishment of a statewide program to protect, enhance, and reestablish, where practical, beneficial instream uses of water, including the development and establishment of standards for instream flows and the creation of a permit system to regulate the alteration of stream channels.

HAR Chapter 13-170: Hawaii Water Plan, Subchapter 2, Water Resource Protection Plan

This chapter provides guidelines for preparation of the HWP. Interagency consultation is advised between appropriate county, State, and federal agencies. CWRM is further advised to set forth programs to conserve, augment, and protect water resources, and to consider any other elements necessary or desirable for inclusion in the WRPP.

HAR Chapter 13-170: Hawaii Water Plan, Subchapter 6, Integration of Plan Elements

This subchapter delineates implementation priorities and the structure of the HWP as follows:

- Integration of the HWP is dependent on the creation of a master water resource inventory, designation of hydrologic units as identified in Section 13-170-20, and formulation of water quality criteria as described in Section 13-170-52.
- The WRPP and the WQP shall be created as soon as practicable in order that the State and county may use the information in preparing their respective plans.
- The WRPP shall incorporate, where applicable, data contained within the WQP for the purpose of protecting, conserving and augmenting the state's water resources.
- Both the SWPP and each County WUDP shall be subject to the WRPP.
- The HWP shall guide CWRM in the designation of water management areas and in the issuance of permits as set forth in the State Water Code.

HAR Chapter 13-171: Designation and Regulation of Water Management Areas

The purpose of this section is to provide for the designation and regulation of hydrologic areas where water resources are being threatened by existing or proposed withdrawals or diversions of water, water quality problems, or serious disputes. The rules state, "[I]t shall be the duty of the [Water] Commission to designate areas for the purpose of establishing administrative control over the withdrawals and diversions of ground and surface water in threatened areas to ensure the most beneficial use, development, or management of the water resources in the interest of the people of the State."

2.3. Goals and Objectives of the Commission on Water Resource Management

The general mission of CWRM is to protect and enhance the water resources of the State of Hawaii through wise and responsible management. Pursuant to this mission, CWRM applies broad resource management principles in its decisions, actions, declaratory orders, and program implementation. These principles are captured in the following list of CWRM goals and objectives. Other CWRM goals specifically pertinent to resource assessment, monitoring, regulation, conservation, and planning are discussed in Sections 3 through 10 of the WRPP.

CWRM Goals:

- To protect the water resources of the State and provide for the maximum beneficial use of water by present and future generations.
- To develop sound management policies and a regulatory framework to facilitate decisions that are: a) proactive and timely, b) based on best available information and sound science, c) focused on the long-term protection and reasonable and beneficial use of both ground and surface water resources, and d) protective of water rights and public trust purposes.
- To achieve sound water-resource planning, extensive baseline and current data collection for ground and surface water, and statewide compliance with the State Water Code.

CWRM Objectives:

- Fulfill the State's responsibility, as trustee of water resources, to set policies, protect resources, define uses, establish priorities while assuring rights and uses, and establish regulatory procedures through the implementation and administration of the State Water Code.
- Seek legislative support, budget appropriations, federal funding, and grants to execute CWRM policies, goals, objectives, and programs, as they are defined and implied by the State Water Code and its directives for interpretation included in HRS §174C-2.

- Seek maximum beneficial use of the waters of the State with adequate provisions for the protection of public interest objectives, as declared in HRS §174C-2.

- Foster comprehensive water-resource planning for the development, use, protection, and conservation of water via implementing and updating the HWP, in accordance with the HWP requirements and objectives, as declared in the State Water Code and associated HAR.

- Fulfill the specific duties for research, resource protection, instream use protection, interagency cooperation, public education, program coordination, resource inventory and assessment, and determination of appurtenant rights, as declared in HRS §174C-5.

- Provide the regulatory and internal framework, including best use of information technology, for efficient ground and surface water management.

- Develop the best available information on water resources, including current and future water use monitoring and data collection, modeling activities, surface and ground water quality (chloride levels) and availability, stream flow, stream biota, and watershed health to make wise decisions about reasonable and beneficial use and protection of the resource.

- Support community-based management of water resources and develop short- and long-range plans to avoid judicial and quasi-judicial disputes.

- Enhance and improve current stream protection and ground water protection programs for the benefit of future generations.

- Carefully consider the requirements of public trust uses, as determined by the Supreme Court's use of the Public Trust Doctrine to inform the Court's interpretation of the State Water Code.

- Administer and amend, as necessary, water use regulation programs to permit reasonable-beneficial uses of water in such a manner as to protect instream flows and maintain sustainable yields of ground water, as defined in the State Water Code.

- Execute, in conjunction with appropriate public, federal, State, and county agency consultation, CWRM's responsibility to designate areas of the State for the purpose of establishing administrative control where water resources may be threatened by existing or proposed withdrawals, diversions, or water use.

- Strive to protect and improve the quality of the waters of the State through the administration of ground and surface water protection programs, in conjunction with the DOH.

2.3.1. CWRM Programs

CWRM currently seeks to meet these goals and objectives primarily through programs administered by CWRM staff. The core responsibilities of CWRM staff include planning, surveying, regulating, monitoring, and conserving the State's water resources within established plans that have been adopted by CWRM. Staff resources are organized into four branches: Survey, Planning, Ground Water Regulation, and Stream Protection and Management (see Figure 2-2).

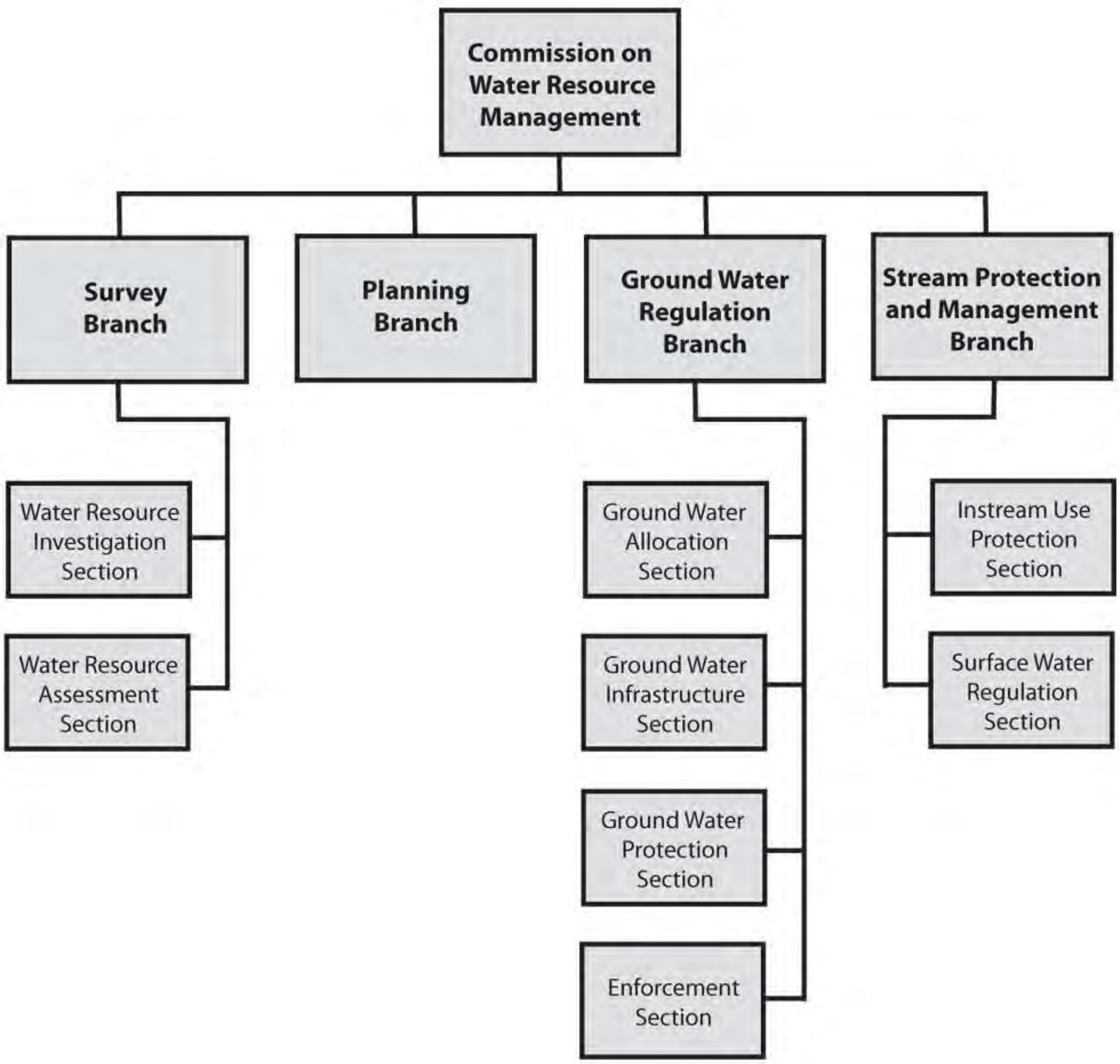

Figure 2-2: CWRM Organization Chart

The general duties and activities of each branch are summarized below.

Survey Branch Responsibilities:

- Collect basic hydrologic data and general water resource information in coordination and cooperation with other agencies.
- Conduct water availability and sustainable yield analyses for aquifers and watersheds statewide.
- Conduct topographic surveys, research, and investigations into all aspects of water occurrence and water use.
- Establish criteria for use by CWRM to determine the existence of water shortages.
- Identify areas of the state where saltwater intrusion is a threat to freshwater resources, and report findings to the appropriate county mayor and the general public.
- Provide technical services in support of CWRM programs administered by the Planning, Survey, Ground Water Regulation, and Stream Protection and Management Branches.
- Recommend acquisition of real property and easements through purchase, gift, lease, eminent domain, or otherwise for water resource monitoring, management and resource conservation purposes.

Planning Branch Responsibilities:

- Develop comprehensive, long-range plans for the protection, conservation, and management of water resources.
- Prepare, administer, and coordinate the development of the HWP and regular plan updates.
- Assist in the development of plans, studies, and scientific investigations involving assessments of water supply and demand, and instream uses of water, including biological, ecological, aesthetic, recreational and hydrological aspects of Hawaiian stream systems.
- Formulate water shortage and drought management plans for implementation during periods of prolonged water shortage.
- Formulate water conservation plans and resource augmentation strategies to address water supply and demand, and resource sustainability.
- Review and analyze statewide data on water consumption by municipal, agricultural, industrial, commercial, domestic, and instream uses.

- Establish and maintain interagency coordination between federal, State, and county governments and the private sector; and provide planning-related oversight in the processing of permits and the setting of instream flow standards to protect beneficial instream uses of water, as mandated by law.

Ground Water Regulation Branch Responsibilities:

- Implement Water Commission policies, procedures, and rules on ground water development and usage established in conformance with the State Water Code.
- Establish minimum standards for the construction of wells and the installation of pumps and pumping equipment.
- Administer permit systems for the construction of wells and installation of pumps and pumping equipment.
- Administer the designation of water management areas and the processing of applications for ground water use permits.
- Administer the investigation and enforcement actions necessary for permit conformance, citizen complaints and in the resolution of ground water related disputes.

Stream Protection and Management Branch Responsibilities:

- Implement CWRM policies, procedures, and rules on stream protection and instream flow standards, appurtenant rights, surface water development, and surface water usage established in conformance with the State Water Code.
- Administer the designation of surface water management areas and the processing of applications for surface water use permits.
- Administer a permit system for the alteration of stream channels and diversion of stream flow.
- Administer a statewide instream use protection program, including the establishment and amendment of instream flow standards.
- Administer the investigation and enforcement actions necessary for permit conformance, citizen complaints and in the resolution of surface water related disputes.

2.4. Summary

As demonstrated by the extensive documentation and literature that resulted from the Waiahole Water Case proceedings, it is difficult to briefly summarize the spectrum of water management and policy issues, and this section is not intended for such a discussion. This section provides an overview of existing water management policies and tools, as well as background information to assist in understanding the provisions of the State Water

Code, its applicability, and the extent of water rights. The remaining sections of the WRPP are presented within this context. Additional discussion of the legislative and administrative context for water planning in Hawaii is provided in Appendix A.

Section 3

Inventory and Assessment of Resources

3. INVENTORY AND ASSESSMENT OF RESOURCES

The State Water Code mandates that the WRPP include an inventory of water resources statewide. This section provides the resource inventory as well as pertinent supporting information and discussions of issues that contribute to resource assessment and management.

3.1. Managing Hawaii's Water Resources for Sustainability

The movement of water between the atmosphere, the land, and the ocean is described by the hydrologic cycle. In Hawaii, solar energy causes the evaporation of water from the ocean. Clouds form and render their moisture over the islands. This rainfall supports stream flow and replenishes ground water, while a portion evaporates back into the atmosphere. The land-related components of the hydrologic cycle have been impacted over time by human settlement and short- and long-term climate change. For example, early Hawaiians diverted the natural flow patterns of streams through auwais to provide water for agriculture, but much of the water was eventually returned to downstream segments of the stream. Later, as the sugar industry became established in Hawaii, large-scale stream diversions and wells were constructed to support the plantations and the needs of the growing population. Most recently, the decline of plantation agriculture and increasing urbanization have significantly altered drainage patterns and the rate of ground water recharge. The cumulative effects of land use changes and other human activities can shift the natural balance of the hydrologic cycle. Such changes can have profound social, environmental, and economic impacts within our island communities.

To sustainably manage water resources, it is critical to apply an organized program for measuring, assessing, and communicating water-related information to decision makers and to the public. Government agencies, resource managers, private purveyors, and the general public benefit from the continued investigation and study of water resources. The best information available should be applied to explore the processes and resource interdependencies implicit in the water cycle. With increasing insight, better resource management strategies can be developed and implemented to achieve sustainability.

3.1.1. Evolving Issues in Water Resource Management

> *Traditionally, management of water resources has focused on surface water or ground water as if they were separate entities. As development of land and water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other. Nearly all surface-water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with ground water. These interactions take many forms. In many situations, surface-water bodies gain water and solutes from ground-water systems and in others the surface-water body is a source of ground-water recharge and causes changes in ground-water quality. As a result, withdrawal of water from streams can deplete ground water or conversely, pumpage of ground water can deplete water in streams, lakes, or wetlands. Pollution of surface water can cause degradation of ground-water quality and conversely pollution of ground water can degrade surface water. Thus, effective land and water management requires a clear understanding of the*

linkages between ground water and surface water as it applies to any given hydrologic setting.

– Robert M. Hirsch, Chief Hydrologist, USGS[1]

In the above excerpt from the 1998 USGS Circular 1139, author Robert M. Hirsch summarizes the difficulties faced by scientists and water managers in understanding the integrated nature of ground and surface water systems. From a government perspective, the typical administrative separation of ground and surface water management creates additional challenges for most water managers, especially as research efforts constantly reveal new aspects and venues by which ground and surface water systems are interdependent. The intent of USGS Circular 1139 is to help Federal, State and local agencies construct a scientific base for the development of policies governing the management and protection of aquifers and watersheds.

The author further asserts that, "Effective policies and management practices must be built on a foundation that recognizes that surface water and ground water are simply two manifestations of a single integrated resource." The document emphasizes that management of one component of the hydrologic system, such as a stream or an aquifer, tends to be only partly effective because each hydrologic component is in continuous interaction with other components. Concerns related to water supply, water quality, and degradation of aquatic environments are frequently at the forefront of water management issues, and the interaction of ground water and surface water has been, and continues to be, a significant area of focus and deliberation. Hirsch provides an example where contaminated aquifers that discharge to streams can result in long-term contamination of surface water and, conversely, streams can be a major source of contamination to aquifers. Although this scenario may be more common throughout the Continental US, this could also occur in Hawaii, where the implications and impacts of cross-contamination may be devastating to our limited water resources, population, and environment.

Although surface water typically has a hydraulic connection to ground water, according to Hirsch, the interactions are difficult to observe and measure and "commonly have been ignored in water-management considerations and policies." The limited understanding of ground and surface water interactions makes it difficult to characterize the processes.

In Hawaii, water managers, government agencies, and hydrologists struggle with ground and surface water interactions, as most dramatically demonstrated by high-profile water disputes in East Maui, in the Wailuku area on Maui (Iao Aquifer System Area), and in Windward Oahu (Waiahole Ditch System). Due to the volcanically-formed aquifers, island topography, and tropical climate, surface water and ground water interactions are most likely unique in comparison with the larger-scale river basin watersheds and expansive sedimentary aquifer systems typical of mainland US areas. Nevertheless, the large-scale concepts, themes, issues, and investigations related to ground and surface water interaction remain pertinent to Hawaii in that they provide insight for consideration and adaptation for island systems. The following examples of common water-resource issues, as adapted from Hirsch, are provided to demonstrate how understanding the interconnections between ground water and surface water is "fundamental to development of effective water-resource management and policy."

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[1] *USGS Circular 1139: Ground Water and Surface Water: A Single Resource,* http://water.usgs.gov/ogw/gwsw.html.

Water Supply

- It has become difficult in recent years to construct reservoirs for surface storage of water because of environmental concerns and because of the difficulty in locating suitable sites. An alternative, which can reduce or eliminate the necessity for surface storage, is to use an aquifer system for temporary storage of water. For example, water stored underground during times of high streamflow can be withdrawn during times of low streamflow. The characteristics and extent of the interactions of ground water and surface water affects the success of such conjunctive-use projects.

- Methods of accounting for water rights of streams invariably account for surface water diversions and surface water return flows. Increasingly, the diversions from a stream that result from ground water withdrawals are considered in accounting for water rights as are ground water return flows from irrigation and other applications of water to the land surface. Accounting for these ground water components can be difficult and controversial. Another form of water-rights accounting involves the trading of ground water rights and surface water rights. This has been proposed as a water management tool where rights to the total water resource can be shared. It is an example of the growing realization that ground water and surface water can essentially be one resource in many suituations.

- In some regions, the water released from reservoirs decreases in volume, or is delayed significantly, as it moves downstream because some of the released water seeps into the stream-banks. These losses of water and delays in travel time can be significant, depending on antecedent ground water and stream flow conditions as well as on other factors such as the condition of the channel and the presence of aquatic and riparian vegetation.

- Storage of water in streambanks, on flood plains, and in wetlands along streams reduces flooding downstream. Modifications of the natural interaction between ground water and surface water along streams, such as drainage of wetlands and construction of levees, can remove some of this natural attenuation of floods. Unfortunately, present knowledge is limited with respect to the effects of land-surface modifications in river valleys on floods and on the natural interaction of ground water and surface water in reducing potential flooding.

Water Quality

- Much of the ground water contamination in the United States is in shallow aquifers that are directly connected to surface water. In some settings where this is the case, ground water can be a major and potentially long-term contributor to contamination of surface water. Determining the contributions of ground water to contamination of streams and lakes is a critical step in developing effective water management practices.

- A focus on watershed planning and management is increasing among government agencies responsible for managing water quality as well as broader aspects of the environment. The watershed approach recognizes the interactions between ground and surface water. Integrating ground water into this "systems" approach is essential, but challenging, because of limitations in knowledge of the interactions of ground water and surface water. These difficulties are further complicated by the fact that surface water watersheds and ground water watersheds may not coincide.

- To meet water quality standards and criteria, States and local agencies need to determine the amount of contaminant movement (wasteload) to surface waters so they can issue permits and control discharges of waste. Typically, ground water inputs are not included in estimates of wasteload; yet, in some cases, water-quality standards and criteria cannot be met without reducing contaminant loads from ground water discharges to streams.

- It is generally assumed that ground water is safe for consumption without treatment. Concerns about the quality of ground water from wells near streams, where contaminated surface water might be part of the source of water to the well, have led to increasing interest in identifying when filtration or treatment of ground water is needed.

- Wetlands, marshes, and wooded areas along streams (riparian zones) are protected in some areas to help maintain wildlife habitat and the quality of nearby surface water. Greater knowledge of the water-quality functions of riparian zones and of the pathways of exchange between shallow ground water and surface water bodies is necessary to properly evaluate the effects of riparian zones on water quality.

Characteristics of Aquatic Environments

- Mixing of ground water with surface water can have major effects on aquatic environments if factors such as acidity, temperature, chlorides, and dissolved oxygen are altered. Thus, changes in the natural interaction of ground water and surface water caused by human activities can potentially have a significant effect on aquatic environments.

- The flow between surface water and ground water creates a dynamic habitat for aquatic fauna near the interface. These organisms are part of a food chain that sustains a diverse ecological community. Studies indicate that these organisms may provide important indications of water quality as well as of adverse changes in aquatic environments.

- Many wetlands are dependent on a relatively stable influx of ground water throughout changing seasonal and annual weather patterns. Wetlands can be highly sensitive to the effects of ground water development and to land-use changes that modify the ground water flow regime of a wetland area. Understanding wetlands in the context of their associated ground water flow systems is essential to assessing the cumulative effects of wetlands on water quality, ground water flow, and stream-flow in large areas.

- The success of efforts to construct new wetlands that replicate those that have been destroyed depends on the extent to which the replacement wetland is hydrologically similar to the destroyed wetland. For example, the replacement of a wetland that is dependent on ground water for its water and chemical input needs to be located in a similar ground water discharge area if the new wetland is to replicate the original. Although a replacement wetland may have a water depth similar to the original, the communities that populate the replacement wetland may be completely different from communities that were present in the original wetland because of differences in hydrogeologic setting.

3.1.2. Applying the "Systems" Approach to Water Resource Management

The WRPP encourages effective ground and surface water management through the application of a hydrologic unit systems approach that focuses on the interaction and feedback that occurs between ground and surface water systems and management decisions. Management practices, including infrastructure, economic, and political factors represent stresses to the ground water system. The physical ground water system (geologic framework, hydraulic properties and boundary conditions) demonstrates environmental effects and responses due to the imposed stresses, which are initially observed in ground water levels, discharge rates, and water-quality conditions. The cumulative effects are sometimes observed in streamflow rates, aquatic habitats, and other environmental conditions. Observing these initial and long-term cumulative effects helps in understanding the properties and processes of ground water systems and the environmental effects and other consequences that result from management decisions.

This section of the WRPP provides information on the nature and occurrence of water resources in the State of Hawaii, as well as discussions on the human impacts to those resources and the issues, challenges, and opportunities for improving management and protection practices. The goals and objectives of this section embrace the "systems" approach to water resource management, recognizing the connections between ground and surface water resources. CWRM encourages the exploration and application of this approach through the information presented herein and through State actions to support sustainable management of water resources.

The remaining sections are generally organized as follows:

- **Goals and Objectives:** This section describes general goals and objectives for resource inventory efforts and tracking to support water planning and management. Also listed are items specifically applicable to ground water and surface water inventory and assessment.

- **Nature and Occurrence of Ground Water:** Information on ground water occurrence and aquifer settings is followed by an explanation of the ground water hydrologic units as delineated by CWRM and how ground water availability is quantified and assessed. Finally, an inventory of aquifer system areas and aquifer system sustainable yields are presented with additional supporting information incorporated by reference.

- **Nature and Occurrence of Surface Water:** Similar to the previous section on ground water, surface water occurrence and settings are described and followed by an explanation of the surface -water hydrologic units delineated by CWRM. Information of the quantification of stream flow is accompanied by a summary of issues associated with quantification and assessment of resources. The section on surface water concludes with an inventory of surface water hydrologic units with information on instream flow standards as determined thus far.

3.2. Goals for Water Resource Inventory and Assessment

The following CWRM goals are intended to guide and influence water resource inventory and assessment efforts in support of sustainable water planning and management activities.

- Study and inventory the water resources of the State to protect resource viability and to provide the maximum beneficial use of water by present and future generations.

- Promote the administrative use of management boundaries designated by CWRM to define the extent of ground water and surface water hydrologic units and ensure the consistent application of these boundaries throughout the State and across State and county jurisdictions.

- Commit to long-term, reliable data collection programs and use of improved methods of analyses; use data to develop improved management decisions through a continuing iterative approach of data collection and analysis, including the use of models to evaluate alternatives in development, management, and decision making.

- Develop the best available information on the occurrence, location, extent, and behavior of water resources to support resource management, policy and regulatory decisions, and planning efforts.

- Catalog and maintain hydrologic data, geologic data, and topographic surveys and apply data to the enhancement and improvement of current stream protection and ground water protection programs wherever appropriate and beneficial.

- Apply inventory information to manage the conservation, protection, and use of the State’s water resources for social, economic, and environmental needs as mandated by the State Water Code.

- Apply inventory and assessment information to the exploration of managed conjunctive use of combined ground water and surface water supplies, as well as the artificial recharge of ground water systems; address both challenges and opportunities through the application of best science practices, improved understanding of resources, and informed consensus of stakeholders.

- Use iterative scientific investigation practices to support the improved understanding of emerging issues and practices in the management of water resources; resource management should address the interaction between management decisions, the dynamic nature of ground and surface water systems, and the consequences that result from management actions.

- Promote effective coordination between land use planning and water availability in the interest of addressing carrying capacity issues, competing values, and urban expansion.

3.3. Nature and Occurrence of Ground Water

Much research and study has been devoted to the nature and occurrence of ground water in Hawaii. Over the past century, various private, federal, State, county and university ground water investigations have helped scientists understand the unique and complex nature of the nature of Hawaii's ground water resources. An Internet search for ground water hydrology of the Hawaiian Islands will return over 162,000 articles related to this subject.

To help communicate Hawaii ground water concepts to the public, the USGS and CWRM cooperatively developed and published in 2000 the reference brochure entitled *Ground Water in Hawaii*. The document contains descriptions of Hawaii's hydrologic settings and hydrogeology. The Honolulu BWS, in consultation with CWRM, has also developed descriptions of Hawaii's ground water settings for inclusion in the BWS's *Koolau Loa Watershed Management Plan* and *Waianae Watershed Management Plan*. The information in the following sections adapts CWRM's collaborative work with the USGS and BWS to provide a basic overview of the nature and occurrence of ground water in the State.

3.3.1. The Hydrologic Cycle

The hydrologic cycle refers to the constant movement of water between the ocean, the atmosphere, and the Earth's surface. A continuous cycle of water can be easily traced on small oceanic islands like Hawaii. Solar energy drives the hydrologic cycle by causing evapotranspiration**.** Evapotranspiration is the loss of water from soils and open water bodies through evaporation and the transfer of water from plants to the air through transpiration. Moisture in the air is carried by trade winds up mountain sides, where it cools and condenses, and finally falls to the land surface as rain or fog drip. Plants immediately absorb and use some of the rain and fog drip, but the remaining volume of water infiltrates through the ground surface, runs off to the ocean or streams, or evaporates into the atmosphere.

The three main elements of the hydrologic cycle are: 1) precipitation; 2) infiltration and recharge; 3) runoff; and 4) evapotranspiration. These can be summarized in the equation:

$$R = P - RO - ET$$

where "R" is natural recharge due to infiltration and subsequent deep percolation, "P" is precipitation, "RO" is runoff, and "ET" is evapotranspiration.

Infiltration is key to sustaining ground water resources. Human activities, especially agricultural and urban activities, alter infiltration and runoff patterns, affecting the components of the hydrologic cycle. As rainwater wets the land surface, shallow infiltration saturates the uppermost soil layer and replaces soil moisture used by plants. Thereafter, excess water percolates slowly downward and to recharge ground water bodies and support stream flow in perennial sections. One factor that affects the rate of infiltration is the permeability of the ground surface. Permeability describes the ease with which water travels through a substance. Ground surfaces with high permeability allow rapid infiltration of rainfall. Conversely, low-permeability surfaces like concrete and asphault inhibit infiltration, causing water to pond or flow across the surface as runoff. Therefore, different land uses can encourage or inhibit infiltration depending on the built environment.

3.3.2. Ground Water Occurrence

The State Water Code defines ground water as "any water found beneath the surface of the earth, whether in perched supply, dike-confined, flowing, or percolating in underground channels or streams, under artesian pressure or not, or otherwise." Water beneath the ground surface occurs in two principle zones: the unsaturated zone and the saturated zone. In the unsaturated zone, the pore spaces in soils and rocks contain both air and water, whereas in the saturated zone, the pore spaces are entirely filled with water.

Ground water occurs within portions of geologic formations that are favorable for receiving, storing, and transporting water. These subsurface formations are called aquifers. The USGS defines an aquifer as follows:

> *Aquifer - a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.*
>
> - USGS Water Science Glossary of Terms
>   http://ga.water.usgs.gov/edu/dictionary.html

Lava erupted during the principal growth stage, or shield building stage, of a volcano tends to form the most extensive and productive aquifers throughout the Hawaiian islands. Lava from the shield building stage consists of basalts that characteristically form thin flows ranging in thickness from a few feet to a few tens of feet. The shield stage is the most voluminous phase of eruptive activity during which 95 to 98 percent of the volcano is formed. Lava flows erupt from the central caldera and rift zones. Intrusive dikes fed by rising magma extend down the rift zones and may erupt if they reach the surface. Some volcanoes have a postshield-stage during which younger lava flows form over the shield-stage basalts. The postshield-stage lava flows are marked by a change in lava chemistry and character that commonly leads to the formation of massive lava flows that can be many tens of feet thick. After a period of volcanic inactivity, lava might issue from isolated vents on the volcano during a final rejuvenated stage.

Permeability refers to the ease with which fluids can move through rock. The permeability of volcanic rocks is variable and depends of the mode of emplacement, amount of weathering, and thickness of the rocks. The three main groups of volcanic rocks (lava flows, intrusive dikes, and pyroclastic deposits) are formed by different modes of emplacement. Weathering reduces the permeability of all types of volcanic rocks. The thickness of a lava flow can depend of the lava chemistry and the topography over which it cooled. Thicker flows generally are less permeable and form from lava accumulating on flat topography or in depressions.

Lava flows are mainly composed of two lava morphologies: pahoehoe and aa. Pahoehoe flows are thinner and form from more fluid lava. Pahoehoe flows have smooth, undulating surfaces, and commonly exhibit ropy textures. Aa flows have coarse surfaces of rubble, or clinker, and thick interior sections composed of massive rock. A typical geologic profile will show a sequence of both aa and pahoehoe flows. The interconnected void spaces in a sequence of pahoehoe flows may lead to high permeability. The layers of clinker at the top and bottom of aa flows also impart high permeability (similar to that of coarse-grained gravel) to volcanic-rock aquifers. However, the lava in the core of an aa flow typically cools as a massive body of rock with much lower permeability. The most productive and most widespread aquifers consist of thick sequences of numerous thin lava flows, however, ground water occurs in a variety of geologic settings in Hawaii, as described in the sections below.

3.3.2.1. Basal Water

The freshwater lenses in basal aquifers, the most important sources of freshwater supply in Hawaii, occur in dike-free volcanic rocks and in sedimentary deposits. Basal waters can be either confined or unconfined. Unconfined aquifers are where the upper surface of the saturated aquifer is not bounded. Confined is where the aquifer is bounded by low permeability formations or poorly permeable formations.

In some coastal areas there is a sediment sequence of low permeability 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 if the caprock was absent. Depending upon the effectiveness of the caprock, the resulting lens could range from local thickening of a relatively thin lens of a hundred feet to over 1800 feet. The amount of water stored in basal lens is significant. Water is withdrawn from the basal aquifer for various uses; basal aquifers provide the primary source for municipal water in Hawaii.

The thickness of the freshwater basal lens can be estimated using the Ghyben-Herzberg formula, which assumes a hypothetical sharp interface between freshwater and seawater, and states that every foot of freshwater above mean sea level indicates 40 feet of freshwater below mean sea level. For example, if freshwater is known to occur at an elevation 20 feet above mean sea level, it can be reasonably estimated that the hypothetical sharp interface would be approximately 800 feet below sea level.

The Ghyben-Herzberg formula provides a reasonable estimate of the freshwater basal lens thickness; however, in actuality, the interface between freshwater and seawater occurs as a brackish transition zone, rather than a sharp interface, with salinity gradually increasing with depth. Therefore, the Ghyben-Herzberg formula is used to estimate the midpoint of the transition zone, which is 50% seawater and

50% freshwater. The thickness of transition zone depends on various chemical and physical parameters including, but not limited to, advection and dispersion, mechanical mixing, physical properties of the aquifer, tidal fluctuation, and atmospheric pressure variation. The movement of the brackish transition zone, both horizontally inland from the seacoast and vertically upward, presents a constant potential danger of saline contamination to the freshwater portion of the system.

3.3.2.2. Dike Water

Water impounded behind dikes in the mountains is called "dike-impounded water," or "high-level water." Dikes are low permeability magmatic intrusions that typically consist of nearly vertical slabs of dense, massive rock, generally a few feet thick, which can extend for considerable distances and cut across existing older lava flows. High-level water impounded in permeable lavas occurring between dikes in the interior portions of the islands is usually of excellent quality due to the elevation of dike impounded aquifers, the low permeability of dike structures, and the distance from the ocean, which prevents sea water instrusion. Tunnels and shafts have been drilled through multiple dike compartments to develop this water source.

Some water leakage occurs across dike boundaries, and this water flows to down-gradient dike compartments or to the basal aquifer. However, the interaction between these dike-confined and basal aquifers is not well understood and is difficult to quantify.

Dike-impounded water may overflow directly to a stream at the ground surface where stream erosion has breached dike compartments. Once breached to the water table, the percentage of overall contribution to total stream flow depends on the head of the stored water, how deep the stream has cut into the high level reservoir, the permeability of the lavas between dikes, the size of the compartments as well as connections to other compartments, and the amount of recharge into the breached compartment.

3.3.2.3. Perched Water

Water in perched aquifers is also classified as high-level water. In this type of system, water is "perched" on top of layers of low permeability material such as dense volcanic rock, weathered and solidified ash, or clay-bearing sediments. Discharge of perched water sometimes occurs as springs where the water table has been breached by erosion. Perched water supplies can be developed by tunnels or by constructing masonry chambers around spring orifices to collect flow and to prevent surface contamination. This type of water is of excellent mineral quality, and like most dike water, is free from seawater encroachment.

Perched water can also be found in alluvial deposits. Alluvial water is found in the more recent alluvial layers and remains perched because of older compacted alluvial layers below. Sometimes small wells can be productive in this area but generally the alluvium provides small amounts of water.

3.3.2.4. Caprock Water

Caprock units found in Hawaiian aquifer system are generally composed of sedimentary formation, and commonly seen in oceanic islands with emergent shorelines. It bears evidences of sedimentation in shallow marine and littoral environments that are shown by the dominant presence of reefal limestone members consist of fringing coralline build-up and associated calcareous sediments with overprinting of fine-grained alluvial sedimentation. Having formed in submarine conditions and with high clay content, young calcareous sedimentary units may preserve the brackish or saline caprock water as interstitial fluid or as perched water within the formation. Moreover, intertidal fluctuation and sea level rise allows sea water intrusion into the caprock units, creating a broad transition zone of brackish water along coastal areas. Recharge from surface flows, local rainfall, return irrigation water, and leakage from confined basal water could result into a potential resource of caprock water, but maybe of limited direct use due to its saline quality. Caprock water occurs, and perhaps is fairly common around older emergent Hawaiian islands, such as Oahu. A good example of an extensive caprock formation is the Ewa Caprock, where brackish water has been pumped and utilized.

3.3.2.5. Brackish Water

Water occurring in the caprock, in a transition zone, and in some basal springs comprises a large resource that is presently unused for municipal supplies due to excessive chlorides (salt) content. Chlorides range from just above recommended drinking water limits to that nearly of seawater. With respect to its potential as an alternative source of water supply, brackish water desalination is generally more cost-effective and environmental-friendly than seawater desalination.

Utilization of brackish water sources for municipal supplies requires the reduction of chloride concentration through blending and/or demineralization. Water exhibiting chloride concentrations greater than 250 milligrams per liter (mg/L) is generally considered unacceptable for drinking purposes. The county water departments generally limit chloride levels of water within their municipal system to less than 160 ppm.

Future updates of this plan may include discussions of other geologic settings where ground water occurs.

3.3.3. Ground Water Hydrologic Units

Ground water hydrologic units have been established by the Commission on Water Resource Management to provide a consistent basis for managing ground water resources. An aquifer coding system is used to reference and describe the ground water hydrologic units delineated by CWRM. This section describes the aquifer coding system and lists all ground water hydrologic units by island. Maps illustrating the hydrologic unit boundaries are included in Section 3.3.3.3.

3.3.3.1. Purpose of Aquifer Coding

As described earlier in section 3.3.2, ground water occurs in variable settings throughout the State of Hawaii. The aquifer coding system described herein was established to provide a consistent method by which to reference and describe ground water resources and to assist in various water planning efforts. The coding system encourages public understanding of ground water hydrology by delineating areas that are related and exhibit similar characteristics.

The primary objective of the coding system is to provide standard aquifer delineations for the coordination of data, information, and resource management practices. The aquifer coding system provides the following benefits:

- Establishment of a consistent and uniform aquifer coding system and a reference for statewide planning, surveying, and regulatory purposes.
- Facilitation of consistent collection and sharing of ground water information amongst CWRM, community organizations, private and public entities, and other agencies;
- Facilitation of public and private implementation of resource protection measures. Such measures include, but are not limited to, permitting, monitoring, best management practices, and etc;
- Effective coordination of monitoring, data collection, and data interpretation.

3.3.3.2. Basis for Ground Water Hydrologic Unit Delineations

In general, each island is divided into regions that reflect broad hydrogeological similarities while maintaining hydrographic, topographic, and historical boundaries where possible. These divisions are known as Aquifer Sector Areas. Smaller sub-regions are then delineated within Aquifer Sector Areas based on hydraulic continuity and related characteristics. These sub-regions are called Aquifer System Areas. In general, these units allow for optimized spreading of island-wide pumpage on an aquifer-system-area scale.

It is important to recognize that Aquifer Sector Area and Aquifer System Area boundary lines were based largely on observable surface conditions (i.e. topography, drainage basins and streams, and surface geology). In general, only limited subsurface information (i.e. well logs and well cores) is availabe. Hydrogeologic features and conditions at the surface may not adequately or accurately reflect subsurface conditions that directly affect groundwater flow. As a result, the Aquifer Sector Area and Aquifer System Area boundary lines should be recognized as management lines and not as hydrologic boundaries. Communication of groundwater between Aquifer Sector Areas and between Aquifer System Areas is known to occur.

The aquifer coding system was first initiated by the State Department of Health in response to directives from the U.S. Environmental Protection Agency. Since then, boundary delineations of ground water hydrologic units were manually drawn or re-traced by the DLNR Division of Water and Land Development (DOWALD) General Flood Control Plan of Hawaii (1983), the State Department of Health (1987), and the Commission on Water Resource Management (1990).

The naming convention for ground water hydrologic units indicates regional and sub-regional divisions as follows:

Island division = Island
Regional division = Aquifer Sector Area
Sub-regional division = Aquifer System Area

3.3.3.3. Aquifer Coding System

The aquifer coding system is based on a hierarchy in which the island is the largest component, followed by the Aquifer Sector Area as the regional component, and the Aquifer System Area as the sub-regional component. The island is identified by a single-digit number in conformance with the first digit of the Hawaii State well numbering system, derived from the U.S. Geological Survey (1976). Each Aquifer Sector Area is identified by a two-digit number and a Hawaiian geographic name or a geographic term such as Windward. Finally, the Aquifer System Area is identified by a two-digit number. Therefore, ground water hydrologic units are assigned a unique code in the five-digit format as follows:

0	**00**	**00**
Island	Aquifer Sector Area	Aquifer System Area

The individual components of the aquifer system area code are described below.

Island **<u>0</u>**0000

The island code component identifies the major Hawaiian island by a unique number assigned by USGS and DLNR. Each island is considered by the USGS to be a distinctive hydrologic unit.

Aquifer Sector Area 0**<u>00</u>**00

The Aquifer Sector Area code component identifies regional hydrologic units within each island. These Aquifer Sector Areas represent large regions with hydrogeological similarities.

Aquifer System Area 000**<u>00</u>**

The Aquifer System Area code component identifies sub-regional hydrologic units within each Aquifer Sector Area. Aquifer System Areas represent aquifers that exhibit hydrogeological continuity.

There are a total of 113 Ground Water Hydrologic Units delineated across the islands of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii. Tables 3-1 to 3-6 below list all units by island and are accompanied by Figures 3-1 to 3-6 showing the unit boundaries.

Table 3-1: Kauai (2) Ground Water Hydrologic Units	
Lihue Aquifer Sector Area (01)	
20101	Koloa
20102	Hanamaulu
20103	Wailua
20104	Anahola
20105	Kilauea
Hanalei Aquifer Sector Area (02)	
20201	Kalihiwai
20202	Hanalei
20203	Wainiha
20204	Napali
Waimea Aquifer Sector Area (03)	
20301	Kekaha
20302	Waimea
20303	Makaweli
20304	Hanapepe

Table 3-2: Oahu (3) Ground Water Hydrologic Units	
Honolulu Aquifer Sector Area (01)	
30101	Palolo
30102	Nuuanu
30103	Kalihi
30104	Moanalua
30105	Waialae-West
30106	Waialae-East
Pearl Harbor Aquifer Sector Area (02)	
30201	Waimalu
30203	Waipahu-Waiawa
30204	Ewa-Kunia
30205	Makaiwa
30207	Ewa Caprock - Malakole
30208	Ewa Caprock - Kapolei
30209	Ewa Caprock - Puuloa
Waianae Aquifer Sector Area (03)	
30301	Nanakuli
30302	Lualualei
30303	Waianae
30304	Makaha
30305	Keaau
North Aquifer Sector Area (04)	
30401	Mokuleia
30402	Waialua
30403	Kawailoa
Central Aquifer Sector Area (05)	
30501	Wahiawa
Windward Aquifer Sector Area (06)	
30601	Koolauloa
30602	Kahana
30603	Koolaupoko
30604	Waimanalo

Table 3-3: Molokai (4) Ground Water Hydrologic Units	
West Aquifer Sector Area (01)	
40101	Kaluakoi
40102	Punakou
Central Aquifer Sector Area (01)	
40201	Hoolehua
40202	Manawainui
40203	Kualapuu
Southeast Aquifer Sector Area (01)	
40301	Kamiloloa
40302	Kawela
40303	Ualapue
40304	Waialua
Northeast Aquifer Sector Area (01)	
40401	Kalaupapa
40402	Kahanui
40403	Waikolu
40404	Haupu
40405	Pelekunu
40406	Wailau
40407	Halawa

Table 3-4: Lanai (5) Ground Water Hydrologic Units	
Central Aquifer Sector Area (01)	
50101	Windward
50102	Leeward
Mahana Aquifer Sector Area (02)	
50201	Hauola
50202	Maunalei
50203	Paomai
Kaa Aquifer Sector Area (03)	
50301	Honopu
50302	Kaumalapau
Kamao Aquifer Sector Area (04)	
50401	Kealia
50402	Manele

Table 3-5: Maui (6) Ground Water Hydrologic Units	
Wailuku Aquifer Sector Area (01)	
60101	Waikapu
60102	Iao
60103	Waihee
60104	Kahakuloa
Lahaina Aquifer Sector Area (02)	
60201	Honokohau
60202	Honolua
60203	Honokowai
60204	Launipoko
60205	Olowalu
60206	Ukumehame
Central Aquifer Sector Area (03)	
60301	Kahului
60302	Paia
60303	Makawao
60304	Kamaole
Koolau Aquifer Sector Area (04)	
60401	Haiku
60402	Honopou
60403	Waikamoi
60404	Keanae
Hana Aquifer Sector Area (05)	
60501	Kuhiwa
60502	Kawaipapa
60503	Waihoi
60504	Kipahulu
Kahikinui Aquifer Sector Area (06)	
60601	Kaupo
60602	Nakula
60603	Lualailua

Table 3-6: Hawaii (8) Ground Water Hydrologic Units	
Kohala Aquifer Sector Area (01)	
80101	Hawi
80102	Waimanu
80103	Mahukona
East Mauna Kea Aquifer Sector Area (02)	
80201	Honokaa
80202	Paauilo
80203	Hakalau
80204	Onomea
West Mauna Kea Aquifer Sector Area (03)	
80301	Waimea
Northeast Mauna Loa Aquifer Sector Area (04)	
80401	Hilo
80402	Keaau
Southeast Mauna Loa Aquifer Sector Area (05)	
80501	Olaa
80502	Kapapala
80503	Naalehu
80504	Ka Lae
Southwest Mauna Loa Aquifer Sector Area (06)	
80601	Manuka
80602	Kaapuna
80603	Kealakekua
Northwest Mauna Loa Aquifer Sector Area (07)	
80701	Anaehoomalu
Kilauea Aquifer Sector Area (08)	
80801	Pahoa
80802	Kalapana
80803	Hilina
80804	Keaiwa
Hualalai Aquifer Sector Area (09)	
80901	Keauhou
80902	Kiholo

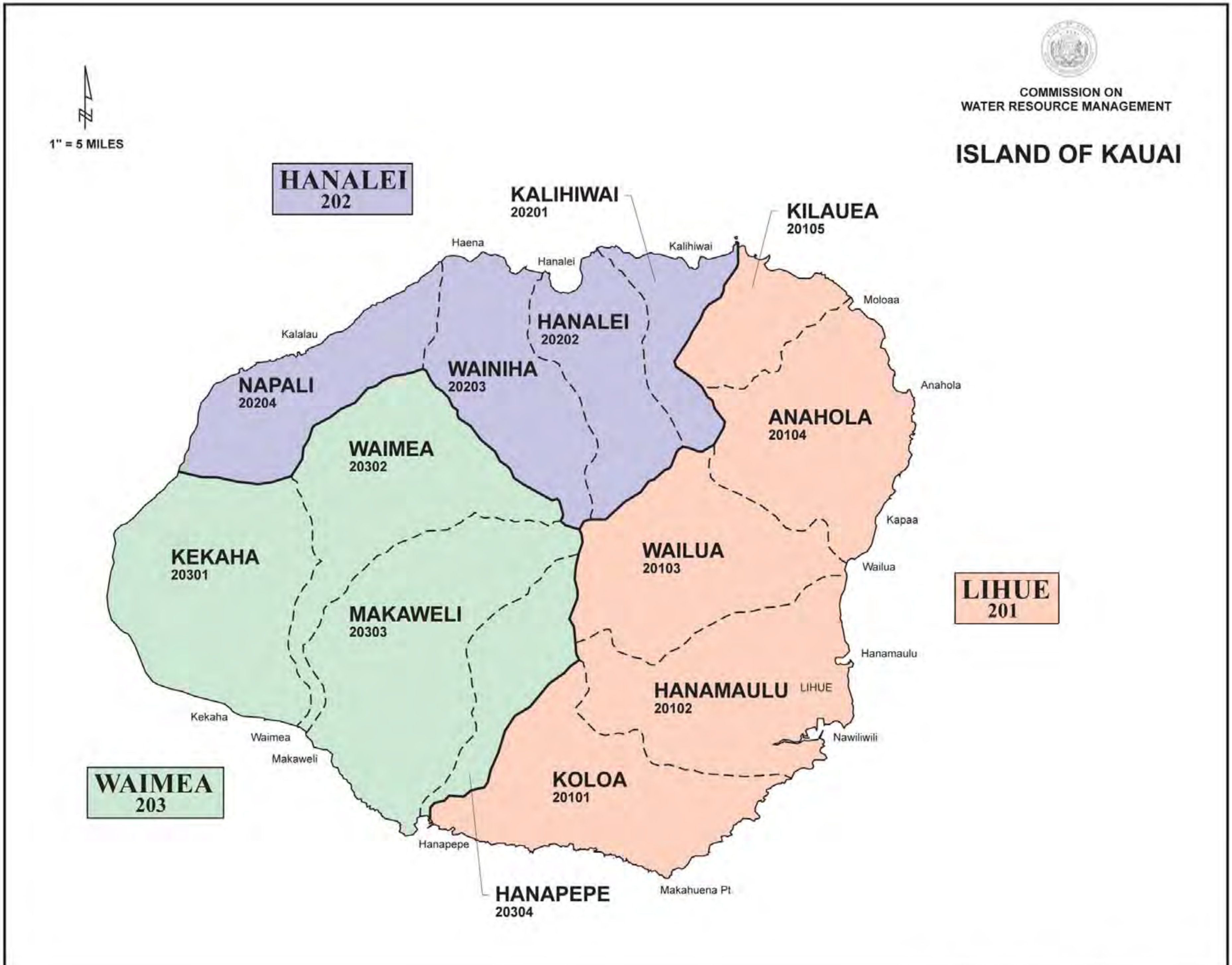


Figure 3-1. Island of Kauai Ground-Water Hydrologic Units

Map Projection: Universal Transverse Mercator

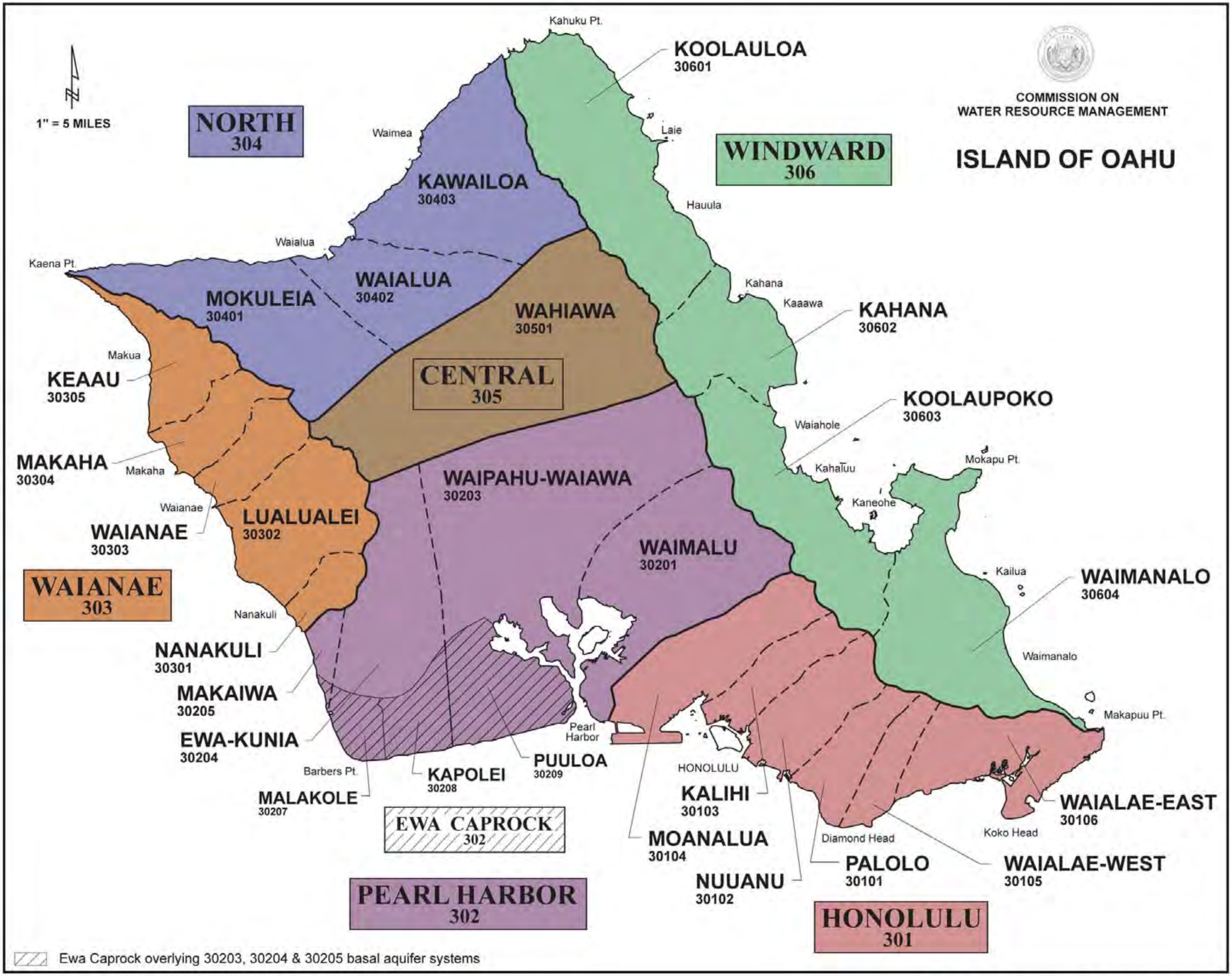


Figure 3-2. Island of Oahu Ground-Water Hydrologic Units

Map Projection: Universal Transverse Mercator

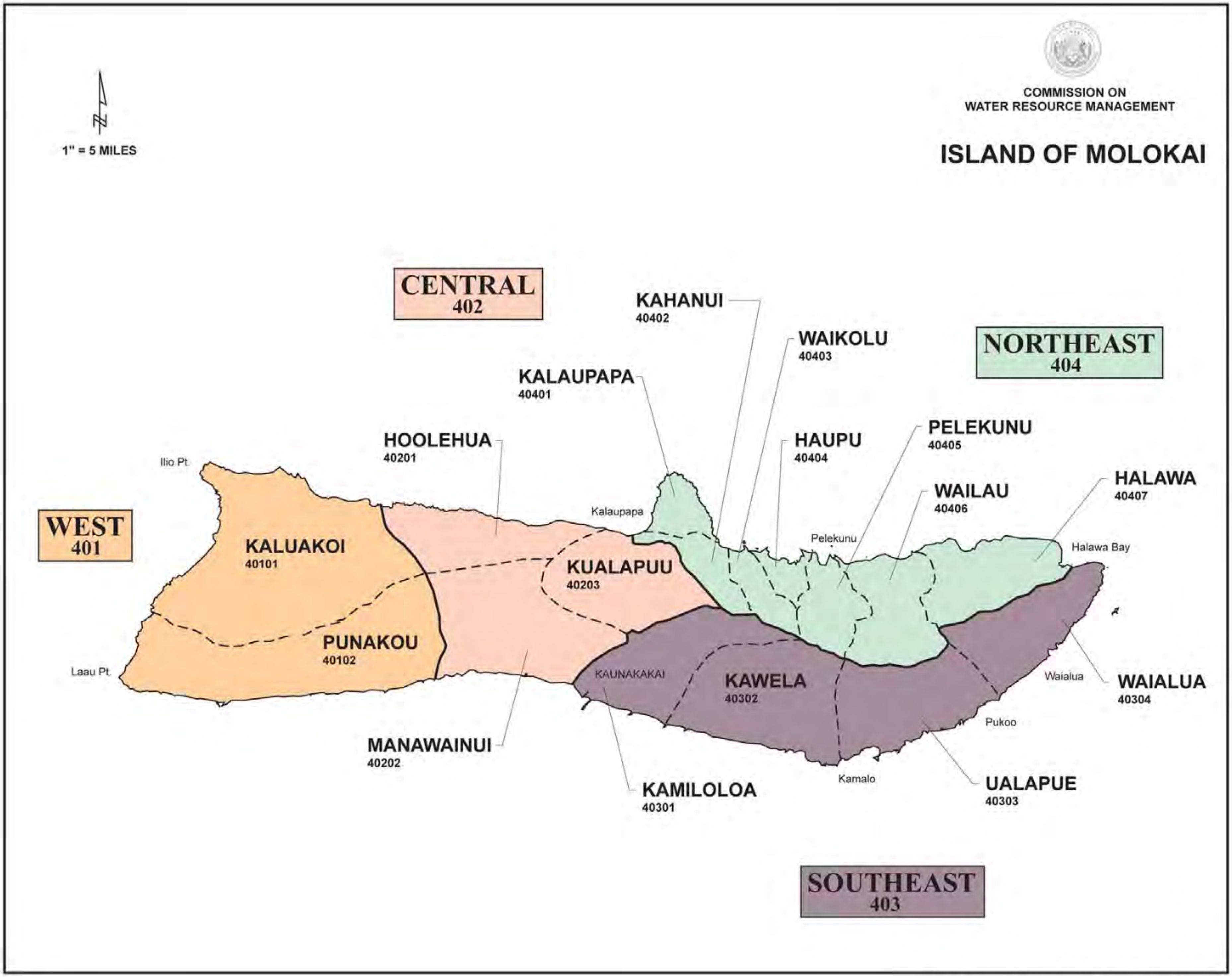


Figure 3-3. Island of Molokai Ground-Water Hydrologic Units

Map Projection: Universal Transverse Mercator

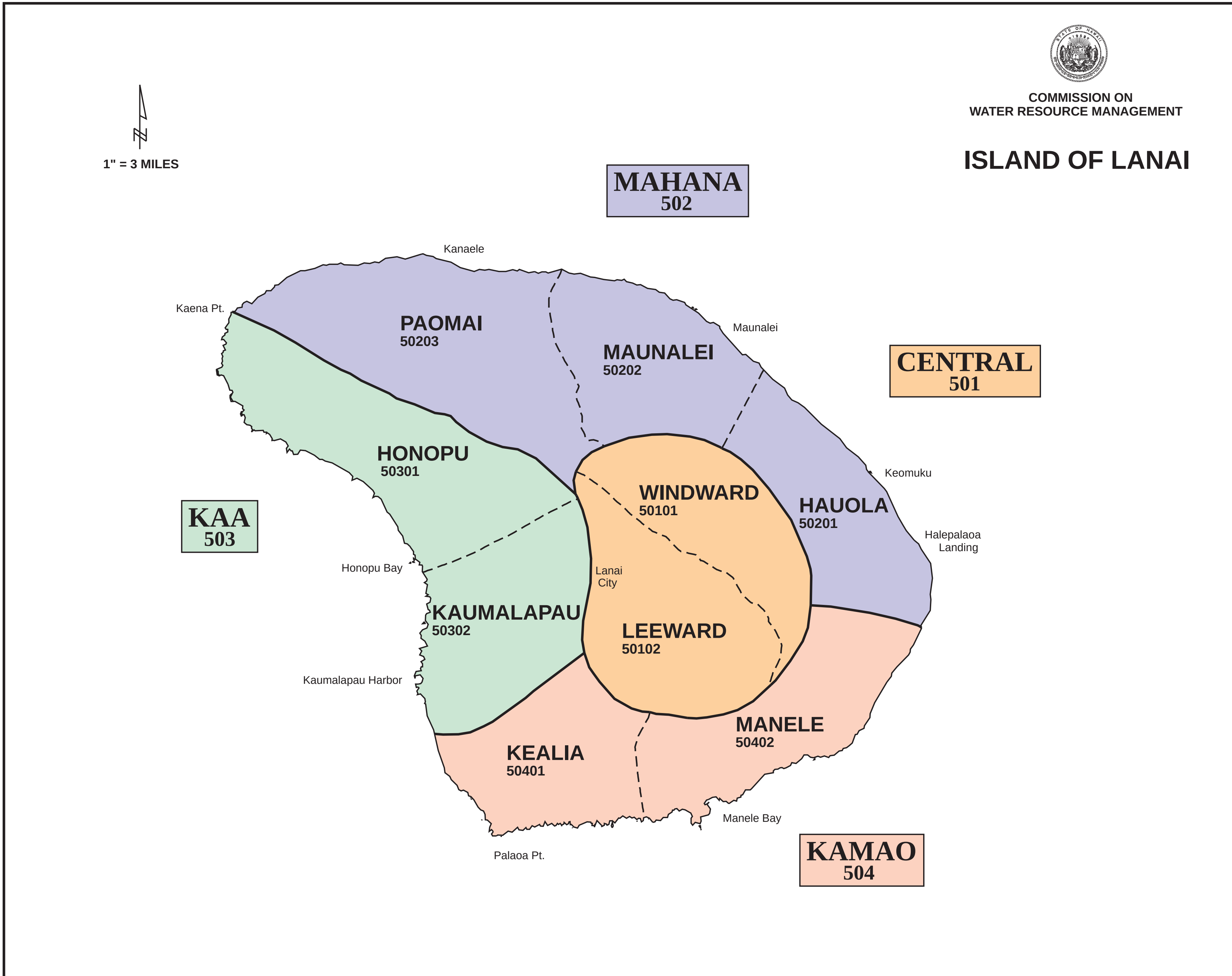


Figure 3-4. Island of Lanai Ground Water Hydrologic Units

Map Projection: Universal Transverse Mercator

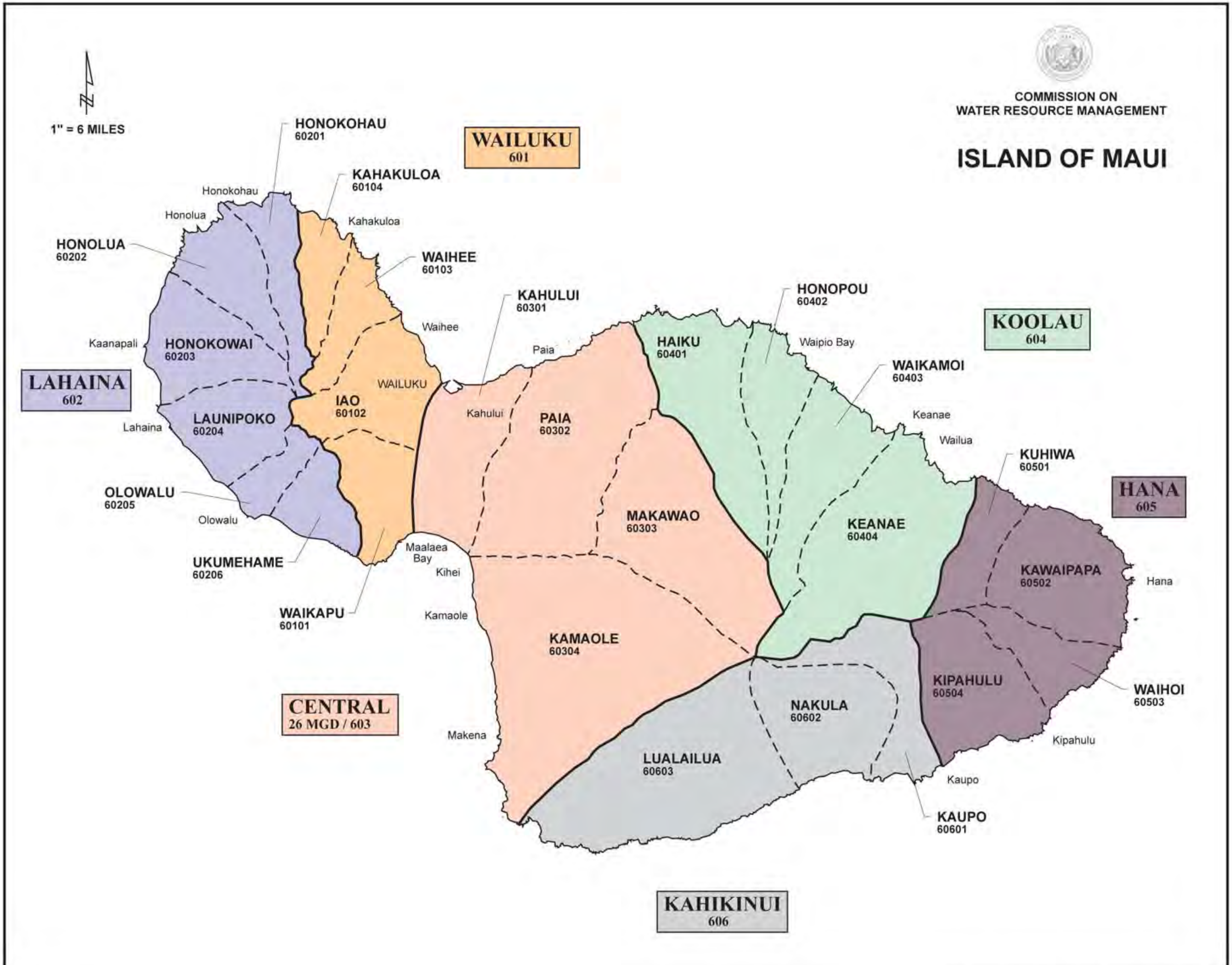


Figure 3-5. Island of Maui Ground-Water Hydrologic Units

Map Projection: Universal Transverse Mercator

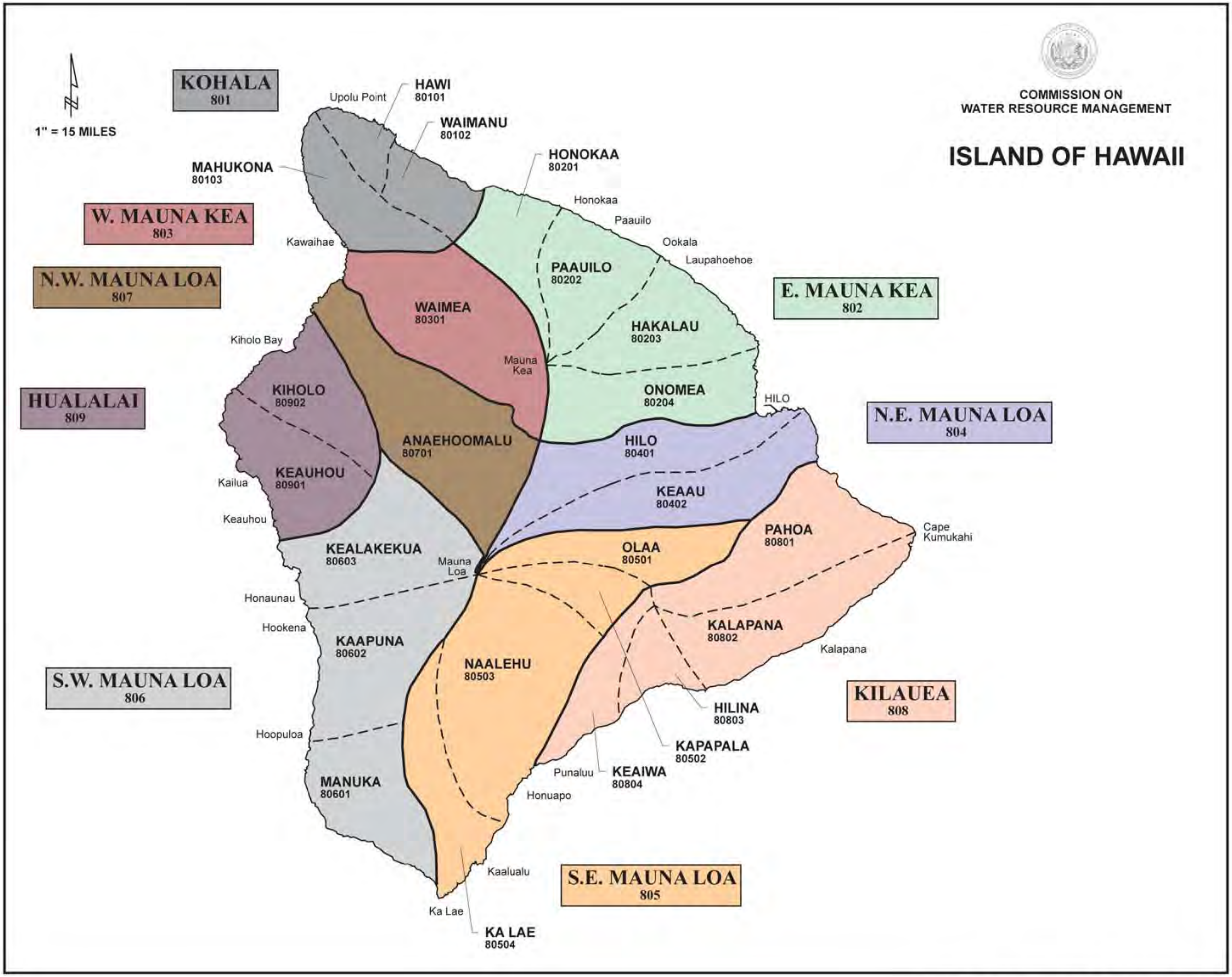


Figure 3-6. Island of Hawaii Ground-Water Hydrologic Units

Map Projection: Universal Transverse Mercator

3.3.4. Determining the Availability of Ground Water Resources: Assessing Recharge, Ground Water/Surface Water Interactions, and Sustainable Yields

Ground water flow patterns and chemical transport processes within that flow can be difficult to understand because they occur below the ground surface. Therefore, scientists must often infer and interpolate the status and characteristics of ground water resources from limited data and modeling tools. Use of these tools requires the establishment of certain assumptions and inputs, which inherently possess varying degrees of uncertainty. The following sections provide an overview of the primary issues related to the quantification of recharge, ground and surface water interaction, and sustainable yield. These issues contribute to uncertainties in the estimation of available ground water resources.

3.3.4.1. Assessing Ground Water Recharge

Ground water recharge is the replenishment of fresh ground water and depends on many natural and human-related factors. Recharge can change over time and in response to changes and events in climatological trends and land use. Ultimately, the goal of water-budget and recharge analysis is to quantify how much and where fresh water eventually reaches and becomes part of a saturated ground water aquifer.

Estimating Recharge

The ground water recharge equation (or ‘soil-moisture water-budget’ or ‘mass-balance’ equation) considered in this plan to estimate ground water recharge over a specified area is:

$$R = RF + FD + IR - DRO - \Delta SMS - ET$$

where:

R = Recharge
RF = Rainfall
FD = Fog drip
IR = Irrigation
DRO = Direct surface runoff
ΔSMS = Change in soil-moisture storage
ET = Evapotranspiration

Various methods have been derived using the above equation in varying levels of complexity and analysis to estimate ground water recharge. Each of the components within this equation have their own ‘best estimate’ quantification issues. Some of these major issues regarding the application of this equation are:

- Spatial Data Coverage
- Time Steps
- Direct Runoff Estimation; and
- Soil-Moisture Storage/ Evapotranspiration Interaction

These are discussed in more detail in the subsections below.

Spatial Data Coverage. The number and location of rainfall, fog-drip, evaporation, streamflow, irrigation return flow, soils, and land use cover data collection and analysis affect the estimation of recharge. There are three entities that maintain major climatological networks: the USGS; the U.S. Department of Commerce, National Oceanic & Atmospheric Adiministration (NOAA), National Weather Service (NWS), and the University of Hawaii - State Climate Office (SCO). The SCO is currently updating the statewide rainfall station index.

Many investigations rely on the DLNR's *Rainfall Atlas*, R76, 1986, which has been used as the standard long-term baseline monthly rainfall average and median throughout the state. Likewise, the DLNR *Pan Evaporation: State of Hawaii 1894-1983*, R74, 1986 provides the best long-term statewide annual estimate of pan evaporation. The best spatial soil coverage is the United States Department of Agriculture Soil Conservation Service's *Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii*, 1972-73. Another source of significant historic and spatial climactic and irrigation data is the Hawaii Agricultural Research Center (formerly the Hawaii Sugar Planters Association and the Pineapple Research Institute of Hawaii), which compiles data collected by sugar plantations for irrigation activities.

Spatial data coverage density varies for both rainfall and streamflow data collection and return irrigation areas such that some areas will have higher density of data compared to others. The most current land cover data is compiled through the Gap Analysis Program (GAP) run by the United States Geological Survey that maps, in part, the land cover of the dominant plant species. This mapping of land use cover will greatly enhance potential evapotranspiration spatial coverage data. Lastly, spatial data coverage differences can be best represented in recharge analysis through the use of Geographic Information Systems (GIS) and preferably on a basin wide scale, coincident with aquifer system area boundaries.

Time Steps. Time steps are periods over which data is available and comparable to each other. Time steps can be annual, monthly, daily, or even hourly. In ground water management, annual recharge is the most conservative approach (monthly or daily recharge data is only needed for detailed modeling analysis). Usually, annual time-step water budget averages are more conservative estimates than monthly, daily, or hourly water budget averages because 'spikes' in precipitation and evaporation intensities and effects of soil-moisture storage are attenuated and significant inputs to recharge can be lost.

Annual water budgets were used in the 1990 WRPP assessment of recharge and are therefore considered reasonably conservative. However, the recharge water budget equation above works best with shorter time steps, with daily time-steps being the most realistically achievable data set. Unfortunately, it is also difficult for all data points to have daily time steps over the same period of analysis. For example, daily readings for rainfall are readily available whereas pan evaporation daily data is much more limited.

Precipitation and evaporation intensities as well as soil-moisture storage vary significantly between and during the wet and dry seasons and have a significant effect on seasonal recharge rates. For numerical ground water modeling, monthly and daily time-steps provide a better way to look at transitory behavior of an aquifer and should provide a better calibration opportunity than annual time-steps. Further, if sufficient data is available, daily time-steps is preferable to monthly time steps.

Total Direct Runoff Estimation. Total direct runoff for an entire drainage basin is difficult to measure. Estimates of total direct runoff do not account for the amount of overland flow to the ocean (which does not contribute to stream flow). Soil properties and land use also change and affect this component. If adequate rainfall and streamflow data is available, direct runoff-to-rainfall ratios can be computed on a basin-wide scale.

Soil-Moisture Storage/Evapotranspiration Interaction. Another critical consideration is when to subtract ET in the water budget. Past recharge studies using the above recharge equation, which includes soil-moisture storage considerations, have used the following two methods:

1. ET is subtracted before soil-moisture storage capacity considerations. Any water left over then goes to soil storage and any water in excess of soil storage then goes to recharge.
2. ET is subtracted only after soil-moisture storage capacity considerations and any recharge has occurred. In other words, ET potential is limited by soil-moisture storage capacities.

Method 1 is considered to be more realistic and conservative than method 2, especially for daily recharge calculations. Method 2 has been used for monthly recharge estimates when daily calculations are not possible, or Method 1 seemed to unreasonably underestimate monthly recharge. The best GIS based soil datasets are available from the U.S. Department of Agriculture's Natural Resources Conservation Service, Soil Survey Geographic Database.

Simplified Ground Water Recharge Calculation: The 1990 WRPP

The June 1990 WRPP used a simplified version of the recharge calculation to determine recharge and is the statewide standard under that portion of the HWP. It can be generally represented as follows:

$$R = RF - DRO - ET$$

where:

R = Recharge
RF = Rainfall
DRO = Direct runoff (surface water flows)
ET = Evapotranspiration

all values are in average annual values (inches/year)

Fog drip, irrigation, and changes in soil-moisture storage, were generally not considered. In some well-studied areas, such as the Pearl Harbor area on Oahu, irrigation return contributions were considered in calculating net draft or pumping rate, which is the actual pumping rate minus the rate of irrigation return flow. In general, though, the 1990 WRPP plainly states that no adjustments to the statewide water budgets were made to account for return irrigation and sought to reflect pre-agricultural and pre-urbanization conditions.

Estimates for rainfall, direct runoff, and evapotranspiration were based on simple but reasonable methods for estimating these recharge parameters at the time. Weighted annual averages for rainfall, direct runoff and evapotranspiration in inches per year (in/yr) over aquifer system areas, based on DLNR rainfall maps[2], were used. Direct runoff calculations were based on empirical correlations between annual average rainfall and runoff based on the following empirical equation:

$$DRO = aRF^n$$

where:

DRO = Direct runoff (surface water flows)
RF = Rainfall
a = empirical constant
n = empirical constant

The 1990 WRPP states these are not very good estimators for direct runoff compared to actual streamflow data but are reasonable estimators at the system area scale where actual data is lacking and provided a simple consistent method for statewide application. Lastly, pan evaporation maps from DLNR pan evaporation maps[3] were not used directly to estimate evapotranspiration. Instead, where rainfall exceeded 55 in/yr, evapotranspiration was assigned as 40 in/yr while in areas where rainfall was less than 55 in/yr evapotranspiration was assigned to be 73% of rainfall.

The differences imparted by seasonal variations and the order in which to subtract evapotranspiration from its relationship with soil-moisture storage were not addressed in the 1990 WRPP. Other soil characteristics available in terms of direct runoff/rainfall ratios available were not considered in detail either.

Though the 1990 WRPP did not consider all of the generally accepted recharge considerations (it did not recognize soil-moisture storage for example), it was a reasonable first cut that could be quickly applied statewide to estimate recharge, especially in areas with little or no data. Future investigations may yield more accurate recharge estimations. These studies should include the additional contributions of fog drip and return irrigation, the effects of soil characteristics on

[2] Giambelluca, T.W., Nullet, M.A., and Schroeder, T.A., 1986, Rainfall Atlas of Hawaii, Report R76, Deptartment of Land and Natural Resources, Division of Water and Land Development, State of Hawaii, 267 p.
[3] Ekern, P.C., and Chang, J.H., 1985, Pan Evaporation: State of Hawaii, 1894-1983, Report R74, Deptartment of Land and Natural Resources, Division of Water and Land Development, State of Hawaii, 172 p.

direct runoff, soil-moisture storage, and shorter time-steps (month-to-month or day-to-day).

Ground Water Recharge Studies in Hawaii since the 1990 WRPP

Since the publication of the June 1990 WRPP, there have been many ground water recharge related studies published for various locations within the state that use the more generalized recharge calculation rather than the 1990 WRPP simplified version. There have also been unpublished private reports that are purported to use the more generalized ground water recharge calculation recognized as the minimal standard by this update of the WRPP.

Further investigation is needed to refine estimates of natural recharge rates. At this time, there are significant variations between reported values of natural recharge to Hawaii basal aquifers. For example, the rate of natural recharge in the Iao Aquifer System Area on Maui was estimated by CWRM in 1990 at 15 mgd (based on a 17.81 square mile recharge area) and by Engott in 2007 at 42 mgd[4] (based on a 18.12 square mile recharge area). These reported values were both derived by hydrologic balance analysis, but Engott's method also included fog drip, daily (instead of annual) time steps, and areal issues with valley fill, caprock, and irrigation return scenarios. According to the principle of hydrology balance, natural recharge equals precipitation minus the total of surface runoff and evapotranspiration. Therefore, more accurate estimation of the rate of natural recharge can only be achieved with an improved understanding of precipitation, including fog drip and rainwater, surface runoff, and evapotranspiration.

Recommendations for Recharge Assessment

- Achieve more accurate estimation of the rate of natural recharge through further study of relevant hydrologic processes such as precipitation (including canopy throughfall of fog water and rainwater), surface runoff, and evapotranspiration.

- Identify the rainfall isohyets described in DLNR's *Rainfall Atlas*, R76, 1986 as the minimum standard to be used in estimating ground water recharge.

- Update recharge estimates statewide for complete island coverage using the general ground water recharge equation in its entirety.

- Review ground water recharge components with other state and federal agencies and produce GIS coverage formats for various time-steps (annual, monthly, and if feasible, daily) and update where feasible.

- Consider exclusion of basal recharge from caprock and valley fill geology.

[4] Engott, John A., and Vana, Thomas T. 2007, Effects of agricultural land-use changes and rainfall on ground-water recharge in central and west Maui, Hawaii, 1926-2004: U.S. Geological Survey Scientific Investigations Report 2007-5103, 56 p. Available online at http://pubs.usgs.gov/sir/2007/5103.

- Consider current and future land use (urban vs. rural vs. agriculture) impacts to water budget component processes.

- Provide recharge updates in GIS coverage format to be placed on the State GIS system.

3.3.4.2. Assessing Ground and Surface Water Interactions

In Hawaii, ground water and surface water interactions may occur under the following conditions:

- High-level water seeps into stream channels to provide baseflow to streams;

- Basal water in coastal areas flows into stream channels to provide baseflow; and

- Stream water between marginal dike zones and coastal areas infiltrates into ground water, as evidenced by losing stream reaches in these areas.

- Basal water discharges through basal and/or caprock springs to provide water to wetlands and ponds.

Author Gordon A. Macdonald and Agatin T. Abbott, in their 1970 book entitled *Volcanoes in the Sea, The Geology of Hawaii*, describe the close interrelationship between surface water and ground water in many of Hawaii's watersheds. The discharge of excess water stored in high-level aquifers provides "a significant portion of the low water flow of many Hawaiian streams." In the following statement, the authors accurately anticipate that controversy over ground water development impacts to streamflow would soon manifest:

> *This is certain to become a source of major conflict in future years, not only on Oahu but also on the neighbor islands, because increasing groundwater development from the headwater areas of the stream basins will surely reduce down-stream supplies for irrigation as well as water for other instream uses such as wildlife habitats and recreation and aesthetic enjoyment.*

In more recent publications, ground and surface water interactions are discussed in the context of the contested case hearing over the Waiahole Ditch irrigation system, located in Windward Oahu. The system provides an example of how the development of water tunnels and stream diversions can impact the base flow (flow supplied by ground water discharge to the stream) of diverted streams as well as the recharge of the basal lens. In his 2002 book Hawaiian Natural History, Ecology, and Evolution, Alan C. Ziegler wrote of the Waiahole Ditch System and its water resource impacts as follows:

> *The entire Waiahole Ditch System is approximately 43.5 km (27 miles) long, and since its opening in 1916 has had an average water flow of over 1.4 m^3/s (32 mg/d). Of the average flow over the life of the project, 1.2 m^3/s (27 mg/d) is estimated to have been groundwater. The average amount of surface water the system collected from streams and perched springs might thus seem to be 0.2 m^3/s (4.5 mg/d). Because the withdrawal of high-level groundwater caused less to seep out to these surface water sources, however, the reduction from predevelopment Windward surface water flow was substantially greater than this amount, conceivably at least twice as much, although no exact figures are available.*[5]

Surface and ground water relationships are further complicated by human impacts and infrastructure installed to transport water between different hydrologic units. The built environment can create artificial relationships between surface and ground water resources, and these situations can be difficult to manage. In his book Water and the Law in Hawaii, published in 2004, Lawrence H. Miike notes that the laws regulating surface and ground water resources have developed separately, although natural and man-made interaction exists. An example of this is the artificial relationship between Windward Oahu surface water and Leeward ground water created by the Waiahole Ditch System. Miike further notes that, as a result of the 2000 Waiahole Ditch Contested Case, where there exists an undisputed interrelationship between surface and ground water, the State's water use permitting authority extends to both ground and surface water withdrawals if there is a designation of either a ground or surface water management area (see Section 5 for discussion on water management areas and CWRM's regulatory programs).

From a regulatory perspective, the Commission on Water Resource Management is primarily concerned with ground and surface water interaction issues as they affect surface water resources and estimates of ground water availability. Where ground water aquifers contribute to streamflow, well withdrawals from the contributing aquifer may cause depletion in stream base flow. This is a concern, as adequate stream flow must be maintained to support instream uses. In the interest of responsible management and protection of surface water resources, CWRM assesses ground and surface water relationships during staff evaluations of well permit applications. CWRM also must consider such relationships in the evaluation of sustainable yield estimates where aquifers are hydraulically connected to streams. The following sections provide examples of different types of interactions, information on methods for assessing ground and surface water interaction, and recommendations for improving monitoring and assessment.

[5] Estimates for natural flow in streams affected by the Waiahole Ditch System can be found in the USGS Scientific Investigations Report 2006-5285, available online at http://pubs.usgs.gov/sir/2006/5285. (Yeung, C.W., and Fontaine, R.A., 2007, Natural and diverted low-flow duration discharges for streams affected by the Waiahole Ditch System, windward Oahu, Hawaii: U.S. Geological Survey Scientific Investigations Report 2006-5285.)

Ground Water Contributions to Stream Flow

Ground water can provide a significant contribution to stream flow. Most perennial stream segments in Hawaii rely on input from dike-impounded ground water or basal water contributions at the coast. Figure 3-7 provides a schematic cross section of a dike-impounded ground water system along the length of a stream.

The upper reaches of many Hawaiian streams are within or near the area where volcanic dikes (near-vertical sheets of massive, low-permeability rock that cut through older rocks) impound ground water to high levels. Streams that intersect the water table of the dike-impounded ground water body are commonly perennial because they are continually recharged by the ground water body.[6] A stream that receives ground water discharge is called a "gaining" stream. In general, the flow increases as one moves downstream within dike zones. The development of a system to capture dike-impounded ground water can affect natural springs and reduce the amount of springflow that feeds the perennial streams in the upper reaches, resulting in diminished streamflows. An example of where such streamflow impacts have occurred is in the windward Oahu watersheds affected by the Waiahole Ditch system of tunnels and ditches.[7]

At low altitudes, water levels in streams and ground water bodies may be affected by ocean tides. Thus, streams in coastal areas may either gain or lose water during the day depending on the relative effects of the ocean tide on streams and ground water levels. Streams may also flow perennially in areas where dikes are not present. For example, in southern Oahu, ground water discharges to streams from a thin freshwater-lens system in permeable rocks at altitudes less than a few tens of feet.[8] Another example can be seen in eastern Kauai, where ground water discharges to streams from a vertically extensive freshwater-lens system in low-permeability rocks at altitudes of several hundred feet.[9]

Stream Flow Contributions to Ground Water

Some streams run dry at lower reaches because water infiltrates into the streambed before reaching the coast. Depending on the local geology and soils, there are stream segments, or reaches, where water seeps down through the stream bed into ground water bodies. These reaches are referred to as "losing" stream reaches because stream flow is lost to ground water recharge. Figure 3-7 illustrates both gaining and losing stream reaches.

Water can move from the stream into the ground if the water table is at a lower elevation than the streamflow level. Losing stream conditions can occur if a rainfall

[6] Oki, D.S., 2003, Surface Water in Hawaii: U.S. Geological Survey Fact Sheet 045-03, 6 p.
[7] Hirashima, G.T., 1971, Tunnels and dikes of the Koolau Range, Oahu, Hawaii, and their effect on storage depletion and movement of ground water: U.S. Geological Survey Water-Supply Paper 1999-M, 21 p.
[8] Oki, D.S., 2003, Surface Water in Hawaii: U.S. Geological Survey Fact Sheet 045-03, 6 p.
[9] Izuka, S.K., and Gingerich, S.B., 1998, Ground water in the southern Lihue Basin, Kauai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 98-4031, 71 p.

event in the upper reaches, or a water diversion causes an increased stream discharge, bulking up the flow to a height above the water table, and subsequently forcing the stream water into the ground water system. Another example of losing stream conditions is where an active water supply well lowers the local water table and attracts the stream water towards the pumping well.

Where ground water development has occurred in areas known to be subject to ground water/surface water interaction, the volume of surface water loss attributable to well pumping is usually not equal to the volume of ground water withdrawal. In rare cases, there is a direct and equal relationship between ground water withdrawals and stream flow depletion. However, this type of relationship depends on many factors, such as a well's proximity to a stream, well depth, and surrounding geology. Figure 3-8 illustrates how well pumping can affect the interaction between a ground water system and a stream. Therefore, it is important to have methods to assess the extent of ground and surface water interaction and the degree to which water development may influence stream discharge.

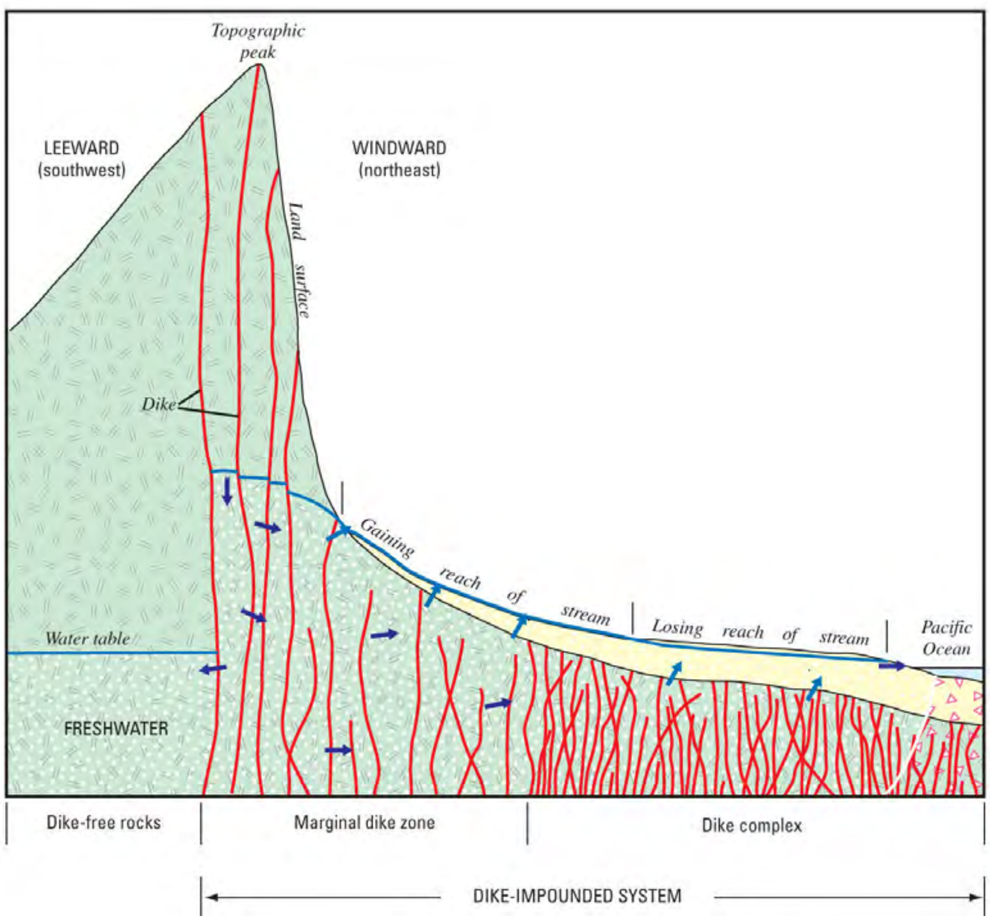
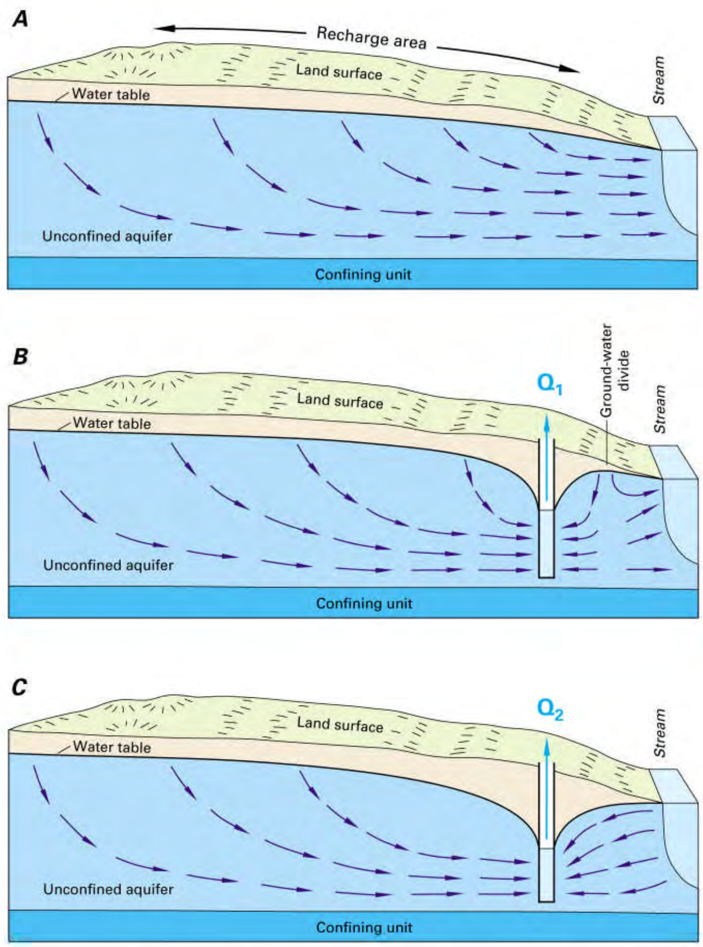


Figure 3-7. Schematic cross section showing a dike-impounded system (adapted from Oki and Brasher, 2003[10])

[10] Oki, Delwyn S. and Anne M.D. Brasher, 2003, Environmental Setting and the Effects of Natural and Human-Related Factors on Water Quality and Aquatic Biota, Oahu, Hawaii: U.S. Geological



Under natural conditions (A), recharge at the water table is equal to ground-water discharge to the stream. Assume a well is installed and is pumped continuously at a rate, Q_1, as in (B). After a new state of dynamic equilibrium is achieved, inflow to the ground-water system from recharge will equal outflow to the stream plus the withdrawal from the well. In this new equilibrium, some of the ground water that would have discharged to the stream is intercepted by the well, and a ground-water divide, which is a line separating directions of flow, is established locally between the well and the stream. If the well is pumped at a higher rate, Q_2, a different equilibrium is reached, as shown in (C). Under this condition, the ground-water divide between the well and the stream is no longer present, and withdrawals from the well induce movement of water from the stream into the aquifer. Thus, pumping reverses the hydrologic condition of the stream in this reach from ground-water discharge to ground-water recharge. Note that in the hydrologic system depicted in (A) and (B), the quality of the stream water generally will have little effect on the quality of ground water. In the case of the well pumping at the higher rate in (C), however, the quality of the stream water can affect the quality of ground water between the well and the stream, as well as the quality of the water withdrawn from the well. Although a stream is used in this example, the general concepts apply to all surface-water bodies, including lakes, reservoirs, wetlands, and estuaries.

Figure 3-8. Effects of pumping from a hypothetical ground water system that discharges to a stream (Adapted from Alley and others, 1999[11]).

Survey Water-Resources Investigatons Report 03-4156, 98 p. Available online at http://pubs.usgs.gov/wri/wri034156.

[11] Alley, W.M., T.E. Reilly, and O.L. Franke, 1999, Sustainability of Ground-Water Resources: U.S. Geological Survey Circular 1186, 79 p. Available online at http://pubs.usgs.gov/circ/circ1186/html/gw_effect.html.

Methods to Assess Ground Water/Surface Water Interaction

Direct Measurement Within the Stream Channel. Base flow is the volume of water in a stream due solely to ground water input. It may be possible to directly measure the interaction of ground and surface water within a stream channel, although such efforts may not be feasible across the vast majority of the State because the investigations are field intensive, time consuming, and very costly. According to the USGS, "Future goals associated with the issue of ground water/surface water interaction can only be minimally addressed with the existing surface water data-collection program (continuous recording, low-flow partial record stations, and crest-stage gages). The current program is structured primarily to provide streamflow data at specific points. Streamflow data that describe the magnitude of changes in base flow (flow supplied by ground water discharge to the stream) or data from seepage runs along stream reaches are required to address the issue of ground water/surface water interaction."[12] Data sets that indicate changes in base-flow characteristics (e.g. changes in low-flow discharge) are generally not available for most areas of the State. Therefore, the wide application of these investigations may not be practicably implemented.

A series of continuously recording stream gages on a stream can provide long-term flow data for analyses using the base-flow index (BFI) or flow duration curves. Such analyses can be used to separate out gains or losses of base flow between the gages. A pumping well can change the quantity of water naturally discharging to a stream, as well as the direction of ground water flux to a stream under different pumping rates.[13] The closer the well is to a stream, the more likely measurable affects will occur. Moreover, the greater the long-term pumping rate, the greater the likelihood that the stream will be affected. In cases where a gaged stream is influenced by the presence of a well, it may be possible to observe and directly measure streamflow losses due to pumping withdrawals. The effects of well withdrawals could be observed at one or multiple stream gages, along the stream reach adjacent to the well, depending on the distance between the well and the stream. Procedures for utilizing continuous gaging techniques have been published by the USGS and are available through the USGS website, "Techniques of Water-Resources Investigations Reports" (http://pubs.usgs.gov/twri/). Continuous gaging is discussed in "Techniques of Water-Resources Investigations Reports Book 3, Chapter A6, General procedure for gaging streams.[14]

A seepage run is a direct way to accurately measure gains and losses of stream discharge. The process is an intensive data collection effort where discharge measurements are made at several locations along a stream reach. The time

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[12] Fontaine, R. A., 1996, Evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii, 1994: U. S. Geological Survey, Water-Resources Investigations Report 95-4212, prepared in cooperation with the Commission on Water Resource Management, Dept. of Land and Natural Resources, State of Hawaii, 125 p.
[13] Alley, W. M., Reilly, T. E., and Franke, O. L., 1999, Sustainability of ground-water resources: U. S. Geological Survey Circular 1186, 86 p.
[14] Carter, R.W. and Davidian, J., 1968, Chapter A6, General procedure for gaging streams, Book 3, Applications of Hydraulics, Techniques of Water Resources Investigations of the U.S. Geological Survey. Available online at http://pubs.usgs.gov/twri/twri3-A6/html/pdf.html.

between the first and last discharge measurement is minimized to reduce the effects of temporal variability. Ideally, a seepage run would be performed on a day where stream discharge is stable, during base-flow or low-flow conditions. A current meter is used to measure flow velocities in designated subsection areas across the stream channel. The product of the subsection areas and velocities (perpendicular to flow direction) are summed to provide the total flow for that stream section. Procedures used in measuring stream discharge across a section have been outlined, and the following formula[15] represents how stream discharge is computed at a specific section:

$$Q = \sum (a\ v)$$

Where: Q = total cross-sectional discharge
a = individual subsection area
v = mean velocity normal to the subsection

The accuracy of the current-meter measurements depends upon choosing good cross-sections with little or no turbulent flow. These are referred to as synoptic streamflow measurements since they were performed on the same day and under the same flow conditions.[16] In some studies, seepage runs are repeated several times over a period of time (using the same measuring sites) to provide an accurate assessment of a stream's gains and losses. Seepage run data may be supplemented by concurrent measurements of specific conductance and temperature, which can aid in the interpretation of the data.

Seepage runs have been used in various stream scenarios to study such parameters as gains to stream base-flow discharge, streamflow losses to the basal lens and coastal sediments, and the impacts of surface water diversions and ground water pumpage.[17] Ideally, prior to conducting a pump test on a well that may affect streamflow, baseline discharge data should be collected along the stream reach most likely to experience impacts. A detailed survey of the stream reach should be conducted before the pump test to determine any obvious changes in flow (gains or losses). Discharge measuring sites should then be established to monitor flow before, during, and after the test. There should be one or more upstream monitoring sites, one or more monitoring sites adjacent to the well, and one or more monitoring sites downstream of the well. Monitoring can be done by direct flow measurements using a flow meter, or by installing temporary weirs and/or partial flumes. Pressure transducers can be used to measure changes in stream stage upstream of the weir or flume before, during, and after the test. Procedures for

[15] Rantz, S. E. and others, 1982, Measurement and computation of streamflow: volume 1. measurement of stage and discharge: U. S. Geological Survey Water-Supply Paper 2175, 284 p.
[16] Fontaine, 1996.
[17] Takasaki, K. J., Hirashima, G. T., and Lubke, E. R., 1969, Water resources of windward Oahu, Hawaii: U. S. Geological Survey, Water-Supply Paper 1894, prepared in cooperation with Dept. of Land and Natural Resource, State of Hawaii, 119 p.; Izuka, S. K., 1992, Geology and stream infiltration of North Halawa Valley, Oahu, Hawaii: U. S. Geological Survey Water Resources Investigations Report 91-4197, prepared in cooperation with the Dept. of Transportation, State of Hawaii, 21 p.; Oki, D. S., Wolff, R. H., and Perreault, J. A., 2006, Effects of surface-diversion and ground-water withdrawal on streamflow and habitat, Punaluu Stream, Oahu, Hawaii: U. S. Geological Survey Scientific Investigations Report 2006-5153, prepared in cooperation with the Honolulu Board of Water Supply, 104 p.

utilizing seepage run techniques are available from the USGS "Techniques of Water-Resources Investigations Reports" website (http://pubs.usgs.gov/twri/) and are discussed in "Techniques of Water-Resources Investigations Reports Book 4, Chapter B1, Low-flow investigations.[18]

There are situations where direct stream monitoring will not provide definitive results as to the effects of pumping on stream discharge. Observed geohydrological conditions may result from a complex mix of geologic formations, aquifers, and streams. Also, human errors in data collection and/or recording can occur during streamflow measurements using flow meters and stream gages (assumed to be about 5 percent). Natural events, of course, can also affect data quality. Rainfall events during pump tests can skew data such that any pumping-induced losses to streamflow are masked by gains to stream discharge caused by runoff and infiltration. Also, the lag time between pumping and the observation of surface water impacts may vary. In some cases, a pump test that lasts for 120 hours (5 days) may not be long enough to show depletions in streamflow, although continued monitoring after the test may display changes in low-flow characteristics.

Indirect Methods for Assessing Ground Water/Surface Water Interaction. Although it is ideal to assess ground water/surface water interaction through the analysis of measurements taken in the field, the logistics and costs associated with direct measurement methods are often prohibitive. Thus, investigators employ various indirect methods to assess the interaction of ground and surface water resources. Indirect assessment methods include numerical ground water models and analytical methods.

Numerical models are generally considered superior to analytical models. However, numerical models require detailed data inputs for multiple variables and such data is not available for most areas of the State. In addition, to date, no numerical models designed for Hawaii aquifers have been designed to account for ground water/surface water interaction. Therefore, ground water/surface water interaction in Hawaii is primarily assessed through the use of analytical models, which are simpler, require fewer data inputs, and are more easily applied than numerical models.

CWRM is primarily concerned with ground water/surface water interaction with respect to potential well impacts on surface water resources. These issues typically arise when a well is proposed near a stream. A variety of methods may be used to estimate the degree to which a proposed well may impact stream flow. Historically, CWRM has used two methods to estimate stream flow impacts: (1) estimating ground water drawdown based on the Theis equation and (2) estimating stream loss utilizing a stream depletion equation based on work by Sophocleous and others. In the first method, the hydraulic conductivity of the aquifer is determined from pump test data. This hydraulic conductivity is then input into the Theis equation to calculate drawdown of the water table at a given distance from the pumping well (e.g. distance to the stream). Potential impacts to the stream are then assessed

[18] Riggs, H.C., 1972, Chapter B1, Low-Flow Investigations, Book 4, Hydrologic Analysis and Interpretation, Techniques of Water Resources Investigations of the U.S. Geological Survey. Available online at http://pubs.usgs.gov/twri/twri4b1/pdf/twri_4-B1_a.pdf.

based on this predicted drawdown. For method two, the hydraulic conductivity of the aquifer is determined from pump test data. This hydraulic conductivity is then input into a stream depletion equation to calculate stream loss, for a given stream reach, as a percentage of the pumping rate of the well.

As a part of the well permit application process, CWRM requires a pump test to be performed for all new wells with a proposed pumping rate greater than 50 gpm. Data from these tests are used for an initial determination on the potential for the well to impact nearby streams, marshes, or other surface water bodies. If it is determined that a new well is likely to adversely impact a surface water body, CWRM may take several actions, including, but not limited to: (1) requiring additional testing and monitoring activities prior to, or as a condition of, permit application approval, (2) submission of an instream flow standard amendment application, (3) approval of the well permit at a reduced pumping rate if it is a requirement of the instream flow standard amendment or if subsequent pumping tests indicate that operation of the well at a lower pump rate will not impact any surface water bodies, or (4) denial of the permit application.

Examples of Ground Water/Surface Water Interaction

Basal Ground Water as Spring Discharge in Pearl Harbor. As mentioned above, many streams are intermittent in their middle reaches and become perennial in their lower reaches due to their intersection of a basal lens. This is particularly the case in Pearl Harbor. Waikele and Waiawa springs are located in the Pearl Harbor Aquifer Sector Area and offer the best examples of surface water where base-flow discharge is dependent upon head.[19]

Oki[20] in the CENCOR numerical model (see Section 3.3.4.3), used the head-discharge relationship at Kalauao Springs in Pearl Harbor to analyze the effects of pumpage to discharge. The base-case was the Visher and Mink[21] condition when agricultural recharge and pumpage was at steady-state or 1950's conditions. For future pumpage scenarios, Oki used the 1967-90 measured head-discharge relationships when agricultural activities ceased as a base-case. The future pumpage scenarios provide an estimate on the loss of basal discharge at one of the Pearl Harbor springs. Future numerical model simulations can calibrate to other Pearl Harbor springs' head-discharge relationships to deduce the amount of discharge reduction throughout the Pearl Harbor area for different pumpage scenarios.

A part of the cooperative agreement between CWRM and the USGS is to directly measure flow and sample the Pearl Harbor springs on a biannual basis. These data

[19] Visher, F. N. and Mink, J. F., 1964, Ground-water resources in Southern Oahu, Hawaii: U. S. Geological Survey Water-Supply Paper 1778, prepared in cooperation with the Division of Land and Water Development, Dept. of Land and Natural Resources, State of Hawaii, 133 p.
[20] Oki, D. S., 1998, Geohydrology of the Central Oahu, Hawaii, ground-water flow system and numerical simulation of the effects of additional pumpage: U. S. Geological Survey Water-Resources Investigations Report 97-4276, prepared in cooperation with the Honolulu Board of Water Supply, 132 p.
[21] Visher and Mink, 1964.

can be directly correlated to water levels in monitor wells and correlated to actual pumpage in the region.

Basal Ground Water as Leakage into Marshes. Basal water also discharges through the caprock and from basal and/or caprock springs in low-lying areas forming marshes and anchialine ponds. Basal water leakage is predominant in the Kahuku area where Punamano and Kii marsh and pond complexes are formed from rainfall, runoff, diffuse leakage of ground water, and from two known springs.[22] In addition there are several flowing artesian wells which supply water to James Campbell Wildlife Refuge at Kii Marsh. The sediments forming the caprock that underlies the marshes, create a semi-confined Koolau basal aquifer. With the basal aquifer having a potentiometric head of about 15 feet above sea level and the elevation of the marsh is only a few feet above sea level, there is ground water leakage through the sediments. Any reduction in the potentiometric head by pumping basal ground water will reduce the amount of leakage through the caprock. The actual amount of leakage cannot be measured directly, but up-gradient increases in basal ground water pumpage will reduce the leakage into the marsh by the same amount.

Kaloko-Honokohau National Historical Park, located on the Kona coast of the Island of Hawaii, is an example of an area where anchialine ponds are present. However, anchialine ponds with greater biodiversity can be found in other areas of the state.

Development of High-Level Ground Water and Impacts to Streams. The development of ground water resources in Hawaii has historically been driven by municipal and agricultural demands. Horizontal tunnels, large shafts, and traditional wells have been constructed to yield water from both basal aquifers and high-level aquifers. The development of high-level aquifers in some areas has been observed to impact stream flow where surface water discharge was dependent upon dike compartment stores.

Between 1900 and 1950, many high-level water sources were developed to supplement plantation irrigation systems. The plantations drilled horizontal tunnels to tap dike impounded water, which was then gravity-fed to irrigation ditches and distribution systems. Tunnels were developed in mountain areas where high spring and stream discharge provided good surface indicators of ground water accumulated in dike compartments. Spring discharge and streamflow, however, was observed to decrease after tunnel development, as the tunnels effectively captured ground water flows before the water could issue forth from springs and seeps.

An example of an area where tunnels impact surface water resources can be found in Windward Oahu, where the Waiahole Ditch system tunnels capture water from numerous dike-impounded reservoirs. Over time, dike-impounded water was

[22] Hunt, C. D., and DeCarlo, E. H., 2000, Hydrology and water and sediment quality at James Campbell National Wildlife Refuge near Kahuku, Island of Oahu, Hawaii: U. S. Geological Survey Water-Resources Investigations Report 99-4171, prepared in cooperation with the U. S. Fish and Wildlife Service, Dept. of Interior, 85 p.

depleted as it discharged through the tunnels. Meanwhile, stream flow diminished as the dike water no longer contributed to flow.

As awareness of surface water impacts increased, water development efforts began to modify tunnel construction. Engineers introduced concrete bulkheads in tunnels to simulate dike boundaries, control water discharge, and to allow ground water to rebuild as storage. The success of bulkheading varies from site to site, and many questions remain as to the effectiveness of such installations in facilitating storage recovery.

Wells have also used to develop high-level aquifers, and well withdrawals have been observed to impact vicinity surface water resources. In 1963, the Honolulu Board of Water Supply drilled two exploratory wells in Waihee Valley, Oahu (T-114 and T-115 wells 2751-02, 03, respectively). A temporary weir was constructed downstream from the wells to measure changes in stream discharge the five-day well pump testing. Measurements at the weir during testing indicated that well withdrawals resulted in loss of stream flow and that there are also some alluvial contributions to ground water. Pumping of these wells has been restricted by court order[23] such that at least 2.78 mgd of water must be allowed to flow downstream.

Examples Where Surface and Ground Water Do Not Interact. There are cases where pumping wells located near streams have been determined not to affect proximal streamflow. When the streambed is higher than the ground water table, well withdrawals typically do not impact streams. For example, wells (e.g. Mokuhau wells) in Wailuku, Maui, which pump ground water from 10 feet above sea level, do not impact the nearby Iao Stream, which is located several hundred feet above sea level. A similar condition exists with the North Waihee Wells located in the neighboring Waihee Aquifer System Area. Water levels are approximately 8 feet above sea level and the Waihee River streambed invert elevation is much higher.

Well pumping tends not to impact streams where the streambed is separated from the ground water table by perching members. In the Honolulu area, the Board of Water Supply has drilled wells into the basal aquifer (e.g., Nuuanu, Manoa, and Palolo) that do not affect vicinity streams. In these instances, streams are not affected by wells because streamflow is dependent upon shallow alluvial aquifers that are not connected to basal ground water aquifers.

Recommendations for Assessing Ground and Surface Water Interaction

The following recommendations are intended to guide future CWRM efforts to improve the assessment of ground and surface water interaction:

- Identify sites statewide where it would be appropriate to conduct seepage runs and incorporate seepage run data collection into the monitoring program.

[23] Reppun v. Board of Water Supply, 1982, 65 Haw. 531, 656 P.d 57, cert. denied, 471 U.S. 014, 105 S. Ct 2016, 85 L Ed 2d 298 (1985).

- Ensure adequate coverage of long-term stream gage sites and identify appropriate low-flow partial record sites.

- Ensure adequate baseline data collection prior to new source development. Coordinate data collection based upon long-range county plans for water development.

- Establish a statewide hydrologic monitoring netwok which will provide a basis for calibrating and validating numerical models of ground water/surface water interaction.

- Promote and encourage the use of calibrated local-scale numerical model of ground water flow in basal aquifers to assess ground water/surface water interaction as part of the well permitting process. In the modeling area, the ground water head and stream base flow are influenced by the proposed pumping.

3.3.4.3. Assessing Aquifer Sustainable Yield

Natural resources are commonly classified as either renewable: capable of being replenished as rapidly as they are used; or non-renewable: a result of accumulation over a long period of geologic time. Ground water, replenished by rainfall recharge, is universally classified as a renewable resource. However, the amount of ground water that can be developed in any Hawaii aquifer is limited by the amount of natural recharge. Additionally, not all natural recharge an aquifer receives can be developed. Some aquifer outflow or leakage must be maintained to prevent seawater intrusion or to maintain some perennial streamflow. Therefore, the sustainable yield of an aquifer normally represents a percentage of the natural recharge. Ideally, this percentage is determined by considering all relevant aquifer hydrogeologic properties and their effects on temporal and spatial variation in flow, hydraulic head, and storage. However, the State Water Code provides CWRM some flexibility in using other methods to define sustainable yield as provided by HRS §174C-3: "'Sustainable yield' means 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."

The basic question that must be addressed to successfully manage Hawaii's ground water resources is: "what is the acceptable minimum storage?" This question can also be stated as: "what is the acceptable rate of forced draft?" The acceptable rate of forced draft from an aquifer is formally defined as the sustainable yield.

Ground water models are used as tools in ground water management. This section provides a general summary of ground water modeling efforts as they have been applied in Hawaii to evaluate aquifer sustainable yield. As background to support the modeling discussion, a brief explanation of ground water storage and movement parameters is provided.

Ground Water Storage and Movement

According to the mass conservation principle, the total storage in an aquifer changes when its inflow is not balanced by its outflow. Under natural conditions, the aquifer is in a hydrologic balance such that the inflow, or the rate of natural rainfall recharge, equals the outflow or the coastal leakage. Thus, the volume of aquifer storage remains constant.

Hydraulic head, or the water level as it relates to water pressure, is an important variable. The spatial distribution of the hydraulic head or gradient determines the speed of water movement. The hydraulic head also determines the storage of an aquifer. The hydraulic head of a basal aquifer is the highest at the inland boundary and gradually reduces toward the coastline. This spatial variation of the hydraulic head induces ground water flow from mountain areas toward the ocean (see Figure 3-9).

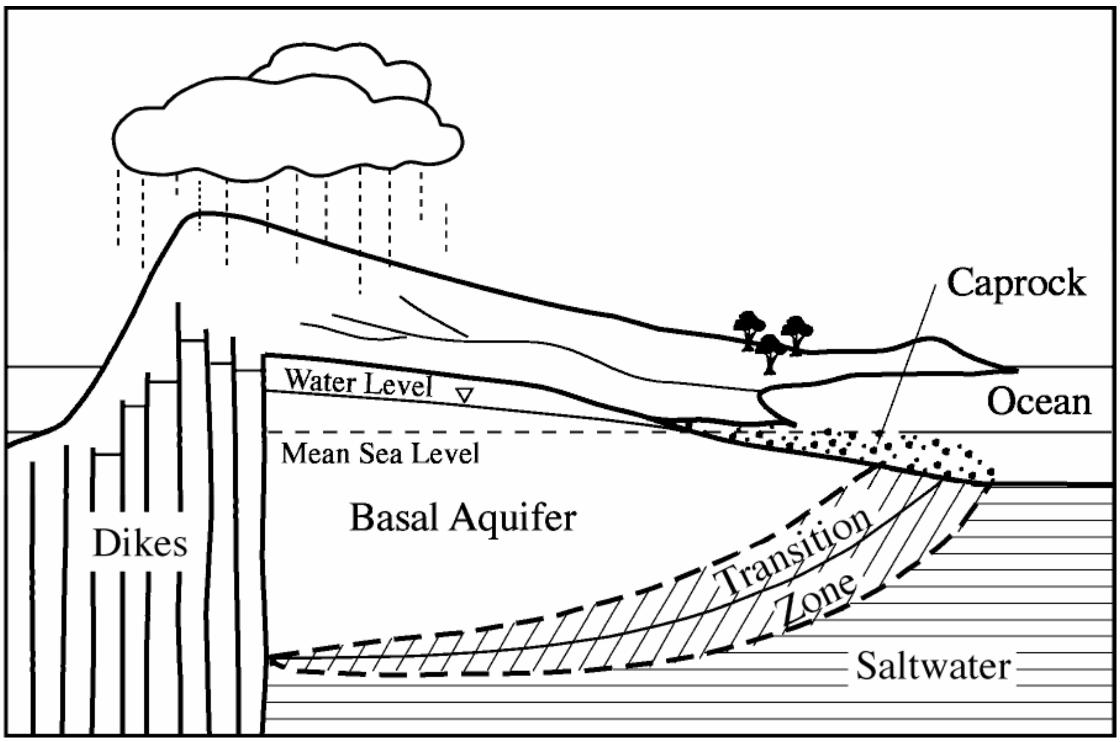

Figure 3-9. Hydrogeologic feature of a typical Hawaiian basal aquifer.

Forced draft or pumping has disrupted the natural balance of Hawaii aquifers. This is evident in the decline of hydraulic head and the reduction of storage. If the rate of forced draft from an aquifer remains constant, the aquifer would eventually reach a new hydrologic balance with a smaller storage. In principle, if the rate of forced draft equals the rate of natural recharge, there will be no leakage outflow and no storage. The hydraulic head or aquifer storage would be reduced to zero. This is not an acceptable scenario. As aquifer storage is reduced, the transition zone would grow to occupy the entire aquifer, gradually replacing all freshwater with brackish or saltwater. Therefore, as a practical matter, it is not possible to create a well network that will capture all recharge.

An aquifer's value as a source of freshwater can be evaluated in terms of hydrogeologic properties that dictate ground water storage and ground water movement. These properties are measured in terms of porosity, storage coefficient, hydraulic conductivity, and transmissivity.

An aquifer's ability to store ground water is determined by porosity and the storage coefficient. Porosity is the ratio of the aquifer's void volume to the total volume of rock material. The void volume of an aquifer is the volume occupied entirely by water. Thus, porosity indicates the maximum amount of water that an aquifer can contain. Generally, only a portion of this water can be developed and extracted for water supply; this is referred to as specific yield. The remaining volume of water is retained as a film on rock surfaces.

The volume of water stored in an aquifer changes in response to hydraulic pressure. The storage coefficient is defined as the volume released from or taken into storage per unit area of the aquifer per unit change in hydraulic head. The typical Hawaiian basal aquifer is unconfined, where the water table comprises the upper boundary (see Figure 3-9). In an unconfined aquifer, the effective porosity or specific yield is equal to the storage coefficient.

Ground water movement through an aquifer can be measured in terms of hydraulic conductivity or transmissivity. Hydraulic conductivity can be decribed as the ease with which water moves through the aquifer. Transmissivity is the product of hydraulic conductivity and the depth of flow.

Ground water supplies may be vulnerable to contamination due to human-induced and natural conditions. The impacts of contamination can be amplified and facilitated by ground water movement. Chemical leaching and seawater intrusion are two common sources of contamination. Chemical leaching occurs when residual pesticides, petrochemicals, or other contaminants percolate down from upper soil layers into the fresh water lens. Saltwater intrusion occurs when increasingly brackish water infiltrates into the freshwater lens. This can occur due to (1) improper pumping of a production well, or (2) over pumping of the aquifer, or (3) migration of the transition zone inland and/or vertically upward.

The susceptibility of an aquifer to contamination can be measured by evaluating advection and dispersion. Advection is the transport of contaminants, as water carries impurites in the direction of flow. Dispersion includes: 1) microscopic mechanical mixing due to varying pore spaces through which water flows and 2) molecular diffusion. Diffusion is defined by Fick's law as the movement of a fluid from an area of higher concentration to an area of lower concentration. Advection and the mechanical mixing portion of dispersion constitututes the majority of contaminant movement within an aquifer while the diffusion component of dispersion usually has much less effect in the spreading of contaminants.

As described earlier, storage and movement of groundwater in basal aquifers is also influenced by the Ghyben-Herzberg equilibrium formula. However, though this formula gives satisfactory results where ground water flow is horizontal, in cases where vertical flow is encountered there may be significant deviation from the 1 to 40 relationship. Vertical flow can be encountered near the coastline and in instances where there is vertical flow in monitoring wells that penetrate differing layers of geologic and aquifer formations.

Laboratory or field tests can be used to assess the parameters described above. Laboratory tests are less reliable, as only a limited portion of the rock matrix can be evaluated. Hawaii aquifers are highly heterogeneous and, at this time, only statistically describable aquifer parameters can be assigned to Hawaii aquifers on a large scale.[24] Field tests can provide effective values appropriate for regional studies, however, site-specific pumping tests should be conducted to evaluate local conditions.

Ground Water Management Model Development and Application

Many types of models have been developed and applied in the U.S. and elsewhere for simulating ground water flow and solute transport. These models help to address sustainability issues. The early simulation attempts used analog models such as sand boxes, electrical conductivity sheets, and resistance-capacitance networks. Analytical models such as RAM have been and continue to be used in Hawaii with limited ground water data to estimate sustainable yields. More recently, mathematical models have been developed that take full advantage of the rapid advancement of numerical methods and computer technology through what is commonly refered to as numerical models. Finite-difference, finite-element, and other boundary-integral numerical modeling techniques are important tools that should be used to aid in the management of well infrastructure and other ground water management problems where sufficient data and monitoring exist.

Mathematical models of ground water flow are formulated by combining the mass conservation principle and Darcy’s law of ground water movement. Darcy’s law states that the ground water flow rate can be calculated if the hydraulic head gradient and hydraulic conductivity is known. A conceptual ground water flow model can simulate a basal aquifer when the width of the transition zone is small relative to the thickness of the aquifer. In this case, the freshwater and salt water are considered to be immiscible fluids separated by a sharp interface. This type of sharp interface model is adequate if the purpose of modeling analysis is to determine the general position, shape, and behavior of the interface; water levels; and flow directions in response to climatic and pumping stresses .

The conceptual sharp interface model may be further divided into two categories: freshwater flow models, and coupled freshwater-saltwater flow models. The freshwater flow models are formulated by assuming the saltwater is stationary. The lower boundary of the freshwater model or the sharp interface can then be located by the Ghyben-Herzberg formula.[25] Coupled freshwater-saltwater models are

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[24] Lau, L. Stephen and Mink, J.F., *Hydrology of the Hawaiian Islands*, University of Hawaii Press: Honolulu, 2006.
[25] Liu, C.C.K., Lau, L.S. and Mink, J.F., 1983, Groundwater Model for a Thick Freshwater Lens, *Ground Water*, 21(3):293-300.

formulated by assuming both freshwater and underlying saltwater are moving. The sharp interface of a coupled freshwater-saltwater flow model can be located based on Hubbert formula.[26]

Mathematical models of ground water solute transport, the movement of solutes in ground water systems, are formulated by combining the mass conservation principle and Fick's law of dispersion. Fick's law states that the mixing of a solute in an aquifer can be calculated if the solute concentration gradient and dispersion coefficient are known. For modeling reactive chemicals, additional mathematical terms representing relevant reaction kinetics must also be included in the transport model formulation.

Because the solution of a transport model requires prior knowledge of flow velocity, solute transport modeling must be conducted following a flow simulation. The flow simulation calculates the flow velocity distribution in the aquifer, which is subsequently applied in transport simulation to calculate the salinity distribution. In modeling seawater intrusion, salinity re-distribution may cause appreciable change in water density, which is a flow model variable. Therefore, a comprehensive ground water model must combine both flow and transport simulation. The flow simulation is first conducted to calculate velocity distribution. The velocity distribution is then used by the transport model to calculate salinity distribution. The density change caused by the new salinity distribution is then determined and used to re-calculate the velocity distribution. The process must continue until stable velocity and salinity distributions are established. SUTRA, a numerical ground water model developed by the US Geological Survey, solved coupled flow and solute transport equations.[27]

Formerly, simple analytical ground water models were developed and tested in aquifers with reasonably defined geological structures and hydrology. Mathematical modeling using simple analytical models highlights the relative importance of aquifer hydrogeologic properties. With the increasing power of computers, the accessibility to and use of more complex numerical ground water models and computer codes has increasely become more important.. However, before a numerical ground water model can be soley relied upon for prediction and management decisions, a rigorous process of model calibration and verification must be completed. The general procedure in model calibration and verification is to estimate a range of values for the ground water flow and the solute transport parameters, then test the model by comparing the calculated hydraulic head and salinity distribution to the observed values. The results of an adequately-calibrated model will reasonably emulate the observed results of historical events that provide the basis for estimated parameters. Anderson provides a very good detailed explanation of numerical

[26] Liu, et al.1983; Essaid, H. I., 1986, A comparison of the coupled fresh water-salt water flow and the Ghyben-Herzberg sharp interface approaches to modeling of transient behavior in coastal aquifer systems, *Journal of Hydrology,* 86:169–193.
[27] Voss, C.J., 1984, A finite-element Simulation Model for Saturated-unsaturated, Fluid-density-dependent Groundwater Flow and Transport Flow with Energy Transport or Chemically Reactive Single-species Solute Transport, *U.S. Geological Survey Water Resources Investigation Report* 84-4369.

model development.[28] Additionally, the CWRM has provided a Guide for Documentation for Ground Water Modelling Reports since 1994.

A comprehensive numerical ground water model contains many model parameters. It may also consist of a huge numerical network with up to one million nodes or computational units. In principle, each node may have different model parameters to address the real world heterogeneity of an aquifer. Therefore, a very close match of calculated and observed head and salinity distribution data is difficult but may be achieved by the simultaneous manipulation of several model parameters.

Inaccurate model calibrations can be corrected by model verification. A model is considered verified if calculated results can reasonably emulate a historical event, or reasonably predict the behavior of water levels under changing circumstances based on an actual data set. New pumpage distribution patterns or changes in recharge due to reduced irrigation are typical examples of changing circumstances. Ideally, some judgment of the values of model parameters should be practiced. In model calibration and verification, it is advantageous for the investigators who developed the model and those who have gathered field data to participate in the calibration and verification process.

Numerical Ground Water Modeling Efforts in Hawaii

Table 3-7 is a listing of numerical modeling efforts in Hawaii that have been reviewed by the CWRM. This is not an exhaustive listing, as there are other private and public reports available that have not been reviewed in depth by the CWRM. As reports come to the attention and are reviewed by the CWRM these documents are compiled in the digital library of the Water Commission for public information. In addition, public and private reports exist which have valuable hydrologic information but are not ground water flow models (e.g., recharge studies).

Table 3-7
Summary of Mathematical Ground Water Flow Models Reports in Hawaii

YEAR	MODEL	APPLICATION	REFERENCES
1974	GE-TEMPO	Long-term head variability in Palolo aquifer, Oahu	Meyers, C.K., Kleinecke, D.C., Todd, D.K., and Ewing, L.E., 1974
1980	Robust Analytical Model (RAM)	Analytical model to assess sustainable yields of Southern Oahu	Mink, J.F., WRRC prepared for Honolulu BWS
1981	2-D Flow Model	Ground water head variability in Pearl Harbor aquifer, Oahu	Liu, C.C.K., Lau, L.S. and Mink, J.F., WRRC TR 139
Early to Mid-80s	Methods of Characteristics (MOC)	2-D/3-D finite difference model of ground water and chemical transport of pesticide residuals in Pearl Harbor aquifer	Konikow, L.F., and Bredehoeft, J.D., 1978 Orr, Shlomo, and Lau, L.S., 1987

[28] Anderson, M.P., Woessner, W.W., 1992, Applied Groundwater Modeling – Simulation of Flow and Advective Transport, 381 p.

Table 3-7 (continued)
Summary of Mathematical Ground Water Flow Models Reports in Hawaii

YEAR	MODEL	APPLICATION	REFERENCES
1985	AQUIFEM-Salt	2-D finite element to water systems in Southeast Oahu	Eyre, P., Ewart, C., Shade, P. USGS WRIR 85-4270
1990	RAM	Analytical ground water model for estimating sustainable yield values in 1990 WRPP	Mink, J.F. Mink & Yuen, prepared for the Water Commission
1993 to 1994	DYNSYSTEM	3-D finite element to study ewa marina construction effects on ewa caprock	Camp Dresser & McKee, 4 Volumes, prepared for HASEKO (Ewa) Inc., CCH-OA96-1
1995	AQUIFEM-Salt	2-D finite element to study water level changes due to increased pumping in Hawi, Big Island.	Underwood, M., Meyer, W. Souza, W. USGS WRIR 95-4113
1995	AQUIFEM-Salt	2-D finite element to study water level changes due to increased pumping from Barbers Point Shaft on Waianae Aquifer.	Souza, W., Meyer, W. USGS WRIR 95-4206
1996	Modular Finite Difference Flow (MODFLOW)	2-D finite difference to study the effects of pumpage on water levels for the entire island of Lanai	Hardy, R. CWRM R-1
1996	MODFLOW	2-D finite difference to study connection between caprock and basal aquifers	Willis, R., prepared for The Hawai'i-La'ieikawai Assoc. Inc., CCH-OA96-02
1996	Saturated-Unsaturated Transport (SUTRA)	2-D finite element to study pumpage impacts to water levels on cross-section of Ewa Caprock	Oki, D., Souza, W., Bolke, E.,Bauer. G USGS OFR 96-442
1997	AQUIFEM-Salt	2-D finite element to study pumpage impacts to water levels and coastal leakage for entire island of Molokai	Oki, D. USGS WRIR 97-4176
1998	SHARP	Quasi 3-D finite difference to study pumpage impacts to water levels in Central Oahu	Oki, D. USGS WRIR 97-4276
1998	SHARP	Quasi 3-D finite difference to study pumpage impacts to water levels in Lihue Kauai	Izuka, S. Gingerich, S. WRIR 98-4031
1998	RAM	Study on sustainable yield for Waipahu, Waiawa and Waimalu Aquifer Systems	Mink, J.F. Mink & Yuen prepared for LURF
1998	RAM	Study on sustainable yield of Ewa-Kunia Aquifer System	Mink, J.F. Mink & Yuen prepared for Estate of James Campbell
1998	FEMWATER	3-D finite element coupled flow and transport to model the Ewa Plain	Woodward Clyde, prepared for C&C of Honolulu
1999	SHARP	Quasi 3-D finite difference to study water levels and coastal leakage at Kaloko-Honokohau National Park	Oki, D., Tribble, G., Souza, W., Bolke, E. USGS WRIR 99-4073
2001	RAM	Comparison between RAM and numerical model results	Oki, D., Meyer. W. USGS WRIR 00-4244

Table 3-7 (continued)
Summary of Mathematical Ground Water Flow Models Reports in Hawaii

YEAR	MODEL	APPLICATION	REFERENCES
2001	SHARP	Quasi 3-D finite difference to study water levels, transition zone, and surface water impacts	Izuka, S., Oki, D. USGS WRIR 01-4200
2002	AQUIFEM-Salt	2-D finite element ground water flow model to study Hawi area on big island	Oki, D. 2002, USGS WRIR 02-4006
2005	FEFLOW	3-D finite element simulation to study transition zone movement due to pumping on the Honolulu aquifer.	Todd Engineers, prepared for BWS 2005
2005	SUTRA	2-D finite element to effects of Honolulu Valley fills	Oki D. USGS SIR 2005-5253
2006	MODFLOW	3-D finite difference study of the Mahukona Aquifer System	Spengler, S., Pacific Hydrogeologic, LLC
2006	AQUIFEM-Salt	2-D finite element simulation to study impacts of future pumpage on water levels and coastal leakage on Molokai	Oki, D. USGS SIR 2006-5177
2006	MODFLOW	3-D finite difference study for DOH SWAP program to identify well capture zones	Whitttier, R, El-Kadi, A., et. al. WRRC prepared for State of Hawaii DOH
2007	AQUIFEM-Salt	2-D finite element simulation to study impacts of pumpage on water levels and coastal leakage on Kaunakakai Stream Molokai	Oki, D. USGS SIR 2007-5128
2007	RAM2	Modified RAM that includes deep monitor well salinity profile data for estimating sustainable yield values in 2008 WRPP	Liu, C.C.K., 2007.WRRC PR-2008-06

Analytical Ground Water Modeling Efforts in Hawaii

Table 3-7 also lists analytical modeling efforts that have been reviewed by the CWRM. This is not an exhaustive listing as there are other private and public reports available. In addition, public and private reports exist which have valuable hydrologic information but are not ground water flow models (e.g., recharge studies).

An analytical model for a particular ground water system can be formulated using simplifying assumptions for system boundaries, flow, and transport processes. With these simplifying assumptions, theoretical or mathematically derived solutions of the model governing equations can be obtained.

Analytical ground water models are used extensively in ground water management for the following reasons:

- Analytical models are essential for the design of field experiments and subsequent data interpretation to estimate aquifer flow and transport parameters;
- Analytical models are useful modeling tools for preliminary ground water investigations; and
- Analytical models can be used to test comprehensive numerical models through comparison of modeling results for simplified conditions and scenarios.

Analytical Ground Water Flow Model RAM

In Hawaii, the most commonly used analytical ground water model is the robust analytical model (RAM) [29] derived by Mink. Sustainable yield values of Hawaii basal aquifers were estimated by RAM and included in the 1990 WRPP.

In RAM, a basal aquifer is represented conceptually by two completely stirred tank reactors (CSTRs) separated by a sharp interface (see Figure 3-10). The freshwater in the upper CSTR flows at a constant rate of $L = I - D$, where L is the coastal leakage; I is the natural rainfall recharge, a constant; and D is the pumping rate, or pumping minus irrigation return flow. The saltwater in the lower CSTR is stationary. RAM calculates the variations over time of the hydraulic head (h) in a basal aquifer in response to pumping stress. The steady-state solution of RAM indicates a simple relationship between the hydraulic head and the pumping rate. This relationship is presented graphically in Figure 3-11.

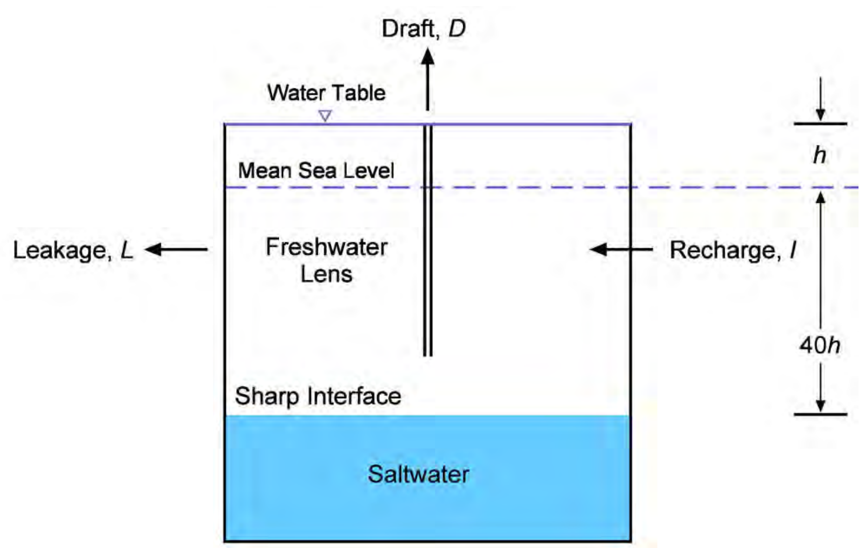

Figure 3-10. Conceptual formulation of the basal aquifer in the robust analytical model (RAM).

[29] Mink, 1980; Mink, J.F., 1981, Determination of Sustainable Yields in Basal Aquifer, in: *Groundwater in Hawaii-A Century of Progress,* Book published by the Water Resources Research Center, University of Hawaii at Manoa, pp.101-116.

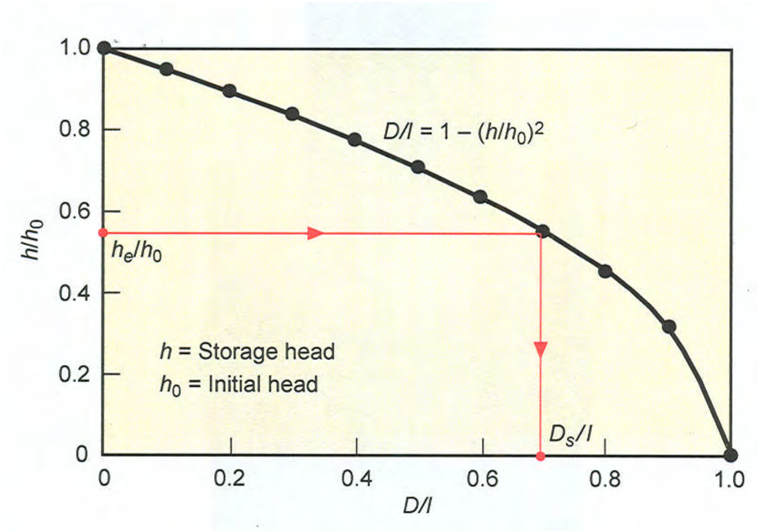

Figure 3-11. Basal aquifer head-draft curve derived by RAM.

Key assumptions of RAM include the following:

- Fresh water occurs as a basal lens floating on top of sea water;
- A sharp interface exists between the fresh and sea water;
- The aquifer is unconfined, its properties are homogeneous and isotropic, and its thickness is constant;
- Groundwater flow is uniform and laminar;
- Head is equivalent to Storage Head; and
- Wells are optimally placed throughout the aquifer system area.

Important limitations of RAM include the following:

- RAM ignores the spatial distribution of (1) recharge, (2) actual well placement, and (3) actual well pumpage;
- Many of the "initial heads" used the in RAM calculation were estimated due to the absence of pre-development groundwater data;
- The "minimum equilibrium head" used in the RAM equation is an estimate based on empirical relationships. It cannot be determined analytically.;
- RAM does not account for (1) convection and dispersion, (2) variability in the transition zone, (3) flow between aquifer system areas, and (4) aquifer system area boundary conditions (such as caprock); and
- RAM does not model ground water flow in three-dimensions.

Analytical Ground Water Flow and Transport Model RAM2

The modified RAM (or RAM2,) consists of two submodels. The flow submodel takes the form of RAM. The transport submodel simulates the variation of salinity over time in the transition zone of a basal aquifer in response to pumping stress. In RAM2, a basal aquifer is represented conceptually as two completely stirred tank reactors (CSTRs) separated by a transition zone of varying salinity (see Figure 3-12).

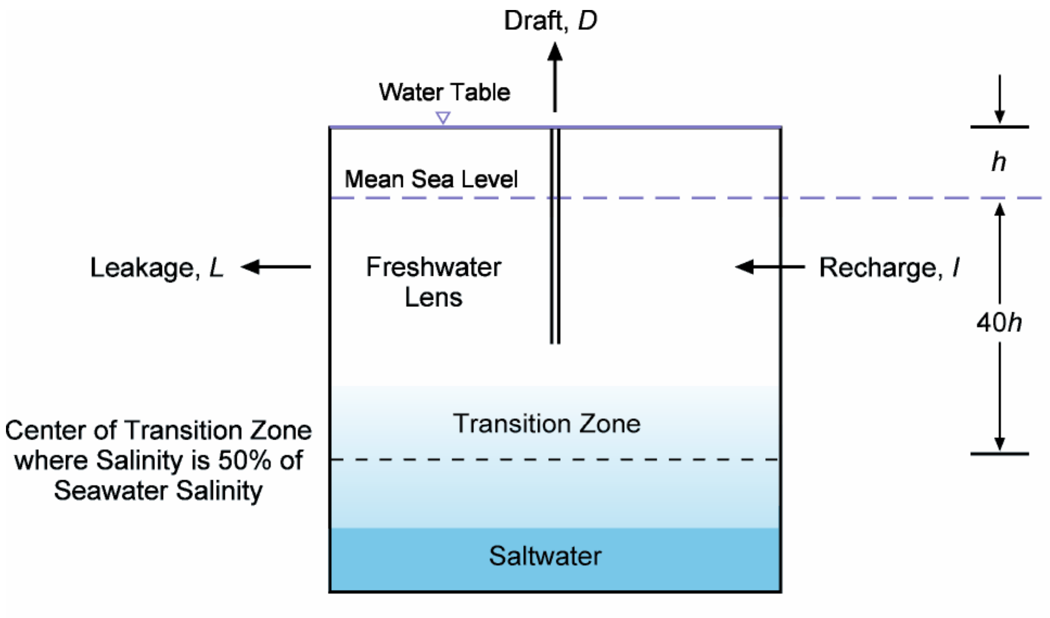

Figure 3-12. Conceptual formulation of the basal aquifer model RAM2.

Assessing Sustainable Yield of the Hawaiian Basal Aquifers by RAM and RAM2

Ideally, the sustainable yield of a basal aquifer would be determined through a numerical simulation using a comprehensive three-dimensional flow and transport model. However, the application of a comprehensive model for this purpose requires significant time and money to produce and is difficult to use. Comprehensive numerical model parameters are very complex and are difficult to quantify. Simple analytical models such as RAM and RAM2 are currently more readily applied to estimate sustainable yields for water planning purposes, especially given the complexities of estimating recharge alone.

According to RAM, a parabolic relationship of hydraulic head and draft rate exists when a basal aquifer is at a steady state, or when recharge to the aquifer equals leakage plus pumping or forced draft. Figure 3-11 shows a plot of head vs. draft in terms of dimensionless variables. The ordinate is a dimensionless variable of head, or h/h_0, where h_0 is constant initial head. The abscissa is a dimensionless variable of draft rate, or D/I.

According to RAM, the sustainable yield of a basal aquifer relates directly to its minimum equilibrium head. Mink stated that "the clearest expression of sustainable yield is that of allowable net draft for a selected (minimum) equilibrium head."[30] Sustainable yield represents the maximum amount of water that can be withdrawn before a given equilibrium head is compromised.

The response of a basal aquifer to pumping stress can be measured in terms of hydraulic head decline and the expansion and upward movement of the transition zone. This expansion and upward movement is a prelude to seawater intrusion. Acceptable source-water salinity in Hawaii is 250 mg/L chlorides or less . Seawater intrusion occurs when water with salinity higher than 250 mg/L chlorides reaches the bottom of a pumping well. Therefore, the minimum equilibrium hydraulic head can generally be defined as the hydraulic head that must be maintained to prevent seawater intrusion into a particular well.

The minimum equilibrium head of a well cannot be determined analytically by solving the governing flow equation of RAM as it does not consider salt water movement or well upconing issues for the spatial distribution of actual wells. Therefore, RAM estimates sustainable yield by establishing a minimum equilibrium head based on selected important well depth within an aquifer or, in the absence of a selected well site, it relies on a relationship for selecting minimum equilibrium head, as suggested by CWRM in the 1990 WRPP (see Table 3-8). In this WRPP update, the CWRM generally used the table to reassess sustainable yields rather than rely on a single important well site.

After an equilibrium head (h_e) and thus (h_e/ h_0) is selected, this value is inserted into Figure 3-11 to obtain the dimensionless variable of draft or D_s/I. Multiplying this value by the known recharge rate gives the sustainable yield

Table 3-8. Relationships between initial head and minimum equilibrium head of Hawaii basal aquifers.[31]

The range of initial head, h_0 (ft)	Ratio of minimum equilibrium head and initial head (h_e/h_0)	D/I or SY = %of Recharge
4 – 10	0.75	0.44
11 – 15	0.70	0.51
16 – 20	0.65	0.58
21 – 25	0.60	0.64
> 26 and High-Level	0.50	0.75

[30] Mink, 1980.
[31] State of Hawaii Department of Land and Natural Resources, Commission on Water Resource Management, 1990, *Hawaii Water Plan, Water Resources Protection Plan:* Honolulu, Hawaii.

The sustainable yield of Hawaii basal aquifers can be determined by the integrated application of both the flow and transport submodels of RAM2. The modeling procedure, as shown in Figure 3-13, consists of the following steps:

1. Use hydraulic heads and salinity profiles from deep monitoring wells and previous studies to estimate the transport parameter values (i.e., dispersion coefficient and mean hydraulic resident time);

2. Use the transport submodel to calculate the minimum equilibrium hydraulic head; and

3. Use the flow submodel to determine the sustainable yield.

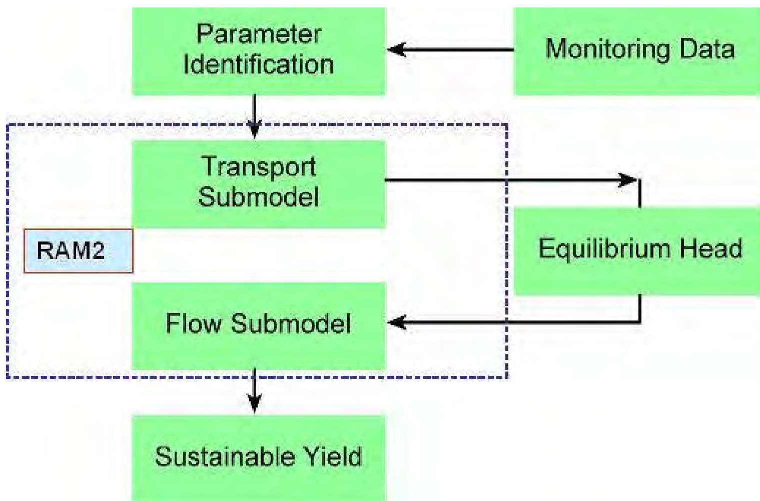

Figure 3-13. RAM2 modeling procedure.

RAM2 was used by two recent studies[32] to re-evaluate the sustainable yield of a few selected Hawaii basal aquifers. Table 3-9 summarizes the results of sustainable yield estimation by both RAM and RAM2.

[32] Liu, 2006; Liu, 2007.

Table 3-9. Sustainable yield estimation of selected Hawaii basal aquifers

Aquifer	Areas (mi^2)	Natural Recharge (in.)	Estimated Sustainable Yield (mgd)	
			RAM	RAM2
Oahu				
Ewa-Kunia	28.1	24.0	11.0	19.4
Waipahu-Waiawa	60.7	136.3	102.0	110.3
Waimalu	32.1	59.7	45.0	48.3
Moanalua	10.9	24.0	18.0	15.8
Kalihi	6.3	12.0	9.0	8.7
Beretania	8.6	20.0	15.0	13.9
Kaimuki	14.4	8.7	--	6.5
Maui				
Iao	24.7	28.0	20.0	18.5
Molokai				
Kualapuu	13.0	9.0	7.0	5.0

Note: According to CWRM, area of Iao is 17.81 mi^2 and area of Kualapuu is 18.2 mi^2

Production Wells in Hawaii Basal Aquifers: Operation and Safe Yield

The sustainable yield of Hawaii basal aquifers represents the maximum aquifer pumping rate (i.e. allowable draft) assuming optimal placement of wells. In principle, if optimally distributed, each of production well in a basal aquifer can be assigned an allowable draft such that the total draft from the aquifer is equal to or less than the sustainable yield. However, the safe yield of an individual production well is also limited by the localized ground water behavior near the well in response to its pumpage. Specific yields, upconing, and pump intake altitudes can severly limit the safe yield of an individual well while the aquifer as a whole is not threatened. Examples of this are wells drilled too deep, too shallow, or are located in very tight (low permeability) formations. The safe yield of an individual production well may be less than the allowable draft based on any model prediction because of localized operational limitations. Safe yield can be optimized in a production well with proper well design, location, and operation. Further, safe yield of an aquifer based on well infrastructure is best esimated utilizing a calibrated and validated numerical model based on sufficient hydrologic data.

Decline in Specific Capacity

Sustainable yield is evaluated assuming an aquifer is experiencing steady state conditions. It should be noted that this assumption does not account for operational conditions at a given production well. A basal aquifer's transient response to pumping stress, in the vicinity of a well, may include a decline in specific capacity and/or upconing.

The safe yield of an individual production well is partly controlled by the specific capacity the available drawdown of that well. When a well is pumped, water is removed from the aquifer surrounding the well, and the water level or hydraulic head is lowered. The drawdown is defined as the vertical distance the water level within the well bore is lowered from the original static (non-pumping) water level. The specific capacity of a production well is its yield per unit drawdown. Available drawdown is the difference between the static head and the lowest practical head, which is normally determined at the time of well construction.

Decline in the specific capacity of a well is measured in terms of operating head. The operating head indicates the transient response of an aquifer to pumping stress. This is usually measured in the field while the aquifer is being pumped. The hydraulic head of a basal aquifer is governed by the Ghyben–Herzberg formula and is called the storage head. The storage head of a large aquifer declines slowly in response to pumping stress. For example, the average decline of the storage head of the Pearl Harbor aquifer was less than 0.25 ft/yr during the last 100 years[33]; during the same period, the measured seasonal changes of the operating head near a pumping well in the Pearl Harbor aquifer fluctuated as much as 10 feet. At pumping wells, operating heads are less than storage heads due to turbulent flow into the well. Therefore, operating heads reflect both well inefficiancies and aquifer storage heads.

In Hawaii, the ground water is often pumped from several production wells in a well field. The drawdown at a given well field is equal to the superposition sum of the individual well drawdowns. In general, wells in a well field should be spaced as far apart as possible to minimize well interference. However, economic factors including the cost and availability of land may dictate the implementation of a least-cost well layout, which results in some interference. Both the specific capacity and the available drawdown for each well in a well field must be closely monitored to achieve for satisfactory well operation.

Deterioration in Water Quality (Saltwater intrusion)

When water from a basal aquifer is pumped through a well, pumping stress causes a localized rising of the underlying saltwater. This phenomenon is called upconing.[34] Most past upconing studies and ground water flow models assumed the existence of a sharp interface between freshwater and the underlying salt water. However, in real-world basal aquifers a gradual transition zone exists between the freshwater and the underlying saltwater (see Figure 3-9), which appear to differ between aquifer system areas based on deep monitor well data. Also, the near-shore toe of the basal aquifer will shift inland as cumulative pumpage is increased and captures leakage to the ocean. These are significant issues regarding well susceptibility to salt water intrusion. Mathematical models can and have been used by the CWRM to estimate upconing and saltwater intrusion, but the dynamics of the transition zone are not well understood.

[33] Mink, 1980.
[34] Todd, D.K., 1980. Groundwater Hydrology, John Wiley & Sons: New York.

Upconing can be minimized through the proper design and operation of production wells. Generally, wells should have the maximum possible vertical separation from the salt water zone. This is why in the *Hawaii Well Construction Standards* the depths of all new basal well depths are limited the top ¼ the thickness of the basal lens encountered during construction. This will reduce the capacity of an individual well but provides a method to optimize the resource and protect future constructed well infrastructure. Wells should also be pumped at a low, uniform rate. The total number of production wells in a well field, well spacing, and pumping rates can be optimized using numerical modeling analyses.

Recommendations for Assessing Sustainable Yield

Ground water can be managed through an understanding of sustainable yield, which is defined as the maximum amount of water that may normally be withdrawn from a source without significantly impairing the source. This definition gives CWRM flexibility to consider and redefine sustainable yields with time and based on case-by-case circumstances. At this time, the sustainable yield of the Hawaii basal aquifers is being evaluated by using analytical ground water models such as the robust analytical model (RAM) and the modified RAM, or RAM2. However, in some areas, including Honolulu, Pearl Harbor, Lanai, Molokai, and (soon) West Maui numerical ground water models have been used to help assess the sustainability of the ground water and refine the uncertainty of analytical ground water models. Additionally, the Ewa Caprock area has used a general chloride limit for wells to establish overall aquifer area sustainable yield.

The most immediate area that requires further investigation is the rate of natural recharge. Reported values of natural recharge vary significantly. These values have been derived from various past studies using differing hydrologic balance analyses. Climate change and data from the last 25 years should also be included into recharge analysis. Recharge should also be standardized such that model studies are comparable. Critical issues for recharge include:

- Estimation of runoff;
- Soil-moisture storage and its relationship to evapotranspiration;
- Assesment of fog drip on precipitation;
- Time steps (daily vs. monthly vs. annual);
- Land use (urban vs. rural vs. agriculture); and
- Results attributed to CWRM formal aquifer system areas.

A second area that requires further investigation is the interaction between ground water and streamflow. In cases where a stream is hydraulically connected to an aquifer, well withdrawals from the aquifer may cause depletion in the base flow of the stream. This is a concern, as adequate stream flow must be maintained to support instream uses. CWRM must consider ground water/streamflow interactions in its evaluation of sustainable yield and in its review of well-permit applications. Also, numerical models must include the baseflow of streams as part of their calibration analysis.

A third area that requires further study is the salinity transport in the transition zone of basal aquifers. This transport is driven by ground water flow and solute dispersion. Additionally, the effects of bore hole flow in deep monitor wells can introduce complexity in salinity profiles. A recently developed field tracer method by a research team at the University of Hawaii estimates the value of the dispersion coefficient of a basal aquifer by using the salinity profiles observed at deep monitoring wells. The success of this method depends on: how accurately the salinity profile is measured at a deep monitoring well; and how accurately the travel time to the monitoring well is determined. More accurate estimates of the dispersion coefficient can be achieved by establishing ground water monitoring well networks, and by mathematical simulations of the head and velocity distributions.

A fourth area that requires further study is impacts of reducing coastal leakage through pumping and how this might be factored in to sustainable yield estimates. Though §174C-4, HRS of the Water Code states nothing under the chapter of the Code shall apply to coastal waters, this is becoming an increasingly important issue raised through public comments received by the CWRM through its processing of other Code responsibilities.

Fifth, more study on spatially detailed analysis of safe yield or well infrastructure along with water use and development plan scenarios is required. Though RAM has its idealized optimization assumptions and RAM2 is formulated by including salinity transport considerations, these models do not simulate the spatial variations of ground water flow and solute transport. Though more spatially detailed analysis can be achieved through monitoring of field data and, if sufficient data exists, numerical ground water models, these approaches must consider clearly defined future land development and pumpage scenarios. Before these comprehensive models can be applied, careful model calibration and verification must be conducted based on adequate field data to ensure that the comprehensive model is a viable management tool. Comprehensive local-scale models may be used for the design and operation of well fields where model parameters can be readily estimated based on sufficient hydrologic data and site-specific field aquifer tests.

Sixth, in the interest of responsible management and protection of water resources and environmental quality, CWRM should expand and improve its hydrologic monitoring network and water use reporting to achieve statewide coverage and to better assses sustainable yields based on actual data. Also, CWRM should integrate its future activities to re-evaluate sustainable yield with the State GIS system, which may allow efficient data storage, retrieval, and model application.

Lastly, the CWRM should consider adaptive management concepts to link the preceeding recommendations, which span both science and societal values. CWRM should explore how adaptive management concepts can be applied to the estimation of sustainable yields. The CWRM permit process applies adaptive management concepts and considers other other factors, such as rights that affect individual well owners. However, the potential application and incorporation of adaptive management concepts in the estimation of aquifer sustainable yield has yet to be evaluated.

3.3.5. Establishment of the 1990 Sustainable Yield Estimates and Subsequent Updates

In 1980, the Honolulu BWS commissioned hydrologists at the University of Hawaii to develop a model to determine sustainable yields for ground water aquifers in Hawaii. The result was the analytical model known as RAM. Sustainable yield estimates derived via RAM reflect the maximum sustainable average-daily-pumpage rates over an entire aquifer system area, assuming wells are spaced optimally throughout the system. These RAM-derived sustainable yield estimates were incorporated into the 1990 WRPP. In cases where RAM-predicted sustainable yield did not correlate with actual observed conditions in an aquifer system area, CWRM evaluated irrigation practices, historical aquifer pumpage, and other data to refine the RAM estimate. This refined estimate was adopted by CWRM, rather than the strict RAM derived valued. A complete list of the 1990 sustainable yield estimates are presented in Table 3-10.

In 1993, CWRM adopted an Aquifer System Area approach to organize and manage ground water resources. This superceded the previous method of managing aquifers by larger Sector area boundaries. The Aquifer System Area approach allows for better optimization of well placement and is a better indicator of where water is located within a Sector area. It is the simplest method for optimizing development of the island's ground water resources while ensuring long-term sustainability from the planning and regulatory perspective. As a result of the new management approach, some aquifer system areas were subdivided into multiple systems and others were consolidated into single systems. This resulted in significant changes in the distribution of sustainable yields amongst affected aquifer system areas. Identification of the aquifers systems that were affected and descriptions of the changes that took place are provided in Comment 6 of Table 3-10.

In 1997, CWRM recognized and adopted the first caprock aquifer sector. The Ewa Caprock Aquifer Sector includes three aquifer system areas. Because the Ewa Caprock Aquifer System Areas overlie basal ground water bodies of other aquifer sectors and systems, and because the dynamics of ground water communication between the caprock and basal aquifers is unclear, CWRM established sustainable yields for the Ewa Caprock Aquifer Aystem Areas based on the chloride content of ground water in individual wells rather than on average-daily-pumping rates across the aquifer system area, as was done for the basal aquifers. A sustainable yield of less than 1,000mg/L chloride was adopted for all three Ewa Caprock Aquifer System Areas (see Table 3-12).

Revisions of individual aquifer system area sustainable yields have also occurred on a case-by-case basis in response to the availability of new data. Sustainable yield estimates have been revised based on recharge studies, groundwater models, other hydrogeologic studies, pumpage and deep monitor well data, and the identification of errors in previous models or studies. All revisions to the sustainable yields have taken place in accordance with statutory requirements and revised sustainable yield estimates adopted by CWRM are official and are used for regulatory and planning purposes.

3.3.5.1. Selection of the 2008 Sustainable Yields

As part of the update to the Hawaii Water Plan, CWRM inventoried all ground water hydrologic units and conducted an evaluation of sustainable yield estimates for all aquifers system areas. The evaluation entailed the following steps:

1. Review of sustainable yield calculation models, recharge calculations, deep monitoring well data, historical pumping data, numerical models for predicting infrastructure safe yields, and other hydrogeologic data and studies;

2. Comparison of the previously adopted sustainable yields (those in effect as of December 31, 2006) against those predicted by other models; and

3. Identification of the most appropriate sustainable yield for each aquifer based on conclusions drawn from steps 1 and 2.

CWRM considered three sustainable yield data sets in its evaluation: RAM (2008), RAM + Updated Recharge, and RAM2. RAM (2008) is a recalculation of sustainable yield using the RAM and the reported original 1990 input values. The recalculation was conducted when errors were found in the original 1990 calculations. RAM + Updated Recharge consists of sustainable yield estimates resulting from the input of updated recharge estimates into the RAM. RAM2 consists of sustainable yield estimates predicted by the RAM2.

Sustainable yield estimates by models other than RAM or RAM2 were available for some areas; however, because the areas modeled did not match the aquifer system area boundaries, the values could not practically be compared to existing sustainable yield values. Similar issues were encountered with some recent recharge studies. Therefore, these models and studies were eliminated from consideration.

The sustainable yields for the three data sets considered are listed in Table 3-10. In addition to these three data sets, the CWRM considered the Previously Adopted SY (2007) when the value originated from a commission action or a numerical ground water model study. The original 1990 RAM sustainable yield numbers are shown in the table for reference; however, they were not considered in the selection process as they were superceded by the RAM (2008) numbers which correct known math errors. The comments in Table 3-10 also provide historical background on changes to aquifer system area boundaries and changes to sustainable yield values.

For a given aquifer system area, the range of sustainable yield estimates shown in Table 3-10 demonstrates that the estimation of aquifer sustainable yields is not an exact science. Insufficient hydrologic, geologic, and meteorological data require the estimation of critical input parameters in any sustainable yield model. Differences in estimates of these input parameters, and in how they are incorporated in a model, can produce a wide range in predicted sustainable yield values for a given aquifer.

Given the range of predicted sustainable yields for each aquifer, and the inherent uncertainty in each prediction, CWRM has applied the *precautionary principle* in selecting sustainable yields for adoption in this update to the WRPP. Application of the precautionary principle is appropriate in light of CWRM's role as a trustee of Hawaii's water resources.

In general, the lowest predicted sustainable yield for an aquifer system area, as shown in Table 3-10, was selected as the 2008 Sustainable Yield. Exceptions to this rule were recognized on a case-by-case basis and alternative sustainable yields were selected depending on the following:

For Aquifer Systems with predominantly basal resources:

- Presence of an operational deep monitor well and other publicly available hydrologeologic data, such as:
  - Recharge studies that follow the convention of section 3.3.4.1;
  - Complete and significant record of historical pumpage, chloride, and water-level data;
  - Numerical model studies for establishing infrastructure safe yields; or
  - Other hydrologic and geologic studies reviewed and accepted by CWRM staff.

- Ground water inputs from adjacent aquifers.

- Post-1990 WRPP CWRM actions.

- Errors in mathematical calculations.

- Clerical errors.

For Aquifer Systems with predominantly high-level resources:

- Presence of an operational ground water-level monitoring network and a stream monitoring network, where applicable, to ensure compliance with instream flow standards, and other publicly available hydrogeologic data, such as:
  - - Recharge studies that follow the convention of section 3.3.4.1;
  - - Complete and significant record of historical pumpage, chloride, and water-level data;
  - - Numerical model studies for establishing infrastructure safe yields; or
  - - Other hydrologic and geologic studies reviewed and accepted by CWRM staff.

- Errors in mathematical calculations.

For basal aquifer dominated aquifer system areas, the existence of an operational deep monitor well is critical in determining the location and characteristics of the transition zone and provides an early warning system on the sustainability of the resource. In high-level aquifer dominated aquifer system areas, a robust operational ground water-level monitoring network provides more valuable information than deep monitor wells to assess the sustainability of the resource. In addition, in high-level aquifer systems where existing pumping wells have the potential to impact perennial stream flows, a stream monitoring network provides essential sustainability data.

When monitoring data (well and/or stream) coupled with other scientifically sound, public, and CWRM-vetted aquifer-specific hydrologic, geologic, or other studies strongly suggested that the lowest predicted sustainable yield in Table 3-10 underestimated the sustainable yield, then selection of an alternatively higher sustainable yield was justified. In cases where an alternate sustainable yield was selected, the basis for the selection is called out in Table 3-10 in the Alternate 2008 SY Selection Criteria column and additional information is provided in the table comments.

Table 3-11 lists the 2008 Sustainable Yields for basal and high-level aquifers along with planning comments and a confidence ranking for each sustainable yield estimate. Figure 3-14 illustrates sustainable yield confidence rankings by island and aquifer system area. Table 3-12 lists the 2008 Sustainable Yields for caprock aquifers. Maps illustrating the ground water hydrologic unit boundaries and the 2008 sustainable yield for each aquifer system area are included as Figures 3-15 to 3-20.

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Table 3-10
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range[(1)]*	Previously Adopted SY (2007)[(2)]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Hawaii									
Kohala	Hawi	27	27	13/29	~	*13-29*	27	**13**	
Kohala	Waimanu	110	110	~	~	*110*	110	**110**	
Kohala	Mahukona	17	17	~	~	*17*	17	**17**	
E. Mauna Kea	Honokaa	31	31	~	~	*31*	31	**31**	
E. Mauna Kea	Paauilo	60	60	~	~	*60*	60	**60**	
E. Mauna Kea	Hakalau	150	150	~	~	*150*	150	**150**	
E. Mauna Kea	Onomea	147	147	~	~	*147*	147	**147**	
W. Mauna Kea	Waimea	24	24	~	~	*24*	24	**24**	
NE. Mauna Loa	Hilo	347	349	~	~	*349*	347	**349**	
NE. Mauna Loa	Keaau	393	395	~	~	*395*	393	**395**	
SE. Mauna Loa	Olaa	124	125	~	~	*125*	124	**125**	
SE. Mauna Loa	Kapapala	19	19	~	~	*19*	19	**19**	
SE. Mauna Loa	Naalehu	117	118	~	~	*118*	117	**118**	
SE. Mauna Loa	Ka Lae	31	31	~	~	*31*	31	**31**	
SW. Mauna Loa	Manuka	42	42	25	~	*25-42*	42	**25**	
SW. Mauna Loa	Kaapuna	50	51	58	~	*51-58*	50	**51**	
SW. Mauna Loa	Kealakekua	38	38	38	~	*38*	38	**38**	

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range[(1)]*	Previously Adopted SY (2007)[(2)]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Hawaii (continued)									
NW. Mauna Loa	Anaehoomalu	30	30	~	~	*30*	30	**30**	
Kilauea	Pahoa	435	437	~	~	*437*	435	**437**	
Kilauea	Kalapana	157	158	~	~	*158*	157	**158**	
Kilauea	Hilina	9	9	~	~	*9*	9	**9**	
Kilauea	Keaiwa	17	17	~	~	*17*	17	**17**	
Hualalai	Keauhou	38	38	38	~	*38*	38	**38**	
Hualalai	Kiholo	18	18	~	~	*18*	18	**18**	
Kauai									
Lihue	Koloa	30	30	34	~	*30-34*	30	**30**	
Lihue	Hanamaulu	40	40	36	~	*36-40*	40	**36**	
Lihue	Wailua	60	60	43	~	*43-60*	60	**43**	
Lihue	Anahola	36	36	17	~	*17-36*	36	**17**	
Lihue	Kilauea	17	17	5	~	*5-17*	17	**5**	
Hanalei	Kalihiwai	16	22	11	~	*11-22*	16	**11**	
Hanalei	Hanalei	35	35	34	~	*34-35*	35	**34**	
Hanalei	Wainiha	24	24	61	~	*24-61*	24	**24**	
Hanalei	Napali	20	20	17	~	*17-20*	20	**17**	
Waimea	Kekaha	12	10	12	~	*10-12*	12	**10**	
Waimea	Waimea	42	37	55	~	*37-55*	42	**37**	
Waimea	Makaweli	30	26	33	~	*26-33*	30	**26**	
Waimea	Hanapepe	26	22	24	~	*22-24*	26	**22**	

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range[(1)]*	Previously Adopted SY (2007)[(2)]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Lanai									
Central	Windward	3[(3)]	3	5	~	*3-5*	3	**3**	
Central	Leeward	3[(3)]	3	5	~	*3-5*	3	**3**	
Mahana Sector	Hauola	~	~	~	~	~	0	~	
Mahana Sector	Maunalei	~	~	~	~	~	0	~	
Mahana Sector	Paomai	~	~	~	~	~	0	~	
Kaa	Honopu	~	~	~	~	~	0	~	
Kaa	Kaumalapau	~	~	~	~	~	0	~	
Kamao	Kealia	~	~	~	~	~	0	~	
Kamao	Manele	~	~	~	~	~	0	~	
Maui									
Wailuku	Waikapu	2	3	6	~	*3-6*	2	**3**	
Wailuku	Iao	20[(4)]	11	31	19	*11-31*	20	**20**[(14)]	8a-c, 10
Wailuku	Waihee	8	6	15	~	*6-15*	8	**8**[(15)]	8a, 8c
Wailuku	Kahakuloa	8	5	8	~	*5-8*	8	**5**	
Lahaina	Honokohau	10	9	17	~	*9-17*	10	**9**	
Lahaina	Honolua	8	8	10	~	*8-10*	8	**8**	
Lahaina	Honokowai	8	6	11	~	*6-11*	8	**6**	
Lahaina	Launiupoko	8	7	14	~	*7-14*	8	**7**	
Lahaina	Olowalu	3	2	7	~	*2-7*	3	**2**	
Lahaina	Ukumehame	3	2	6	~	*2-6*	3	**2**	

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range*[(1)]	Previously Adopted SY (2007)[(2)]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Maui (continued)									
Central	Kahului	1	1	1	~	*1*	1	**1**	
Central	Paia	8	7	8	~	*7-8*	8	**7**	
Central	Makawao	7	7	20	~	*7-20*	7	**7**	
Central	Kamaole	11	11	16	~	*11-16*	11	**11**	
Koolau	Haiku	31	27	27	~	*27*	31	**27**	
Koolau	Honopou	29	25	26	~	*25-26*	29	**25**	
Koolau	Waikamoi	46	40	40	~	*40*	46	**40**	
Koolau	Keanae	96	83	83	~	*83*	96	**83**	
Hana	Kuhiwa	16	14	14	~	*14*	16	**14**	
Hana	Kawaipapa	48	48	48	~	*48*	48	**48**	
Hana	Waihoi	20	18	21	~	*18-21*	20	**18**	
Hana	Kipahulu	49	42	42	~	*42*	49	**42**	
Kahikinui	Kaupo	18	16	16	~	*16*	18	**16**	
Kahikinui	Nakula	7	7	7	~	*7*	7	**7**	
Kahikinui	Lualailua	11	11	11	~	*11*	11	**11**	
Molokai									
West	Kaluakoi	2	2	4	~	*2-4*	2	**2**	
West	Punakou	2	2	3	~	*2-3*	2	**2**	
Central	Hoolehua	2	2	2	~	*2*	2	**2**	
Central	Manawainui	2	2	3	~	*2-3*	2	**2**	
Central	Kualapuu	7	4	6	5	*4-6*	5[(5)]	**5**[(16)]	8a, 8c-d, 9
Southeast	Kamiloloa	3	3	5	~	*3-5*	3	**3**	

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range*[(1)]	Previously Adopted SY (2007)[(2)]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Molokai									
Southeast	Kawela	5	5	10	~	*5-10*	5	**5**	
Southeast	Ualapue	8	8	8	~	*8*	8	**8**	
Southeast	Waialua	8	8	6	~	*6-8*	8	**6**	
Northeast	Kalaupapa	2	2	4	~	*2-4*	2	**2**	
Northeast	Kahanui	3	3	8	~	*3-8*	3	**3**	
Northeast	Waikolu	5	5	8	~	*5-8*	5	**5**	
Northeast	Haupu	2	2	5	~	*2-5*	2	**2**	
Northeast	Pelekunu	9	9	12	~	*9-12*	9	**9**	
Northeast	Wailau	15	15	23	~	*15-23*	15	**15**	
Northeast	Halawa	8	8	11	~	*8-11*	8	**8**	
Oahu									
Honolulu	Palolo	5	5	8	6	*5-8*	5	**5**	
Honolulu	Nuuanu	15	15	19	14	*14-19*	15	**14**	
Honolulu	Kalihi	9	9	12	9	*9-12*	9	**9**	
Honolulu	Moanalua	18	18	19	16	*16-19*	18	**16**	
Honolulu	Waialae[(6a)]	3	3	~	~	~	~	~	
Honolulu	Waialae-West[(6a)]	~	~	4	~	*4*	4[(6a)]	**4**[(17)]	10
Honolulu	Waialae-East[(6a)]	~	~	10	~	*10*	2[(6a)]	**2**[(18)]	10

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range*[1]	Previously Adopted SY (2007)[2]	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Oahu (continued)									
Pearl Harbor	Waimalu	45	47	77	48	*47-77*	45	**45**[19]	8a-c
Pearl Harbor	Waiawa[6c]	52	52	~	See Waipahu-Waiawa	~	~	~	
Pearl Harbor	Waipahu[6c]	50	50	~	See Waipahu-Waiawa	~	~	~	
Pearl Harbor	Waipahu-Waiawa[6c]	~	~	117	110	*110-117*	104[7]	**104**[20]	8a-c, 9, 10
Pearl Harbor	Ewa[6d]	3	3	~	See Ewa-Kunia	~	~	~	
Pearl Harbor	Kunia[6d]	8	10	~	See Ewa-Kunia	~	~	~	
Pearl Harbor	Ewa-Kunia[6d]	~	~	10	19	*10-19*	16[7]	**16**[21]	8a-c, 9, 10
Pearl Harbor	Makaiwa[6e]	~	~	0	~	*0*	0	~	
Central	Wahiawa[6b]	104	104	141	~	*104-141*	23[6b]	**23**[22]	10
Waianae	Nanakuli	1	2	2	~	*2*	1	**2**	
Waianae	Lualualei	4	4	9	~	*4-9*	3[6f]	**4**	
Waianae	Waianae	2	2	4	~	*2-4*	3[6f]	**3**[23]	13a-b
Waianae	Makaha	3	3	4	~	*3-4*	4[6f]	**3**	
Waianae	Keaau	4	4	10	~	*4-10*	4	**4**	

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Aquifer Sector	Aquifer System	RAM (1990)	RAM (2008)	RAM + Updated Recharge	RAM 2	*SY Range(1)*	Previously Adopted SY (2007)(2)	Sustainable Yield (2008)	Alternate 2008 SY Selection Criteria
Oahu (continued)									
North	Mokuleia	9	8	16	~	*8-16*	12(6g)	**8**	
North	Waialua	5	4	12	~	*4-12*	40(6g)	**25(24)**	9
North	Kawailoa	32	29	31	~	*29-31*	39(6g)	**29**	
Windward	Koolauloa	42	36	41	~	*36-41*	35(6h)	**36**	
Windward	Kahana	15	15	23	~	*15-23*	13(6h)	**15**	
Windward	Koolaupoko	30	30	46	~	*30-46*	43(6h)	**30**	
Windward	Waimanalo	13	13	10	~	*10-13*	8(6h)	**10**	

Notes:

~	Sustainable Yield Not Calculated
CWRM	Commission on Water Resource Management
RAM	Robust Analytical Model
SY	Sustainable Yield
WRPP	Water Resources Protection Plan

General Comments & Historical Background on Changes to Aquifer System Boundaries and Sustainable Yield Values
(1) SY Range - Ranges listed in this colum do not incorporate the RAM (1990) values as some of the numbers were found to be incorrect due to mathematical errors (see RAM 2008 below). The bounds of the sustainable yield range were set based on numbers in the RAM 2008, RAM + Updated Recharge, and RAM 2 columns.
(2) Previously Adopted Sustainable Yield (2007) - Sustainable Yields in effect as of December 2007. These values include updates made to the RAM (1990) SY values based on the results of hydrologic studies or actions of the CWRM.
(3) The Sustainable Yield values for the Windward and Leeward Aquifer System areas were calculated in 1990 but were accidentally omitted from the Water Resources Protection Plan.

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

General Comments & Historical Background on Changes to Aquifer System Boundaries and Sustainable Yield Values (cont.)
(4) The 20 mgd sustainable yield number is based on a higher recharge value than that reported in the 1990 WRPP. This higher recharge value, along with a slightly modified version of the RAM equation into which it was input, were believed by John F. Mink (developer of the RAM) to more accurately reflect conditions in the Iao Aquifer System Area. *Reference: Mink, John.F, 1995, Sustainable Yields Maui and Molokai, Letter to the CWRM from Mink & Yuen Inc., dated September 9, 1995.*
(5) In 1993, a mathematical error was discovered in the calculation of the 1990 sustainable yield for the Kualapuu Aquifer System Area. A recalculation of the sutainable yield by John F. Mink in 1995 resulted in a revised recommendation of 5 mgd for the sustainable yield. This number was based on (1) revised estiamtes for direct runoff and evapotranspiration, (2) a modified RAM calculation for sustainable yield, and (3) the presumption of additional recharge to the system from Waikolu Valley. *Reference: Mink, John.F, 1995, Sustainable Yields Maui and Molokai, Letter to the CWRM from Mink & Yuen Inc., dated September 9, 1995.*
(6) In 1993, the CWRM adopted an aquifer system areas approach to managing ground water resources in Hawaii. This approach is considered the best method for optimizing development of an aquifer while ensuring long-term stability of the water resource. As a result, some aquifer system areas were divided into multiple systems, some aquifer system areas were consolidated into a single system, and new aquifer system areas were created. In addition, revised sustainable yields were proposed for several systems. Specific changes in aquifer system area management and sustainable yields are discussed below: (a) The Waialae Aquifer System Area was subdivided into two separate aquifer system areas due to the presence of a hydrologic boundary at Waialae Iki Ridge. This boundary results in a siginificant hydrologic head difference between the Waialae East and Waialae West Aquifer System Areas. The 6 mgd sustainable yield for the original combined aquifer system was redistributed, based on the best available hydrogeologic information, with two-thirds (4mgd) going to Waialae West and one-third (2mgd) going to Waialae East. (b) The Central Aquifer Sector (Wahiawa Aquifer System) was separated out from the Pearl Harbor and North Aquifer Sectors because the water is high-level rather than basal. The exisiting pumping withdrawal from the system, which totalled 23 mgd, was set as the sustainable yield to maintain spillover of ground water into the Pearl Harbor and North Sectors, thus ensuring sufficient ground water availability in these Sectors to meet demand. The spillover was variably redistributed between the Pearl Harbor and North Aquifer Sectors based on the best available hydrogeologic information. (c) The Waipahu and Waiawa Aquifer System Areas were combined to allow for more flexibility in pumping. The original subdivision of the aquifer system area was not based on hydrogeologic properties. The combined Waipahu-Waiawa Aquifer System Area was assigned the aquifer code (30203).

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

General Comments & Historical Background on Changes to Aquifer System Boundaries and Sustainable Yield Values (cont.)
– In addition, the sustainable yield for the combined aquifer system area was raised for two reasons. (1) To account for 62 mgd of additional recharge via groundwater spillover from the Wahiawa Aquifer System Area (see comment 6b above) and (2) because historic pumping above the 1990 sustainable yields did not adversely affect properly installed wells, indicating that the true sustainable yield of the aquifer system area was greater than that predicted by the RAM.
[d] The Ewa & Kunia Aquifer System Areas were combined to manage the aquifer as a whole. The original division of the aquifer was based on the irrigation source (well water versus ditch water) and not hydrologeologic properties. The combined Ewa-Kunia Aquifer System Area was assigned the aquifer code (30204).
– In addition, the sustainable yield for the combined aquifer system area was raised to account for 14 mgd of additional recharge via groundwater spillover from the Wahiawa Aquifer System Area (see comment 6b above).
[e] The Makaiwa Aquifer System Area was separated out from the Waianae Aquifer System Area due to a difference in ground water behavior in the two aquifer systems. No sustainable yield was established for this system. The Makaiwa Aquifer System Area was assigned the aquifer code (30205), which was previously assigned to the Kunia Aquifer System Area.
[f] Revised sustainable yields were proposed for the Lualualei, Waianae, and Makaha Aquifer System Areas of the Waianae Sector. The basis for the revised numbers was not documented.
[g] Revised sustainable yields were proposed for all North Sector aquifer system areas to account for groundwater spillover from the Central Sector (see comment 6b above). The additional recharge was variably applied to the North Sector systems; however, the exact amount and distribution of the recharge was not documented. The revised sustainable yields also likely account for significant return irrigation from large-scale sugar cultivation. For the Waialua Aquifer System Area, the sutainable yield number also likely considers the historic pumpage (several decades) of groundwater above 50 mgd without noticeable impacts to the aquifer system area, indicating that the true sustainable yield is significantly higher than the RAM predicted sustainable yield of 4 mgd.
[h] Revised sustainable yields were proposed for all Windward Sector aquifer system areas. The basis for the revised numbers was not documented.
Reference: Hawaii Department of Land and Natural Resources - Commission on Water Resource Management, 1993, Commission Meeting Submittal - Boundary Reclassifications within the Honolulu, Pearl Harbor, and Waialua Ground Water Management Areas, dated March 3, 1993.

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

General Comments & Historical Background on Changes to Aquifer System Boundaries and Sustainable Yield Values (cont.)
(7) Sustainable Yield adopted by the CWRM in 2000 based on a review of three ground water models: RAM (analytical), RASA (numerical), CENCOR (numerical). The impetus for the reassessment of the sustainable yields was the demise of large-scale agriculture in the area and the resultant loss of significant volumes of return irrigation recharge to the aquifer systems. The three models assumed significant ground water spillover was occuring from the Central Sector into the Pearl Harbor Sector and reflected various pumping scenarios designed to protect existing infrastructure. The sustainable yield values calculated by the models provided a range of sustainable yield estimates for the Ewa-Kunia and Waipahu-Waiawa Aquifer System Areas. The adopted sustainable yields of 16 mgd for Ewa-Kunia and 104 mgd for Waipahu-Waiawa reflect the high end of the range for each system. The middle and lower range values were adopted as regulatory action milestones. *Reference: Hawaii Department of Land and Natural Resources - Commission on Water Resource Management, 2000, Commission Meeting Submittal - Request for Approval to Adopt New Sustainable Yields for Ewa-Kunia and Waipahu-Waiawa Aquifer Systems, Pearl Harbor Aquifer Sector, Oahu, dated March 15, 2000.*

Alternate Sustainable Yield Selection Criteria

In general, the lowest predicted sustainable yield for an aquifer system area was selected as the 2008 Sustainable Yield. Exceptions to this rule were recognized on a case-by-case basis and alternative sustainable yields were selected based on the following:

Basal Ground Water Source

8 - Presence of an operational deep monitor well AND other publicly available hydrogeologic data, such as:

- 8a - Recharge studies that follow the convention of section 3.3.4.1 of the WRPP;
- 8b - Complete and significant record of historical pumpage, chloride, and water-level data;
- 8c - Numerical model studies for establishing infrastructure safe yields;
- 8d - Other hydrologic and geologic studies reviewed and accepted by CWRM Staff; or

9 - Ground water inputs from adjacent aquifers;
10 - Post 1990 WRPP CWRM actions;
11 - Errors in mathematical calculations; or
12 - Clerical errors.

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Alternate Sustainable Yield Selection Criteria (continued)
High-Level Ground Water Source
13 - Presence of an operational ground water-level monitoring network and a stream monitoring network, where applicable, to ensure compliance with instream flow standards, AND other publicly available hydrogeologic data, such as: 13a - Recharge studies that follow the convention of section 3.3.4.1 of the WRPP 13b - Complete and significant record of historical pumpage, chloride, and water-level data; 13c - Numerical model studies for establishing infrastructure safe yields; 13d - Other hydrologic and geologic studies reviewed and accepted by CWRM Staff.

Sustainable Yield (2008) Comments
(14) The sustainable yield for the Iao Aquifer System Area was maintained at 20 mgd as this is believed to be the best estimate to date. This 1995 estimate (see comment 4 above) falls within the range of predicted sustainable yields for the system. In addition, numerical models, deep monitor well data, and historical pumpage records all suggest a sustainable yield within the middle of the predicted range. *Reference: Hawaii Department of Land and Natural Resources - Commission on Water Resource Management, 2002, Waihee Aquifer Systems State Aquifer Codes 60102 and 60103 Ground-Water Management Area Designation Findings of Fact, dated November 11, 2002.*
(15) RAM (2008) revealed an error in the calculation of the original RAM (1990) sustainable yield for the Waihee Aquifer System Area. The 1990 value is 8 mgd. The correct value is 6 mgd. However, based on (1) current groundwater demands within the system, (2) the fact that the 8 mgd falls within the predicted range of sustainable yields for the aquifer system, and (3) the presence of a deep monitor well within the system that will allow for long-term monitoring of the transition zone, the CWRM elected to maintain the sustainable yield at 8 mgd. *Reference: Hawaii Department of Land and Natural Resources - Commission on Water Resource Management, 2002, Waihee Aquifer Systems State Aquifer Codes 60102 and 60103 Ground-Water Management Area Designation Findings of Fact, dated November 11, 2002.*
(16) The Previously Adopted SY (2007) for the Kualapuu Aquifer System Area dates to a 1996 recalculation of sustainable yield based on a revised recharge number and modified RAM calculation (see comment 5 above). Based on (1) current groundwater demands within the system, (2) the fact that the 5 mgd falls within the predicted range of sustainable yields for the aquifer system, (3) the presence of a deep monitor well within the system that will allow for long-term monitoring of the transition zone, and (4) the existence of groundwater models for the system, the CWRM elected to maintain the sustainable yield at 5 mgd.
(17) Updated recharge data suggest a sustainable yield of the Waialae East Aquifer System Area equivalent to the Previously Adopted SY (2007). The CWRM maintained the sustainable yield at 4 mgd.

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

Sustainable Yield (2008) Comments (continued)
(18) Updated recharge data suggest that the sustainable yield of the Waialae West Aquifer System Area may be higher than the Previously Adopted SY (2007). However, in the absence of a deep monitor well or groundwater model, the CWRM elected to maintain the sustainable yield at the more conservative 1996 number. See comment 6a above.
(19) RAM (2008) revealed an error in the calculation of the original RAM (1990) sustainable yield for the Waimalu Aquifer System Area. The 1990 value is 45. The correct value is 47 mgd. However, due to exisiting salinity issues in wells in this aquifer system, the CWRM elected to maintain the sustainable yield at 45 mgd. A higher sustainable yield may be possible if well placement and pumping are optimized.
(20) The sustainable yield for the Waipahu-Waiawa Aquifer System Area was maintained at 104 mgd as this is believed to be the best estimate to date. The number is based on the analysis and comparison of three groundwater models for this aquifer system area. See comment 7 above.
(21) The sustainable yield for the Ewa-Kunia Aquifer System Area was maintained at 16 mgd as this is believed to be the best estimate to date. The number is based on the analysis and comparison of three groundwater models for this aquifer system area. See comment 7 above.
(22) The sustainable yield for the Wahaiwa Aquifer System Area was held at 23 mgd to ensure sufficient ground water spillover into the Pearl Harbor and North Sectors to meet demands. See Comment 6b above.
(23) RAM (2008) revealed an error in the calculation of the original RAM (1990) sustainable yield for the Waianae Aquifer System Area. The 1990 value is 3 mgd. The correct value is 2 mgd. However, based on (1) current groundwater demands within the system, (2) the fact that the 3 mgd falls within the predicted range of sustainable yields for the aquifer system, (3) the presence of a ground water monitoring network, and (4) a complete and significant record of historical pumpage, chloride, and water-level data, the CWRM elected to maintain the sustainable yield at 3 mgd.
(24) The 2008 sustainable yield for Wailua Aquifer System Area was derived by assuming that 38% of the reserved recharge from the Central Sector spills over into the Waialua Aquifer System (see comment 6b above). This conforms to the North Sector and Pearl Harbor Sector spillover allocation defined in the CENCOR model (see comment 7 above). The reserved recharge is the difference between the actual recharge to the Wahiawa Aquifer System Area (which yields a sustainable yield of 104 mgd) and the recharge necessary to yield the adopted sustainable yield of 23 mgd (see comment 1f above). Thirty-eight percent (38%) of the reserved recharge was added to the recharge for the Wailua Aquifer System Area and the resulting total recharge value was plugged into the RAM, resulting in a predicted sustainable yield of 25 mgd. Though some ground water spillover does occur from the Central Sector into the other North Sector Aquifer Systems, based on the hydrogeology of the region, the volume is believed to be small relative to that flowing into the Waialua Aquifer System Area. Therefore the entire 38% of Central Sector reserved recharge was applied to the Waialua Aquifer System Area.

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

References	
RAM (1990)	Sustainable Yield Values calculated using the 1990 Robust Analytical Model. *Source: Hawaii Department of Land and Natural Resources - Commission on Water Resource Management, 1990, Water Resources Protection Plan, 127pp.*
RAM (2008)	Sustainable Yield Values recalculated by the CWRM in 2008 using the 1990 Robust Analytical Model and reported original input values. SY values were recalculated after mathematical errors were discovered in calculations for some aquifer systems. Ram (2008) values supercede RAM (1990) values.
RAM + Updated Recharge	Sustainable Yield Values calculated by inputting updated recharge values into the 1990 Robust Analytical Model. Sources of the update recharge values are provided below by island:
Hawaii	*Oki, D.S., 2002, Reassessment of ground-water recharge and Simulated ground-water availability for the Hawi Area of North Kohala, Hawaii:.U.S. Geological Survey Water-Resources Investigations Report 02-4006, 62pp. (Hawi)*
	Oki, D.S., 1999, Geohydrology and numerical simulation of the ground-water flow system of Kona, Island of Hawaii: U.S. Geological Survey Water-Resources Investigations Report 99-4073, 70pp. (Manuka, Kaapuna, Kealakekua, Keauhou)
Kauai	*Shade, P.J., 1995, Water Budget for the Island of Kauai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 95-4128, 25pp.*
Lanai	*Hardy, W.R., 1996, A numerical ground-water model for the Island of Lanai, Hawaii: Commission on Water Resource Management, Department of Land and Natural Resources, State of Hawaii, 126pp.*
Maui	*Engott, J.A., 2007, Effects of agricultural land-use changes and rainfall on ground-water recharge in Central and West Maui, Hawaii, 1926-2004: U.S. Geological Survey Scientific Investigations Report 2007-5103, 56pp. (Scenario 'C' Waikapu through Ukumehame; Scenario 'D' Kahului through Kamaole)*
	Shade, P.J., 1999, Water budget of East Maui, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 97-4159, 36pp. (Haiku through Lualailua)
Molokai	*Shade, P.J., 1997, Water budget for the Island of Molokai, Hawaii: U.S. Geologic Survey Water-Resources Investigations Report 97-4155, 20pp.*
Oahu	*Shade, P.J., and W.D. Nichols, 1996, Water budget and the effects of land-use changes on ground-water recharge, Oahu, Hawaii: U.S. Geological Survey Professional Paper 1412-C, 38pp.*

Table 3-10 (continued)
Comparison of Predicted Sustainable Yields Considered by the CWRM
Sustainable Yield (SY) in Million Gallons Per Day (mgd)

References (continued)	
RAM 2	Sustainable Yield values calculated using the Robust Analytical Model 2. Sources by Aquifer System are provided below: *Liu,C.C.K., 2006, Analytical Groundwater Flow and Transport Modeling For the Estimation of the Sustainable Yield of Pearl Harbor Aquifer: University of Hawaii Water Resources Research Center, Project Report PR-2006-06, 53pp. (Waimalu, Waipahu-Waiawa, Ewa-Kunia)*
	Liu, C.C.K., 2007, RAM2 Modeling and the Determination of Sustainable Yields of Hawaii Basal Aquifers: University of Hawaii Water Resources Research Center, Project Report PR-2008-06, 81pp. (Maui-Iao, Molokai-Kualapuu; Oahu-Palolo, Nuuanu, Kalihi, Moanalua)

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Hawaii					
Kohala	Hawi	80101	**13**	The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	2
Kohala	Waimanu	80102	**110**		3
Kohala	Mahukona	80103	**17**		2
E. Mauna Kea	Honokaa	80201	**31**		3
E. Mauna Kea	Paauilo	80202	**60**		3
E. Mauna Kea	Hakalau	80203	**150**		3
E. Mauna Kea	Onomea	80204	**147**		3
W. Mauna Kea	Waimea	80301	**24**		2
NE. Mauna Loa	Hilo	80401	**349**		3
NE. Mauna Loa	Keaau	80402	**395**		3
SE. Mauna Loa	Olaa	80501	**125**	Predominantly high-level ground water	3
SE. Mauna Loa	Kapapala	80502	**19**	Predominantly high-level ground water	3
SE. Mauna Loa	Naalehu	80503	**118**		3
SE. Mauna Loa	Ka Lae	80504	**31**		3
SW. Mauna Loa	Manuka	80601	**25**		2
SW. Mauna Loa	Kaapuna	80602	**51**		2

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Hawaii (continued)					
SW. Mauna Loa	Kealakekua	80603	**38**		2
NW. Mauna Loa	Anaehoomalu	80701	**30**	Assumes all recharge discharges at the coast between Anaehoomalu and Puako. Possible significant underflow of ground water out of Anaehoomalu into adjacent aquifer system areas was not accounted for in the recharge estimate used to calculate the sustainable yield. Accounting for such underflows may yield a much lower sustainable yield for Anaehoomalu.	3
Kilauea	Pahoa	80801	**437**		3
Kilauea	Kalapana	80802	**158**		3
Kilauea	Hilina	80803	**9**		3
Kilauea	Keaiwa	80804	**17**		3
Hualalai	Keauhou	80901	**38**		2
Hualalai	Kiholo	80902	**18**		3
Kauai					
Lihue	Koloa	20101	**30**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	3
Lihue	Hanamaulu	20102	**36**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	2

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Kauai (continued)					
Lihue	Wailua	20103	**43**	(1) Predominantly high-level ground water. (2) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (3) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	2
Lihue	Anahola	20104	**17**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	2
Lihue	Kilauea	20105	**5**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	3
Hanalei	Kalihiwai	20201	**11**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	3
Hanalei	Hanalei	20202	**34**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	3
Hanalei	Wainiha	20203	**24**	Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood.	3

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Kauai (continued)					
Hanalei	Napali	20204	**17**	(1) Due to the presence of a discontinuous, unmapped confining layer, the nature and extent of the basal ground water lens is not well understood. (2) Predominantly Basal Ground Water. (3) The recharge value used to calculate the Sustainable Yield INCLUDES return irrigation inputs to ground water.	3
Waimea	Kekaha	20301	**10**	Predominantly Basal Ground Water.	3
Waimea	Waimea	20302	**37**		3
Waimea	Makaweli	20303	**26**		3
Waimea	Hanapepe	20304	**22**		3
Lanai					
Central	Windward	50101	**3**	Only high-level ground water.	1
Central	Leeward	50102	**3**	(1) Only high-level ground water. (2) Ground water may be brackish in the Palawai Basin area.	1
Mahana Sector	Hauola	50201	**~**	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Mahana Sector	Maunalei	50202	**~**	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Mahana Sector	Paomai	50203	**~**	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Lanai (continued)					
Kaa	Honopu	50301	~	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Kaa	Kaumalapau	50302	~	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Kamao	Kealia	50401	~	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Kamao	Manele	50402	~	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Ground water is brackish	~
Maui					
Wailuku	Waikapu	60101	**3**		2
Wailuku	Iao	60102	**20**		1
Wailuku	Waihee	60103	**8**		2
Wailuku	Kahakuloa	60104	**5**		2
Lahaina	Honokohau	60201	**9**		2
Lahaina	Honolua	60202	**8**		2
Lahaina	Honokowai	60203	**6**		2
Lahaina	Launiupoko	60204	**7**		2
Lahaina	Olowalu	60205	**2**		2
Lahaina	Ukumehame	60206	**2**		2

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Maui (continued)					
Central	Kahului	60301	**1**	(1) Only basal ground water. (2) Sustainable Yield ignores significant importation of surface water into Kahului from outside the aquifer system area. This explains the ability to withdraw fresh water from the aquifer at significantly higher rates than the sustainable yield without apparent negative impacts (i.e. rising chloride concentrations or decreasing water levels).	2
Central	Paia	60302	**7**	(1) Only basal ground water. (2) Sustainable Yield ignores significant importation of surface water into Paia from outside the aquifer system area. This explains the ability to withdraw fresh water from the aquifer at significantly higher rates than the sustainable yield without apparent negative impacts (i.e. rising chloride concentrations or decreasing water levels).	2
Central	Makawao	60303	**7**	Only basal ground water.	3
Central	Kamaole	60304	**11**		3
Koolau	Haiku	60401	**27**		2
Koolau	Honopou	60402	**25**		3
Koolau	Waikamoi	60403	**40**		3
Koolau	Keanae	60404	**83**		3
Hana	Kuhiwa	60501	**14**		3
Hana	Kawaipapa	60502	**48**		3
Hana	Waihoi	60503	**18**		3
Hana	Kipahulu	60504	**42**		3
Kahikinui	Kaupo	60601	**16**		3
Kahikinui	Nakula	60602	**7**		3
Kahikinui	Lualailua	60603	**11**		3

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Molokai					
West	Kaluakoi	40101	**2**	(1) Predominantly basal ground water. (2) Ground water is brackish.	3
West	Punakou	40102	**2**	(1) Predominantly basal ground water. (2) Ground water is brackish.	3
Central	Hoolehua	40201	**2**	(1) Predominantly basal ground water. (2) Ground water is brackish.	3
Central	Maunawainui	40202	**2**	(1) Predominantly basal ground water. (2) Ground water is brackish.	2
Central	Kualapuu	40203	**5**	Predominantly basal ground water.	1
Southeast	Kamiloloa	40301	**3**		2
Southeast	Kawela	40302	**5**		3
Southeast	Ualapue	40303	**8**		3
Southeast	Waialua	40304	**6**		3
Northeast	Kalaupapa	40401	**2**	Predominantly high-level ground water	3
Northeast	Kahanui	40402	**3**	Predominantly high-level ground water	3
Northeast	Waikolu	40403	**5**	Predominantly high-level ground water	3
Northeast	Haupu	40404	**2**	Predominantly high-level ground water	3
Northeast	Pelekunu	40405	**9**	Predominantly high-level ground water	3
Northeast	Wailau	40406	**15**	Predominantly high-level ground water	3
Northeast	Halawa	40407	**8**		3
Oahu					
Honolulu	Palolo	30101	**5**		2

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Oahu (continued)					
Honolulu	Nuuanu	30102	**14**		2
Honolulu	Kalihi	30103	**9**		2
Honolulu	Moanalua	30104	**16**		2
Honolulu	Waialae-West	30105	**4**		2
Honolulu	Waialae-East	30106	**2**	Ground Water is predominantly brackish.	2
Pearl Harbor	Waimalu	30201	**45**	The lowest model-predicted sustainable yield is 47 mgd. However, due to exisiting salinity issues in wells in this aquifer system, the CWRM elected to maintain the sustainable yield at 45 mgd. A higher sustainable yield may be possible if well placement and pumping are optimized.	2
Pearl Harbor	Waipahu-Waiawa	30203	**104**	The recharge value used in the Sustainable Yield calculation includes spillover of ground water from the Wahiawa Aquifer System Area.	1
Pearl Harbor	Ewa-Kunia	30204	**16**	(1) Predominantly Basal Ground Water. (2) The recharge value used in the Sustainable Yield calculation includes spillover of ground water from the Wahiawa Aquifer System area.	1

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Aquifer Sector	Aquifer System	Aquifer Code	Sustainable Yield (2008)	Comments	Confidence Ranking
Oahu (continued)					
Pearl Harbor	Makaiwa	30205	~	(1) Sustainable Yield has not been calculated due to a lack of recharge data for this aquifer system area. (2) Predominantly Basal Ground Water. (3) Ground Water is Brackish.	~
Central	Wahiawa	30501	**23**	Only high-level ground water.	1
Waianae	Nanakuli	30301	**2**	Predominantly basal ground water	3
Waianae	Lualualei	30302	**4**	Predominantly basal ground water	3
Waianae	Waianae	30303	**3**	Predominantly high-level ground water	1
Waianae	Makaha	30304	**3**	Predominantly high-level ground water	1
Waianae	Keaau	30305	**4**		3
North	Mokuleia	30401	**8**	Predominantly basal ground water	2
North	Waialua	30402	**25**	Predominantly basal ground water	2
North	Kawailoa	30403	**29**	Predominantly basal ground water	2
Windward	Koolauloa	30601	**36**	Predominantly basal ground water	2
Windward	Kahana	30602	**15**	Predominantly high-level ground water	2
Windward	Koolaupoko	30603	**30**	(1) Predominantly high-level ground water. (2) Ground water removed from the aquifer system area by the Waiahole Tunnel was subtracted from the total recharge value used to calculate sustainable yield.	2
Windward	Waimanalo	30604	**10**	Predominantly high-level ground water	3

Notes:

~ Sustainable Yield Not Calculated

Ground water within an aquifer system area is available from both basal and high-level sources, and includes both fresh and brackish water, unless otherwise indicated

The recharge value used in the Sustainable Yield calculation DID NOT incorporate return irrigation inputs to ground water, unless otherwise indicated. For recharge reference citations see Table 3-10.

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Sustainable Yield Confidence Ranking

For reference purposes, the Sustainable Yield values have been ranked according to the degree of confidence that the CWRM places on the number, ranging from (1) most confident to (3) least confident. The degree of confidence is directly related to the type, quality, and quantity of hydrologic data used in the sustainable yield determination. Ranking criteria are as follows:

(1) Most Confident - Significant Hydrologic Data	The CWRM is fairly confident, based on available information, that the adopted sustainable yield does not over estimate the true sustainable yield of the aquifer system area. Given the presence of deep monitor wells in basal ground water systems or a ground water-level and stream monitoring network in high-level ground water systems, long-term monitoring will provide additional information critical to refining the Sustainable Yield range. * The Sustainable Yield is based on deep monitor well data (for basal ground water sources) or ground water-level and stream monitoring network data (for high-level ground water sources, where applicable) AND hydrologic studies, ground water models, and other data sources that are significant to comprehensive in scope and generally conform to section 3.3.4 of the WRPP.
(2) Moderately Confident - Moderate Hydrologic Data	Sufficient data or studies are available to indicate that the adopted Sustainable Yield is not likely to over estimate the true Sustainable Yield of the aquifer system area. However, more detailed studies are required to better refine the potential range of Sustainable Yields. * The Sustainable Yield is based on hydrologic studies or ground water models AND other data sources. The hydrologic studies, ground water models, and data sources range in scope from limited to comprehensive, and may or may not conform to section 3.3.4 of the WRPP. No deep monitor well data is available.

Table 3-11
2008 Sustainable Yields for Hawaii Aquifers (continued)

Sustainable Yield Confidence Ranking (continued)

(3) Least Confident - Limited to No Hydrologic Data	The CWRM recognizes the adopted Sustainable Yield as a reasonable planning Sustainable Yield until more detailed geologic and hydrologic information is available for these aquifer system areas. There is significant uncertainty associated with this Sustainable Yield due to the lack of hydrogeologic and pumpage information.

* The Sustainable Yield is primarily based on an understanding of the general geologic and hydrologic properties of the aquifer and, where available, (1) pumpage, chloride, and water-level data and (2) recharge studies that do not conform to section 3.3.4.1 of the WRPP.

Table 3-12
Sustainable Yield Values for Hawaii Caprock Aquifers

Sustainable Yield = Miligrams Per Liter (mg/L) Sodium

Aquifer Sector Area	Aquifer System Area	Code	Caprock Aquifer
Oahu			
Ewa Caprock	Malakole	30207	1000
Ewa Caprock	Kapolei	30208	1000
Ewa Caprock	Puuloa	30209	1000

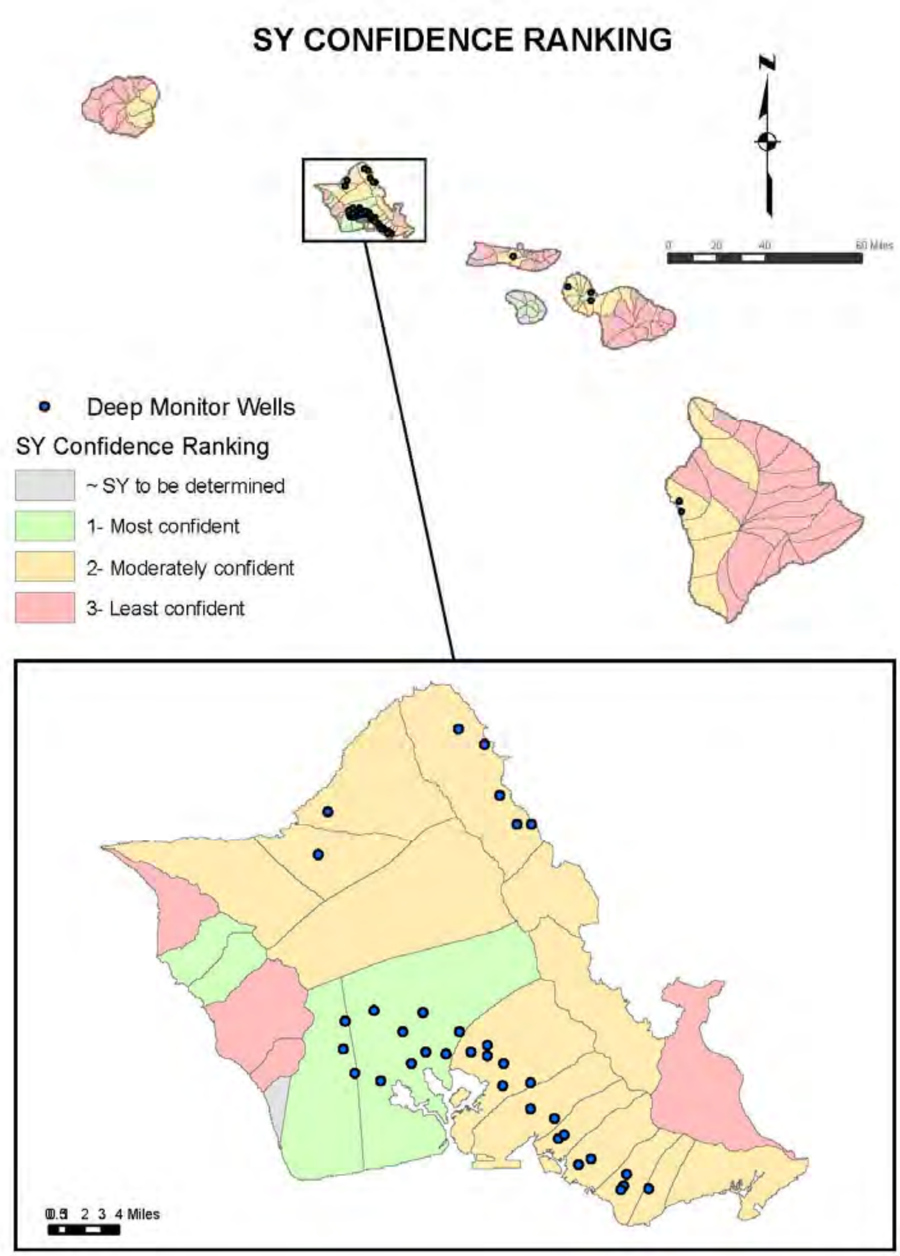

Figure 3-14: Sustainable Yield Confidence Ranking

3.3.5.2 Future Sustainable Yield Selection Criteria

As the WRPP is a living document, sustainable yields will be re-estimated continually based on the best information available as new information is acquired with time. In general, the best information that is scientifically sound and CWRM-vetted for aquifer-specific hydrologic, geologic, or other data will be used for future sustainable yield revisions on case-by-case basis. Revisions shall be consistent with the following criteria:

For Aquifer Systems with predominantly basal resources:

- Presence of an operational deep monitor well and other publicly available hydrogeologic data, such as:
  - Recharge studies that follow the convention of section 3.3.4.1;
  - Complete and significant record of historical pumpage, chloride, and water-level data;
  - Numerical model studies for establishing infrastructure safe yields; or
  - Other hydrologic and geologic studies reviewed and accepted by CWRM staff.
- Ground water inputs from adjacent aquifers.

For Aquifer Systems with predominantly high-level resources:

- Presence of an operational ground water-level monitoring network and a stream monitoring network, where applicable, to ensure compliance with instream flow standards and other publicly available hydrogeologic data, such as:
  - Recharge studies that follow the convention of section 3.3.4.1;
  - Complete and significant record of historical pumpage, chloride, and water-level data;
  - Numerical model studies for establishing infrastructure safe yields; or
  - Other hydrologic and geologic studies reviewed and accepted by CWRM staff.
- Ground-water spill-over from adjacent aquifers.

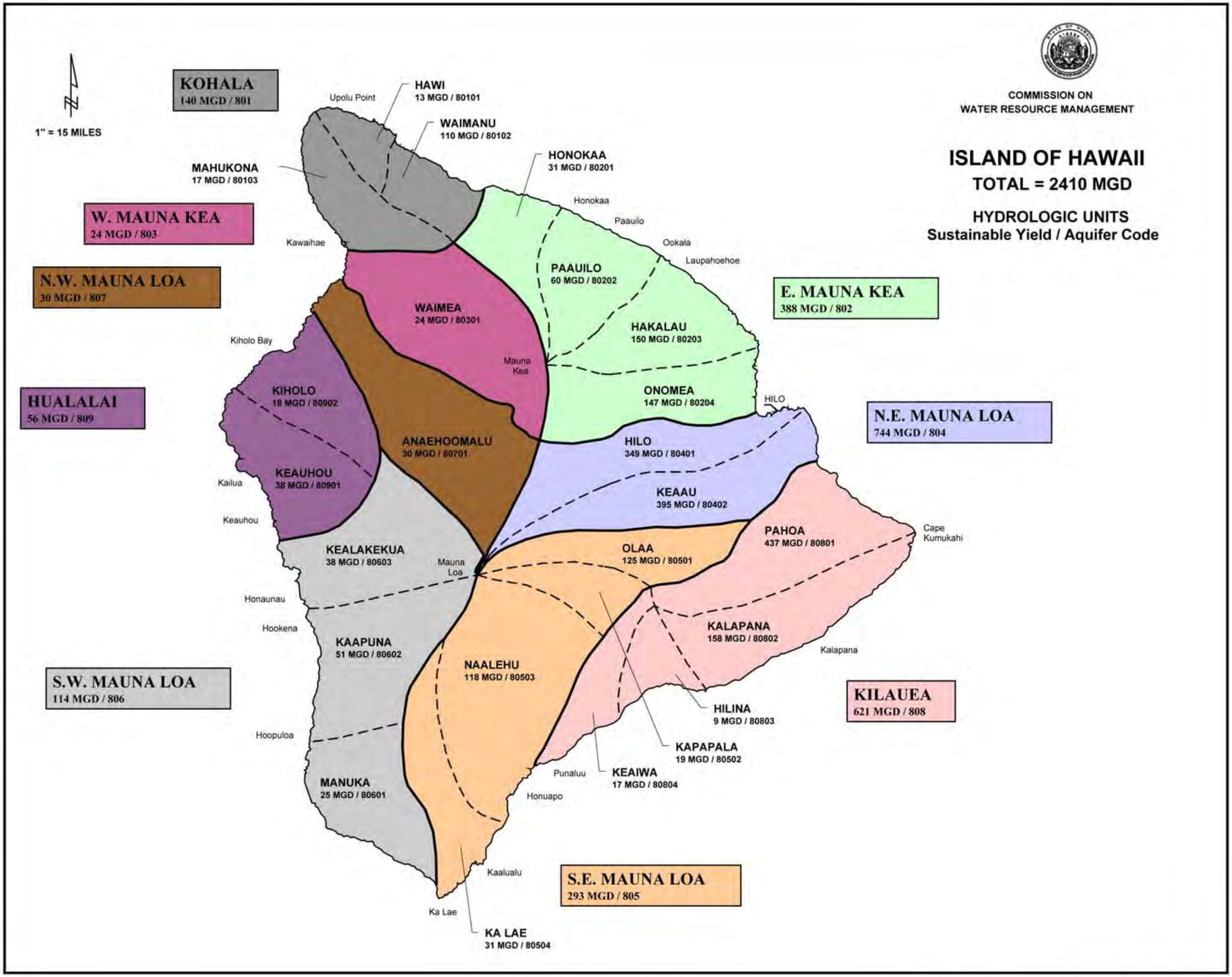

Figure 3-15: Island of Hawaii Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

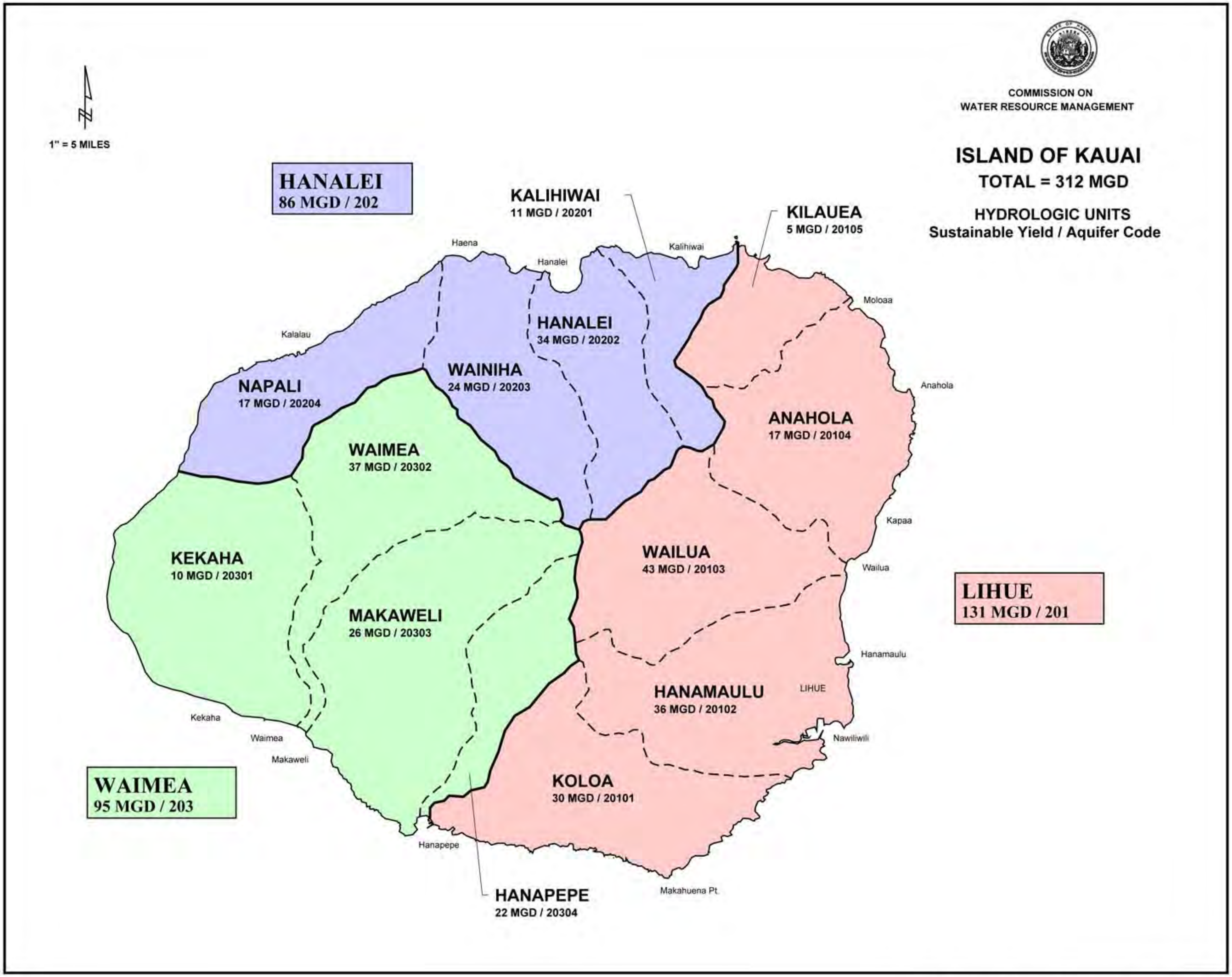

Figure 3-16: Island of Kauai Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

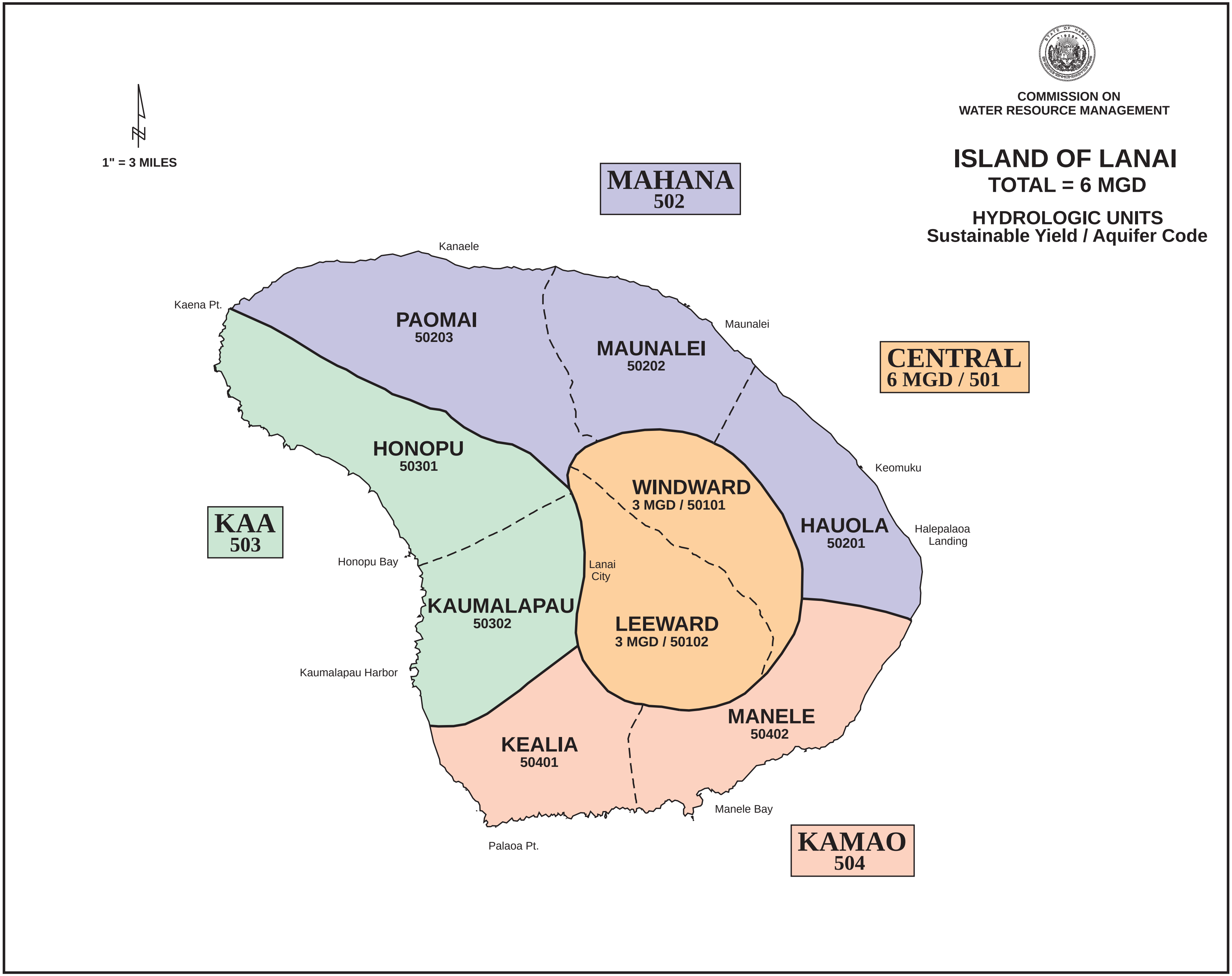

Figure 3-17: Island of Lanai Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

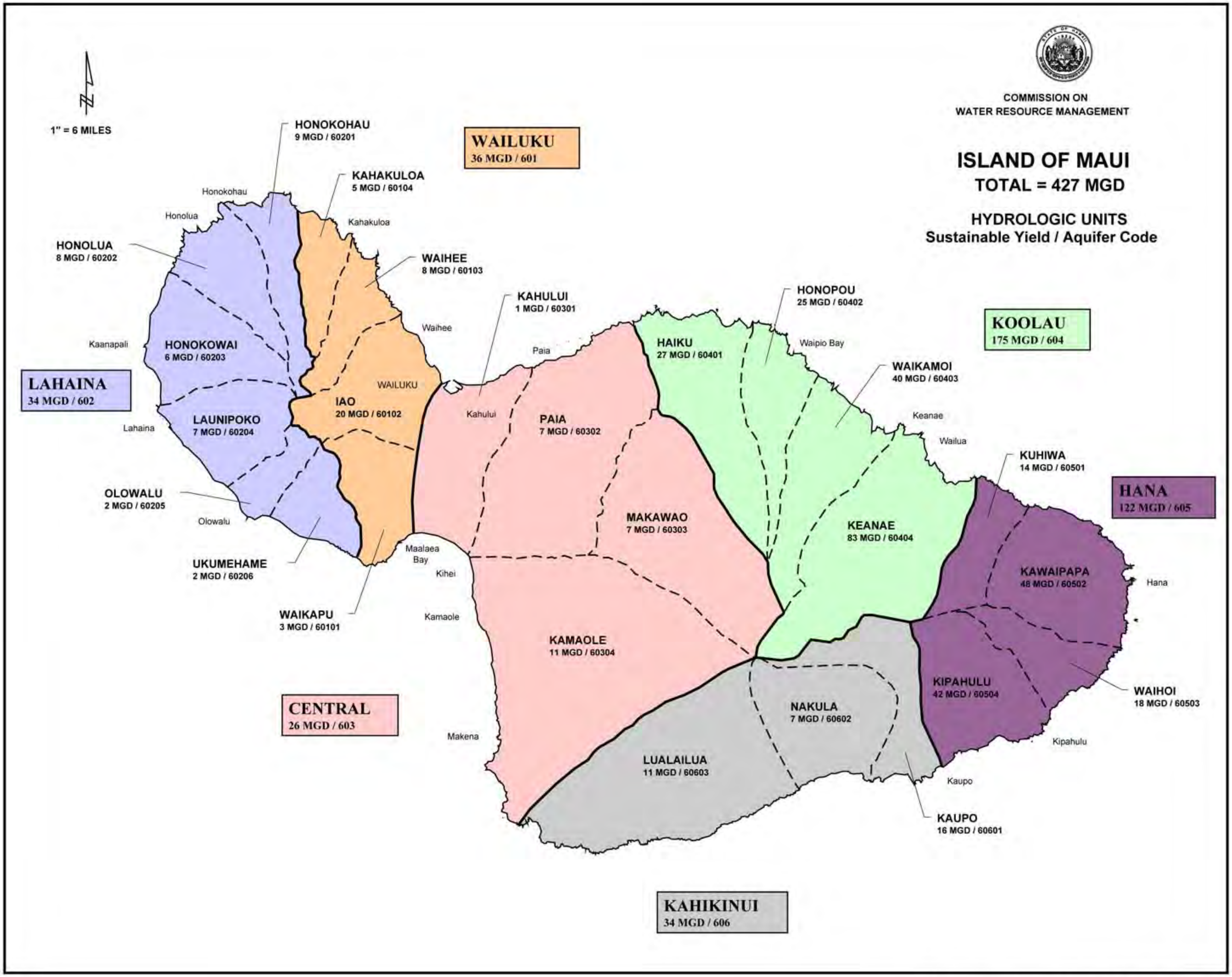

Figure 3-18: Island of Maui Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

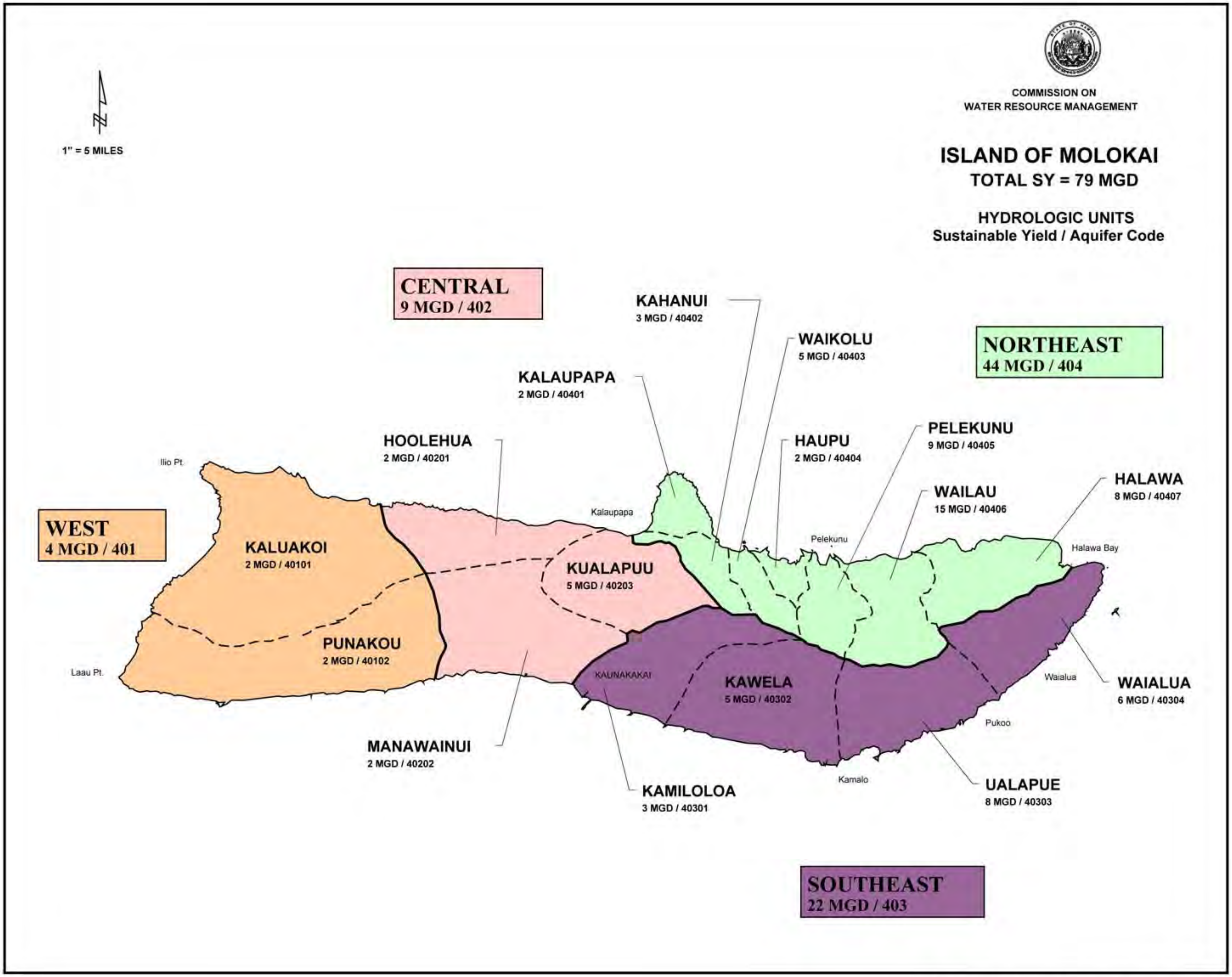

Figure 3-19: Island of Molokai Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

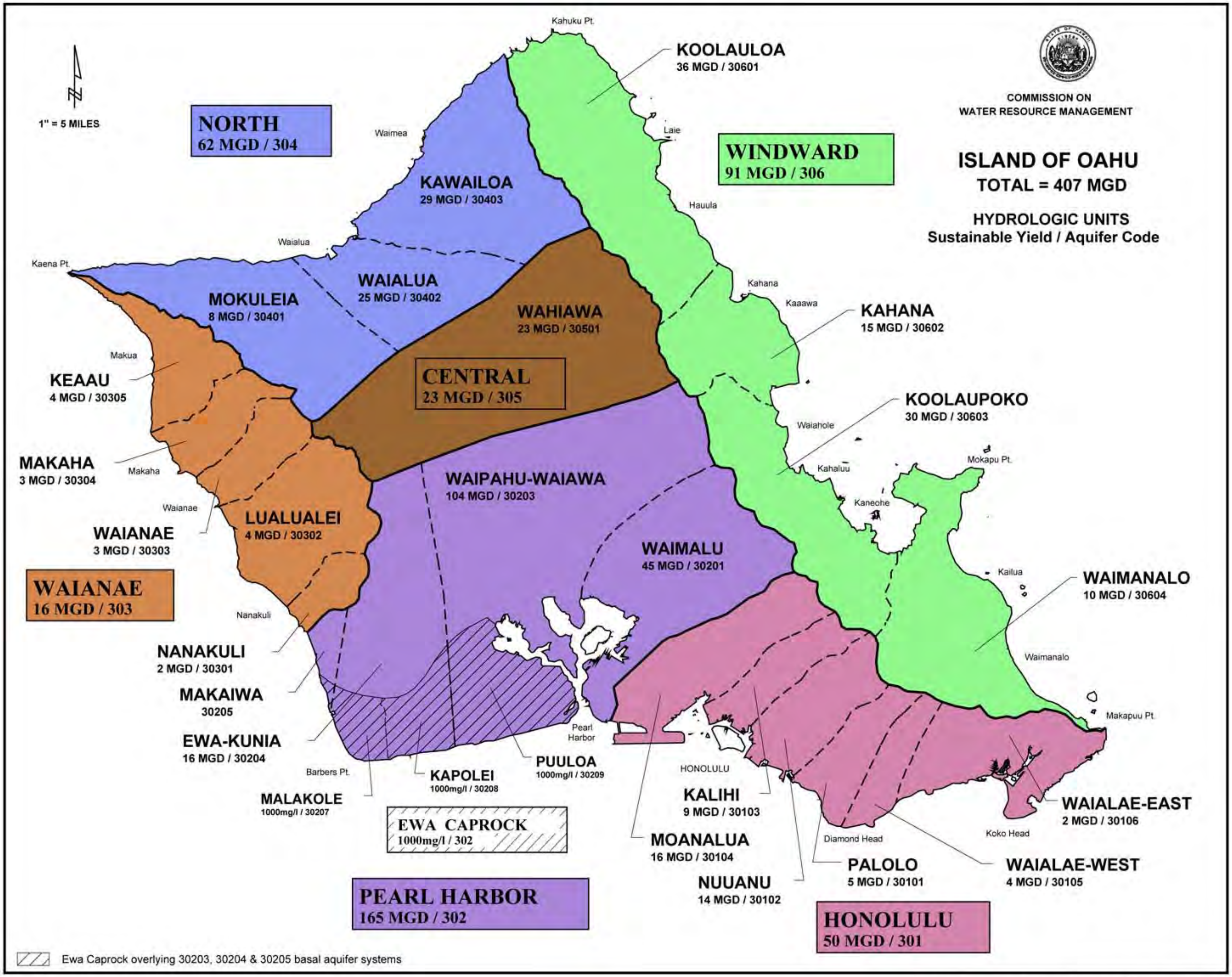

Figure 3-20: Island of Oahu Ground Water Hydrologic Units and 2008 Sustainable Yields

Map Projection: Universal Transverse Mercator

3.4. Nature and Occurrence of Surface Water

Early in its history, CWRM recognized the need for a broad-based collection of existing information on Hawaii's surface water resources to enable sensible water management and decision making. As a result, CWRM and the U.S. National Park Service (USNPS) undertook a cooperative project that produced the 1990 document entitled *Hawaii Stream Assessment: A Preliminary Appraisal of Hawaii's Stream Resources* (HSA). This document continues to serve as a key reference for stream-related research in Hawaii. To provide the general public with an introduction to Hawaii's surface water resources, CWRM and the USGS cooperated to develop the *Surface Water in Hawaii* information brochure published in 2003. The brochure includes information on basic surface water characteristics, system components and behavior, and natural and human-related impacts. The information in this section adapts CWRM's collaborative work with the USNPS and the USGS to provide a basic overview of the nature and occurrence of surface water in Hawaii and implications for surface water management through instream flow standards.

3.4.1. Surface Water Occurrence

The State Water Code defines surface water as consisting of both contained surface water and diffused surface water. Contained surface water exists upon the surface of the earth in naturally or artificially created water bodies such as streams, man-made watercourses, lakes, reservoirs, and coastal waters. Diffused surface water includes all other waters on the surface of the earth that are not contained within waterbodies.

Surface water occurs in areas that, due to topographic slope, contribute to surface water drainage systems that typically manifest as streams or rivers. These drainage areas are confined by topographic divides and are generally referred to as watersheds. Watersheds are sometimes called drainage basins or catchments. Hawaii watersheds are consistently small in comparison to mainland systems, however, watershed profiles vary widely across the main islands. For example, watersheds on the geologically young island of Hawaii tend to be short in length, have fairly shallow channels, exhibit simple stream networks with few tributaries, and may sometimes terminate in a waterfall at the ocean. On the older island of Kauai, watershed systems exhibit eroded features, such as deeper incised channels, complex stream networks with many tributary branches, and large riverine estuaries at the ocean interface.

Watersheds are influenced by human alterations to natural stream systems that affect both surface water hydrology, stream biota, and water quality. Infrastructure significantly changes the path and flow of water. Ditches and canals, even storm drain systems, are built to convey water from one area to another, while reservoirs are used to store water on and off stream systems. Stream channel alterations also influence watershed processes. Channel alterations may include hardened channel linings and embankments, retention basins, culverts, drainage inlets and outlets, and channel realignments.

Within a watershed, surface water resources occur in various settings, both natural and altered. Streams, springs, ditches and canals, and reservoirs are the most common surface water settings in Hawaii. These are described in the sections below.

3.4.1.1. Streams

Streams originating in mauka rainfall belts are the principle drainage features of Hawaii watersheds. The USGS defines the term “stream” as follows:

> *Stream – a general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.*

Streamflow consists of five components: 1) Direct runoff of rainfall in the form of overland flow and subsurface flow, which rapidly returns infiltrated water to the stream; 2) Water returned from bank storage; 3) Ground water discharge in the form of base flow, where the stream intersects the water table; 4) Rain that falls directly on streams; and 5) any additional water, including excess irrigation water, discharged to the stream by humans[35].

Direct runoff occurs during and immediately following a period of rainfall when the capacity of the soil to accept and store water is exceeded, causing water to runoff in a sheet of overland flow. Water may also enter the stream as subsurface flow when rainfall infiltrates the ground surface and moves laterally in the near-surface soils. Subsurface flow is generally slower and may continue for days after a rainfall event, but may also occur quickly if water is able to move through preferential pathways. Similarly, during a period of high rainfall, water may be absorbed into the banks of the stream as bank storage. This water can be returned to the stream to contribute to total streamflow.

Water that infiltrates the ground surface may also recharge ground water bodies such as perched aquifers or dike compartments, which subsequently discharge water to streams. This ground water discharge to the stream, referred to as base flow, may occur during extended dry periods as well as during rainfall events. Base flow contributions occur where the stream intersects the ground water table and where the ground water body is above the water level in the stream. Since ground water levels vary with time, base flow also varies with time. However, variations in base flow are much smaller than variations in direct runoff.

Perennial Streams: A perennial stream is defined as a stream which flows continuously throughout the year. Some streams flow perennially throughout their entire course, while others flow perennially over parts of their course. Streams in Hawaii are commonly perennial in mountainous interior areas, where streams gain water from dike-impounded ground water systems and where rainfall is persistent. Perennial flow is also common in lower stream reaches near the coast where streams gain water from freshwater-lens systems. Where a vertically extensive freshwater-lens system exists, streams may gain water and flow perennially at higher altitudes inland from the coast[36].

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[35] Oki, D.S., 2004, Trends in Streamflow Characteristics in Hawaii, 1913-2003: U.S. Geological Survey Fact Sheet 2004-3104, 4 p.

[36] Izuka, S.K., and Gingerich, S.B., 1998, Ground water in the southern Lihue basin, Kauai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 98-4031, 71 p.

The HSA provided a listing of 376 perennial streams which were defined using data from various sources. The authors acknowledged that, although over one third of the streams on the list did not flow continuously from their headwaters to the ocean, these streams have perennial sections. This list of streams is used by CWRM to make preliminary determinations in regulatory permitting, though streams must often be assessed on a case-by-case basis.

Intermittent Streams: A stream or part of a stream is considered intermittent when it only flows at certain times of the year. Flow generally occurs for several weeks or months in response to seasonal precipitation and subsequent ground water discharge. An intermittent stream may also exist where a perched ground water body contributes to streamflow during certain times of the year. Intermittent streams are often able to support small communities of native freshwater species, either due to upstream or downstream perennial reaches or the persistence of pool habitats between flowing stream segments.

Ephemeral Streams: Ephemeral streams usually manifest in dry gulches on the leeward side of mountain ranges, where there is little or no ground water influence. Ephemeral streams only flow in direct response to rainfall, which indicates that the stream channel is not in contact with the water table. In general, flows last but a few hours or days following a single storm event.

3.4.1.2. Springs

Springs occur where ground water discharges naturally from the ground surface at a more or less continuous rate. Springs are largely dependent upon the permeability of rock layers, the position of the water table, and surface topography.

3.4.1.3. Ditches and Canals

The ditches and canals that traverse the Hawaiian landscape are largely a result of the sugar industry’s need to transport water for cane cultivation in the late 1800s. By 1884, there were a total of 90 sugar planters, plantations, and mills. Extensive irrigation systems often consisted of concrete-lined or unlined channels, tunnels, and flumes that moved water from wet, windward areas to arable plains in dry, leeward areas. By 1920, an estimated 800 million gallons of surface water, in addition to almost 400 million gallons of pumped ground water, was consumed by the sugar industry daily.

The demise of the sugar industry towards the end of the 20th Century brought the closure of large-scale plantations and the conversion of plantation fields to diversified agriculture. Associated changes also occurred in irrigation practices and agricultural water consumption. Many of the irrigation systems that once served plantation agriculture still continue to divert water, however, most systems do not function as efficiently as they once did. System maintenance, which was executed by the plantations, is no longer coordinated and many new owners of former plantation lands do not have the means or desire to carry out refurbishment and repair projects. These irrigation systems are significant in that, not only do they contribute to the viability of agriculture, they impact the surface water hydrology of diverted streams; they impact the hydrology of the streams they pass via leakage, overflows, and controlled releases (for maintenance); and they impact the ground water hydrology of the area receiving irrigation.

3.4.1.4. Reservoirs

A reservoir is generally an artificial basin created for the purpose of collecting, storing, and regulating water. Reservoirs are usually created by damming the downstream end of a drainage basin. In Hawaii, there are very few natural lakes, so these man-made reservoirs often serve as recreational boating and fishing lakes. Many of the reservoirs that dot the landscape were constructed to serve the sugar and pineapple industries, while others were built for flood control or as impoundment reservoirs for drinking water prior to treatment. Reservoirs can influence local climatological patterns, habitat conditions for stream organisms, water quality, and ground water infiltration.

3.4.2. Surface Water Hydrologic Units

Surface water hydrologic units have been established by CWRM to provide a consistent basis for managing surface water resources. A surface water hydrologic unit coding system is used to reference and describe the units delineated by CWRM. This section describes the coding system and lists all surface water hydrologic units by island. Maps illustrating the hydrologic unit boundaries are included in Section 3.4.2.3.

3.4.2.1. Purpose of Surface Water Hydrologic Unit Coding

As described earlier in Section 3.4.1, surface water occurs in variable settings throughout Hawaii. The surface water hydrologic unit coding system described herein was established to provide a consistent method by which to reference and describe surface water resources and to assist in various water planning efforts. The coding system is an important first-step towards improving the organization and management of surface water information that CWRM collects and maintains.

The primary goal of the coding system is to provide standard surface water hydrologic unit delineations for the coordination of data, information, and resource management practices. Key objectives of CWRM Surface Water Hydrologic Units include the following:

- Define and delineate unique units that can accommodate the relational requirements in a database environment, while providing a system that can be easily understood by the general public;

- Develop an information management system which utilizes a coding system to relate surface water permits and other resource information to a given unit;

- Define hydrologic units to be considered in the analysis and development of instream flow standards;

- Provide a reference system that promotes better information management of other resource inventories;

- Promote the sharing and collection of surface water resource data between government agencies, the public, private entities, and community organizations; and

- Improve the overall coordination of monitoring, data collection, and field investigation efforts.

3.4.2.2. Basis for Surface Water Hydrologic Unit Delineations

The State Water Code mandates that the WRPP shall include:

> *"…Hydrologic units and their characteristics, including the quantity and quality of available resource, requirements for beneficial instream uses and environmental protection, desirable uses worthy of preservation by permit, and undesirable uses for which permits may be denied."*[37]

The State Water Code defines a hydrologic unit as "[a] surface drainage area or a ground water basin or a combination of the two."[38]

Ground water hydrologic units were established by CWRM under the 1990 WRPP. For surface water units, however, the 1990 WRPP only suggests a complex classification scheme.

In 2005, CWRM adopted surface water hydrologic units and the coding system described below. In developing CWRM Surface Water Hydrologic Units, it was necessary to review the HSA, *State Delineation of Watersheds* (1994), and *Refinement of Hawaii Watershed Delineations* (1999) reports to arrive at a coding system that could meet the requirements for organizing and managing surface water information.

The naming convention for surface water hydrologic units indicates regional and sub-regional divisions as follows:

Island division = Island
Regional division = Surface Water Hydrologic Unit

3.4.2.3. Surface Water Hydrologic Unit Coding System

The surface water hydrologic unit code is a unique combination of four digits. In the *State Definition and Delineation of Watersheds* report, a watershed unit is defined as follows:

> *"A watershed unit is comprised of a drainage basin (or basins) which include both stream and overland flow, whose runoff either enters the ocean along an identified segment of coastline (coastal segment) or enters an internal, landlocked drainage basin. The watershed units for an island are defined so*

[37] HRS §174C-31(d)(2).
[38] HRS §174C-3.

that all segments of coastline are assigned to a unique watershed unit and so that all areas of an island are assigned to one, and only one, watershed unit."

The surface water hydrologic unit coding system is based on a hierarchy in which the island is the largest component and the surface water hydrologic unit is the regional component. The island is identified by a single-digit number. Each surface water hydrologic unit is identified by a three-digit number and a Hawaiian geographic name or local geographic term.

Therefore, surface water hydrologic units are assigned a unique code in the four-digit format as follows:

0	**000**
Island	Surface Water Hydrologic Unit

The individual components of the coding system are described below.

ISLAND: **0**000

The first digit represents the eight main Hawaiian Islands using a unique number assigned by CWRM. The Island Code is the same 1-digit number used in the Hawaii Stream Assessment. The islands of Niihau, Kahoolawe and Lanai did not appear in the HSA database because these islands do not have perennial streams, however they have been included in the coding system as part of a more comprehensive surface water management scheme.

SURFACE WATER HYDROLOGIC UNIT SYSTEM: 0**000**

The last three digits are sequentially assigned, generally beginning in the north and continuing around each island in a clockwise manner. This method is similar to previous coding efforts.

There are a total of 558 Surface Water Hydrologic Units statewide. Tables 3-13 to 3-20 below list all units by island and are accompanied by maps showing the unit boundaries (see Figures 3-21 to 3-28). For the majority of hydrologic units, unit boundaries closely match drainage basin boundaries. Individual stream systems are contained entirely within the hydrologic unit boundaries (from the headwater to the mouth). However, in a few instances, streams were found to cross hydrologic unit boundaries, and in these cases, drainage basins were refined to more accurately determine the natural flow of water based on elevation gradients. In these instances, the hydrologic unit boundaries were evaluated together with the drainage basin and redrawn through on-screen digitizing using ArcGIS software.

Table 3-13: Niihau (1) Surface Water Hydrologic Units			
1001	Kaaukuu	1008	Mauuloa
1002	Kooeaukani	1009	Nonopapa
1003	Kaailana	1010	Puuwai
1004	Nomilu	1011	Kaumuhonu
1005	Kalaoa	1012	Keanauhi
1006	Honuaula	1013	Keawanui
1007	Halaii		

Table 3-14: Kauai (2) Surface Water Hydrologic Units			
2001	Awaawapuhi	2038	Moikeha
2002	Honopu	2039	Waikaea
2003	Nakeikionaiwi	2040	Wailua
2004	Kalalau	2041	Kawailoa
2005	Pohakuao	2042	Hanamaulu
2006	Waiolaa	2043	Lihue Airport
2007	Hanakoa	2044	Nawiliwili
2008	Waiahuakua	2045	Puali
2009	Hoolulu	2046	Huleia
2010	Hanakapiai	2047	Kipu Kai
2011	Maunapuluo	2048	Mahaulepu
2012	Limahuli	2049	Waikomo
2013	Manoa	2050	Aepo
2014	Wainiha	2051	Lawai
2015	Lumahai	2052	Kalaheo
2016	Waikoko	2053	Wahiawa
2017	Waipa	2054	Hanapepe
2018	Waioli	2055	Kukamahu
2019	Hanalei	2056	Kaumakani
2020	Waileia	2057	Mahinauli
2021	Anini	2058	Aakukui
2022	Kalihikai West	2059	Waipao
2023	Kalihikai Center	2060	Waimea
2024	Kalihikai East	2061	Kapilimao
2025	Kalihiwai	2062	Paua
2026	Puukumu	2063	Hoea
2027	Kauapea	2064	Niu
2028	Kilauea	2065	Kaawaloa
2029	Kulihaili	2066	Nahomalu
2030	Pilaa	2067	Kaulaula
2031	Waipake	2068	Haeleele
2032	Moloaa	2069	Hikimoe
2033	Papaa	2070	Kaaweiki
2034	Aliomanu	2071	Kauhao
2035	Anahola	2072	Makaha
2036	Kumukumu	2073	Milolii
2037	Kapaa	2074	Nualolo

**Table 3-15:
Oahu (3) Surface Water Hydrologic Units**

3001	Kalunawaikaala	3045	Niu
3002	Pakulena	3046	Wailupe
3003	Paumalu	3047	Waialaenui
3004	Kawela	3048	Diamond Head
3005	Oio	3049	Ala Wai
3006	Malaekahana	3050	Nuuanu
3007	Kahawainui	3051	Kapalama
3008	Wailele	3052	Kalihi
3009	Koloa	3053	Moanalua
3010	Kaipapau	3054	Keehi
3011	Maakua	3055	Manuwai
3012	Waipuhi	3056	Salt Lake
3013	Kaluanui	3057	Halawa
3014	Papaakoko	3058	Aiea
3015	Halehaa	3059	Kalauao
3016	Punaluu	3060	Waimalu
3017	Kahana	3061	Waiawa
3018	Makaua	3062	Waipio
3019	Kaaawa	3063	Kapakahi
3020	Kualoa	3064	Waikele
3021	Hakipuu	3065	Honouliuli
3022	Waikane	3066	Kaloi
3023	Waianu	3067	Makaiwa
3024	Waiahole	3068	Nanakuli
3025	Kaalaea	3069	Ulehawa
3026	Haiamoa	3070	Mailiili
3027	Kahaluu	3071	Kaupuni
3028	Heeia	3072	Kamaileunu
3029	Keaahala	3073	Makaha
3030	Kaneohe	3074	Keaau
3031	Kawa	3075	Makua
3032	Puu Hawaiiloa	3076	Kaluakauila
3033	Kawainui	3077	Manini
3034	Kaelepulu	3078	Kawaihapai
3035	Waimanalo	3079	Pahole
3036	Kahawai	3080	Makaleha
3037	Makapuu	3081	Waialua
3038	Koko Crater	3082	Kiikii
3039	Hanauma	3083	Paukauila
3040	Portlock	3084	Anahulu
3041	Kamiloiki	3085	Loko Ea
3042	Kamilonui	3086	Keamanea
3043	Hahaione	3087	Waimea
3044	Kuliouou		

Table 3-16:
Molokai (4) Surface Water Hydrologic Units

4001	Waihanau	4026	Honouliwai
4002	Waialeia	4027	Waialua
4003	Waikolu	4028	Kainalu
4004	Wainene	4029	Honomuni
4005	Anapuhi	4030	Ahaino
4006	Waiohookalo	4031	Mapulehu
4007	Keawanui	4032	Kaluaaha
4008	Kailiili	4033	Kahananui
4009	Pelekunu	4034	Ohia
4010	Waipu	4035	Wawaia
4011	Haloku	4036	Kamalo
4012	Oloupena	4037	Kawela
4013	Puukaoku	4038	Kamiloloa
4014	Wailele	4039	Kaunakakai
4015	Wailau	4040	Kalamaula
4016	Kalaemilo	4041	Manawainui
4017	Waiahookalo	4042	Kaluapeelua
4018	Kahiwa	4043	Waiahewahewa
4019	Kawainui	4044	Kolo
4020	Pipiwai	4045	Hakina
4021	Halawa	4046	Kaunala
4022	Papio	4047	Papohaku
4023	Honowewe	4048	Kaa
4024	Pohakupili	4049	Moomomi
4025	Honoulimaloo	4050	Maneopapa

Table 3-17:
Lanai (5) Surface Water Hydrologic Units

5001	Puumaiekahi	5017	Awehi
5002	Lapaiki	5018	Kapua
5003	Hawaiilanui	5019	Naha
5004	Kahua	5020	Kapoho
5005	Kuahua	5021	Kawaiu
5006	Poaiwa	5022	Mahanalua
5007	Halulu	5023	Manele
5008	Maunalei	5024	Anapuka
5009	Wahane	5025	Palawai Basin
5010	Hauola	5026	Ulaula
5011	Nahoko	5027	Kaumalapau
5012	Kaa	5028	Kalamanui
5013	Haua	5029	Kalamaiki
5014	Waiopa	5030	Paliamano
5015	Kahea	5031	Honopu
5016	Lopa	5032	Kaapahu

Table 3-18: Maui (6) Surface Water Hydrologic Units

6001	Waikapu	6050	Punalau
6002	Pohakea	6051	Honomanu
6003	Papalaua	6052	Nuaailua
6004	Ukumehame	6053	Piinaau
6005	Olowalu	6054	Ohia
6006	Launiupoko	6055	Waiokamilo
6007	Kauaula	6056	Wailuanui
6008	Kahoma	6057	West Wailuaiki
6009	Wahikuli	6058	East Wailuaiki
6010	Honokowai	6059	Kopiliula
6011	Kahana	6060	Waiohue
6012	Honokahua	6061	Paakea
6013	Honolua	6062	Waiaaka
6014	Honokohau	6063	Kapaula
6015	Anakaluahine	6064	Hanawi
6016	Poelua	6065	Makapipi
6017	Honanana	6066	Kuhiwa
6018	Kahakuloa	6067	Waihole
6019	Waipili	6068	Manawaikeae
6020	Waiolai	6069	Kahawaihapapa
6021	Makamakaole	6070	Keaaiki
6022	Waihee	6071	Waioni
6023	Waiehu	6072	Lanikele
6024	Iao	6073	Heleleikeoha
6025	Kalialinui	6074	Kawakoe
6026	Kailua Gulch	6075	Honomaele
6027	Maliko	6076	Kawaipapa
6028	Kuiaha	6077	Moomoonui
6029	Kaupakulua	6078	Haneoo
6030	Manawaiiao	6079	Kapia
6031	Uaoa	6080	Waiohonu
6032	Kealii	6081	Papahawahawa
6033	Kakipi	6082	Alaalaula
6034	Honopou	6083	Wailua
6035	Hoolawa	6084	Honolewa
6036	Waipio	6085	Waieli
6037	Hanehoi	6086	Kakiweka
6038	Hoalua	6087	Hahalawe
6039	Hanawana	6088	Puaaluu
6040	Kailua	6089	Oheo
6041	Nailiilihaele	6090	Kalena
6042	Puehu	6091	Koukouai
6043	Oopuola	6092	Opelu
6044	Kaaiea	6093	Kukuiula
6045	Punaluu	6094	Kaapahu
6046	Kolea	6095	Lelekea
6047	Waikamoi	6096	Alelele
6048	Puohokamoa	6097	Kalepa
6049	Haipuaena	6098	Nuanuaaloa

Table 3-18: (continued) Maui (6) Surface Water Hydrologic Units (continued)			
6099	Manawainui	6106	Kipapa
6100	Kaupo	6107	Kanaio
6101	Nuu	6108	Ahihi Kinau
6102	Pahihi	6109	Mooloa
6103	Waiopai	6110	Wailea
6104	Poopoo	6111	Hapapa
6105	Manawainui Gulch	6112	Waiakoa

Table 3-19: Kahoolawe (7) Surface Water Hydrologic Units			
7001	Lae Paki	7013	Waaiki
7002	Honokoa	7014	Kealia Luna
7003	Makaakae	7015	Hakioawa
7004	Ahupuiki	7016	Oawawahie
7005	Ahupu	7017	Pali o Kalapakea
7006	Kaukamoku	7018	Kaukamaka
7007	Moaulaiki	7019	Lae o Kaka
7008	Olohia	7020	Kamohio
7009	Kuheeia	7021	Kanaloa
7010	Kaulana	7022	Waikahalulu
7011	Papakanui	7023	Honokanaia
7012	Papakaiki	7024	Wai Honu

Table 3-20: Hawaii (8) Surface Water Hydrologic Units			
8001	Kealahewa	8050	Malanahae
8002	Hualua	8051	Honokaia
8003	Kumakua	8052	Kawela
8004	Kapua	8053	Keaakaukau
8005	Ohanaula	8054	Kainapahoa
8006	Hanaula	8055	Nienie
8007	Hapahapai	8056	Papuaa
8008	Pali Akamoa	8057	Ouhi
8009	Wainaia	8058	Kahaupu
8010	Halelua	8059	Kahawailiili
8011	Halawa	8060	Keahua
8012	Aamakao	8061	Kalopa
8013	Niulii	8062	Waikaalulu
8014	Waikama	8063	Kukuilamalamahii
8015	Pololu	8064	Alilipali
8016	Honokane Nui	8065	Kaumoali
8017	Honokane Iki	8066	Pohakuhaku
8018	Kalele	8067	Waipunahina
8019	Waipahi	8068	Waipunalau
8020	Honokea	8069	Paauilo
8021	Kailikaula	8070	Aamanu

Table 3-20: (continued)
Hawaii (8) Surface Water Hydrologic Units (continued)

8022	Honopue	8071	Koholalele
8023	Kolealiilii	8072	Kalapahapuu
8024	Ohiahuea	8073	Kukaiau
8025	Nakooko	8074	Puumaile
8026	Waiapuka	8075	Kekualele
8027	Waikaloa	8076	Kaala
8028	Waimaile	8077	Kealakaha
8029	Kukui	8078	Keehia
8030	Paopao	8079	Kupapaulua
8031	Waiaalala	8080	Kaiwiki
8032	Punalulu	8081	Kaula
8033	Kaimu	8082	Kaohaoha
8034	Pae	8083	Kaawalii
8035	Waimanu	8084	Waipunalei
8036	Pukoa	8085	Laupahoehoe
8037	Manuwaikaalio	8086	Kilau
8038	Naluea	8087	Manowaiopae
8039	Kahoopuu	8088	Kuwaikahi
8040	Waipahoehoe	8089	Kihalani
8041	Wailoa/Waipio	8090	Kaiwilahilahi
8042	Kaluahine Falls	8091	Haakoa
8043	Waiulili	8092	Pahale
8044	Waikoekoe	8093	Kapehu Camp
8045	Waipunahoe	8094	Paeohe
8046	Waialeale	8095	Maulua
8047	Waikoloa	8096	Pohakupuka
8048	Kapulena	8097	Kulanakii
8049	Kawaikalia	8098	Ahole
8099	Poupou	8133	Paukaa
8100	Manoloa	8134	Honolii
8101	Ninole	8135	Maili
8102	Kaaheiki	8136	Wainaku
8103	Waikolu	8137	Pukihae
8104	Waikaumalo	8138	Wailuku
8105	Waiehu	8139	Wailoa
8106	Nanue	8140	Kaahakini
8107	Opea	8141	Kilauea
8108	Peleau	8142	Keauhou Point
8109	Umauma	8143	Kilauea Crater
8110	Hakalau	8144	Kapapala
8111	Kolekole	8145	Pahala
8112	Paheehee	8146	Hilea
8113	Honomu	8147	Naalehu
8114	Laimi	8148	Kiolakaa
8115	Kapehu	8149	South Point
8116	Makea	8150	Kauna
8117	Alia	8151	Kiilae
8118	Makahanaloa	8152	Kealakekua
8119	Waimaauou	8153	Waiaha
8120	Waiaama	8154	Honokohau

Table 3-20: (continued) Hawaii (8) Surface Water Hydrologic Units (continued)			
8121	Kawainui	8155	Keahole
8122	Onomea	8156	Kiholo
8123	Alakahi	8157	Pohakuloa
8124	Hanawi	8158	Kamakoa
8125	Kalaoa	8159	Haloa
8126	Aleamai	8160	Lamimaumau
8127	Kaieie	8161	Waikoloa
8128	Puuokalepa	8162	Kawaihae
8129	Kaapoko	8163	Honokoa
8130	Papaikou	8164	Keawanui
8131	Kapue	8165	Lapakahi
8132	Pahoehoe	8166	Mahukona

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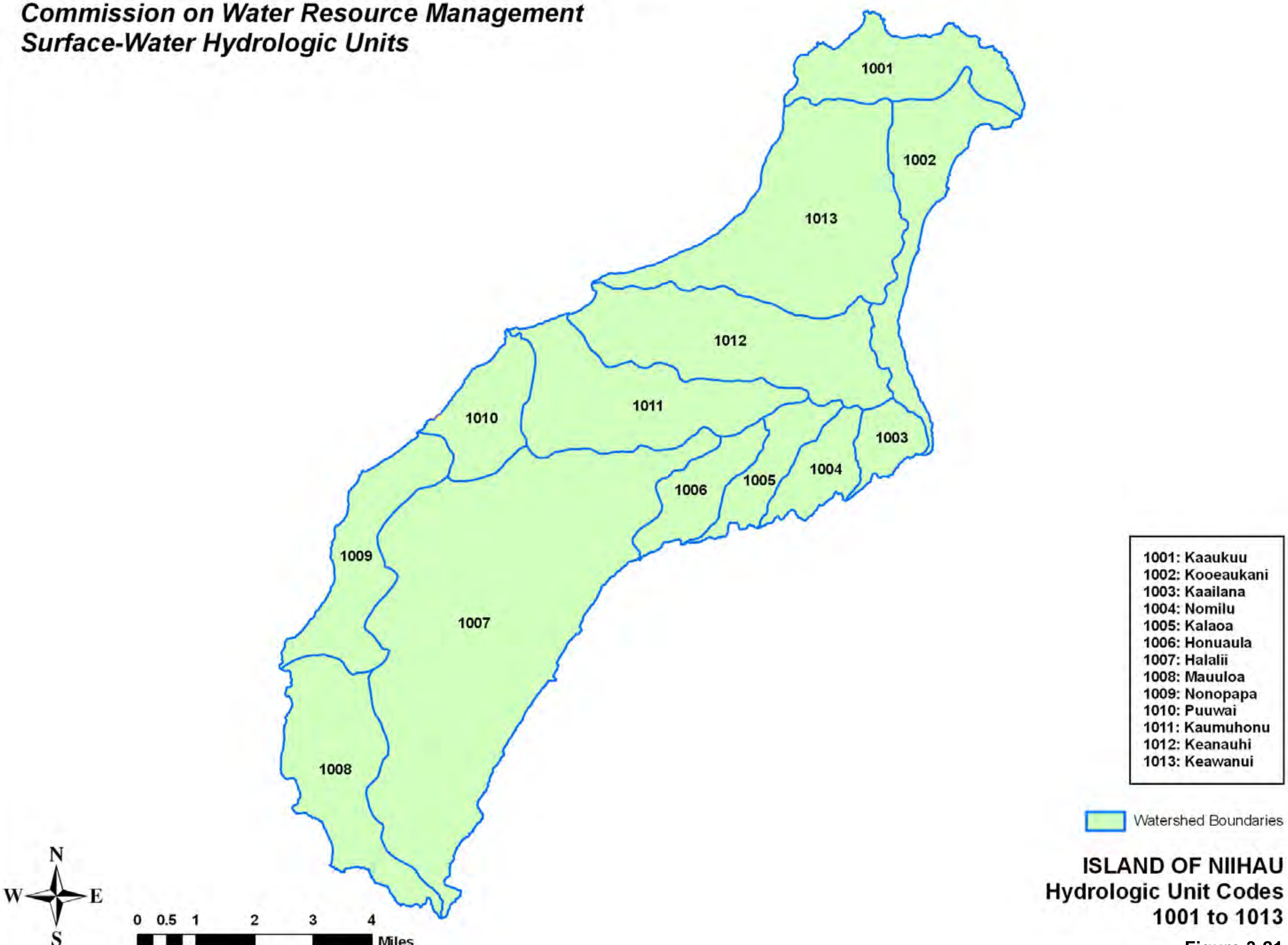
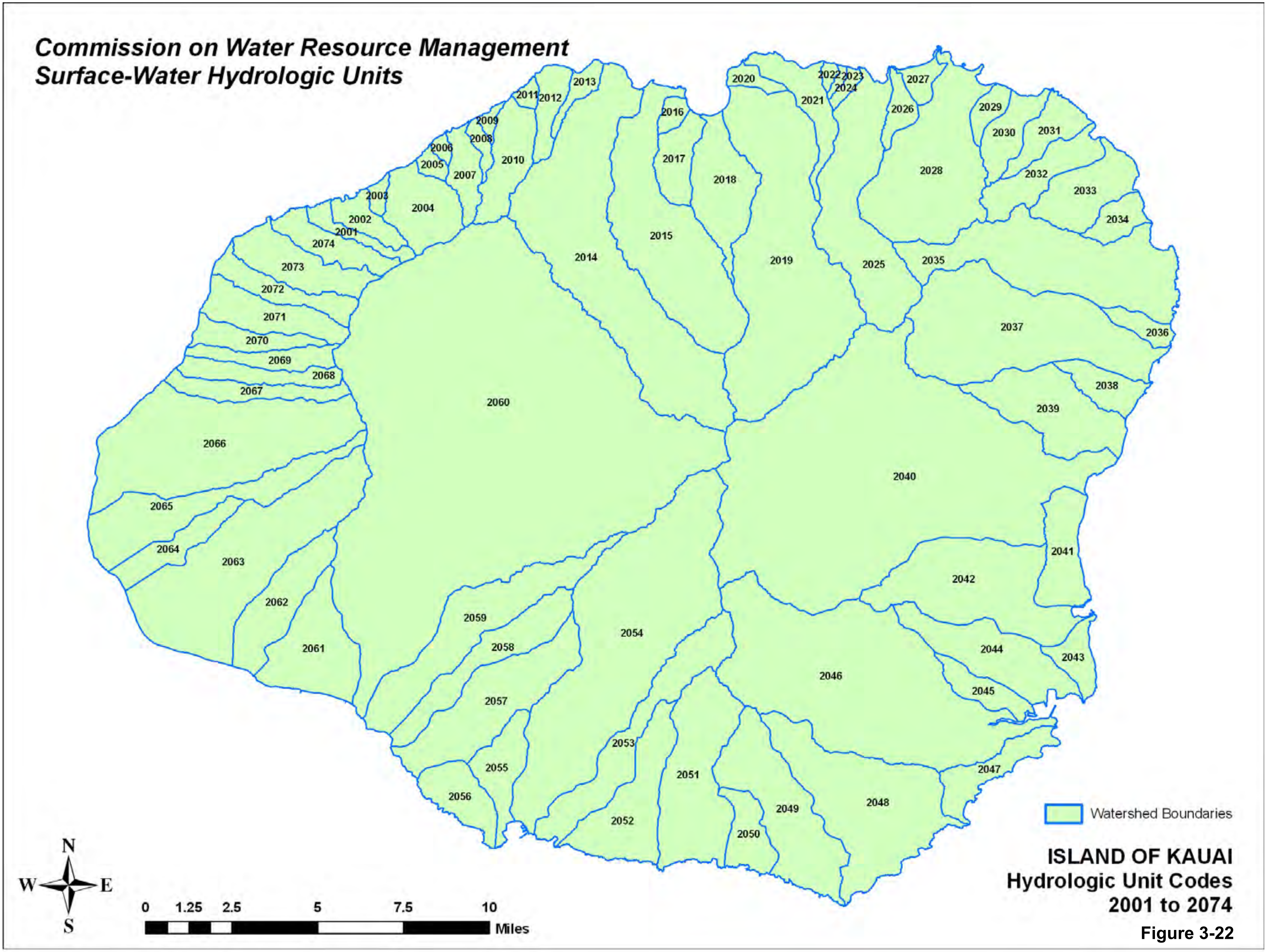
Commission on Water Resource Management
Surface-Water Hydrologic Units



ISLAND OF NIIHAU
Hydrologic Unit Codes
1001 to 1013

Figure 3-21



Commission on Water Resource Management
Surface-Water Hydrologic Units
2001
2002
2003
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2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
N
W
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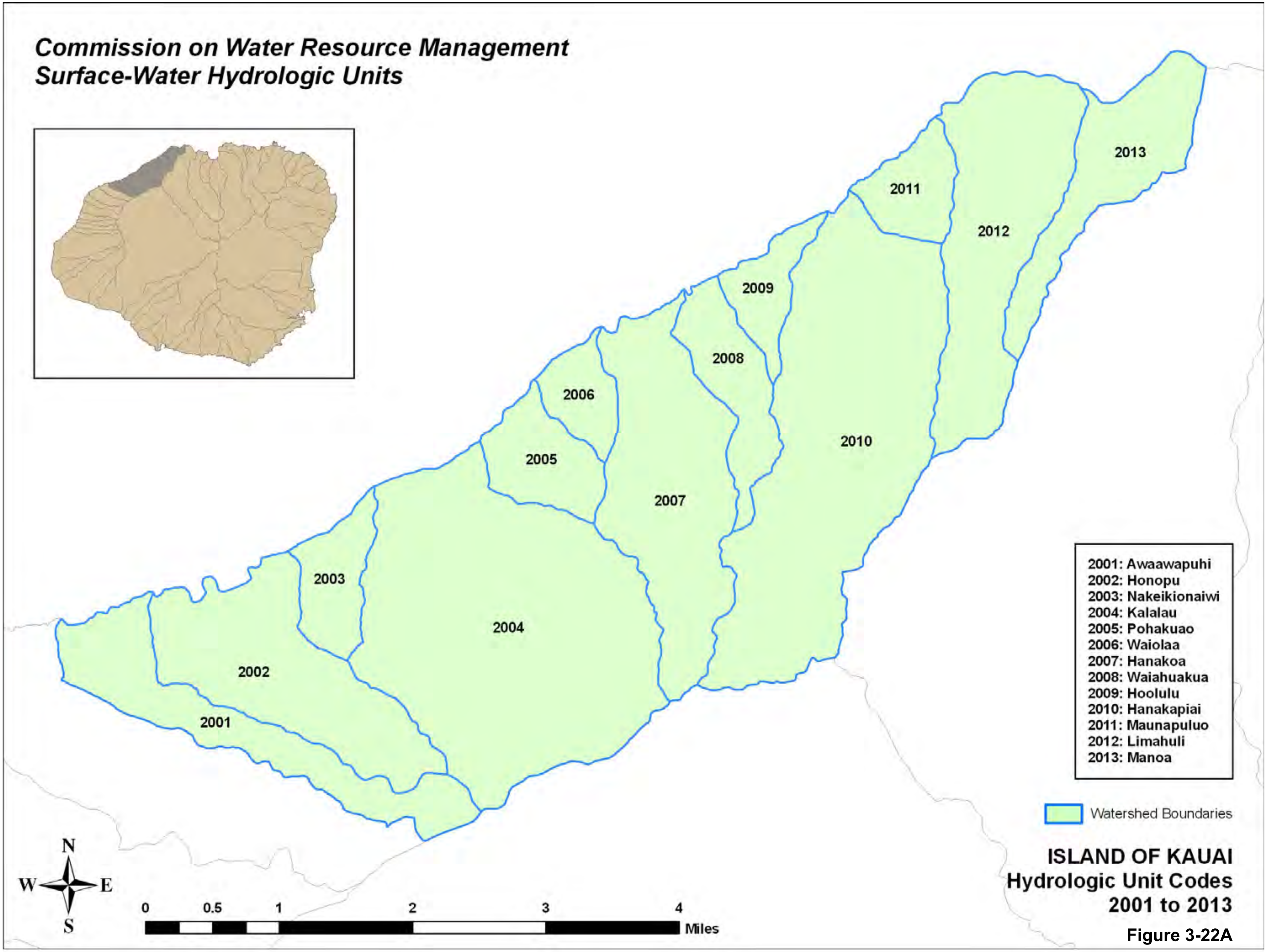
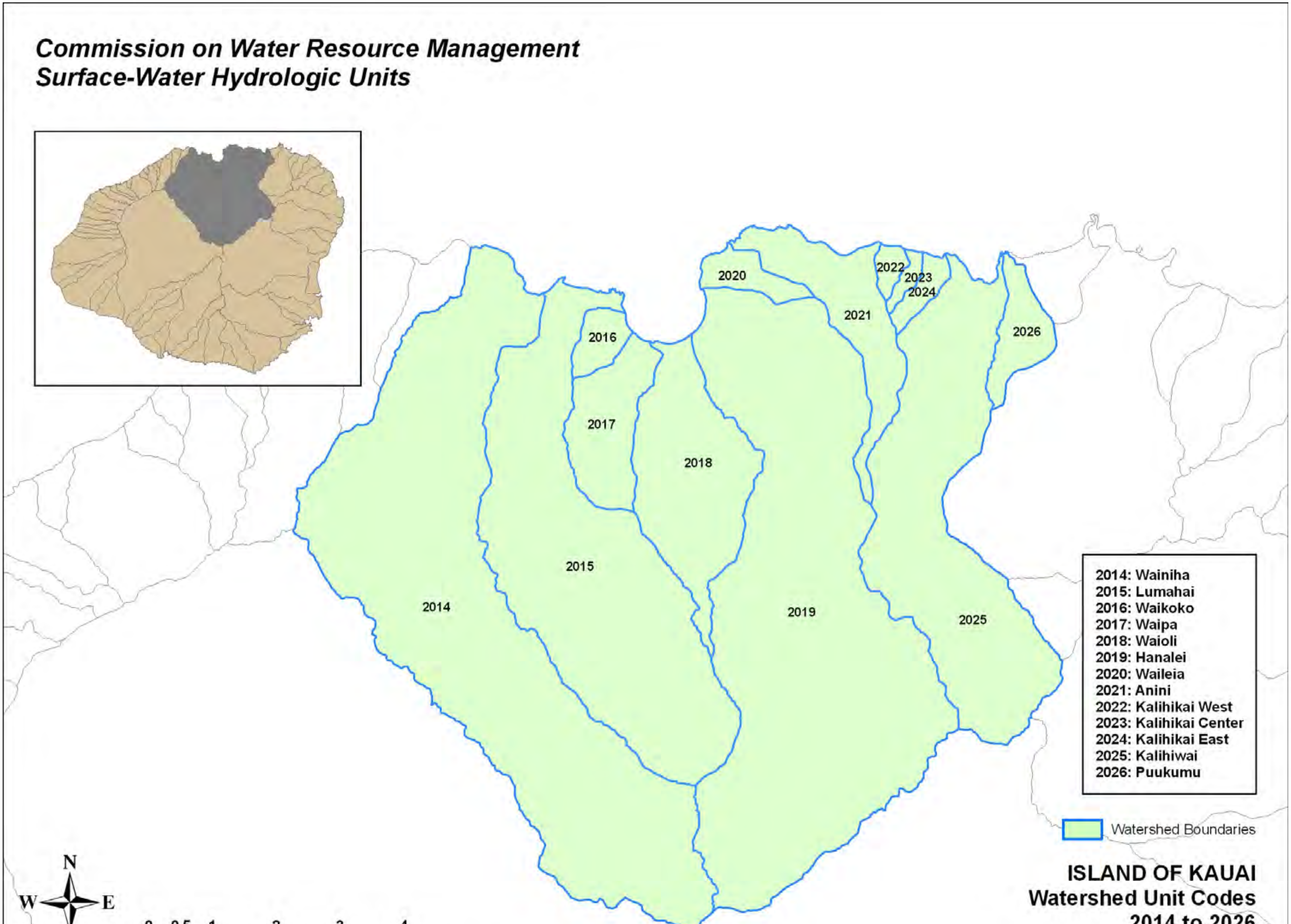
S
0
1.25
2.5
5
7.5
10
Miles
Watershed Boundaries
ISLAND OF KAUAI
Hydrologic Unit Codes
2001 to 2074

Figure 3-22



Commission on Water Resource Management
Surface-Water Hydrologic Units
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2001: Awaawapuhi
2002: Honopu
2003: Nakeikionaiwi
2004: Kalalau
2005: Pohakuao
2006: Waiolaa
2007: Hanakoa
2008: Waiahuakua
2009: Hoolulu
2010: Hanakapiai
2011: Maunapuluo
2012: Limahuli
2013: Manoa
Watershed Boundaries
N
W
E
S
0
0.5
1
2
3
4
Miles
ISLAND OF KAUAI
Hydrologic Unit Codes
2001 to 2013

Figure 3-22A


Commission on Water Resource Management
Surface-Water Hydrologic Units
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2014: Wainiha
2015: Lumahai
2016: Waikoko
2017: Waipa
2018: Waioli
2019: Hanalei
2020: Waileia
2021: Anini
2022: Kalihikai West
2023: Kalihikai Center
2024: Kalihikai East
2025: Kalihiwai
2026: Puukumu
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF KAUAI
Watershed Unit Codes
2014 to 2026
Figure 3-22B

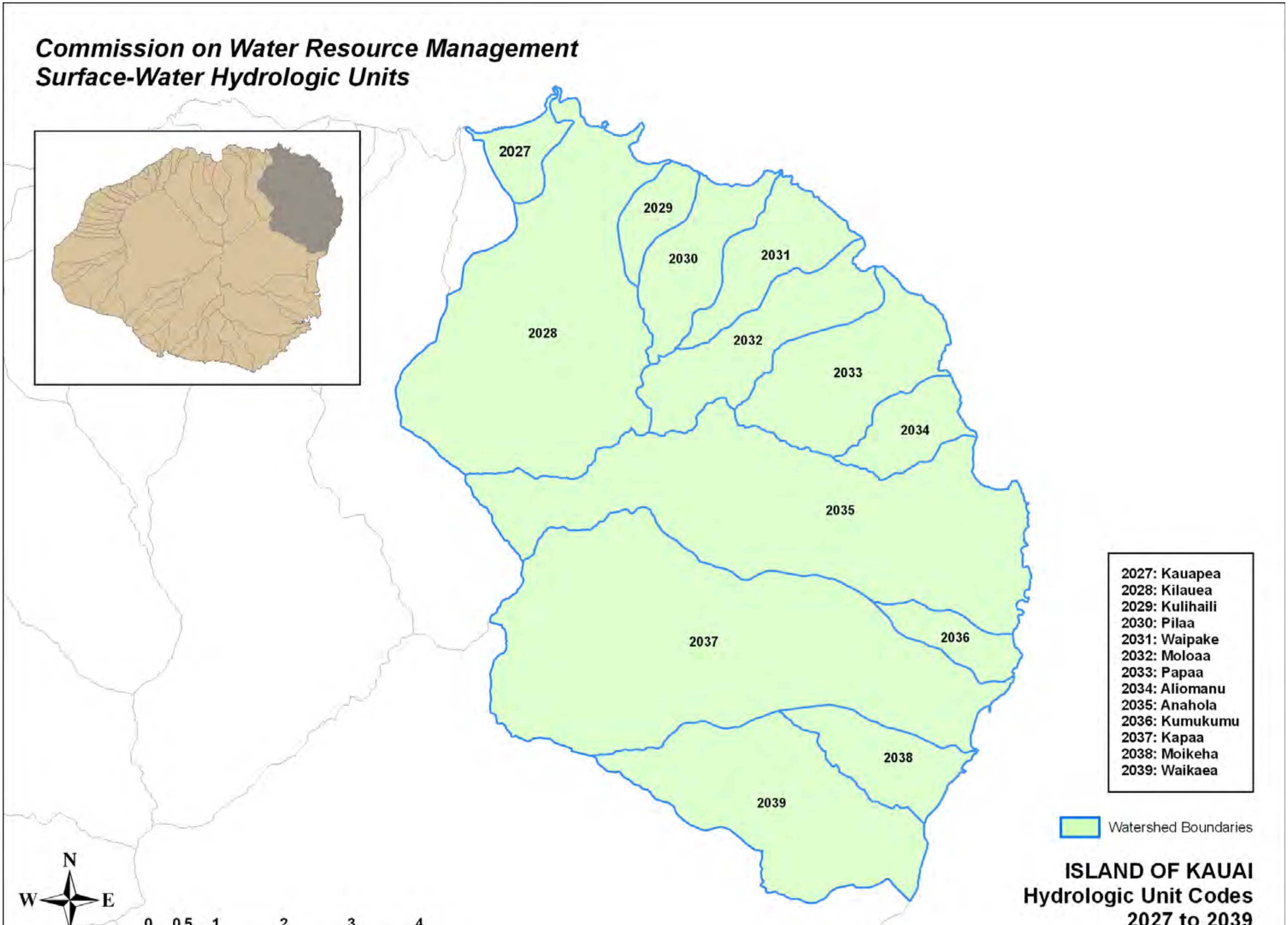

Commission on Water Resource Management
Surface-Water Hydrologic Units
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2027: Kauapea
2028: Kilauea
2029: Kulihaili
2030: Pilaa
2031: Waipake
2032: Moloaa
2033: Papaa
2034: Aliomanu
2035: Anahola
2036: Kumukumu
2037: Kapaa
2038: Moikeha
2039: Waikaea
Watershed Boundaries
N
W
E
S
0
0.5
1
2
3
4
Miles
ISLAND OF KAUAI
Hydrologic Unit Codes
2027 to 2039

Figure 3-22C

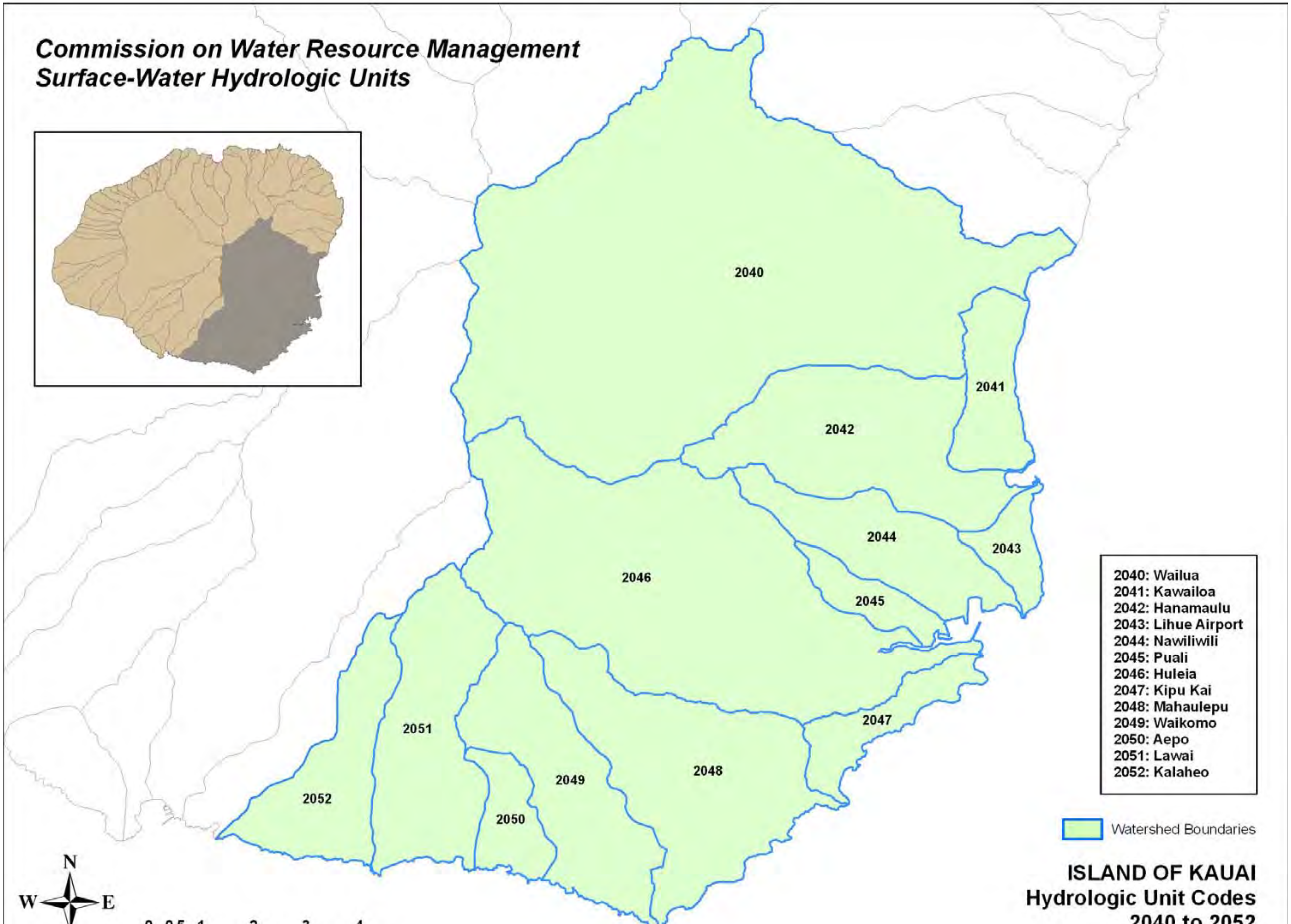
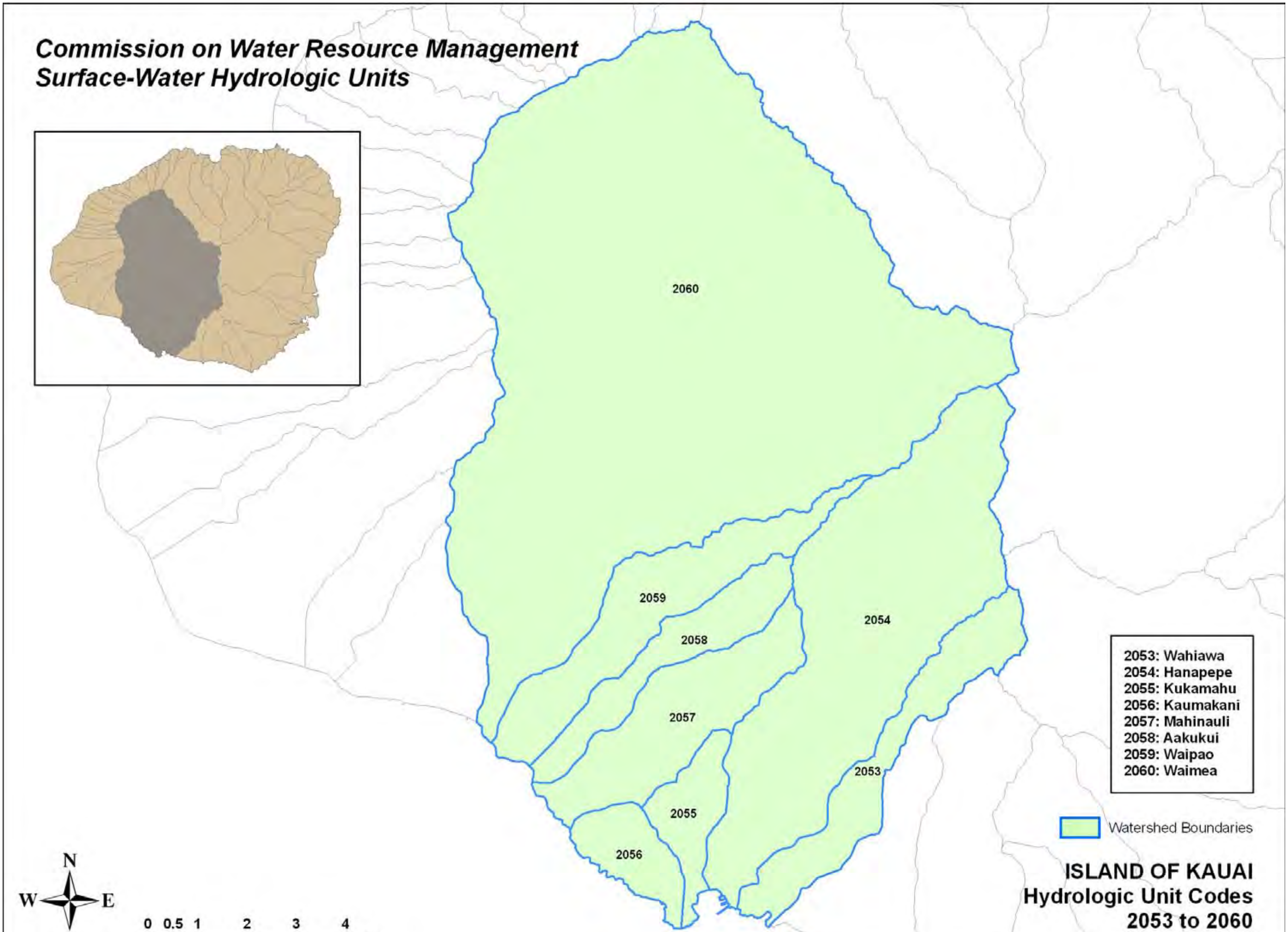
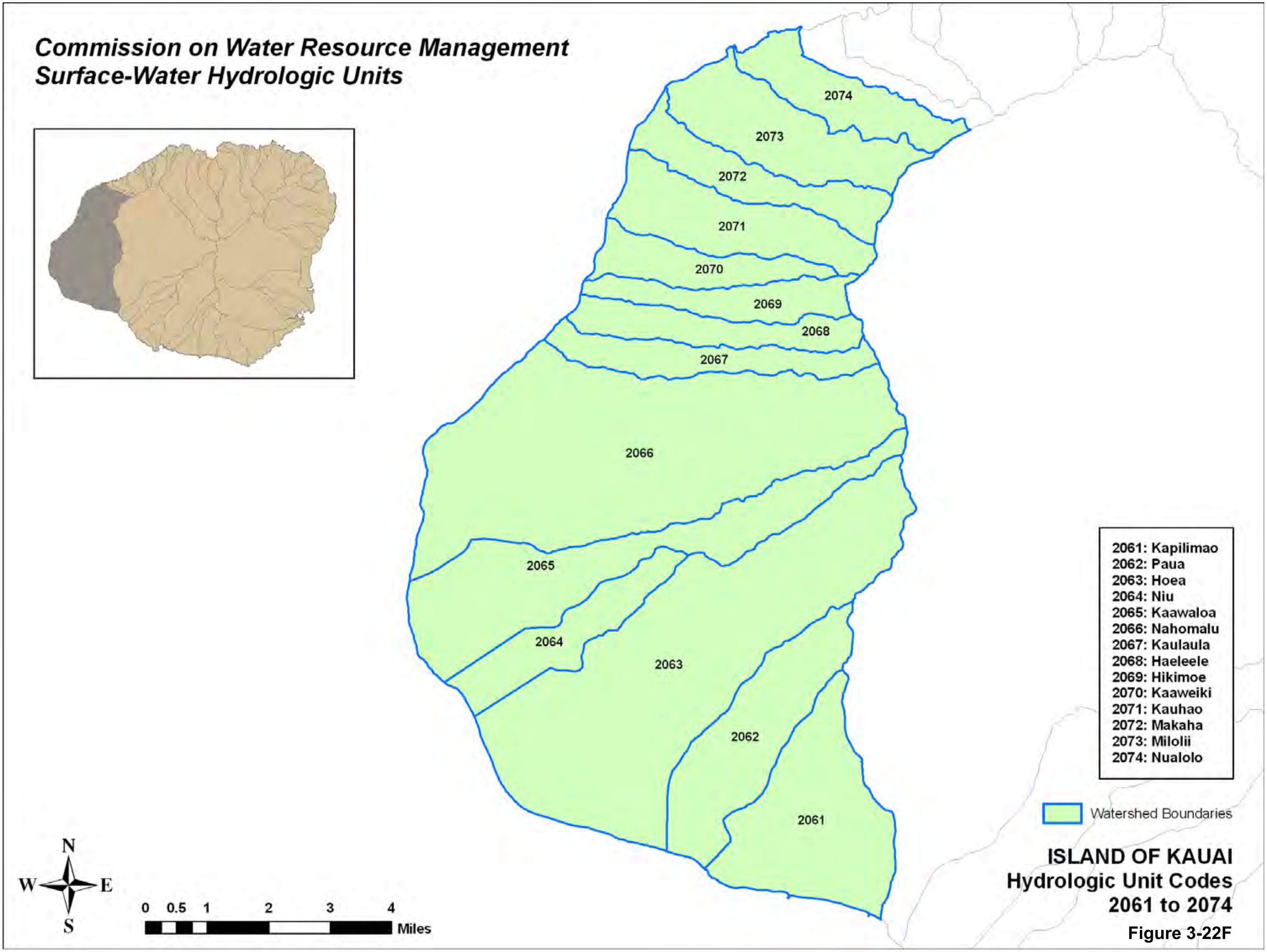

Commission on Water Resource Management
Surface-Water Hydrologic Units
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2040: Wailua
2041: Kawailoa
2042: Hanamaulu
2043: Lihue Airport
2044: Nawiliwili
2045: Puali
2046: Huleia
2047: Kipu Kai
2048: Mahaulepu
2049: Waikomo
2050: Aepo
2051: Lawai
2052: Kalaheo
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF KAUAI
Hydrologic Unit Codes
2040 to 2052

Figure 3-22D



Commission on Water Resource Management
Surface-Water Hydrologic Units
2060
2059
2058
2057
2054
2053
2055
2056
2053: Wahiawa
2054: Hanapepe
2055: Kukamahu
2056: Kaumakani
2057: Mahinauli
2058: Aakukui
2059: Waipao
2060: Waimea
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF KAUAI
Hydrologic Unit Codes
2053 to 2060

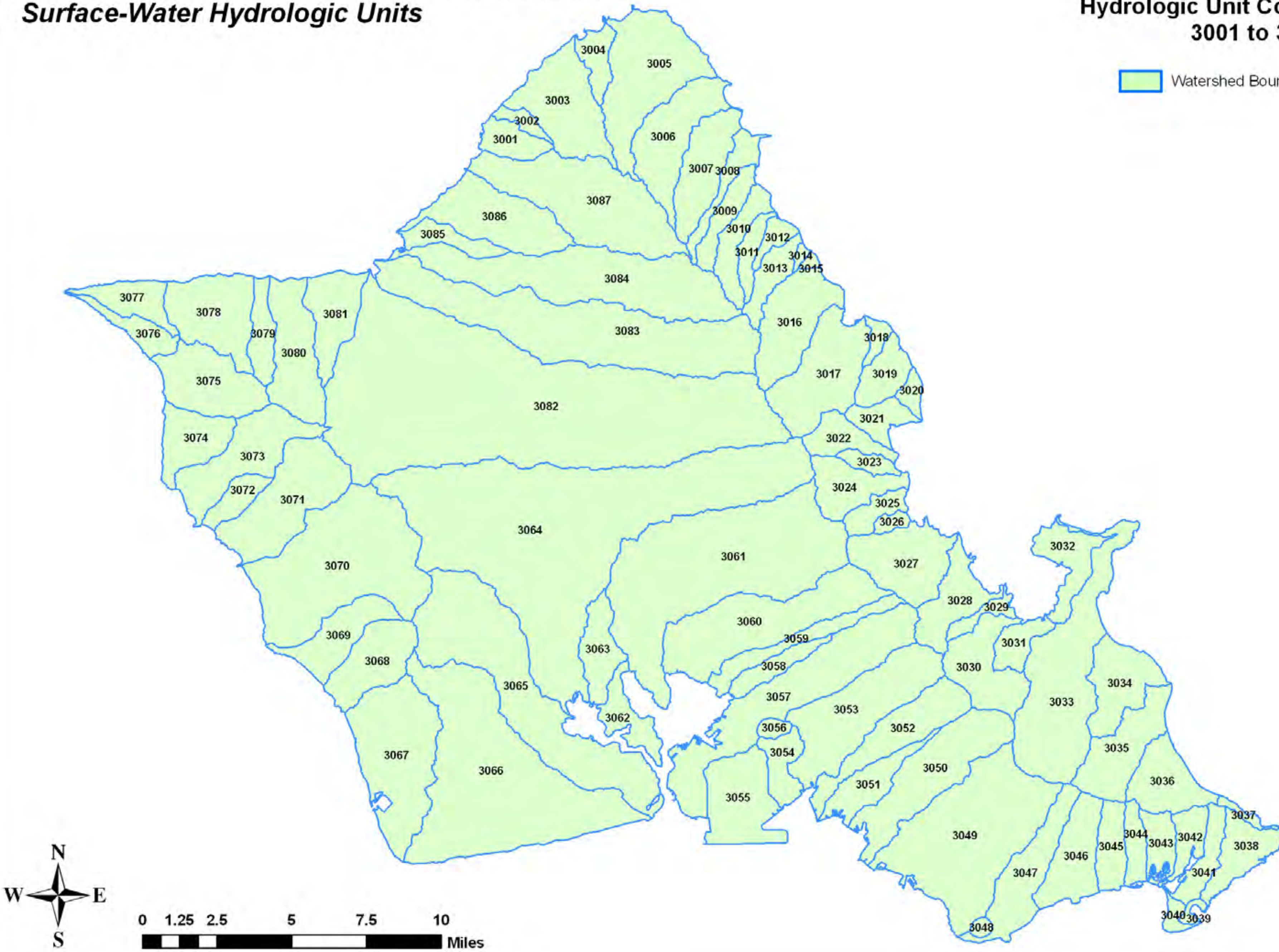
Figure 3-22E


Commission on Water Resource Management
Surface-Water Hydrologic Units
2074
2073
2072
2071
2070
2069
2068
2067
2066
2065
2064
2063
2062
2061
2061: Kapilimao
2062: Paua
2063: Hoea
2064: Niu
2065: Kaawaloa
2066: Nahomalu
2067: Kaulaula
2068: Haeleele
2069: Hikimoe
2070: Kaaweiki
2071: Kauhao
2072: Makaha
2073: Milolii
2074: Nualolo
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF KAUAI
Hydrologic Unit Codes
2061 to 2074
Figure 3-22F

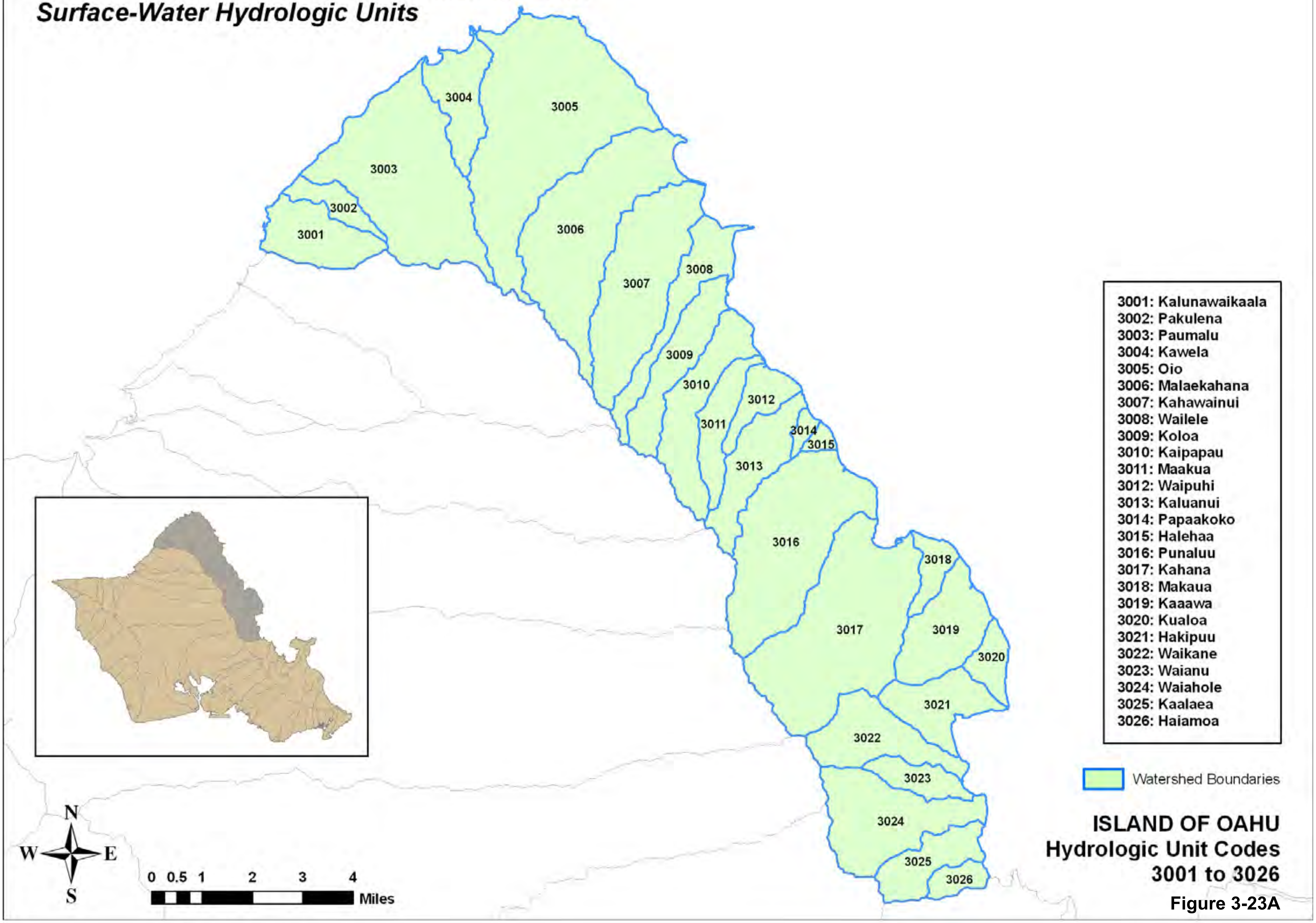
Commission on Water Resource Management
Surface-Water Hydrologic Units

Figure 3-23

ISLAND OF OAHU
Hydrologic Unit Codes
3001 to 3087

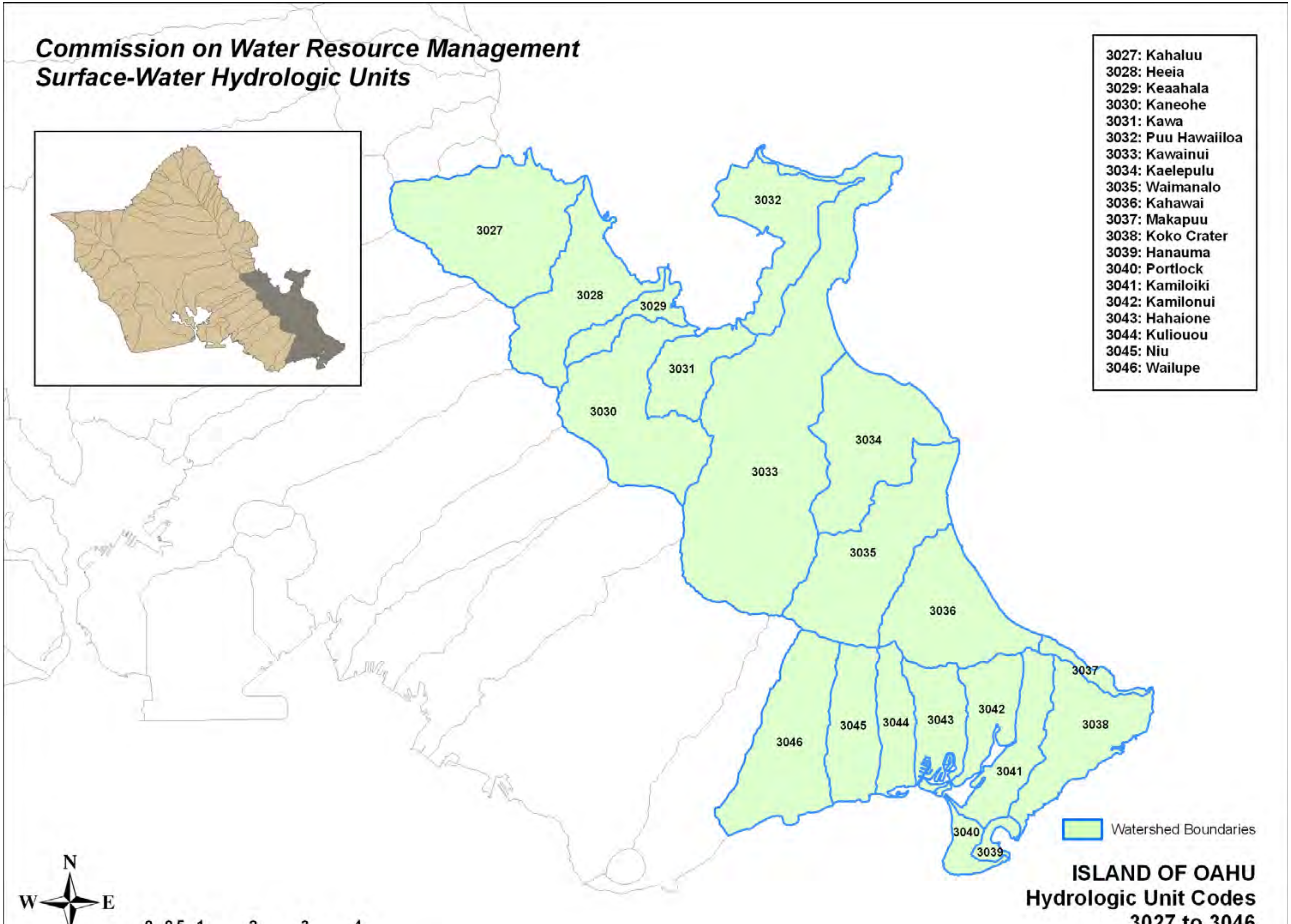


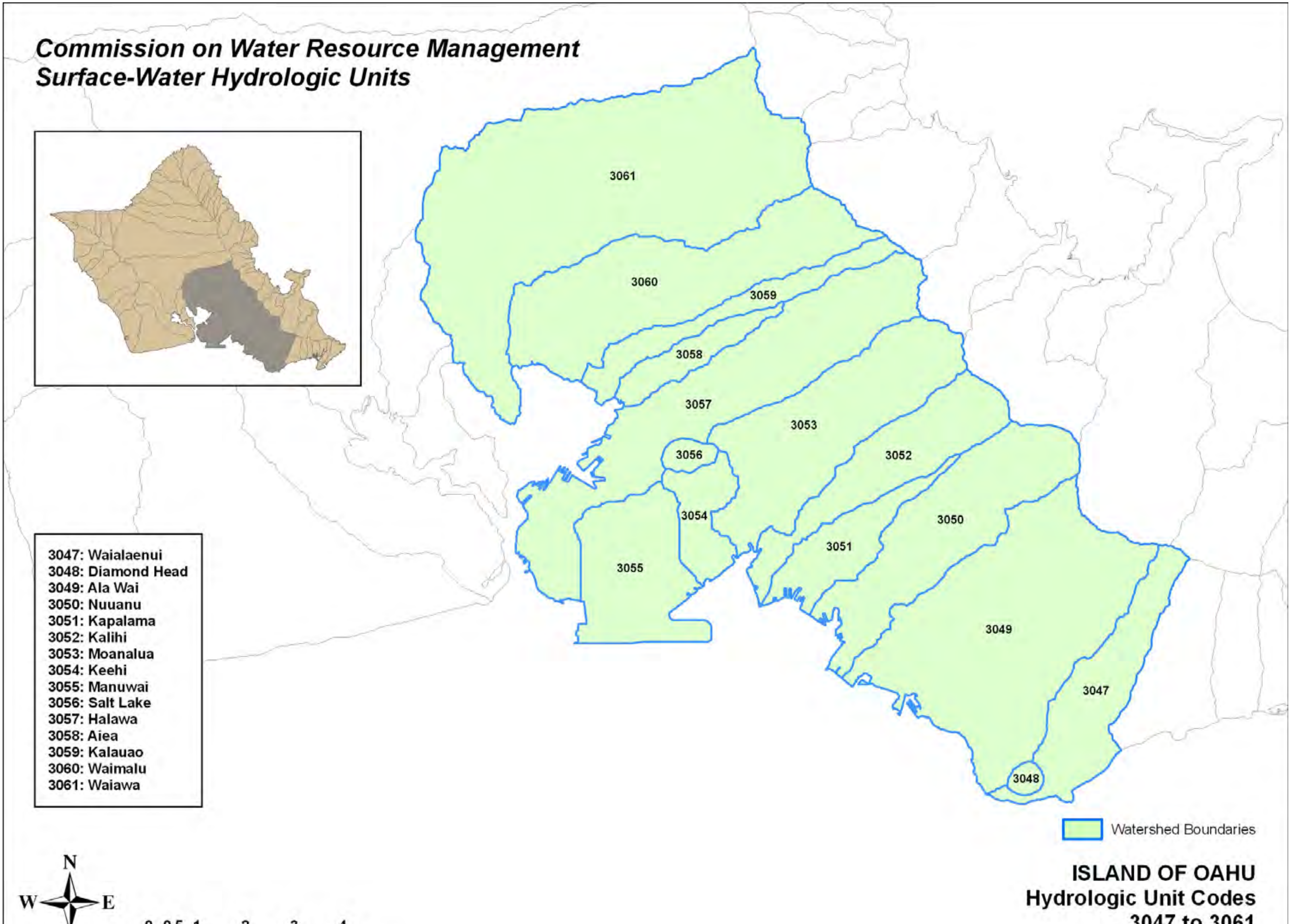
Commission on Water Resource Management
Surface-Water Hydrologic Units



ISLAND OF OAHU
Hydrologic Unit Codes
3001 to 3026

Figure 3-23A


Commission on Water Resource Management
Surface-Water Hydrologic Units
3027: Kahaluu
3028: Heeia
3029: Keaahala
3030: Kaneohe
3031: Kawa
3032: Puu Hawaiiloa
3033: Kawainui
3034: Kaelepulu
3035: Waimanalo
3036: Kahawai
3037: Makapuu
3038: Koko Crater
3039: Hanauma
3040: Portlock
3041: Kamiloiki
3042: Kamilonui
3043: Hahaione
3044: Kuliouou
3045: Niu
3046: Wailupe
3027
3028
3029
3030
3031
3032
3033
3034
3035
3036
3037
3038
3039
3040
3041
3042
3043
3044
3045
3046
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF OAHU
Hydrologic Unit Codes
3027 to 3046
Figure 3-23B


Commission on Water Resource Management
Surface-Water Hydrologic Units
3061
3060
3059
3058
3057
3056
3053
3052
3054
3055
3051
3050
3049
3047
3048
3047: Waialaenui
3048: Diamond Head
3049: Ala Wai
3050: Nuuanu
3051: Kapalama
3052: Kalihi
3053: Moanalua
3054: Keehi
3055: Manuwai
3056: Salt Lake
3057: Halawa
3058: Aiea
3059: Kalauao
3060: Waimalu
3061: Waiawa
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF OAHU
Hydrologic Unit Codes
3047 to 3061
Figure 3-23C

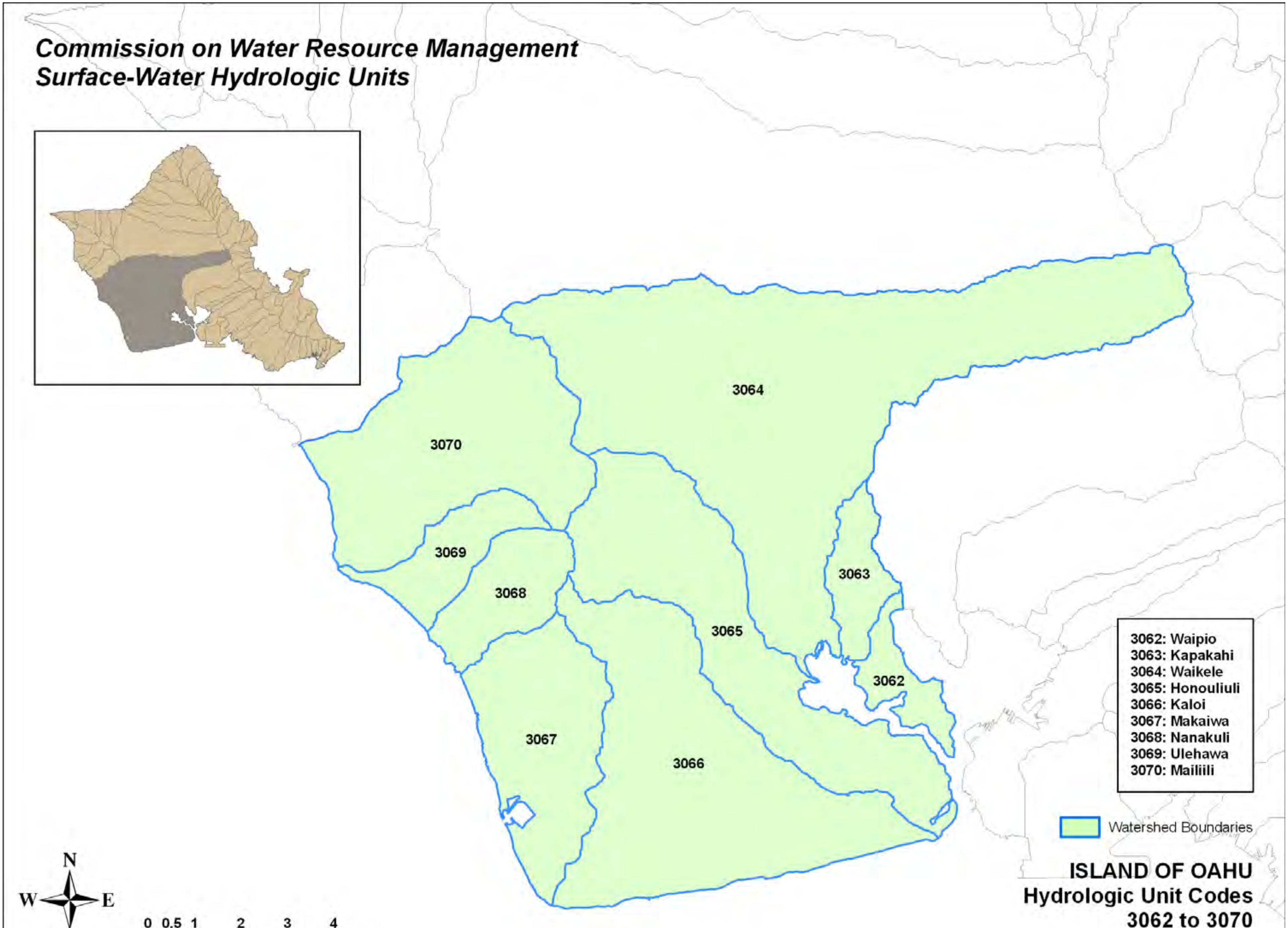
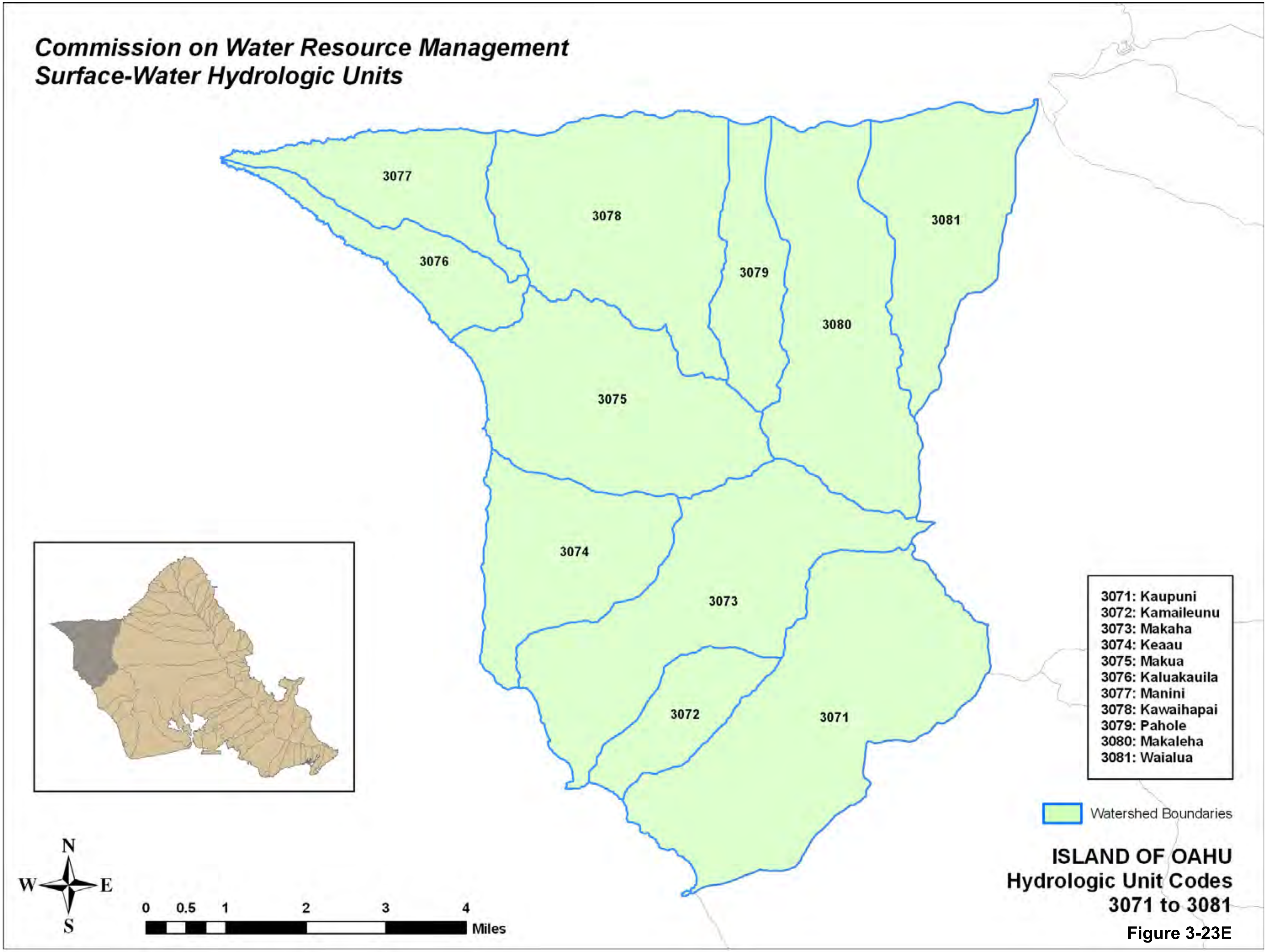
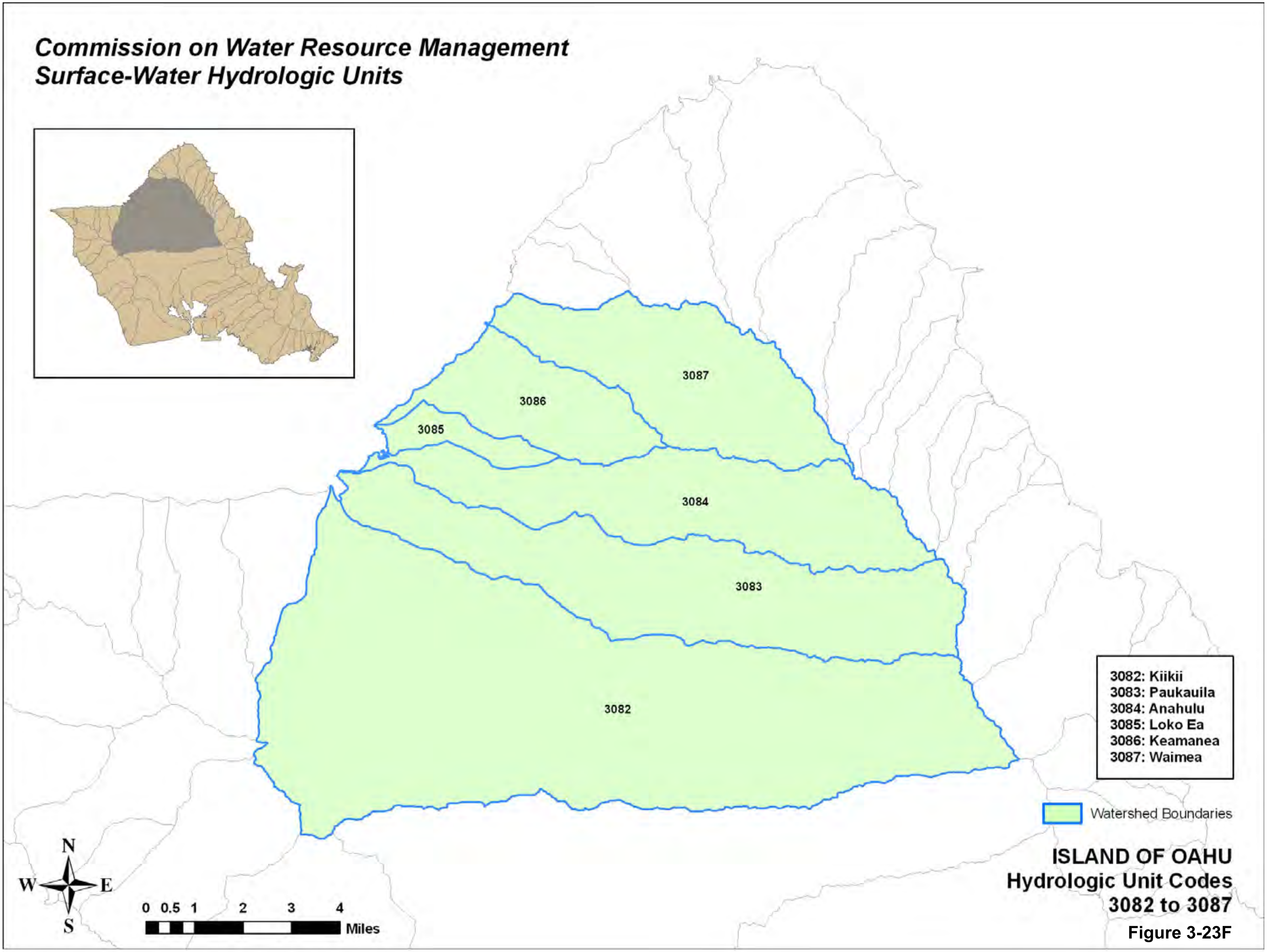
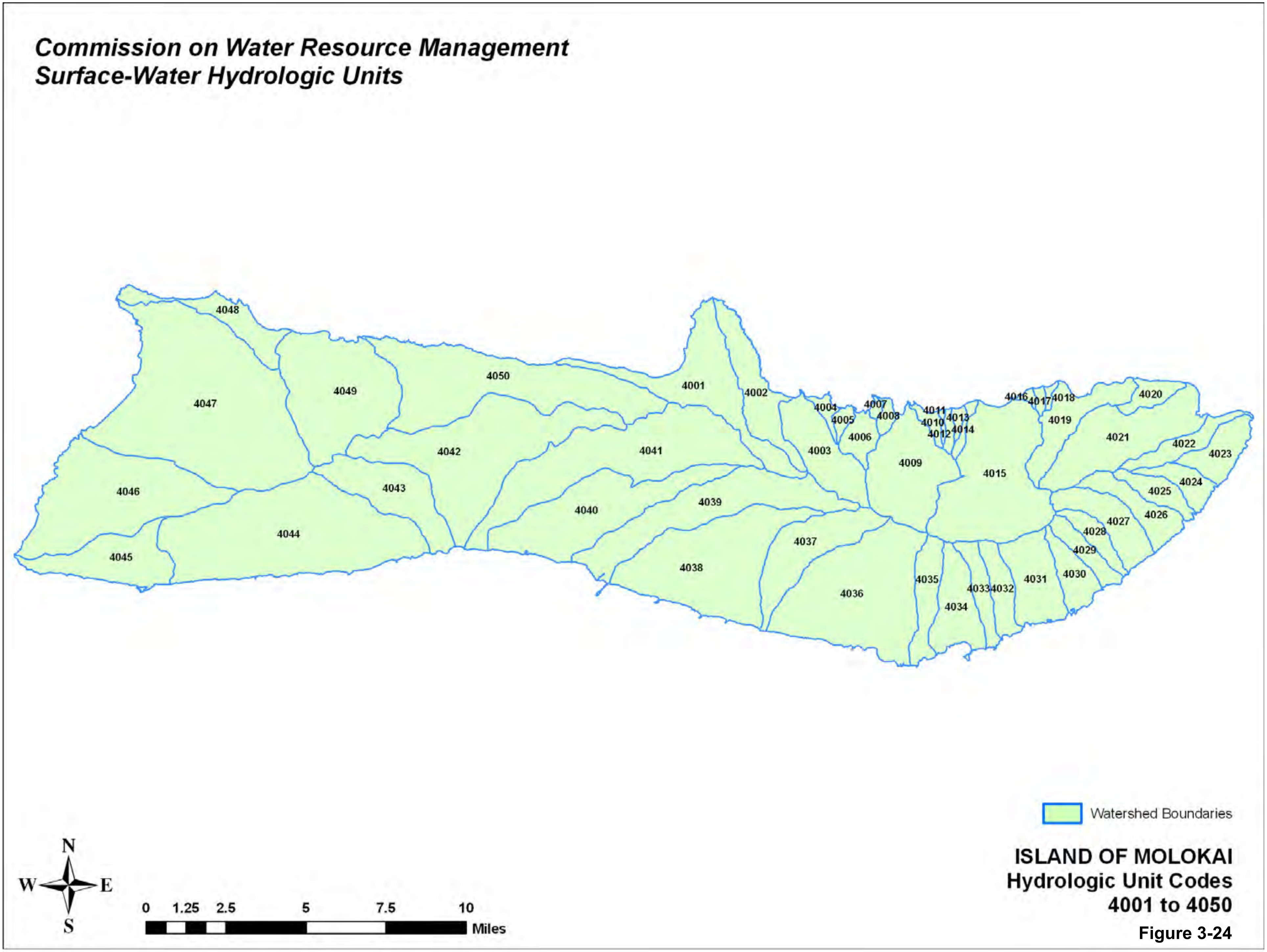

Commission on Water Resource Management
Surface-Water Hydrologic Units
3064
3070
3069
3068
3063
3065
3062
3067
3066
3062: Waipio
3063: Kapakahi
3064: Waikele
3065: Honouliuli
3066: Kaloi
3067: Makaiwa
3068: Nanakuli
3069: Ulehawa
3070: Mailiili
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF OAHU
Hydrologic Unit Codes
3062 to 3070

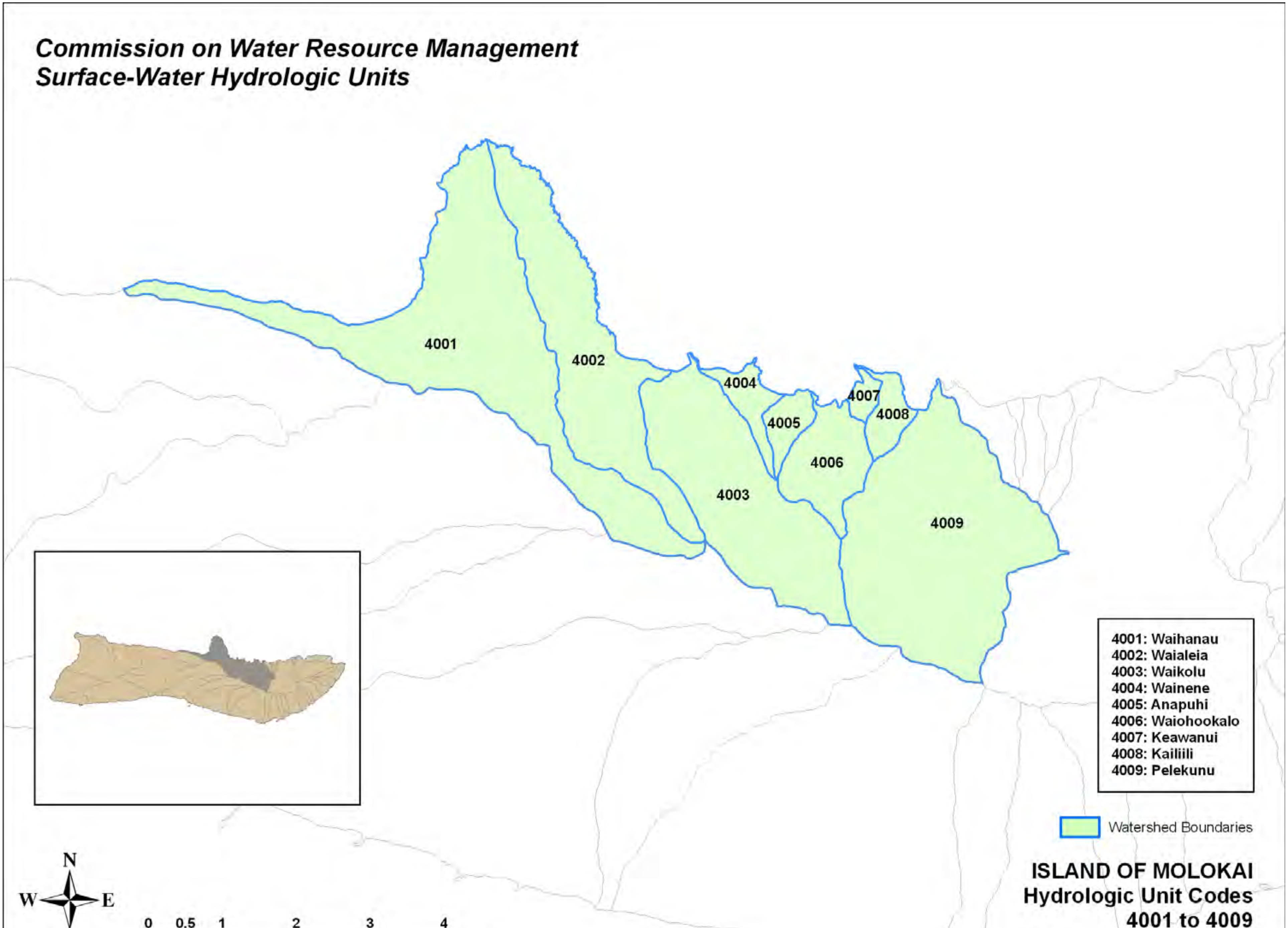
Figure 3-23D


Commission on Water Resource Management
Surface-Water Hydrologic Units
3077
3078
3081
3076
3079
3080
3075
3074
3073
3072
3071
3071: Kaupuni
3072: Kamaileunu
3073: Makaha
3074: Keaau
3075: Makua
3076: Kaluakauila
3077: Manini
3078: Kawaihapai
3079: Pahole
3080: Makaleha
3081: Waialua
Watershed Boundaries
N
W
E
S
0
0.5
1
2
3
4
Miles
ISLAND OF OAHU
Hydrologic Unit Codes
3071 to 3081
Figure 3-23E


Commission on Water Resource Management
Surface-Water Hydrologic Units
3087
3086
3085
3084
3083
3082
3082: Kiikii
3083: Paukauila
3084: Anahulu
3085: Loko Ea
3086: Keamanea
3087: Waimea
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF OAHU
Hydrologic Unit Codes
3082 to 3087
Figure 3-23F



ISLAND OF MOLOKAI
Hydrologic Unit Codes
4001 to 4050
Figure 3-24


Commission on Water Resource Management
Surface-Water Hydrologic Units
4001
4002
4003
4004
4005
4006
4007
4008
4009
4001: Waihanau
4002: Waialeia
4003: Waikolu
4004: Wainene
4005: Anapuhi
4006: Waiohookalo
4007: Keawanui
4008: Kailiili
4009: Pelekunu
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MOLOKAI
Hydrologic Unit Codes
4001 to 4009
Figure 3-24A

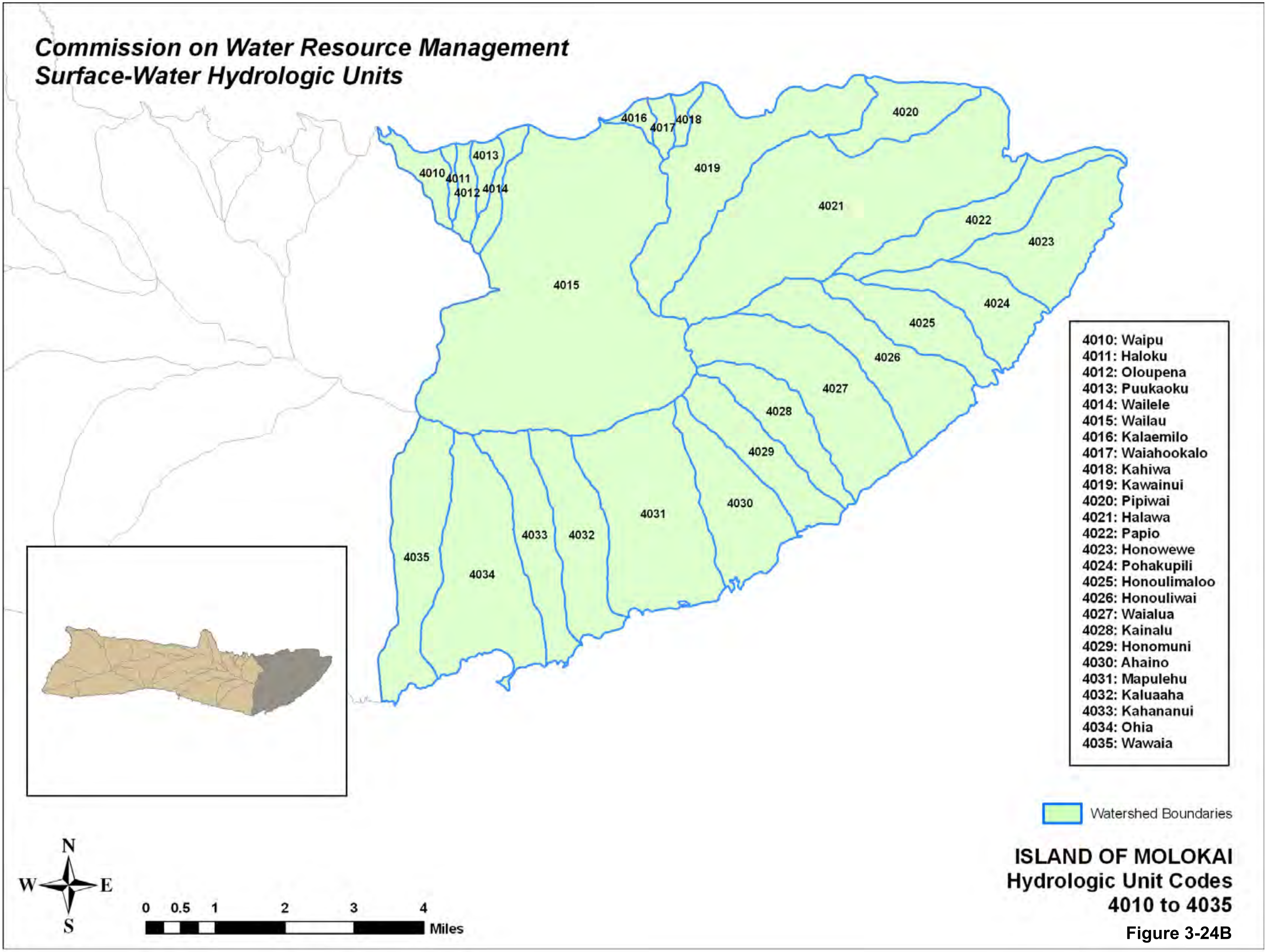
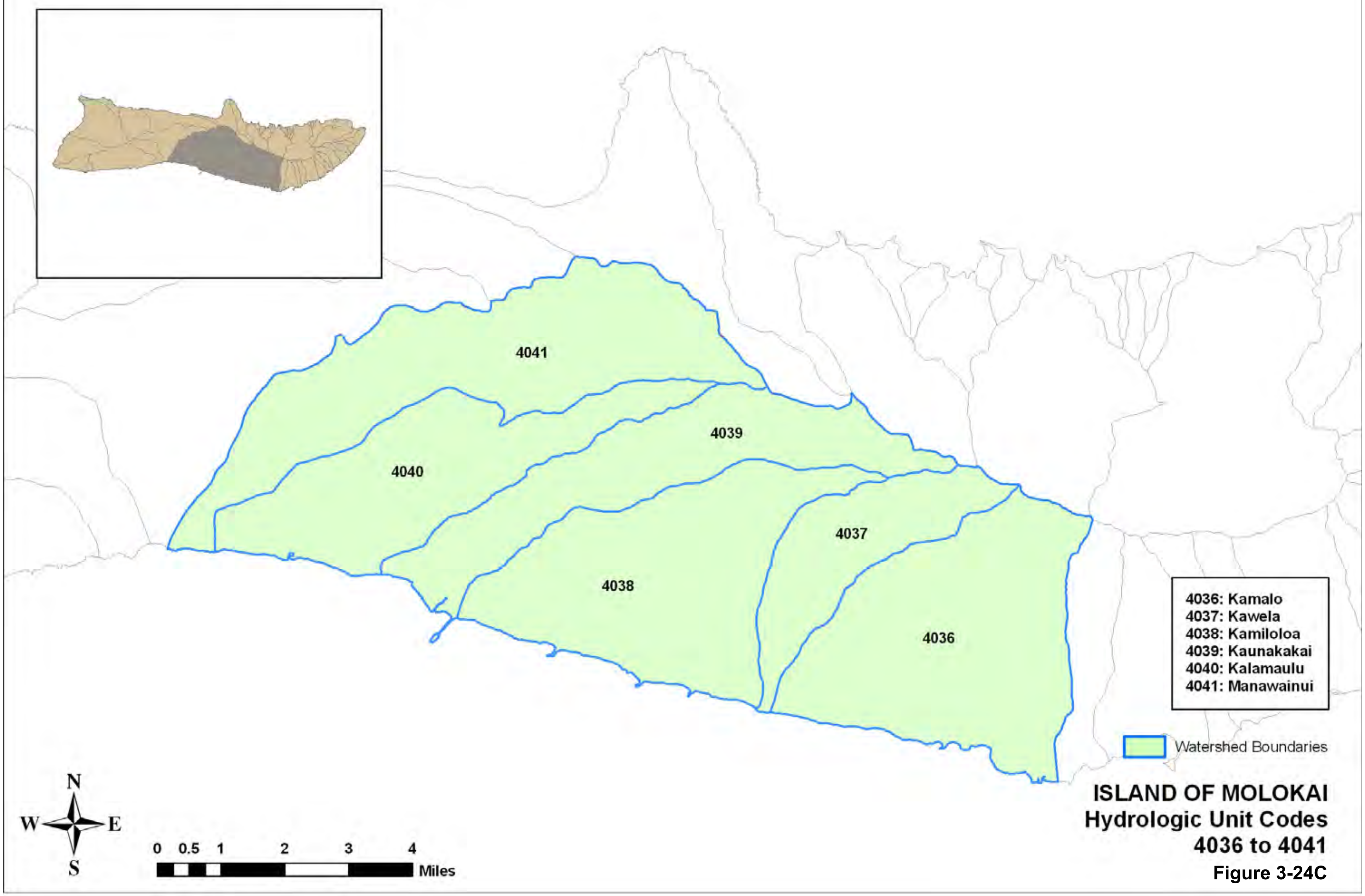

Commission on Water Resource Management
Surface-Water Hydrologic Units
4010
4011
4012
4013
4014
4015
4016
4017
4018
4019
4020
4021
4022
4023
4024
4025
4026
4027
4028
4029
4030
4031
4032
4033
4034
4035
4010: Waipu
4011: Haloku
4012: Oloupena
4013: Puukaoku
4014: Wailele
4015: Wailau
4016: Kalaemilo
4017: Waiahookalo
4018: Kahiwa
4019: Kawainui
4020: Pipiwai
4021: Halawa
4022: Papio
4023: Honowewe
4024: Pohakupili
4025: Honoulimaloo
4026: Honouliwai
4027: Waialua
4028: Kainalu
4029: Honomuni
4030: Ahaino
4031: Mapulehu
4032: Kaluaaha
4033: Kahananui
4034: Ohia
4035: Wawaia
Watershed Boundaries
N
W
E
S
0
0.5
1
2
3
4
Miles
ISLAND OF MOLOKAI
Hydrologic Unit Codes
4010 to 4035

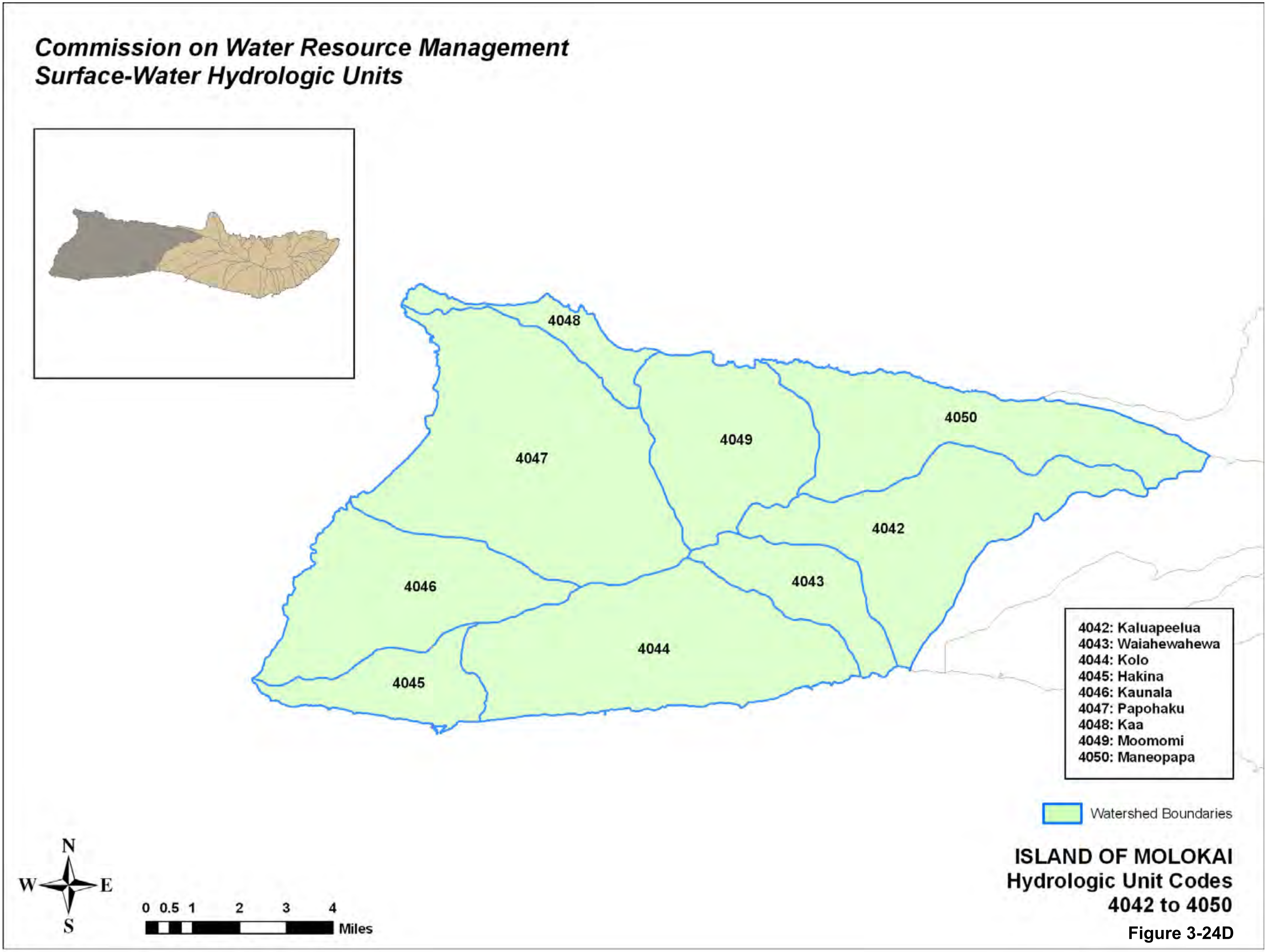
Figure 3-24B

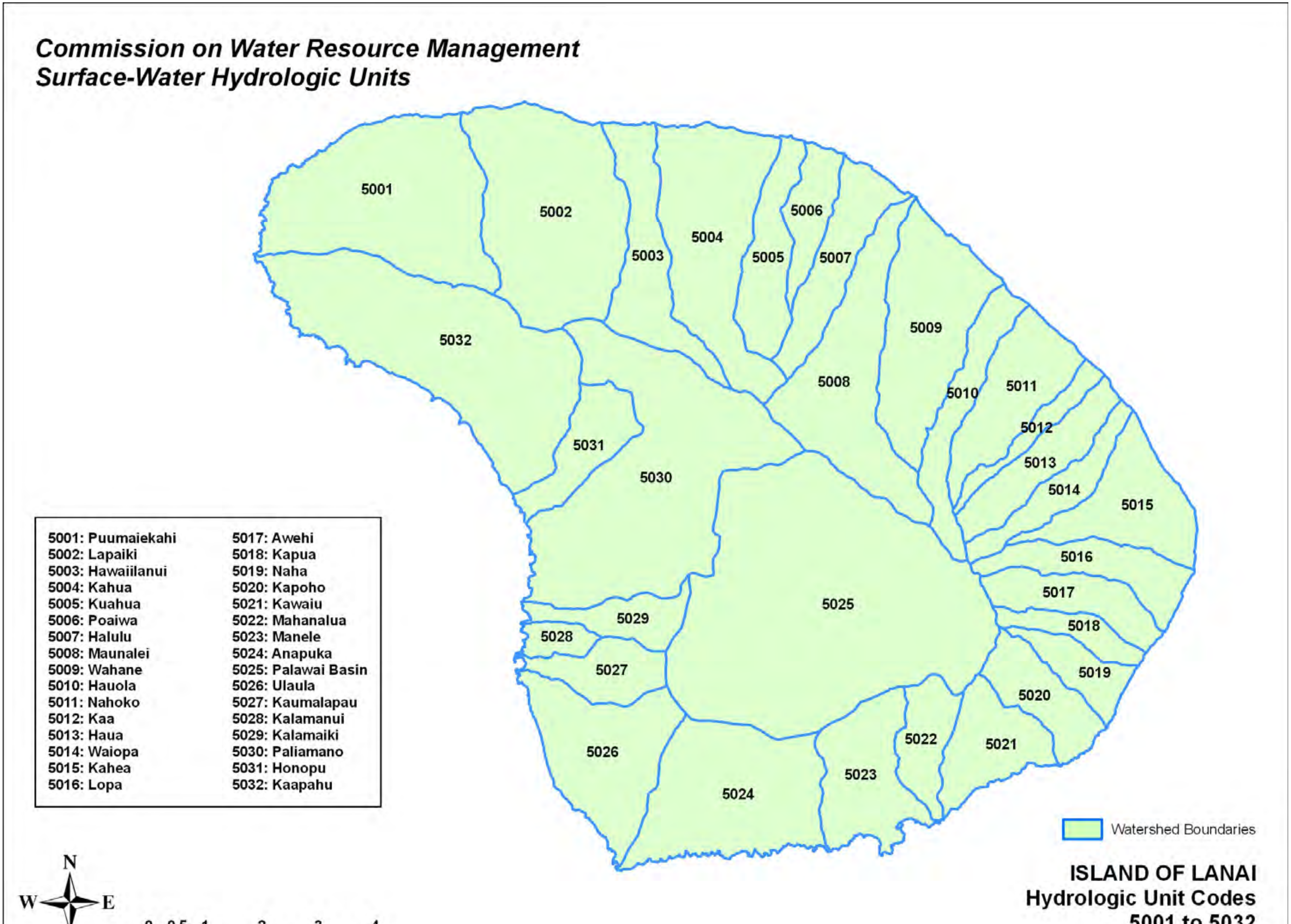
Commission on Water Resource Management
Surface-Water Hydrologic Units



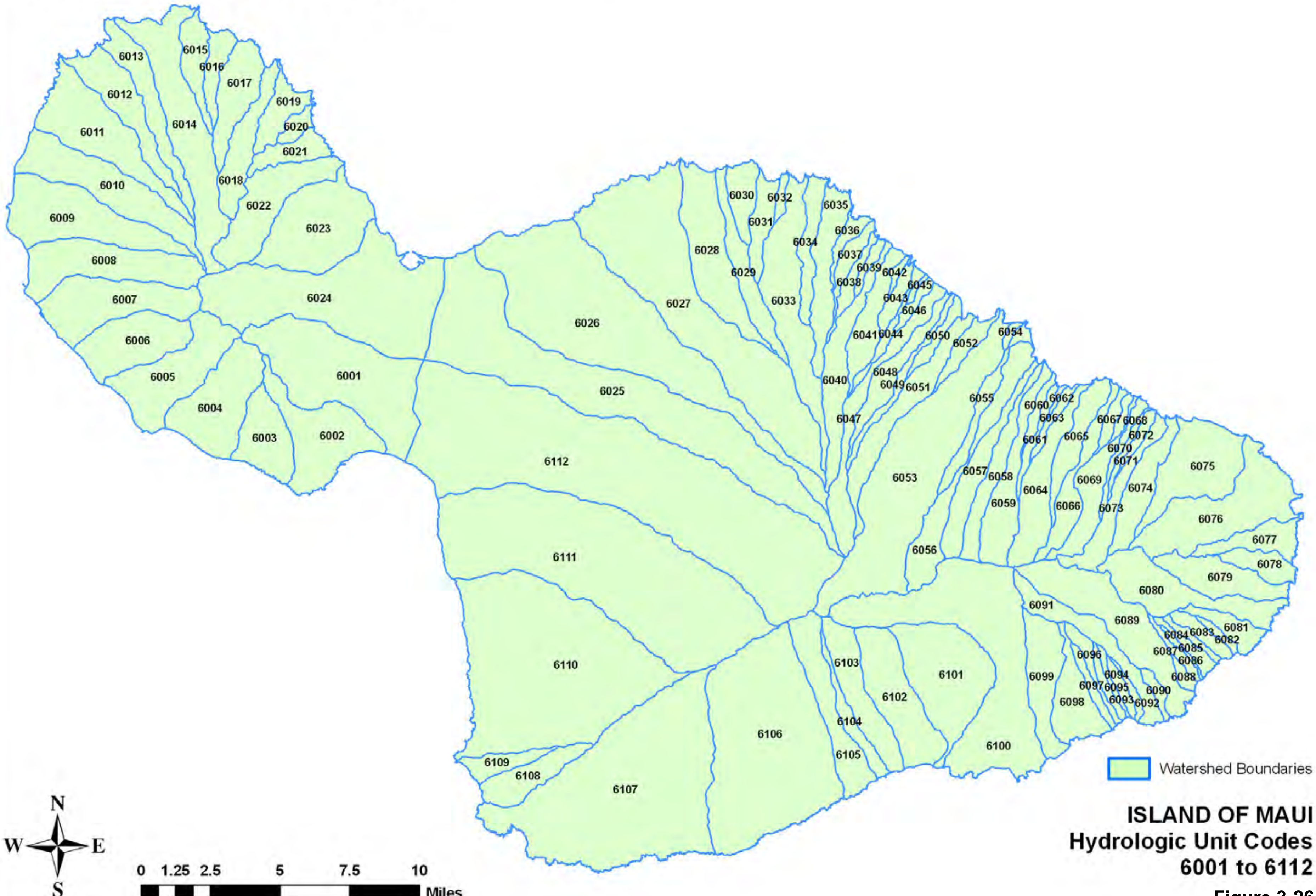
ISLAND OF MOLOKAI
Hydrologic Unit Codes
4036 to 4041

Figure 3-24C


Commission on Water Resource Management
Surface-Water Hydrologic Units
4042
4043
4044
4045
4046
4047
4048
4049
4050
4042: Kaluapeelua
4043: Waiahewahewa
4044: Kolo
4045: Hakina
4046: Kaunala
4047: Papohaku
4048: Kaa
4049: Moomomi
4050: Maneopapa
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MOLOKAI
Hydrologic Unit Codes
4042 to 4050
Figure 3-24D

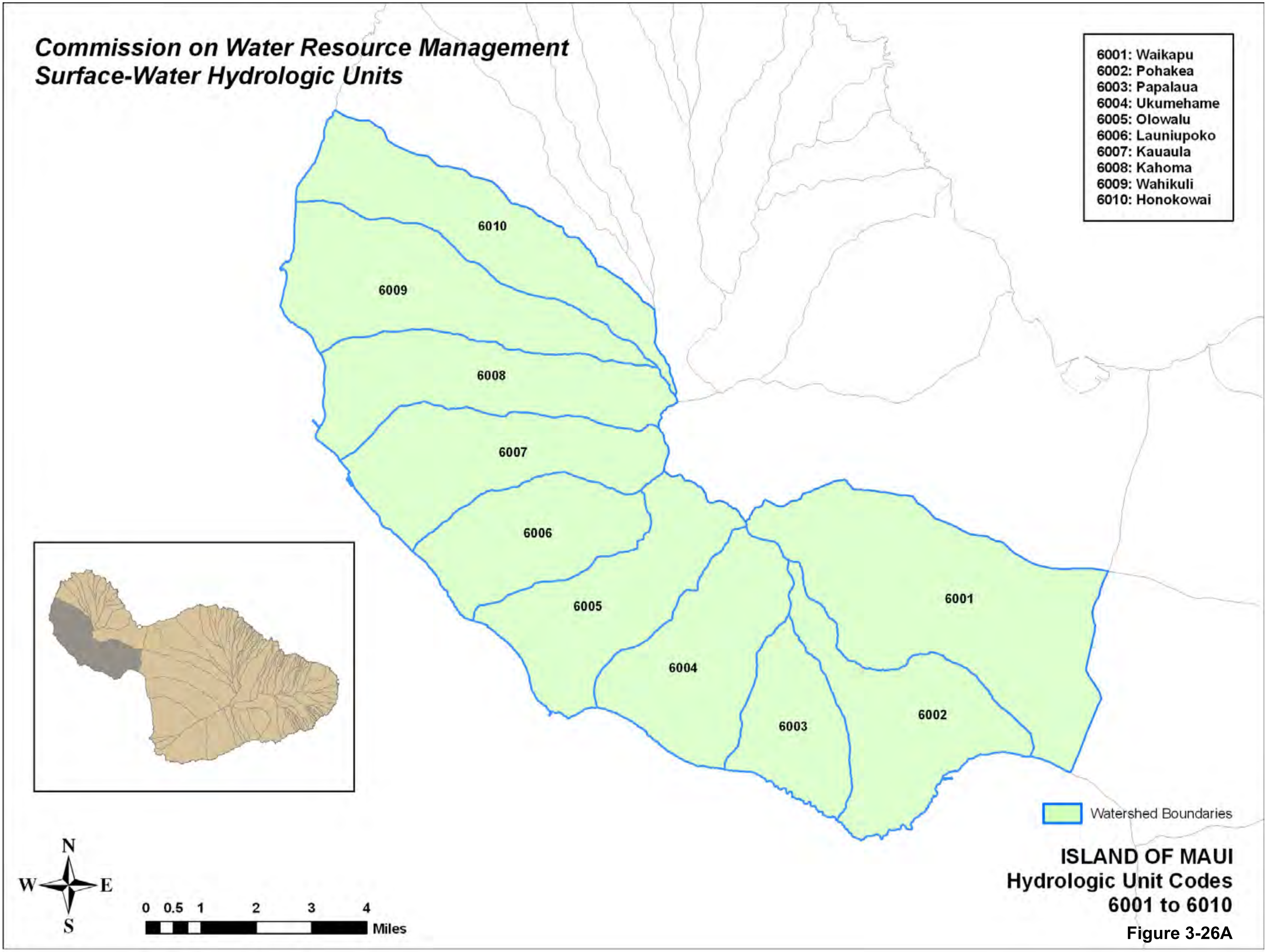

Commission on Water Resource Management
Surface-Water Hydrologic Units
5001
5002
5003
5004
5005
5006
5007
5008
5009
5010
5011
5012
5013
5014
5015
5016
5017
5018
5019
5020
5021
5022
5023
5024
5025
5026
5027
5028
5029
5030
5031
5032
5001: Puumaiekahi
5002: Lapaiki
5003: Hawaiilanui
5004: Kahua
5005: Kuahua
5006: Poaiwa
5007: Halulu
5008: Maunalei
5009: Wahane
5010: Hauola
5011: Nahoko
5012: Kaa
5013: Haua
5014: Waiopa
5015: Kahea
5016: Lopa
5017: Awehi
5018: Kapua
5019: Naha
5020: Kapoho
5021: Kawaiu
5022: Mahanalua
5023: Manele
5024: Anapuka
5025: Palawai Basin
5026: Ulaula
5027: Kaumalapau
5028: Kalamanui
5029: Kalamaiki
5030: Paliamano
5031: Honopu
5032: Kaapahu
N
W
E
S
0 0.5 1 2 3 4
Miles
Watershed Boundaries
ISLAND OF LANAI
Hydrologic Unit Codes
5001 to 5032
Figure 3-25

Commission on Water Resource Management
Surface-Water Hydrologic Units



ISLAND OF MAUI
Hydrologic Unit Codes
6001 to 6112

Figure 3-26


Commission on Water Resource Management
Surface-Water Hydrologic Units
6001: Waikapu
6002: Pohakea
6003: Papalaua
6004: Ukumehame
6005: Olowalu
6006: Launiupoko
6007: Kauaula
6008: Kahoma
6009: Wahikuli
6010: Honokowai
6010
6009
6008
6007
6006
6005
6004
6003
6002
6001
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4 Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6001 to 6010
Figure 3-26A

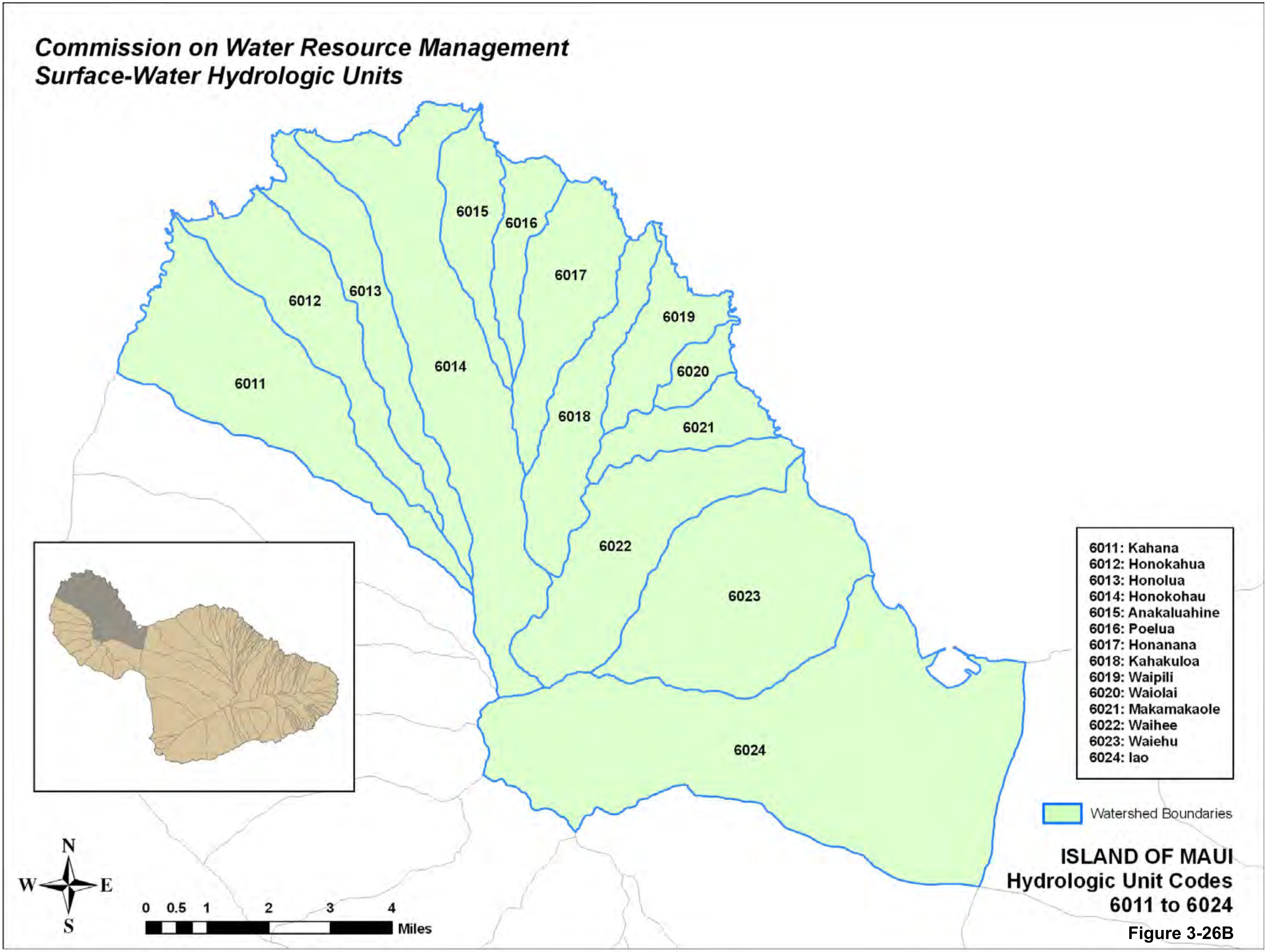
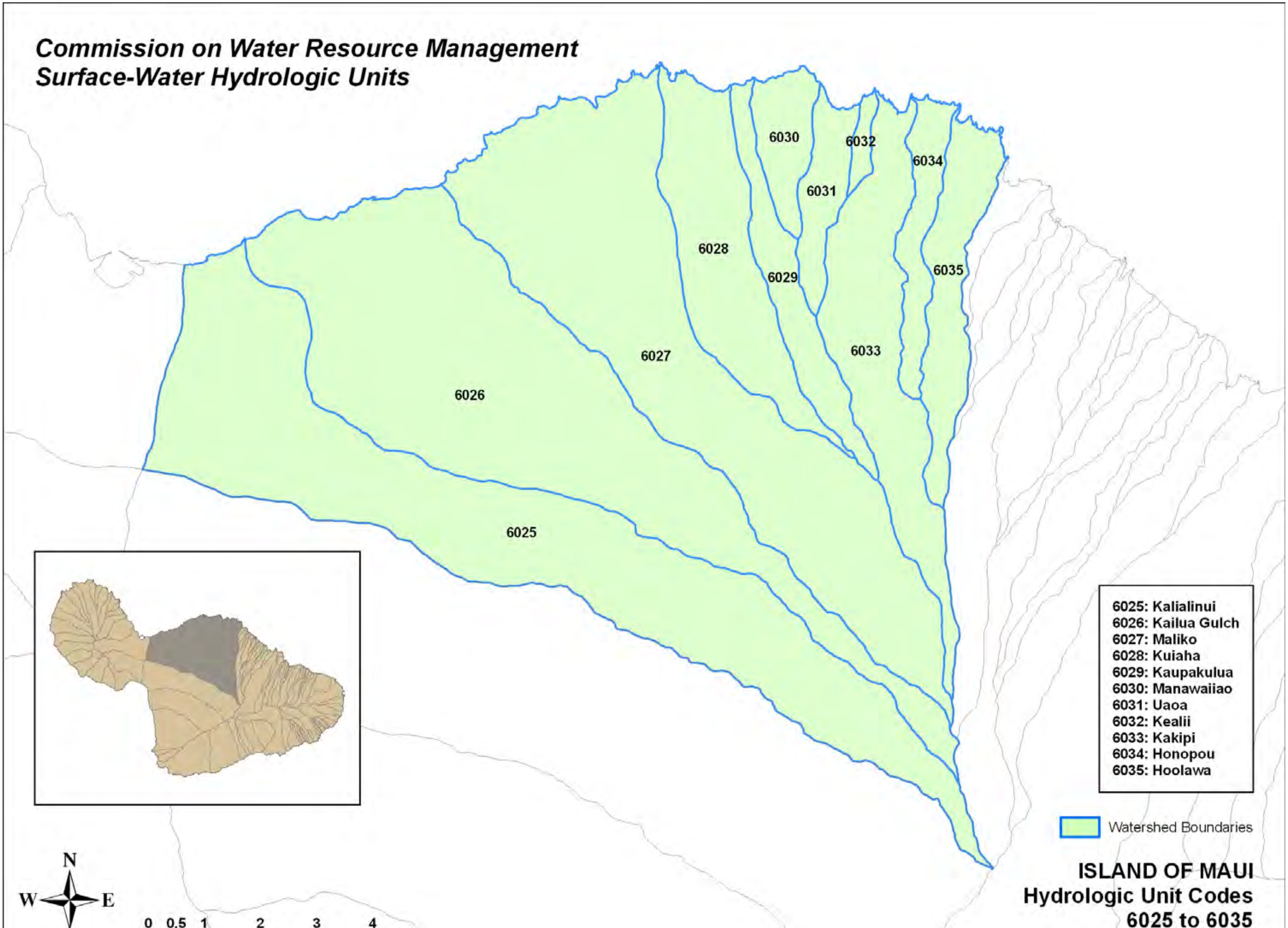

Commission on Water Resource Management
Surface-Water Hydrologic Units
6011
6012
6013
6014
6015
6016
6017
6018
6019
6020
6021
6022
6023
6024
6011: Kahana
6012: Honokahua
6013: Honolua
6014: Honokohau
6015: Anakaluahine
6016: Poelua
6017: Honanana
6018: Kahakuloa
6019: Waipili
6020: Waiolai
6021: Makamakaole
6022: Waihee
6023: Waiehu
6024: Iao
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6011 to 6024

Figure 3-26B


Commission on Water Resource Management
Surface-Water Hydrologic Units
6025
6026
6027
6028
6029
6030
6031
6032
6033
6034
6035
6025: Kalialinui
6026: Kailua Gulch
6027: Maliko
6028: Kuiaha
6029: Kaupakulua
6030: Manawaiiao
6031: Uaoa
6032: Kealii
6033: Kakipi
6034: Honopou
6035: Hoolawa
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6025 to 6035
Figure 3-26C

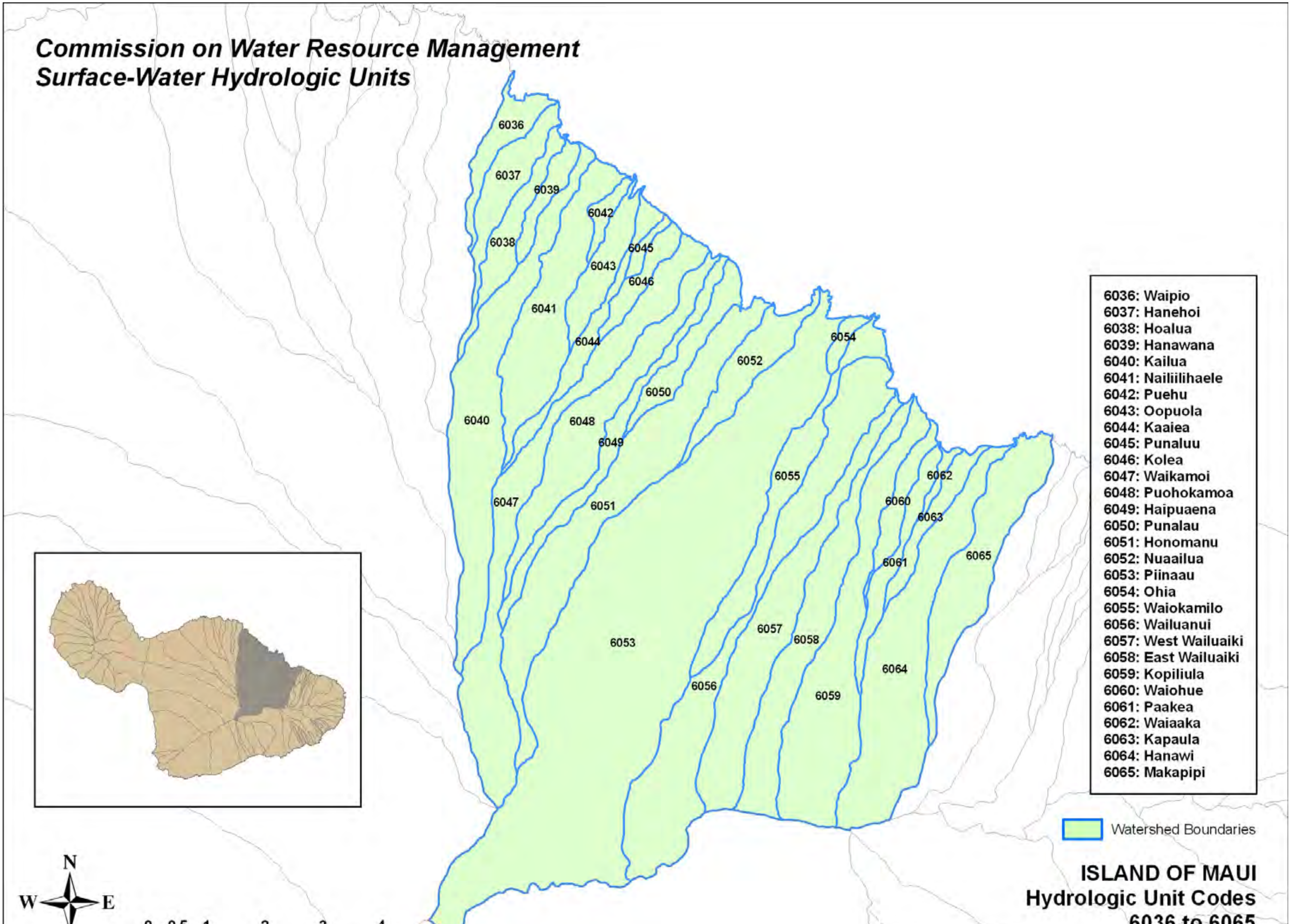
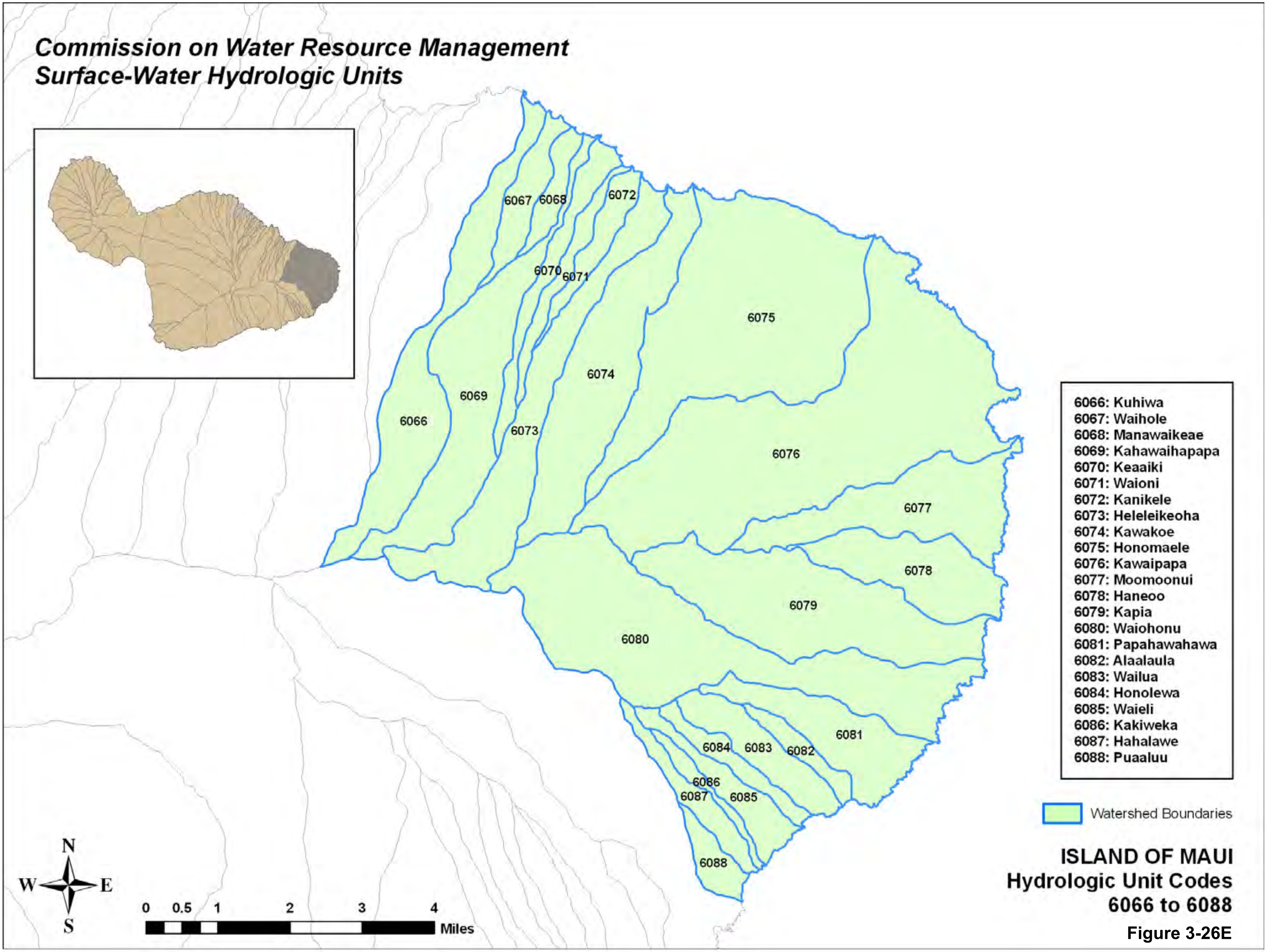

Commission on Water Resource Management
Surface-Water Hydrologic Units
6036
6037
6039
6042
6038
6045
6043
6046
6041
6044
6052
6054
6050
6040
6048
6049
6055
6062
6047
6051
6060
6063
6065
6061
6057
6053
6058
6064
6056
6059
6036: Waipio
6037: Hanehoi
6038: Hoalua
6039: Hanawana
6040: Kailua
6041: Nailiilihaele
6042: Puehu
6043: Oopuola
6044: Kaaiea
6045: Punaluu
6046: Kolea
6047: Waikamoi
6048: Puohokamoa
6049: Haipuaena
6050: Punalau
6051: Honomanu
6052: Nuaailua
6053: Piinaau
6054: Ohia
6055: Waiokamilo
6056: Wailuanui
6057: West Wailuaiki
6058: East Wailuaiki
6059: Kopiliula
6060: Waiohue
6061: Paakea
6062: Waiaaka
6063: Kapaula
6064: Hanawi
6065: Makapipi
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6036 to 6065

Figure 3-26D


Commission on Water Resource Management
Surface-Water Hydrologic Units
6066
6067
6068
6069
6070
6071
6072
6073
6074
6075
6076
6077
6078
6079
6080
6081
6082
6083
6084
6085
6086
6087
6088
6066: Kuhiwa
6067: Waihole
6068: Manawaikeae
6069: Kahawaihapapa
6070: Keaaiki
6071: Waioni
6072: Kanikele
6073: Heleleikeoha
6074: Kawakoe
6075: Honomaele
6076: Kawaipapa
6077: Moomoonui
6078: Haneoo
6079: Kapia
6080: Waiohonu
6081: Papahawahawa
6082: Alaalaula
6083: Wailua
6084: Honolewa
6085: Waieli
6086: Kakiweka
6087: Hahalawe
6088: Puaaluu
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6066 to 6088
Figure 3-26E

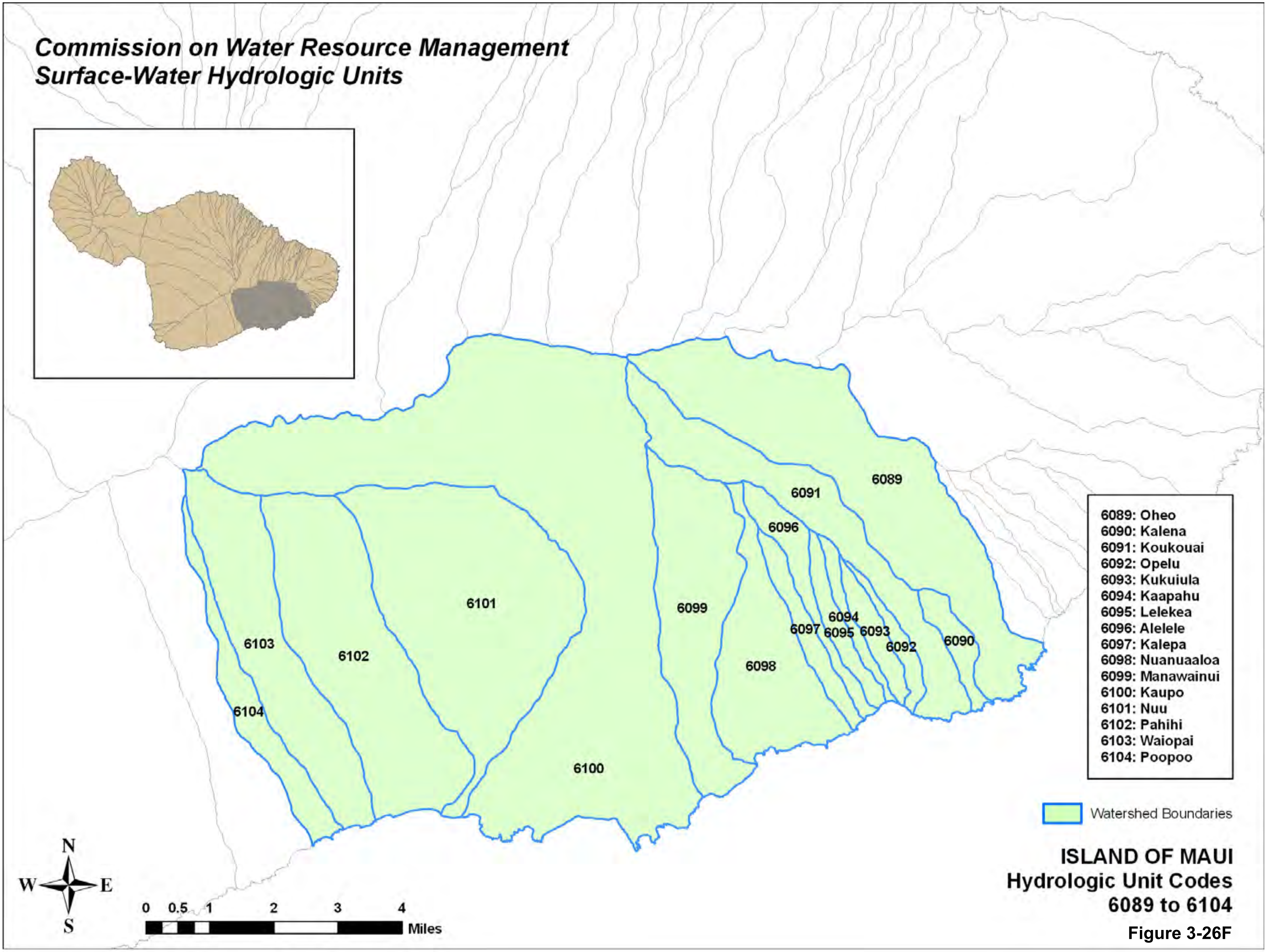
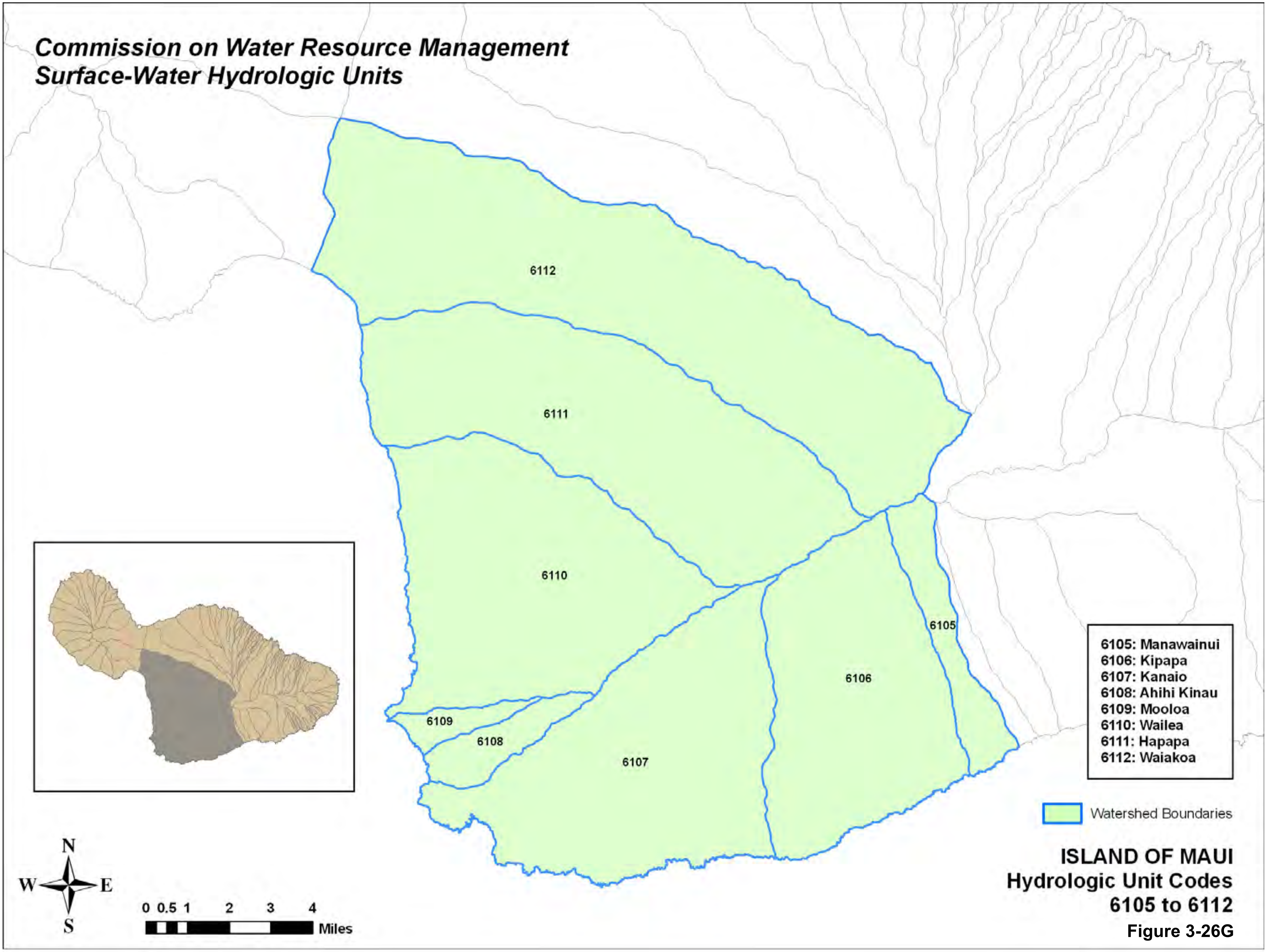
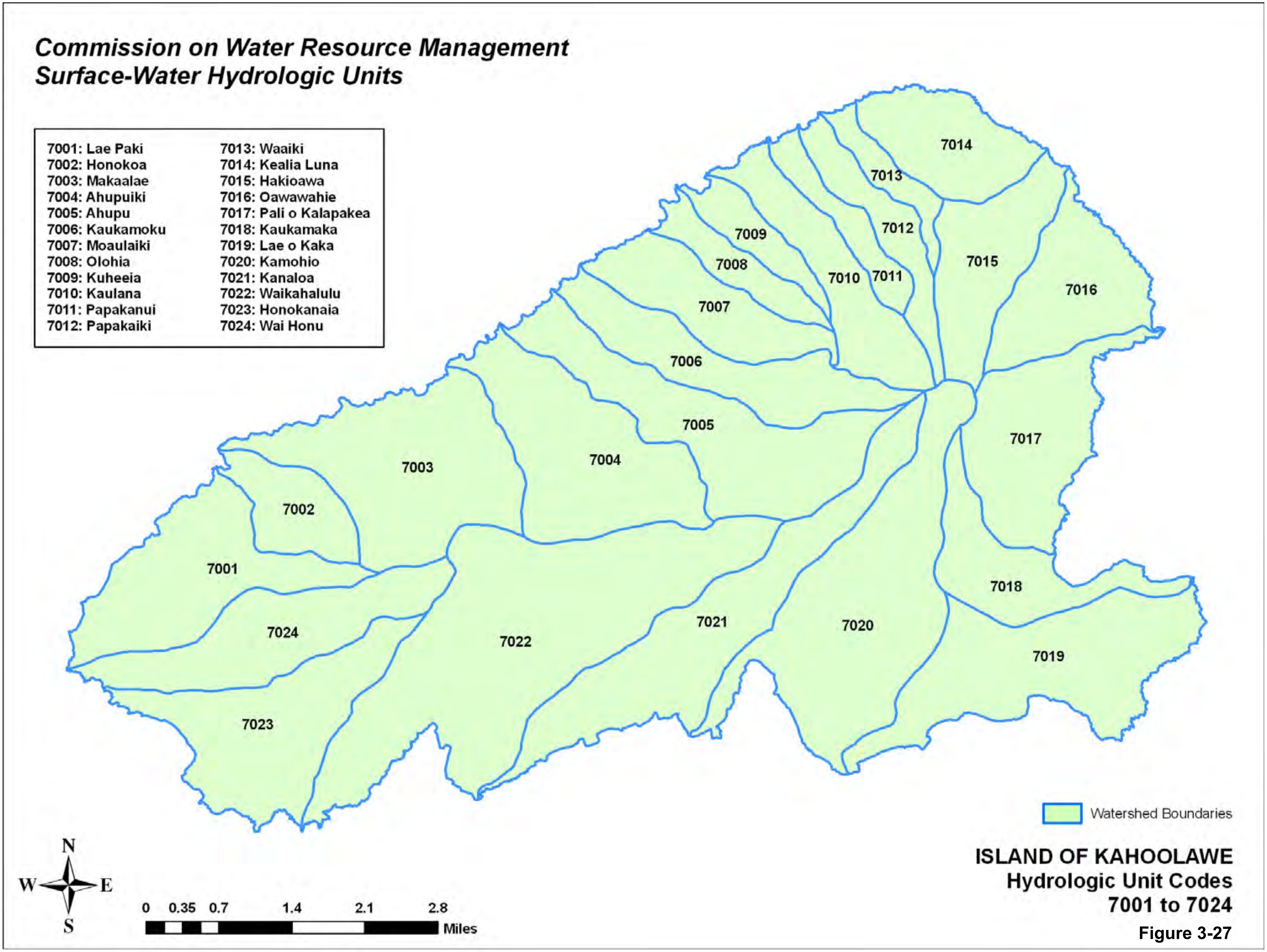
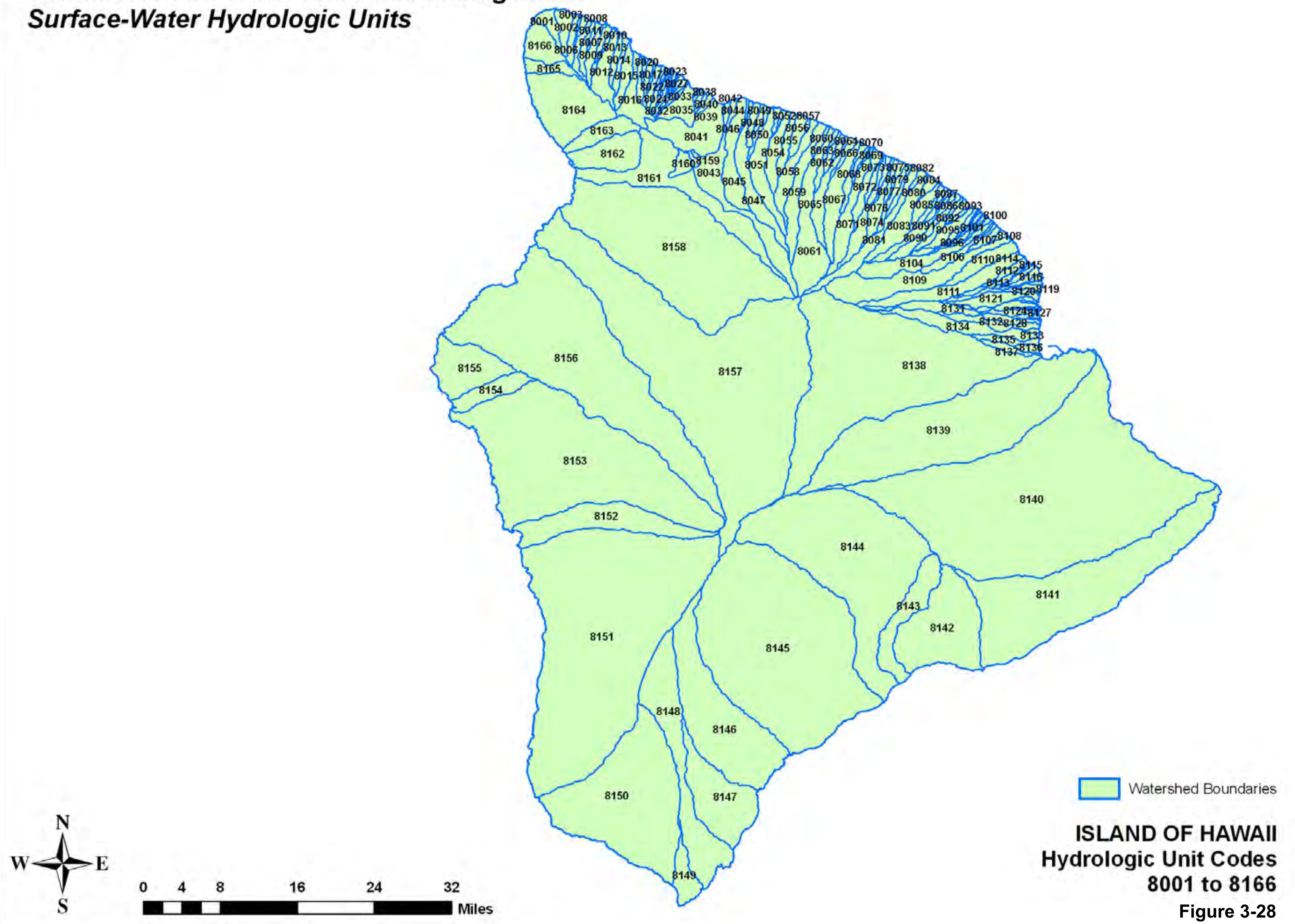

Commission on Water Resource Management
Surface-Water Hydrologic Units
6089
6090
6091
6092
6093
6094
6095
6096
6097
6098
6099
6100
6101
6102
6103
6104
6089: Oheo
6090: Kalena
6091: Koukouai
6092: Opelu
6093: Kukuiula
6094: Kaapahu
6095: Lelekea
6096: Alelele
6097: Kalepa
6098: Nuanuaaloa
6099: Manawainui
6100: Kaupo
6101: Nuu
6102: Pahihi
6103: Waiopai
6104: Poopoo
Watershed Boundaries
ISLAND OF MAUI
Hydrologic Unit Codes
6089 to 6104
N
W
E
S
0 0.5 1 2 3 4
Miles

Figure 3-26F

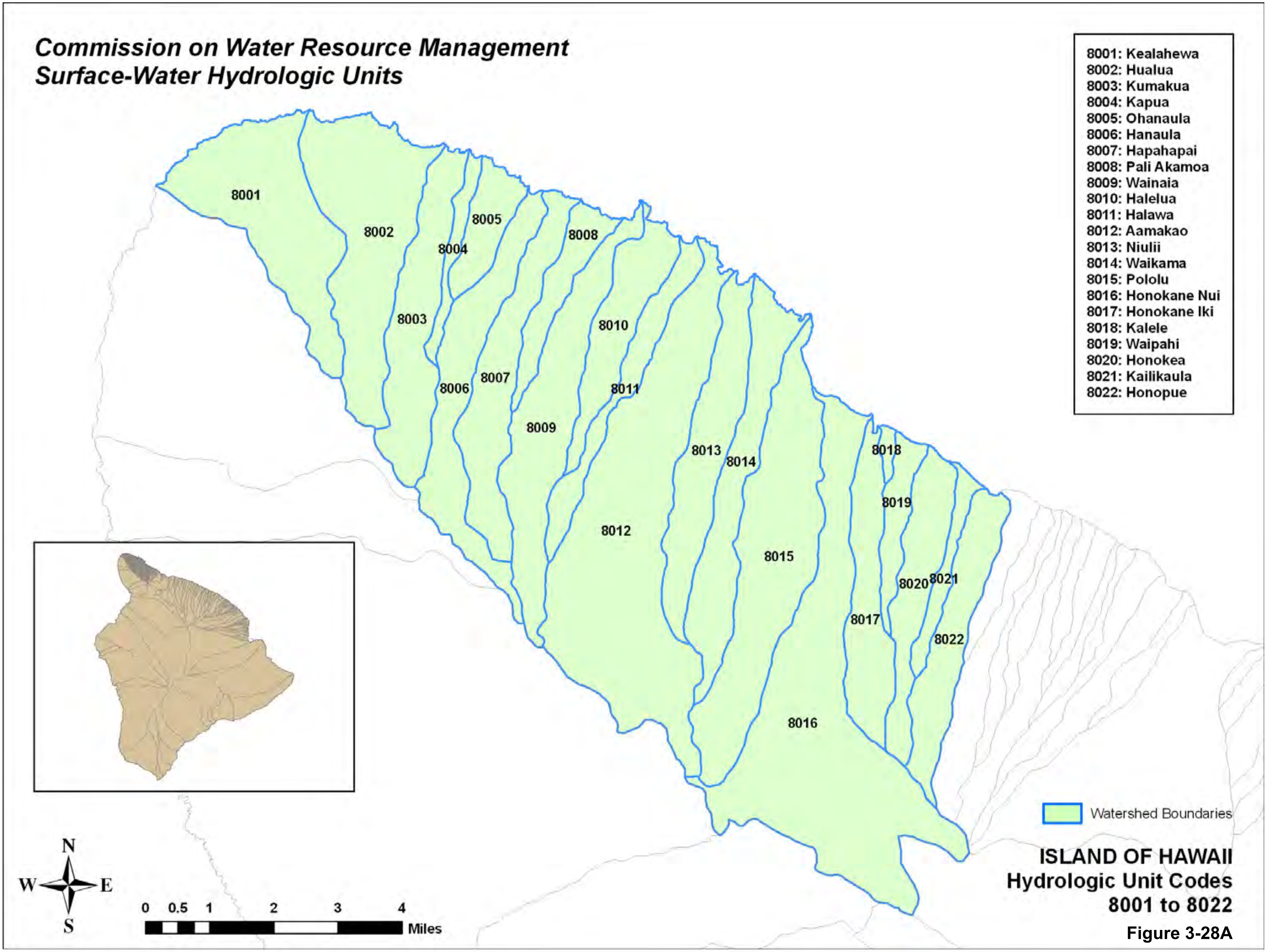

Commission on Water Resource Management
Surface-Water Hydrologic Units
6112
6111
6110
6109
6108
6107
6106
6105
6105: Manawainui
6106: Kipapa
6107: Kanaio
6108: Ahihi Kinau
6109: Mooloa
6110: Wailea
6111: Hapapa
6112: Waiakoa
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF MAUI
Hydrologic Unit Codes
6105 to 6112
Figure 3-26G


Commission on Water Resource Management
Surface-Water Hydrologic Units
7001: Lae Paki
7002: Honokoa
7003: Makaalae
7004: Ahupuiki
7005: Ahupu
7006: Kaukamoku
7007: Moaulaiki
7008: Olohia
7009: Kuheeia
7010: Kaulana
7011: Papakanui
7012: Papakaiki
7013: Waaiki
7014: Kealia Luna
7015: Hakioawa
7016: Oawawahie
7017: Pali o Kalapakea
7018: Kaukamaka
7019: Lae o Kaka
7020: Kamohio
7021: Kanaloa
7022: Waikahalulu
7023: Honokanaia
7024: Wai Honu
7001
7002
7003
7004
7005
7006
7007
7008
7009
7010
7011
7012
7013
7014
7015
7016
7017
7018
7019
7020
7021
7022
7023
7024
N
W
E
S
0
0.35
0.7
1.4
2.1
2.8
Miles
Watershed Boundaries
ISLAND OF KAHOOLAWE
Hydrologic Unit Codes
7001 to 7024
Figure 3-27

Commission on Water Resource Management
Surface-Water Hydrologic Units

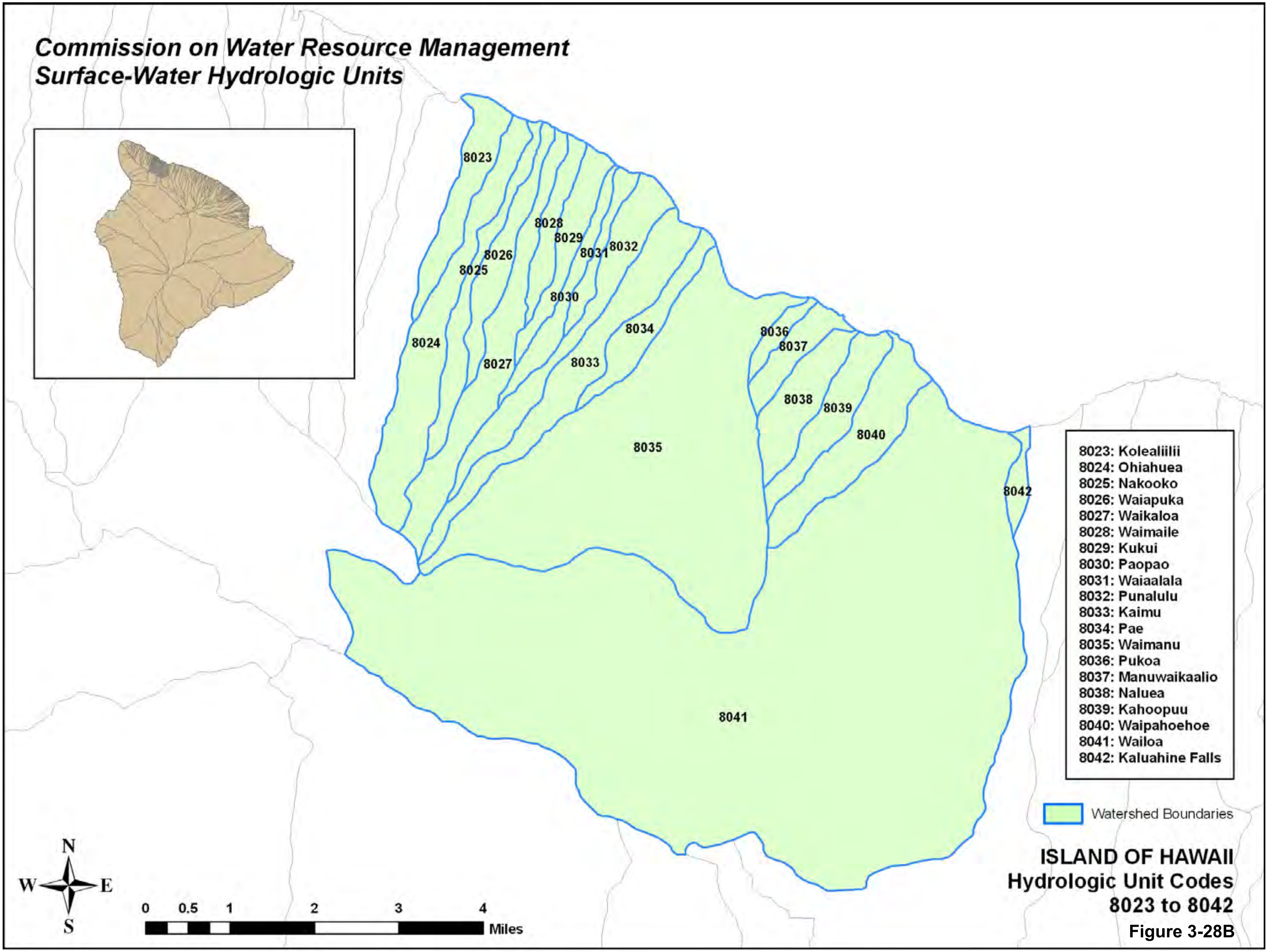


ISLAND OF HAWAII
Hydrologic Unit Codes
8001 to 8166
Figure 3-28



Commission on Water Resource Management
Surface-Water Hydrologic Units
8001: Kealahewa
8002: Hualua
8003: Kumakua
8004: Kapua
8005: Ohanaula
8006: Hanaula
8007: Hapahapai
8008: Pali Akamoa
8009: Wainaia
8010: Halelua
8011: Halawa
8012: Aamakao
8013: Niulii
8014: Waikama
8015: Pololu
8016: Honokane Nui
8017: Honokane Iki
8018: Kalele
8019: Waipahi
8020: Honokea
8021: Kailikaula
8022: Honopue
8001
8002
8003
8004
8005
8006
8007
8008
8009
8010
8011
8012
8013
8014
8015
8016
8017
8018
8019
8020
8021
8022
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8001 to 8022

Figure 3-28A



Commission on Water Resource Management
Surface-Water Hydrologic Units
8023
8024
8025
8026
8027
8028
8029
8030
8031
8032
8033
8034
8035
8036
8037
8038
8039
8040
8041
8042
8023: Kolealiilii
8024: Ohiahuea
8025: Nakooko
8026: Waiapuka
8027: Waikaloa
8028: Waimaile
8029: Kukui
8030: Paopao
8031: Waiaalala
8032: Punalulu
8033: Kaimu
8034: Pae
8035: Waimanu
8036: Pukoa
8037: Manuwaikaalio
8038: Naluea
8039: Kahoopuu
8040: Waipahoehoe
8041: Wailoa
8042: Kaluahine Falls
Watershed Boundaries
N
W
E
S
0
0.5
1
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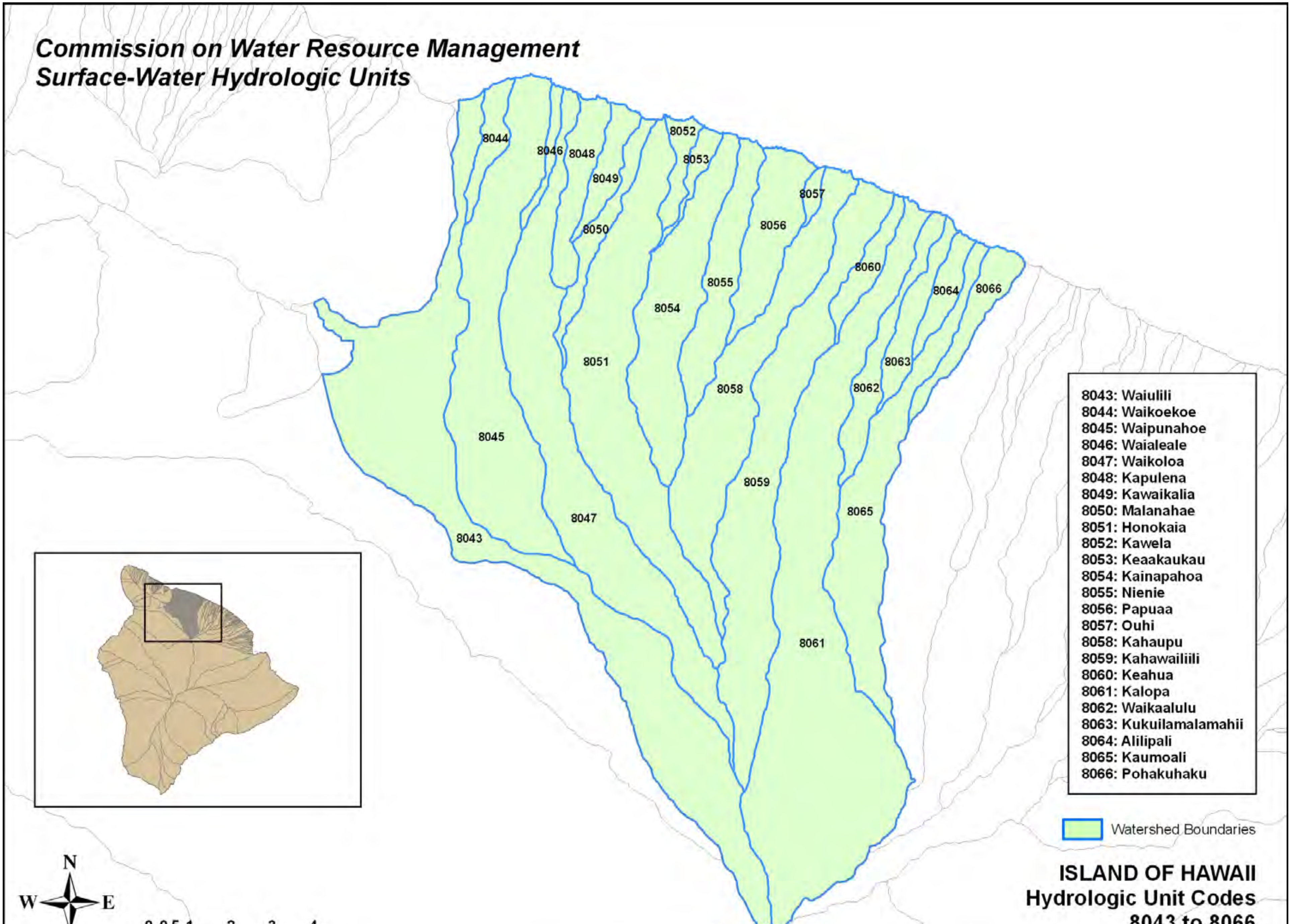
4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8023 to 8042

Figure 3-28B



Commission on Water Resource Management
Surface-Water Hydrologic Units
8044
8046
8048
8052
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8049
8057
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8056
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8054
8064
8066
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8063
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8045
8059
8065
8047
8043
8061
8043: Waiulili
8044: Waikoekoe
8045: Waipunahoe
8046: Waialeale
8047: Waikoloa
8048: Kapulena
8049: Kawaikalia
8050: Malanahae
8051: Honokaia
8052: Kawela
8053: Keaakaukau
8054: Kainapahoa
8055: Nienie
8056: Papuaa
8057: Ouhi
8058: Kahaupu
8059: Kahawailiili
8060: Keahua
8061: Kalopa
8062: Waikaalulu
8063: Kukuilamalamahii
8064: Alilipali
8065: Kaumoali
8066: Pohakuhaku
Watershed Boundaries
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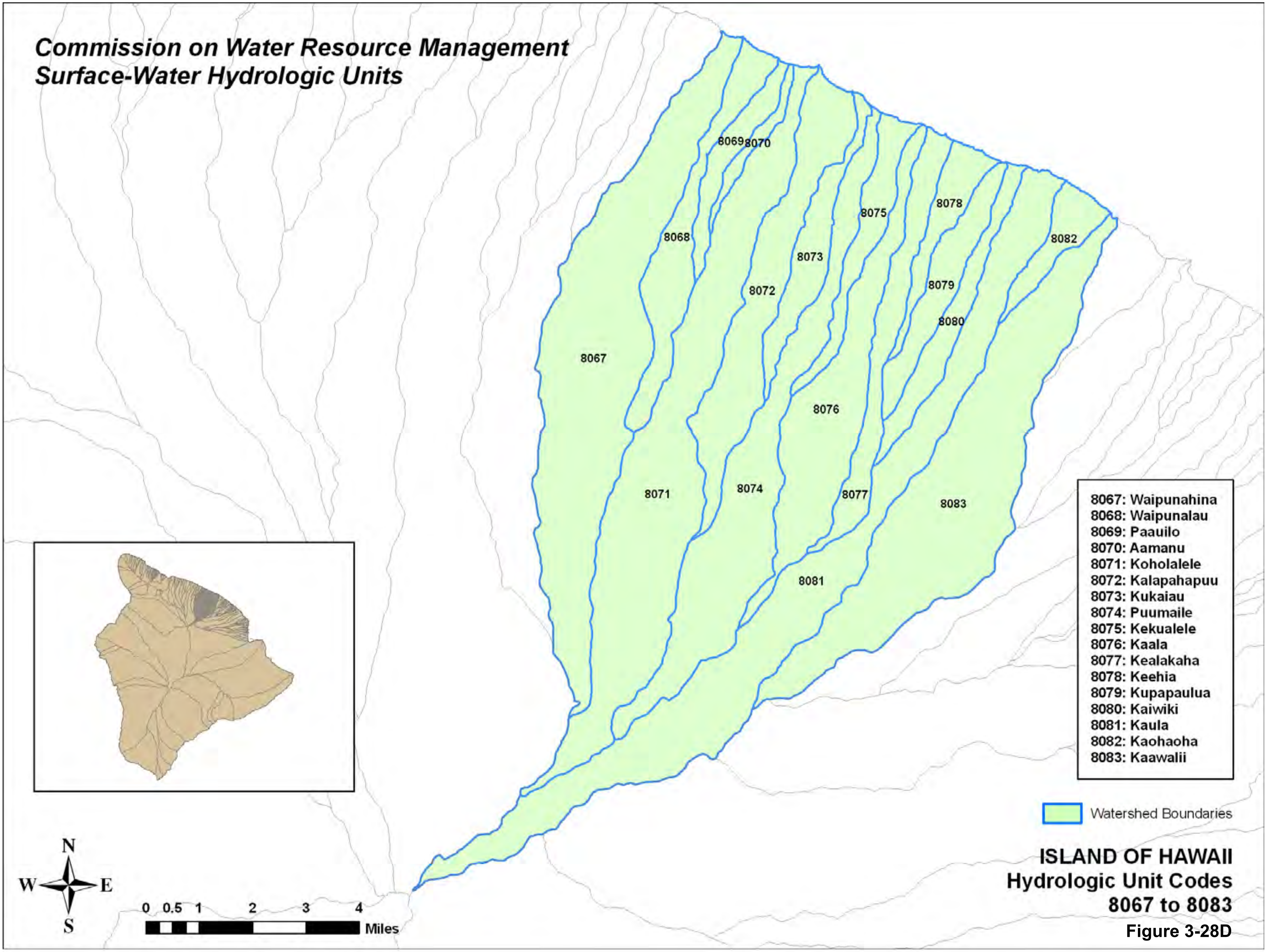
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8043 to 8066

Figure 3-28C


Commission on Water Resource Management
Surface-Water Hydrologic Units
8067
8068
8069
8070
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8072
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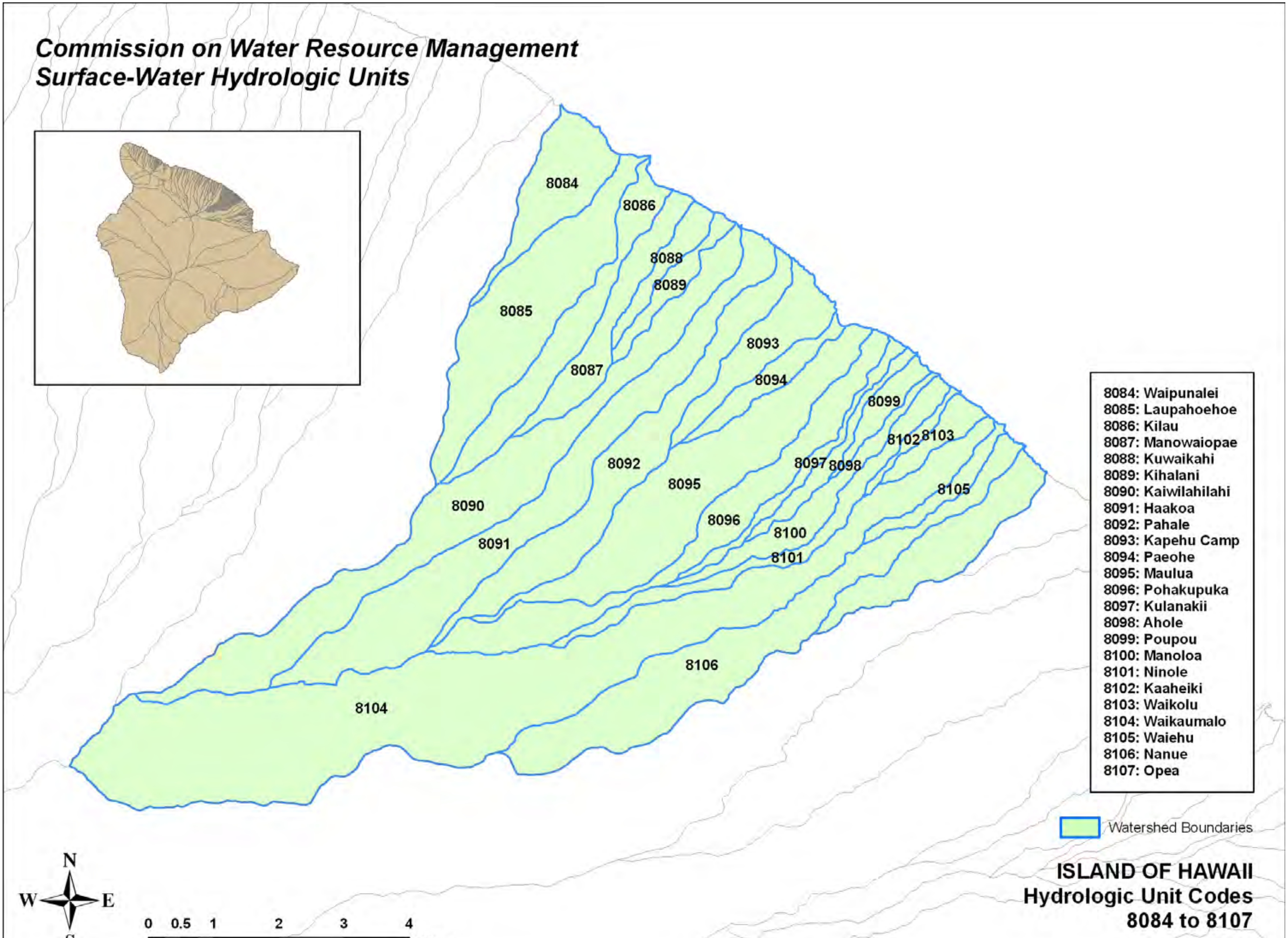
8074
8075
8076
8077
8078
8079
8080
8081
8082
8083
8067: Waipunahina
8068: Waipunalau
8069: Paauilo
8070: Aamanu
8071: Koholalele
8072: Kalapahapuu
8073: Kukaiau
8074: Puumaile
8075: Kekualele
8076: Kaala
8077: Kealakaha
8078: Keehia
8079: Kupapaulua
8080: Kaiwiki
8081: Kaula
8082: Kaohaoha
8083: Kaawalii
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8067 to 8083
Figure 3-28D


Commission on Water Resource Management
Surface-Water Hydrologic Units
8084
8085
8086
8087
8088
8089
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8092
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8096
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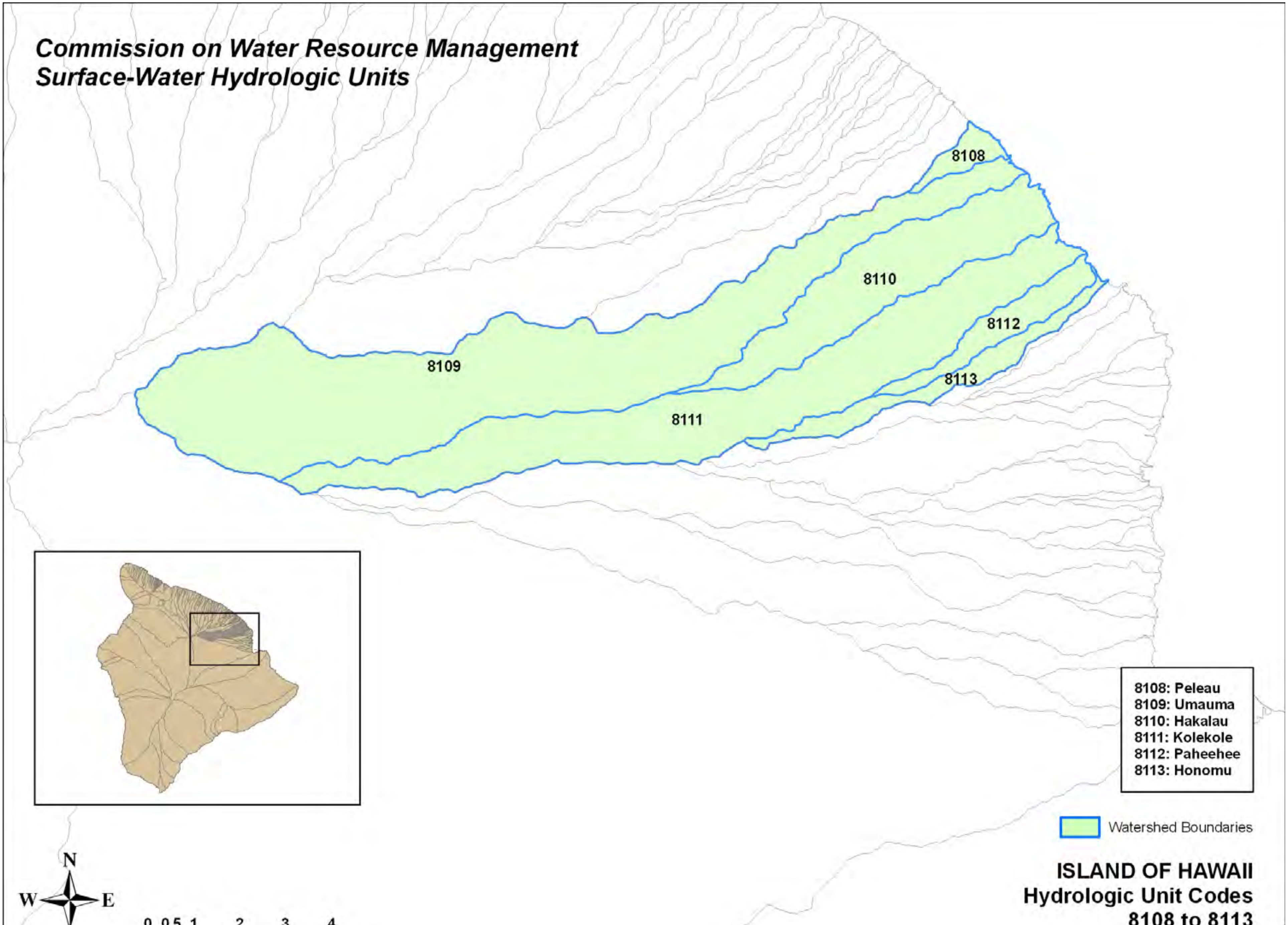
8098
8099
8100
8101
8102
8103
8104
8105
8106
8084: Waipunalei
8085: Laupahoehoe
8086: Kilau
8087: Manowaiopae
8088: Kuwaikahi
8089: Kihalani
8090: Kaiwilahilahi
8091: Haakoa
8092: Pahale
8093: Kapehu Camp
8094: Paeohe
8095: Maulua
8096: Pohakupuka
8097: Kulanakii
8098: Ahole
8099: Poupou
8100: Manoloa
8101: Ninole
8102: Kaaheiki
8103: Waikolu
8104: Waikaumalo
8105: Waiehu
8106: Nanue
8107: Opea
Watershed Boundaries
N
W
E
S
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8084 to 8107
Figure 3-28E



Commission on Water Resource Management
Surface-Water Hydrologic Units
8108
8109
8110
8111
8112
8113
8108: Peleau
8109: Umauma
8110: Hakalau
8111: Kolekole
8112: Paheehee
8113: Honomu
Watershed Boundaries
N
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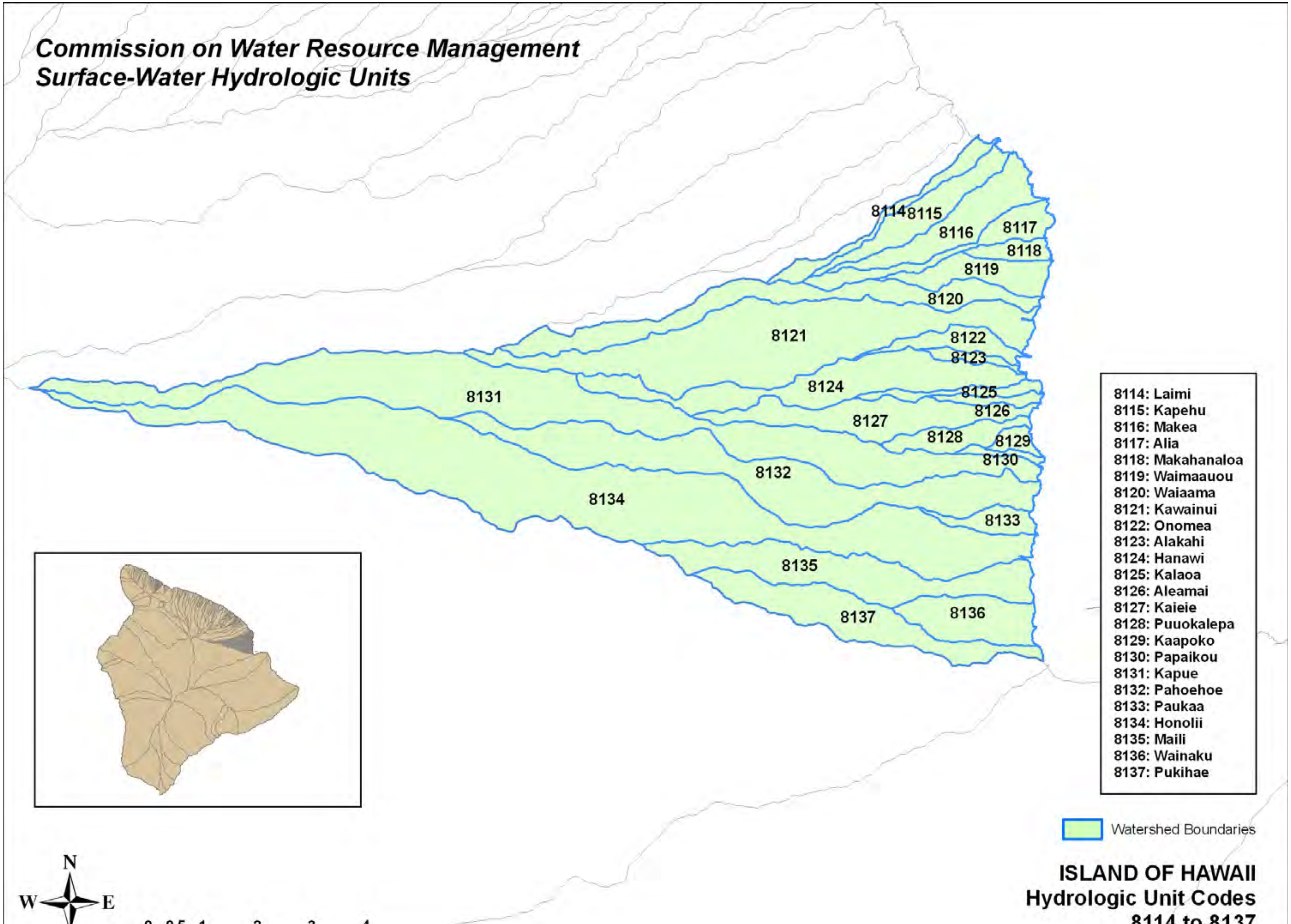
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8108 to 8113

Figure 3-28F


Commission on Water Resource Management
Surface-Water Hydrologic Units
8114
8115
8116
8117
8118
8119
8120
8121
8122
8123
8124
8125
8126
8127
8128
8129
8130
8131
8132
8133
8134
8135
8136
8137
8114: Laimi
8115: Kapehu
8116: Makea
8117: Alia
8118: Makahanaloa
8119: Waimaauou
8120: Waiaama
8121: Kawainui
8122: Onomea
8123: Alakahi
8124: Hanawi
8125: Kalaoa
8126: Aleamai
8127: Kaieie
8128: Puuokalepa
8129: Kaapoko
8130: Papaikou
8131: Kapue
8132: Pahoehoe
8133: Paukaa
8134: Honolii
8135: Maili
8136: Wainaku
8137: Pukihae
Watershed Boundaries
N
W
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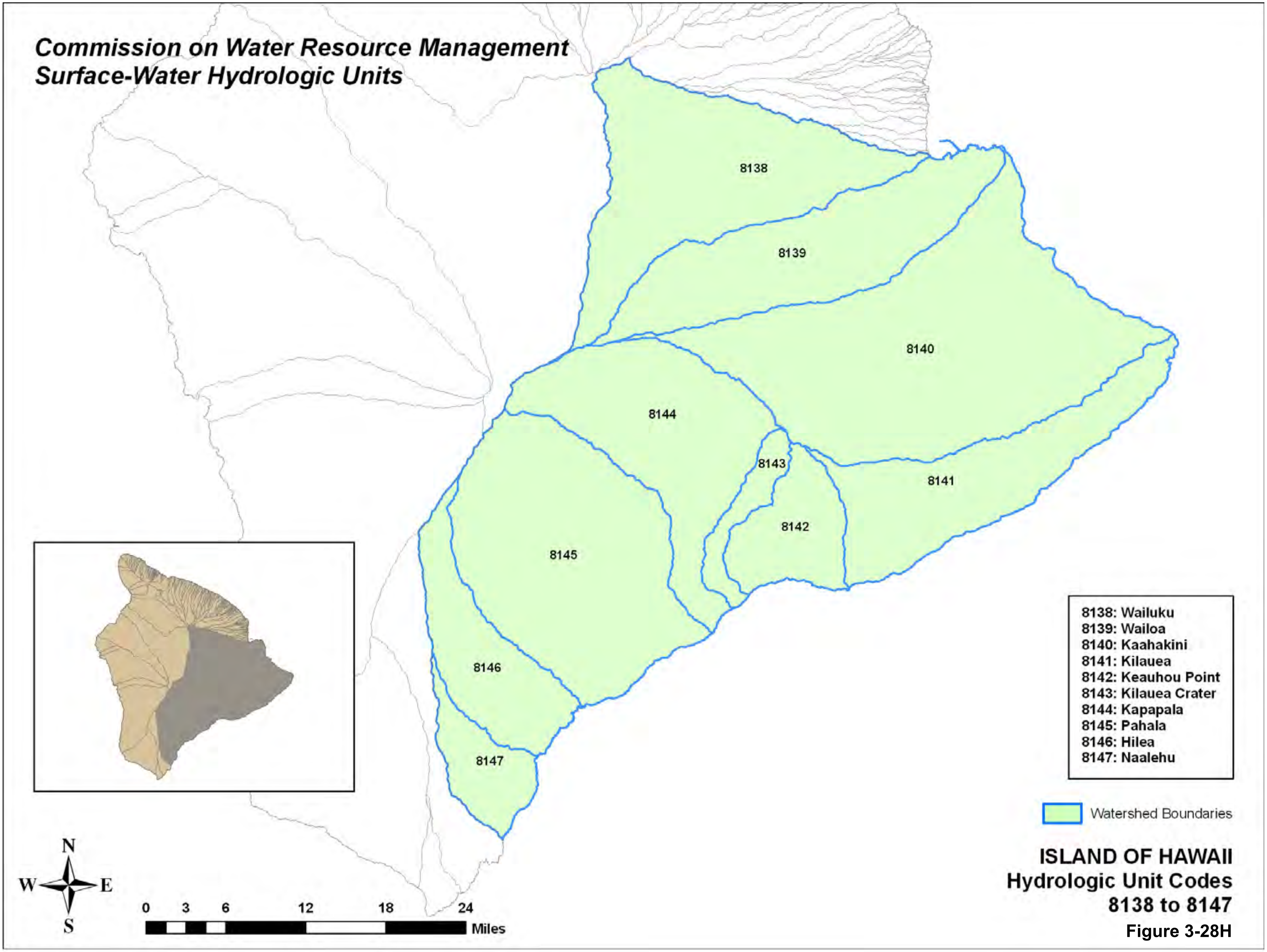
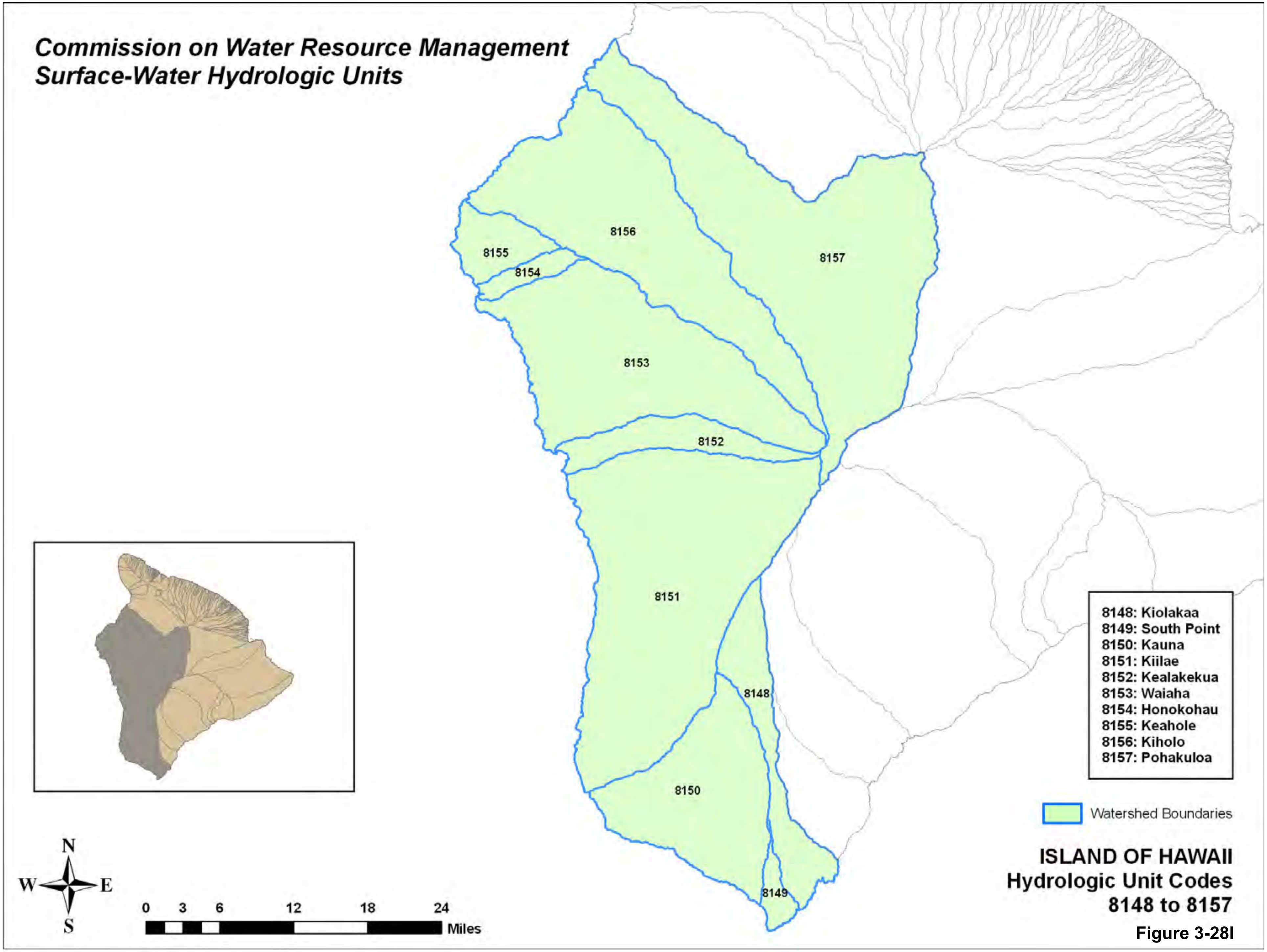
0 0.5 1 2 3 4
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8114 to 8137
Figure 3-28G


Commission on Water Resource Management
Surface-Water Hydrologic Units
8138
8139
8140
8141
8142
8143
8144
8145
8146
8147
8138: Wailuku
8139: Wailoa
8140: Kaahakini
8141: Kilauea
8142: Keauhou Point
8143: Kilauea Crater
8144: Kapapala
8145: Pahala
8146: Hilea
8147: Naalehu
Watershed Boundaries
ISLAND OF HAWAII
Hydrologic Unit Codes
8138 to 8147
N
W
E
S
0
3
6
12
18
24
Miles
Figure 3-28H


Commission on Water Resource Management
Surface-Water Hydrologic Units
8155
8154
8156
8157
8153
8152
8151
8148
8150
8149
8148: Kiolakaa
8149: South Point
8150: Kauna
8151: Kiilae
8152: Kealakekua
8153: Waiaha
8154: Honokohau
8155: Keahole
8156: Kiholo
8157: Pohakuloa
Watershed Boundaries
N
W
E
S
0
3
6
12
18
24
Miles
ISLAND OF HAWAII
Hydrologic Unit Codes
8148 to 8157
Figure 3-28I

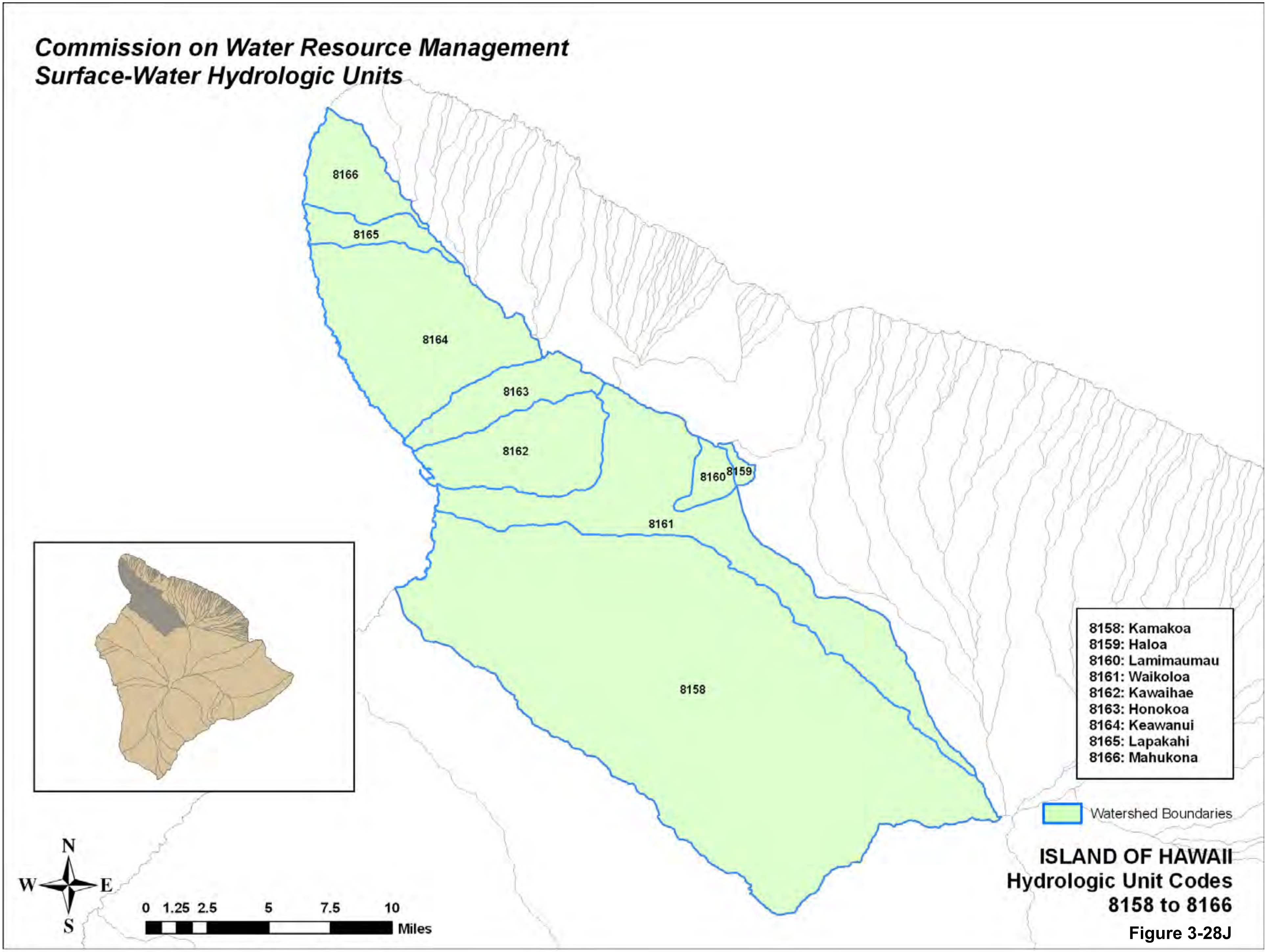

Commission on Water Resource Management
Surface-Water Hydrologic Units
8166
8165
8164
8163
8162
8161
8160
8159
8158
8158: Kamakoa
8159: Haloa
8160: Lamimaumau
8161: Waikoloa
8162: Kawaihae
8163: Honokoa
8164: Keawanui
8165: Lapakahi
8166: Mahukona
Watershed Boundaries
ISLAND OF HAWAII
Hydrologic Unit Codes
8158 to 8166
N
W
E
S
0 1.25 2.5 5 7.5 10
Miles

Figure 3-28J

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3.4.3. Determining the Availability of Surface Water Resources: Assessing Instream Flow Standards

Unlike ground water resources that occur in subsurface aquifers, surface water resources are readily observed and measured. Scientists can rely on large amounts of field data and direct measurements, rather than assumptions based on interpolation and modeling tools. Field measurements can provide reliable information on streamflow and spring discharge, effectively indication how much water is present in surface water settings. However, it is a different exercise to determine the amount of surface water available for human use and consumption. Determining the availability of surface water resources requires the evaluation of environmental, social, cultural, and economic considerations as indicated by the State Water Code. The following sections provide an overview of the factors that must be addressed in the establishment of instream flow standards and the data available for review. For a discussion of the regulatory process for setting instream flow standards, see Section 5.

3.4.3.1. Assessing Instream Flow Standards

Instream flow standards are defined by the State Water Code as "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 fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses." However, the State Water Code also prescribes that "in formulating the proposed standard, the commission shall weigh the importance of the present or potential uses of water from the stream for noninstream purposes, including the economic impact of restriction of such use." CWRM is developing a methodology for establishing measurable instream flow standards based upon best available information, along with input from interested parties and agencies.

The sections below describe the types of information, based on the State Water Code's definition of instream use, to be evaluated in establishing instream flow standards. In addition, instream flow standards must address water for public trust purposes (see Section 2 for a discussion of the Public Trust Doctrine and public trust purposes). Figure 3-29 provides a conceptual illustration of information categories that should inform instream flow standard assessments.

Maintenance of Fish and Wildlife Habitats: A stream's ability to provide for fish and wildlife habitat is largely dependent upon the condition of the stream bed and/or stream banks. A stream in its natural, unaltered condition tends to have a higher potential for ensuring the survival of native stream animals. Streams that are highly altered, with features such as embankments, hardened channels, realignments, and culverts, have a tendency to inhibit the recruitment and viability of native species. Channelizations and, conversely, the integrity of stream channels are major factors in defining faunal habitat.

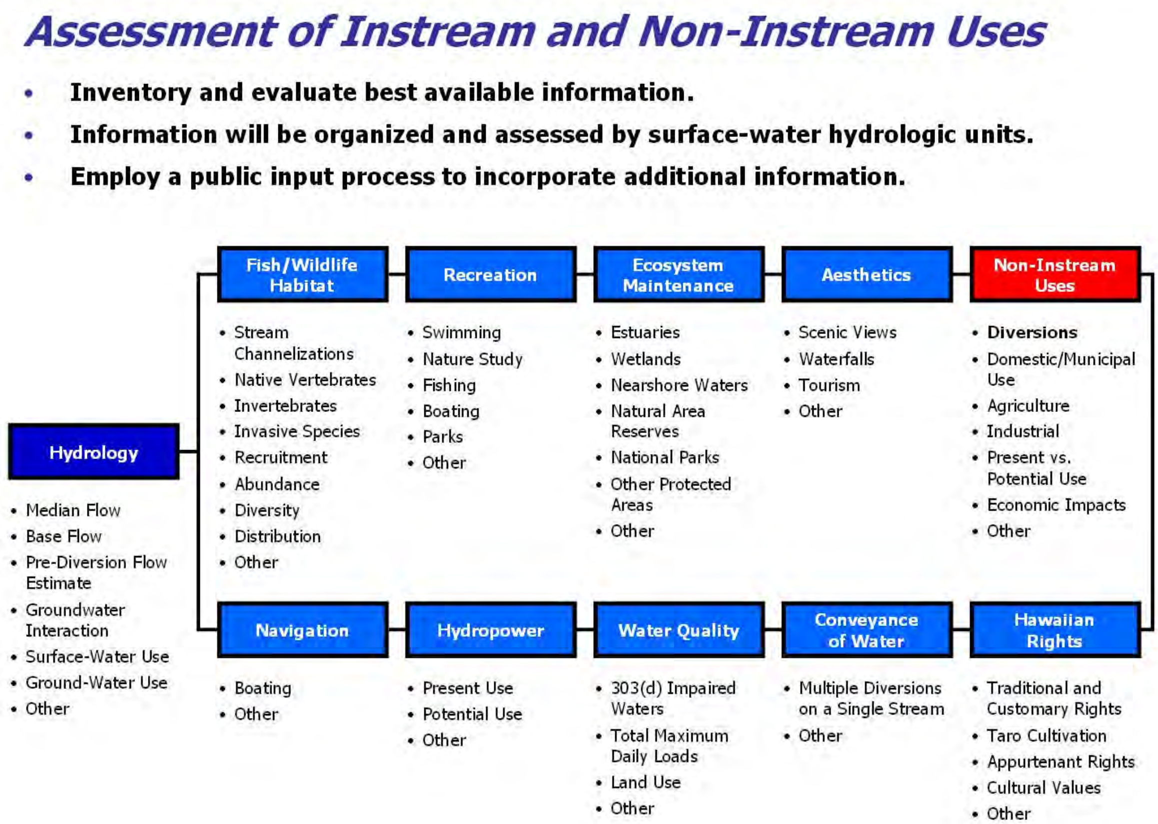

Figure 3-29: Conceptual illustration of information that should be considered in assessments of instream flow standards and in the evaluation of instream and non-instream uses.

Stream channelization projects are generally implemented to reduce flood risk, drain low-lying areas, mitigate erosion, and provide road crossings or other construction. The effect is an increase in developable land area. Channellization can result in the loss of habitat for marine, aquatic and riparian species. Other negative impacts may include reduced recreational opportunities, loss of view planes and aesthetic resources, and reduced ground water recharge.

Hawaiian streams support a relatively small number of native aquatic fauna, including freshwater fish, mollusks, crustaceans, and insects. A number of these native stream animals have a life cycle involving both the stream and the ocean. This type of life history, in which an animal lives its entire adult life in freshwater and its early larval period in the ocean, is called amphidromy.

Although the habitat requirements of native stream animals are not fully understood, it is widely accepted that some native species utilize the entire stream in their life history. Stream connectivity with nearshore waters is important for recruitment of amphidromous organisms. Another consideration is the prevalence of non-native species that compete for food and habitat any may prey upon native species. Habitat requirements of native stream animals generally include clear, well-oxygenated stream water that flows over cobble and gravel. Some native fishes are clearly adapted to life in turbulent streams with modified (fused) ventral fins that function as suction disks. These organisms can climb waterfalls and colonize stream reaches inaccessible to other fishes.

In addition to native stream fauna, waterbirds such as stilts, coots, and the native duck Koloa, rely upon stream systems for breeding, nesting, and feeding. Aquatic stream fauna provide a food supply, while natural riparian areas present quality nesting and breeding habitats.

The HSA includes an assessment of biological and riparian resources for perennial streams statewide, including an inventory of channelizations statewide. Recent work by the DLNR Division of Aquatic Resources will provide an updated and improved database of information on biological resources statewide. Other sources of habitat information include the DLNR Division of Forestry and Wildlife, the U.S. Fish and Wildlife Service, and other studies conducted for specific streams. CWRM is also developing a comprehensive statewide database of stream channel activities (i.e., stream channel alteration permits, requests for determination, complaints, etc.). Information from the database may provide additional insight as to stream habitat availability.

Outdoor Recreational Activities: Water-related recreation is a part of everyday life in Hawaii, and though beaches clearly attract more users, many local residents grew up recreating in backyard streams. Certain recreational water activities, such as fishing, swimming, boating, and nature study, are relatively limited in Hawaii due to the short, narrow, and shallow nature of typical Hawaii streams in comparison to continental streams and rivers. Although not directly dependent upon streamflow, other land-based recreational activities, such as hiking, camping, and hunting, are enhanced by streams that provide added value to the experience.

A state Recreational Resources Committee was formed as part of the Hawaii Stream Assessment to design a recreation inventory and assessment that identified various opportunities related to specific streams. Regional committees were established on each island. Committees were tasked with compiling an inventory for their respective island. The regional committees ranked each stream using a modified U.S. Forest Service Recreation Opportunity Spectrum, based on factors such as diversity of experiences, quality of experiences, specific unique characteristics, and unique combinations of attributes. This assessment provides an excellent starting point for assessing streamflow requirements for outdoor recreational activities.

Maintenance of Estuarine, Wetland, and Stream Ecosystems: The maintenance of estuarine, wetland, and stream vegetation are directly dependent upon streamflow. These areas provide important riparian habitats for many species, often serving as nursery areas. Although relatively few studies have been conducted on the function of estuaries within the larger ecosystem, it is widely believed that estuaries play a vital role in the recruitment of native stream macrofauna and the development of fish species in the nearshore waters. For example, one study indicates that increases in salinity resulting from a reduction of freshwater to the estuary could affect the juvenile development of two native fish species.[39] In general, estuaries are regarded as some of the most ecologically productive areas in the world, primarily attributed to two general phenomena; 1) the continual movement of water, and 2) the trapping of nutrients. Tidal influences, salinity gradients, freshwater discharge, runoff, and winds, all contribute to water movement, while nutrients are washed into the estuary from the entire watershed and metabolic wastes are removed. The movement of nutrients throughout the entire estuarine system is critical to sustain both plants and animals.

There are various types of wetland classifications, not all of which are directly related to streamflow. However it is widely accepted that wetlands are valuable because they perform multiple ecosystem functions. Wetlands encourage ground water recharge, provide flood water storage, offer biological habitat, and promote the cycling, storage, and removal of nutrients. In Hawaii, many wetlands have been drained and converted to agricultural or urban land uses. It is increasingly important to protect remaining wetland areas.

The HSA briefly addresses wetlands, however, there are few studies of estuaries, wetlands, and stream vegetation in relation to instream uses. In recent years, awareness of the importance of estuaries and wetlands to the greater ecosystem has been emphasized. The DLNR Division of Aquatic Resources plans to expand its biological assessments into estuaries and study the recruitment patterns of native stream fishes, the function of estuaries as fishery nurseries, and energy flows within estuaries.

Aesthetic Values such as Waterfalls and Scenic Waterways: The relationship between streamflow and aesthetic value cannot be determined in quantitative or absolute terms. Aesthetic value depends on the perception of multi-sensory experiences that which vary between individuals. Despite the qualitative nature of aesthetics, the HSA attempts to address scenic views as part of its recreational resource assessment, considering view planes from roads, trails, and the ocean. Additional studies would need to be conducted and other resources should be examined to further assess the present and potential streamflow requirements to support aesthetic values.

Navigation: There are few navigable streams in Hawaii. Streams tend to be short, narrow, and shallow. Only a few areas have developed estuaries where recreational boating is possible. Even fewer streams are actually used for commercial boating operations. The HSA addresses boating as part of its recreational resource assessment, but does not differentiate between recreational and commercial use. Additional studies should be conducted and other resources should be examined to further assess the present and potential uses of streams for navigation and boating.

Instream Hydropower Generation: Hydroelectricity is typically generated by instream dams and power generators, but the nature of Hawaii streams requires a different hydropower plant design whereby surface water is usually diverted to an

[39] Englund, R. 1998, Biological assessment and the effects of water withdrawls on Waikele Stream, Oahu, Aquatic biota, Report prepared for Belt-Collins Hawaii, 31 p.

offstream power plant. Generally, water is diverted through ditches, pipes and penstocks to the power plant, then returned to the stream. Hydropower plants may take advantage of changes in elevation to generate power; energy is recovered from the change in head and diverted water is subsequently applied to irrigate agricultural fields at lower elevations. When the HSA was conducted, 18 hydroelectric power plants were identified (seven on Kauai, four on Maui, and seven on Hawaii). At the time, hydroelectricity accounted for roughly 1.5% of the state's total electrical energy consumption.

In 1981, the State Department of Planning and Economic Development (now Department of Business, Economic Development and Tourism (DBEDT)), published *Hydrolectric Power in Hawaii: A Reconnaissance Survey*, in conjunction with the U.S. Department of Energy. The purpose of the survey was to assess potential sources of hydroelectric power, in consideration of various parameters such as storage, utilization of irrigation systems and reservoirs, upgrading of existing facilities, and construction of new power plants. Although the appeal of hydropower has since declined, renewed interest may be spurred by the desire to reduce Hawaii's dependence on oil, provided environmental considerations can be satisfied.

Maintenance of Water Quality: Water quality is an essential part of any evaluation of water requirements for health, safety and habitat protection. Information on surface water quality has been collected in Hawaii since the 1960's, however most agencies collect water quality data to meet specific short-term goals that are usually problem-oriented. The results of water quality monitoring are often used to assess mitigation actions and improve management practices. Though surface water monitoring at instream locations is ideal, testing of nearshore waters may also provide information about the quality of contributing surface water flows. Water quality parameters range widely, but can generally be grouped into the four categories listed below:

- **Physical characteristics** include temperature, specific conductance, turbidity, color, odor, pH, and suspended solids.
- **Biological characteristics** include bacteria (fecal coliform and fecal **streptococcus**), phytoplankton, zooplankton, periphyton, and macroinvertebrates.
- **Chemical characteristics** include total dissolved solids, major ions, hardness, silica, phosphorus species, nitrogen species, detergents, other minor elements, radiochemical species, organic species, pesticide species, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, and other dissolved gasses.
- **Sediment characteristics** include suspended sediment concentration, suspended sediment discharge, bed load, total concentration, and particle size and distribution.

The two primary sources of surface water quality information are the USGS and the DOH. The USGS has collected basic water quality information at stream gaging stations since 1967 as part of a nationwide program. More detailed water quality parameters are collected at certain sites for specific programs (e.g., National Stream Quality Accounting Network, National Water Quality Assessment) and projects. The DOH is responsible for monitoring the quality of water used for consumptive or recreational purposes and has varying standards for acceptable levels of contaminants, depending on the use. County water departments are another source of water quality information, as these agencies cooperate with DOH to monitor drinking water. Water quality data, both general and site-specific, may also be found in studies and reports that have been completed for particular projects.

The Conveyance of Irrigation and Domestic Water Supplies to Downstream Points of Diversion: To ensure the availability of steam water for irrigation and domestic use in downstream areas, upstream diversions must allow the bypass of sufficient water supplies and the stream channel must be protected to allow for unimpeded flow downstream. The State Water Code provides for the regulation stream diversions and alterations through a permitting system. In addition, CWRM has jurisdiction statewide to hear and render decisions on any dispute regarding water resource protection, water permits, constitutionally protected water interests, or insufficient water supply to meet competing needs.

CWRM is in the process of developing a comprehensive database to manage surface water resources statewide, which will include all registered and permitted surface water diversions, permitted stream channel alterations, complaints, and requests for determination of permitting requirements. A project to verify and characterize all registered surface water diversions is also being executed by CWRM to provide updated information on diversion structures, water uses, and basic stream conditions. Additional information related to stream channel conditions can be obtained through the various regulatory agencies that have jurisdiction related to stream channel alteration. Example of such agencies include the U.S. Army Corps of Engineers, the DOH's Environmental Management Division, DBEDT's Coastal Zone Management Program, and county planning and/or permitting departments.

The Protection of Traditional and Customary Hawaiian Rights: With regard to surface water resources, the State Water Code provides for the protection of traditional and customary rights including, but not limited to, the cultivation or propagation of taro and the gathering of hihiwai, opae, and oopu for subsistence, cultural, and religious purposes. This State Water Code also protects appurtenant water rights (see Section 2 for a discussion of water rights and uses in Hawaii).

The process for claiming and proving an appurtenant water right is the responsibility of the landowner and can be arduous, however, the State Water Code also assures that appurtenant rights shall not be diminished or extinguished by a failure to apply for, or claim such right. Very few claims for appurtenant rights have been made. Therefore, it is difficult to quantify the amount of water required to satisfy all appurtenant rights for a given area or hydrologic unit. Regardless, if an appurtenant right is established, it is CWRM's responsibility to assure that an appropriate volume of water is afforded to the claimant.

One method for assessing the protection of traditional and customary Hawaiian rights is to evaluate incidental sources of information, such as taro cultivation and various other cultural resources and studies. The HSA provides an initial assessment of cultural resources in relation to the stream valley, considering the extent of archaeological survey coverage, the ability to predict what historic sites might be in unsurveyed areas, the actual number of known historic sites, the overall significance of the valley, the density and significance of historic sites, and the overall sensitivity of the valley.

The HSA Cultural Resources Committee identified a number of factors important to current Hawaiian cultural practices: current taro cultivation, the potential for taro cultivation, appurtenant rights, subsistence gathering areas, and stream-related hydrology. Though the committee felt that these items should be included in the assessment, information was limited at the time such that only current taro cultivation could be assessed. Various other cultural studies and surveys are available for specific regions and may provide additional information with respect to present and potential surface water requirements.

3.4.3.2. Recommendations for Assessing Instream Flow Standards

Considerably more research and study should be completed to accumulate the data and perspective necessary to conduct a thorough and meaningful assessment of instream flow standards. While some of the information categories described above are partially addressed through existing federal, State, and county programs, other categories remain virtually unexplored. In many respects, CWRM's ability to assess instream flow standards are dependant upon policy and program direction, funding availability, and staffing requirements. However, CWRM recognizes that the information in the HSA should be updated, expanded, and interpreted in light of developing case law. Notwithstanding the requirements of CWRM's process for adopting interim instream flow standards (see Section 5 for discussion of the IFS and interim IFS adoption process), the following actions are recommended.

- Continue to execute work tasks described in the CWRM Stream Protection and Management Branch, Instream Use Protection Section Program Implementation Plan, as updated.

- Develop, fund, and conduct cultural resource studies or surveys in priority areas;

- Fund and complete an inventory of stream channel alterations; and

- Continue to coordinate with the USGS to fund and execute stream studies and share surface water information.

3.4.4. Inventory of Surface Water Resources and Interim IFS

Table 3-21 lists the surface water hydrologic units by island according to hydrologic unit code. Key characteristics of each hydrologic unit are listed, including the total area (in square miles), the number of registered and/or permitted stream diversions, and the number of historic and currently active USGS gages within the unit. The final column indicates the current interim IFS. In most cases, the current interim IFS were established pursuant to amendments to HAR §13-169, as noted here.

- Interim Instream Flow Standard for East Maui, HAR §13-169-44
  Date of Adoption: 6/15/1988
  Effective Date: 10/8/1988
- Interim Instream Flow Standard for Kauai, HAR §13-169-45
  Date of Adoption: 6/15/1988
  Effective Date: 10/8/1988
- Interim Instream Flow Standard for Hawaii, HAR §13-169-46
  Date of Adoption: 6/15/1988
  Effective Date: 10/8/1988
- Interim Instream Flow Standard for Molokai, HAR §13-169-47
  Date of Adoption: 6/15/1988
  Effective Date: 10/8/1988
- Interim Instream Flow Standard for West Maui, HAR §13-169-48
  Date of Adoption: 10/19/1988
  Effective Date: 12/10/1988
- Interim Instream Flow Standard for Leeward Oahu, HAR §13-169-49
  Date of Adoption: 10/19/1988
  Effective Date: 12/10/1988
- Interim Instream Flow Standard for Windward Oahu, HAR §13-169-49.1
  Date of Adoption: 4/19/1989
  Effective Date: 5/4/1992

Generally, the interim IFS for all streams in a given region were adopted by the Commission and defined as the “amount of water flowing in each stream on the effective date of this standard.” The interim IFS of individual streams have subsequently been amended as a direct result of petitions to amend the instream flow standards, contested case hearings, or other regulatory actions. References to specific actions amending the interim instream flow standard of specific streams are also provided in the last column of Table 3-21. For further clarification, refer to HAR §13-169. For a discussion of the regulatory process for setting IFS, see Section 5.

Table 3-21: Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
KAUAI						
2001	Awaawapuhi	1.29	0	0	0	HAR §13-169-45
2002	Honopu	1.74	0	0	0	HAR §13-169-45
2003	Nakeikionaiwi	0.49	0	0	0	HAR §13-169-45
2004	Kalalau	4.23	0	1	0	HAR §13-169-45
2005	Pohakuao	0.58	0	0	0	HAR §13-169-45
2006	Waiolaa	0.36	0	0	0	HAR §13-169-45
2007	Hanakoa	2.01	0	1	0	HAR §13-169-45
2008	Waiahuakua	0.66	0	0	0	HAR §13-169-45
2009	Hoolulu	0.38	0	0	0	HAR §13-169-45
2010	Hanakapiai	3.76	0	1	0	HAR §13-169-45
2011	Maunapuluo	0.45	0	0	0	HAR §13-169-45
2012	Limahuli	1.92	7	0	0	HAR §13-169-45. Amended to include SCAP KA-155 on Limahuli Stream for diversion of 0.115 mgd for landscape irrigation (7/19/1995).
2013	Manoa	1.04	1	0	0	HAR §13-169-45
2014	Wainiha	23.71	29	5	1	HAR §13-169-45
2015	Lumahai	14.44	0	1	0	HAR §13-169-45
2016	Waikoko	0.69	0	0	0	HAR §13-169-45
2017	Waipa	2.52	2	0	0	HAR §13-169-45
2018	Waioli	5.48	1	1	0	HAR §13-169-45
2019	Hanalei	23.96	10	5	1	HAR §13-169-45
2020	Waileia	0.82	0	0	0	HAR §13-169-45
2021	Anini	3.20	4	0	0	HAR §13-169-45
2022	Kalihikai West	0.30	0	0	0	HAR §13-169-45
2023	Kalihikai Center	0.24	0	0	0	HAR §13-169-45
2024	Kalihikai East	0.49	0	0	0	HAR §13-169-45
2025	Kalihiwai	11.36	6	4	0	HAR §13-169-45. Amended to include SCAP KA-060 on Pake Stream for diversion of 0.028 mgd for aquaculture (10/18/89).
2026	Puukumu	1.28	3	1	0	HAR §13-169-45
2027	Kauapea	1.05	0	0	0	HAR §13-169-45
2028	Kilauea	12.87	9	6	1	HAR §13-169-45
2029	Kulihaili	1.10	0	0	0	HAR §13-169-45
2030	Pilaa	2.58	4	1	0	HAR §13-169-45
2031	Waipake	2.46	1	0	0	HAR §13-169-45
2032	Moloaa	3.67	7	0	0	HAR §13-169-45
2033	Papaa	4.41	5	0	0	HAR §13-169-45
2034	Aliomanu	1.64	0	0	0	HAR §13-169-45
2035	Anahola	13.86	6	9	0	HAR §13-169-45
2036	Kumukumu	1.21	0	0	0	HAR §13-169-45
2037	Kapaa	16.74	13	9	0	HAR §13-169-45
2038	Moikeha	2.26	1	0	0	HAR §13-169-45

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
KAUAI (continued)						
2039	Waikaea	7.13	2	9	0	HAR §13-169-45. Amended to include SCAP KA-396 on Waikaea and Konohiki Streams for streams are impacted by a pumped well (7/12/2006).
2040	Wailua	53.34	30	17	3	HAR §13-169-45
2041	Kawailoa	3.94	0	0	0	HAR §13-169-45
2042	Hanamaulu	11.65	4	1	0	HAR §13-169-45
2043	Lihue Airport	1.83	0	0	0	HAR §13-169-45
2044	Nawiliwili	6.40	3	0	0	HAR §13-169-45
2045	Puali	2.05	6	0	0	HAR §13-169-45
2046	Huleia	28.32	26	9	0	HAR §13-169-45
2047	Kipu Kai	3.04	1	0	0	HAR §13-169-45
2048	Mahaulepu	13.43	6	1	0	HAR §13-169-45
2049	Waikomo	9.12	11	0	0	HAR §13-169-45
2050	Aepo	2.58	5	0	0	HAR §13-169-45
2051	Lawai	9.73	11	1	0	HAR §13-169-45
2052	Kalaheo	6.56	9	0	0	HAR §13-169-45
2053	Wahiawa	7.34	1	0	0	HAR §13-169-45
2054	Hanapepe	27.09	9	12	1	HAR §13-169-45
2055	Kukamahu	3.21	0	0	0	HAR §13-169-45
2056	Kaumakani	3.09	0	0	0	HAR §13-169-45
2057	Mahinauli	8.78	1	0	0	HAR §13-169-45
2058	Aakukui	5.27	3	0	0	HAR §13-169-45
2059	Waipao	9.26	1	1	0	HAR §13-169-45
2060	Waimea	86.50	46	28	3	HAR §13-169-45
2061	Kapilimao	6.44	1	0	0	HAR §13-169-45
2062	Paua	5.10	0	0	0	HAR §13-169-45
2063	Hoea	16.64	1	0	0	HAR §13-169-45
2064	Niu	2.82	0	0	0	HAR §13-169-45
2065	Kaawaloa	7.50	0	0	0	HAR §13-169-45
2066	Nahomalu	17.63	1	1	0	HAR §13-169-45
2067	Kaulaula	2.55	0	0	0	HAR §13-169-45
2068	Haeleele	2.45	0	0	0	HAR §13-169-45
2069	Hikimoe	2.20	0	0	0	HAR §13-169-45
2070	Kaaweiki	2.15	0	0	0	HAR §13-169-45
2071	Kauhao	3.98	1	1	0	HAR §13-169-45
2072	Makaha	2.80	0	0	0	HAR §13-169-45
2073	Milolii	4.34	1	0	0	HAR §13-169-45
2074	Nualolo	2.83	0	0	0	HAR §13-169-45

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
OAHU						
3001	Kalunawaikaala	2.30	1	0	0	HAR §13-169-49.1
3002	Pakulena	0.90	0	0	0	HAR §13-169-49.1
3003	Paumalu	7.79	1	2	0	HAR §13-169-49.1
3004	Kawela	2.07	1	0	0	HAR §13-169-49.1
3005	Oio	10.74	3	1	0	HAR §13-169-49.1
3006	Malaekahana	7.03	0	5	0	HAR §13-169-49.1
3007	Kahawainui	5.49	1	1	0	HAR §13-169-49.1
3008	Wailele	2.28	0	1	0	HAR §13-169-49.1
3009	Koloa	2.41	1	1	0	HAR §13-169-49.1
3010	Kaipapau	3.00	0	1	0	HAR §13-169-49.1
3011	Maakua	1.55	1	0	0	HAR §13-169-49.1
3012	Waipuhi	1.10	2	0	0	HAR §13-169-49.1
3013	Kaluanui	2.37	0	3	1	HAR §13-169-49.1
3014	Papaakoko	0.29	0	0	0	HAR §13-169-49.1
3015	Halehaa	0.25	0	0	0	HAR §13-169-49.1
3016	Punaluu	6.79	9	5	2	HAR §13-169-49.1
3017	Kahana	8.42	2	4	1	Pending. Amended to 13.3 mgd on Kahana Stream in accordance with the Commission's Decision and Order on Second Remand in the Waiahole Combined Contested Case Hearing (7/13/2006).
3018	Makaua	0.83	0	1	0	HAR §13-169-49.1
3019	Kaaawa	2.76	5	0	0	HAR §13-169-49.1
3020	Kualoa	0.87	0	0	0	HAR §13-169-49.1
3021	Hakipuu	2.09	7	1	1	HAR §13-169-49.1
3022	Waikane	2.69	3	3	1	Pending. Amended to 3.5 mgd on Waikane Stream in accordance with the Commission's Decision and Order on Second Remand in the Waiahole Combined Contested Case Hearing (7/13/2006).
3023	Waianu	1.07	0	0	0	HAR §13-169-49.1
3024	Waiahole	3.99	9	12	1	Pending. Amended to 8.7 mgd on Waiahole Stream and 3.5 mgd on Waianu Stream in accordance with the Commission's Decision and Order on Second Remand in the Waiahole Combined Contested Case Hearing (7/13/2006).
3025	Kaalaea	1.78	9	0	0	HAR §13-169-49.1
3026	Haiamoa	0.64	9	0	0	HAR §13-169-49.1

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
OAHU (continued)						
3027	Kahaluu	6.74	23	12	2	HAR §13-169-49.1
3028	Heeia	4.47	1	9	1	HAR §13-169-49.1
3029	Keaahala	1.17	1	2	0	HAR §13-169-49.1
3030	Kaneohe	5.73	2	21	0	HAR §13-169-49.1
3031	Kawa	2.11	1	1	0	HAR §13-169-49.1
3032	Puu Hawaiiloa	3.68	0	0	0	HAR §13-169-49.1
3033	Kawainui	15.05	15	17	1	HAR §13-169-49.1
3034	Kaelepulu	5.27	0	3	0	HAR §13-169-49.1
3035	Waimanalo	5.95	9	3	0	HAR §13-169-49.1
3036	Kahawai	4.68	0	1	0	HAR §13-169-49.1
3037	Makapuu	0.51	0	0	0	HAR §13-169-49.1
3038	Koko Crater	3.66	0	0	0	HAR §13-169-49
3039	Hanauma	0.39	0	0	0	HAR §13-169-49
3040	Portlock	0.74	0	0	0	HAR §13-169-49
3041	Kamiloiki	2.39	0	0	0	HAR §13-169-49
3042	Kamilonui	2.02	0	0	0	HAR §13-169-49
3043	Hahaione	2.18	0	0	0	HAR §13-169-49
3044	Kuliouou	1.82	0	1	0	HAR §13-169-49
3045	Niu	2.70	0	0	0	HAR §13-169-49
3046	Wailupe	5.12	0	1	0	HAR §13-169-49
3047	Waialaenui	6.03	0	1	0	HAR §13-169-49. Amended to include SCAP OA-309 on Kapakahi Stream for restoration of wetland habitat at Pouhala Marsh (6/21/2000).
3048	Diamond Head	0.39	0	0	0	HAR §13-169-49
3049	Ala Wai	19.02	16	11	3	HAR §13-169-49
3050	Nuuanu	9.54	9	12	0	HAR §13-169-49
3051	Kapalama	3.38	3	0	0	HAR §13-169-49
3052	Kalihi	6.27	1	3	1	HAR §13-169-49
3053	Moanalua	10.70	0	7	0	HAR §13-169-49
3054	Keehi	2.49	0	0	0	HAR §13-169-49
3055	Manuwai	6.65	0	0	0	HAR §13-169-49
3056	Salt Lake	0.62	0	0	0	HAR §13-169-49
3057	Halawa	14.21	1	5	3	HAR §13-169-49
3058	Aiea	2.06	0	0	0	HAR §13-169-49
3059	Kalauao	3.34	0	3	0	HAR §13-169-49
3060	Waimalu	12.30	1	8	0	HAR §13-169-49
3061	Waiawa	27.47	5	4	0	HAR §13-169-49. Amended to include SCAP OA-221 on Panakauahi Stream to address instream uses impacted by an arched culvert (10/22/1997).
3062	Waipio	2.81	0	0	0	HAR §13-169-49
3063	Kapakahi	3.45	3	0	0	HAR §13-169-49

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
OAHU (continued)						
3064	Waikele	48.92	13	7	4	HAR §13-169-49. Amended to include SCAP OA-046 on Waikele Stream for diversion of 2.95 mgd for irrigation of three golf courses (7/15/1992)
3065	Honouliuli	19.93	0	1	0	HAR §13-169-49
3066	Kaloi	26.53	0	1	0	HAR §13-169-49
3067	Makaiwa	12.03	0	2	0	HAR §13-169-49
3068	Nanakuli	5.45	0	1	0	HAR §13-169-49
3069	Ulehawa	4.62	0	1	0	HAR §13-169-49
3070	Mailiili	19.85	0	2	0	HAR §13-169-49
3071	Kaupuni	9.41	6	3	0	HAR §13-169-49
3072	Kamaileunu	1.97	0	0	0	HAR §13-169-49
3073	Makaha	7.37	0	2	1	HAR §13-169-49
3074	Keaau	4.24	0	0	0	HAR §13-169-49
3075	Makua	6.62	0	1	0	HAR §13-169-49
3076	Kaluakauila	2.14	0	0	0	HAR §13-169-49
3077	Manini	3.03	1	1	0	HAR §13-169-49
3078	Kawaihapai	7.01	0	0	0	HAR §13-169-49
3079	Pahole	2.45	0	0	0	HAR §13-169-49
3080	Makaleha	6.85	1	1	0	HAR §13-169-49
3081	Waialua	4.70	0	0	0	HAR §13-169-49
3082	Kiikii	59.03	4	14	2	HAR §13-169-49
3083	Paukauila	22.11	9	3	1	HAR §13-169-49
3084	Anahulu	16.48	4	3	0	HAR §13-169-49
3085	Loko Ea	2.17	4	0	0	HAR §13-169-49
3086	Keamanea	7.77	0	1	0	HAR §13-169-49
3087	Waimea	13.89	1	3	1	HAR §13-169-49
MOLOKAI						
4001	Waihanau	7.73	1	2	0	HAR §13-169-47
4002	Waialeia	4.36	0	0	0	HAR §13-169-47
4003	Waikolu	4.63	6	4	0	HAR §13-169-47. Amended to include SCAP MO-169 onWaikolu Stream for the installation of a fish ladder (3/14/1995).
4004	Wainene	0.54	0	0	0	HAR §13-169-47
4005	Anapuhi	0.44	0	0	0	HAR §13-169-47
4006	Waiohookalo	1.40	0	0	0	HAR §13-169-47
4007	Keawanui	0.21	1	0	0	HAR §13-169-47
4008	Kailiili	0.50	0	0	0	HAR §13-169-47
4009	Pelekunu	7.11	2	9	0	HAR §13-169-47
4010	Waipu	0.54	0	0	0	HAR §13-169-47
4011	Haloku	0.15	0	0	0	HAR §13-169-47
4012	Oloupena	0.37	0	0	0	HAR §13-169-47
4013	Puukaoku	0.31	0	0	0	HAR §13-169-47
4014	Wailele	0.42	1	0	0	HAR §13-169-47

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
MOLOKAI (continued)						
4015	Wailau	11.94	4	2	0	HAR §13-169-47
4016	Kalaemilo	0.19	0	0	0	HAR §13-169-47
4017	Waiahookalo	0.25	0	0	0	HAR §13-169-47
4018	Kahiwa	0.20	0	0	0	HAR §13-169-47
4019	Kawainui	3.74	0	1	0	HAR §13-169-47
4020	Pipiwai	1.21	0	0	0	HAR §13-169-47
4021	Halawa	7.64	3	1	1	HAR §13-169-47
4022	Papio	1.90	1	1	0	HAR §13-169-47
4023	Honowewe	2.45	0	0	0	HAR §13-169-47
4024	Pohakupili	1.61	0	1	0	HAR §13-169-47
4025	Honoulimaloo	1.62	2	0	0	HAR §13-169-47
4026	Honouliwai	2.65	8	0	0	HAR §13-169-47. Amended to include SCAP MO-139 on Honouliwai Stream for diversion of 1.008 mgd for taro and aquaculture (4/14/1994).
4027	Waialua	3.41	4	0	0	HAR §13-169-47
4028	Kainalu	1.41	0	0	0	HAR §13-169-47
4029	Honomuni	1.59	1	0	0	HAR §13-169-47
4030	Ahaino	2.14	1	0	0	HAR §13-169-47
4031	Mapulehu	4.22	1	1	0	HAR §13-169-47
4032	Kaluaaha	2.05	1	0	0	HAR §13-169-47
4033	Kahananui	1.78	0	0	0	HAR §13-169-47
4034	Ohia	3.77	2	0	0	HAR §13-169-47
4035	Wawaia	2.67	1	1	0	HAR §13-169-47
4036	Kamalo	13.74	1	0	0	HAR §13-169-47
4037	Kawela	5.44	5	1	1	HAR §13-169-47
4038	Kamiloloa	12.54	0	1	0	HAR §13-169-47
4039	Kaunakakai	9.23	0	2	1	HAR §13-169-47
4040	Kalamaula	9.65	0	0	0	HAR §13-169-47
4041	Manawainui	13.82	1	3	0	HAR §13-169-47
4042	Kaluapeelua	14.70	0	2	0	HAR §13-169-47
4043	Waiahewahewa	5.64	0	0	0	HAR §13-169-47
4044	Kolo	19.02	0	1	0	HAR §13-169-47
4045	Hakina	5.32	0	0	0	HAR §13-169-47
4046	Kaunala	13.27	0	1	0	HAR §13-169-47
4047	Papohaku	25.42	0	3	0	HAR §13-169-47
4048	Kaa	3.19	0	0	0	HAR §13-169-47
4049	Moomomi	11.45	0	0	0	HAR §13-169-47
4050	Maneopapa	13.79	0	1	0	HAR §13-169-47
MAUI						
6001	Waikapu	16.40	12	4	0	HAR §13-169-48
6002	Pohakea	8.31	0	1	0	HAR §13-169-48
6003	Papalaua	4.88	0	0	0	HAR §13-169-48
6004	Ukumehame	8.28	1	2	0	HAR §13-169-48
6005	Olowalu	8.40	2	3	0	HAR §13-169-48
6006	Launiupoko	6.60	1	1	0	HAR §13-169-48

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
MAUI (continued)						
6007	Kauaula	8.44	1	5	0	HAR §13-169-48
6008	Kahoma	8.50	7	8	0	HAR §13-169-48
6009	Wahikuli	9.79	0	0	0	HAR §13-169-48
6010	Honokowai	8.86	2	6	0	HAR §13-169-48. Amended to include SCAP MA-117 on Honokowai Stream for the installation of a flow-through desilting basin (8/17/1994).
6011	Kahana	9.07	1	1	0	HAR §13-169-48
6012	Honokahua	5.35	0	0	0	HAR §13-169-48
6013	Honolua	4.79	4	4	0	HAR §13-169-48
6014	Honokohau	11.58	8	2	1	HAR §13-169-48
6015	Anakaluahine	2.73	0	0	0	HAR §13-169-48
6016	Poelua	2.02	0	2	0	HAR §13-169-48
6017	Honanana	4.66	2	0	0	HAR §13-169-48
6018	Kahakuloa	4.24	10	3	1	HAR §13-169-48. Amended to include SCAP MA-133 on Kahakuloa Stream for reconstruction of an existing stream diversion (6/2/1994).
6019	Waipili	2.65	2	0	0	HAR §13-169-48
6020	Waiolai	0.97	1	0	0	HAR §13-169-48
6021	Makamakaole	2.28	4	2	0	HAR §13-169-48
6022	Waihee	7.11	5	4	1	HAR §13-169-48
6023	Waiehu	10.14	12	5	0	HAR §13-169-48
6024	Iao	22.55	9	6	1	HAR §13-169-48
6025	Kalialinui	30.28	0	3	0	HAR §13-169-44
6026	Kailua Gulch	29.76	0	0	0	HAR §13-169-44
6027	Maliko	27.38	10	2	0	HAR §13-169-44
6028	Kuiaha	8.38	30	0	0	HAR §13-169-44
6029	Kaupakulua	3.84	15	2	0	HAR §13-169-44
6030	Manawaiiao	2.37	3	0	0	HAR §13-169-44
6031	Uaoa	2.39	6	0	0	HAR §13-169-44
6032	Kealii	0.53	4	0	0	HAR §13-169-44
6033	Kakipi	9.53	21	8	0	HAR §13-169-44
6034	Honopou	2.73	23	9	1	HAR §13-169-44
6035	Hoolawa	4.86	37	2	0	HAR §13-169-44
6036	Waipio	1.03	15	0	0	HAR §13-169-44
6037	Hanehoi	1.43	12	0	0	HAR §13-169-44
6038	Hoalua	1.24	4	0	0	HAR §13-169-44
6039	Hanawana	0.65	5	0	0	HAR §13-169-44
6040	Kailua	5.25	6	13	0	HAR §13-169-44
6041	Nailiilihaele	3.57	12	8	0	HAR §13-169-44
6042	Puehu	0.36	1	0	0	HAR §13-169-44
6043	Oopuola	1.24	15	4	0	HAR §13-169-44
6044	Kaaiea	1.15	3	1	0	HAR §13-169-44
6045	Punaluu	0.22	1	0	0	HAR §13-169-44

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
MAUI (continued)						
6046	Kolea	0.71	8	3	0	HAR §13-169-44
6047	Waikamoi	5.30	11	10	0	HAR §13-169-44
6048	Puohokamoa	3.18	8	12	0	HAR §13-169-44
6049	Haipuaena	1.59	5	9	0	HAR §13-169-44
6050	Punalau	1.16	3	2	0	HAR §13-169-44
6051	Honomanu	5.60	8	5	0	HAR §13-169-44
6052	Nuaailua	1.56	2	0	0	HAR §13-169-44
6053	Piinaau	21.95	14	2	0	HAR §13-169-44
6054	Ohia	0.28	1	0	0	HAR §13-169-44
6055	Waiokamilo	2.47	18	0	0	HAR §13-169-44
6056	Wailuanui	6.05	8	3	1	HAR §13-169-44
6057	W. Wailuaiki	4.18	1	1	1	HAR §13-169-44
6058	E. Wailuaiki	3.52	1	1	0	HAR §13-169-44
6059	Kopiliula	5.20	2	1	0	HAR §13-169-44. Temporarily amended to include SCAP MA-352 on Kopiliula Stream for the implementation of a Land Restoration Plan (11/20/2002).
6060	Waiohue	0.82	3	1	0	HAR §13-169-44
6061	Paakea	1.05	2	1	0	HAR §13-169-44
6062	Waiaaka	0.19	1	2	0	HAR §13-169-44
6063	Kapaula	0.84	2	2	0	HAR §13-169-44
6064	Hanawi	5.60	6	2	1	HAR §13-169-44
6065	Makapipi	3.32	3	3	0	HAR §13-169-44
6066	Kuhiwa	3.41	0	0	0	HAR §13-169-44
6067	Waihole	0.88	2	0	0	HAR §13-169-44
6068	Manawaikeae	0.52	0	0	0	HAR §13-169-44
6069	Kahawaihapapa	3.73	0	0	0	HAR §13-169-44
6070	Keaaiki	1.03	2	0	0	HAR §13-169-44
6071	Waioni	0.63	2	0	0	HAR §13-169-44
6072	Lanikele	0.70	1	0	0	HAR §13-169-44
6073	Heleleikeoha	3.48	14	0	0	HAR §13-169-44
6074	Kawakoe	4.04	15	0	0	HAR §13-169-44
6075	Honomaele	7.94	4	1	0	HAR §13-169-44
6076	Kawaipapa	10.78	0	2	0	HAR §13-169-44
6077	Moomoonui	2.95	0	1	0	HAR §13-169-44
6078	Haneoo	2.13	0	0	0	HAR §13-169-44
6079	Kapia	4.71	3	0	0	HAR §13-169-44
6080	Waiohonu	7.15	0	1	0	HAR §13-169-44
6081	Papahawahawa	1.96	0	0	0	HAR §13-169-44
6082	Alaalaula	0.48	2	0	0	HAR §13-169-44
6083	Wailua	1.26	4	0	0	HAR §13-169-44
6084	Honolewa	0.63	1	0	0	HAR §13-169-44
6085	Waieli	0.96	0	0	0	HAR §13-169-44
6086	Kakiweka	0.34	1	0	0	HAR §13-169-44
6087	Hahalawe	0.74	1	1	0	HAR §13-169-44

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
MAUI (continued)						
6088	Puaaluu	0.53	4	0	0	HAR §13-169-44
6089	Oheo	9.70	0	2	1	HAR §13-169-44
6090	Kalena	0.71	1	0	0	HAR §13-169-44
6091	Koukouai	4.56	2	0	0	HAR §13-169-44
6092	Opelu	0.53	2	0	0	HAR §13-169-44
6093	Kukuiula	0.74	1	1	0	HAR §13-169-44
6094	Kaapahu	0.50	0	0	0	HAR §13-169-44
6095	Lelekea	0.78	0	0	0	HAR §13-169-44
6096	Alelele	1.20	0	0	0	HAR §13-169-44
6097	Kalepa	0.97	2	0	0	HAR §13-169-44
6098	Nuanuaaloa	4.24	3	0	0	HAR §13-169-44
6099	Manawainui	5.17	3	0	0	HAR §13-169-44
6100	Kaupo	22.50	1	0	0	HAR §13-169-44
6101	Nuu	10.48	0	1	0	HAR §13-169-44
6102	Pahihi	7.85	0	0	0	HAR §13-169-44
6103	Waiopai	5.38	0	0	0	HAR §13-169-44
6104	Poopoo	1.92	0	0	0	HAR §13-169-44
6105	Manawainui Gulch	6.07	0	0	0	HAR §13-169-44
6106	Kipapa	28.42	0	1	0	HAR §13-169-44
6107	Kanaio	34.11	0	0	0	HAR §13-169-44
6108	Ahihi Kinau	3.68	0	0	0	HAR §13-169-44
6109	Mooloa	1.90	0	0	0	HAR §13-169-44
6110	Wailea	35.76	4	2	0	HAR §13-169-44
6111	Hapapa	40.89	0	1	0	HAR §13-169-44
6112	Waiakoa	55.76	0	2	0	HAR §13-169-44
HAWAII						
8001	Kealahewa	5.08	0	0	0	HAR §13-169-46
8002	Hualua	5.53	0	0	0	HAR §13-169-46
8003	Kumakua	3.48	0	0	0	HAR §13-169-46
8004	Kapua	0.65	0	0	0	HAR §13-169-46
8005	Ohanaula	1.26	0	0	0	HAR §13-169-46
8006	Hanaula	3.55	0	0	0	HAR §13-169-46
8007	Hapahapai	3.33	1	1	0	HAR §13-169-46
8008	Pali Akamoa	1.36	0	0	0	HAR §13-169-46
8009	Wainaia	4.30	5	0	0	HAR §13-169-46
8010	Halelua	2.28	0	0	0	HAR §13-169-46
8011	Halawa	1.75	2	0	0	HAR §13-169-46
8012	Aamakao	10.56	7	0	0	HAR §13-169-46
8013	Niulii	3.27	9	1	0	HAR §13-169-46
8014	Waikama	3.39	7	0	0	HAR §13-169-46
8015	Pololu	6.31	6	1	0	HAR §13-169-46
8016	Honokane Nui	10.51	6	10	0	HAR §13-169-46
8017	Honokane Iki	2.62	0	2	0	HAR §13-169-46
8018	Kalele	0.17	0	0	0	HAR §13-169-46
8019	Waipahi	1.00	0	0	0	HAR §13-169-46
8020	Honokea	2.38	0	0	0	HAR §13-169-46

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
HAWAII (continued)						
8021	Kailikaula	0.79	0	0	0	HAR §13-169-46
8022	Honopue	2.65	0	0	0	HAR §13-169-46
8023	Kolealiilii	0.86	0	0	0	HAR §13-169-46
8024	Ohiahuea	1.96	0	0	0	HAR §13-169-46
8025	Nakooko	0.76	0	0	0	HAR §13-169-46
8026	Waiapuka	0.73	0	0	0	HAR §13-169-46
8027	Waikaloa	1.62	0	0	0	HAR §13-169-46
8028	Waimaile	0.48	0	0	0	HAR §13-169-46
8029	Kukui	0.67	0	1	0	HAR §13-169-46
8030	Paopao	0.54	0	1	0	HAR §13-169-46
8031	Waiaalala	0.34	0	1	0	HAR §13-169-46
8032	Punalulu	1.25	0	1	0	HAR §13-169-46
8033	Kaimu	1.70	0	1	0	HAR §13-169-46
8034	Pae	0.65	0	0	0	HAR §13-169-46
8035	Waimanu	8.79	0	2	0	HAR §13-169-46
8036	Pukoa	0.21	0	0	0	HAR §13-169-46
8037	Manuwaikaalio	0.50	0	0	0	HAR §13-169-46
8038	Naluea	0.88	0	0	0	HAR §13-169-46
8039	Kahoopuu	0.86	0	0	0	HAR §13-169-46
8040	Waipahoehoe	1.34	0	0	0	HAR §13-169-46
8041	Wailoa/Waipio	25.84	37	24	2	HAR §13-169-46
8042	Kaluahine Falls	0.22	0	0	0	HAR §13-169-46
8043	Waiulili	28.93	1	4	0	HAR §13-169-46
8044	Waikoekoe	1.61	0	0	0	HAR §13-169-46
8045	Waipunahoe	16.51	0	0	0	HAR §13-169-46
8046	Waialeale	0.79	0	0	0	HAR §13-169-46
8047	Waikoloa	16.95	0	0	0	HAR §13-169-46
8048	Kapulena	3.08	0	0	0	HAR §13-169-46
8049	Kawaikalia	1.84	0	0	0	HAR §13-169-46
8050	Malanahae	2.24	0	0	0	HAR §13-169-46
8051	Honokaia	16.09	0	1	0	HAR §13-169-46
8052	Kawela	1.31	0	0	0	HAR §13-169-46
8053	Keaakaukau	0.87	0	0	0	HAR §13-169-46
8054	Kainapahoa	9.08	1	1	0	HAR §13-169-46
8055	Nienie	4.95	2	0	0	HAR §13-169-46
8056	Papuaa	4.73	0	2	0	HAR §13-169-46
8057	Ouhi	0.45	0	0	0	HAR §13-169-46
8058	Kahaupu	11.27	0	0	0	HAR §13-169-46
8059	Kahawailiili	15.56	0	0	0	HAR §13-169-46
8060	Keahua	1.70	0	0	0	HAR §13-169-46
8061	Kalopa	30.94	0	0	0	HAR §13-169-46
8062	Waikaalulu	3.06	0	0	0	HAR §13-169-46
8063	Kukuilamalamahii	2.28	0	0	0	HAR §13-169-46
8064	Alilipali	1.60	0	0	0	HAR §13-169-46
8065	Kaumoali	9.39	0	0	0	HAR §13-169-46
8066	Pohakuhaku	2.45	0	0	0	HAR §13-169-46
8067	Waipunahina	15.86	0	0	0	HAR §13-169-46

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
HAWAII (continued)						
8068	Waipunalau	3.84	0	0	0	HAR §13-169-46
8069	Paauilo	1.57	1	0	0	HAR §13-169-46
8070	Aamanu	0.64	0	0	0	HAR §13-169-46
8071	Koholalele	14.40	0	0	0	HAR §13-169-46
8072	Kalapahapuu	6.43	0	0	0	HAR §13-169-46
8073	Kukaiau	2.40	0	0	0	HAR §13-169-46
8074	Puumaile	9.13	0	0	0	HAR §13-169-46
8075	Kekualele	2.18	0	0	0	HAR §13-169-46
8076	Kaala	6.62	0	0	0	HAR §13-169-46
8077	Kealakaha	3.49	0	0	0	HAR §13-169-46
8078	Keehia	1.72	0	1	0	HAR §13-169-46
8079	Kupapaulua	2.54	0	0	0	HAR §13-169-46
8080	Kaiwiki	2.24	0	0	0	HAR §13-169-46
8081	Kaula	14.35	0	0	0	HAR §13-169-46
8082	Kaohaoha	1.49	0	0	0	HAR §13-169-46
8083	Kaawalii	13.93	0	0	0	HAR §13-169-46
8084	Waipunalei	2.07	0	0	0	HAR §13-169-46
8085	Laupahoehoe	4.71	0	0	0	HAR §13-169-46
8086	Kilau	2.43	1	0	0	HAR §13-169-46
8087	Manowaiopae	1.74	2	1	0	HAR §13-169-46. Amended to include SCAP HA-195 on Manowaiopae Stream for a permitted diversion (5/3/1996).
8088	Kuwaikahi	0.72	1	0	0	HAR §13-169-46
8089	Kihalani	0.70	1	0	0	HAR §13-169-46
8090	Kaiwilahilahi	6.69	1	0	0	HAR §13-169-46
8091	Haakoa	6.26	0	0	0	HAR §13-169-46
8092	Pahale	3.92	0	0	0	HAR §13-169-46
8093	Kapehu Camp	1.74	2	0	0	HAR §13-169-46
8094	Paeohe	0.85	0	0	0	HAR §13-169-46
8095	Maulua	5.30	0	0	0	HAR §13-169-46
8096	Pohakupuka	3.63	1	1	0	HAR §13-169-46
8097	Kulanakii	0.71	0	0	0	HAR §13-169-46
8098	Ahole	0.67	0	0	0	HAR §13-169-46
8099	Poupou	0.62	0	0	0	HAR §13-169-46
8100	Manoloa	1.32	0	0	0	HAR §13-169-46
8101	Ninole	1.67	2	0	0	HAR §13-169-46
8102	Kaaheiki	0.27	1	0	0	HAR §13-169-46
8103	Waikolu	0.63	4	0	0	HAR §13-169-46
8104	Waikaumalo	16.10	0	0	0	HAR §13-169-46
8105	Waiehu	0.61	1	0	0	HAR §13-169-46
8106	Nanue	5.53	1	0	0	HAR §13-169-46
8107	Opea	2.31	0	0	0	HAR §13-169-46

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
HAWAII (continued)						
8108	Peleau	1.12	3	0	0	HAR §13-169-46. Amended to include SCAP HA-314 on Peleau Stream for diversion of 8.0 mgd for agricultural use (8/23/2000).
8109	Umauma	33.83	1	0	0	HAR §13-169-46
8110	Hakalau	10.26	0	0	0	HAR §13-169-46
8111	Kolekole	20.82	8	0	0	HAR §13-169-46
8112	Paheehee	2.87	0	0	0	HAR §13-169-46
8113	Honomu	3.12	2	0	0	HAR §13-169-46. Amended to include SCAP HA-317 on Malamalamaiki Stream for 2.0-in. pipe diversion for washing farm equipment (2/28/2001).
8114	Laimi	0.89	1	0	0	HAR §13-169-46
8115	Kapehu	1.60	2	1	0	HAR §13-169-46
8116	Makea	2.08	4	0	0	HAR §13-169-46
8117	Alia	1.31	2	1	0	HAR §13-169-46. Amended to include SCAP HA-387 on Alia Stream for diversion of 0.058 mgd for agricultural use (5/24/2006).
8118	Makahanaloa	0.48	0	0	0	HAR §13-169-46
8119	Waimaauou	1.33	1	0	0	HAR §13-169-46
8120	Waiaama	3.53	2	0	0	HAR §13-169-46
8121	Kawainui	8.52	1	1	0	HAR §13-169-46
8122	Onomea	0.85	5	0	0	HAR §13-169-46. Amended to include SCAP HA-214 on Onomea Stream for relocation of a pipe diversion to mitigate concerns over an existing diversion dam (3/19/1997).
8123	Alakahi	0.30	1	0	0	HAR §13-169-46
8124	Hanawi	3.96	0	0	0	HAR §13-169-46
8125	Kalaoa	0.51	3	0	0	HAR §13-169-46
8126	Aleamai	0.32	0	1	0	HAR §13-169-46
8127	Kaieie	2.75	0	0	0	HAR §13-169-46
8128	Puuokalepa	0.93	2	0	0	HAR §13-169-46
8129	Kaapoko	0.32	0	0	0	HAR §13-169-46
8130	Papaikou	0.19	0	0	0	HAR §13-169-46
8131	Kapue	11.86	0	0	0	HAR §13-169-46
8132	Pahoehoe	6.96	1	0	0	HAR §13-169-46
8133	Paukaa	0.65	0	0	0	HAR §13-169-46
8134	Honolii	16.59	0	2	1	HAR §13-169-46
8135	Maili	4.09	1	0	0	HAR §13-169-46
8136	Wainaku	1.86	0	0	0	HAR §13-169-46
8137	Pukihae	3.23	0	0	0	HAR §13-169-46

Table 3-21: (continued)
Inventory of Surface Water Resources

Unit Code	Unit Name	Area (mi^2)	No. of Diversions	No. of Gages	Active Gages	Interim IFS
HAWAII (continued)						
8138	Wailuku	225.56	11	14	1	HAR §13-169-46. Amended to include SCAP HA-219 on Waiau Stream for a diversion dam constructed to generate electricity for a farm operation (10/22/1997). Amended to include SCAP HA-047 on Hookelekele Stream for three diversions structures constructed as part of a hydroelectric project (10/18/89).
8139	Wailoa	180.18	1	5	0	HAR §13-169-46
8140	Kaahakini	388.99	3	0	0	HAR §13-169-46
8141	Kilauea	152.29	0	0	0	HAR §13-169-46
8142	Keauhou Point	66.58	0	0	0	HAR §13-169-46
8143	Kilauea Crater	27.10	0	0	0	HAR §13-169-46
8144	Kapapala	183.57	0	0	0	HAR §13-169-46
8145	Pahala	271.38	1	3	1	HAR §13-169-46
8146	Hilea	94.44	6	3	0	HAR §13-169-46
8147	Naalehu	46.45	1	4	0	HAR §13-169-46
8148	Kiolakaa	66.21	0	0	0	HAR §13-169-46
8149	South Point	11.75	1	0	0	HAR §13-169-46
8150	Kauna	140.63	0	0	0	HAR §13-169-46
8151	Kiilae	340.31	4	1	0	HAR §13-169-46
8152	Kealakekua	45.29	0	0	0	HAR §13-169-46
8153	Waiaha	224.39	8	4	0	HAR §13-169-46
8154	Honokohau	14.20	0	0	0	HAR §13-169-46
8155	Keahole	32.73	0	0	0	HAR §13-169-46
8156	Kiholo	236.29	0	0	0	HAR §13-169-46
8157	Pohakuloa	348.76	4	0	0	HAR §13-169-46
8158	Kamakoa	192.20	0	2	0	HAR §13-169-46
8159	Haloa	1.07	0	1	0	HAR §13-169-46
8160	Lamimaumau	3.88	0	1	0	HAR §13-169-46
8161	Waikoloa	51.96	11	4	2	HAR §13-169-46
8162	Kawaihae	22.03	0	1	0	HAR §13-169-46
8163	Honokoa	12.61	10	0	0	HAR §13-169-46
8164	Keawanui	43.90	2	0	0	HAR §13-169-46
8165	Lapakahi	6.27	0	0	0	HAR §13-169-46
8166	Mahukona	12.61	0	0	0	HAR §13-169-46

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Section 4

Monitoring of Water Resources

4. MONITORING OF WATER RESOURCES

A vital component of water resource protection is the implementation of an effective program to monitor resource conditions. In 2001, the USGS published Circular 1217, entitled *Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data*[1], intending to highlight the importance of ground water-level measurements, and to foster a more comprehensive and systematic approach to the long-term collection of water-level data. The report calls attention to the need for a nationwide program to obtain more systematic and comprehensive records of water levels in observation wells, as a joint effort among the USGS and state and local agencies:

> *"…[W]ater-level monitoring in the United States is fragmented and largely subject to the vagaries of existing local projects. A stable, base network of water-level monitoring wells exists only in some locations. Moreover, agency planning and coordination vary greatly throughout the United States with regard to construction and operation of water-level observation networks and the sharing of collected data."*
>
> *…More recently, the National Research Council (2000) reiterated, "An unmet need is a national effort to track water levels over time in order to monitor water-level declines."*
>
> *…It is hoped that this report [Circular 1217] will provide a catalyst toward the establishment of a more rigorous and systematic nationwide approach to ground-water-level monitoring – clearly an elusive goal thus far. The time is right for progress toward this goal. Improved access to water data over the Internet offers the opportunity for significant improvements in the coordination of water-level monitoring and the sharing of information by different agencies, as well as the potential means for evaluation of water-level monitoring networks throughout the United States."*

The need for improved monitoring programs and agency coordination described in Circular 1217 is true for Hawaii's ground water monitoring activities, but the need is even more apparent for Hawaii's surface water and climate monitoring programs, which are fairly new and in need of sensible expansion. The overall goal of establishing a "rigorous and systematic" approach to resource monitoring across the State should be carefully addressed by program planning, implementation of prioritized actions, plan update and revision, and interagency cooperation. This section of the WRPP describes Hawaii's existing ground water, surface water, and climate monitoring and assessment programs, as well as recommendations for follow-up action, program expansion, and agency coordination.

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[1] Taylor, Charles J. and William M. Alley. 2001. *Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data: U.S. Geological Survey Circular 1217.* Internet, available online at: http://pubs.usgs.gov/circ/circ1217/html/pdf.html.

4.1. Overview

The CWRM, in cooperation with federal and county agencies, is responsible for monitoring ground water resources, surface water resources, and climate conditions throughout the state of Hawaii. Monitoring activities include the collection of:

- Vertical-profile conductivity and temperature data (indicates the extent of saltwater intrusion and the behavior of the freshwater and transition zone over time) from State, Honolulu BWS, USGS, and private deep monitor wells;
- Instantaneous and long-term continuous water-level data from water-level monitoring wells;
- Continuous and long-term stream discharge data and surface water quality data;
- Rainfall data from the NWS, the USGS, the State, and privately operated raingages; and
- Fog drip data from State fog drip stations.

As water usage increases, it is necessary for accompanying hydrologic data to be collected and made available for decision-making, regarding availability and use of the resource. Water uses must be continuously inventoried, and the impacts of water consumption must be monitored to protect and prevent any degradation of ground and surface water sources.

Continuous and consistent water data collection is critical to CWRM's ability to protect water resources. CWRM collects, analyzes, and verifies hydrologic data; this is then correlated, or analyzed to provide an understanding of water within a particular area. Deep monitor well data are used to calibrate computer models that will refine sustainable yield estimates. Data is also obtained through required, regular reports by water users. Although some users diligently report water use on a monthly basis, other users do not comply with reporting requirements until enforcement actions are taken by CWRM. At the time of this publication, a new water use database is being tested that will provide reports on water use by aquifer system, island, user, or type of use (e.g., domestic, municipal, and agricultural).

CWRM also administers a cooperative agreement with the USGS to gather stream, spring flow, water level, and rainfall data. The State budget for the cooperative agreement has been reduced in recent years. Therefore, CWRM has sought the funding assistance for resource monitoring programs from other programs and agencies (including county water departments).

The following goals, policies, and objectives have been determined by CWRM to guide and focus water resource monitoring programs and the use of resultant monitoring data:

Goals

- To protect the water resources of the State, and provide for the maximum-beneficial use of water by present and future generations.

- To develop sound management policies and a regulatory framework that facilitates decisions that are:

  - Proactive and timely;

  - Based on the best available information and sound science;

  - Focused on the long-term protection and reasonable and beneficial use of both ground and surface water resources; and

  - Protective of water rights and public trust purposes.

- To achieve sound water resource planning, extensive baseline and current data collection for ground and surface water, and statewide compliance with the State Water Code.

Policies and Objectives

Policy: Develop the best available information on water resources, including current and future water use monitoring and data collection, surface water and ground water quality (e.g., chlorides) and availability, stream flow, stream biota, and watershed health to make wise decisions about reasonable and beneficial use and protection of the resource.

Objectives:

- Compile water-use and resource data collected by CWRM, other government agencies, community organizations, and other private entities into a comprehensive database.

- Establish measurable interim instream flow standards on a stream-by-stream basis whenever necessary to protect the public interest in waters of the State.

- Develop methodology to establish instream flow standards.

- Enhance surface and ground water use data collection throughout the State, such that stream diversion and well operators and users participate in recording and reporting stream diversion withdrawals, well discharges, and well water chloride concentrations.

- Designate priority areas for new ground and surface water monitoring. Submit funding requests, as needed, for monitoring programs (e.g., deep monitor wells, water-level observation wells, spring flow measurements, rain gage data, fog drip analysis, stream gaging, stream surveys, etc.).

- Pursue cooperative agreements and partnerships with other departmental divisions and county water supply departments to work with the USGS in the collection of hydrologic data.

- Participate in watershed partnerships.

- Update:

  - Geographic Information System (GIS) coverage for State:

  - Rainfall isohyets;

  - Evaporation information;

  - Recharge information;

  - Standards for ground and surface water models;

  - Benchmark ground water well network for water level elevations; and

  - Deep monitor well network.

Policy: Provide the regulatory and internal framework, including best use of information technology, for efficient ground and surface water management.

Objectives:

- Establish standardized, internal procedures for processing ground water use permits and stream-related permits. Continue efforts to streamline permit processing.

- Continue efforts to modernize internal processing of permits, including development of electronic checklists, permits, form-letter merge files, and desktop GIS services.

- Establish web-based permit application and processing and water use reporting.

- Expand and enhance the water use reporting program to include surface water use and data on chlorides present in well sources.

- Establish a user-friendly GIS-based information system.

4.2. Monitoring of Ground Water Resources

Management of ground water resources cannot be responsibly accomplished without long-term monitoring information. Long-term data allows water scientists and managers to identify emerging trends and problems in Hawaii's ground water aquifers. For example, the effects of natural climatic variations and induced stresses upon aquifer systems could be better identified. Since ground water provides much of the municipal and drinking water statewide, and demand for high-quality ground water continues to increase, long-term monitoring data is needed to determine the response of island aquifers to climatic variability, changing land use, and increasing withdrawals. Such data is useful in defining trends, providing a basis for comparison, measuring the impacts of water development, detecting ground water threats, and determining the best management and corrective measures.

The practical applications of data from monitoring activities are numerous and varied, but generally include actions toward:

- Managing ground water withdrawals;
- Providing insight into regional hydrology; and
- Providing data to construct and test analytical and numerical ground water models.

The following comprise the main elements that contribute to ground water monitoring activities in Hawaii, and these elements are further described in the sections below:

- Deep monitor wells;
- Water-level observation wells;
- Spring discharge measurements and conductivity measurements;
- Pumpage and chloride data; and
- Rainfall data.

Deep Monitor Wells: Deep monitor wells penetrate through the freshwater zone and transition zone and terminate in the saltwater zone. Deep monitor wells allow for the study of the entire water column. The wells are used to track changes in the thickness of the freshwater lens over time; thereby providing data on the aquifer's response to groundwater withdrawals and longer-term precipitation changes. In addition, deep monitor wells serve as water-level observation wells and can be used to sample the water chemistry at depth.

Water-Level Observation Wells: Water level data can be obtained from any well that penetrates the desired aquifer. Water level is the height of water in a well above mean sea level. Such data provides information on aquifer response to rainfall patterns and ground water withdrawals. Water level data can be analyzed in combination with spring discharge, pumpage, and chloride data to study aquifer response to climatic events and induced stresses.

Spring Discharge and Conductivity Measurements: Spring flow can represent the visible discharge from a basal freshwater lens or from dike-impounded ground water. Information on the rate of spring discharge and chloride concentrations can be correlated to water-level data and chloride trends at observation wells in the vicinity of the spring. The relationship between the amount of ground water withdrawals (pumpage) and spring discharge can provide estimates on the amount of ground water flux through an aquifer.

Pumpage and Chloride Data: Water use and chloride data provide information on the rate of ground water withdrawals and the resulting water quality within aquifer systems. Water use and chloride information can be compared with water level data, deep monitor well data, irrigation practices, and land use and demographic changes to gain insight into the behavior of the freshwater-saltwater flow system.

Temperature Data: Temperature data can provide information to help identify and interpret flow relationships between ground water bodies, and can also be indicative of geothermal activity. For example, if ground water temperature remains constant throughout a pumping test, it is most likely that all water derived from the borehole or test well is from the same source. Conversely, if water temperature changes, it could be that observed variations are due to the introduction of water from another related source. As for indicating geothermal activity, a rise in water temperature accompanied by an increase in chloride concentration, typically suggests that the water is associated with regions of geothermal activity.

Rainfall Data: Rainfall data represents the "input" to ground water systems, and provides basic information to complete the water balance equation. Ground water recharge models rely on rainfall and land use information to determine how much rainfall percolates into the subsurface aquifer systems. Rainfall data should be complemented by fog drip and evapotranspiration data to allow computation of more accurate recharge information. Rainfall and precipitation monitoring are discussed further in Section 4.4.

4.2.1. Existing CWRM Ground Water Monitoring Programs in Hawaii

CWRM is responsible for collecting basic hydrologic data and conducting water availability and sustainable yield analyses statewide. The purpose of the monitoring network is to meet the goals, policies, and objectives outlined in Section 4.1 by improving our understanding of (1) the movement and behavior of ground water within and between aquifer systems; (2) the interactions between basal, dike impounded, and other ground water sources; (3) the interactions between ground water and surface water bodies; (4) the response of individual aquifers and ground water systems to short and long term changes in rainfall; and (5) the impacts of groundwater withdrawals on aquifers and ground water systems.

CWRM's monitoring activities support the protection, conservation, planning, and utilization of water resources for social, economic, and environmental needs, as mandated by the State Water Code. The information presented below describes CWRM's monitoring activities, as well as monitoring programs undertaken in cooperation with the USGS and the Honolulu BWS. On Oahu, the CWRM, the USGS, and the Honolulu BWS have robust monitoring networks; however, monitoring networks in other counties are not as expansive and area data may be lacking.

4.2.1.1. CWRM Deep Monitor Well Program

Hawaii's unique volcanic geology provides for large aquifers that are able to support the State's population by supplying domestic and municipal potable ground water, as well as water for agriculture and other purposes. These aquifers are replenished by rainfall. Because fresh ground water is slightly less dense than seawater, it floats on top of the saline water, forming what is known as a Ghyben-Herzberg lens, referred to in Hawaii as a "basal" aquifer (see Section 3 for a discussion of the Ghyben-Herzberg relationship). According to the Ghyben-Herzberg relationship, for every foot of freshwater above sea level, there is 40 feet of freshwater below sea level. Between the freshwater and saltwater portions of the lens is a zone of mixing, known as the "transition zone."

In Hawaii, the chloride-ion concentration (milligrams per liter or mg/L) is used to determine the freshness or saltiness of ground water. It is also listed as a contaminant in the EPA Secondary Drinking Water Regulations. Chloride in small concentrations is not harmful to humans, but in concentrations above 250 mg/L, or two percent that of seawater, it imparts a salty taste in water that is objectionable to many people. By definition, the transition zone is the vertical zone with water quality that varies from 250 mg/L chloride to 19,000 mg/L chloride (approximately seawater). The midpoint (MPTZ) of the transition zone is defined as the area in the vertical profile where the water contains 9,500 mg/L chloride. Because the amount of water that can be developed from a freshwater lens for potable use is constrained by the salinity of the water, the altitude of the top of the transition zone (where chloride concentration is two percent that of seawater) and the thickness of the transition zone are important. The transition zone is in constant flux, responding to changes caused by variations in pumping and ground water recharge.

A deep monitor well penetrates the entire water column from freshwater into saltwater (see Figure 4-1). Data collected from the well is used to track the changes in and movement of the transition zone over time. This can be accomplished either by direct sampling at discrete elevations (below mean sea level) or by lowering an instrument known as a CTD logger, which measures changes in the electrical conductance, temperature, and depth of the water as the CTD is lowered to the bottom of the well. The saltier the water, the more conductive it is. A sample graph of CTD data, indicating the changes in water salinity and temperature with depth, is shown in Figure 4-2.

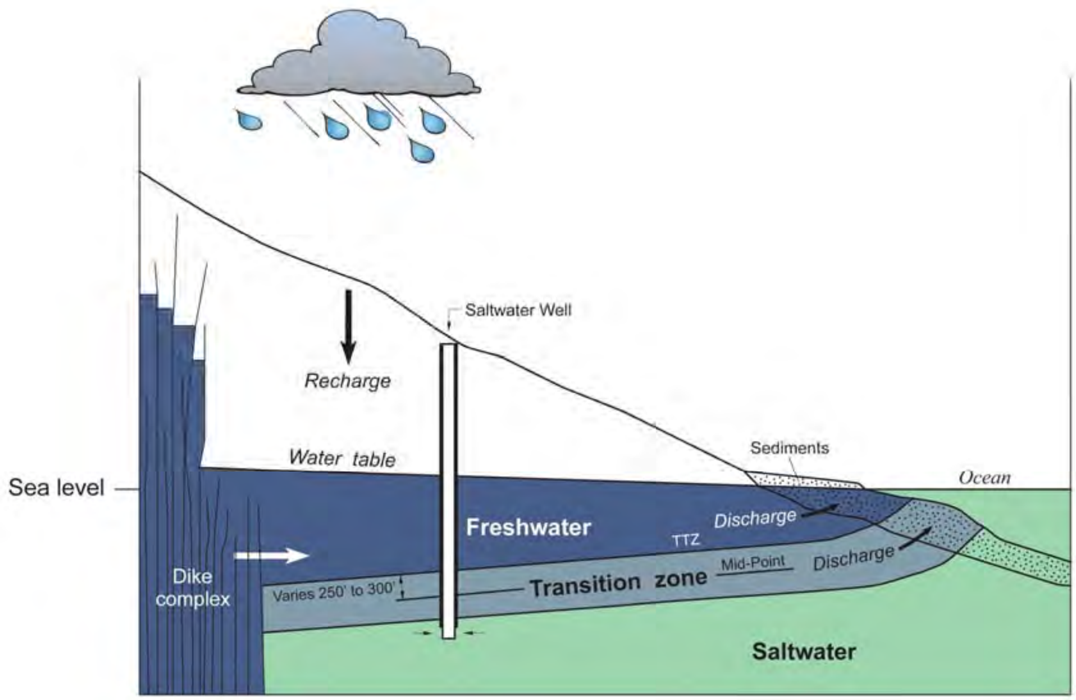

Figure 4-1. Schematic diagram of a deep monitor well. A deep monitor well penetrates through the freshwater zone and the transition zone, and terminates in the saltwater zone.

Going inland, water levels increase and the elevation of the MPTZ below mean sea level decreases. Ideally there should be enough deep monitor wells to provide data that adequately defines the vertical cross-section of the transition zone from the mountains to the sea. The deep monitor wells should be roughly located on a ground water flow line. Often, three properly spaced deep monitor wells are adequate for this purpose.

Table 4-1 summarizes the deep monitor wells included in the CWRM program. CWRM owns and operates deep monitor wells on Oahu, Maui, and Hawaii. Two deep monitor wells are located in the Keauhou Aquifer System, where rapid development in West Hawaii is putting pressure on regional water resources. Two deep monitor wells are located in the Iao Aquifer System, which is an essential municipal water source for the Maui Department of Water Supply and is showing signs of over pumpage. One deep monitor well is located in the Waihee Aquifer System to provide data to augment information collected from the Iao aquifer wells. Six deep monitor wells are located in the Pearl Harbor Aquifer Sector, which is the most important water supply aquifer on Oahu.

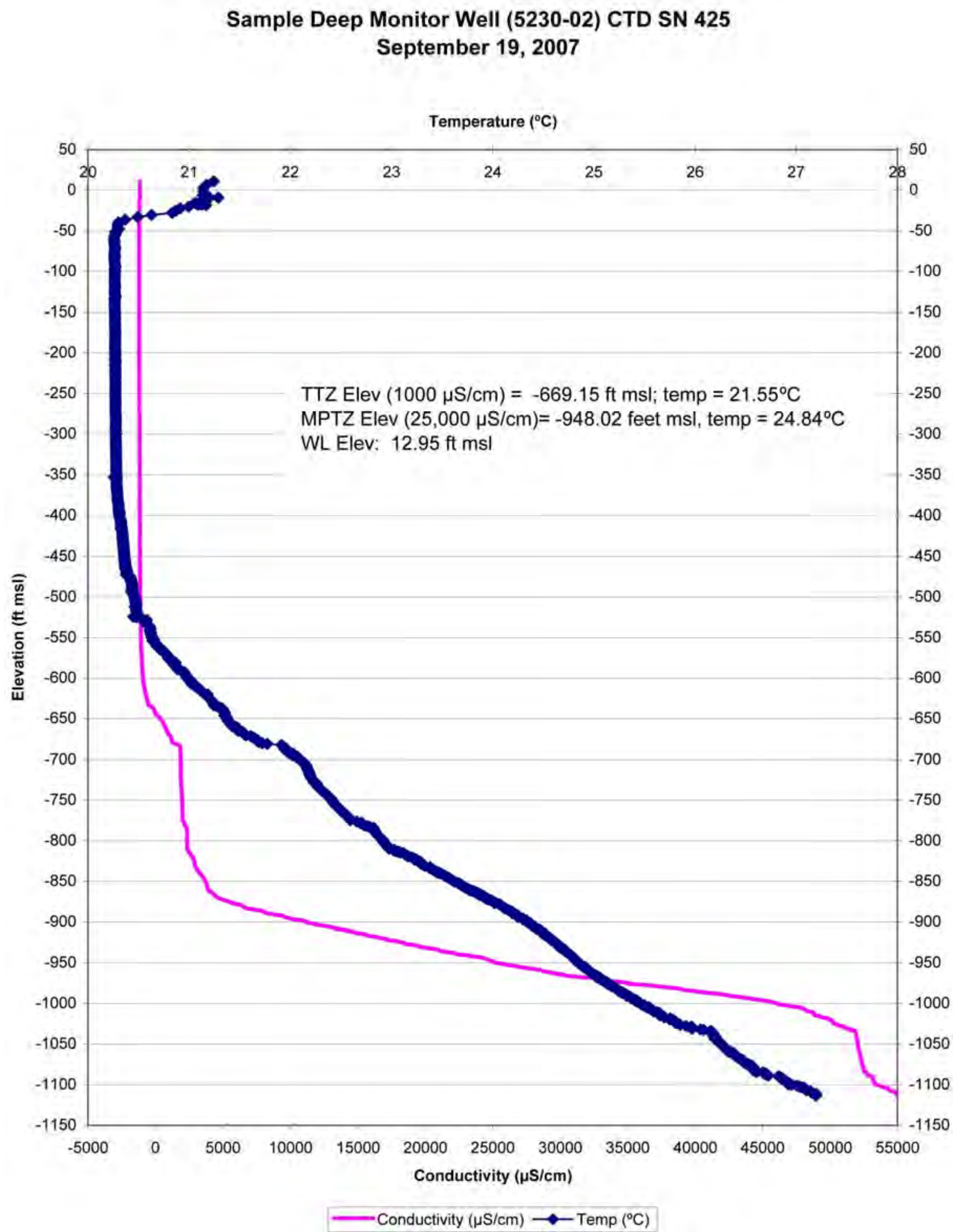

Figure 4-2. Sample Graph of CTD Data from a Deep Monitor Well.

Table 4-1 Summary of CWRM Deep Monitor Wells				
Summary of CWRM Deep Monitor Wells	**Aquifer System Code**	**Aquifer System Name**	**Well Number**	**Well Name**
Hawaii	80901	Keauhou	3457-04	Kahaluu Deep Monitor
Hawaii	80901	Keauhou	3858-01	Keopu Deep Monitor
Maui	60102	Iao	5230-02	Iao Deep Monitor
Maui	60102	Iao	5430-05	Waiehu Deep Monitor
Maui	60103	Waihee	5631-09	Waihee Deep monitor
Maui	60203	Honokowai	5739-03	Lahaina (Mahinahina) Deep Monitor
Oahu	30201	Waimalu	2253-03	Halawa Deep Monitor
Oahu	30201	Waimalu	2456-05	Waimalu Deep Monitor
Oahu	30203	Waipahu-Waiawa	2300-18	Waipahu Deep Monitor
Oahu	30203	Waipahu-Waiawa	2659-01	Waipio Mauka Deep Monitor
Oahu	30204	Ewa-Kunia	2403-02	Kunia Middle Deep Monitor
Oahu	30204	Ewa-Kunia	2503-03	Kunia Mauka Deep Monitor

4.2.1.2. Kona Water-Level Monitoring Program

Since 1991, the CWRM has collected ground water elevation measurements in public and private wells and test holes throughout the North and South Kona and South Kohala Districts of the County of Hawaii. In September 2003, CWRM published the findings and conclusions of area monitoring activities in a report titled "A Study of the Ground-Water Conditions in North and South Kona and South Kohala Districts, Island of Hawaii, 1991-2002." The following background information and the findings of the Kona ground water monitoring activities are summarized from CWRM's 2003 report.

During the 1980s and through the early 1990s, and continuing into the current millennium, Kailua-Kona has experienced tremendous growth. Associated with the activities of the early 1990s was the high demand on water supplies and competition among large landowners and developers for new sources. As wells were drilled, new and interesting geological and hydrological information began to emerge that spurred additional wells at higher elevations, and at greater cost.

CWRM initiated a series of meetings in the North Kona and South Kohala Districts among the major landowners, developers, engineers, and hydrologic consultants, in order to come to agreement as to the proper development of ground water resources. This effort was in response to competition for well-site locations and CWRM concerns regarding planning, well placement, and well interference. The two ad-hoc groups were formed. The Hualalai Users Group focused on problems near Kailua-Kona and the North Kona District, while the Lalamilo Users Group focused on problems related to the South Kohala District. These meetings provided an avenue to diffuse disputes and to forestall any designation of the West Hawaii region as a ground water management area. As these meetings took place, it became clear that good baseline ground water data was sparse and that major decisions were not made using a “complete data-set,” but rather by incomplete knowledge of the resource. It was for this reason that CWRM started its ground water monitoring program in West Hawaii.

Major findings and conclusions are listed below and are based upon 171 individual water-level measurements in high-level wells, and 636 measurements in the basal wells:

- The data strongly suggests a slow decline of water levels in some of the high-level wells, and an apparent relationship to water-level decline and climatic conditions as recorded in the Lanihau and Huehue Ranch rain gages. Prior to pump installation, future wells drilled into this resource should be used as observation wells to verify the trends documented in the CWRM report.

- The data suggests that the high-level wells tap interconnected, though bounded, aquifers whose rate of water level decline is inversely proportional to its volume. Future well drilling for high-level potable sources must include accurate, well-designed aquifer tests that will aid in the determination of geologic boundaries to provide information on the geometry of the aquifer.

- The data suggests that there may be more than one geological mechanism that created the high-level aquifer.

- The data suggests that there is a water-level pattern observed in the high-level wells with Keopu being the “drain” for the ground water flow system. The ground water flux south of Keopu is to the north, and north of Keopu, the ground water flow is to the south.

- Some high-level wells do exhibit quasi-stable water levels, and show little variation over time. Long-term, continuous water-level monitoring should continue in these wells. Real-time correlation between water levels in the wells with climatic conditions measured at Lanihau Rain Gage will provide better insight into the behavior of the potable high-level aquifers.

- The data suggests the influence of climate over long-term trends in the basal aquifers.

- The strong correlation between well pairs will aid in predicting a water level, if only one of the wells can be measured.

- The data suggests that the variability of the ground water flow direction in a shallow basal lens system, as can be seen at the West Hawaii Landfill, is translatable to other areas.

- The low ground water gradients suggest a highly permeable basal coastal aquifer where basaltic lavas comprise the aquifer, and this finding is supported by tidal analysis. The composition of the lava flows determines its permeability, and in turn, the ground water gradient.

- This data will become the calibration target for future numerical and analytical ground water models, and will aid in the site selection for new wells.

4.2.1.3. Pearl Harbor Ground Water Monitoring Plan

CWRM is currently developing the Pearl Harbor Ground Water Monitoring Plan (PHGMP) for the Pearl Harbor Aquifer Sector Area. The purpose of the monitoring plan is to provide for the long-term management, protection, and sustainability of the basal ground water resources comprising the Pearl Harbor Aquifer Sector Area (consisting of the Ewa-Kunia, Waipahu-Waiawa, and Waimalu Aquifer System Areas). The PHGMP effort is the direct result of CWRM adopting new sustainable yield estimates for the Ewa-Kunia and Waipahu-Waiawa Aquifer System Areas in March 2000, and the application of a “milestone” approach to manage the Pearl Harbor resource. The Waimalu Aquifer System Area is included in the plan because of its hydraulic connection to the Waipahu-Waiawa Aquifer System Area, and the degree to which Waimalu has been developed as a major source of potable drinking water on Oahu. In addition, the plan will include a monitoring framework that is reflected in the organization of the plan itself and that is transferable and should serve as a template for other ground water monitoring plans and actions to be developed throughout the state.

The application of a “milestone” approach to manage the Pearl Harbor resource required the creation of the Pearl Harbor Monitoring Working Group (PHMWG) in March 2002. Core members include the USGS, Honolulu BWS, and CWRM. The USGS, Honolulu BWS, and CWRM signed a Memorandum of Agreement (MOA) for the formation of the PHMWG. It states that the major objectives of the monitoring plan are to collect comprehensive hydrologic data to monitor the long-term status of ground water conditions in Pearl Harbor, while sharing and disseminating hydrologic data in a timely manner. The MOA also acknowledges the need for well-infrastructure optimization and the establishment of ground water indicators.

The PHGMP will consist of three phases. Phase I discusses the nature of hydrologic data currently being collected, and recommends data components that should be collected in the future, based on observable ground water trends. Phase II examines the issues of aquifer and well optimization, refinement of ground water models, and partnerships for plan implementation. Phase III of the PHGMP describes the implementation of Phases I and II. The forthcoming document from CWRM will represent the work of the PHMWG toward the first composition of the PHGMP, and it should be refined and updated as additional information becomes available.

4.2.1.4. CWRM-USGS Cooperative Monitoring Program

CWRM-USGS cooperative monitoring program includes activities on the Islands of Kauai, Oahu, Molokai, Maui, and Hawaii. The objectives of the ground water data collection program in Hawaii are to collect, analyze, and publish data on ground water levels and quality (chloride concentration) data from a network of springs, observation wells, pumping wells, and deep monitoring wells to allow assessment of regional ground water resources and to identify trends in response to natural climatic variations and induced stresses. Data is used by federal, State, local officials, and private parties to: assess the ground water resources, predict future conditions, detect and define saltwater intrusion problems, and manage water resources. Data is particularly useful in determining long-term trends in water levels, sustainable yields, climatic effects on water levels, and in the development of flow- and salt-transport models that allow prediction of future conditions and detection and definition of contaminant and water-supply problems.

Data from the cooperative monitoring program is published annually and is available online from the USGS at http://waterdata.usgs.gov/nwis. The Fiscal Year 2008 CWRM-USGS Cooperative Monitoring Program will include data on ground and surface water as follows[2]:

- Discharge records for 32 stream-gaging stations;
- Discharge record for 1 ditch gage station;
- Water-level records for 34 observation wells;
- Salinity profiles for 2 wells; and
- Rainfall records for 21 rainfall stations.

The cooperative agreement between the USGS and the State officially began in 1909 when the USGS entered into an agreement with the Territory of Hawaii to install and monitor gages on 12 streams. Ground water data collection was initiated in 1972 to gather baseline data throughout the state. The program began with 170 wells, where new knowledge of ground water conditions was needed. Currently, a regionally representative network of wells is maintained on the islands of Kauai, Oahu, Molokai, Maui, and Hawaii to allow measurement of water levels and collection of water quality samples in most aquifers within the state. The ground water well networks are designed to meet the needs of the cooperators. New wells are added to the network as old wells are sealed or as other needs arrive.

Significant changes in the ground water monitoring network have occurred since 1995, when a total of 187 wells were included in the program. Program reductions induced by budgetary constraints reduced the number of wells to 160 for fiscal year 1996. By 2000, budget constraints caused monitoring activities to be discontinued at three more wells, bringing the total program well sites to 157. Fiscal Year (FY) 2001 saw another dramatic decrease, with the total number of program wells falling

[2] The number of stream-gaging stations, streamflow-gaging stations, water level observation wells, water-quality observation wells, and rainfall stations that are included in the CWRM-USGS cooperative monitoring program may change from year to year.

to 120. From 2002 to 2003, another 39 wells were cut, along with 10 more wells in 2004. Another well was discontinued in 2005 to bring the total well sites to 70. The budget for FY 2006 shows another severe decrease in monitor wells, as only 56 wells are included in the contract. For FY 2007, the contract includes 31 water-level monitor wells. Over a period of only 8 years, 156 of the 187 monitoring well sites that were active in 1999 have been discontinued; that translates to an 83% reduction in the number of monitoring locations statewide.

Organizations that participate (FY 07) as cooperators with the CWRM and USGS are listed in Table 4-2 by government jurisdiction:

Table 4-2
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Cooperators

Agency/Entity	Abbreviation
Federal:	
U.S. Army Corps of Engineers	COE
U.S. Army Garrison Hawaii Directorate of Public Works	Army
U.S. Navy NAVFACMAR Public Works	Navy
USGS National Streamflow Information Program	NSIP
National Weather Service	NWS
State of Hawaii:	
Department of Land and Natural Resources, Commission on Water Resource Management	CWRM
Department of Land and Natural Resources, Engineering Division	DNLR-Eng. Div.
Department of Land and Natural Resources, Land Division	DLNR-Land Div.
Department of Transportation	DOT
Department of Health	DOH
Office of Hawaiian Affairs	OHA
Civil Defense Department	SCD
County of Kauai:	
Department of Water	KDOW
City and County of Honolulu:	
Board of Water Supply	BWS
Department of Planning and Permitting	DPP
County of Maui:	
Department of Water Supply	MDOW
County of Hawaii:	
Department of Water Supply	DWS
Department of Public Works	DPW
Other	
Kahoolawe Island Reserve Commission	KIRC

The FY 2007 data collection stations for the USGS Cooperative Monitoring Program record the types of data shown in Table 4-3.

Table 4-3
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Station Types

Station Type	Abbreviation
Ground Water:	
Ground water levels, periodic measurements	GW WL
Ground water levels, continuous recording	GW WL-Cont
Ground water, periodic chloride concentrations	GW QW
Ground water, periodic chloride concentrations and water levels	GW WL+QW
Ground water, periodic salinity profiles	QW profile
Surface Water:	
Streamflow, real-time telemetry	SW RT-Cont
Streamflow, continuous recording	SW Cont
Agricultural ditch, continuous recording	SW-ditch
Streamflow, crest-stage gage (peak stage and discharge)	SW CSG
Flood-alert gage with telemetry, stage only	SW CSG RT-stage
Streamflow, crest-stage gage (peak stage only)	SW CSG-Stage
Streamflow, crest-stage gage (continuous stage only)	SW CSG-StageRec
Streamflow, periodic low-flow measurements	SW LFPR
Rainfall:	
Rainfall, real-time telemetry	RF-RT
Rainfall, continuous recording	RF-rec.
Water Quality:	
Periodic sampling for water quality	QW
Daily suspended-sediment records	sediment
Continuous monitoring of turbidity	turbidity

The data collection station locations for FY 2007 are listed by island in Table 4-4. Cooperating agencies for each station are also noted.

Table 4-4
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Stations for the State of Hawaii

Island	Station Number	Station Name	Station Type	Cooperator
Hawaii				
Hawaii	190423155371501	0437-01 Waiohinu Ex. Well	GW WL	CWRM
Hawaii	190602155325901	0632-01 Kau Ag, Honuapo 2	GW WL	CWRM
Hawaii	193251155072101	3207-04 Mountain View	GW WL	CWRM
Hawaii	194731155080401	4708-02 Kaieie Ex. Well	GW WL	CWRM
Hawaii	194945155534401	4953-01 Kiholo Well	GW WL	CWRM
Hawaii	200132155471101	6147-01 State of Hawaii, Kawaihae 3	GW WL	CWRM
Hawaii	201347155470501	7347-03 Halaula Makai E	GW WL-Cont	DWS
Hawaii	194117155174801	83.0 Quarry at Saddle Road	RF-rec.	CWRM
Hawaii	194945155534402	92.5 Kiholo RG	RF-rec.	CWRM
Hawaii	200518155405801	185.7 Kawainui RG	RF-rec.	CWRM
Hawaii	16704000	Wailuku Riv at Piihonua	SW Cont	CWRM
Hawaii	16720000	Kawainui Str nr Kamuela	SW Cont	CWRM
Hawaii	16756100	Kohakohau Str abv DWS div.	SW Cont	DWS
Hawaii	16758000	Waikoloa Str at Marine Dam	SW Cont	DWS
Hawaii	16770500	Pa'auau Gl at Pahala	SW Cont	CWRM
Hawaii	16701300	Waiakea Stream at Hilo	SW CSG	COE
Hawaii	16701400	Palai Str at Hilo	SW CSG	DOT
Hawaii	16701600	Alenaio Stream at Hilo	SW CSG	DPW
Hawaii	16717400	Kalaoa Mauka Str nr Hilo	SW CSG	DOT
Hawaii	16717650	Kapehu Str nr Pepeekeo	SW CSG	DOT
Hawaii	16717850	Keehia Gl nr Ookala	SW CSG	DOT
Hawaii	16717920	Ahualoa Gl at Honokaa	SW CSG	DOT
Hawaii	16752600	Hapahapai Gl at Kapaau	SW CSG	DOT
Hawaii	16755800	Luahine Gl nr Waimea	SW CSG	DOT
Hawaii	16756500	Keanuiomano Str nr Kamuela	SW CSG	DOT
Hawaii	16759060	Kamakoa Gl nr Waimea	SW CSG	DOT
Hawaii	16717000	Honolii Str nr Papaikou	SW RT-Cont	CWRM
Hawaii	16725000	Alakahi Str nr Kamuela	SW RT-Cont	CWRM
Kahoolawe				
Kahoolawe	16682000	Kaulana Gulch	SW RT-Cont	KIRC
Kahoolawe	16681000	Hakioawa Gulch	SW RT-Cont	KIRC
Kahoolawe	16682000	Kaulana Gulch	sediment	KIRC
Kahoolawe	16681000	Hakioawa Gulch	sediment	KIRC
Kauai				
Kauai	215434159263301	5426-03 McBryde Sugar, Koloa	GW WL	CWRM
Kauai	215454159274201	5427-01 Koloa A DOW	GW WL	KDOW
Kauai	215522159342601	5534-03 Hanapepe Vly DOW	GW WL	KDOW

Table 4-4 (continued)
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Stations for the State of Hawaii

Island	Station Number	Station Name	Station Type	Cooperator
Kauai (continued)				
Kauai	215630159265101	5626-01 Pua Kukui DOW	GW WL	KDOW
Kauai	215803159401201	5840-01 Waimea DOW	GW WL	KDOW
Kauai	215857159430101	5843-01 Kekaha shaft DOW	GW WL	KDOW
Kauai	215901159235301	5923-01 Kilohana A	GW WL	CWRM
Kauai	215958159214301	5921-01 Kalepa Ridge DOW	GW WL	CWRM
Kauai	220013159224001	0022-01 Hanamaulu DOW	GW WL	KDOW
Kauai	220057159210301	0021-01 Kalepa ridge, State	GW WL	KDOW
Kauai	220825159185301	0818-03 Anahola C DOW	GW WL	KDOW
Kauai	221247159324801	1232-01 Wainiha No. 1 DOW	GW WL	KDOW
Kauai	215509159340401	5534-06 Eleele	GW WL-Cont	CWRM
Kauai	215607159344301	5634-01 Hanapepe Ridge 439	GW WL-Cont	CWRM
Kauai	215856159243201	5824-02 Kilohana D	GW WL-Cont	KDOW
Kauai	215950159231601	5923-08 Hanamaulu TZ DOW	GW WL-Cont	CWRM
Kauai	220019159444801	0044-14 Kekaha Sug, Kaunalewa KS8	GW WL-Cont	CWRM
Kauai	220126159261501	0126-01 NW Kilohana DOW	GW WL-Cont	KDOW
Kauai	220133159242001	0124-01 NE Kilohana DOW	GW WL-Cont	CWRM
Kauai	220356159281401	1051.0 N. Wailua Ditch RG	RF-rec.	CWRM
Kauai	220443159235601	1068.0 LB Opaekaa nr Kapaa	RF-rec.	CWRM
Kauai	220504159321401	1045.0 Waialeale trail nr Lihue	RF-rec.	CWRM
Kauai	220703159351201	1085.0 Mohihi-Koaie Divide RG	RF-rec.	CWRM
Kauai	220713159361201	1083.0 Mohihi crossing nr Waimea	RF-rec.	CWRM
Kauai	220739159373001	1082.0 Waiakoali RG nr Waimea	RF-rec.	CWRM
Kauai	220927159355001	1084.0 Kilohana gage nr Hanalei	RF-rec.	CWRM
Kauai	220427159300201	1047.0 Mt Waialeale nr Lihue	RF-RT	NWS/NSIP
Kauai	220523159341201	1042.0 Waialae RG nr Waimea	RF-RT	NSIP
Kauai	221101159280801	1131.7 Hanalei River RG	RF-RT	NSIP
Kauai	16052500	Lawai Str nr Koloa	SW CSG	DOT
Kauai	16073500	Konohiki Str nr Kapaa	SW CSG	DOT
Kauai	16081200	Akulikuli Str nr Kapaa	SW CSG	DOT
Kauai	16084500	Kapaa Str at old hwy crossing	SW CSG	DOT
Kauai	16097900	Puukumu Str nr Kilauea	SW CSG	DOT
Kauai	16130000	Nahomalu Vly nr Mana	SW CSG	DOT
Kauai	16051500	Alexander Reservoir	SW CSG RT-stage	DLNR-Eng. Div.
Kauai	16094150	Ka Loko Reservoir	SW CSG RT-stage	DLNR-Eng. Div.
Kauai	16094600	Puu Ka Ele Reservoir	SW CSG RT-stage	DLNR-Eng. Div.
Kauai	16052000	Hanapepe Riv at Hanapepe	SW CSG-stage	COE
Kauai	16104200	Hanalei Riv at hwy 56 bridge	SW CSG-stage	COE
Kauai	16010000	Kawaikoi Stream nr Waimea	SW RT-Cont	CWRM
Kauai	16019000	Waialae Str at 3,820 ft.	SW RT-Cont	NSIP

Table 4-4 (continued)
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Stations for the State of Hawaii

Island	Station Number	Station Name	Station Type	Cooperator
Kauai (continued)				
Kauai	16036000	Makaweli Riv nr Waimea	SW RT-Cont	CWRM
Kauai	16049000	Hanapepe Riv blw Manuahi Str	SW RT-Cont	CWRM
Kauai	16060000	South Fork Wailua Riv nr Lihue	SW RT-Cont	CWRM
Kauai	16068000	EB of NF Wailua Riv	SW RT-Cont	CWRM
Kauai	16071500	LB Opaekaa Str nr Kapaa	SW RT-Cont	CWRM
Kauai	16097500	Halaulani Str at 400 ft	SW RT-Cont	CWRM
Kauai	16103000	Hanalei Riv nr Hanalei	SW RT-Cont	CWRM
Kauai	16108000	Wainiha Riv nr Hanalei	SW RT-Cont	CWRM
Maui				
Maui	204827156242201	4824-01 CWRM, Kihei Ex.	GW WL	CWRM
Maui	205140156304501	5130-01 CWRM, Waikapu 1	GW WL	CWRM
Maui	205154156303801	5130-02 CWRM, Waikapu 2	GW WL	CWRM
Maui	205312156321402	5332-04 Kepaniwai testhole, Iao Vly	GW WL	CWRM
Maui	205617156311101	5631-01 Waihee TH-A1	GW WL	CWRM
Maui		5418-01 EMWDP Pauwela	GW WL	CWRM
Maui	205437156310501	5431-01 TH-B	GW WL-Cont	CWRM
Maui	205705156312401	5731-05 Kanoa Ridge test bore	GW WL-Cont	MDOW
Maui	205856156400101	5840-01 CWRM, Alaeloa 318	GW WL-Cont	CWRM
Maui	205405156305401	5430-05 CWRM, Waiehu mon	QW profile/GW WL	CWRM
Maui	203721156151601	255.0 Kepuni Gl nr Kaupo	RF-rec.	CWRM
Maui	204923156371501	297.0 Olowalu	RF-rec.	CWRM
Maui	204017156031701	280.1 Oheo Gulch	RF-RT	NSIP
Maui	204916156083701	348.5 West Wailuaiki	RF-RT	NSIP
Maui	205327156351101	Puu Kukui RG	RF-RT	MDOW
Maui	16508000	Hanawi Str nr Nahiku	SW Cont	CWRM
Maui	16599500	Opana Tunnel at Kailiili	SW Cont	MDOW
Maui	16604500	Iao Str at Kepaniwai Park	SW Cont	CWRM
Maui	16614000	Waihee Riv at Dam nr Waihee	SW Cont	CWRM
Maui	16618000	Kahakuloa Str nr Honokohau	SW Cont	NSIP
Maui	16620000	Honokohau Str nr Honokohau	SW Cont	CWRM
Maui	16650200	Waikapu Stream at Hwy. 30	SW CSG	DOT
Maui	16500100	Kepuni Gl nr Kahikinui	SW CSG	DOT
Maui	16500300	Hawelewele Gl nr Kaupo	SW CSG	DOT
Maui	16500800	Kukuiula Gl nr Kipahulu	SW CSG	DOT
Maui	16502800	Moomoonui Gl at Hana	SW CSG	DOT
Maui	16502900	Kawaipapa Gl at Hana	SW CSG	DOT
Maui	16603700	Kalialinui Gl Trib nr Pukalani	SW CSG	DOT
Maui	16603800	Kaluapulani Gl Trib nr Pukalani	SW CSG	DOT
Maui	16603850	Kalialinui Gl nr Kahului	SW CSG	DOT

Table 4-4 (continued)
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Stations for the State of Hawaii

Island	Station Number	Station Name	Station Type	Cooperator
Maui (continued)				
Maui	16607000	Iao Str at Wailuku	SW CSG	COE
Maui	16619700	Poelua Gl nr Kahakuloa	SW CSG	DOT
Maui	16630200	Honokowai Str at Honokowai	SW CSG	DOT
Maui	16638500	Kahoma Str at Lahaina	SW CSG	COE
Maui	16643300	Kauaula Str nr mouth nr Lahaina	SW CSG	DOT
Maui	16646200	Olowalu Str nr Olowalu	SW CSG	DOT
Maui	16647500	Malalowaiaole Gl nr Maalaea	SW CSG	DOT
Maui	16658500	Waiakoa Gl Tributary nr Waialoa	SW CSG	DOT
Maui	16659000	Waiakoa Gl at Kihei	SW CSG	DOT
Maui	16501200	Oheo Gulch nr Kipahulu	SW RT-Cont	NSIP
Maui	16518000	West Wailuaiki Str nr Keanae	SW RT-Cont	CWRM
Maui	16587000	Honopou Str nr Huelo	SW RT-Cont	CWRM
Maui	16588000	Wailoa Dt at Honopou	SW-LFPR	DLNR-Land Div.
Maui	16589000	New Hamakua Dt at Honopou	SW-LFPR	DLNR-Land Div.
Maui	16592000	Lowrie Dt at Honopou	SW-LFPR	DLNR-Land Div.
Maui	16594000	Haiku Dt at Honopou	SW-LFPR	DLNR-Land Div.
Molokai				
Molokai	210402156495801	0449-01 DWS, Ualapue, Molokai	GW WL	CWRM
Molokai	210419156570501	0457-01 DWS, Kawela, Molokai	GW WL	CWRM
Molokai	211039157123101	551.5 Kakaako nr Mauna Loa	RF-rec.	CWRM
Molokai	16414200	Kaunakakai Gl at Kaunakakai	SW Cont	COE
Molokai	16415600	Kawela Stream near Moku	SW Cont	DOT
Molokai	16415600	Kawela Stream near Moku	sediment	DOH
Molokai	16411300	Kakaako Gl at Hwy. 46	SW CSG	DOT
Molokai	16411640	Halena Gl nr Mauna Loa	SW CSG	DOT
Molokai	16413500	Manawainui Gl nr Kualapuu	SW CSG	DOT
Molokai	16415400	Wawaia Gl at Kamalo	SW CSG	DOT
Molokai	16400000	Halawa Str nr Halawa	SW RT-Cont	MDOW
Molokai		spring measurements	SW-LFPR	CWRM
Oahu				
Oahu	211828157515801	1851-22 USGS, Ala Moana Blvd	GW WL	CWRM
Oahu	212010157531501	2053-08 Kalihi	GW WL	CWRM
Oahu	212046157531401	2053-10 Fort Shafter Well	GW WL	Army
Oahu	212106157533701	2153-02 Damon Estate, Moanalua	GW WL	CWRM
Oahu	212117157534601	2153-08 Tripler Army Medical Center	GW WL	Army
Oahu	212154158015201	2101-03 DOWALD, Honouliuli	GW WL	CWRM
Oahu	212738158034301	2703-02 Kunia Basal Mon.	GW WL	CWRM
Oahu	213430158071601	3407-37 Kiikii Exp. Well	GW WL	CWRM
Oahu	213438158091101	3409-16 Mendonca, Mokuleia	GW WL	CWRM

Table 4-4 (continued)
CWRM-USGS Cooperative Monitoring Program
Fiscal Year 2007 Data Collection Stations for the State of Hawaii

Island	Station Number	Station Name	Station Type	Cooperator
Oahu (continued)				
Oahu	211832157515501,2	1851-19 A,B HECO, Halekauwila St	GW WL+QW	CWRM
Oahu	213446158104901	3410-08 Waialua Sugar, Mokuleia	GW WL+QW	CWRM
Oahu	212238157561101	2256-10 Navy, Aiea (187B)	GW WL-Cont	CWRM
Oahu	212927158014801	2901-07 Schofield Shaft, Oahu	GW WL-Cont	Army
Oahu	212359157502601	772.3 Moanalua no.1 at 1,000 ft	RF-rec.	CWRM
Oahu	213000157515401	886.6 Waikane at 75 ft	RF-rec.	CWRM
Oahu	213215157552800	883.12 Poamoho gage no. 1	RF-rec.	CWRM
Oahu	213221157541501	884.4 Punaluu	RF-rec.	CWRM
Oahu	213237157530701	886.4 Kahana at 95 ft	RF-rec.	CWRM
Oahu	213608158011101	897.9 Pupukea Rd at 1,600 ft	RF-rec.	CWRM
Oahu	213725158010401	897.1 Kamananui at Pupukea Mil Rd	RF-rec.	CWRM
Oahu	211747157485601	711.6 Kanewai Field, Manoa	RF-RT	COE
Oahu	212932157595401	SFK RG	RF-RT	SCD
Oahu	213016158105901	842.1 Makaha nr Makaha	RF-RT	CWRM
Oahu	213211157562400	882.4 Poamoho gage no. 2	RF-RT	CWRM
Oahu	16229000	Kalihi Str nr Honolulu	SW Cont	CWRM
Oahu	16240500	Waiakeakua Str at Honolulu	SW Cont	CWRM
Oahu	16247100	Manoa-Palolo Drainage Canal	SW Cont	CWRM
Oahu	16275000	Haiku Str nr Heeia	SW Cont	BWS
Oahu	16283200	Kahaluu Str nr Ahuimanu	SW Cont	BWS
Oahu	16284200	Waihee Str nr Kahaluu	SW Cont	BWS
Oahu	16294900	Waikane Str at alt 75 ft at Waikane	SW Cont	CWRM
Oahu	16295300	Hakipuu Stream nr Kaaawa	SW Cont	CWRM
Oahu	16303000	Punaluu Str nr Punaluu	SW Cont	CWRM
Oahu	16345000	Opaeula Str nr Wahiawa	SW Cont	CWRM
Oahu	16211300	Makaleha Str nr Waialua	SW CSG	DPP
Oahu	16212200	Mailiilii Str nr Waianae	SW CSG	DPP
Oahu	16212300	Nanakuli Str nr Nanakuli	SW CSG	DPP
Oahu	16212450	Kaloi Gl trib nr Honouliuli	SW CSG	DPP
Oahu	16212500	Honouliuli Str nr Waipahu	SW CSG	DPP
Oahu	16212601	Waikele Str at Wheeler Fld	SW CSG	DPP
Oahu	16212700	Waikakalaua Str nr Wahiawa	SW CSG	DPP
Oahu	16223000	Waimalu Str nr Aiea	SW CSG	DPP
Oahu	16228200	Moanalua Str nr Aiea	SW CSG	DPP
Oahu	16232000	Nuuanu Stream at Honolulu	SW CSG	DPP
Oahu	16247000	Palolo Stream at Honolulu	SW CSG	DPP
Oahu	16248950	Kahawai Stream at Waimanalo	SW CSG	DPP
Oahu	16265000	Kawa Str at Kaneohe	SW CSG	DPP
Oahu	16274499	Keaahala Str at Kam Hwy at Kaneohe	SW CSG	DPP

Table 4-4 (continued) CWRM-USGS Cooperative Monitoring Program Fiscal Year 2007 Data Collection Stations for the State of Hawaii				
Island	**Station Number**	**Station Name**	**Station Type**	**Cooperator**
Oahu (continued)				
Oahu	16283480	Ahuimanu Str nr Kahaluu	SW CSG	DPP
Oahu	16310501	Malaekahana Str at 30 ft	SW CSG	DPP
Oahu	16311000	Oio Stream nr Kahuku	SW CSG	DPP
Oahu	16210000	Lake Wilson flood warning	SW CSG RT-stage	SCD
Oahu	16264600	Kawainui Marsh SE Levee	SW CSG RT-stage	SCD
Oahu	16308500	Kahawainui Str at Laie	SW CSG-Stage	COE
Oahu	16210500	Kaukonahua Str nr Waialua	SW CSG-StageRec	DPP/SCD
Oahu	16211600	Makaha Str nr Makaha	SW RT-Cont	CWRM
Oahu	16200000	NF Kaukonahua Stream abv. RB	SW RT-Cont	CWRM/SCD
Oahu	16208000	SF Kaukonahua Stream	SW RT-Cont	SCD
Oahu	16213000	Waikele Str at Waipahu	SW RT-Cont	CWRM
Oahu	16294100	Waiahole Str at Waiahole	SW RT-Cont	CWRM
Oahu	16296500	Kahana Str at alt 30 ft nr Kahana	SW RT-Cont	CWRM
Oahu	16304200	Kaluanui Str nr Punaluu	SW RT-Cont	CWRM
Oahu	16330000	Kamananui Str at Maunawai	SW RT-Cont	OHA
Oahu	16302000	Punaluu Dt nr Punaluu	SW-ditch	CWRM
Oahu	16226200	North Halawa Str nr Honolulu	SW RT-Cont	DOT
Oahu	16226400	North Halawa Str nr Quarantine	SW RT-Cont	DOT
Oahu	212353157533001	H-3 Storm Drain C	SW RT-Cont	DOT
Oahu	211722157485601	H-1 RT SW/QW gage	SW RT-Cont	DOT
Oahu	212304157542201	771.9 N Halawa nr Honolulu	RF-RT	DOT
Oahu	212428157511201	771.11 N Halawa at Tunnel Portal	RF-RT	DOT
Oahu	211722157485602	H-1 raingage	RF-rec.	DOT
Oahu	16225900	North Halawa Str @ Bridge 8	QW	DOT
Oahu	16226200	North Halawa Str nr Honolulu	QW/sed/turbidity	DOT
Oahu	16226400	North Halawa Str nr Quarantine	QW/sed/turbidity	DOT
Oahu	16227100	Halawa Stream @ Stadium	QW	DOT
Oahu	212353157533001	H-3 Storm Drain C	QW	DOT
Oahu	211722157485601	H-1 RT SW/QW gage	QW	DOT
Oahu	212134157543901	AMR-2	SW CSG RT-stage	Army

4.2.2. Other Ground Water Monitoring Programs

4.2.2.1. Honolulu BWS Ground Water Monitoring Program

The Honolulu BWS has developed an extensive ground water monitoring program. The program includes 29 deep monitor wells and 12 water level monitor wells on Oahu. The Honolulu BWS utilizes data from these wells to operate and manage the integrated municipal water system serving the City and County of Honolulu. Kauai

County, Maui County, and Hawaii County currently utilize data from wells included in the USGS Cooperative Monitoring Program.

Table 4-5 lists the deep monitor wells included in the Honolulu BWS monitoring program. Table 4-6 lists the water level monitoring wells included in the Honolulu BWS Monitoring program. The BWS uses data from the deep monitor wells to identify changes in the freshwater lens, while data from the water level monitor wells are used to ensure operational safety and prevent water shortages.

Table 4-5
Summary of Deep Monitor Wells in the Honolulu BWS Monitoring Program

Aquifer System Code	Well Number	Well Name
30101	1748-14	Kaimuki Sta Deep Mon
30101	1749-22*	Kaimuki HS Deep Mon
30101	1848-01	Waahila Deep Monitor
30102	1850-30	Punchbowl Deep Mon
30102	1851-57	Beretania Deep Mon
30103	1952-48	Kalihi Sta Deep Mon
30103	2052-10	Kapalama
30103	2052-12	Jonathan Springs
30103	2052-15	Kalihi Sh Deep Mon
30104	2153-05	Moanalua Deep Mon
30105	1747-04	Waialae SH Deep Mon
30201	2255-40	Halawa-BWS Deep Mon
30201	2355-15	Kaamilo Deep Monitor
30201	2456-04	Newtown Deep Monitor
30201	2457-04	Punanani Deep Mon
30201	2557-04	Waimano Deep Mon
30203	2201-10*	Kunia T41 Deep Mon
30203	2300-18*	Waipahu Deep Monitor
30203	2458-06*	Manana Deep Mon
30203	2459-26	Waiawa Deep Mon
30203	2500-03	Waiola Deep Monitor
30203	2602-02	Poliwai Deep Mon
30402	3405-05	Helemano Deep Mon
30403	3604-01	Kawailoa Deep Mon
30601	3553-05*	Punaluu Deep Monitor
30601	3554-05	Kaluanui 2 Monitor
30601	3755-10	Hauula Deep Monitor
30601	3956-08	Laie Deep Monitor
30601	4057-17	Kahuku Deep Mon

* Wells that also provide data for the water level monitoring program

Table 4-6
Summary of Water Level Monitor Wells in the Honolulu BWS Monitoring Program

Aquifer System Code	Well Number	Well Name
30101	1748-01	Kanewai Park Obs
30101	1749-22*	Kaimuki HS Deep Mon
30102	1851-02	Thomas Square
30103	2052-10	Kapalama
30104	2153-09	Moanalua
30105	1748-12	Keanu
30201	2255-33	Halawa Obs.
30201	2356-53	Aiea
30201	2455-01	Upper Waimalu
30203	2201-10*	Kunia T41 Deep Mon
30203	2300-18*	Waipahu Deep Monitor
30203	2358-20	Pearl City Obs
30203	2458-06*	Manana Deep Mon
30204	2103-01	Puu Makakilo
30304	2812-01	Makaha Shaft
30402	3406-04	Waialua
30601	3553-05*	Punaluu Deep Monitor

* Wells that also provide data for the deep monitor well program

4.2.2.2. Public and Private Observation Wells

There are several federal, State, and county agencies that own and operate observation wells. Many private landowners and corporations also have wells permitted for observation purposes. These publicly and privately owned wells are not included in the CWRM, USGS, or Honolulu BWS monitoring programs. Table 4-7 lists all observation wells registered with the CWRM that are not part of the CWRM, USGS, or Honolulu BWS monitoring programs (the table does not include temporary monitor wells, such as the Kona area water level wells that are developed into production wells).

CWRM is not aware of the type of data that may be collected at these wells or if they are actively being monitored. CWRM is considering expanding its ground water reporting program to require all owners/operators of observation wells to submit monthly or quarterly reports containing water level and chloride data as well as indicating well use status (e.g. active, inactive, or abandoned). Any water quality data from observation wells should be submitted to the DOH.

Table 4-7
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Hawaii				
Hawaii	80101	7345-03	Makapala A	U S G S
Hawaii	80101	7347-04	Halaula Mauka B	U S G S
Hawaii	80101	7347-05	Halaula B	U S G S
Hawaii	80101	7445-01	Hapuu Bay D	U S G S
Hawaii	80101	7448-06	Kohala Obs F	U S G S
Hawaii	80101	7448-07	Honopueo F	U S G S
Hawaii	80101	7451-01	Upolu Obs J-A	U S G S
Hawaii	80101	7451-02	Upolu J-B	U S G S
Hawaii	80101	7549-03	Hawi Makai I	U S G S
Hawaii	80103	6141-01	Waiaka Tank	U S G S
Hawaii	80103	6240-01	Waimea Obs.	U S G S
Hawaii	80201	6428-01	Honokaa A	State DLNR-Engineering
Hawaii	80401	4007-01	Waiakea Monitor	Okahara & Assc
Hawaii	80401	4010-01	Kaumana	U S G S
Hawaii	80501	2714-01	Volcano TH-4	State DLNR-Engineering
Hawaii	80501	2714-02	Volcano TH5	State DLNR-Engineering
Hawaii	80501	2715-02	Volcano TH 3	State DLNR-Engineering
Hawaii	80503	0831-01	Ninole Gu TH-1	Hawaiiana Inv
Hawaii	80504	0339-01	South Point Tank	U S G S
Hawaii	80504	8836-01	Kaalualu TH 1	Kawaihae Ranch
Hawaii	80504	8837-01	Kaalualu TH 2	Kawaihae Ranch
Hawaii	80603	3057-01	Hokukano Mon 2	Hokulia
Hawaii	80603	3155-01	Kealakekua Obs.	U S G S
Hawaii	80603	3157-01	Hokukano Mon 1	Hokulia
Hawaii	80802	2883-07	Puna Geo MW2	Puna Geo Ventr
Hawaii	80803	2317-01	Haw Vol Nat Pk	Haw Vol Nat Pk
Hawaii	80901	3255-01	Kainaliu Obs.	U S G S
Hawaii	80901	3957-02	Komo Monitor	U S G S
Hawaii	80901	4061-01	Kaho Obs 3	Natl Park Serv
Hawaii	80901	4161-01	Kaho Obs. 1	Natl Park Serv
Hawaii	80901	4161-02	Kaho Obs. 2	Natl Park Serv
Hawaii	80901	4462-05	Keahole MW-11	State Dot-Airp
Hawaii	80901	4462-06	Keahole MW-13A	State Dot-Airp
Hawaii	80901	4462-07	Keahole MW-13B	State Dot-Airp
Hawaii	80901	4463-01	Keahole MW-14A	State Dot-Airp
Hawaii	80901	4463-02	Keahole MW-14B	State Dot-Airp
Hawaii	80901	4463-03	Keahole MW-14C	State Dot-Airp
Hawaii	80902	4959-10	Kukio Obs C	WB Kukio Resort
Hawaii	80902	4959-11	Kukio Obs E	WB Kukio Resort
Hawaii	80902	4959-12	Kukio Obs F	WB Kukio Resort
Hawaii	80902	4960-01	Kukio Obs D	WB Kukio Resort

Table 4-7 (continued)
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Hawaii (continued)				
Hawaii	80902	4960-03	Kukio Obs B	Huehue Ranch
Hawaii	80902	4960-04	Kukio Obs A	Huehue Ranch
Kauai				
Kauai	20101	5430-01	Lawai TH 3	Mcbryde Sugar
Kauai	20101	5529-02	Kalawai TH 5	Mcbryde Sugar
Kauai	20102	0023-01	Pukaki Res Mon	U S G S
Kauai	20102	0121-01	South Wailua	U S G S
Kauai	20102	5723-01	MW-1	Kauai DPW
Kauai	20102	5723-02	MW-2	Kauai DPW
Kauai	20102	5723-03	MW-3	Kauai DPW
Kauai	20102	5821-02	Kauai Inn Tank	Kauai DWS
Kauai	20102	5823-03	Garlinghouse Obs	Kauai DWS
Kauai	20102	5824-07	Puhi Obs 3	Grove Farm Co
Kauai	20102	5825-02	Haiku Mauka Obs	Grove Farm Co
Kauai	20102	5825-03	Haiku Mauka Obs	Grove Farm Co
Kauai	20103	0123-01	Maalo Road Mon	U S G S
Kauai	20103	0222-01	Aahoaka Mon	U S G S
Kauai	20103	0327-01	Waikoko Mon	U S G S
Kauai	20104	0518-02	Mahelona Hosp	State DOH
Kauai	20104	0523-02	Wailua Hmstds 3	U S G S
Kauai	20104	1019-01	Aliomanu	Lihue Plntn
Kauai	20201	1126-03	Test Well B	Princeville Utilities Co Inc
Kauai	20304	5537-01	8-inch Mill Test	Olokele Sugar
Maui				
Maui	60101	4831-01	Maalaea 272	State DLNR-Engineering
Maui	60102	5329-18	Waiale Obs	A&B
Maui	60102	5330-03	Field 63	Wailuku Sugar
Maui	60102	5330-04	Wailuku Mill TH	Wailuku Sugar
Maui	60102	5330-06	Mokuhau TH 1	Maui DWS
Maui	60102	5330-07	Mokuhau TH 2	Maui DWS
Maui	60102	5330-08	Mokuhau TH 3	Maui DWS
Maui	60102	5331-01	Iao Valley TH	Wailuku Sugar
Maui	60102	5430-03	Waiehu TH-E	Wailuku Agribusiness Co., Inc.
Maui	60102	5430-04	Waiehu TH-D	State DLNR-Engineering
Maui	60102	5529-01	Waiehu TH	U S G S
Maui	60102	5530-01	Waiehu Tunnel	Wailuku Sugar
Maui	60202	5637-01	Honokowai TH 1	Amfac
Maui	60202	5637-02	Honokowai TH 2	Amfac
Maui	60202	5637-03	Honokowai TH 3	Amfac

Table 4-7 (continued)
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Maui (continued)				
Maui	60202	5637-04	Honokowai	Amfac
Maui	60203	5638-01	Honokowai TH 6	Amfac
Maui	60203	5638-02	Honokowai TH 7	Amfac
Maui	60203	5639-01	Honokowai TH 5	Amfac
Maui	60203	5639-02	Honokowai TH 8	Amfac
Maui	60204	5237-01	Kauaula TH 1	State DLNR-Engineering
Maui	60204	5237-02	Kauaula TH 2	State DLNR-Engineering
Maui	60204	5338-01	Kanaha TH 1	State DLNR-Engineering
Maui	60204	5338-02	Kanaha TH 2	State DLNR-Engineering
Maui	60301	5028-02	Waikapu Shaft TH	U S G S
Maui	60301	5425-02	Sprecklesville	HC & S Co
Maui	60302	5125-01	Wailuku MW-1	Maui DPW
Maui	60302	5125-02	Wailuku MW-2	Maui DPW
Maui	60302	5125-03	Wailuku MW-3	Maui DPW
Maui	60302	5125-04	Wailuku MW-4	Maui DPW
Maui	60302	5125-05	Wailuku MW-5	Maui DPW
Maui	60302	5125-06	Wailuku MW-6	Maui DPW
Maui	60304	3925-01	Makena 68	State DLNR-Engineering
Maui	60304	4026-05	Wailea 6	Wailea Res Co
Maui	60304	4126-01	Wailea 1	Wailea Res Co
Maui	60304	4422-01	Waiohuli	U S G S
Maui	60304	4426-01	Kihei Inject TH	Maui Dpw
Maui	60402	5313-01	EMI Kailua Mon	East Maui Irr
Molokai				
Molokai	40202	0905-01	Airport TH	U S G S
Molokai	40203	0800-01	Kualapuu Deep Mon	U S G S
Oahu				
Oahu	30101	1748-11	Kaimuki Deep 1	Honolulu BWS
Oahu	30101	1749-07	Kapahulu	State Of Hawaii
Oahu	30101	1749-14	Kaimuki High Sch	Honolulu BWS
Oahu	30102	1849-11	Wilder Ave	Honolulu BWS
Oahu	30102	1849-12	Wilder Ave	Honolulu BWS
Oahu	30102	2047-03	Manoa	Honolulu BWS
Oahu	30102	2047-04	Manoa	Honolulu BWS
Oahu	30103	1952-04	Kapalama	Ahin Y Trust
Oahu	30103	1952-46	HCC O-6	Hon Comm Coll
Oahu	30105	1646-02	Waialae Golf	KS/Bishop Estate
Oahu	30105	1647-01	Kahala	Cromwell D D
Oahu	30201	2255-21	Halawa	
Oahu	30201	2255-22	Halawa	

Table 4-7 (continued)
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30201	2255-26	Halawa	
Oahu	30201	2255-27	Halawa	
Oahu	30201	2256-11	Aiea	State Of Hawaii
Oahu	30201	2256-12	Aiea	U S Navy
Oahu	30201	2355-01	Aiea	
Oahu	30201	2355-08	Kalauao	Honolulu BWS
Oahu	30201	2356-51	Pearl Harbor	U S G S
Oahu	30201	2356-57	Waimalu	Honolulu BWS
Oahu	30203	1800-01	Ewa Beach B	N O A A
Oahu	30203	1959-05	Ft Weaver Rd	H I G
Oahu	30203	1959-06	Ft Weaver Rd	H I G
Oahu	30203	1959-07	Ewa Beach A	N O A A
Oahu	30203	2100-02	Pearl Harbor	H I G
Oahu	30203	2101-09	Honouliuli F	Ewa Plantn
Oahu	30203	2300-10	Waipahu P6	KS/Bishop Estate
Oahu	30203	2400-07	Waikele Obs. D	USGS
Oahu	30203	2401-02	Royal Kunia A-1	Royal Oahu Res
Oahu	30203	2401-03	Royal Kunia A-2	Royal Oahu Res
Oahu	30203	2459-15	Waipahu	Ii Estate
Oahu	30203	2558-08	Waiawa	U S Navy
Oahu	30203	2600-05	Kipapa Mon MW-8	U S Air Force
Oahu	30203	2600-06	Kipapa ST01MW05	U S Air Force
Oahu	30203	2600-07	Kipapa ST01MW06	U S Air Force
Oahu	30203	2600-08	Kipapa ST01MW07	U S Air Force
Oahu	30203	2600-09	Kipapa ST01MW10	U S Air Force
Oahu	30203	2702-01	Waikakalaua MW-6	U S Air Force
Oahu	30203	2702-02	Waikakalaua MW-7	U S Air Force
Oahu	30203	2702-06	Waikaka ST12MW03	U S Air Force
Oahu	30203	2702-07	Waikaka ST12MW04	U S Air Force
Oahu	30203	2702-08	Waikaka ST12MW05	U S Air Force
Oahu	30203	2702-09	Waikaka ST12MW08	U S Air Force
Oahu	30203	2702-10	Waikaka ST12MW09	U S Air Force
Oahu	30203	2702-11	RW001	U S Air Force
Oahu	30203	2802-01	Schofield MW2-6	U S Army
Oahu	30204	2006-12	Kahe Point	Honolulu BWS
Oahu	30204	2006-16	Makaiwa Mon TH	Campbell Estate
Oahu	30204	2103-02	Puu Makakilo	U S Navy
Oahu	30204	2103-04	Barbers Pt. Mon	U S Navy
Oahu	30204	2103-05	Barbers Pt Shall	U S Navy
Oahu	30204	2107-07	Waimanalo Gulch	Waste Mgmt Haw
Oahu	30204	2303-07	Honouliuli Deep Mon	Ewa Wtr Dev

Table 4-7 (continued)
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30204	2503-04	BMW 5	Del Monte Fresh Produce
Oahu	30204	2703-05	BMW 6	
Oahu	30205	2703-03	BMW 2	Del Monte Fresh Produce
Oahu	30205	2703-04	BMW 4	Del Monte Fresh Produce
Oahu	30205	2704-01	BMW 3	Del Monte Fresh Produce
Oahu	30207	1806-07	Conaco Ref Obs 2	Dill-Conoco
Oahu	30207	1806-08	Conaco Ref Obs 1	Dill-Conoco
Oahu	30207	1906-08	Barbers Pt. MW-1	State DOT-Harbors
Oahu	30207	1906-10	Barbers Pt. MW-3	State DOT-Harbors
Oahu	30207	2006-18	Barbers Pt. MW-4	State Dot-Harb
Oahu	30209	1900-14	Ewa Beach C	N O A A
Oahu	30209	1900-15	Ewa Beach D	N O A A
Oahu	30209	1902-05	Coral Creek 5	Coral Creek
Oahu	30209	2001-16	Coral Creek 3	Coral Creek
Oahu	30301	2307-01	Nanakuli	Honolulu BWS
Oahu	30303	2711-03	Waianae	U S G S
Oahu	30303	2711-04	Waianae	U S G S
Oahu	30303	2809-02	Waianae Valley	Honolulu BWS
Oahu	30305	3113-02	ERDC-MW-1	U S Army
Oahu	30305	3213-08	ERDC-MW-2	U S Army
Oahu	30305	3213-09	ERDC-MW-3A	U S Army
Oahu	30305	3213-10	ERDC-MW-3B	U S Army
Oahu	30401	3307-20	Thompson Corner 1	U S G S
Oahu	30401	3308-01	Mokuleia	U S G S
Oahu	30401	3408-07	Mokuleia	U S G S
Oahu	30401	3409-18	Mokuleia	U S G S
Oahu	30401	3409-19	Mokuleia	U S G S
Oahu	30401	3410-11	Mokuleia	U S G S
Oahu	30401	3411-14	Kawaihapai	U S G S
Oahu	30401	3412-03	Dillingham Afb	U S G S
Oahu	30401	3414-01	Kaena Point	U S G S
Oahu	30401	3511-01	Mokuleia Bch	U S G S
Oahu	30402	3204-01	Kaheaka Obs.	U S G S
Oahu	30402	3307-16	Waialua	Waialua Sugar
Oahu	30402	3307-21	Thompson Corner 2	U S G S
Oahu	30402	3404-02	Waialua	Waialua Sugar
Oahu	30402	3406-07	Waialua	U S G S
Oahu	30402	3406-12	Twin Bridge Deep	U S G S
Oahu	30402	3406-13	Kamooloa Obs.	U S G S
Oahu	30402	3406-14	Helemano Cap 1	U S G S
Oahu	30402	3406-15	Helemano Cap 2	U S G S

Table 4-7 (continued)
Statewide Summary of Registered Observation Wells Not Included in the CWRM, CWRM-USGS, or Honolulu BWS Monitoring Programs

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30402	3407-26	Waialua	U S G S
Oahu	30402	3407-27	Waialua	U S G S
Oahu	30402	3407-28	Waialua	U S G S
Oahu	30402	3407-29	Waialua	Waialua Sugar
Oahu	30402	3505-26	Opaeula Obs	U S G S
Oahu	30402	3506-08	Haleiwa	U S G S
Oahu	30403	3503-01	N Upper Anahulu	U S G S
Oahu	30403	3505-23	Kawailoa	U S G S
Oahu	30403	3505-25	N Lower Anahulu	U S G S
Oahu	30403	3506-09	Haleiwa	U S G S
Oahu	30403	3604-01	Kawailoa Deep Mon	U S G S
Oahu	30403	3605-24	Kawailoa Pump 4	Waialua Sugar
Oahu	30403	3605-25	Kawailoa Pump 4	Waialua Sugar
Oahu	30403	3605-26	Kawailoa	U S G S
Oahu	30403	4101-03	Waialee	State Of Hawaii
Oahu	30501	2801-02	Schofield MW2-4	U S Army
Oahu	30501	2900-02	Schofield MW2-1	U S Army
Oahu	30501	2901-13	Schofield MW1-1	U S Army
Oahu	30501	2902-03	Schofield MW2-3	U S Army
Oahu	30501	2903-01	Schofield MW2-2	U S Army
Oahu	30501	2959-01	Schofield MW2-5	U S Army
Oahu	30501	3004-01	Schofield MW4-1	U S Army
Oahu	30501	3004-02	Schofield MW4-2	U S Army
Oahu	30501	3004-03	Schofield MW4-3	U S Army
Oahu	30501	3004-04	Schofield MW4-4	U S Army
Oahu	30501	3004-05	Schofield MW4-2A	U S Army
Oahu	30601	4057-05	Kahuku	Tsukamoto B
Oahu	30602	3453-12	Makalii 2	Koolau Ag Co
Oahu	30603	2348-01	Kuou TH	Honolulu BWS
Oahu	30603	2348-04	Kuou TH	Honolulu BWS
Oahu	30603	2751-04	Waihee Obs	Honolulu BWS
Oahu	30604	2042-05	Waimanalo STP 1	Hon Sewers
Oahu	30604	2042-06	Waimanalo STP2	Hon Sewers
Oahu	30604	2042-07	Waimanalo STP 3	Hon Sewers
Oahu	30604	2042-08	Waimanalo STP 4	Hon Sewers
Oahu	30604	2042-09	Waimanalo STP 5	Hon Sewers
Oahu	30604	2042-10	Waimanalo STP 6	Hon Sewers
Oahu	30604	2042-11	Waimanalo STP 7	Hon Sewers
Oahu	30604	2042-12	Waimanalo Stp 8	Hon Sewers
Oahu	30604	2042-13	Waimanalo	Pac Conc Quar
Oahu	30604	2044-01	Olomana Golf	State Of Hawaii

4.2.3. Statewide Summary of Ground Water Monitoring Sites

There are currently over 300 registered observation wells within the state. Table 4-8 is a complete list of registered observation wells and compiles the information previously presented in Tables 4-1 and 4-4 through 4-7. Deep monitor wells are called out with an asterisk. Figure 4-3 shows the location of all deep monitor wells within the state. Figure 4-4 shows the location of all observation wells within the state.

Table 4-8
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Hawaii				
Hawaii	80101	7345-03	Makapala A	U S G S
Hawaii	80101	7347-03	Halaula Makai E	U S G S
Hawaii	80101	7347-04	Halaula Mauka B	U S G S
Hawaii	80101	7347-05	Halaula B	U S G S
Hawaii	80101	7445-01	Hapuu Bay D	U S G S
Hawaii	80101	7448-06	Kohala Obs F	U S G S
Hawaii	80101	7448-07	Honopueo F	U S G S
Hawaii	80101	7451-01	Upolu Obs J-A	U S G S
Hawaii	80101	7451-02	Upolu J-B	U S G S
Hawaii	80101	7549-03	Hawi Makai I	U S G S
Hawaii	80103	6141-01	Waiaka Tank	U S G S
Hawaii	80103	6240-01	Waimea Obs.	U S G S
Hawaii	80201	6428-01	Honokaa A	State DLNR-Engineering
Hawaii	80204	4708-02	Kaieie Mauka	U S G S
Hawaii	80401	4007-01	Waiakea Monitor	Okahara & Assc
Hawaii	80401	4010-01	Kaumana	U S G S
Hawaii	80501	2714-01	Volcano TH-4	State DLNR-Engineering
Hawaii	80501	2714-02	Volcano TH5	State DLNR-Engineering
Hawaii	80501	2715-02	Volcano TH 3	State DLNR-Engineering
Hawaii	80501	3207-04	Olaa-Mt. View	U S G S
Hawaii	80503	0437-01	Waiohinu Expl	U S G S
Hawaii	80503	0831-01	Ninole Gu TH-1	Hawaiiana Inv
Hawaii	80504	0339-01	South Point Tank	U S G S
Hawaii	80504	8836-01	Kaalualu TH 1	Kawaihae Ranch
Hawaii	80504	8837-01	Kaalualu TH 2	Kawaihae Ranch
Hawaii	80603	3057-01	Hokukano Mon 2	Hokulia
Hawaii	80603	3155-01	Kealakekua Obs.	U S G S
Hawaii	80603	3157-01	Hokukano Mon 1	Hokulia
Hawaii	80802	2883-07	Puna Geo MW2	Puna Geo Ventr
Hawaii	80803	2317-01	Haw Vol Nat Pk	Haw Vol Nat Pk
Hawaii	80901	3255-01	Kainaliu Obs.	U S G S
Hawaii	80901	3457-04*	Kahaluu Deep Monitor*	State CWRM
Hawaii	80901	3858-01*	Kalaoa Keopu Deep Monitor*	State CWRM

Table 4-8 (continued)
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Hawaii				
Hawaii	80901	3957-02	Komo Monitor	U S G S
Hawaii	80901	4061-01	Kaho Obs 3	Natl Park Serv
Hawaii	80901	4161-01	Kaho Obs. 1	Natl Park Serv
Hawaii	80901	4161-02	Kaho Obs. 2	Natl Park Serv
Hawaii	80901	4462-05	Keahole MW-11	State Dot-Airp
Hawaii	80901	4462-06	Keahole MW-13A	State Dot-Airp
Hawaii	80901	4462-07	Keahole MW-13B	State Dot-Airp
Hawaii	80901	4463-01	Keahole MW-14A	State Dot-Airp
Hawaii	80901	4463-02	Keahole MW-14B	State Dot-Airp
Hawaii	80901	4463-03	Keahole MW-14C	State Dot-Airp
Hawaii	80902	4959-10	Kukio Obs C	WB Kukio Resort
Hawaii	80902	4959-11	Kukio Obs E	WB Kukio Resort
Hawaii	80902	4959-12	Kukio Obs F	WB Kukio Resort
Hawaii	80902	4960-01	Kukio Obs D	WB Kukio Resort
Hawaii	80902	4960-03	Kukio Obs B	Huehue Ranch
Hawaii	80902	4960-04	Kukio Obs A	Huehue Ranch
Kauai				
Kauai	20101	5430-01	Lawai TH 3	Mcbryde Sugar
Kauai	20101	5529-02	Kalawai TH 5	Mcbryde Sugar
Kauai	20101	5534-06	Upper Eleele Mon	U S G S
Kauai	20102	0023-01	Pukaki Res Mon	U S G S
Kauai	20102	0121-01	South Wailua	U S G S
Kauai	20102	0124-01	Ne Kilohana	U S G S
Kauai	20102	5626-01	Puakukui Springs	U S G S
Kauai	20102	5723-01	MW-1	Kauai DPW
Kauai	20102	5723-02	MW-2	Kauai DPW
Kauai	20102	5723-03	MW-3	Kauai DPW
Kauai	20102	5821-02	Kauai Inn Tank	Kauai DWS
Kauai	20102	5823-03	Garlinghouse Obs	Kauai DWS
Kauai	20102	5824-07	Puhi Obs 3	Grove Farm Co
Kauai	20102	5825-02	Haiku Mauka Obs	Grove Farm Co
Kauai	20102	5825-03	Haiku Mauka Obs	Grove Farm Co
Kauai	20102	5923-08	Hanamaulu TZ	U S G S
Kauai	20103	0123-01	Maalo Road Mon	U S G S
Kauai	20103	0126-01	NW Kilohana Mon	U S G S
Kauai	20103	0222-01	Aahoaka Mon	U S G S
Kauai	20103	0327-01	Waikoko Mon	U S G S
Kauai	20104	0518-02	Mahelona Hosp	State DOH
Kauai	20104	0523-02	Wailua Hmstds 3	U S G S
Kauai	20104	1019-01	Aliomanu	Lihue Plntn
Kauai	20201	1126-03	Test Well B	Princeville Utilities Co Inc

Table 4-8 (continued)
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Kauai (continued)				
Kauai	20301	0044-14	Kaunalewa Ks8	Kekaha Sugar
Kauai	20304	5537-01	8-inch Mill Test	Olokele Sugar
Maui				
Maui	60101	4831-01	Maalaea 272	State DLNR-Engineering
Maui	60102	5230-02*	Iao Deep Monitor*	State CWRM
Maui	60102	5329-18	Waiale Obs	A&B
Maui	60102	5330-03	Field 63	Wailuku Sugar
Maui	60102	5330-04	Wailuku Mill TH	Wailuku Sugar
Maui	60102	5330-06	Mokuhau TH 1	Maui DWS
Maui	60102	5330-07	Mokuhau TH 2	Maui DWS
Maui	60102	5330-08	Mokuhau TH 3	Maui DWS
Maui	60102	5331-01	Iao Valley TH	Wailuku Sugar
Maui	60102	5332-04	Kepaniwai TH	State DLNR-Engineering
Maui	60102	5430-03	Waiehu TH-E	Wailuku Agribusiness Co., Inc.
Maui	60102	5430-04	Waiehu TH-D	State DLNR-Engineering
Maui	60102	5430-05*	Waiehu Deep Monitor*	State CWRM
Maui	60102	5431-01	Waiehu TH-B	Wailuku Agribusiness Co, Inc.
Maui	60102	5529-01	Waiehu TH	U S G S
Maui	60102	5530-01	Waiehu Tunnel	Wailuku Sugar
Maui	60102	5631-01	Waihee TH A1	Wailuku Agribusiness Co., Inc.
Maui	60102	5631-09*	Waihee Deep Monitor*	State CWRM
Maui	60103	5731-05	Kanoa TH	Maui DWS
Maui	60202	5637-01	Honokowai TH 1	Amfac
Maui	60202	5637-02	Honokowai TH 2	Amfac
Maui	60202	5637-03	Honokowai TH 3	Amfac
Maui	60202	5637-04	Honokowai	Amfac
Maui	60202	5840-01	Alaeloa	State DLNR-Engineering
Maui	60203	5638-01	Honokowai TH 6	Amfac
Maui	60203	5638-02	Honokowai TH 7	Amfac
Maui	60203	5639-01	Honokowai TH 5	Amfac
Maui	60203	5639-02	Honokowai TH 8	Amfac
Maui	60203	5739-03*	Lahaina Deep Monitor (Mahinahina)*	State CWRM
Maui	60204	5237-01	Kauaula TH 1	State DLNR-Engineering
Maui	60204	5237-02	Kauaula TH 2	State DLNR-Engineering
Maui	60204	5338-01	Kanaha TH 1	State DLNR-Engineering
Maui	60204	5338-02	Kanaha TH 2	State DLNR-Engineering
Maui	60301	5028-02	Waikapu Shaft TH	U S G S
Maui	60301	5425-02	Sprecklesville	HC & S Co

Table 4-8 (continued) Statewide Summary of All Registered Observation Wells				
Island	**Aquifer System Code**	**Well No.**	**Well Name**	**Well Owner/Operator**
Maui (continued)				
Maui	60302	5125-01	Wailuku MW-1	Maui DPW
Maui	60302	5125-02	Wailuku MW-2	Maui DPW
Maui	60302	5125-03	Wailuku MW-3	Maui DPW
Maui	60302	5125-04	Wailuku MW-4	Maui DPW
Maui	60302	5125-05	Wailuku MW-5	Maui DPW
Maui	60302	5125-06	Wailuku MW-6	Maui DPW
Maui	60304	3925-01	Makena 68	State DLNR-Engineering
Maui	60304	4026-05	Wailea 6	Wailea Res Co
Maui	60304	4126-01	Wailea 1	Wailea Res Co
Maui	60304	4422-01	Waiohuli	U S G S
Maui	60304	4426-01	Kihei Inject TH	Maui Dpw
Maui	60401	5418-01	EMWDP Monitor	Maui DWS
Maui	60402	5313-01	EMI Kailua Mon	East Maui Irr
Molokai				
Molokai	40202	0905-01	Airport TH	U S G S
Molokai	40203	0800-01*	Kualapuu Deep Monitor*	U S G S
Oahu				
Oahu	30101	1748-01	Kanewai Park Obs	KS/Bishop Estate
Oahu	30101	1748-11	Kaimuki Deep 1	Honolulu BWS
Oahu	30101	1748-14*	Kaimuki Sta Deep Monitor*	Honolulu BWS
Oahu	30101	1749-07	Kapahulu	State Of Hawaii
Oahu	30101	1749-14	Kaimuki High Sch	Honolulu BWS
Oahu	30101	1749-22*	Kaimuki HS Deep Monitor*	Honolulu BWS
Oahu	30101	1848-01*	Waahila Deep Monitor*	Honolulu BWS
Oahu	30102	1849-11	Wilder Ave	Honolulu BWS
Oahu	30102	1849-12	Wilder Ave	Honolulu BWS
Oahu	30102	1850-30*	Punchbowl Deep Monitor*	Honolulu BWS
Oahu	30102	1851-02	Thomas Square	Honolulu BWS
Oahu	30102	1851-19	Halekauwila St	Heco
Oahu	30102	1851-22	Ala Moana Blvd	U S G S
Oahu	30102	1851-57*	Beretania Deep Monitor*	Honolulu BWS
Oahu	30102	2047-03	Manoa	Honolulu BWS
Oahu	30102	2047-04	Manoa	Honolulu BWS
Oahu	30103	1952-04	Kapalama	Ahin Y Trust
Oahu	30103	1952-46	HCC O-6	Hon Comm Coll
Oahu	30103	1952-48*	Kalihi Sta Deep Monitor*	Honolulu BWS
Oahu	30103	2052-10	Kapalama	Honolulu BWS
Oahu	30103	2052-12*	Jonathan Springs*	Honolulu BWS
Oahu	30103	2052-15*	Kalihi Sh Deep Monitor*	Honolulu BWS
Oahu	30104	2053-10	Ft Shafter Mon.	U S Army
Oahu	30104	2153-05*	Moanalua Deep Monitor*	Honolulu BWS

Table 4-8 (continued)
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30104	2153-09	Moanalua	Honolulu BWS
Oahu	30105	1646-02	Waialae Golf	KS/Bishop Estate
Oahu	30105	1647-01	Kahala	Cromwell D D
Oahu	30105	1747-04*	Waialae SH Deep Monitor*	U S G S
Oahu	30105	1748-12	Keanu	Honolulu BWS
Oahu	30201	2253-03*	Halawa Deep Monitor*	State CWRM
Oahu	30201	2255-21	Halawa	
Oahu	30201	2255-22	Halawa	
Oahu	30201	2255-26	Halawa	
Oahu	30201	2255-27	Halawa	
Oahu	30201	2255-33	Halawa Obs.	Honolulu BWS
Oahu	30201	2255-40*	Halawa-BWS Deep Monitor*	Honolulu BWS
Oahu	30201	2256-10	Aiea	U S Navy
Oahu	30201	2256-11	Aiea	State Of Hawaii
Oahu	30201	2256-12	Aiea	U S Navy
Oahu	30201	2355-01	Aiea	
Oahu	30201	2355-08	Kalauao	Honolulu BWS
Oahu	30201	2355-15*	Kaamilo Deep Monitor*	Honolulu BWS
Oahu	30201	2356-51	Pearl Harbor	U S G S
Oahu	30201	2356-53	Aiea	Honolulu BWS
Oahu	30201	2356-57	Waimalu	Honolulu BWS
Oahu	30201	2455-01	Upper Waimalu	Honolulu BWS
Oahu	30201	2456-04*	Newtown Deep Monitor*	Honolulu BWS
Oahu	30201	2456-05*	Waimalu Deep Monitor*	State CWRM
Oahu	30201	2457-04*	Punanani Deep Monitor*	Honolulu BWS
Oahu	30201	2557-04*	Waimano Deep Monitor*	Honolulu BWS
Oahu	30203	1800-01	Ewa Beach B	N O A A
Oahu	30203	1959-05	Ft Weaver Rd	H I G
Oahu	30203	1959-06	Ft Weaver Rd	H I G
Oahu	30203	1959-07	Ewa Beach A	N O A A
Oahu	30203	2100-02	Pearl Harbor	H I G
Oahu	30203	2101-03	Honouliuli	State Dot-Highways
Oahu	30203	2101-09	Honouliuli F	Ewa Plantn
Oahu	30203	2201-10*	Kunia T41 Deep Monitor*	Honolulu BWS
Oahu	30203	2300-10	Waipahu P6	KS/Bishop Estate
Oahu	30203	2300-18*	Waipahu Deep Monitor*	State CWRM
Oahu	30203	2358-20	Pearl City Obs	Honolulu BWS
Oahu	30203	2400-07	Waikele Obs. D	USGS
Oahu	30203	2401-02	Royal Kunia A-1	Royal Oahu Res
Oahu	30203	2401-03	Royal Kunia A-2	Royal Oahu Res
Oahu	30203	2458-06*	Manana Deep Monitor*	Honolulu BWS

Table 4-8 (continued) Statewide Summary of All Registered Observation Wells				
Island	**Aquifer System Code**	**Well No.**	**Well Name**	**Well Owner/Operator**
Oahu (continued)				
Oahu	30203	2459-15	Waipahu	Ii Estate
Oahu	30203	2459-26*	Waiawa Deep Monitor*	Honolulu BWS
Oahu	30203	2500-03*	Waiola Deep Monitor*	Honolulu BWS
Oahu	30203	2558-08	Waiawa	U S Navy
Oahu	30203	2600-05	Kipapa Mon MW-8	U S Air Force
Oahu	30203	2600-06	Kipapa ST01MW05	U S Air Force
Oahu	30203	2600-07	Kipapa ST01MW06	U S Air Force
Oahu	30203	2600-08	Kipapa ST01MW07	U S Air Force
Oahu	30203	2600-09	Kipapa ST01MW10	U S Air Force
Oahu	30203	2602-02*	Poliwai Deep Monitor*	Honolulu BWS
Oahu	30203	2659-01*	Waipio Mauka Deep Monitor*	State CWRM
Oahu	30203	2702-01	Waikakalaua MW-6	U S Air Force
Oahu	30203	2702-02	Waikakalaua MW-7	U S Air Force
Oahu	30203	2702-06	Waikaka ST12MW03	U S Air Force
Oahu	30203	2702-07	Waikaka ST12MW04	U S Air Force
Oahu	30203	2702-08	Waikaka ST12MW05	U S Air Force
Oahu	30203	2702-09	Waikaka ST12MW08	U S Air Force
Oahu	30203	2702-10	Waikaka ST12MW09	U S Air Force
Oahu	30203	2702-11	RW001	U S Air Force
Oahu	30203	2802-01	Schofield MW2-6	U S Army
Oahu	30204	2006-12	Kahe Point	Honolulu BWS
Oahu	30204	2006-16	Makaiwa Mon TH	Campbell Estate
Oahu	30204	2103-01	Puu Makakilo	U S Navy
Oahu	30204	2103-02	Puu Makakilo	U S Navy
Oahu	30204	2103-04	Barbers Pt. Mon	U S Navy
Oahu	30204	2103-05	Barbers Pt Shall	U S Navy
Oahu	30204	2107-07	Waimanalo Gulch	Waste Mgmt Haw
Oahu	30204	2303-07*	Honouliuli Deep Monitor*	Ewa Wtr Dev
Oahu	30204	2403-02*	Kunia Middle Deep Monitor*	State CWRM
Oahu	30204	2503-03*	Kunia Mauka Deep Monitor*	State CWRM
Oahu	30204	2503-04	BMW 5	Del Monte Fresh Produce
Oahu	30204	2703-02	Kunia Basal Mon	Campbell Estate
Oahu	30204	2703-05	BMW 6	
Oahu	30205	2703-03	BMW 2	Del Monte Fresh Produce
Oahu	30205	2703-04	BMW 4	Del Monte Fresh Produce
Oahu	30205	2704-01	BMW 3	Del Monte Fresh Produce
Oahu	30207	1806-07	Conaco Ref Obs 2	Dill-Conoco
Oahu	30207	1806-08	Conaco Ref Obs 1	Dill-Conoco
Oahu	30207	1906-08	Barbers Pt. MW-1	State DOT-Harbors
Oahu	30207	1906-10	Barbers Pt. MW-3	State DOT-Harbors
Oahu	30207	2006-18	Barbers Pt. MW-4	State Dot-Harb

Table 4-8 (continued)
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30209	1900-14	Ewa Beach C	N O A A
Oahu	30209	1900-15	Ewa Beach D	N O A A
Oahu	30209	1902-05	Coral Creek 5	Coral Creek
Oahu	30209	2001-16	Coral Creek 3	Coral Creek
Oahu	30301	2307-01	Nanakuli	Honolulu BWS
Oahu	30303	2711-03	Waianae	U S G S
Oahu	30303	2711-04	Waianae	U S G S
Oahu	30303	2809-02	Waianae Valley	Honolulu BWS
Oahu	30305	3113-02	ERDC-MW-1	U S Army
Oahu	30305	3213-08	ERDC-MW-2	U S Army
Oahu	30305	3213-09	ERDC-MW-3A	U S Army
Oahu	30305	3213-10	ERDC-MW-3B	U S Army
Oahu	30401	3307-20	Thompson Corner 1	U S G S
Oahu	30401	3308-01	Mokuleia	U S G S
Oahu	30401	3408-07	Mokuleia	U S G S
Oahu	30401	3409-18	Mokuleia	U S G S
Oahu	30401	3409-19	Mokuleia	U S G S
Oahu	30401	3410-08	Mokuleia	Waialua Sugar
Oahu	30401	3410-11	Mokuleia	U S G S
Oahu	30401	3411-14	Kawaihapai	U S G S
Oahu	30401	3412-03	Dillingham Afb	U S G S
Oahu	30401	3414-01	Kaena Point	U S G S
Oahu	30401	3511-01	Mokuleia Bch	U S G S
Oahu	30402	3204-01	Kaheaka Obs.	U S G S
Oahu	30402	3307-16	Waialua	Waialua Sugar
Oahu	30402	3307-21	Thompson Corner 2	U S G S
Oahu	30402	3404-02	Waialua	Waialua Sugar
Oahu	30402	3405-05*	Helemano Deep Monitor*	Honolulu BWS
Oahu	30402	3406-04	Waialua	Waialua Sugar
Oahu	30402	3406-07	Waialua	U S G S
Oahu	30402	3406-12	Twin Bridge Deep	U S G S
Oahu	30402	3406-13	Kamooloa Obs.	U S G S
Oahu	30402	3406-14	Helemano Cap 1	U S G S
Oahu	30402	3406-15	Helemano Cap 2	U S G S
Oahu	30402	3407-26	Waialua	U S G S
Oahu	30402	3407-27	Waialua	U S G S
Oahu	30402	3407-28	Waialua	U S G S
Oahu	30402	3407-29	Waialua	Waialua Sugar
Oahu	30402	3407-37	Kiikii Cap Mon 2	U S G S
Oahu	30402	3505-26	Opaeula Obs	U S G S
Oahu	30402	3506-08	Haleiwa	U S G S

Table 4-8 (continued)
Statewide Summary of All Registered Observation Wells

Island	Aquifer System Code	Well No.	Well Name	Well Owner/Operator
Oahu (continued)				
Oahu	30403	3503-01	N Upper Anahulu	U S G S
Oahu	30403	3505-23	Kawailoa	U S G S
Oahu	30403	3505-25	N Lower Anahulu	U S G S
Oahu	30403	3506-09	Haleiwa	U S G S
Oahu	30403	3604-01*	Kawailoa Deep Monitor*	U S G S
Oahu	30403	3605-24	Kawailoa Pump 4	Waialua Sugar
Oahu	30403	3605-25	Kawailoa Pump 4	Waialua Sugar
Oahu	30403	3605-26	Kawailoa	U S G S
Oahu	30403	4101-03	Waialee	State Of Hawaii
Oahu	30501	2801-02	Schofield MW2-4	U S Army
Oahu	30501	2900-02	Schofield MW2-1	U S Army
Oahu	30501	2901-13	Schofield MW1-1	U S Army
Oahu	30501	2902-03	Schofield MW2-3	U S Army
Oahu	30501	2903-01	Schofield MW2-2	U S Army
Oahu	30501	2959-01	Schofield MW2-5	U S Army
Oahu	30501	3004-01	Schofield MW4-1	U S Army
Oahu	30501	3004-02	Schofield MW4-2	U S Army
Oahu	30501	3004-03	Schofield MW4-3	U S Army
Oahu	30501	3004-04	Schofield MW4-4	U S Army
Oahu	30501	3004-05	Schofield MW4-2A	U S Army
Oahu	30601	3553-05*	Punaluu Deep Monitor*	Honolulu BWS
Oahu	30601	3554-05*	Kaluanui 2 Monitor*	Honolulu BWS
Oahu	30601	3755-10*	Hauula Deep Monitor*	Honolulu BWS
Oahu	30601	3956-08*	Laie Deep Monitor*	Honolulu BWS
Oahu	30601	4057-05	Kahuku	Tsukamoto B
Oahu	30601	4057-17*	Kahuku Deep Monitor*	Honolulu BWS
Oahu	30602	3453-12	Makalii 2	Koolau Ag Co
Oahu	30603	2348-01	Kuou TH	Honolulu BWS
Oahu	30603	2348-04	Kuou TH	Honolulu BWS
Oahu	30603	2751-04	Waihee Obs	Honolulu BWS
Oahu	30604	2042-05	Waimanalo STP 1	Hon Sewers
Oahu	30604	2042-06	Waimanalo STP2	Hon Sewers
Oahu	30604	2042-07	Waimanalo STP 3	Hon Sewers
Oahu	30604	2042-08	Waimanalo STP 4	Hon Sewers
Oahu	30604	2042-09	Waimanalo STP 5	Hon Sewers
Oahu	30604	2042-10	Waimanalo STP 6	Hon Sewers
Oahu	30604	2042-11	Waimanalo STP 7	Hon Sewers
Oahu	30604	2042-12	Waimanalo Stp 8	Hon Sewers
Oahu	30604	2042-13	Waimanalo	Pac Conc Quar
Oahu	30604	2044-01	Olomana Golf	State Of Hawaii

*Indicates Deep Monitor Well

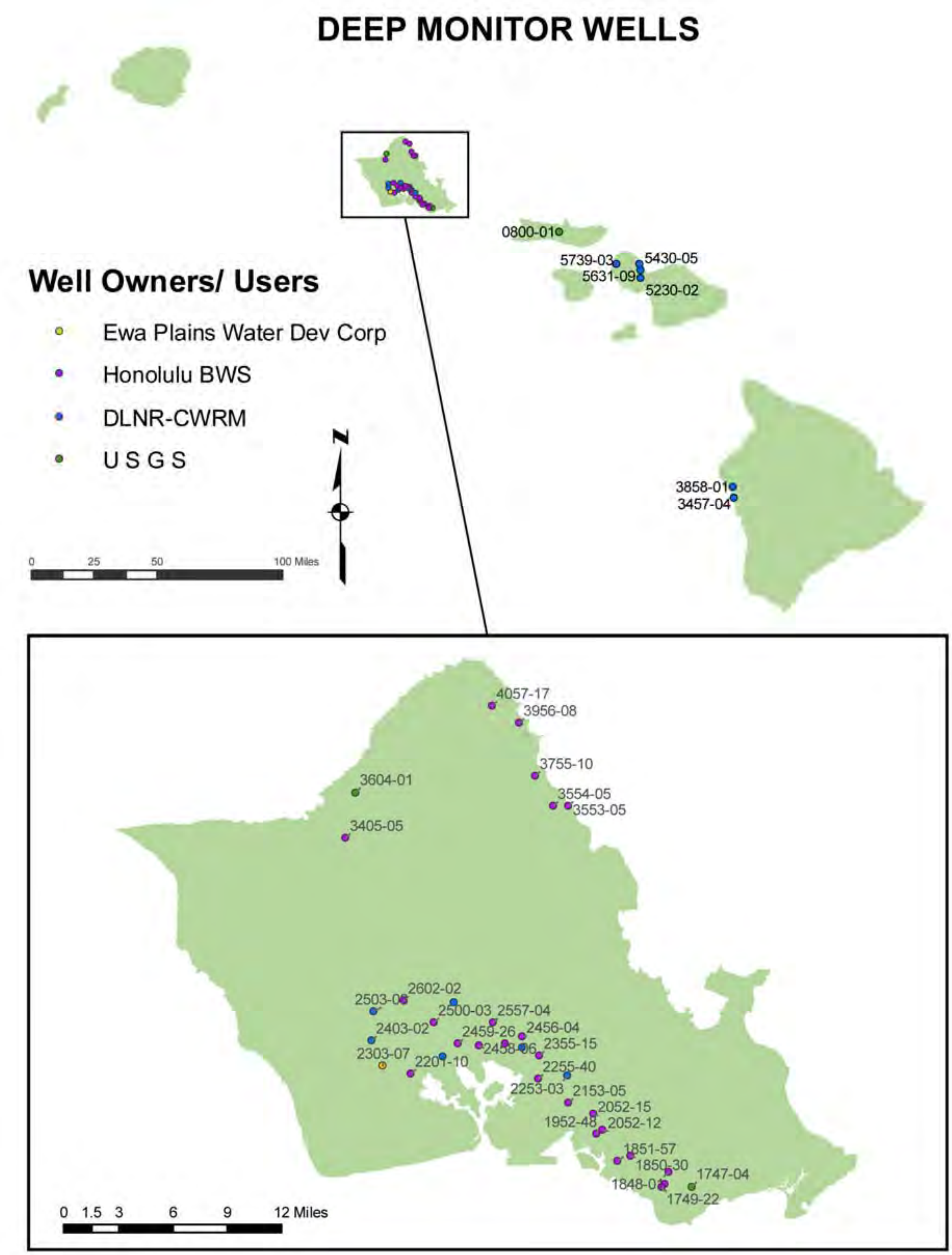

Figure 4-3. Deep monitor wells in the State of Hawaii.

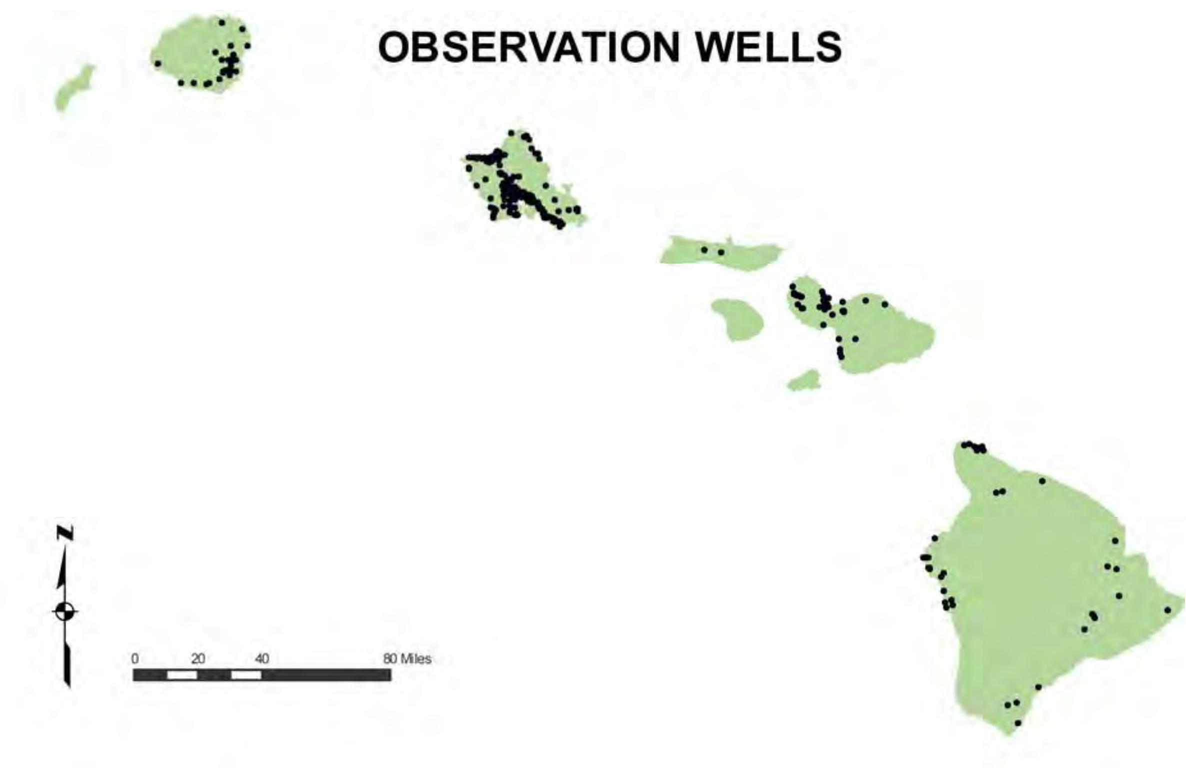

Figure 4-4: Water -level observation wells in the State of Hawaii.

4.2.4. CWRM Management of Ground Water Data

CWRM utilizes three tools to manage information on groundwater: a well index database, verifications of ground water well sources, and water use reports submitted by individual well owners or operators. These tools are described below.

4.2.4.1. CWRM Well Index Database

CWRM maintains a well index database to track specific information pertaining to the construction and installation of production wells in Hawaii. The database contains information on well location, ownership, operation, well construction, pump type and capacity, and contractor information. The database assists CWRM staff in protecting ground water resources from excessive withdrawals. The well index contains aquifer properties and geologic information from well-drilling logs and pump-test reports.

4.2.4.2. Ground Water Well Verification

In 1988, CWRM initiated a program for well registration and declaration of existing water uses and began requiring well owners and operators to report water use to CWRM (see Section 6.3 for more information on water use reporting requirements). To date, CWRM has completed field verifications of all registered wells located in ground water management areas on Oahu, Molokai, and Maui. In non-water management areas, CWRM has not completed field verification of some wells drilled prior to 1988.

Verification of wells since 1988 has been accomplished via correspondence information and photo documentation provided by the drilling contractor in construction reports. Well construction and pump installation permits require the contractor to file completion reports as a condition of the permits. On occasion, staff will make a field visit to an existing or new well, but for the most part, well verification is based on information provided by the drilling contractor.

CWRM can indirectly verify information on a well by examining ground water use reports submitted by the owner or operator. Water-use reports must identify the volume of ground water withdrawn over specific intervals, the water level in the well referenced to mean sea level, and the temperature of well water. Until the Hawaii Well Construction and Pump Installation Standards were adopted by the Water Commission in 1997, CWRM did not consistently require pumpage metering and elevation benchmark references on all new wells. CWRM has not revised water use reporting policies to require the installation of meters and benchmarks at wells located outside water management areas and wells drilled before 1988. Such requirements would better enable CWRM to indirectly verify reported well data.

4.2.4.3. CWRM Water Use Reports

Ground water withdrawal data is obtained through reports submitted to CWRM by well operators/owners. Report submittals are inconsistent, with some users diligently reporting on a monthly basis, and others filing no reports until enforcement actions are taken against them. A monthly ground water use reporting form is available for use by well operators/owners on the CWRM website. The form asks for the following information:

- Well identification information;
- Start date and end date of reporting period;
- Quantity pumped (gallons);
- Method of quantity measurement;
- Chloride concentration (milligrams per liter);
- Water temperature (°F); and
- Non-pumping water level (elevation in feet above mean sea level).

To improve data collection from well operators/owners, CWRM has developed a database for tracking water use reports, and is enhancing the database to include an automated system for issuing notices of reporting delinquencies to permittees. Also, a web-based reporting program could eventually enable water users to more efficiently report water usage to CWRM.

4.2.5. Gaps in Ground Water Monitoring Activities

Statewide Ground Water Monitoring Plan

There is a need for a statewide plan to coordinate and implement monitoring activities, and to direct the expansion of monitoring networks. There is also the associated need to increase funding for data collection networks. For recommendations on the design and implementation of a Statewide Hydrologic Monitoring program, refer to Section 11 of the Water Resource Protection Plan.

Deep Monitor Wells

There are 40 deep monitor wells in the state (see Figure 4-3 and Table 4-8). All but six of them are on Oahu. Although Oahu has the most deep monitor wells, there is still a need for more wells in inland locations. Also, development is proceeding rapidly on Kauai, Maui and Hawaii, and basal aquifers are often developed to supply these developments. Deep monitor wells should be drilled on the neighbor islands to provide baseline data and to provide data on the influence of pumpage and climate change on ground water.

Aquifer-wide monitoring is severely limited throughout most of the state. Useful data on the behavior and status of ground water resources is lacking. This data gap may be especially dangerous in aquifers that are critical municipal sources. The coverage of water level and deep monitor wells should be increased. The State, in cooperation with the USGS, counties, and private entities should plan for idealized well placement in each aquifer sector area and create maps showing the ideal well locations, exisiting wells, funded wells, and planned wells.

Considerations for locating future deep monitor wells include:

- Providing the necessary *mauka*-to-*makai* spatial coverage within each aquifer system area;
- Enhancing hydrologic knowledge of the ground water system;
- Locating wells in areas that are not directly influenced by pumping centers and replacing those that are;
- Where feasible, identifying and converting former production and/or existing water-level observation wells into deep monitor wells; and
- Minimizing site requirements to obtain well easements, rights-of-entry, and property ownership.

Primary locations for deep monitor wells are areas where:

- The aquifer is a major potable resource and/or is being heavily pumped; and
- There is uncertainty about the sustainable yield, and concern about the relationship between pumpage and saltwater intrusion.

Secondary locations for deep monitor wells should be chosen in light of the following considerations:

- Collecting baseline data from an aquifer system area before it is developed to capacity (e.g., Kailua-Kona and Lahaina);
- Planning an additional well in an aquifer to provide greater understanding of the ground water hydrology (e.g., Pearl Harbor); and
- Minimizing cost by converting unused wells to deep monitor wells.

Water-Level Observation Wells

The statewide water-level observation well network is inadequate. In most areas of the state, the present water-level observation network lacks wells that continuously measure water levels from interior sites within aquifer system areas. There are also not enough wells in the high-level aquifers, which are important in measuring the effects of pumpage on streamflow. Also, high-level aquifers are often relatively small and need to be monitored for resource depletion. Interior water-level observation wells are important in defining the inland extent of basal aquifers.

Additionally, wells used to measure water levels are not tied into the same datum. It is essential to have well measuring points tied to the same datum, otherwise the measured water levels may not be comparable. Elevations in Hawaii are related using geodetic control points. The geodetic control in Hawaii was last updated by the National Geodetic Survey in the 1970s. Construction and land development over the last 30 years has resulted in the destruction or disturbance of many of the control benchmarks. In addition, land subsidence, changes in sea level, and other natural causes have also altered these controls. The Hawaii Department of Transportation is leading an effort to modernize elevations in Hawaii by obtaining funding and assistance from the National Geodetic Survey. Once a new geodetic control is in place it will be possible to link elevations at the current and future monitor well networks. Recent work reestablishing benchmarks on Maui by the National Geodetic Survey (NGS), using global positioning satellite (GPS) technology, has shown benchmark elevations can be rapidly and accurately reestablished (vertical accuracy with the NGS survey is about 2 cm).

Spring Discharge and Chemistry Measurements

Although spring discharge and chemistry data are collected in some areas (e.g., the Pearl Harbor Aquifer Sector Area), there has been minimal progress toward using the data in a meaningful way. Little has been done to correlate spring chemistry with land use changes over time, and the following opportunities should be explored:

- Because basal spring discharge essentially occurs at the coast, the challenge is to use such springs to monitor changes within the basal lens. Springs can provide information on the impacts of past land use activities and other changes to recharge.

- Continued sampling and discharge measurements are imperative, but other chemical constituents or measurable parameters (e.g., completing an annual mineral analysis of selected spring sampling points) should be measured to present a more complete understanding of the dynamics of ground water flow.

- The effect of spring data on the calibration of numerical ground water models should be further studied, as such data may provide additional insight.

- Databases on spring information are kept by multiple agencies; however, these databases are generally not integrated. Although jurisdictional issues must be addressed, the integration and sharing of data would be useful in understanding flow dynamics, and would allow for better application of shared resources and information.

Pumpage, Water-Level, and Chloride Information

Currently, all reported well pumpage data is entered into CWRM's water use reporting database. It is CWRM's priority to update and maintain ground water pumpage information. Pumpage data is updated on a regular basis, however, other functions of the database are still undergoing beta testing.

Due to staff constraints, CWRM has prioritized pumpage data collection to focus on designated water management areas and large users in non-designated areas. Once a CWRM achieves a greater level of compliance with the reporting of pumpage data, CWRM intends to improve compliance with chloride data reporting, followed by water-level reporting.

The following issues and concerns are associated with pumpage, water-level, and chloride data collection:

- Immediate correlation between pumpage, chloride, and water levels cannot be achieved. Time lags exist between pumping activities and aquifer response. Changes in water levels and chlorides may not manifest immediately, and lag periods may be several months long. In addition, water levels in coastal monitoring wells may be overwhelmingly governed by ocean level and tidal signals, and may completely mask changes due to recharge or withdrawal.

- It is difficult to correlate water uses with the associated changes in chloride levels and water levels; the effects of additional variables such as subsurface geology are also difficult to correlate.

- It is difficult to execute analyses of small-user data versus large-user data.

- Presently, pumpage, water-level, and chloride data is not shared between agencies through integrated databases. As is the case with spring discharge information, agency jurisdictional issues must be addressed before the integration and sharing of data can occur.

CWRM anticipates that the issues listed above can be addressed by the agency when the water use reporting database is fully operational. The completion of beta testing of the water use database is of utmost importance for CWRM to expand and enhance the reporting program. Also, it must be a priority to obtain more ground water pumpage, chloride, and water level information. Without this data, comprehensive, accurate and timely hydrologic analysis cannot be executed; CWRM will be unable to asses all stresses placed on ground water and the resulting individual well reaction to such stresses. Water use reporting (large and small users) in a generally uniform and timely fashion is a major goal of the water use database, as is the capability of having online reporting. This will greatly speed up correlations between pumpage, chloride concentrations, and water levels.

CWRM enforcement of water use reporting requirements is essential to improving the quality and timeliness of the CWRM database, which will in turn provide a quicker and more accurate picture of aquifer health. An example of timely reporting and information can be found on the Iao Aquifer System Area web page, maintained by the USGS in cooperation with the County of Maui (see http://hi.water.usgs.gov/iao/iao_summary.htm).

4.2.6. Recommendations for Monitoring Ground Water Resources

Recommendations for the improvement and expansion of ground water monitoring activities in the State of Hawaii are listed below and are categorized by activity type.

General Recommendations

The recommendations listed below apply to statewide activities for maintaining current programs and planning for future monitoring activities.

- **Maintain/increase USGS co-op funding:** The number of wells monitored by the USGS in the UGSG-CWRM cooperative agreement has declined by 83 percent since 1995. Water-level monitoring on the neighbor islands is not adequate and must be expanded. Funding for the cooperative program should be increased. The increased funding would reflect inflationary costs as well as expanding the data collection network to monitor new centers of water development.

- **Planning a Statewide Ground Water Monitoring Network:** It is recommended that a statewide plan be developed to implement monitoring activities and to direct the expansion of monitoring networks, especially for deep monitoring wells. This plan should also project funding requirements for data collection activities and improvements to the monitoring networks. Section 11 of the WRPP discusses this recommendation in greater detail.

Deep Monitor Wells

The items below summarize the recommendations for the Deep Monitor Well Program. Included in this listing are planned near-term improvements, as well as other projects that require the approval and appropriation of funds.

- **Drill new deep monitor and water level monitor wells:** Deep monitor wells should be drilled in most of the basal aquifers in Hawaii. Also, dedicated water-level monitor wells should be located or drilled in all of the aquifers in Hawaii.

- **Better Spatial Coverage:** Ideally, deep monitor wells within an aquifer should be located to provide coverage from an inland or mauka site, a middle site near withdrawal areas, and a makai site to monitor changes in the distal portion of the basal lens. Locating wells in this fashion provides a cross-section of the basal aquifer.

- **Review Monitoring Well Network:** The monitoring well network should be reviewed to: 1) identify wells located in large pumping batteries, that are directly influenced by pumpage, and should be considered for replacement; and 2) identify former production and/or existing water-level observation wells where it may be feasible to convert existing wells to deep monitoring wells.

- **New Data Collection:** Existing wells or new wells should be outfitted with nested piezometers or multiple piezometers to observe vertical flow in the aquifer system areas where such information is important. In addition, conductivity data loggers could be lowered to depths identified in the conductivity profile logs that suggest vertical flow, and left to monitor changes in conductivity over time. Where available, calibrated dispersion coefficients from deep monitor well data should be included in new 3-D solute transport ground water flow models.

- **Graphical Mapping of Data**: Conduct GIS mapping of top of TZ, MPTZ, and water-level elevations. These maps would show actual water levels and expected water levels from the deep monitor well data.

Water-Level Observation Wells

The items below summarize the recommendations for water-level observation wells. Included in this listing are planned near-term improvements, as well as other projects that require the approval and appropriation of funds.

- **Improve Data Collection:** 1) Outfit all new CWRM deep monitor wells with devices that will collect water-level data on a continuous basis. 2) Add transducers (or other devices) to provide continuous water-level data collection at existing BWS and USGS deep monitor wells in the network throughout the Pearl Harbor Aquifer Sector Area. 3) Eliminate redundant data collection from some monitoring sites.

- **Drill New Water-Level Observation Wells**: The primary considerations for drilling new observation wells is to better delineate the basal aquifer boundaries, and to locate geological boundaries and/or structures that would affect ground water flow. In general, even with the addition of water-level measuring devices in the existing deep monitor and water-level observation wells, coverage is lacking toward the interior of aquifer sector areas. New water-level observation wells or test holes should be drilled or developed in interior areas following a mauka-to-makai orientation.

- **Resurvey All Measuring Points for Water-level Observation Wells, Including Deep Monitor Wells:** In addition to new water-level monitoring, a priority goal is to resurvey all measuring points (benchmarks) related to water-level data. This action would include all new wells and existing wells. Because many of the observation wells were drilled over a timespan of several years, it is uncertain whether the elevation of measuring points located on the wells (from which the water-level elevations are derived) are referenced to the same datum. Therefore, synoptic water-level maps may not provide an accurate representation of water-level gradients. Geodetic-control benchmarks in the State of Hawaii should be resurveyed to ensure consistent and accurate water level measurements.

- **Conduct More Synoptic Water-level Surveys:** In a cooperative effort the USGS, Honolulu BWS, and CWRM completed two synoptic water-level surveys of the Pearl Harbor Aquifer Sector Area (October 31, 2002 and May 15, 2003). Water-level measuring tapes owned by the three agencies were calibrated against a USGS reference steel tape. Correction factors to the individual tapes were applied to each measurement. All measurements within the Pearl Harbor Aquifer Sector Area were completed within a four-hour period on each day.

  Synoptic water level surveys should be conducted at least twice a year in all important areas. All water-level tapes should be calibrated against the USGS reference steel tape at least once every two years and correction factors updated. With the height modernization of measuring point benchmarks, the synoptic water levels will provide an accurate “snapshot” into the direction of ground water movement.

Spring Discharge and Chemistry Measurements

The items below summarize the recommendations regarding spring discharge and chemistry data collection, information management, and data analyses. Included in this listing are planned near-term improvements, as well as other projects that require the approval and appropriation of funds.

- **Integration of Databases:** Secure commitments from agencies who collect spring data, to further the use and integration of the spring discharge and chemistry databases, and to explore options for data application/studies to help understand flow dynamics of basal lenses.

- **Additional Analyses**: Analyze spring data for parameters, such as nitrate, and compare with data analyses performed in well water. This may provide insight on the velocity of ground water flux over time.

- **Additional Monitoring:** Use data loggers to monitor temperature and conductance at spring orifices, logging daily changes. Temperature and conductance data may provide greater insight into the movement of the lens.

Pumpage, Water-Level, and Chloride Information

The items below summarize the recommendations for well pumpage, water-level, and chloride data management and dissemination. Included in this listing are planned near-term improvements, as well as other projects that require the approval and appropriation of funds.

- **Completion of CWRM's Water Use Reporting Database**: Completion and operation of this database is paramount for timely analysis and reporting of pumpage, water-level, and chloride data statewide. CWRM should focus on obtaining pumpage reports from all users in designated water management areas and from large users in non-designated areas. Subsequently, CWRM should pursue statewide reporting of pumpage, water-level, and chloride data.

- **Integration of Databases and Public Access**: Honolulu BWS historical pumpage and chloride data should be integrated with CWRM and USGS information in an appropriately managed database. Assuming that security and sensitivity of the data can be preserved, there should be limited public access via the Internet. Based on the success of this effort, the database should be expanded to include information from other county water departments.

- **Application of Internet and GIS Technology**: CWRM should utilize Internet and geographical information system technology to facilitate well operator/owner reporting and spatial analysis of pumpage, chloride, and water-level data.

4.3. Surface Water Monitoring

Similar to ground water resources, long-term monitoring information is critical to developing appropriate management scenarios for surface water resources. There is a long history of surface water monitoring in Hawaii; however, much of the historic record is focused on large, agricultural irrigation systems that were active throughout the state for much of the 20th Century. Surface water management has grown in complexity, due largely to recent closures of sugar and pineapple plantations and the potential for restoration of stream ecosystems. These changes are further complicated by the demands of a burgeoning population that requires high-quality ground water for drinking purposes, as well increasing amounts of surface water for irrigation needs (e.g., diversified agriculture, golf courses, landscaping, etc.) and for the perpetuation of cultural gathering rights.

Monitoring various stream characteristics, along with appropriate climate and physical data, can provide valuable information on stream health and integrity. Important considerations for surface water monitoring are described below.

Streamflow: Streamflow is the primary surface water characteristic measured during surface water monitoring activities. Most often, streamflow is measured at continuous-record gaging stations, which are permanent structures constructed on the bank of a stream. These stations typically remain in operation for a number of years, provided that funding is available. The stations provide annual flow values and allow for long-term trend analysis. The USGS maintains numerous stations throughout Hawaii. These stations collect data with sufficient frequency to identify daily mean values and daily variations in flow. Streamflow may also be measured at specific sites intermittently or as necessary for a specific study. The USGS refers to these sites as partial-record stations. While flow is often not measured with sufficient frequency to provide daily statistics, these measurements may aid in trend analysis and provide a snapshot of flow at a specific period in time.

Rainfall: Rainfall data represents the "input" to surface water systems, and provides basic information to complete the water balance equation. Surface water runoff models rely on rainfall, landcover, soil, geology, and land use information to determine how much rainfall percolates into subsurface layers, and how much water runs off the land as surface water. Ideally, rainfall data should be complemented with fog drip and evapotranspiration data to provide for more accurate modeling conditions. Rainfall and precipitation monitoring are discussed further in Section 4.4.

Diversions: There are approximately 1,260 registered and permitted stream diversions statewide. Many of these diversions have not yet been verified in the field, and the condition of existing structures and the amount of water removed at each diversion have not been confirmed. Therefore, in 2007, CWRM initiated a statewide field investigations project to verify registered stream diversions.

A wide range of methods are employed to divert stream water. Diversion structures may consist of various materials and installations, including PVC pipes, hoses, concrete intakes, or hand-built rock walls. Water can be moved from the stream channel into the diversion by pump or by gravity flow. It is difficult to quantify the amount of diverted stream flow statewide, as most diversions are not equipped with gages, and access to diversion sites may be restricted or require special arrangements. Often, particularly for irrigation systems associated with former plantation lands, intake structures are located high in the mauka sections of the watershed and are only accessible by four-wheel drive or on foot. The quantification of diverted flow, whether estimated or measured directly, is a key component in streamflow analysis, allowing investigators to estimate natural streamflow and identify diversion impacts to instream uses. Continuous, long-term measurement of diverted streamflow is ideal. A long-term monitoring program must be supported by an initial verification of each registered and permitted diversion structure and the amount of flow diverted at each site. This is a critical first step towards comprehensive management of surface water, and is being executed by CWRM. Long-term monitoring programs and improved regulation of stream diversion structures will be facilitated by field verification activities.

Irrigation Systems: Throughout Hawaii, large irrigation systems are responsible for the majority of the annual volume of diverted surface water flow. While this water was traditionally used for irrigation of sugarcane and pineapple, the decline of these industries has made both land and irrigation water available for diversified agriculture and other applications. Due to the complex nature of large irrigation systems, it is difficult for irrigation managers to measure flow diverted at all surface water intakes. Instead, water flow through irrigation systems is usually measured at a handful of key locations along the system alignment. As a result of the September 1992 Commission action exempting surface water users from reporting requirements until standard methods are approved (see Section 6.3), few irrigation system managers provide CWRM with water use reports. These water use reports are the primary information source for CWRM's monitoring and regulating of stream diversions and surface water use by irrigation systems.

End Uses: End use primarily refers to the diversion of water from large irrigation systems. Reporting water use amounts for end uses is not required by CWRM, except in designated surface water management areas. However, via the registration of stream diversion works process (circa 1989), CWRM received a large number of applications by end users reporting their water use. In addition, CWRM may often request end use amounts when addressing surface water issues for a specific area. This information is particularly useful when trying to determine the reasonable and beneficial use of water.

Biology: Stream biology is an important factor in determining CWRM's regulatory authority for a stream channel and in the setting of instream flow standards. CWRM relies heavily on biological information provided by the DLNR Division of Aquatic Resources (DAR), along with data collected by other agencies such as USGS and DOH. The point-quadrat study method preferred by DAR is a combined survey of macrofauna and microhabitat, often performed randomly along the length of a stream segment. Biological surveys generally provide information on species composition (native v. exotic), distribution, flow type, substrate, and basic water quality parameters.

Water Quality: Water quality monitoring falls under the jurisdiction of the DOH. However, the State Water Code provides that CWRM consider surface water quality in determining instream flow standards, in the issuance of stream channel alteration permits, and in permitting stream diversion works. Stream channel alterations, such as channel hardening, ford crossings, culverts, and diversion structures, may have a direct impact upon water quality. Conversely, CWRM must weigh the impact of existing alterations and diversions in its determination of appropriate instream flow standards. Relationships between water quality, aquatic species habitat, biodiversity, and land use may be taken into consideration when determining water availability for instream and offstream uses.

4.3.1. Existing CWRM Surface Water Monitoring Programs in Hawaii

The Hawaii Administrative Rules, Chapter 13-169-20 (2), recognizes that, "a systematic program of baseline research is…a vital part of the effort to describe and evaluate stream systems, to identify instream uses, and to provide for the protection and enhancement of such stream systems and uses." CWRM's Stream Protection and Management (SPAM) Branch currently lacks the resources to establish an independent, long-term monitoring program, but works closely with the USGS to operate and maintain a statewide network of surface water gaging stations (see Figures 4-6 to 4-10[3]) . The data collected through the CWRM-USGS cooperative monitoring program serves as the backbone of CWRM's SPAM Program. The long-term record provided by the gaging station network supports a wide range of statewide studies (e.g., flood analysis, water quality, ground/surface water interaction, biology, etc.).

4.3.1.1. CWRM-USGS Cooperative Monitoring Program

Collecting hydrologic information is important for water resource monitoring and assessment. Since 1909, the USGS and Hawaii's government have recognized this need for data, and are committed to monitor Hawaii's water resources through cooperative efforts. Of the 376 perennial streams in Hawaii, over 140 have been

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[3] Fontaine, R.A., 2006, Water Resources Data, Hawaii and other Pacific Islands, Water Year 2005, Volume 1. Hawaii, U.S. Geological Survey Water-Data Report HI-05-1, 344p.

gaged since the inception of the cooperative agreement. CWRM is the lead State agency working with the USGS to gather hydrologic information. Stream gage data is collected and analyzed as part of the overall hydrologic data-collection network. CWRM staff continuously reviews and evaluates the data-collection network for duplication of effort, usefulness of information, and for monitoring deficiencies in a particular geographic area. USGS data collection and analysis methods are described below.

Data Collection

Continuous-Record Gaging Stations: The Hawaii surface water data collection program operated by the USGS officially began in 1909, with the establishment of 12 continuous-record gaging stations. The program quickly expanded; so by 1914, there were 87 continuous-record gages in operation, however most gages were installed to evaluate potential sources of irrigation water for agriculture. The program continued to grow, and peaked in 1966 with a total of 197 continuous-record gages. The program has since gradually declined as operation costs have increased and funding has decreased. Figure 4-5 shows the number of continuous-record gaging stations in operation from 1909 to 2008. The surface water data-collection stations in operation for Fiscal Year 2007 are listed in Table 4-3.

Continuous-record gaging stations are gages that record some type of data, generally water-surface elevation, on a continuous basis. This data can be used to compute streamflow for any instantaneous period or for selected periods of time (ie.g., day, month, year). These stations collect long-term baseline data, in order to provide a series of consistent streamflow observations. Streamflow data is used to identify trends in streamflow over time, analyze the statistical structure of hydrologic time series, and to evaluate flow regime trends in response to various local, regional, or global changes.

Some continuous-record gaging stations have been designated as long-term trend stations. These stations provide data used analyzing the statistical structure of hydrologic time series, and can be used as a baseline for evaluating the flow regimes of other streams. For a gage to be considered a long-term trend station, it must be on a stream in a drainage basin that has undergone no significant human alterations and is expected to remain that way into the future.[4]

[4] Fontaine, R.A., 1996, *Evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii, 1994*: U.S. Geological Survey Water-Resources Investigations Report 95-4212, 125 p.

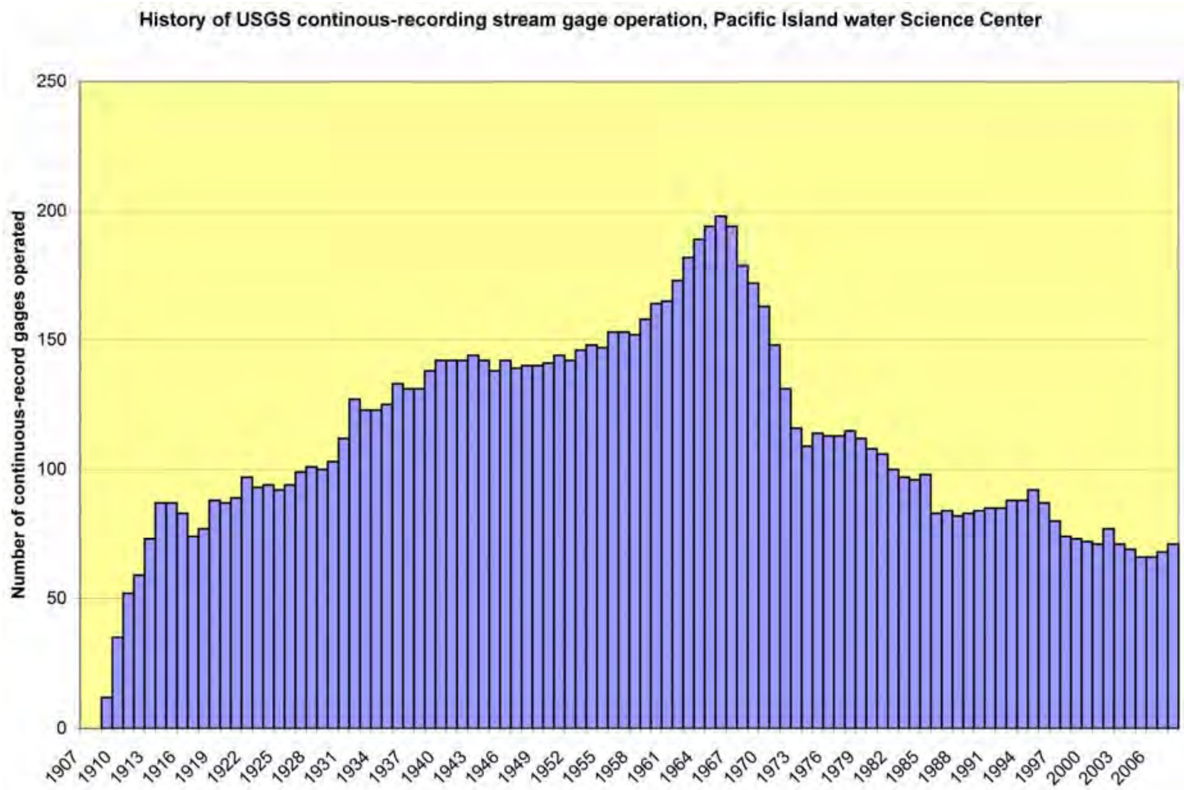

Figure 4-5. History of USGS continuous-recording stream gage operation.

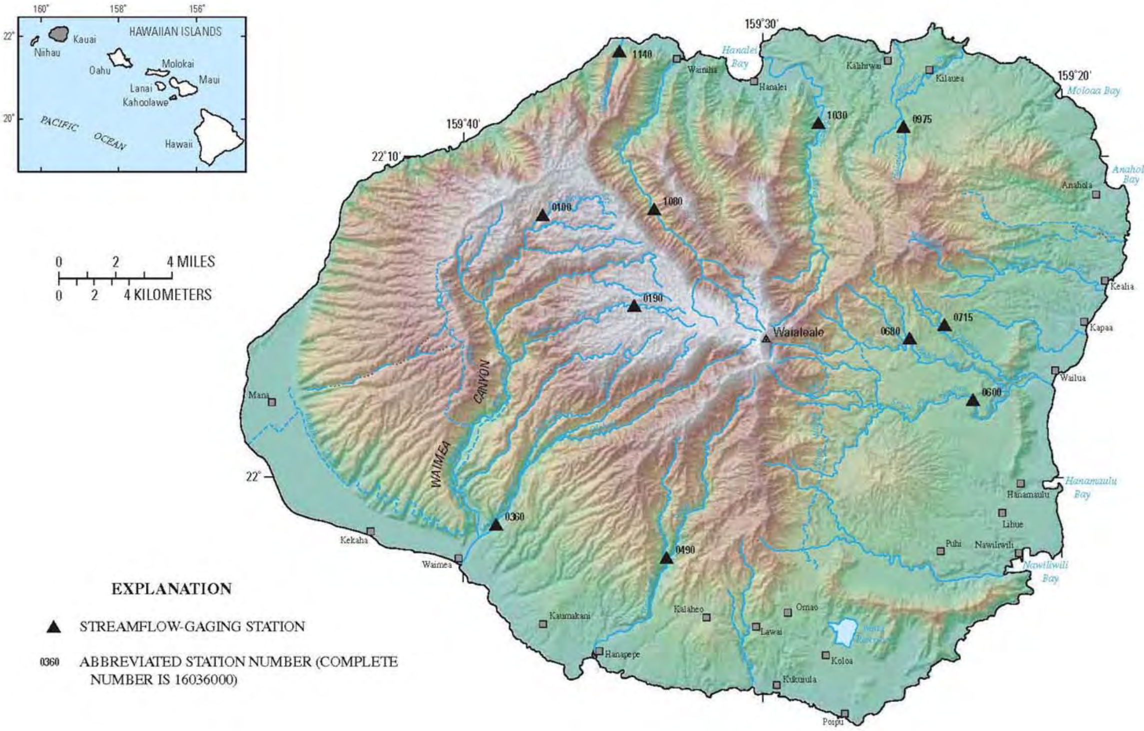

Figure 4-6. Locations of Streamflow gaging stations on Kauai (Water Year 2005).

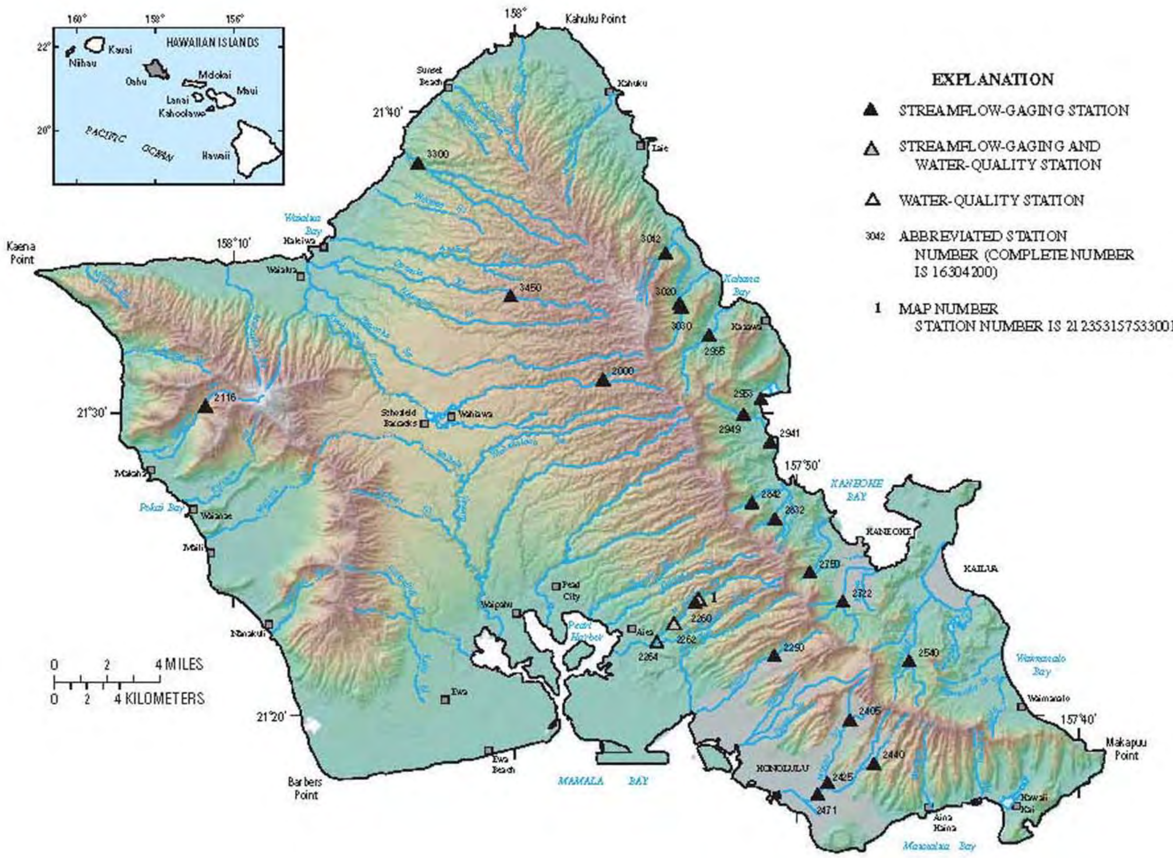

Figure 4-7. Locations of Streamflow gaging stations on Oahu (Water Year 2005).

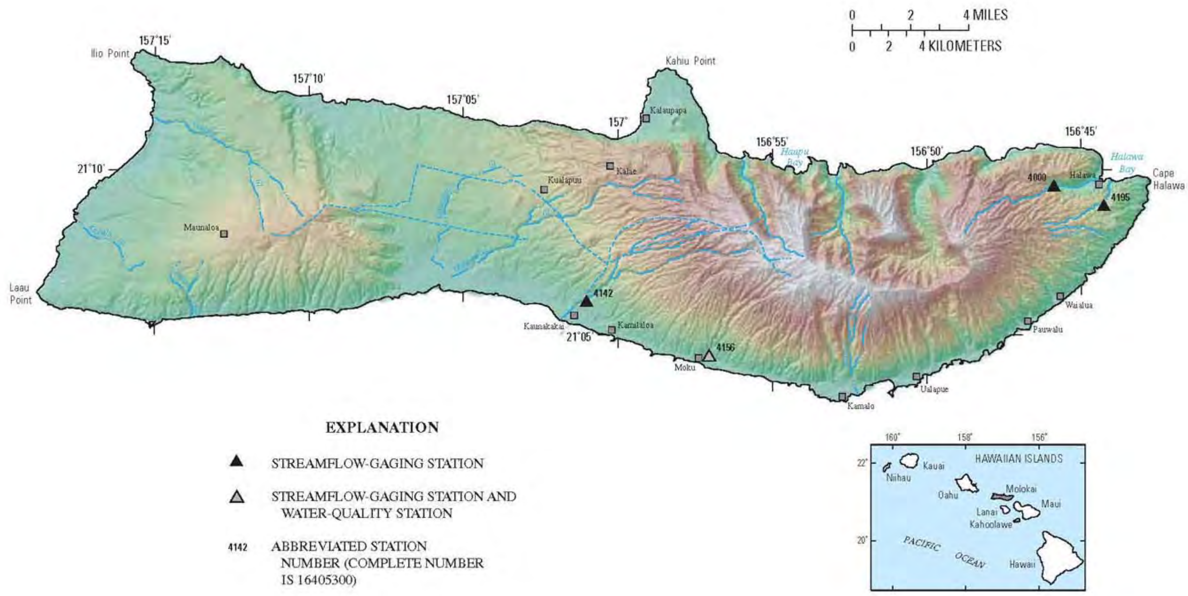

Figure 4-8. Locations of Streamflow gaging stations on Molokai (Water Year 2005).

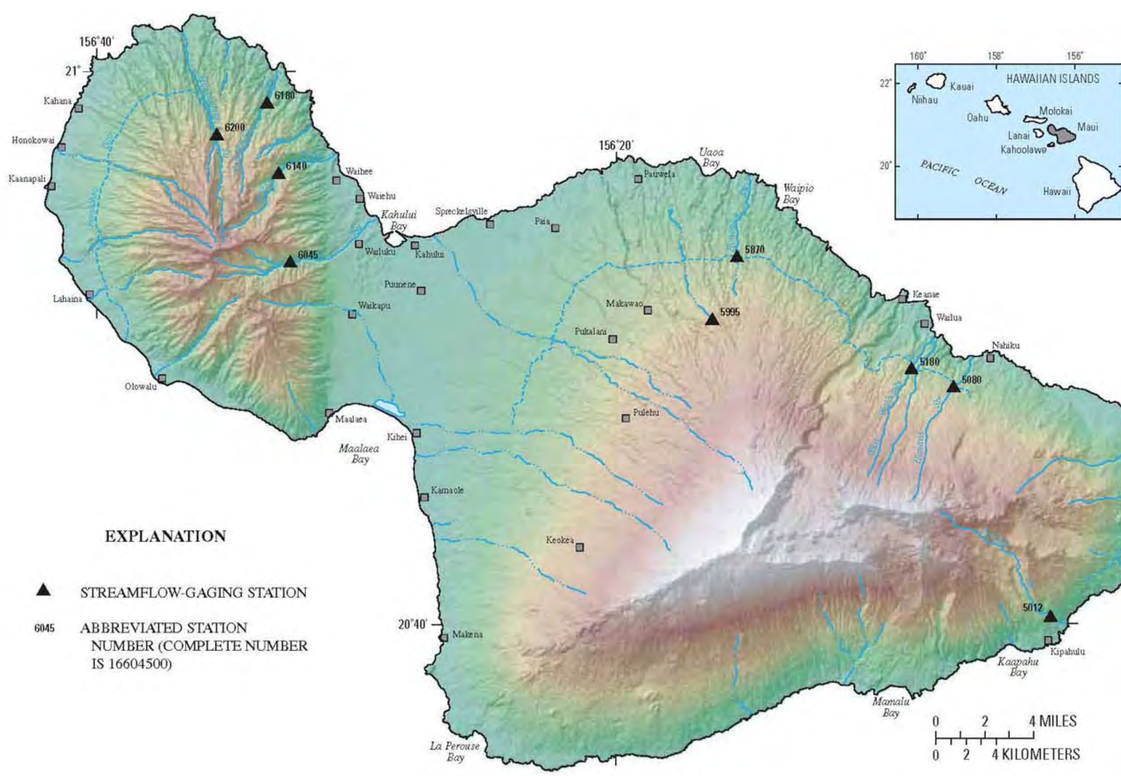

Figure 4-9. Locations of Streamflow gaging stations on Maui (Water Year 2005).

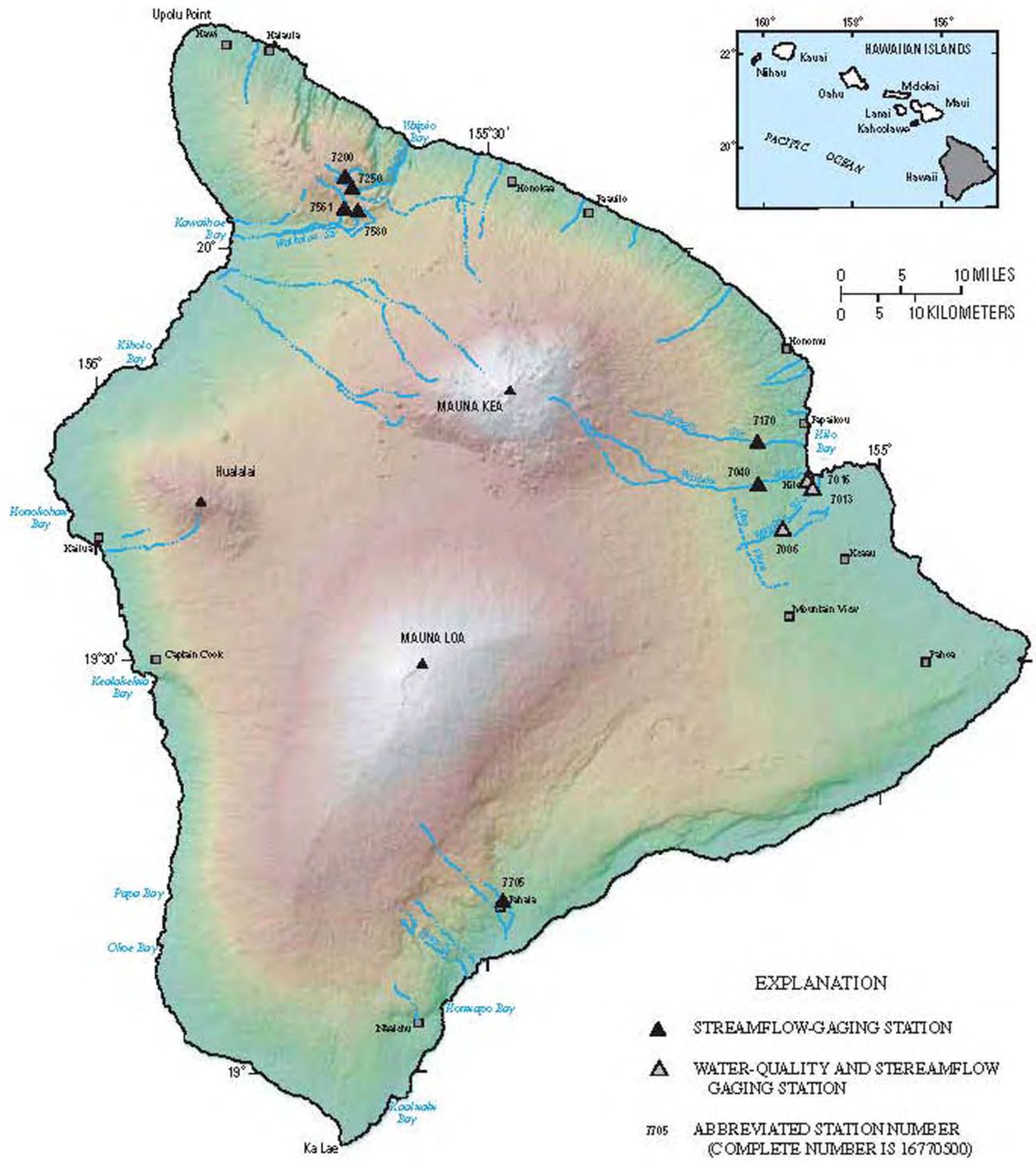

Figure 4-10. Locations of Streamflow gaging stations on Hawaii (Water Year 2005).

Crest-Stage Gaging Stations: Crest-stage gages provide only the peak surface water elevation that occurred between servicing visits to the gages. Peak elevation data is often used to compute discharges for selected flood peaks, and only the maximum flood peak for each water year is typically published.

Data from crest-stage gaging stations can be incorporated into a regional flood frequency analysis, by determining the magnitude and frequency of peak flow data for a period of at least ten years. This is especially important in areas where continuous-record gaging stations do not exist, as crest-stage gages are an efficient and cost-effective means of collecting flood stage data.

Low-Flow Partial Record Stations: For streams that lack an extensive or comprehensive long-term gaging station record, alternative methods that are both timely and cost-effective may be required. Low-flow partial records stations have been demonstrated to be a viable alternative in Hawaii for use in estimating base flow at sites without long-term gaging stations.[5]

Low-flow, partial records stations require a minimum of ten discharge measurements during periods of base flow. Measurements should be made over a variety of baseflow conditions and during independent recessions, following periods of direct runoff. The discharge measurements are then correlated with the concurrent daily discharges recorded at an index station (a nearby gaging station with long-term data available) to accurately estimate streamflow statistics.[6]

Seepage Runs: With the complex nature of ground and surface water interactions, it is often necessary to conduct seepage runs to identify gaining stream reaches (where base flow increases due to ground water discharge) and losing stream reaches (where base flow decreases due to outflow through the streambed into the underlying ground water body). Seepage runs are particularly important when conducting hydrologic investigations on streams that have been altered by diversions and return-flow practices. Seepage runs can accurately identify stream flow losses and gains throughout the system.

A seepage run is an intensive data collection effort, in which discharge measurements are made at several locations along a stream reach. Measurements are made during periods of base flow when flow rates at any given location in the stream are relatively constant. The time between the first and last measurement in the seepage runs are minimized to reduce the effects of temporal variability.

Data Analysis

Similar to the data collection efforts identified above, CWRM depends on the data analysis efforts of the USGS. These analyses are based on the data compiled from USGS' extensive network and historical records of surface water gaging stations.

[5] Fontaine, R.A., Wong, M.F., and Matsuoka, Iwao, 1992, *Estimation of median streamflows at perennial stream sites in Hawaii*: U.S. Geological Survey Water-Resources Investigations Report 92-4099, 37 p.
[6] Fontaine, R.A., 2003, *Availability and distribution of base flow in lower Honokohau Stream, Island of Maui, Hawaii*: U.S. Geological Survey Water-Resources Investigations Report 03-4060, 37 p.

Data analysis is important in characterizing past and present streamflow conditions, identifying short-term and long-term trends, and understanding the interaction of ground and surface water. In turn, this information is applied to a wide range issues, such as stream biology, water quality, flooding, agriculture, and ultimately water resource management and planning. The basic analyses identified below are essential to understanding the general nature and occurrence of surface water. More detailed analyses are conducted by USGS on a project-specific basis.

Streamflow Hydrograph: A streamflow hydrograph is a graphical representation illustrating changes in flow or water-level elevation over time. This is the simplest analysis of data obtained from continuous-record gaging stations. At a glance, the hydrograph is useful in identifying periods of high- and low-flows and making general observations of streamflow characteristics.

Summary Statistics: Under the cooperative agreement between the USGS, CWRM, and various other agencies, the USGS produces an annual hydrologic data report for Hawaii, documenting the information gathered from its surface and ground water data collection network. The data is analyzed and published in summary tables that are useful in understanding basic streamflow characteristics. Such data is also valuable for infrastructure design and water resources planning and management. A description of the summary statistics and the most recent data (by water year) is available for download from the USGS website (http://hi.water.usgs.gov).

Flow Duration Curves: Flow duration curves provide a simple and useful way of representing streamflow data by illustrating the flow characteristics of a stream throughout the range of discharge.[7] By definition, a flow duration curve is a cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded. For example, one of the most frequently used points on a flow duration curve is the 50th percentile, or median discharge. This is the discharge that is equaled or exceeded 50 percent of the time.

Generally, a smooth flow duration curve indicates that there are no flow manipulations of significance affecting the discharge recorded. A curve with a steep slope denotes a highly variable stream that receives flow volumes largely from direct runoff, whereas a curve with a flat slope that levels out at the higher percentiles is indicative of a significant, sustained source of base flow.

Hydrograph Separation: Identifying a stream's base flow component is important for water resource planning and management, as base flow indicates the long-term flow volume that can be sustained by the stream. Streamflow data recorded from a gaging station is frequently divided into two basic components, base flow and direct runoff. Base flow is that part of stream flow, derived from ground water, while direct runoff is the remainder of stream flow, derived from surface and subsurface flow occurring in response to excess rainfall.[8]

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[7] Searcy, J.K., 1959, *Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A*, 33p.
[8] Fontaine, R.A., 2003.

The USGS commonly uses an automated hydrograph separation method.[9] This computerized base flow separation program, or Base Flow Index (BFI), is a FORTRAN program based on a set of procedures developed by the Institute of Hydrology (United Kingdom). The method requires the input of two variables, *N* (number of days) and *f* (turning-point test factor). The separation method divides the daily streamflow data into non-overlapping periods, each *N*-days long, and determines the minimum flow in each period. If the minimum flow within a period is less than *f* times the minimums of the adjacent periods, then the central period minimum is made a pivot (or turning point) on the base-flow hydrograph. Conceptually, the variable *N* represents the number of days following a storm before direct runoff generally ceases.[10]

4.3.2. Other Surface Water Monitoring Programs

4.3.2.1. USGS Cooperative Agreements with Other Entities

The cooperative agreement between USGS and CWRM is one component of a larger gaging network that is cost-shared by several cooperators, including county water departments, State and federal agencies, DLNR divisions, and private landowners (for a complete list, see Section 4.2.1.1). The aggregate of data collected through these various agreements is compiled in an annual hydrologic data report for Hawaii produced by the USGS. The report includes the entire range of data collected through the USGS's extensive network: discharge at surface water gaging stations, crest-stage partial record stations, low-flow partial record stations, water surface elevation for ground water wells, rainfall records, and water quality for both surface and ground water stations. All USGS hydrologic data is available online at http://hi.water.usgs.gov.

4.3.2.2. Division of Aquatic Resources Aquatic Survey Database

As noted earlier in Section 4.3, CWRM works closely with the DLNR Division of Aquatic Resources in collecting and managing biological data related to streams. This data is necessary to evaluate applications for Stream Channel Alteration Permits (SCAP) and anticipated impacts to instream uses. Biological data is also a key consideration in the establishment of measurable instream flow standards.

DAR has recently completed the development of a fairly comprehensive aquatic survey database to store and maintain information on a wide range of biological data. The database was originally intended to update the information from the 1990 Hawaii Stream Assessment, and to store data obtained through DAR's point-quadrat survey method. In the course of database development, DAR discovered and incorporated into the database historic records from the early Hawaii Division of Fish and Game. The database is constantly being updated as new sources of information, including various independent biological studies, are encountered and

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[9] Wahl, K.L., and Wahl, T.L., 1995, *Determining the flow of Comal Springs at New Braunfels, Texas: Proceedings of Texas Water '95, A Component Conference of the First International Conference on Water Resources Engineering, American Society of Civil Engineers, August 16-17, 1995*, San Antonio, Tex., 77-86.

[10] Fontaine, R.A., 2003.

reviewed. Most recently, new data has been added pertaining to macroinvertebrates (e.g., damselflies). By evaluating the information in the DAR database, CWRM will be able to identify biological resources associated with each stream, as well as to identify those streams which have little or no data.

4.3.2.3. DOH Water Quality Data

The Department of Health is the agency responsible for the collection of water quality data statewide. Specifically, the DOH's Clean Water Branch, Monitoring Section oversees the collection, assessment, and reporting of numerous water quality parameters in three high priority categories as follows:

- Possible presence of water-borne human pathogens;
- Long-term physical and chemical characteristics of coastal waters; and
- Watershed assessments, including the integrity of natural aquatic environments[11].

DOH plays an integral role in the review process for all of CWRM's surface water related permits, as DOH's water quality data and assessments are vital to instream use considerations.

Under the federal Clean Water Act, DOH is required to prepare and submit lists biennially of waterbodies not expected to meet State water quality standards. This list is referred to as the 303(d) List of Impaired Waters (303(d) List), which was most recently prepared and approved in 2004. The DOH Environmental Planning Office has developed a methodology for preparation of the 303(d) List. Part of this methodology involves the review of various sources of water quality data including:

- DOH Clean Water Branch data;
- USGS North American Water Quality Assessment Program data;
- AECOS, Inc. stream survey data (surveys conducted using the National Resource Conservation Service Visual Assessment Protocol); and
- Biological Assessments and various other studies and reports.[12]

The 303(d) List for Hawaii serves to contribute to the assessment of instream flow standards.

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[11] Department of Business, Economic Development and Tourism's Office of Planning–Coastal Zone Management and Department of Health's Clean Water Branch Polluted Runoff Control Program, 2000, *Hawaii's Implementation Plan for Polluted Runoff Control*.
[12] Koch, Linda, Harrigan-Lum, June, and Henderson, Katina, 2004, *Final 2004 List of Impaired Waters in Hawaii*, *Prepared Under Clean Water Act §303 (d):* Hawaii State Department of Health, Environmental Planning Office.

4.3.3. CWRM Management of Surface Water Data

CWRM is currently in the process of developing a comprehensive database to manage surface water use and stream permitting information statewide. Similar to CWRM's Ground Water Regulation program, the SPAM program requires an information management system to track and maintain data for water use reports, stream channel alterations, and stream diversion works. Labeled the Surface Water Information Management (SWIM) System, this database will ultimately facilitate the setting of instream flow standards by helping CWRM to track and manage water use data, location and type of alterations to stream channels, and water use for various offstream purposes. This information will allow CWRM to assess impacts upon instream uses and to develop appropriate management scenarios at the watershed level.

4.3.3.1. Surface Water Information Management (SWIM) System

The Surface Water Information Management (SWIM) System addresses CWRM's need for a single, comprehensive database to store and manage all stream-related CWRM activities. This includes requests for determination, permits, petitions, complaints and disputes, and emergency authorizations. CWRM staff continues to input data into the SWIM System and improve the database design.

The SWIM System was primarily developed as a means of storing and managing data. The database will contribute to improved surface water use reporting statewide as the SPAM Branch increases staffing. The SWIM System also provides CWRM with another tool to improve CWRM operations and the agency's ability to manage surface water resources. For example, the database enables CWRM to generate reports identifying pending activities and follow-up actions. Geographic location data from the SWIM System allows staff to perform geospatial analyses of stream diversions and CWRM regulatory actions.

The SWIM System's ultimate utility is as a tool for developing measurable instream flow standards. Issues related to permitted stream channel alterations and diversions, determinations, and complaints provide information regarding on-the-ground activities occurring within watersheds. CWRM plans to expand the SWIM System to include information on stream channel alterations (e.g., channelizations, bridges, culverts, etc.) constructed prior to the establishment of CWRM; and reference materials (e.g., bibliographical information on published reports and studies) for various watersheds. The compilation of these resources into a single system will further CWRM's efforts to establish instream flow standards throughout Hawaii.

4.3.3.2. Stream Diversion Verification

In 1988, CWRM began registering declarations of water use (see Section 6). At the time, staffing and funding constraints largely prevented CWRM from completing field verifications for the majority of stream diversions statewide. Policy developments placed an emphasis on ground water protection, while the statewide decline of plantations raised questions about the continued diversion of water to plantation irrigation systems. As a result, there is a deficit of surface water use data and increasing concerns regarding watershed health, stream and riparian ecosystems, and surface water resource protection.

CWRM is currently undertaking a project to verify surface water diversions statewide. This project is expected to provide specific information on the location, construction, and use of water for all diversions that were registered with the Commission in 1988. The data collected from this effort will contribute to the assessment of instream uses and the establishment of instream flow standards statewide. This project is critical to the development of appropriate surface water monitoring programs and will identify water users that should be included in a surface water use reporting program.

4.3.3.3. CWRM Water Use Reports

Currently, CWRM does not actively enforce requirements for reporting of surface water use (see Section 6). CWRM's current policy is that the "requirement for monthly measurement and reporting of water use from gravity-flow, open ditch stream diversion works which are not already being measured and which are not in designated surface water management areas be deferred until the Commission adopts guidelines regarding appropriate devices and means for measuring water use." Since this policy was initiated, there has been increasing concern regarding surface water issues, and CWRM has responded with the creation of the Stream Protection and Management Branch (SPAM Branch).

The SPAM Branch is establishing a surface water use reporting process similar to that employed by the Ground Water Regulation Branch. This would require stream diversion works owners and operators to complete and submit a monthly water-use report form to CWRM. The form would provide information including, but not limited to, stream diversion works identification, begin date and end date of reporting period, quantity of water diverted, and method of quantity measurement. CWRM's surface water database would be expanded to allow for data entry, storage, and management of reported water use data.

4.3.4. Gaps in Surface Water Monitoring Activities

Surface Water Monitoring: Since the inception of the CWRM-USGS cooperative monitoring program, the USGS cost of operating a continuous-record stream gaging station has steadily increased, while CWRM funding available for monitoring has severely declined. The resulting gaps in the statewide monitoring network could potentially affect the integrity of hydrologic studies and investigations, as well as increase risk to public safety. Public safety is impacted, where the monitoring network maintained by USGS serves the additional purpose of alerting the public of potential flood hazards. This is true particularly in large watersheds where real-time gaging stations provide government agencies and the public with up-to-date streamflow data via the Internet. Also, public agencies rely heavily on surface water discharge data for streams serving municipal water systems and for consideration in the design of highway culverts, bridges, flood structures, and other infrastructure. Maintenance of the current surface water monitoring network will require greater funding commitments in light of rising costs, along with the need for additional partner agencies that rely on the network to share in overall operating expenses.

Water Use Data: Surface water use data for the State of Hawaii is inadequate. For certain areas, water use studies have been conducted either by the USGS or other government agencies. However, comprehensive watershed-wide studies are important to understanding processes within the entire drainage area, and most studies only assess a small portion of the watershed. Therefore, the extent and intensity of surface water use remains unknown in many areas of the state. Increased surface water use data is critical to the protection and management of surface water resources.

4.3.5. Recommendations for Monitoring Surface Water Resources

In light of the gaps in surface water-monitoring activities summarized in Section 4.3.4., CWRM has identified the following recommendations for the improvement and expansion of surface water monitoring activities in the State of Hawaii:

- **Establish surface water use reporting process:** The SPAM Branch must initiate development of a surface water use reporting process. The SWIM System needs to be expanded for data entry and analysis of water use information. Also, the Ground Water Regulation Branch currently uses a 12-month moving average (12-MAV) to assess ground water use, but a 12-MAV may not be appropriate for surface water. The ground water database, which is still being tested and refined, will serve as the template for development of the surface water use database within the SWIM System. In lieu of data entry and analysis, CWRM should incorporate notification of monthly water use reporting as part of the statewide stream diversion verification project.

- **Adopt guidelines for surface water monitoring**: CWRM currently faces difficulties in regulating the amount of water diverted via registered and permitted stream diversion works. This problem stems from the lack of guidelines for surface water monitoring and the wide range of methods for diverting water. Additionally, technical knowledge among water users varies considerably. Public understanding of water use regulations must be encouraged, especially among water users and diversion works operators. Users should be educated on the correct application of water use metering and gaging methods that are appropriate for each end use. A small user, who may divert water for landscaping and small water features, has very different water metering needs compared to that of a large irrigation system operator diverting millions of gallons daily over large expanses of agricultural land. These issues offer considerable challenges, and CWRM must continue its work to develop a standardized set of methods for measuring diverted flow and water use, in accordance with CWRM's policy directive. CWRM should also enhance or develop methods and mathematical relationships (such as regression equations) that can be used to estimate flow characteristics at ungaged locations. Currently, there are equations to estimate median flow in streams across the state, but similar equations for low-flow (to assess instream flow and stream diversion issues) and high-flow (to assist in flood frequency planning) could be developed.

- **Maintain/increase funding for the CWRM-USGS cooperative monitoring program:** The number of continuous surface water gages maintained by the USGS has declined roughly 30 percent since 2000. Continuous monitoring in various areas throughout the state is currently inadequate to appropriately measure and monitor surface water resources, and must be expanded. Funding for the cooperative program should be increased. Funding increases should reflect inflationary costs, as well as the need to expand the data collection network in areas where competition for surface water resources is greatest.

- **Instream flow standard monitoring**: In anticipation of setting measurable instream flow standards statewide, CWRM must plan for and develop a streamflow monitoring program. This program should include appropriate staff training, establishing protocols, assessing the existing USGS stream-gaging network, and developing a schedule to measure streams at regular time intervals on a regional scale.

- **Increase collaboration to achieve goals**: The involvement of public agencies, private entities, and community organizations in watershed partnerships, alliances, and other collaborative efforts is critical in identifying water uses and assessing watershed conditions. Such partnerships foster relationships and build trust within the communities ultimately impacted by surface water management decisions. Partnerships also contribute to sound planning, and can help in obtaining funding for local implementation of stream-related studies and programs.

4.4. Rainfall Monitoring Activities

4.4.1. Overview

Rainfall data collection is fundamental to monitoring hydrologic conditions and water resources in Hawaii. Rainfall is the ultimate natural source of freshwater for streams, springs, and underground aquifers. Fog drip and melting snow (to a much lesser degree) may contribute to ground water recharge in some areas.

Long-term rainfall data is also important in analyzing the effects of long-term climate changes, as well as decadal and shorter-term atmospheric fluctuations, such as the Pacific Decadal Oscillation, El Niño, and La Niña events, on Hawaiian water resources. This data is also important when analyzing the effects of extreme weather events, such as floods and droughts, on water resources.

Rain gages are grouped into two categories: non-recording, and recording rain gages. Non-recording instruments are manually read rain gages, which are typically sampled on a daily basis. Recording instruments are typically tipping-bucket rain gages, which can be programmed to sample at different intervals, usually 15 minutes or one hour. Some recording rain gages are telemetered to provide real-time data.

4.4.2. Rainfall Data Collection Networks

Rainfall data has been collected in Hawaii since the mid 1800s. Sugar and pineapple plantations and ranches established and operated the majority of rain gages across the state. There have been over 2,000 rain gages operating at some time or another since rainfall data collection began in Hawaii. In many instances, however, data quality is uncertain, due to the lack of data quality control and standardized collection methods.

Hawaii has one of the densest rainfall monitoring networks in the world, due in part to the large gradient in average rainfall over very short distances and the varied microclimates across the state. There are several principal rainfall data collection networks in Hawaii. The NWS has the cooperative observer program, which includes approximately 270 rain gages. The NWS also operates the Hydronet network of 111-telemetered rain gages, which are used operationally (see Figures 4-10 to 4-14[13]). Some overlap exists in rain gage locations, between the NWS cooperative and Hydronet programs. The Hawaii State Climate Office at the University of Hawaii oversees a statewide network of approximately 84 rain gages. The USGS has 39 rain gage sites across the state. On a much smaller scale, large plantations and the county water departments have their own network of rain gages. The NWS cooperative observer and the USGS rainfall network probably have the best quality assurance and quality control measures in place.

4.4.3. Rainfall Data Availability

Over the years there have been numerous data summaries published on rainfall in Hawaii, and many of these are available in the public or University of Hawaii libraries' reference section. Monthly summaries of data collected through the NWS cooperative observer program are published and available in hard copy or electronically from the National Climatic Data Center (NCDC).

Individual NWS station data is also available electronically and on hard copy through NCDC for a fee. Data is available in daily, monthly, and annual formats. In some cases, 15-minute and one-hour data is available. This data is also available from the Western Regional Climate Center for a fee.

Some USGS rainfall data is made available on their website and annual summaries are published in their Annual Water Data report. Specialized data requests can be accommodated for a fee.

The State Department of Business, Economic Development and Tourism's Office of Planning provides downloadable GIS data for rainfall isohyets. The Hawaii State Climate Office can also provide data for a fee.

[13] National Weather Service Forecast Office, Honolulu, HI, *Hydrology in Hawaii, Additional Hydrology Resources, Rainfall Summary Gage Location Maps*, Internet, accessed September 7, 2007. Available at *http://www.prh.noaa.gov/hnl/pages/hydrology.php.*

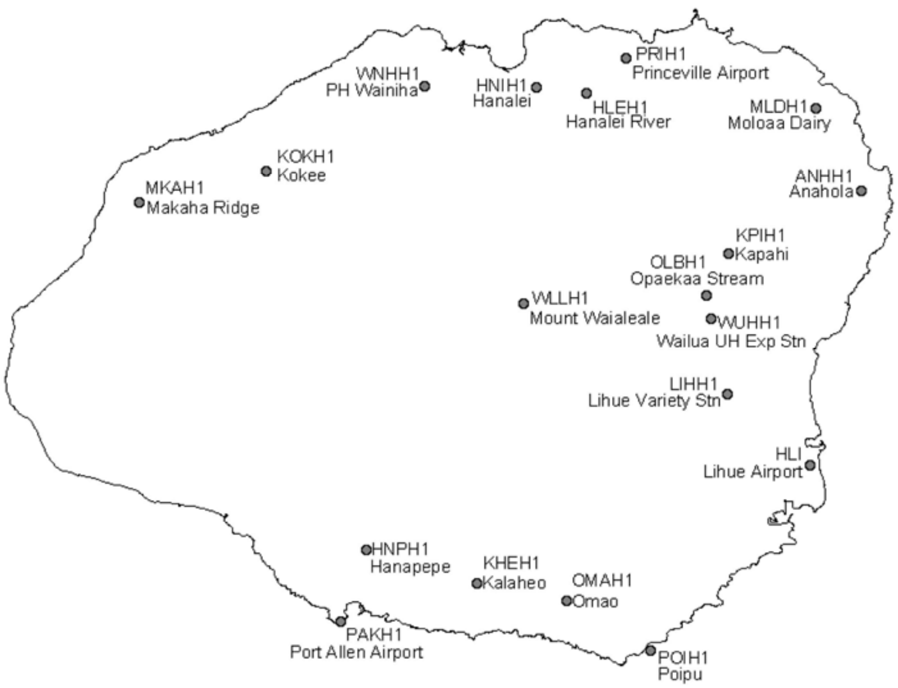

Figure 4-11. NWS Hydronet rain gages on Kauai.

Figure 4-12. NWS Hydronet rain gages on Oahu.

Figure 4-13. NWS Hydronet rain gages on Molokai and Lanai.

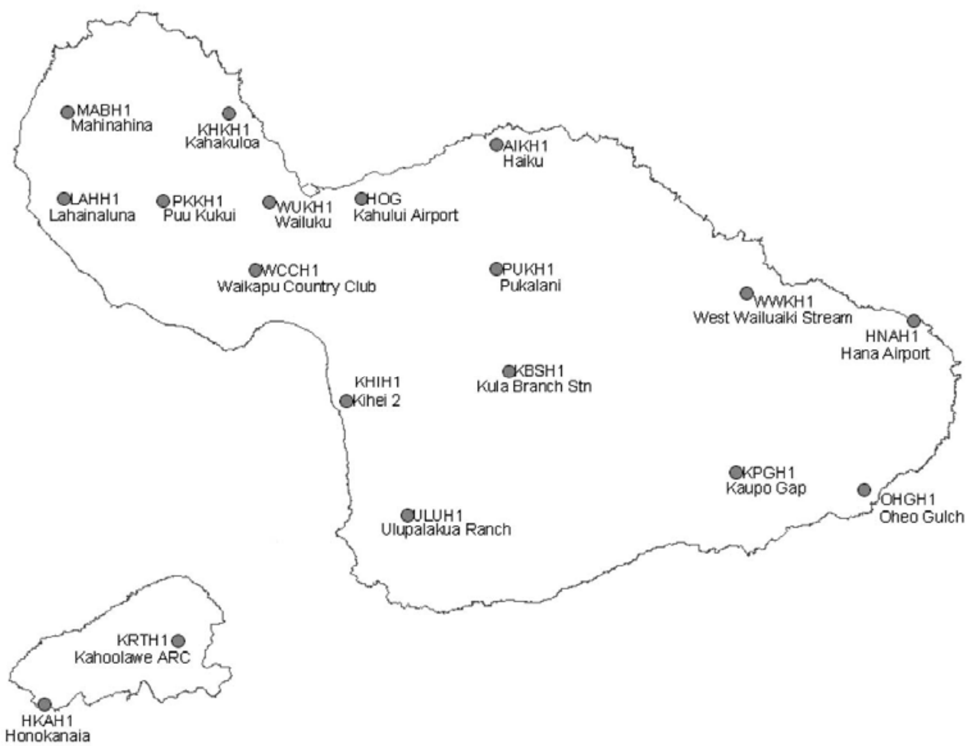

Figure 4-14. NWS Hydronet rain gages on Maui and Kahoolawe.

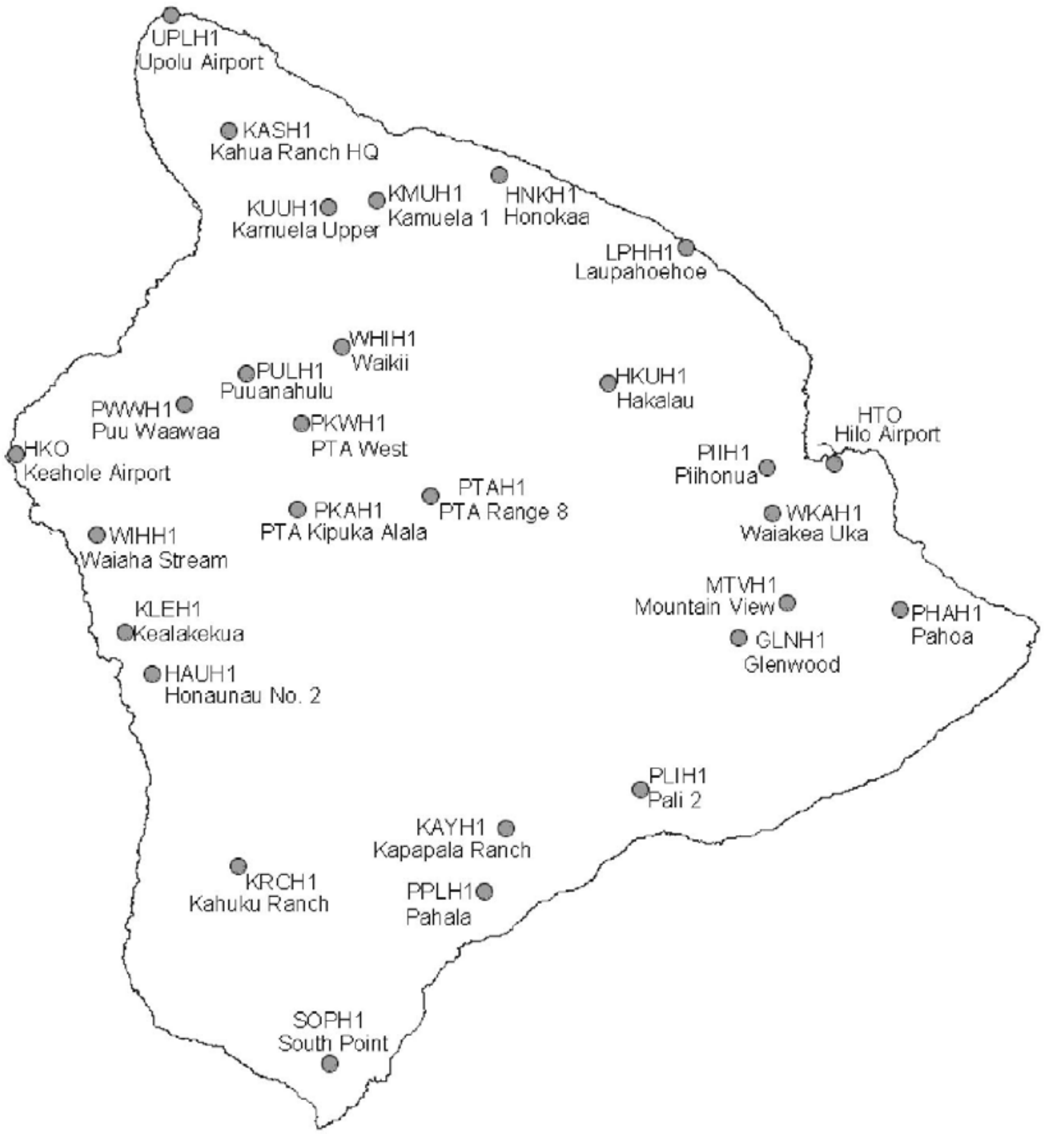

Figure 4-15. NWS Hydronet rain gages on Hawaii.

4.4.4. Rainfall Data Analysis

There have been several analyses done of mean and median rainfall for monthly and annual data for Hawaii. The most recent report, *Rainfall Atlas of Hawaii* (1986), has resulted in monthly and annual rainfall maps for each of the islands. In general, the maps provided in the *Rainfall Atlas of Hawaii* serve as the standard isohyet maps for use in hydrologic studies. CWRM supports the consistent use of these maps to ensure consistent assumptions in data analyses. It should be noted, however, that there are other data sources available that may not be controlled to the data standards of the NWS. The results of studies that use such data are difficult to compare with the results of investigations that use standardized data.

There have been three statewide rainfall frequency studies done, *Rainfall-Frequency Atlas of the Hawaiian Islands for Areas to 200 Square Miles, Durations to 24 Hours, and Return Periods from 1 to 100 Years* (1962), *Two to Ten Day Rainfall for Return Periods of 2 to 100 Years in Hawaiian Islands* (1965), and *Probable Maximum Precipitation in the Hawaiian Islands* (1963). A more recent analysis was done for the island of Oahu, *Rainfall Frequency Study For Oahu* (1984).

One drought study, *Drought In Hawaii* (1991) and one drought risk and vulnerability study, *Drought Risk and Vulnerability Assessment and GIS Mapping Project* (2003) were done for the State.

The latest report indexing climate stations in Hawaii was done in 1973, *Climatologic Stations in Hawaii*.

The State DLNR has produced numerous reports on flooding events and drought occurrences. There are also studies on the relationship between El Niño events and rainfall in Hawaii.

Several types of rainfall analyses are available from the Western Regional Climate Center, including mean number of days of rain, thunderstorm days, cloudy days, etc.

4.4.5. Gaps in Rainfall Data

Due to the closing of sugar and pineapple plantations across the state beginning around 1990, there has been a drastic decrease in rain gage sites in the former plantation areas. This has resulted in the discontinuation of monitoring activities at many rainfall stations with long periods (50-100 years) of record. To illustrate this decrease, Figure 4-16[14] shows the locations of current stations and historic stations on Kauai.

On Kauai, Oahu, Maui, and Molokai, there is a lack of rain gages located in high rainfall areas (areas receiving more than 80 inches of rain annually), which often correspond to forest reserve, watershed, and ground water recharge areas. There is also insufficient rain gage coverage in many agricultural areas across the state.

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[14] Chu, P.S., 2006 (unpublished report), Rainfall Station Index and Atlas for Kauai County, County of Kauai Department of Water and State of Hawaii Department of Land and Natural Resources, Commission on Water Resource Management, 30 p.

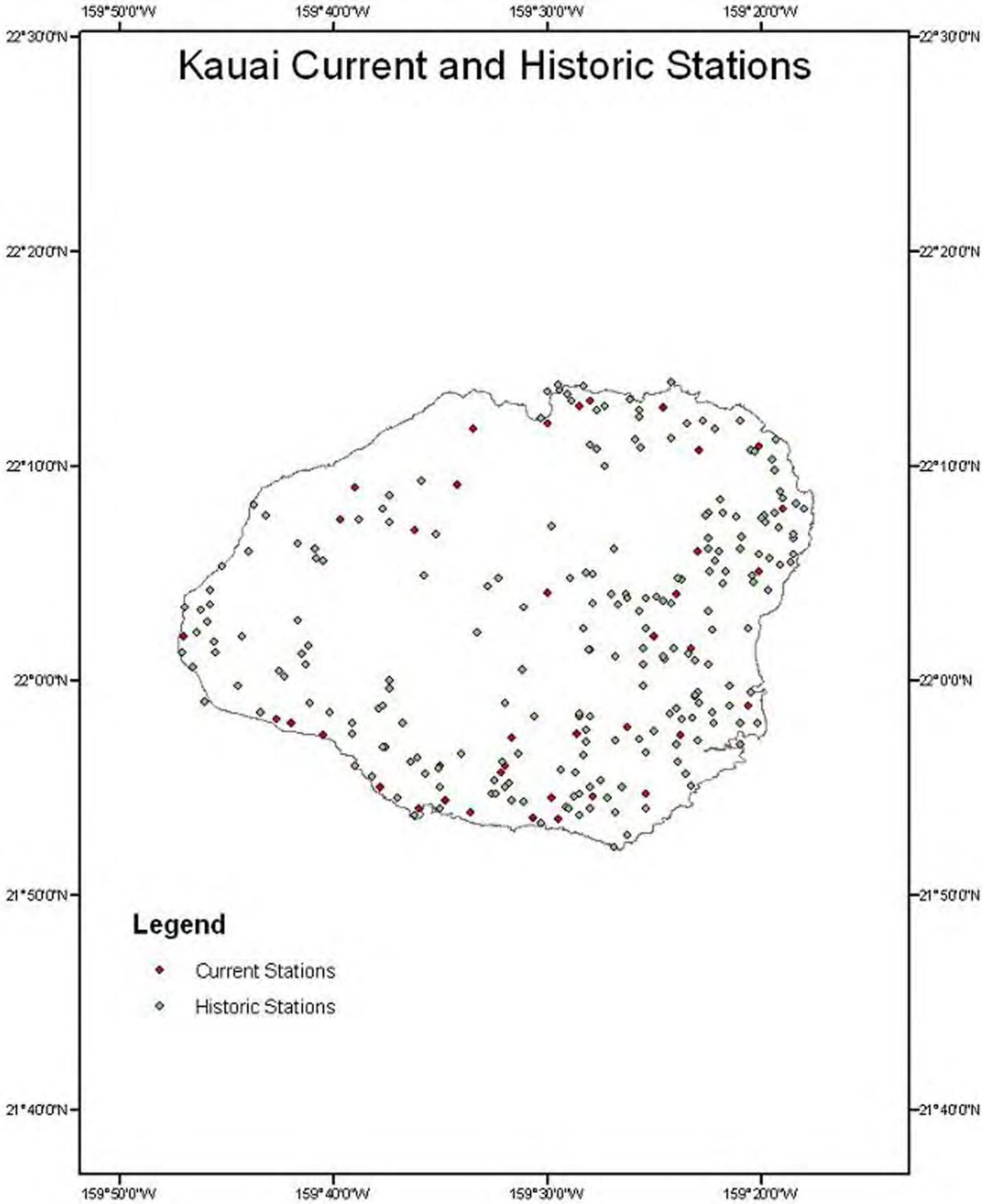

Figure 4-16: Current and historic rainfall monitoring stations on Kauai. Historic stations are not active.

The NWS uses Doppler radar to detect rainfall and thunderstorms. Doppler radar can detect movement of objects (e.g., raindrops, hailstones) toward or away from the radar antenna. Doppler radar is used to estimate rainfall intensities, in order to issue flood warnings and special weather statements. In areas without rain gage coverage, Doppler radar can estimate rainfall accumulations. However, there is uncertainty in these estimates since they are not based on measurements.

4.4.6. Gaps in Rainfall Analysis

There is a need for further or updated analysis statewide for indexing climate stations, flooding frequency, drought frequency, the effects of climate change on Hawaiian rainfall, and monthly and annual median rainfall maps. There is a particular need for updating the long-term monthly and annual rainfall maps, in order to determine current ground water recharge quantities, which is needed to update aquifer sustainable yields. The most recent analysis of annual mean and median rainfall (*Rainfall Atlas of Hawaii*) was completed in 1986 using rainfall data collected until 1983. Since this time, there have been changes in the number of rainfall stations, as well as changes in spatial distribution. For the rainfall stations that have continued to be active since 1983, there are many more years of data that can be used to complete an update of the *Rainfall Atlas of Hawaii*; in addition, there have been a number of extreme precipitation events such as droughts and floods since the *Rainfall Atlas of Hawaii* was completed.

4.4.7. Recommendations for Rainfall Monitoring

While the rainfall data collection network in Hawaii is quite dense, there are still areas around the state that have little or no rain gage coverage, especially in remote areas. The loss of rainfall stations due to the closure of sugar and pineapple plantations have reduced rain gage coverage and ended many stations with long periods of record. The historic rainfall record should be properly maintained and easy access to this data should be provided. Reports of rainfall analysis of all types need to be updated, and the effects of climate change on Hawaiian rainfall should be studied. The following recommendations hope to address these concerns:

- Increase rainfall data collection, especially in the watershed and agricultural areas.
- Continue or reestablish long-term rain-gage stations.
- Better coordinate rainfall data sharing between major data collection networks and improve delivery of data for public consumption (including the acquisition and review of historic plantation data kept by the Hawaii Agricultural Research Center).
- Update the statewide, comprehensive climate station index and accompanying maps.
- Update the statewide rainfall frequency study and maps.
- Update the statewide median/average rainfall maps.
- Update the drought frequency study.
- Investigate the effects of climate change on precipitation in Hawaii.
- Study newer technologies and tools for rainfall estimation in Hawaii.

4.5. Cloud Water Interception and Fog Drip Monitoring Activities

4.5.1. Overview

Cloud water interception or fog drip is the direct interception of water, from clouds or fog, by vegetation. Some of this water makes its way into the ground. Fog drip is likely an important contribution to the hydrologic budget in Hawaii's forested areas frequently enveloped in clouds. This is especially true when there is little or no precipitation occurring. Although this subject has been studied to some degree in Hawaii and other locations around the world, there are still uncertainties as to what contributions cloud interception and fog drip make to the hydrologic cycle, and specifically to ground water recharge.

4.5.2. Measuring Fog Drip

The interception of cloud water, or fog drip, can be measured by fog collectors, which use screens, strings, or some other surface to capture cloud or fog droplets, which is then collected by receptacles or tipping bucket gages. Another method of measuring fog beneath vegetative canopies is by using throughfall collectors, which capture fog drip and precipitation using gutter-like troughs situated beneath the forest canopy. A rain gage is usually positioned nearby to account for the precipitation's contribution.

4.5.3. Existing Programs

There is no systematic, long-term cloud water/fog drip collection network in Hawaii. There have been several fog drip studies conducted on Lanai, Maui, and Hawaii, which yielded site-specific fog collection data of various periods of record. These sites have typically been in the cloud covered mountainous regions of these islands, ranging from approximately 1,500' to 10,000' elevation.

4.5.4. Analyses and Reports

There are few analyses and reports done on the subject of cloud water interception / fog drip in Hawaii. The University of Hawaii Water Resource Research Center published two technical reports, *Methodical Approaches in Hawaiian Fog Research*[15], and *A Climatology of Mountain Fog on Mauna Loa Hawaii Island*[16]. Other researchers have conducted studies and investigations[17] on this subject. It should be noted that due to the lack of data on cloud

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[15] McKnight, J. H. and Juvik, J. O., 1975, Methodological approaches in Hawaiian fog research, Technical Report No. 85, Project Completion Report for fog precipitation along topo-climatic gradients on the Island of Hawaii, OWRT Project No. A-041-HI, Grant Agreement No. 14-31-0001-4011, Project Period: July 1, 1972 to June 30, 1975.

[16] Juvik, J. O. and Ekern, P. C., 1978, A climatology of mountain fog on Mauna Loa, Hawaii Island, Technical Report No. 118, Project Completion Report for fog precipitation along topo-climatic gradients on the Island of Hawaii, OWRT Project No. A-041-HI, Grant Agreement No. 14-34-0001-5011, Project Period: 1 July 1974 to 31 December 1975.

[17] Juvik, J. O, and Nullet, D., 1994, A climate transect through tropical montane rain forest in Hawaii: Journal of Applied Meteorology, v. 33, No.11, p. 1304.
Juvik, J. O, and Nullet, D., 1995, Comments on "A Proposed Standard Fog Collector for Use in High Elevation Regions": Journal of Applied Meteorology, v. 34, No.9, p. 2108-2110.
Scholl, M., T. W. Giambelluca, S. B. Gingerich, M. A. Nullett, and L. L. Loope (2007), Cloud water in windward and leeward mountain forests: The stable isotope signature of orographic cloud water,

water interception, there is uncertainty of the contribution of cloud water to the overall water budget of our forested watersheds.

4.5.5. Gaps

Since there is no fog drip data collection network, almost all of the islands' mountainous regions within the cloud belt have no data. Most of these areas have no vehicular access, and the difficult and often steep terrain prevents easy access for installation and maintenance of the fog drip data collection instruments.

4.5.6. Recommendations for Cloud Water Interception and Fog Drip Monitoring

As mentioned above, there is no long-term or widespread data collection network that gathers cloud water interception information in Hawaii. The amount of research and study on this subject is sparse compared to those of other hydrologic elements, especially rainfall. The following recommendations aim to increase the knowledge of cloud water interception and its contribution to watershed hydrology and water balance:

- Increase cloud water interception data collection in important watersheds.
- Increase research into cloud water interception and its contribution to the hydrologic budget and aquifer sustainable yield; and
- Develop methods to estimate cloud water interception over large areas.

4.6. Evaporation Data

4.6.1. Overview

The most common way of determining evaporation is direct measurement from an instrument called an evaporation pan. Factors that influence evaporation include temperature, humidity, wind speed, and solar radiation. Other instruments, such as evaporimeters, can measure evaporation indirectly. Other empirical and psuedo-physical models can be used to estimate evaporation, based on other observed weather elements.

Evaporation data was used extensively in Hawaii to assist in crop irrigation and to assess the amount of water used by crops. Evaporation is also an important tool in determining an area's hydrologic budget, since evaporation can be used to estimate evapotranspiration, which is an important component of the hydrologic budget. Evapotranspiration equals the water evaporated from the soil and other surfaces combined with the transpiration from

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Water Resour. Res., doi:10.1029/2007WR006011, in press. http://www.agu.org/journals/pip/wr/2007WR006011-pip.pdf" (accepted 31 August 2007).
Scholl, M.A., Gingerich, S.B., and Tribble, G.W., 2002, The influence of microclimates and fog on stable isotope signatures used in interpretation of regional hydrology: East Maui, Hawaii: Journal of Hydrology, v. 264, p. 170-184.
Giambelluca, T.W., DeLay, J.K., Nullet, M.A., Scholl, M.A., and Gingerich, S.B. Interpreting canopy water balance and fog screen observations: Separating cloud water from wind-blown rainfall at two contrasting forest sites in Bruijnzeel, L.A., Juvik, J., Scatena, F.N., Hamilton, L.S., and Bubb, P., Mountains in the Mist: Science for Conserving and Managing Tropical Montane Cloud Forests, Honolulu, HI, University of Hawaii Press.

plants in a vegetated area. Evapotranspiration can be directly measured, computed from meteorological data, or estimated from pan evaporation data. In Hawaii, pan evaporation data is relied upon heavily when estimating evapotranspiration, since there are few direct measurements of evapotranspiration and the meteorological data to compute evapotranspiration is sparse.

4.6.2. Data Collection

In Hawaii, pan evaporation data collection began in the late 19th century, with the majority of stations beginning in the mid 1950s. The proliferation of pan evaporation stations was directly influenced by the expanse of sugar and pineapple cultivation, and the vast majority of this network was comprised of sugar and pineapple plantation stations. Some of these stations were co-located with the NWS cooperative observer program rainfall stations. However, since the closure of these plantations, most of these pan evaporation stations have been discontinued. Many of these stations were located in the areas where sugar was grown, which were usually lower elevation areas with relatively low rainfall, although there are some data from higher elevations in wetter areas.

4.6.3. Existing Programs

As described above, the network of pan evaporation stations has almost disappeared due to the plantation closures. The NWS currently maintains two evaporation stations, one in Lihue, Kauai, and the other in Ewa, Oahu. The remaining plantations on Maui and Kauai may still be collecting pan evaporation data; however, this data is not published or reported to the State Climate Office. There may be a few stations collecting evapotranspiration data for the purpose of research in selected areas, which probably utilize sophisticated instruments to directly measure or compute evapotranspiration. Historic data can be found in the reports mentioned below. Evaporation data from the Lihue and Ewa stations are available from the National Climatic Data Center.

4.6.4. Analyses and Reports

The Department of Land and Natural Resources published three pan evaporation reports. *Pan Evaporation Data, State of Hawaii* (1961) and *Pan Evaporation in Hawaii 1894-1970* (1973) described the pan evaporation data collection network in Hawaii, presented data from these stations, and discussed data analysis. *Pan Evaporation: State of Hawaii 1894-1983* (1985) is a similar report with in-depth technical discussion of pan evaporation methods and analysis, as well as maps of annual evaporation isopleths for Kauai, Oahu, Maui, and Hawaii. There are also numerous scientific journal and technical papers written on evaporation and evapotranspiration.

4.6.5. Gaps

The concern for lack of data reflects the importance of accurate evapotranspiration data when computing water budgets and aquifer sustainable yields in Hawaii. There is a lack of direct evapotranspiration measurements in the forested watershed areas. There is also a lack of meteorological data for computing evapotranspiration. Raw pan evaporation data is not readily available, and there is uncertainty in estimating evapotranspiration data using pan evaporation data.

4.6.6. Recommendations for Evaporation Monitoring

Although fairly long periods of evaporation data exist for a number of pan evaporation stations, much of this data is for low elevation and low rainfall areas, and the data is not readily available to the general public. There is little measured and computed evapotranspiration data in the State, and the availability of this data is unknown at this time. The following recommendations address these main concerns with evaporation and evapotranspiration data:

- Identify sources of evaporation and evapotranspiration data and improve access to this data;
- Establish evapotranspiration measurement stations in areas where aquifer sustainable yields need to be reassessed or improved;
- Increase and improve evapotranspiration estimates in areas where aquifer sustainable yields need to be reassessed or improved; and
- Conduct additional research on evapotranspiration in areas where aquifer sustainable yields need to be reassessed or improved.

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Section 5

CWRM Regulatory Programs

5. CWRM REGULATORY PROGRAMS

This section of the WRPP summarizes CWRM's current regulatory programs and recommendations for program implementation. Ground water regulation and permitting programs and surface water regulation and permitting programs are discussed, as well as CWRM's authority to designate ground and surface water management areas, resolve complaints and disputes, and declare water shortage and water emergency conditions.

5.1. Regulation of Ground Water

CWRM uses regulatory controls to implement its policies and Hawaii Water Plan guidelines for well development and water use. Regulations are also used to protect ground water quantity and quality, optimize ground water availability, and obtain maximum reasonable-beneficial uses. CWRM relies on a permit system to apply and implement regulations concerning well development and water use.

In making decisions on permit applications, CWRM looks to the Hawaii Water Plan for guidance. Therefore, the regulations also help to implement the counties' long-range plans and policies regarding land and water use. The regulations are also aimed at promoting hydrologic data gathering by requiring specific data to be collected at permitted well sites and submitted to CWRM. In turn, this helps to assure wise decision-making in the future based on new and better information.

5.1.1. Well Construction and Pump Installation Permits

A well construction permit from CWRM is required prior to the construction, modification, or sealing of any well that will explore for, develop, recharge[1], or permanently monitor ground water aquifers. A pump installation permit is required prior to the installation or replacement of well pumps.[2]

The standard conditions of all well construction and pump installation permits require that the work be done in accordance with the Hawaii Well Construction and Pump Installation Standards (HWCPIS). The HWCPIS, discussed in Section 5.1.2, contains all of CWRM's goals and policies regarding proper well construction and pump installation to ensure protection and optimization of ground water resources.

The following policy promotes enforcement of the information-gathering function of the permitting process, which helps CWRM better protect the resource, because their decisions can be made in the light of the most current and best available information:

Policy: **Permits are only issued to licensed contractors in good standing (i.e., no outstanding CWRM permit or Department of Commerce and Consumer Affairs licensing requirements).[3]**

[1] Injection wells are regulated by the State Department of Health.
[2] HRS §174C-84.
[3] Ground Water Regulation Branch Internal Enforcement Guideline, February 16, 2005 meeting of the Commission on Water Resource Management.

Under the HWCPIS, approval and issuance of well construction permits are generally ministerial actions.[4] A diagram illustrating the well construction and pump installation permitting process is included in Appendix B.

5.1.2. The Hawaii Well Construction and Pump Installation Standards

The State Water Code requires CWRM to develop minimum standards for the construction, modification, repair/maintenance, and sealing/abandonment of wells[5], in order to prevent polluting, contaminating, and wasting ground water, and to minimize saltwater intrusion into wells and ground water. The HWCPIS is a technical document that contains minimum standards governing virtually all aspects of well construction and pump installation, from a resource protection and optimization perspective. The HWCPIS was initially adopted by CWRM in 1997 and revised in 2004.

Protection of ground water quality is done through coordination with the DOH to determine appropriate permit conditions. All applications for well construction and pump installation permits are sent to the DOH for their review. The DOH review comments, including recommended permit conditions, are attached as special conditions to all permits issued by CWRM.

Since well construction and pump installation permits require adherence to the HWCPIS, CWRM is ensuring adequate protection, testing, and optimization of aquifers with respect to the development of new ground water sources. The DCCA requires well drillers to demonstrate adequate understanding of the HWCPIS through a testing and licensing process. However, licensed drillers are not required to pass any additional tests or complete any continuing education programs to retain their license. Currently, only licensed drillers are notified of changes to the HWCPIS. While the HWCPIS also provides adequate standards for the proper sealing of abandoned wells, the timely decommissioning of abandoned wells is an issue.

5.1.3. Abandoned Wells

The State Water Code defines an abandoned well as any well that has been permanently discontinued, or which is in such a state of disrepair that continued use for the purpose of obtaining ground water is impractical.[6] Section 3.1 of the HWCPIS further provides that all wells and test borings must be properly abandoned and sealed whenever:

- The well has served its purpose;
- The use of the well has been permanently discontinued;
- The well is not being properly maintained;
- The physical condition of the well is causing a waste of ground water, or is impairing or threatens to impair the quality of the ground water resources; or
- The well is in such a state of disrepair that its continued use is impractical or it is a hazard to public health or safety.

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[4] January 23, 1997 meeting of the Commission on Water Resource Management, Staff Submittal Item 3.
[5] HRS §174C-86.
[6] HRS §174C-81.

Because wells are generally considered assets to the property and can be expensive to properly seal, many well owners are reluctant to declare their well abandoned. The Hawaii Administrative Rules give additional authority to CWRM to determine when a well is abandoned[7]; however, making such a determination is still difficult. If the well owner states that there may be some future use of the well, CWRM must then determine abandonment by assessing the physical condition of the well and find that it is either leaking, polluting, deteriorating in quality, uncontrollable, or is in such a state of disrepair that continued use for the purpose of obtaining ground water is impracticable or unsafe. Making such an assessment requires specialized equipment, which the CWRM does not currently have..

If a well is determined to be abandoned by CWRM or is declared by the well owner to be abandoned, the HWCPIS requires that it be completely sealed with concrete or other similar materials. Depending on the size and depth of these wells, the cost will average about several thousand dollars for most wells up to tens and even hundreds of thousands of dollars for especially large or deep wells or shafts. Recommendations for wells that should be properly sealed are included in Section 11 of the WRPP.

If a well owner does not or is unable to seal their well, CWRM has the authority to seal the well and place a lien on the property.[8] CWRM currently lacks a funding mechanism to initiate and execute sealing of abandoned wells. It is estimated that there are approximately 1,168 production wells statewide that are not in use and are candidates for well abandonment.

5.2. Designation of Ground Water Management Areas and Water Use Permitting

When the water resources of an area are determined to be threatened by existing or proposed withdrawals of water, CWRM may designate the area as a water management area. Figure 5-1 shows the location of designated ground water management areas. In water management areas, CWRM limits the total quantity of water that can be withdrawn. The State Water Code provides eight criteria for CWRM to consider in designating an area for regulation of ground water use[9]:

- Whether an increase in water use or authorized planned use may cause the maximum rate of withdrawal from the ground water source to reach ninety per cent of the sustainable yield of the proposed ground water management area;
- There is an actual or threatened water quality degradation as determined by the department of health;
- Whether regulation is necessary to preserve the diminishing ground water supply for future needs, as evidenced by excessively declining ground water levels;
- Whether the rates, times, spatial patterns, or depths of existing withdrawals of ground water are endangering the stability or optimum development of the ground water body due to upconing or encroachment of salt water;

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[7] HAR §13-168-16.
[8] HRS §174C-86.
[9] HRS §174C-44.

- Whether the chloride contents of existing wells are increasing to levels which materially reduce the value of their existing uses;

- Whether excessive preventable waste of ground water is occurring;

- Serious disputes respecting the use of ground water resources are occurring; or

- Whether water development projects that have received any federal, state, or county approval may result, in the opinion of the commission, in one of the above conditions.

CWRM applies a water use permitting process to regulate use in designated water management areas. A water use permit must be obtained in order to continue existing uses and prior to commencing any new water use.[10] The permitting system allows for maximum reasonable-beneficial use of water resources, while ensuring that the integrity of the resource is not threatened. Water use permit applications are evaluated according to seven criteria identified in the State Water Code.[11] A diagram illustrating the permitting process is included in Appendix B.

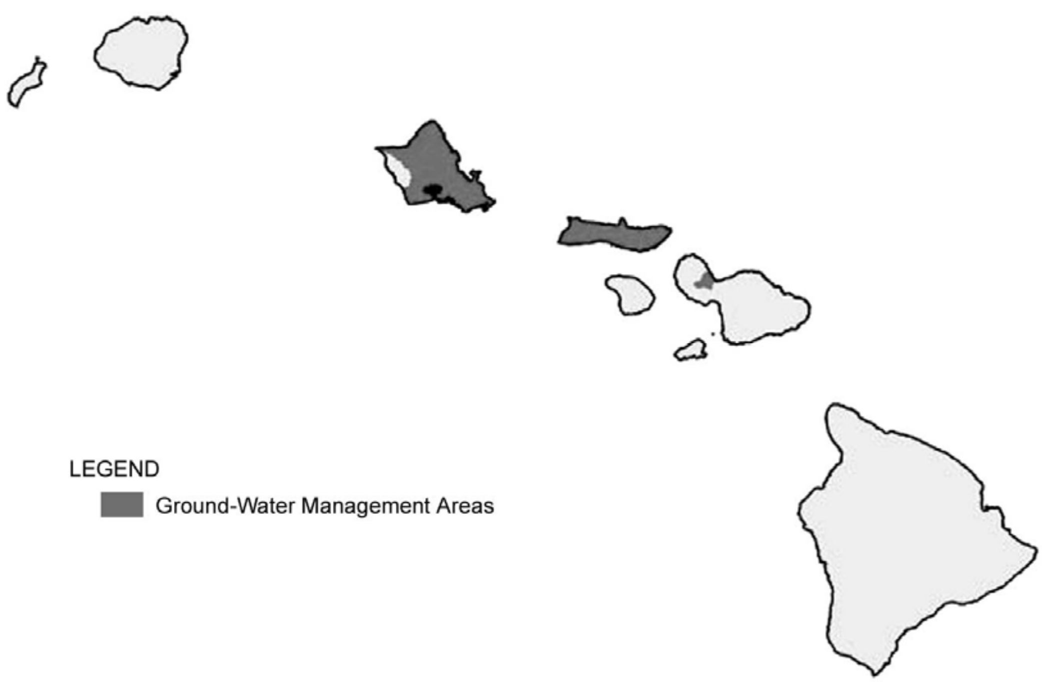

Figure 5-1. Designated Ground Water Management Areas

CWRM has established a policy to provide for water use permit modifications through a declaratory ruling on §174C-57 HRS:

[10] HRS §174C-48.
[11] HRS §174C-49(a).

Policy: **Water use permit modifications that meet the following criteria may be approved administratively:**

1) **The net change in permitted use within an aquifer is zero.**
2) **The modification would result in more efficient and optimal operation of multiple sources under a single operator.**
3) **No adverse impacts to water resources or other existing legal uses are anticipated.**
4) **End use location and type remain unchanged.**[12]

This policy clarifies and streamlines the water use permit modification process for well owners with multiple wells within a single aquifer system area. CWRM encourages more efficient and optimal water source operations, which can also result in minimizing the potential for overpumpage violations, for situations that meet the above criteria.

CWRM continues to refine and streamline the water use permitting process in response to Hawaii Supreme Court rulings, Water Commission decisions and actions, statutory changes to the State Water Code, and requests from the public or government agencies. Water Commission decisions on permit applications are recorded in the CWRM water use permit database, which serves as the agency's system for documenting and indexing formal decisions and actions. CWRM water use permitting policies described below have been identified through Hawaii Supreme Court rulings and Water Commission actions:

Policy: **There are four identified public trust purposes: 1) resource protection; 2) domestic water use; 3) Native Hawaiian traditional and customary rights**[13]**; and 4) Department of Hawaiian Home Lands (DHHL) reservations.**[14]

Through its review of various contested case hearing decisions and orders, the Hawaii Supreme Court has identified the above four public trust purposes. There is no hierarchy of priorities between these public trust purposes, but there is a presumption in their favor over other interests that seek water use permits. CWRM is obligated to consider, protect, and advance public rights to the resource at every stage of the planning and decision-making process.

In addition, CWRM has already given greater priority to agricultural uses over golf course uses, which was endorsed by the Hawaii Supreme Court in its first decision in the Waiahole Water Case hearing.

The Water Code is silent regarding any requirements for alternative source analysis in the water use permitting process. The only instance where an analysis of alternatives is mentioned in the Water Code is in the instream flow standard setting process. However, the Hawaii Supreme Court has issued an opinion that permit applicants are required to demonstrate the absence of practicable mitigating measures, including the use of alternative water sources. The evaluation of reasonable-beneficial use includes an efficiency test and requires the assessment of alternative water sources. Such an

[12] Declaratory Ruling No. DEC-ADM97-A1.
[13] Supreme Court Decision in Waiahole Ditch Contested Case Hearing CCH-OA95-1.
[14] Supreme Court Decision in Waiola O Molokai Contested Case Hearing CCH-MO96-1.

assessment is intrinsic to the protection of public trust purposes and essential to balancing competing interests.[15] CWRM has therefore established the following policy:

Policy: An analysis of alternatives is required to establish that proposed water uses are reasonable-beneficial for any water use permit.

CWRM has endorsed a policy of non-degradation, primarily for chloride levels, as follows:

Policy: The application of lower quality water over a higher quality aquifer is disallowed for water use permits.[16]

Proposed uses that will result in a degradation of aquifer water quality are not allowed, especially where the chloride concentration of ground water may increase. Either the same or higher-quality water must be used or the lower-quality water must be treated until it is at least of the same quality as the affected underlying aquifer. Generally, the ground water source and end use occur at the same site or within the same aquifer system area. The application of water of a relatively lower quality (i.e., brackish) over an aquifer that yields high-quality water (i.e., potable) is not allowed. CWRM examines water quality in terms of chloride concentration, and the DOH has authority over other water quality parameters should other quality issues be raised.

With the Supreme Court ruling in the Waiahole Water Case hearing, an analysis of alternatives is now being required for all water use permit applications. Recycled wastewater may be a viable alternative to the use of ground water. However, because there are certain constituents (e.g., endocrine disruptors) that are not removed in the wastewater treatment process, the DOH has indicated that there may be shallow drinking water aquifers over which recycled wastewater should not be applied. Identification of such aquifers would help CWRM to determine whether recycled water is a practical alternative for a proposed water use. Future DOH policy may provide additional guidance regarding the appropriate application of recycled water, as may vary dependent upon the level of wastewater treatment, over different aquifer types.

Similar to well construction and pump installation permit applications, the DOH is afforded an opportunity to review all water use permit applications. The DOH may recommend special conditions to address contamination concerns resulting from the proposed land use, such as pesticides and fertilizer that may be applied for golf courses. CWRM attaches any special conditions recommended by the DOH to water use permits, to ensure that aquifer water quality is not threatened or degraded.

CWRM's policy is that water should be put to its best and highest use. Operationally, this means that potable water should be used for drinking water purposes and other domestic needs, and non-potable water should be used for agriculture, landscape and golf course irrigation, and other non-potable needs, with agriculture uses being a higher priority than other non-potable uses. But, the Water Code does not preclude potable water from being

[15] Waiahole I, 94 Hawaii at 161, 9 P.3d at 473.
[16] March 15, 1990 meeting of the Commission on Water Resource Management, Staff Submittal Item 3.

used for non-potable purposes, if the proposed use meets the regulatory requirements and there are no practical non-potable alternatives. In such cases, CWRM will attach a special condition to reinforce standard conditions requiring that conversion to an alternative non-potable source is required when that source becomes available. This is stated in the following policy:

Policy: **The quality of the water supply should be matched to the quality of water needed, and the highest quality water should be allocated for the highest uses. However, potable water can be used for non-potable purposes if the proposed use meets the regulatory requirements and there are no practical non-potable alternatives. In these cases, special conditions are attached to the water use permit to require conversion to an alternate non-potable source when it becomes available.**[17]

CWRM adopted the following policy to promote the use of recycled wastewater over the Ewa Caprock:

Policy: **It is the policy of the Water Commission to promote the viable and appropriate reuse of reclaimed water insofar as it does not compromise beneficial uses of existing water resources.**
Recognizing that reclaimed water is a valuable resource in the Ewa Plain, direct or indirect reuse will be championed by the Water Commission. It is the policy of the Water Commission that the water resources of the Ewa Caprock Aquifer will be allocated only for nonpotable uses.[18]

CWRM does not have the authority to require recycled water use, but CWRM may require the installation of dual-line plumbing systems, and furthermore, it may deny an application for use of public trust resources if an alternate source, such as reclaimed water, is available.

The second part of the policy above was adopted to address DOH's concerns regarding the use of recycled wastewater over potable aquifers. Adopting the policy that the Ewa Caprock Aquifer will only be allocated for non-potable uses clears the way for recycled water use for landscape, golf courses, and other non-potable uses over the Ewa Caprock.

The State Water Code does not specify the use of a certain statistic to assess water use over time. The only instance where guidance is given in the State Water Code is the use of the prior three-month average water use to determine whether or not an existing water use in a newly designated water management area will require a public hearing.[19] However, it

[17] October 25, 2005 meeting of the Commission on Water Resource Management, Staff Submittal Item C-1.
[18] March 13, 1996 meeting of the Commission on Water Resource Management, Staff Submittal Item 3.
[19] HRS §174C-50(b).

should be noted that three-month average water use varies throughout the year, depending on the season and antecedent rainfall conditions (e.g., summer versus winter weather), and most likely does not accurately reflect actual annual water demand.

Existing ground water uses certified under Chapter 177 HRS, which was repealed and replaced by the State Water Code, were determined based on the prior five-year average of water use. Some parties have advocated the continued use of a five-year moving average for water use assessment; others have advocated the use of a 10-year moving average, which would better accommodate the cyclical nature of drought conditions. However, these longer-term statistics may conflict with the State Water Code's provision for revocation of water use permits due to four continuous years of nonuse.[20] In addition, allocating water based on assumed drought conditions would conflict with CWRM's mandate to ensure maximum reasonable-beneficial use because, in most years, the full amount of the allocation would not be used and new uses could not be accommodated if aquifers are fully allocated, even if aquifers are not actually being pumped up to their sustainable yields.

CWRM currently uses a twelve-month moving average (12-MAV) to assess ground water use, as stated in the following policy:

Policy: The Water Commission uses a twelve-month moving average for ground water use assessment.[21]

The first official reference to the use of a 12-MAV for assessing hydrologic data appeared in the October 21, 1992 issue of *Rainfall Trend,* a monthly newsletter issued by CWRM.[22] The newsletter provided up-to-date information on rainfall and water level information collected by CWRM, discussed the relationship between rainfall trends and water levels, and presented an outlook for rainfall. It was distributed to about 100 governmental agencies and private businesses interested in rainfall information.

The use of a 12-MAV has been used with reference to ground water use permits since 1993.[23] The 12-MAV considers an entire climatic cycle, accounting for seasonal variations in water use, where typically water use is higher in the summer when the weather is dry and lower in the winter due to increased precipitation. Further exploration of an appropriate statistic for water use assessment, allocation, and enforcement would be beneficial. If an alternative measure is identified, the State Water Code should be updated to include the assessment measure.

The State Water Code requires that permitted uses be reasonable and reflect efficient water use. CWRM has established the following policy:

Policy: Reasonable water use quantities are determined through the use of established guidelines and standards.

[20] HRS §174C-58(4).
[21] CWRM actions referencing the use of a twelve-month moving average to assess water use began on March 17, 1993.
[22] *Rainfall Trend* newsletter was published monthly by the Commission on Water Resource Management's Hawaii Climate Center. The Hawaii Climate Center ceased to exist in 2000, when the rainfall program was transferred to the University of Hawaii.
[23] March 17, 1993 meeting of the Commission on Water Resource Management.

To determine reasonable water quantities, CWRM utilizes actual metered use data, when possible, in conjunction with established guidelines and standards.

Actual metered use data can be used to project future water needs for a particular use. Metered use data can also be extended to estimate the future water use requirements of similar, nearby uses. However, even if local climatic conditions are consistent, a variety of factors can influence actual water use. For example, agricultural irrigation needs are determined not only by crop type, but by crop practices, such as the number of crop rotations, row spacing, and irrigation application method. Physical site differences also contribute to uncertainty in irrigation demand, such as soil type, slope, and depth to the water table. Evaluations of metered use data must also consider that data may not reflect efficient water use practices.

CWRM does not have a fully functioning, comprehensive water use reporting program, and metered water use data may not be available in many cases (see Section 6 for a discussion of CWRM's water use reporting program). Where use data is not available, CWRM must utilize other means to determine reasonable quantities for future demands. To estimate domestic consumption, CWRM refers to the *Water System Standards*[24], which include domestic consumption guidelines prepared by the county water departments. The water departments use these standards for the design and construction of municipal water system facilities. The standards also include water consumption guidelines for commercial, resort, light industrial, school/park, and agricultural water use for each county. Guidelines are system-wide averages that do not reflect variations between drier and wetter service areas. It is difficult to determine reasonable water use quantities for agricultural purposes. For the City and County of Honolulu, CWRM has utilized information from the Honolulu BWS and the DOA to estimate water requirements for irrigation of selected crop types on Oahu. The Agricultural Water Use and Development Plan, published by the DOA in 2004, estimates the irrigation rate for diversified crop farming in Hawaii as 3,400 gallons per acre per day (gpd/ac). This estimate is based on the eight-year average irrigation rate for diversified crop farming within the Lalamilo Section of the Waimea Irrigation System on the island of Hawaii. Diversified crop farming involves active cultivation of land to produce commercial crops throughout the crop's growing cycle. Depending on the crop, the growing cycle may include several harvesting cycles in a calendar year. Portions of the land may be rotated out of cultivation and left unirrigated for a short period of time as part of routine farming activities. The DOA uses 3,400 gpd/ac to forecast agricultural water demands and recommends that this figure be used until demand estimates can be refined through future records and analyses. This estimate is most appropriate for estimating diversified irrigation use in the area of the Waimea Irrigation System. Estimates of irrigation water requirements for other agricultural irrigation systems were not provided in the AWUDP report.

Water requirements for aquaculture activities are determined using draft guidelines prepared by the DOA's Aquaculture Development Program. Two ranges of use (Intensive and Semi-Intensive) were developed by the DOA for selected aquaculture species. Economics and various management factors dictate the aquaculture management system and actual water consumption rates.

[24] State of Hawaii, 2002, *Water System Standards*.

CWRM's reliance on the methods, standards, and guidelines described above are subject to change with new information and technological advances. In the interest of improving irrigation water demand projections and evaluation of reasonable irrigation water use quantities, CWRM contracted the University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR) to develop a model for estimating irrigation water demands in different physical areas. The computer software application is based on a water budget irrigation consumption mass balance that utilizes a Geographical Information System (GIS) platform to determine local climate and soil characteristics. GIS inputs include digitized maps from the *Rainfall Atlas of Hawaii*[25]*, Pan Evaporation: State of Hawaii, 1894-1983*[26]*, Soil Survey Island of Hawaii, State of Hawaii*[27]*,* and *Soil Survey Islands of Kauai, Oahu, Maui, Molokai, and Lanai.*[28] The irrigation model also considers differences in crop type and crop practices. This model provides CWRM with a standardized methodology to estimate the regional water requirements of various crop types.

5.3. Recommendations for Ground Water Regulation

The following actions are recommended for implementation by CWRM and the State to improve ground water regulatory programs:

Recommendations for Well Construction and Pump Installation Permits

- CWRM should explore further education programs for drillers to ensure they are knowledgeable of current construction standards.

Recommendations for Well Abandonment/Sealing

- CWRM should explore available funding sources and mechanisms to immediately address priority abandoned wells that need to be sealed (list of priority abandoned wells recommended for sealing is included in the Implementation Plan in Section 11 of the WRPP).

- Because improperly abandoned wells are largely a contamination and pollution issue, CWRM should coordinate with the DOH to identify funding sources and implement a program for sealing wells that pose existing or potential pollution concerns.

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[25] Giambelluca, T.W., Nullet, M.A., and Schroeder, T.A., 1986, Rainfall atlas of Hawaii: State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Report R76, 267 p.
[26] Ekern, P.C., and Chang, J.-H., 1985, Pan evaporation: State of Hawaii, 1894-1983: State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Report R74, 172 p.
[27] Sato, H. et al., 1973, *Soil Survey of the Island of Hawaii*, *State of Hawaii:* United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C. 115 pp., 195 map sheets.
[28] Foote, D. E. et al., 1972, *Soil Surveys of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii:* United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C. 232 pp., 130 map sheets.

- A comprehensive, statewide survey of all potentially abandoned wells should be conducted. CWRM should secure a continuous, dedicated funding source in order to obtain the specialized equipment required to assess other unused wells that may also meet the criteria for abandonment.

- If sufficient funding cannot be obtained for CWRM to begin sealing those abandoned wells which the landowner/well owner will not or cannot do, then CWRM should consider revising the State Water Code to give CWRM clear authority to order landowners/well owners to seal abandoned wells, subject to daily fines for noncompliance.

Recommendations for Ground Water Use Permitting

- It is recommended that the DOH update the WQP to provide additional guidance regarding the appropriate application of recycled water, as may vary dependent upon the level of wastewater treatment, over different aquifer types.

- CWRM should further explore the use of different statistics, methods, and measures to assess water use over time. If an alternative measure is identified, the State Water Code should be updated to include the assessment measure.

5.4. Regulation of Surface Water

The term “surface water” can refer to both contained surface water and diffused surface water. Contained surface water occurs upon the surface of the Earth in bounds that can be created naturally or artificially. Examples of contained surface water include, but are not limited to, streams, other watercourses, lakes, reservoirs, and coastal waters subject to State jurisdiction. Diffused surface water is water occurring upon the surface of the ground other than in contained waterbodies. For example, water from natural springs is diffused surface water when it exits from a spring onto the Earth’s surface.[29]

The State Water Code mandates CWRM to establish and administer a statewide instream use protection program. Under the Stream Protection and Management Program, surface water regulation provides for the protection of instream uses and reasonable-beneficial uses of water. The State Water Code defines "instream use" as beneficial uses of stream water for significant purposes which are located in the stream and which are achieved by leaving the water in the stream. According to HRS §174C-3, instream uses include, but are not limited to:

- Maintenance of fish and wildlife habitats;

- Outdoor recreational activities;

- Maintenance of ecosystems such as estuaries, wetlands, and stream vegetation;

- Aesthetic values such as waterfalls and scenic waterways;

[29] HRS §174C-3.

- Navigation;
- Instream hydropower generation;
- Maintenance of water quality;
- The conveyance of irrigation and domestic water supplies to downstream points of diversion; and
- The protection of traditional and customary Hawaiian rights.

CWRM has regulatory jurisdiction over the use of surface waters of the State, with the exception of coastal waters[30], through Stream Channel Alteration Permits (SCAP), Stream Diversion Works Permits (SDWP), and Instream Flow Standards (IFS).

5.4.1. Request for Determination

CWRM has the duty to protect stream channels from alteration, whenever practicable, to provide for fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses as defined by the State Water Code. Thus, CWRM requires a SCAP whenever a stream channel alteration is to be undertaken. However, the variable nature of Hawaiian streams often challenges the requirement for a SCAP, and a request for determination may be made.

A Request for Determination (RFD) is a public request to establish the existence and location of a stream channel and/or to determine whether a project is impacting the stream channel, thereby requiring a SCAP. Initially, it must be determined whether the watercourse is actually a stream as defined in the State Water Code. Subsequently, it must be discerned whether the project is actually within the bed or banks of the stream.

The State Water Code defines the term "stream" as inclusive of any river, creek, slough, or natural watercourse in which water usually flows in a defined bed or channel. It is not essential that the flow be uniform or uninterrupted. The fact that some parts of the bed or channel have been dredged or improved does not prevent the watercourse from being a stream.[31]

"Stream channel" means a natural or artificial watercourse with a definite bed and banks which periodically or continuously contains flowing water. The channel referred to is that which exists at the present time, regardless of where the channel may have been located at any time in the past.[32]

The following policy identifies the types of watercourses that, as determined by the Water Commission through declaratory ruling, do not meet the definition of a stream:

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[30] HRS §174C-4(a).
[31] HRS §174C-3.
[32] HRS §174C-3.

Policy: **Watercourses which are: 1) man-made or are part of an irrigation system; 2) excavated subdivision drains; 3) man-made drainage channels in low-lying coastal plain areas; 4) highway interceptor ditches; 5) auwai; or 6) dry gulches (per Declaratory Ruling No. DEC-MO94-S3) do not meet the definition of a stream and, therefore, are not subject to SCAP requirements.**

On April 17, 1999, the Water Commission approved Declaratory Ruling No. DEC-ADM99-S8, which included the above listing of types of watercourses that do not meet the definition of a stream and, therefore, do not require a SCAP. Earlier declaratory rulings dealt with specific watercourses and subsequently laid the framework for the approved list.

Under Declaratory Ruling No. DEC-KA94-S2, Grove Farm Properties, Inc. claimed that streamflow in Puali Stream, Kauai, was a direct result of recharge from irrigation water and transmission facilities, and that the stream would most probably be dry except during periods of direct runoff. Staff concluded that while Puali Stream may be largely sustained by irrigation return water, it could not be definitely concluded that the perennial flows of Puali Streams resulted wholly from irrigation practices, especially in the lower reaches of the stream. The Water Commission determined and declared that since Puali Stream conveys irrigation water to downstream points of diversion, and since its use is considered a beneficial instream use of water, any stream channel alteration work on the stream would require a SCAP. In this case, the stream channel, though part of an irrigation system, was determined to be a natural watercourse.

In Declaratory Ruling No. DEC-MO94-S3, the Molokai community raised concerns that the Kukui (Molokai), Inc. water pipeline construction project had altered Manawainui, Waiahewahewa and Kaluapeelua streambeds without obtaining the proper permits from CWRM. The Water Commission ruled that Kukui (Molokai), Inc. did not require SCAPs for gulch crossings related to the pipeline project because: 1) The gulches did not have natural sources of fresh water such as springs, seeps, and frequent or continuous rainfall in sufficient quantities or frequencies to support instream uses; and 2) the gulches did not have aquatic resources in the form of fish or aquatic plant communities from the points of alteration to their upstream sources of water, nor did the gulches provide for the migration and movement of aquatic life.

It is often difficult to determine the difference between a gulch that is usually dry except for periods of heavy rainfall, and a stream that may be dry much of the time but still provides for instream uses. If it can be determined that a watercourse does not provide for one or more instream uses, such as aquatic animals or aquatic vegetation, in either upstream or downstream areas, then a SCAP is generally not required. The definitions under this policy are guidelines intended to allow for prompt and proficient decisions by CWRM staff, however determinations on potential impacts to instream uses are often made on a case-by-case basis.

5.4.2. Stream Channel Alteration Permit

CWRM must protect stream channels from alteration, whenever practicable, to provide for fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses. Such protection of stream channels is made possible through the requirement that a SCAP be obtained from CWRM prior to undertaking a stream channel alteration. "Channel alteration" means: (1) to obstruct, diminish, destroy, modify, or relocate a stream channel; (2) to change the direction of flow of water in a stream channel; (3) to place any material or structures in a stream channel; or (4) to remove any material or structures from a stream channel.[33] A diagram illustrating the SCAP process is included in Appendix B.

Generally, SCAPs are required for projects that are in the streambed itself, or on the banks of the stream. The exact delineation of the bank is sometimes problematic, but it is usually within the regular or common flow variations of a particular stream, as opposed to flood stages where the normal banks are overtopped. In these cases, CWRM may refer to Declaratory Ruling No. DEC-OA96-S5, in which Pacific Atlas Hawaii submitted a SCAP application to construct a pedestrian bridge at the mouth of Kawa Stream, Oahu. While most streams have a distinct break in the top of the slope which defines the extent of the stream channel, the proposed location of the pedestrian bridge lacked a distinct break. Based upon the evidence, CWRM determined that where a watercourse perennially or continuously contains flowing water, but may not have a definite break in slope facilitating a determination of the stream channel, the stream channel for that portion of the stream shall be defined as the area within 50 feet from the water's edge during a non-flooding event.

SCAPs are issued for all projects that alter a stream channel, including those that divert water away from the stream. Such projects include, but are not limited to, armoring stream banks (such as the installation of retaining walls to protect banks from erosion), lining of stream channels (for flood control), placing structures in streams (bridge foundations, pipelines, etc.), removing of material and structures from streams (boulders, sand from stream mouths, existing walls and structures, etc.), realigning streams, and constructing stream diversion works.

Past declaratory rulings issued by the Water Commission have effectuated policies as to the applicability of SCAP requirements for certain situations, and for maintenance and repair activities. Certain declaratory rulings have created specific exemptions from SCAP requirements, while others provide the DLNR Chairperson with particular authority to approve the issuance of a SCAP.

The following policies relate to the applicability of SCAP requirements for specific activities which CWRM supports:

Policy: CWRM supports routine maintenance of channels, streambeds, streambanks, and drainageways.

[33] HRS §174C-3.

The maintenance of stream channels, streambeds, streambanks, and drainageways is mandated by law, under HRS §46-11.5. The statute asserts that each county shall provide for the maintenance of channels, streambeds, streambanks, and drainageways, unless such features are privately owned or owned by the State. In which case, it becomes the responsibility of their respective owners. The statute also provides each county with the ability to enforce maintenance work on privately owned channels, streambeds, streambanks, and drainageways, and assess civil penalties for non-compliance by private entities or individuals.

CWRM supports this policy by exempting routine streambed and drainageway maintenance activities and maintenance of existing facilities from the SCAP requirements, as provided for under the State Water Code, HRS §174C-71(3)(A). The State Water Code is silent on defining "routine maintenance" and the specific activities allowed therein. As a result, CWRM has defined maintenance activities for which SCAPs are not required under the context of Declaratory Ruling Nos. DEC-ADM99-S8 and DEC-ADM03-S9. Provided the watercourse is determined to be "natural," thereby meeting the definition of a stream, CWRM then assesses the magnitude of channel alteration and the reasonable expectation of impacts to instream uses. The following stream clearing activities qualify as "routine maintenance" and do not constitute significant channel alteration or impact on instream uses, and therefore qualify to be exempt from the SCAP requirements:

- Manual clearing of streams or work without the use of heavy equipment.
- Clearing of sand plugs at stream mouths, as long as the sand plugs are not submerged or do not contain silt or mud.
- Clearing of lined channels, as long as the work does not disturb submerged (accumulated) silt and mud.
- Clearing of vegetation, rock, silt, and debris of artificially lined (concrete or grouted rubble paving), non-submerged portions of streams. These activities also include removal of rocks from boulder basins.
- Reconstruction of channel linings to original configuration. These include activities such as repairing of spalls, patching concrete channel linings, and re-grouting of rubble pavement.

Many projects, while they may be considered "routine" by the landowner, are rather large in scope and thus do not meet CWRM's criteria of "routine maintenance." These projects tend to affect longer lengths of stream channel, result in greater amounts of removed material, require the use of heavy equipment, and are typically undertaken by government agencies. As a result, the Water Commission supports streamlining the permitting process for specific government agencies by delegating the approval of agency SCAPs to the Chairperson:

Policy: **Applications by government agencies for stream channel alteration permits to perform streambed and drainageway maintenance activities *not* considered "routine maintenance" may be delegated to the Chairperson for approval if certain criteria are met.**

CWRM requires that a Declaratory Ruling be approved for each respective agency seeking action under this policy. Specific Declaratory Rulings have been approved for the City and County of Honolulu (DEC-ADM99-S8) and the State Department of Transportation (DEC-ADM03-S9).

Under CWRM policy, SCAP applications must meet the following criteria, as stated in the related Declaratory Rulings:

The Chairperson may approve stream channel alteration permits for stream clearing activities that may affect instream uses, but meet the following criteria:

1. *The stream channel alteration permit application must contain the following:*

   a. *A copy of the Clean Water Act, Section 404 permit from the U.S. Army Corps of Engineers, and the Clean Water Act, Section 401 Water Quality Certification and Best Management Practices Plan from the Department of Health. In the event that the project is not subject to these sections of the Clean Water Act the applicant shall submit written documentation from the Corps of Engineers citing the exemption.*

   b. *Clean Water Act Section 402 (NPDES) permit if applicable.*

   c. *Written description of the scope of work including:*

      1) *A location map showing affected stream reach. Cross section(s) showing typical contours of the before and after removal of material. Photographs.*

      2) *Amount of material to be removed.*

      3) *Method of clearing including description of the types of equipment to be used.*

      4) *Location and practice of spoils disposal.*

      5) *Frequency of clearing time required for each clearing.*

      6) *Written concurrence from the State Historic Preservation Division and the Division of Aquatic Resources that the work may proceed.*

2. *Must not alter stream diversions works or interim instream flow standard.*

3. *The amount of material to be removed is less than 500 cubic yards and will take less than two weeks to complete the work.*

4. *Clearing activity does not include the placement or removal of any structures in the stream.*

5. *Clearing must not be after-the-fact.*

6. *Clearing must not be in violation of any other applicable federal, State, or county permit.*

7. *Must not restrict access to property.*

8. *Must not be subject to a Special Management Area Permit (HRS, Chapter 205A).*

9. *Chairperson approved SCAPs are subject to the following conditions:*

   a. *Standard Chairperson Approved SCAP Conditions.*

   b. *Special conditions may be added by the Chairperson including but not limited to:*

      1) *Requiring the applicant to produce a Best Management Practice Plan acceptable to the Department of Health.*

      2) *Requiring the applicant to notify the State Historic Preservation Division on start of clearing activities.*

   c. *The permit will be valid as long as the Commission does not revoke the permit or until the Commission amends this Declaratory Ruling.*

Stream monitoring is a fundamental component of surface water resource management. Monitoring of water quantity and water quality supports baseline data collection and characterization, documents changes over time, provides a scientific basis for making sound management decisions, and is an essential tool in water resource planning.

Declaratory Ruling DEC-ADM97-S6 provides the basis for the following CWRM policy:

Policy: CWRM supports the establishment of stream monitoring equipment, provided the installation of such devices does not require substantial alteration of the stream channel.

In 1997, the Water Commission approved a SCAP (SCAP-OA-222) allowing for the installation of two temporary V-notch weirs to monitor streamflow at two points within the stream during low-flow periods. CWRM found that the two weirs would minimally impact the stream channel, water quantity, and water quality, and recommended that the Water Commission consider delegating the approval of future SCAPs for stream gages to the Chairperson.

Under Declaratory Ruling DEC-ADM97-S6 in 1998, the Water Commission delegated the approval of stream channel alteration permits to the Chairperson for surface water gaging stations which meet all of the following criteria:

- The gages are installed using manual construction practices only, without the use of heavy equipment.

- The length of time for the work in the stream to be completed is not greater than four days.

- No fill or discharge will be made into the stream, and no stream water will be removed from the stream channel.

- Concrete or masonry may be constructed or placed in the stream channel if it meets the following criteria:

  - It is confined to one bank of the stream;

  - It is for foundational or anchoring purposes only; and

  - The gages uses natural, rather than artificial, means of flow control (e.g., it does not span the entire width of the stream channel).

5.4.3. Stream Diversion Works Permit

The term "stream diversion" is defined by the State Water Code as the act of removing water from a stream into a channel, pipeline, or other conduit.[34] CWRM issues Stream Diversion Works Permits for any artificial or natural structure placed within a stream for the purpose of diverting stream water. The range of such projects include small diversions of several tens of gallons per minute by means of small pumps, medium-sized diversions such as those that supply water to taro *loi* and other smaller irrigation systems, and large diversion intake structures that could divert all of a stream's flow except for flood flows. A diagram illustrating the SDWP process is included in Appendix B.

Any new stream diversion, or expansion of an existing stream diversion, may require a petition to amend the interim instream flow standard (see section 5.4.4 for further discussion of instream flow standards), depending on the stream of interest.

A SDWP is also required when a stream diversion works is abandoned. A filing fee is not required when applying to abandon a stream diversion works.[35]
SDWPs are not required for normal maintenance activities[36], which would include repairing pumps or replacing them with pumps of equal or less capacity, repairing and maintaining existing diversion structures, cleaning out diversion structures to restore capacity, and other repair and maintenance operations that do not expand or increase the diversion capacity of a structure beyond the original design of the structure.

5.4.4. Instream Flow Standards

As part of the instream use protection program required by the State Water Code, CWRM is charged with establishing "instream flow standards on a stream-by-stream basis whenever necessary to protect the public interest in waters of the State." [37] The "instream flow

[34] HRS §174C-3.
[35] HAR §13-168-35(b).
[36] HRS §174C-93.
[37] HRS §174C-71.

standard" is defined as 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 specified times of the year to protect fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses.[38] According to the State Water Code, an IFS is to be established by CWRM, on its own motion, on a stream-by-stream basis. Acting upon the establishment of IFS, HRS §174C-71(1)(B) requires CWRM to set forth the conclusion "that the public interest does or does not require, as is appropriate, an instream flow standard to be set for the stream," and the supporting reasons and findings. A diagram illustrating the IFS process is included in Appendix B.

Each IFS needs to describe the flow necessary to protect the public interest in the particular stream. Flows are to be expressed in terms of variable flows of water necessary to adequately protect fishery, wildlife, recreational, aesthetic, scenic, or other beneficial instream uses in the stream. When investigating a stream to set an IFS, CWRM shall consult with and consider the recommendations of the DOH, the aquatic biologist from DLNR, the Natural Area Reserves System Commission, the University of Hawaii Cooperative Fishery Unit, the U.S. Fish and Wildlife Service, and other agencies with an interest in or information on the stream. Finally, prior to setting an IFS, CWRM shall give notice and hold a hearing on its proposed standard or modification.

Currently, no permanent IFS have been established for any streams or stream reaches in the state, and CWRM manages surface water resources based on interim IFS adopted by the Water Commission in 1988 and 1989 (see Section 5.4.4.1 for further discussion).

The State Water Code and the Hawaii Administrative Rules include provisions by which the permanent IFS, after they are established by CWRM, can be modified. A modification of the IFS may be required for any activity that affects the natural flow of a stream. In general, the process for modifying an IFS is similar to that for establishing an IFS. The modification of an established IFS can be initiated by CWRM or can be initiated by petition brought to CWRM by any person with proper standing.

5.4.4.1. Interim Instream Flow Standards

The State Water Code distinguishes between an Instream Flow Standard and an *interim* Instream Flow Standard. "Interim instream flow standard" means a temporary standard of immediate applicability, adopted by the Water Commission without the necessity of a public hearing, and terminating upon the establishment of an Instream Flow Standard.[39] The State Water Code further provides that interim IFS may be adopted on a stream-by-stream basis or may consist of a general instream flow standard applicable to all streams within a specified area.[40]

The Hawaii Administrative Rules for the Protection of Instream Uses of Water recognizes that "[i]nterim IFS are by their nature temporary and subject to

[38] HRS §174C-3.
[39] HRS §174C-3.
[40] HRS §174C-71(2)(F).

change".[41] Any existing interim IFS shall terminate upon the establishment of a permanent IFS.[42]

In 1988 and 1989, the newly formed Water Commission, working with the deadlines set by the Legislature to set Interim IFS, reached consensus in defining the interim IFS for all streams statewide to be "that amount of water flowing in each stream on the effective date of this standard, and as that flow may naturally vary throughout the year and from year to year without further amounts of water being diverted offstream through new or expanded diversions, and under the stream conditions existing on the effective date of the standard…"

The interim IFS was based on the requirements of the State Water Code, comments received at six public meetings held across the state, and several redrafts of the language at the Water Commission's meeting on June 15, 1988. Interim IFS were set for regions of the state as follows:

East Maui:	Adopted by the Commission on June 15, 1988 Effective October 8, 1988
Kauai:	Adopted by the Commission on June 15, 1988 Effective October 8, 1988
Hawaii:	Adopted by the Commission on June 15, 1988 Effective October 8, 1988
Molokai:	Adopted by the Commission on June 15, 1988 Effective October 8, 1988
West Maui:	Adopted by the Commission on October 19, 1988 Effective December 10, 1988
Leeward Oahu:	Adopted by the Commission on October 19, 1988 Effective December 10, 1988
Windward Oahu:	Adopted by the Commission on April 19, 1989 Effective May 4, 1992.

In setting the interim IFS according to stream flows occurring on the effective dates of the standards, the Water Commission recognized the following:

- Long-term studies and research are required to define ecologically necessary flows;
- Stream-management decisions and assessment methods should acknowledge the preliminary and incomplete nature of existing data; and

[41] HAR §13-169-43(b).
[42] HAR §174C-71(2)(A) HRS and §13-169-43(a).

- For the foreseeable future, it will be necessary to manage and protect streams through a system of working presumptions, rather than on the basis of firm scientific knowledge.

The State Water Code allows for establishing and modifying interim and permanent IFS, with the assumption that scientific data will eventually provide reliable, empirical information that will improve CWRM's management capabilities.[43]

The interim IFS must be modified to account for any new or expanded diversion of surface water from a stream.[44] This additional diversion may be direct or indirect. An example of an indirect diversion would be a situation where there is interaction between surface and ground water (where the withdrawal of ground water from a well could affect a stream, or where testing indicates that pumping from a well could affect the stream).

Any person with proper standing may petition CWRM to modify an interim IFS. In contrast to the permanent IFS adoption process, the State Water Code does not require agency or public consultation in the adoption of interim IFS. CWRM anticipates that public input will be beneficial to the interim IFS adoption process. As such, on December 13, 2006, the Water Commission authorized CWRM staff to seek agency comment and hold public fact-gathering meetings to support the establishment of measurable interim IFS. This action effectuated a process by which CWRM can pursue the adoption of measurable interim IFS and evaluate petitions for adoption of interim IFS.

5.5. Designation of Surface Water Management Areas and Water Use Permitting

The State Water Code provides CWRM with the authority to designate Surface Water Management Areas and to require and administer a surface water use permitting system. As with ground water regulation, the intent of surface water management area designation is to ensure reasonable-beneficial use of water resources in the public interest.

CWRM must consider the following criteria in designating an area for surface water use regulation:

- Whether regulation is necessary to preserve the diminishing surface water supply for future needs, as evidenced by excessively declining surface water levels, not related to rainfall variations, or increasing or proposed diversions of surface waters to levels which may detrimentally affect existing instream uses or prior existing off stream uses;

- Whether the diversions of stream waters are reducing the capacity of the stream to assimilate pollutants to an extent which adversely affects public health or existing instream uses; or

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[43] Summarized from page 16 and 17 of the Commission on Water Resource Management *Findings of Fact, Conclusions of Law and Decision and Order In the Matter of Water Use Permit Applications, Petitions for Interim Instream Flow Standard Amendments, and Petitions for Water Reservations for the Waiahole Ditch Combined Contested Case Hearing*, *Case No. CCH-OA95-1*, December 24, 1997.
[44] HRS §174C-71.

- Serious disputes respecting the use of surface water resources are occurring.[45]

Currently, there are no designated surface water management areas. Therefore, no surface water use permits have been issued.

5.6. Recommendations for Surface Water Regulation

There are two principal issues that should be addressed to improve surface water regulation across agencies and governmental jurisdictions statewide:

Regulatory coordination: Ongoing coordination is required between government agencies that regulate the various, and oftentimes overlapping, aspects of water resources. Laws and rules periodically change, as does the interpretation of existing laws and rules. Agency policies continue to adjust to new situations and rulings by administrators and courts. Coordination is required to prevent duplication of effort, excessive regulation, and unnecessary regulation.

Surface water use data collection and data quality: The lack of water use data for surface water makes it difficult to resolve disputes between competing users of the resource. Without good water use records, complaints of wasting or dumping of water are difficult to substantiate or refute.

Inter-agency coordination at the staff level must be ongoing to most efficiently manage and protect resources. Examples of agencies with programs related to surface water regulation include the Army Corps of Engineers, the DOH, county planning and permitting departments, and county water departments. Therefore, it is recommended that agencies organize and coordinate periodic workshops whenever new laws, rules, or policies are adopted and implemented.

Regarding data collection and data quality, it is recommended that additional staff be provided for field investigations and water use data collection and management. Funding mechanisms should be sought or enhanced to increase knowledge of resources, and to improve protection and management programs. For more information on surface water use reporting, see Section 6.2.4.1.

Finally, activities should be executed for the verification of stream diversions and abandoned diversions works. This will improve and refine data collection sites and increase the reliability of surface water use data.

5.7. Complaints and Dispute Resolution

The State Water Code provides CWRM with the authority to process citizen complaints[46], and statewide jurisdiction to hear any dispute regarding water use, resource protection and management, water rights, and competing uses, or other water issues, regardless of whether the area involved has been designated as a water management area.[47]

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[45] HRS §174C-45(3).
[46] HRS §174C-13.
[47] HRS §174C-10.

Citizen complaints are usually related to unpermitted construction activities, stream and spring ownership disputes, and environmental and public health concerns. Disputes can be related to any water resource issue within CWRM's jurisdiction.

CWRM typically receives more surface water related complaints, and more ground water related disputes, as described below:

Table 5-1
Complaint and Dispute Cases Filed with CWRM

	Surface Water Related	Ground Water Related
Complaints	209	21
Disputes	1	5

Source: CWRM Staff Communication, August 31, 2006.

Pursuant to HRS §174C-13 and Chapter 91, CWRM adopted procedural rules to process citizen complaints, including the right of appeal to the Water Commission. If any person files a complaint that any other person is wasting or polluting water or is making a diversion, withdrawal, impoundment, consumptive use of waters, or any other activity occurring within or outside of a water management area, not expressly exempted under the State Water Code, without a permit where one is required, CWRM has authority to investigate, take appropriate action, and notify the complainant thereof.

In the past, citizen complaints have included the following:

- Reports of unpermitted activity (such as grading, removing material, adding material, dumping, etc.) in or next to streams;
- Reports of illegal building (such as walls, lanais, fences, etc.) in or close to a stream;
- Reports of fish kills or aquatic plant "blooms" in streams;
- Property disputes regarding locations of streams, springs, ponds, and *auwai*;
- Reports of too little water in a stream;
- Reports of too much water in a stream;
- Reports of structures in streams causing flooding;
- Reports of illegal alteration of streams;
- Reports of illegal diversions of steams;

- Reports of waste and dumping of stream water; and

- Illegal well drilling, illegal use of well water, and leaky wells.

Staff responds to complaints that fall within the jurisdiction of CWRM that generally include wasting or dumping of water, and any work done in or near streams, without the required permits, that could affect instream uses. Water quality complaints are referred to the DOH[48]. Complaints concerning flooding and flooding-related maintenance of stream banks are referred to the respective counties.[49]

Complaints lead to CWRM issuing stop-work orders, where persons who start projects requiring permits, but have not yet completed them, are ordered to stop work until the proper permits are obtained. Where projects without the required permits are completed, CWRM requires the persons who did the work to apply for after-the-fact permits.

HRS §174C-10 describes CWRM's authority in dispute resolution. The State Water Code provides CWRM with jurisdiction statewide to hear any dispute regarding water resource protection, water permits, constitutionally protected water interests, and insufficient water for competing uses, regardless of whether the area involved is designated as a water management area. Under the provisions of the State Water Code, the final decision on any disputed matter shall be made by the Water Commission. Unlike complaints, which are generally related to permits, disputes can occur for any problem related to water resources under the jurisdiction of CWRM.

Examples of disputes include the following:

- *Auwai* disputes – where neighboring users on an *auwai* system have disputes over various aspects of *auwai* use such as maintenance of the *auwai*, maintenance of the intake, taking too much water, altering the auwai, etc;
- Location of resources – property disputes between adjacent owners regarding the location of a water resource; and
- Surface water and ground water interaction disputes – disputes that occur where the pumping of water from a well could adversely affect nearby stream flow, or where blockage (damming or diverting) of ground water could adversely affect the flow of surface water.

5.8. Water Shortage and Water Emergency Declarations

5.8.1. Declaration of Water Shortage

The State Water Code (HRS §174C-62) mandates that CWRM formulate a plan to be implemented during periods of water shortage, and describes the CWRM's authority as follows:

> *The commission, by rule, may declare a that a water shortage exists within all or part of an area when insufficient water is available to meet the requirements of the*

[48] HAR §13-167-82.
[49] HRS §46-11.5.

permit system or when conditions are such as to require a temporary reduction in total water use within the area to protect water resources from serious harm.

The State Water Code further states that CWRM must publish a set of criteria for identifying a water shortage, and CWRM must adopt a reasonable system for water use permit classification to be included in the water shortage plan. The water shortage plan must also set forth provisions and guidelines for imposing use restrictions on different classes of permits as may be necessary to protect the resource.

The set of criteria for identifying a water shortage is established in HAR §13-171-41. This rule specifies that CWRM can issue water shortage declarations for water management areas or portions of water management areas where CWRM has determined and publicly declared that usage has caused, or may cause within the foreseeable future, any of the following:

- Withdrawals that exceed the recharge;
- Declining water levels or heads;
- Deterioration in the quality of water due to increasing chloride content;
- Excessive waste of water which can be prevented; or
- A situation in which any further water development would endanger the ground water aquifer or the existing sources of supply.

5.8.1.1. CWRM Water Shortage Declaration Process

The State Water Code specifies that a water shortage declaration by the Water Commission must undergo rulemaking proceedings. Proposed issuance, amendment, or repeal of a rule is subject to the public hearing process, which specifies certain public notice and participation requirements. Such notice of the proposed rulemaking must be issued at least 20 days prior to the date of the hearing and must be published in "a newspaper of general circulation in the state and in each county affected by the proposed rule."[50] All interested persons and agencies must be provided reasonable opportunity at the hearing to offer evidence with respect to the proposed rule. Additionally, written protest, comments, or recommendations are accepted by CWRM within 15 days from the end of hearing proceedings. CWRM may either issue its decision on the proposed rule at the end of the hearing, or announce a date when the decision will be issued.

In general, the rulemaking process can take a considerable amount of time to complete. CWRM has never moved toward the declaration of a water shortage in any part of the state; however, in light of the above description of the rulemaking process, it is very possible that impacts due to a water shortage situation could considerably intensify before CWRM completed the rulemaking process. It should be noted, though, that the Hawaii Administrative Rules include provisions for

[50] HAR §13-167-42.

emergency rulemaking that can be invoked if CWRM “finds that an imminent peril to public health, safety, or morals requires adoption, amendment, or repeal of a rule upon less than twenty days’ notice of hearing.”[51] In this situation, CWRM may proceed to adopt an emergency rule “with abbreviated notice and hearing” or “without prior notice or hearing.” The emergency rule can remain in effect for a maximum period of 120 days without renewal.

A declaration of water shortage and any measures adopted pursuant thereto may be rescinded by rule by CWRM.

Upon declaration of a water shortage, the State Water Code also provides that CWRM shall contact each permittee within the affected aquifer system(s) by regular mail to provide notice of the water shortage declaration and of any change in the conditions of the permittee's permit, any suspension thereof, or of any other restriction on the use of water for the duration of the water shortage. In addition, CWRM should conduct public outreach and educational programs, as needed, and coordinate efforts with county water agencies and private water system purveyors.

5.8.1.2. Existing CWRM Water Shortage Plans

Lanai Water Shortage Plan

In 1991, the Water Commission approved Lanai Company’s water shortage plan to be used in regulating water use on Lanai if an emergency condition arose due to a water shortage. The requirement to develop a water shortage plan was one of five conditions that the Water Commission imposed to protect Lanai’s water resources without the need for water management area designation.

The water shortage plan for Lanai establishes water use priorities and specific actions to be taken within each water use group in the event of a water shortage. Usage in areas deemed to be the lowest priority would be rationed. In order of importance, the following ranking has been established:

a. Residential
b. Commercial (including resorts)
c. Agricultural
d. Irrigation
    1. Residential
    2. Large scale (such as golf course)

In the event of an emergency condition, the first action would be to reduce irrigation on projects such as golf courses. Water use would be reduced to the point at which any further reduction would result in a destruction of plant life. If further cutbacks are necessary, voluntary reductions in residential irrigation would be sought, followed by mandatory reductions as needed. Actions to accomplish mandatory residential irrigation reductions would include: 1) alternate day watering, 2) monitoring of meters, and 3) pricing mechanisms. Further reductions would impact agricultural operations by limiting usage on dry land crops (most drought-resistant),

[51] HAR §13-167-45.

followed by vegetables and ornamentals. Restrictions on commercial activities would be voluntary at first. If further use reductions are needed, each business would be required to develop an individual plan to reduce consumption, differentiating between critical and non-critical usages. A monitoring program would be initiated to ensure compliance. Residential use, as the highest priority, would be unaffected.

Puuloa Aquifer System Water Shortage Plan

In 1997, the Water Commission adopted a permit classification system for the non-potable Puuloa Aquifer System Area, located in the Ewa Caprock Aquifer Sector Area on Oahu. The permit classification system is based on type of water use. Four classes of use are identified: agriculture, golf course irrigation, landscape irrigation, and dust control. All of the permitted uses are for nonpotable uses, and none have been identified as a public trust purpose. The highest priority of is agriculture, because the State's policy is to promote agriculture, and also because agricultural correlative uses are assured through the 1978 Constitutional Amendment. The second priority in water use is golf course irrigation, because of the economic impacts that may result from inadequate water supply. The lowest priority in uses are landscape irrigation and dust control.

Although it is uncertain whether a water shortage could occur in the Puuloa Aquifer System Area, given CWRM's establishment of sustainable capacities for individual irrigation wells at 1,000 mg/l of chloride, a water shortage plan was formulated because of the former reliance on brackish caprock water to supply the non-potable needs of the growing Ewa and Kapolei urban areas.

In the event of a water shortage in the Puuloa Aquifer System Area, phased cutbacks will be implemented according to the established water use priorities and the individual users' water shortage plans. Water shortage plan cutbacks are based on the users' permitted allocation.

To keep the water shortage plan current, CWRM delegated the authority to the Chairperson to approve or modify individual water shortage plans and to approve the regional water shortage plan.

5.8.1.3. Recommendations for Implementing Water Shortage Provisions

The following recommendations are intended to guide CWRM actions in the development and implementation of future water shortage plan provisions and the development of an integrated water shortage program:

- CWRM should formulate and adopt rules to streamline the public hearing process for the water shortage declarations.
- All individual water shortage plans shall be required from water use permittees. Plans shall be submitted as part of the permit application so that CWRM can perform actions on the water use permits and updates to the regional plan simultaneously. HRS §174C-51(8) and HRS §174C-62(a) & (c) of the State Water Code provide the authority for CWRM to implement this recommendation.

- Permittees whose individual water shortage plan indicates a 0% reduction in water use shall be required to provide supporting justification. CWRM shall conduct site visits as necessary to verify the permittee's inability to reduce water use during shortage conditions. If it is determined that the permittee has the ability to reduce water use during water shortage conditions, CWRM shall modify the permittee's individual water shortage plan.

- CWRM should consider requiring all artesian wells and other free-flowing sources to be outfitted with a flow control device such as a valve. Permittees of sources which are not required to have flow control devices shall be exempt from water shortage plan provisions.

- All permittees who either have sources out of service or not in use (for a period of four years or longer) shall be field verified, and CWRM shall consider revoking the water use permits of such permittees.

- All permittees shall be required to report to CWRM monthly water usage from their water source. CWRM shall review reports and send a notice of request to all permittees who do not report monthly water use.

- CWRM shall review and compare the current monthly water usage data of all permittees with their permitted allocation in order to determine if there are any permittees whose monthly withdrawal is greater than their permitted allocation. For those permittees whose water usage exceeds their allocation, CWRM shall proceed with enforcement of permit restrictions.

- CWRM shall request all large water users (e.g., BWS, United States military) to separate out and make known any of their permitted water uses or users that fall within identified public trust purposes.

- CWRM should pursue the development and adoption of water shortage plans, in coordination with drought, conservation, and resource augmentation plans and programs, which is practical and provides realistic conservation and response measures. CWRM should seek legislation to provide for formulation and implementation of water shortage plan provisions, including funding and the mechanism for timely enforcement of the penalty policy for non-compliance with water shortage restrictions, which will be developed as part of the plan.

5.8.2. Declaration of Water Emergency

The State Water Code provides CWRM with emergency powers that can be exercised statewide during periods of water emergency, including non-water management areas and despite permitted water use allocations. Thus far, CWRM has never issued a water emergency declaration.

CWRM has broad powers to order the "apportioning, rotating, limiting, or prohibiting the use of water resources" in any area if it declares an emergency condition. In spite of having such broad powers, it is unlikely that CWRM would act precipitously or unilaterally in making decisions. CWRM is charged with conducting necessary investigations and consulting with all interested parties before taking action toward a water emergency declaration.

5.8.2.1. Recommendations for Implementing Water Emergency Provisions

CWRM, in consultation with county water agencies and other public/private water system purveyors who operate systems, should formulate and adopt rules specifically for the issuance of a water emergency declaration. Such rules should detail:

- Criteria for determining when a water emergency exists;
- A streamlined process for emergency declaration, notification, public comment processes;
- Extent of the regulatory authority of a water emergency declaration;
- Restrictions that may be imposed by CWRM under a water emergency declaration; and
- Suggested relief measures to be taken by county water agencies and water system operators.

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Section 6

Existing and Future Demands

6. EXISTING AND FUTURE DEMANDS

This section of the WRPP focuses on data available on existing and future water demands statewide, as well as the issues that are associated with quantifying water use and projecting water demand. Available data on existing ground water use and surface water use are presented, followed by a summary of water demand projections through 2030, as prepared by each county. The section concludes with a discussion of county-level water planning and the status of each county's planning efforts.

6.1. CWRM Goals for Assessing Water Demands

The following CWRM goals and objectives are intended to guide the assessment of existing and future water demands:

- Identify potential "hot spots" where water demands approach or exceed available supply.
- Provide State guidance, advice, and oversight in the preparation of the County WUDPs.
- Ensure equitable water allocation for all users in accordance with the State Water Code.
- Utilize the best available information on water resources to make wise decisions about reasonable and beneficial use and protection of the resource.
- Provide the regulatory and internal framework, including the best use of information technology, for efficient ground and surface water management.
- Support community-based management of water resources and develop short- and long-range plans to avoid judicial and quasi-judicial disputes.
- Develop, implement, and update comprehensive short- and long-range plans protecting, conserving, and managing water resources.
- Foster comprehensive resource planning for the development, use, protection, and conservation of water.
- Promote sustainable resource management.
- Encourage and assist with the development and execution of drought planning and mitigation projects.
- Promote coordination and collaboration among agencies and private entities.

6.2. CWRM Water Use Categories

CWRM classifies water use information based on six broad categories of water use (see Figure 6-1). Within each category, sub-categories identify more specific applications.

CWRM water use categories reflect common water uses occurring in the State of Hawaii, and are based on the types of uses identified in the State Water Code and in the County Water System Standards.

Well Operator	Category	Sub-Category
Individual Operator	**Agriculture**	• Aquatic plants and animals • Crop irrigation and processing • Livestock water, pasture irrigation, and processing • Ornamental and nursery plants • Taro • Other agricultural applications
	Domestic Residential Domestic, includes potable and non-potable water needs	• Single- and multi-family households, including non-commercial gardening
	Non-residential Domestic, includes potable (and non-potable) water needs	• Commercial businesses • Office buildings • Hospitals • Churches • Hotels • Schools
	Industrial	• Fire protection • Mining, dust control • Geothermal, thermoelectric cooling, power development, hydroelectric power • Other industrial applications
	Irrigation	• Golf course • Hotel • Landscape and water features • Parks • Schools • Habitat maintenance
Agency Operator	**Military**	• All military use
	Municipal	• State • County • Private

Figure 6-1. Water Use Categories and Sub-Categories

Figures 6-2 to 6-5 show the locations of production wells on each of the major Hawaiian Islands. Each well is coded according to one of the six CWRM water use categories. The primary use of each well was determined based upon available records.

6.3. CWRM Water Use Reporting Requirements

The collection and analysis of water use information is essential to understand the behavior and response of water resources to stresses from water withdrawals. Such information also ensures that demand is managed effectively within the sustainable limits of supply. Water use information can also be used to: evaluate the effectiveness of alternative water management policies, regulations, and conservation activities; assess the impacts of population growth and corresponding increases in water demands; develop trends in water use; and make projections of future demands.

In 1987, the State Water Code was enacted and HRS §174C-26 required water users to file a declaration of water use with CWRM, in compliance with the rules subsequently adopted for that chapter. The Hawaii Administrative Rules, §13-168-5(c), specify that declarations of water use shall at a minimum include information on the following:

> *"[T]he location of the water sources and all usage-related facts, or information within his knowledge or possession…the manner, purposes, and time in which the water source is being used and operated, the rate and volume of water being withdrawn or diverted therefrom, and the method or means of measuring and controlling the water taken or used."*

In 1989, CWRM began the process of registering declarations of water use and stream diversion works in accordance with the State Water Code and administrative rules. By 1990, the declaration of water use program identified approximately 1,550 users statewide who were using water from wells, stream diversions, and water systems. Approximately 250 declarants were identified by CWRM as having "medium-to-large" uses. The remaining 1,300 water use declarations were for small uses, identified by CWRM to include individual domestic supplies, water systems involving small water capacities (pump motors less than five horsepower, or gravity-fed pipes less than two inches in diameter), and agricultural irrigation of fewer than three acres.

The Hawaii Administrative Rules of the State Water Code require owners or operators of wells and stream diversion works to measure their water use and submit regular monthly reports of the use. In particular, HAR §13-168-7(a) and (c) provide that:

> *(a) The owner or operator of any well or stream diversion works from which water is being used shall provide and maintain an approved meter or other appropriate device or means for measuring and reporting total water usage on a monthly (calendar or work schedule) basis. If a well or stream diversion works is one of a battery of interconnected water sources, a centralized measuring device or facility may be approved by the commission.*

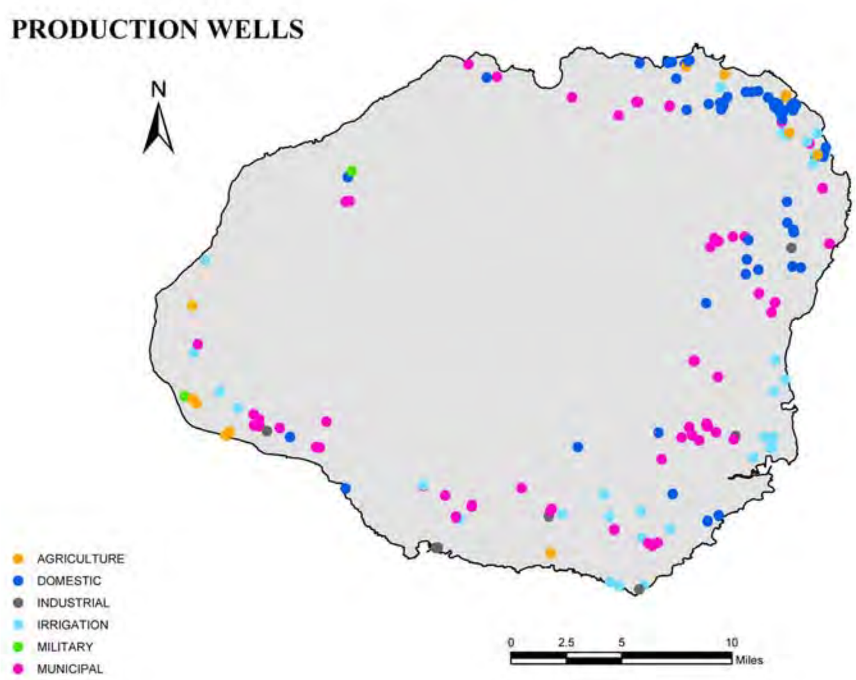

Figure 6-2: Island of Kauai Production Wells

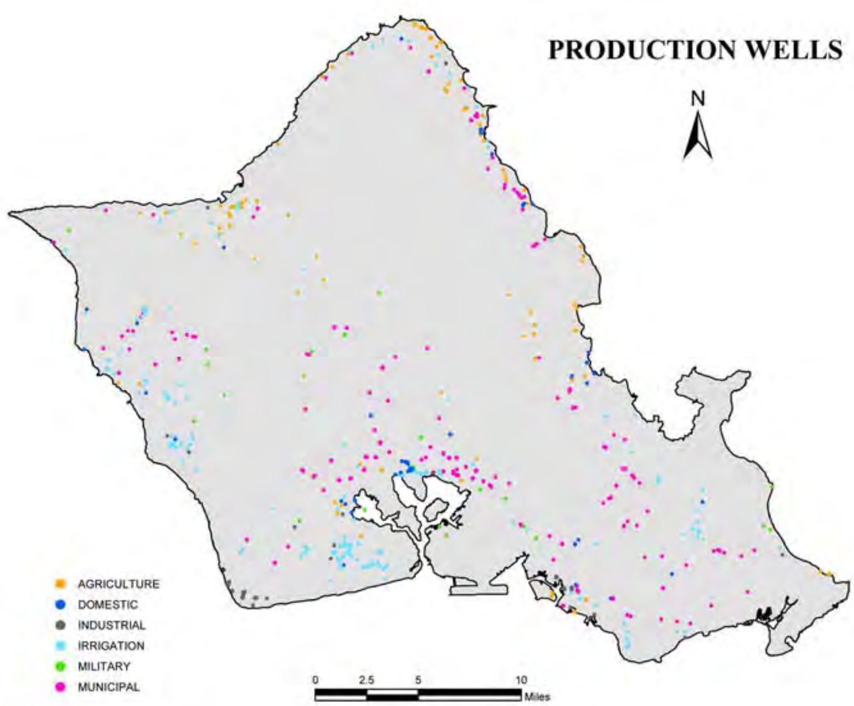

Figure 6-3: Island of Oahu Production Wells

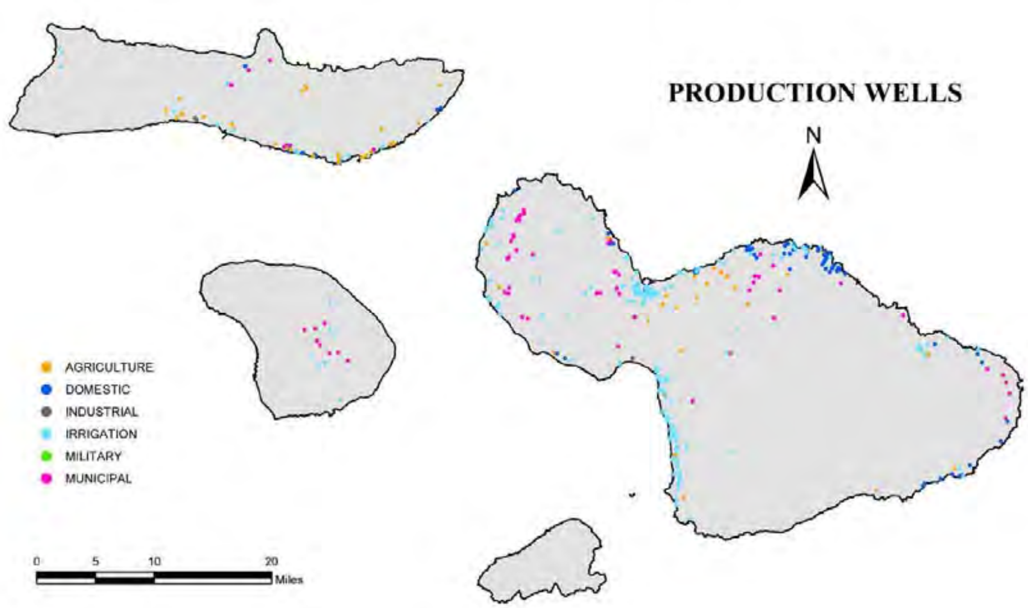

Figure 6-4: County of Maui Production Wells

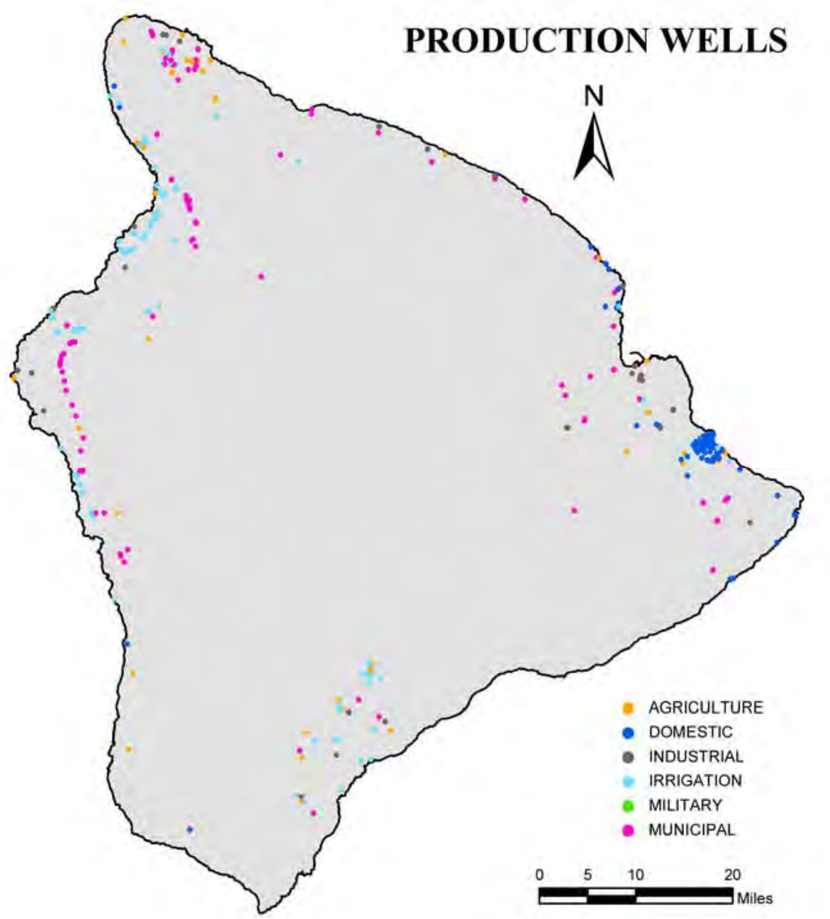

Figure 6-5: Island of Hawaii Production Wells

(c) At the discretion of the commission, requirements for measuring and reporting monthly water usage may be lessened, modified, or exempted for owners or operators of small individual wells or stream diversion works. The lessening, modification, or exemption of such requirements shall be approved, disapproved, or otherwise decided by the commission on a case-by-case basis.

Monthly water use reporting requirements were difficult to implement and enforce. Enforcement of the water-use reporting requirements began in 1988, with the monthly collection of water use reports from major users, including county departments of water supply and large plantations. Water purveyors and large plantations already had monitoring equipment in place to measure and record water usage. However, the monthly reporting requirement specified in HAR §13-168-7(a) proved burdensome on other users, as evidenced by the requests for reporting exemptions received by CWRM.

By August 1992, approximately 140 medium and large users of water from well sources were submitting regular reports of their monthly water use to CWRM. CWRM continued to pursue approximately 20 other users who did not responded to the request for water use reports, and also followed up on requests from some of the medium and large well users to be exempted from reporting, or to be approved for modified reporting requirements.

Meanwhile, CWRM had not attempted to enforce reporting requirements for the 1,300 water use declarants identified as “small users,” or for approximately 100 medium-to-large users who indicated water use from stream sources and third-party distribution systems. At the time, CWRM anticipated that the majority of these 1,400 users would find the reporting requirements to be burdensome. CWRM further anticipated that these users would request exemption from, or modification of the reporting requirements.

Therefore, in August and September 1992, CWRM staff submitted to the Water Commission a request for authority to exempt certain cases of water use from reporting requirements and to modify the reporting requirements in other cases.[1] The Water Commission action during the September 16, 1992 meeting was to unanimously approve the staff request, effectively creating policies regarding measurement and reporting of water use. These CWRM policies are listed below:

Policy: The following cases of water use are exempt from the requirements for measuring and reporting monthly water use, unless CWRM determines a specific need for these data for purposes such as resolving disputes, establishing instream flow standards, or quantifying the amount of water use for a water use permit in a water management area:

- Individual end uses of water on multi-user distribution systems, where the end user does not control or operate the water supply source(s) to the system, providing that the operator of the system reports the total usage from the system and also maintains records which are available to CWRM upon request to describe the specific location, type, and quantity of individual end uses;

[1] Commission on Water Resource Management, 1992, Staff Submittal, Approval to Allow Exemptions from Requirements or Measuring and Reporting Monthly Water Use.

- Water uses from individual water systems where the quantity of use averaged over a one-year period does not exceed 50,000 gallons per month (1,700 gallons per day);

- Passive agricultural consumption, such as when crops are planted in or adjacent to springs and natural wetland areas; and

- Livestock drinking from dug wells or stream channels.

Policy: The following cases of water use are allowed to report monthly water use on an appropriate quarterly, semi-annual, or annual basis, as determined by CWRM staff, unless a specific need is determined for monthly reporting:

- Water uses from individual water systems where the quantity of use averaged over a one-year period does not exceed five million gallons per month;

- Water uses from saltwater or brackish water sources; and

- Water uses from surface water sources.

Policy: The requirement for monthly measurement and reporting of water use from gravity-flow, open-ditch stream diversion works which are not already being measured and which are not in designated surface water management areas is deferred until CWRM adopts guidelines regarding appropriate devices and means for measuring water use which are not unduly burdensome on water users.

The three policies listed above had the effect of focusing water use monitoring and reporting where it was most needed at the time: ground water sources and drinking-water wells. These policies allowed for more effective allocation of staff resources and prioritization of water use monitoring and tracking. Enforcement of the ground water use reporting requirement currently remains focused on large water users (e.g. municipal purveyors), and uses in designated water management areas[2], where competition for water is greatest and aquifers may be pumping close to their sustainable yields. Unfortunately, the focus on ground water sources has resulted in a lack of historical surface water use data. To date, very few users report surface water use to CWRM.

6.3.1. Water Use Reporting for Ground Water Sources

In 2005, CWRM collected ground water pumpage data from 133 well owners/water users statewide. These ground water users report for about 600 individual wells. Table 6-1 summarizes the status of ground water use reporting by island.

[2] CWRM Internal Enforcement Guideline.

Table 6-1 shows that for all islands except Lanai, the major portion of most ground water use reports is submitted by the county water departments. Better reporting is needed for non-municipal wells. The use of Internet technology could provide well owners and water users the option of submitting pumpage reports electronically. This would increase convenience and efficiency, and should also reduce data input errors.

Table 6-1: Status of Ground Water Use Reporting by Island

Island	Total # of Production Wells[1]	# Reporters/ # Wells Reported	Largest Reporter/ # Wells Reported
Kauai	228	6/59	DWS[2]/47
Oahu	948	59/237	BWS[3]/97
Molokai	99	7/17	DWS[2]/4
Lanai	16	1/11	Lanai Co.[4]/11
Maui	450	32/119	DWS[2]/32
Hawaii	400	27/130	DWS[2]/55

1. Production Wells are defined as all wells that are not abandoned, observation, or unused wells.
2. County Department of Water Supply
3. County Board of Water Supply
4. Lanai Company

The coverage for ground water pumpage data varies by island, and pumpage reporting is not complete on any island. Water use data is reported for only 573 of the 2,141 existing production wells in the state, a compliance rate of 29%. However, this is a conservative estimate, because it includes individual water systems that are exempt from the reporting requirement (less than 1,700 gpd). If it is assumed that all productions wells with installed pump capacities of less than 25 gallons per minute (gpm) are individual water systems that are exempt, then the reporting percentage increases substantially, as shown in Table 6-2.

This assumption was tested against the known reporting compliance rate for water use permits issued on Oahu. Comparing current water use permits with the number of water use reports received for water use permitted wells, there is a compliance rate of about 75%.[3] Because the Waianae Aquifer Sector Area is not a designated water management area (water use permits are therefore not required for wells in this aquifer sector area), it is reasonable to expect that the island-wide compliance rate would decrease slightly from 75% to some lower percentage when Waianae wells are included. Table 6-2 shows that island-wide, the compliance rate for Oahu water use reports jumps to 63% when small-capacity wells are excluded from the calculations. Therefore, the number of small-capacity wells appears to be significant.

[3] Water use permits are not required for individual domestic users.

Table 6-2: Percent of Wells Reporting Water Use

Island	# Wells Reported	Total # Production Wells	Percent Reporting	Total # Production Wells >25 gpm	Percent Reporting
Kauai	59	228	**26%**	130	**45%**
Oahu	237	948	**25%**	379	**63%**
Molokai	17	99	**17%**	34	**50%**
Lanai	11	16	**69%**	12	**92%**
Maui	119	450	**26%**	191	**62%**
Hawaii	130	400	**33%**	204	**64%**
TOTAL	**573**	**2141**		**950**	

Due to staff constraints, enforcement of the ground water use reporting requirement is focused on large water users (e.g. municipal purveyors) and uses in designated water management areas, where competition for water is greatest and water development may be close to the aquifer sustainable yields. However, as shown in Table 6-2, small capacity-wells, which include individual water system wells, comprise a significant amount of total production wells (1,191 wells or about 44%). The cumulative impact of withdrawals from small-capacity wells could be substantial. Assuming that each production well with a 25 gpm pump capacity or less is pumping 1,700 gpd, the statewide withdrawal rate is 2.025 mgd. The cumulative impacts of small, domestic wells are particularly important to assess for areas where municipal water is unavailable.

6.3.1.1. Reported Ground Water Use by Island and Category

Table 6-3 summarizes reported total ground water use as of July 31, 2005 for six of the major Hawaiian islands by ground water use category:

Table 6-3: Summary of 2005 Reported Ground Water Use[1]

Island	Use Category (mgd)						Island Total
	Agriculture	Domestic	Industrial	Irrigation	Military	Municipal	
Kauai	0	0	0	0.094	0	11.454[2]	11.548
Oahu[3]	6.099	0.289	4.893	6.740	26.352	149.389	193.762
Molokai	0.108	0	0	0.856	0	1.878	2.842
Lanai	0	0	0	0.717	0	1.073	1.79
Maui[4]	48.134	0.001	1.683	9.611	0	30.172	89.601
Hawaii	0.770	0.174	46.364	7.505	0	37.818	92.631
Use Total	**55.111**	**0.464**	**52.94**	**25.523**	**26.352**	**231.784**	**392.174**

1. For all ground water sources, including saltwater and caprock sources.
2. Kekaha Aquifer System Area pumpage as of 11/04.
3. Ewa Caprock Aquifer Sector Area pumpage as of 12/04.
4. Pumpage data period varies (see footnotes for Table 6-7: Existing Demands by Aquifer System, Island of Maui).

Based on reported water use, Oahu uses the most ground water, withdrawing over 193 mgd primarily for municipal purposes (which includes many categories and subcategories of use). By contrast, ground water use is lowest on Lanai, with less than 2 mgd of ground water being withdrawn. Municipal uses account for about 60% of total reported water use statewide. This is partly a reflection of the high reporting compliance rate of the municipalities, relative to other ground water users. Statewide, total reported ground water use exceeds 392 mgd.

The water use categories were developed in 2005, and each well is assigned a category and sub-category, based on the primary use of the well. The 1990 WRPP did not include a section on existing demands. Therefore, a trend analysis of water use based on CWRM categories is not possible at this time, but could be conducted in subsequent updates of the WRPP using the above figures as a base.

6.3.1.2. Gaps in Ground Water Use Reporting

Better reporting is needed for all islands, except Lanai. Ground water pumpage reporting on Kauai and Molokai are not adequate to supply a reasonable representation of water usage. Oahu, Maui, and Hawaii have adequate reporting but all three islands have significant gaps in data.

6.3.1.3. Recommendations for Ground Water Use Reporting

The following actions are recommended for improving ground water use reporting:

- CWRM should continue development of the ground water use database to implement an automatic notification system that will flag delinquent reports, and send notices to well owners/water users that have neglected to send in pumpage reports.

- CWRM should utilize Internet technology to provide well owners and water users the option of submitting pumpage reports online. This will be far more efficient for ground water users and should also reduce data input errors.

- CWRM should obtain additional funding and staff resources for the water use reporting program and amend its current policy to instead require currently-exempt individual water systems using less that 1,700 gpd to report water use.

- CWRM should consider resurrecting the monthly newsletter (see Section 5.2) to provide up-to-date information on deep monitor well, chloride, water-level, and/or water use information currently collected by CWRM.

6.3.2. Water Use Reporting for Surface Water Sources

As stated previously, CWRM policy effectively exempts most surface water users from water use reporting requirements, until CWRM adopts guidelines regarding appropriate devices and means for measuring water use. To date, very few users report surface water use to CWRM.

6.3.2.1. Reported Surface Water Use by Island and Category

Table 6-4 summarizes reported surface water use as of July 31, 2005, for six of the major Hawaiian islands, by water use category:

Table 6-4: Summary of Reported Surface Water Use

Island	Total (mgd)[1]
Kauai	0.000
Oahu	0.000
Molokai[2]	0.660
Lanai	0.000
Maui[3]	70.282
Hawaii	0.000

[1] Total of computed 12-month moving average for August 2004 to July 2005.
[2] Includes Molokai Ranch.
3 Includes Wailuku Water Company and Launiupoko Water Company.

6.3.2.2. Gaps in Surface Water Use Reporting

Surface water use data: There is a deficit of surface water use data statewide. Water use reporting is needed for stream diversions, particularly those providing water to large irrigation systems. For specific regions, water use studies have been conducted either by the USGS or other government agencies. However, water use data has not been collected by CWRM on a broad scale, largely due to policies that emphasize reporting requirements on ground water uses. With the exception of a few users that were required to report as part of a dispute resolution, surface water use reporting is very limited.

Currently, CWRM does not have a program for surface water use reporting or a system to store and manage surface water use data, similar to that of the Ground Water Regulation Branch's database for ground water use data. CWRM is developing a Surface Water Information Management (SWIM) System database to store and manage the wide range of data related to the regulation and management of surface water in general. One key component of the SWIM System will involve the collection and management of water use data. In conjunction with the establishment of a surface water use reporting program, CWRM policies should be amended to provide for, at a minimum, a reliable, annual sampling of data on public and private surface water use statewide.

Guidelines for measuring water use: The policy regarding the deferral of reporting requirements for stream diversions without monitoring devices is important, in that it directs CWRM to create and adopt guidelines for appropriate measuring devices and methods for measuring diverted flow. CWRM should pursue the development of such guidelines for diverted-flow measurement, including methods and approved devices, to facilitate the implementation of a surface water use reporting program.

Field Verification of Declared Stream Diversions: When CWRM conducted the Registration/Declaration process in 1990, many of the Registration of Stream Diversion Works and Declaration of Water Use applications were not field verified. Much of the information has also not been maintained (e.g., change of recorded ownership). In addition to CWRM's efforts to verify surface water diversions (see section 4.3.3.1), a regular field-investigation schedule should be established to enable CWRM staff to inspect surface water diversions and monitor water use.

Plantation-Ditch Systems: Formerly, surface water use was tied primarily to sugar cane and other plantation crops. Many plantation-ditch operators monitored streams and ditch systems for flow volumes and kept detailed records of rainfall conditions and diverted flows. The remaining plantation-ditch systems are typically underutilized, as former sugar cane lands are no longer in crop production or have been converted to other uses. Different portions of a ditch system may be under the ownership of several different entities, and maintenance and monitoring efforts may vary considerably between owners. Also, flow monitoring gages for these systems may no longer be in existence or may no longer be useful for monitoring the total diverted flow.

6.3.2.3. Recommendations for Surface Water Use Reporting

The following actions are recommended for improving surface water use reporting:

- Due to the wide variety of existing surface water diversion structures, CWRM should develop protocols and make equipment recommendations for the standard measurement of surface water use.

- CWRM should complete the development of the SWIM System and begin implementing a monthly surface water use reporting program. The program should first focus on large irrigation systems and should include broad notification of water users, development of a reporting form, and the distribution of the form and information reporting via the Internet.

- Upon completion of statewide field verification of surface water diversions, CWRM should utilize the information to identify key surface water users to focus implementation of surface water use reporting requirements.

- CWRM should revise surface water use reporting policies, in conjunction with the development of a surface water use reporting program.

6.4. Assessing Existing Water Demands

Existing water demands are recorded and archived to varying degrees by several entities statewide. However, water demand data provided by different sources may not represent the same water users or water demand categories, as each agency or entity produces demand information in the form most useful for their respective purpose.

CWRM examines water demands in terms of hydrologic units. CWRM demand data is regional in scale and dependent upon the accuracy and completeness of water use reports provided to the agency by users.

In contrast, municipal water agencies can monitor water demand by looking at customer service areas and billing categories. This data provides an excellent picture of water use by customer distribution, but typically does not provide information on water use outside of the system service area.

The USGS also compiles water demand from public and private water systems, including military bases. Water demand data as assessed by CWRM, county water agencies, and the USGS are provided in the following sections.

6.4.1. CWRM Assessment of Existing Water Demands

CWRM relies on reported water use data to quantify ground water and surface water demands. While CWRM receives considerable information on statewide ground water demand, surface water demand data is lacking.

6.4.1.1. Summary of Existing Ground Water Demands

CWRM is able to track and quantify ground water demand through its water use reporting program. To protect ground water resources, CWRM must continually monitor water use, to ensure that the total withdrawal from an aquifer does not exceed its sustainable yield. Pumping an aquifer above its sustainable yield can result in seawater intrusion and negative impacts to the resource. CWRM uses a twelve-month moving average to assess water use (see Section 5.2).

As discussed in Section 5, when actual ground water withdrawals or authorized planned uses may cause the maximum rate of withdrawal to exceed 90% of the aquifer's sustainable yield, CWRM may designate the area as a water management area and regulate water use through the issuance of water use permits. Once an area has been designated, CWRM continues to monitor water use for compliance with allocation limits.

Tables 6-5 to 6-10 summarize existing demands in relation to aquifer system area sustainable yields (as of July 2005) for each of the six major Hawaiian Islands. Water use is based on reported pumpage as of July 31, 2005, unless otherwise noted. Likewise, aquifer sustainable yields are those that were established as of July 31, 2005. Because caprock and saltwater withdrawals do not count against aquifer sustainable yields, water withdrawn from caprock and saltwater sources are excluded from the tables. The only exception is the inclusion of the Ewa Caprock Aquifer Sector Area on Oahu, consisting of the Malakole, Kapolei, and Puuloa Aquifer System Areas, which overlies portions of the Pearl Harbor Sector Area. The Ewa Caprock Aquifer Sector Area has been designated as a separate ground water management area.[4] For the islands of Oahu and Molokai, where most or all of the aquifer system areas have been designated as ground water management areas, a comparison of total allocations to sustainable yields established as of July 31, 2005 is also presented.

Table 6-5 shows that total reported pumpage on Kauai is within the sustainable yield for all aquifer system areas. Islandwide, reported water use is only 3% of the island's total sustainable yield. Unlike Oahu, Kauai does not have an extensive municipal distribution system. Residents in many areas rely on individual, domestic wells. For the most part, water used by individual, domestic users is not reflected in Table 6-5, due to exemptions from water use reporting, and lack of compliance and enforcement of reporting requirements for small-capacity, domestic wells.

Table 6-6 shows that total reported pumpage on Oahu is within the sustainable yield for all aquifer system areas. The table also shows that the total existing ground water withdrawals are over 100 mgd less than total water use permit allocations. A portion of the unused allocation is earmarked to provide for future demands. There is also a significant volume of water allocated to agricultural water use permits that remains unused due to the closure of plantation agriculture, particularly in the North Sector Area. CWRM may revoke permitted allocations due to non-use.

Existing ground water demand on Maui is summarized in Table 6-7. The table indicates that the Kahului Aquifer System Area within the Central Aquifer Sector Area is being overpumped by over 2,500%. Pumpage in the Paia Aquifer System Area also appears to exceed permitted allocations. However, it is noted that the substantial quantity of return irrigation recharge in the Central Aquifer Sector Area has not been factored into the established sustainable yields of these two aquifers. Further discussion on sustainable yields is contained in Section 3 of the WRPP.

[4] The Ewa Caprock Aquifer Sector has been declared a non-potable aquifer by CWRM. This brackish resource support mainly irrigation and industrial uses. CWRM has adopted a chloride limit of 1,000 mg/l for individual irrigation wells in lieu of an aggregate sustainable yield figure. No chloride limit has been set for industrial wells.

Another noteworthy statistic on Maui is the pumpage of the Iao Aquifer System Area at 95% of its sustainable yield. CWRM designated the Iao Aquifer System Area as a ground water management area, effective July 21, 2003. Water use permits are now required for all non-individual domestic ground water uses.

Water use permit allocations on Molokai are only about 11% of the island's total sustainable yield. Existing withdrawals are even less, at 3% of total sustainable yield (see Table 6-8). The Kualapuu Aquifer System Area is the most heavily utilized, with reported water use at about 41% of the aquifer's sustainable yield.

Lanai is mostly privately owned and is the least populated island. Ground water pumpage is reported for two of its nine aquifer system areas. Existing withdrawals, shown in Table 6-9, total about 26% of total sustainable yield for the island.

The island of Hawaii has the greatest amount of ground water resources, with over 2,431 mgd estimated to be available for development. Pumpage from all aquifers systems is less than 40%, as shown in Table 6-10. Islandwide, only 4% of ground water is reportedly being used. Like Kauai, the municipal water distribution system does not cover large parts of the island. There are many private domestic wells that serve residential needs. For the most part, these uses are not reflected in the table.

Table 6-5: Existing Demands by Aquifer System Area, Island of Kauai, July 2005

Aquifer Sector Aquifer System	Sustainable Yield (SY) (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)	Existing Water Use as a Percent of SY
Hanalei	**95**	**1.300**	**93.700**	**1%**
Napali	20	0.000	20.000	0%
Wainiha	24	0.300	23.700	1%
Hanalei	35	0.000	35.000	0%
Kalihiwai	16	1.000	15.000	7%
Lihue	**183**	**7.000**	**176.000**	**4%**
Kilauea	17	0.400	16.600	2%
Anahola	36	1.400	34.600	4%
Wailua	60	0.900	59.100	2%
Hanamaulu	40	2.000	38.000	5%
Koloa	30	2.300	27.700	8%
Waimea	**110**	**3.154**	**106.846**	**3%**
Hanapepe	26	0.000	26.000	0%
Makaweli	30	1.330	28.670	5%
Waimea	42	0.000	42.000	0%
Kekaha	12	1.824[1]	10.176	18%
KAUAI TOTAL	**388**	**11.454**	**376.546**	**3%**

1. Pumpage as of November 2004.

Table 6-6: Existing Demands by Aquifer System Area, Island of Oahu, July 2005

Aquifer Sector / Aquifer System	Sustainable Yield (SY) (mgd)	Existing Permit Allocations (mgd)	Unallocated SY (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)
Honolulu	**53**	**53.226**	**-0.224**	**44.116**	**8.884**
Waialae-East	2	0.79	1.21	0.193	1.807
Waialae-West	4	2.797	1.203	0.385	3.615
Palolo	5	5.6461	-0.646	4.431	0.569
Nuuanu	15	15.2711	-0.270	13.351	1.649
Kalihi	9	8.7611	0.239	8.416	0.584
Moanalua	18	19.9611	-1.960	17.340	0.660
Pearl Harbor	**165**	**146.3**	**18.7**	**103.457**	**61.543**
Waimalu	45	46.951	-1.951[1]	39.011	5.989
Waipahu-Waiawa	104	83.892	20.108	53.354	50.646
Ewa-Kunia	16	15.457	0.543	11.092	4.908
Makaiwa[2]		0	0	0.000	0.000
Central	**23**	**20.386**	**2.614**	**9.245**	**13.755**
Wahiawa	23	20.386	2.614	9.245	13.755
Waianae	**15**	**0**	**15**	**3.57**	**11.430**
Nanakuli[3]	1	0	1	0.000	1.000
Lualualei[3]	3	0	3	0.112	2.888
Waianae[3]	3	0	3	2.515	0.485
Makaha[3]	4	0	4	0.943	3.057
Keaau[3]	4	0	4	0.000	4.000
North	**91**	**40.161**	**50.839**	**4.189**	**86.811**
Mokuleia	12	8.301	3.699	0.401	11.599
Waialua	40	30.311	9.689	3.106	36.894
Kawailoa	39	1.549	37.451	0.682	38.318
Total Windward	**99**	**34.577**	**64.423**	**23.371**	**75.629**
Koolauloa	35	21.508	13.492	9.738	25.262
Kahana	13	1.101	11.899	0.085	12.915
Koolaupoko	43	10.312	32.688	12.828	30.172
Waimanalo	8	1.656	6.344	0.72	7.280
Total Ewa Caprock		**22.778**		**8.688**	
Malakole[4]	1,000 mg/l	5.928		5.8005	
Kapolei[4]	1,000 mg/l	2.033		0.471	
Puuloa[4]	1,000 mg/l	14.817		2.417	
OAHU TOTAL[6]	**446**	**294.648**	**151.352**	**187.948**	**258.052**

1. For the Palolo, Nuuanu, Moanalua, and Waimalu Aquifer System Areas, total water use permit allocations exceed the aquifers' sustainable yield because declared existing uses at the time of designation exceeded the subsequent establishment of sustainable yields for these aquifers. The Commission is monitoring the conditions in these over-allocated aquifers to determine whether the sustainable yields can be adjusted based on operational experience or water use permit allocations may be reduced due to nonuse as land use changes or new sources come online.
2. The Commission has not established a sustainable yield for the Makaiwa Aquifer System Area in the Pearl Harbor Sector Area.
3. None of the aquifer systems in the Waianae Sector Area have been designated as ground water management areas.

4. The aquifer system areas within the Ewa Caprock Sector Area are managed by a chloride limit of 1,000 mg/l for individual irrigation wells rather than an aggregate sustainable yield number. The Commission has not yet established a chloride limit for individual industrial wells.
5. Pumpage as of 12/04.
6. Excludes Ewa Caprock Aquifer Sector Area.

Table 6-7. Existing Demands by Aquifer System, Island of Maui, July 2005

Aquifer Sector / Aquifer System	Sustainable Yield (SY) (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)	Existing Water Use as a Percent of SY
Lahaina	**40**	**5.900**	**34.100**	**15%**
Honokohau	10	0.000	10.000	0%
Honolua	8	2.125	5.875	27%
Honokowai	8	3.053	4.947	38%
Launiupoko	8	0.689	7.311	9%
Olowalu	3	0.033	2.967	1%
Ukumehame	3	0.000	3.000	0%
Wailuku	**38**	**23.222**	**14.778**	**61%**
Waikapu	2	0.000	2.000	0%
Iao	20	18.940	1.060	95%
Waihee	8	4.282	3.718	54%
Kahakuloa	8	0.000	8.000	0%
Central	**27**	**45.334**[3]	**-18.334**	**168%**[3]
Kahului	1	25.978[1,3]	-24.978	2,598%[3]
Paia	8	17.208[1,3]	-9.208	215%[3]
Makawao	7	0.289[2]	6.711	4%
Kamaole	11	1.859	9.141	17%
Koolau	**202**	**2.136**	**199.864**	**1%**
Haiku	31	1.962	29.038	6%
Honopou	29	0.012[1]	28.988	0%
Waikamoi	46	0.000	46.000	0%
Keanae	96	0.162	95.838	0%
Hana	**133**	**0.309**	**132.691**	**0%**
Kuhiwa	16	0.003[1]	15.997	0%
Kawaipapa	48	0.306	47.694	1%
Waihoi	20	0.000	20.000	0%
Kipahulu	49	0.000	49.000	0%
Kahikinui	**36**	**0.000**	**36.000**	**0%**
Kaupo	18	0.000	18.000	0%
Nakula	7	0.000	7.000	0%
Lualailua	11	0.000	11.000	0%
MAUI TOTAL	**476**	**76.901**	**399.099**	**16%**

1. Pumpage as of 12/04.
2. Pumpage as of 6/05.
3. Sustainable yield does not include return irrigation recharge.

Table 6-8: Existing Demands by Aquifer System Area, Island of Molokai, July 2005

Aquifer Sector / Aquifer System	Sustainable Yield (SY) (mgd)	Existing Permit Allocations (mgd)	Unallocated SY (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)
West	**4**	**0**	**4.000**	**0.000**	**4.000**
Kaluakoi	2	0	2.000	0.000	2.000
Punakou	2	0	2.000	0.000	2.000
Central	**9**	**5.505**	**3.495**	**2.070**	**6.930**
Hoolehua	2	0	2.000	0.000	2.000
Kualapuu	5	4.842	0.158	2.069	2.931
Manawainui	2	0.663	1.337	0.001	1.999
Northeast	**44**	**0.947**	**43.053**	**0.000**	**44.000**
Kalaupapa	2	0	2.000	0.000	2.000
Kahanui	3	0.094	2.906	0.000	3.000
Waikolu	5	0.853	4.147	0.000	5.000
Haupu	2	0	2.000	0.000	2.000
Pelekunu	9	0	9.000	0.000	9.000
Wailau	15	0	15.000	0.000	15.000
Halawa	8	0	8.000	0.000	8.000
Southeast	**24**	**2.615**	**21.385**	**0.718**	**23.282**
Waialua	8	0.437	7.563	0.000	8.000
Ualapue	8	0.243	7.757	0.232	7.768
Kawela	5	1.068	3.932	0.432	4.568
Kamiloloa	3	0.867	2.133	0.054	2.946
MOLOKAI TOTAL	**81**	**9.067**	**71.933**	**2.788**	**78.212**

Table 6-9: Existing Demands by Aquifer System Area, Island of Lanai, July 2005

Aquifer Sector / Aquifer System	Sustainable Yield (SY) (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)	Existing Water Use as a Percent of SY
Mahana	**0**	**0.000**	**0.000**	**0%**
Paomai	0	0.000	0.000	0%
Maunalei	0	0.000	0.000	0%
Hauola	0	0.000	0.000	0%
Kamao	**0**	**0.000**	**0.000**	**0%**
Manele	0	0.000	0.000	0%
Kealia	0	0.000	0.000	0%
Kaa	**0**	**0.000**	**0.000**	**0%**
Kaumalapau	0	0.000	0.000	0%
Honopu	0	0.000	0.000	0%
Central	**6**	**1.548**	**4.452**	**26%**
Windward	3	0.468	2.532	16%
Leeward	3	1.080	1.920	36%
LANAI TOTAL	**6**	**1.548**	**4.452**	**26%**

Table 6-10: Existing Demands by Aquifer System Area, Island of Hawaii, July 2005

Aquifer Sector / Aquifer System	Sustainable Yield (SY) (mgd)	Existing Water Use (mgd) 12 MAV July 2005	SY minus pumpage (mgd)	Existing Water Use as a Percent of SY
Kohala	**154**	**1.389**	**152.611**	**1%**
Mahukona	17	0.660	16.340	4%
Hawi	27	0.582	26.418	2%
Waimanu	110	0.147	109.853	0%
E. Mauna Kea	**388**	**1.977**	**386.023**	**1%**
Honokaa	31	1.348	29.652	4%
Paauilo	60	0.131	59.869	0%
Hakalau	150	0.126	149.874	0%
Onomea	147	0.372	146.628	0%
N.E. Mauna Loa	**740**	**56.312**	**683.688**	**8%**
Hilo	347	42.228		12%
Keaau	393	14.084	378.916	4%
Kilauea	**618**	**1.502**	**616.498**	**0%**
Pahoa	435	1.455	433.545	0%
Kalapana	157	0.047	156.953	0%
Hilina	9	0.000	9.000	0%
Keaiwa	17	0.000	17.000	0%
S.E. Mauna Loa	**291**	**0.059**	**290.941**	**0%**
Olaa	124	0.000	124.000	0%
Kapapala	19	0.000		0%
Naalehu	117	0.059	116.941	0%
Ka Lae	31	0.000	31.000	0%
S.W. Mauna Loa	**130**	**2.144**	**127.856**	**2%**
Manuka	42	0.079	41.921	0%
Kaapuna	50	0.008	49.992	0%
Kealakekua	38	2.057	35.943	5%
Hualalai	**56**	**14.426**	**41.574**	**26%**
Kiholo	18	3.703	14.297	21%
Keauhou	38	10.723	27.277	28%
N.W. Mauna Loa	**30**	**4.900**	**25.100**	**16%**
Anaehoomalu	30	4.900	25.100	16%
W. Mauna Kea	**24**	**9.173**	**14.827**	**38%**
Waimea	24	9.173	14.827	38%
HAWAII TOTAL	**2431**	**91.882**	**1933.845**	**4%**

6.4.1.2. Summary of Existing Surface Water Demands

Surface water demands are difficult to quantify for numerous reasons. Presently, there is a deficiency in surface water use data. In addition to policy issues regarding surface water use reporting (see Section 6.3), quantification of surface water demand is hindered by the lack of information on stream diversions (field verification information), changes in water use by large-scale agricultural systems, and the difficulties associated with measuring diverted flow. The types of diversion structures range widely from PVC pipes, or large concrete structures set within the stream bed, to hand-built rock walls for taro *loi*. As a result, diversion amounts may also vary widely with rainfall freshets, as well as the relative ease with which some diversions can be installed, removed, or altered. Another difficulty in measuring surface water use is the utilization, cost and location of accurate and appropriate water measurement devices. For many large irrigation systems, the practicality in measuring every stream diversion is nearly impossible, therefore only a handful of gaging stations may exist at key locations along the length of the system to provide cumulative flow amounts. For smaller water users, the cost, operation and maintenance of installing a gaging device is a prohibitive factor. CWRM data on surface water demand is limited to information on reported water use, as shown in Table 6-4.

CWRM has limited information to contribute to the quantification of historical surface water use and demand. Section 6.3 discusses CWRM's 1989 efforts to register declarations of water use and stream diversion works in accordance with the State Water Code and administrative rules. Through the registration process, CWRM collected information on stream diversions and surface water use at that time. Appendix C is a summary of the 1989 declared surface water use for each Surface Water Hydrologic Unit. Field verifications of declared stream diversions and surface water use were conducted for diversions on Molokai and in parts of Oahu. Most of the quantities listed in Appendix C are, therefore, unverified, and may represent the declarant's desire to reserve or claim water for intended future use. Many water use declarations indicate volumes of water that do not correlate with the declared use, while other declarations claim use of all available stream flow. Furthermore, some declared water use volumes are omitted from Appendix C because the declarant provided cumulative use amounts across several Surface Water Hydrologic Units; these volumes could not be assigned to specific hydrologic units. Thus, much of the information in Appendix C is based on unverified and dated user declarations and the information is included in this document for reference purposes only.

6.4.2. County Assessments of Existing Water Demands

For the purposes of this report, county water departments provided municipal water use data to characterize existing water demands in terms of the agency's customer billing categories. This data represents existing water use only from county water systems, and is intended to provide information on the relative distribution of demands across various use categories. County assessments of existing water demand data are presented in the tables below.

Table 6-11: County of Kauai
2005 and 2006 Municipal Water Use (mgd)

Water Use Category Department of Water Premise Type	**2005**	**2006**
Agriculture		
Agriculture	0.148	0.137
Domestic – Residential		
Single-Family Dwelling	2.433	2.477
Multi Family Dwelling	0.671	0.684
Housing – State	0.002	0.002
Domestic – Non-Residential		
Commercial	0.354	0.344
Hotel	0.676	0.643
Religious	0.030	0.034
Schools – State	0.011	0.009
Industrial		
Industrial	0.020	0.022
Irrigation		
Golf Course – Private	0.000[1]	0.000[2]
Irrigation – Private	0.050	0.054
Parks – County	0.003	0.004
Military		
United States Military Facility	0.021	0.014
Municipal		
County of Kauai	0.118	0.137
State Facility	0.219	0.199
United States Non-Military Facility	0.002	0.002
Total	**4.758**	**4.762**

[1] Private golf course water use for 2005 was 13,360 gallons.
[2] Private golf course water use for 2006 was 13,550 gallons.
Note: Consumption rounded to the nearest thousandth of a unit.
Source: Staff communication, Kauai Department of Water, June 26, 2007.

Table 6-12: City and County of Honolulu
2005 and 2006 Municipal Water Use (mgd)

Water Use Category Honolulu BWS Metered User Type	2005	2006
Agriculture		
BWS Agriculture	3.08	3.13
Domestic – Residential[1]		
BWS Residential		
Mixed Residential	0.46	0.48
Multi-Family High Rise	1.41	1.40
Multi-Family Low Rise	2.63	2.58
Single-Family Dwelling	54.41	50.34
Multi-Family Dwelling	24.46	23.01
Domestic – Non-Residential[1]		
BWS Commercial		
Commercial	20.69	19.79
Hotel	5.90	5.19
Mixed Use	2.16	2.06
Private Schools	0.46	0.44
Religious	0.51	0.45
BWS Government		
City	1.20	1.04
United States Military	2.76	2.52
United States Non-Military	0.14	0.13
State	3.51	3.25
State Schools	3.36	3.48
Industrial		
BWS Industrial	2.85	2.62
Irrigation		
BWS Commercial		
City Golf Courses	0.00	0.00
Irrigation – Private	1.72	1.60
Private Golf Courses	0.86	0.84
BWS Government		
City Parks	3.22	3.01
Irrigation – City	0.08	0.06
Irrigation – State	0.24	0.29
State Parks	0.02	0.02
Other		
Unknown	0.02	0.02
Total	**136.11**	**127.74**

[1] Includes potable and non-potable water needs.

Source: Staff communication, Honolulu BWS, February 9, 2007.

Table 6-13: County of Maui
2006 Municipal Water Use (mgd)

Billing Class	2006
Single Family	15.780
Multi-Family	5.966
Commercial	3.157
Hotel	2.994
Industrial	1.415
Government	2.777
Agriculture	3.386
Religious Inst.	0.234
Total	**35.707**

Notes: Projections include Molokai Island DWS system demands, but do not include the private system demands for Lanai Island.

Source: Staff communication, Maui Department of Water Supply, August 21, 2008.

Table 6-14: County of Hawaii
2005 Municipal Water Use (mgd)

Water Use Category DWS Category	2005
Agriculture	
AG Agriculture Rate	2.084
AO Agriculture-Other	0.043
Domestic – Residential	
RM Residential – Multi	2.148
RO Residential – Other	0.032
RS Residential – Single	12.109
Domestic – Non-Residential	
SK Schools – K/12	0.026
SO Schools – Other	0.033
SU Schools – Univ	0.000
CH Comm – Hotel	2.241
CO Comm – Other	4.227
CR Comm – Restaurants	0.000
CS Comm – Stores	0.000
CV Comm – Service Station	0.001
CY Comm – Laundry	0.000
F TD Flat Rate	0.000
MH Medical – Hospital	0.003
MO Medical – Other	0.059
NC Nonprofit – Church	0.287
NO Nonprofit – Other	0.006
Industrial	
DC DC Meters	0.012
IG Industrial – General	0.000
IL Industrial – Limited	0.000
IO Industrial – Other	0.000
SP Standpipe	0.002
Irrigation	
IC Irrigation – Comm	0.031
IR Irrigation – Res	0.203
Military	0.00
Municipal	
GC Gov't – County	0.402
GF Gov't – Federal	0.031
GS Gov't – State	1.275
Total	**25.257**

Note: Consumption rounded to the nearest thousandth of a unit.

Source: Staff communication, Fukunaga & Associates, Inc., February 10, 2006.

Hawaii County estimates the 2005 domestic water use from privately-owned public water systems and catchment water systems at 8.40 mgd and 4.97 mgd, respectively. These estimates provide additional perspective as to total domestic water use throughout Hawaii County.

6.4.3. USGS Assessment of Existing Water Demands

Freshwater use data is compiled by the USGS and is updated approximately every five years. The data includes water use from public and private water systems serving cities and military bases. Water used for domestic, commercial, recreational, industrial, and thermoelectric purposes is included, as well as water used in water and wastewater treatment, pools, parks, and other facilities.

Table 6-15: 2000 Freshwater Demand by Type and by County

Use	State Total	Hawaii	Honolulu	Kalawao	Kauai	Maui
	(Million gallons per day)					
Ground Water	428.00	44.55	208.84	0.09	25.83	148.69
Public Supply	242.83	31.16	164.81	0.09	14.94	31.83
Industrial[1]	14.50	0.04	12.93	-	0.27	1.26
Thermoelectric	-	-	-	-	-	-
Irrigation	170.67	13.35	31.10	-	10.62	115.60
Surface Water	200.43	8.86	8.07	-	19.37	164.13
Public Supply[1]	7.60	2.50	-	-	-	5.10
Industrial	-	-	-	-	-	-
Thermoelectric	-	-	-	-	-	-
Irrigation	192.83	6.36	8.07	-	19.37	159.03
Total	**628.43**	**53.41**	**216.91**	**0.09**	**45.20**	**312.82**

1. Includes water withdrawn by public and private water systems for use by cities and military bases. Water withdrawn by these facilities may be delivered to users for domestic, commercial, industrial, and thermoelectric purposes, or may be used for water and wastewater treatment, pools, parks and city buildings.

Source: *2005 State of Hawaii Data Book*, Table 5.22, Department of Business, Economic Development, and Tourism (http://www.hawaii.gov/dbedt/).

6.5. Estimating Future Water Demands

Projections of future water use over a long-term planning period are subject to many influences on water demand, including economic conditions, population growth, land use policies, and conservation practices. There are several methods that can be used to derive demand projections and increase the accuracy of estimates.

Land use-based water demand projections can be used to plan for future water needs. These projections are intended to evaluate the water demands of an area, relative to a certain density level based on zoning and/or land use type. Land use-based demand projections indicate the water needs anticipated with current land use policies. This method, however, can produce overly conservative water demand projections in the full build-out scenario at maximum allowable density. Projections based on more moderate development densities may be more useful.

Future water demand can also be estimated based on population growth projections. These projections assume a per-capita water demand, to provide estimates over planning horizon increments of 5, 10, 15, or 20 years. Multiple growth scenarios are usually evaluated for each time increment to provide a range of projected demand, with the most conservative projection derived from the “high population growth” scenario.

Regional population growth rates for various land use categories can also be applied to predict future residential water demand. Additionally, recent consumption rates by region and land use type can help to improve predictions of future water demand.

Demand projections, whether derived from land use or population, can be refined using information contained in other State and county plans, information on federal and private water systems, and historical water use data. The SWPP identifies future water demands for State of Hawaii projects. The AWUDP identifies both State and private agricultural water demands.

6.5.1. Projected Future County Water Demands

According to county water agency projections, by the year 2030, water demands will approach 430 mgd statewide. This translates to an approximate 34% increase in demand from year 2010 to year 2030.

Tables 6-16 through 6-20 describe the water demands projected by the county water agencies, in terms of water demand categories or billing classes (as designated by the water departments). The tables are useful in comparing demands associated with potable and non-potable water uses. Notwithstanding the discussion of land use and population-based projections in Section 6.4, it is noted that the demand forecasts in the tables below were prepared independently by each county; therefore, assumptions and forecast methods vary between counties. Figures 6-7 to 6-10 are provided to illustrate the data in the tables.

Lanai water demand information, beyond that which is shown in Table 6-17, was not available from the County of Maui Department of Water Supply at the time of this writing.

Table 6-16: Projected Water Demand for All Counties, 2010 to 2030 (mgd)

County	2010	2015	2020	2025	2030
Kauai[1]	16.160	16.997*	17.794	18.744*	19.695*
C&C of Honolulu[2]	164.280	176.840	185.210	195.680	206.150
Maui[3] (DWS system)	36.468	39.936	43.310	46.942	50.692
Maui	35.610	39.045	42.391	45.990	49.703
Molokai	0.858	0.891	0.919	0.952	0.989
Lanai[4] (private system)	1.669	1.857	2.046	2.235	2.423
Hawaii[5]	97.794	108.890	121.570	135.981	148.709**
Total	**316.371**	**344.520**	**369.930**	**399.582**	**427.669**

* Data interpolated from county demand projections through 2050 published in Tables 4.5 and 4.6 of the County of Kauai's *Water Plan 2020 (*Kauai Department of Water, March 21, 2001).

**Data interpolated from county demand projections from 2005 to 2025 provided by Fukunaga & Associates, Inc., on behalf of the County of Hawaii Department of Water Supply.

1 Source: Kauai Department of Water, *Water Plan 2020,* March 21, 2001.

2 Source: Staff communication, Honolulu BWS, March 20, 2007.

3 Source: Maui Department of Water Supply, Figure 28: Base Case Econometric DWS Water Demand Projections by DWS District by Use Classification, *Maui County Water Use and Development Plan, Water Use and Demand, Department of Water Supply Systems, Draft,* May 1, 2007.

4 Source: Staff communication, Maui Department of Water Supply, August 8, 2007.

5 Source: Staff communication, Fukunaga & Associates, Inc., June 22, 2007.

Table 6-17: Kauai County Projected Water Demand, 2010 to 2030 (mgd)

Use Category	2010	2015*	2020	2025*	2030*
Single Family	8.565	8.998	9.431	9.934	10.438
Multi Family/Resort	4.040	4.244	4.449	4.686	4.924
Commercial	1.293	1.358	1.424	1.500	1.576
Industrial	0.162	0.170	0.178	0.187	0.197
Government	1.454	1.528	1.601	1.687	1.773
Agriculture	0.646	0.679	0.712	0.750	0.788
Total	**16.160**	**16.977**	**17.794**	**18.744**	**19.695**

* Data interpolated from County historical water use for 1998-99 and County demand projections for 2005-2050 published in Figure 4.1 and Tables 4.5 to 4.6 of the County of Kauai's *Water Plan 2020 (*Kauai Department of Water, March 21, 2001).

Source: Kauai Department of Water, *Water Plan 2020,* March 21, 2001.

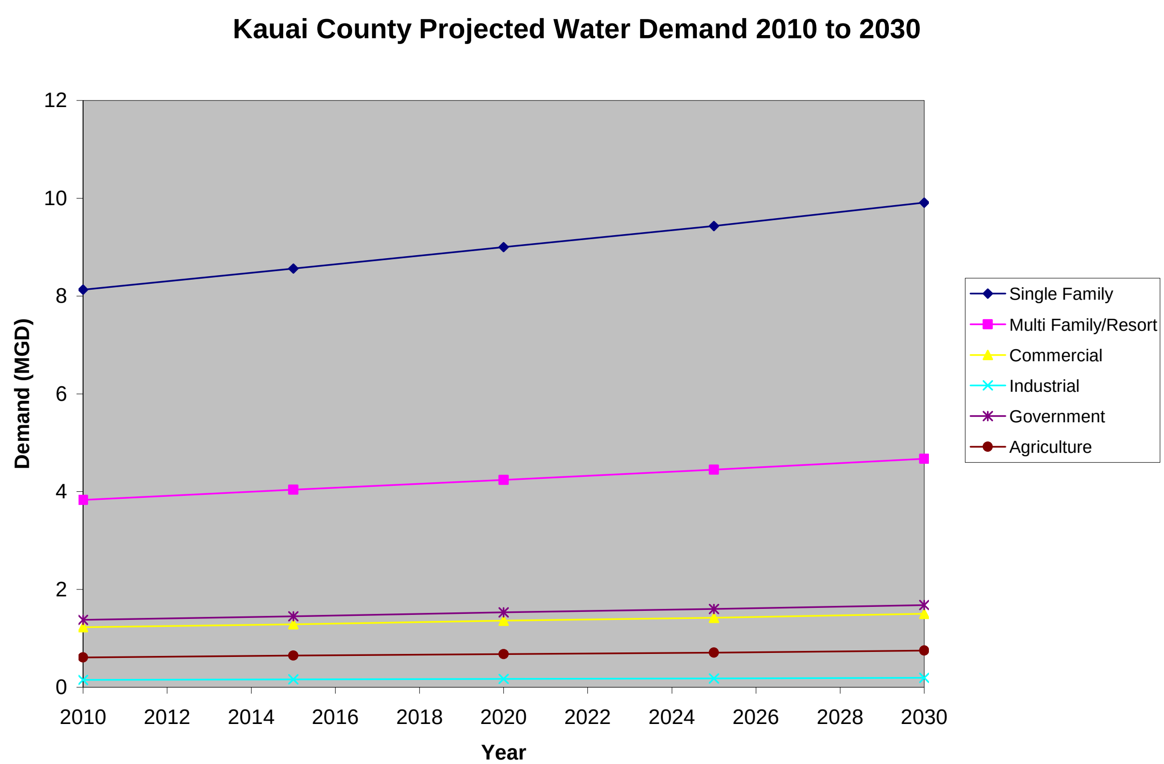

Figure 6-7. Kauai County Projected Water Demand 2010 to 2030

Table 6-18: City and County of Honolulu Projected Water Demand, 2010 to 2030 (mgd)

Use Category	2010	2015	2020	2025	2030
Agriculture	3.720	4.00	4.190	4.430	4.660
Domestic Residential[1]	100.620	108.310	113.440	119.850	126.260
Domestic Non-Residential[1]	49.090	52.840	55.340	58.480	61.600
Industrial	3.440	3.700	3.870	4.090	4.310
Irrigation	7.400	7.960	8.340	8.810	9.290
Other	0.020	0.020	0.020	0.020	0.020
Total	**164.280**	**176.840**	**185.210**	**195.680**	**206.150**

[1] Includes potable and non-potable water needs.

Source: Staff communication, Honolulu BWS, March 20, 2007.

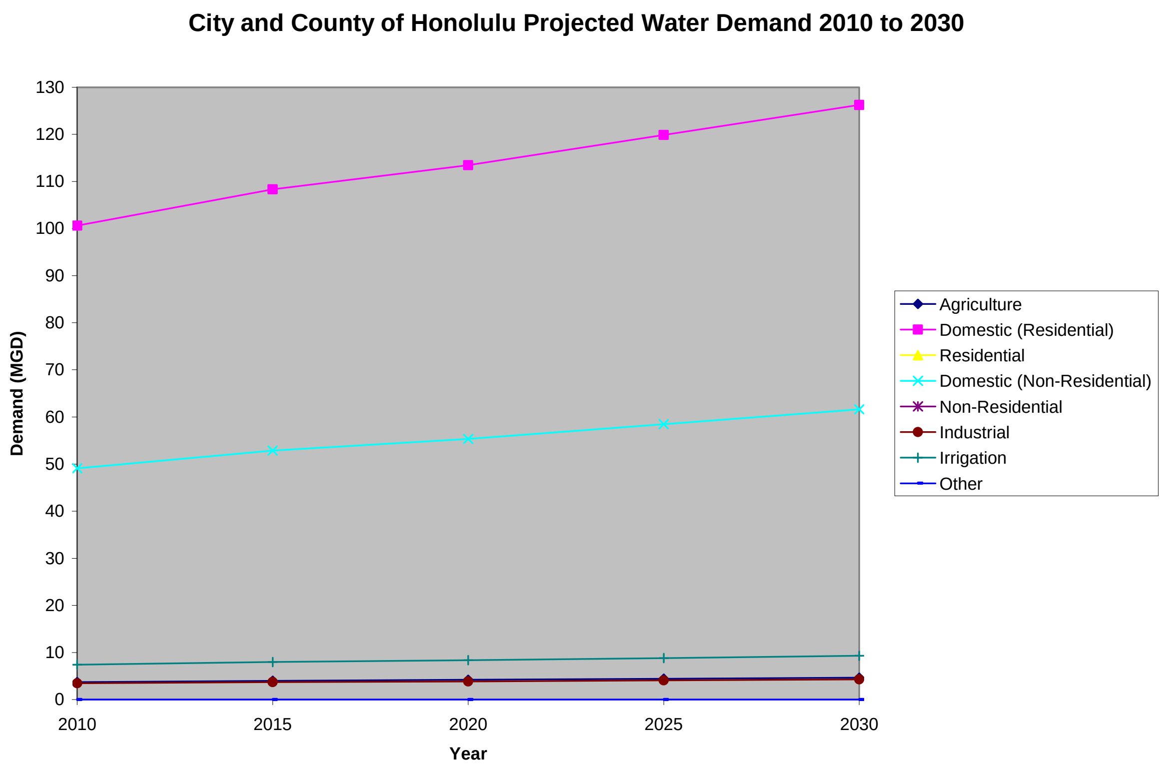

Figure 6-8. City and County of Honolulu Projected Water Demand 2010 to 2030

Table 6-19: Maui County Projected Water Demand for Maui Island and Molokai Island, 2010 to 2030 (mgd)

Use Category	2010	2015	2020	2025	2030
General	33.046	36.417	39.688	43.213	46.849
Agriculture – Potable	2.83	2.907	2.989	3.075	3.167
Total Potable	35.876	39.324	42.677	46.288	50.016
Agriculture – Non-Potable	0.592	0.612	0.633	0.654	0.676
Total	**36.468**	**39.936**	**43.31**	**46.942**	**50.692**

Notes: "Use Category" corresponds to the Maui Department of Water Supply billing class.

Source: Maui Department of Water Supply, Figure 28: Base Case Econometric DWS Water Demand Projections by DWS District by Use Classification, *Maui County Water Use and Development Plan, Water Use and Demand, Department of Water Supply Systems, Draft,* May 1, 2007.

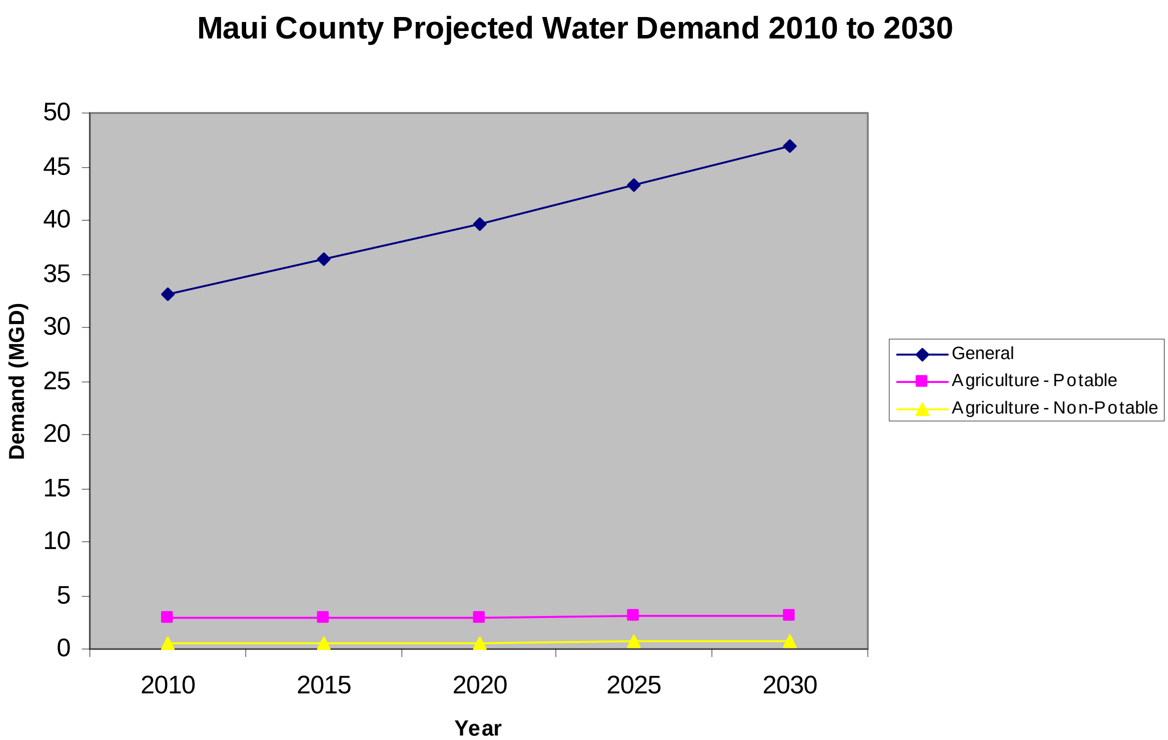

Figure 6-9. County of Maui Projected Water Demand 2010 to 2030

As reflected in Table 6-20, Maui County has projected non-potable water demand for agricultural purposes separately from potable water demand for agriculture. As freshwater sources are committed to residential, commercial, sanitary and other human consumptive uses, it will be necessary for the counties to incorporate use of alternative water sources and service appropriate use categories with non-potable water.

Table 6-20: Hawaii County Projected Water Demand, 2010 to 2030 (mgd)

Use Category	2010	2015	2020	2025	2030*
Catchment (domestic)	5.658	6.435	7.334	8.369	9.273
Industrial	9.668	10.105	10.588	11.096	11.572
Irrigation	13.018	14.856	16.958	19.365	21.481
Agriculture	31.784	35.337	39.404	44.034	48.118
Military	0.035	0.040	0.047	0.054	0.061
Municipal[1]	37.631	42.117	47.239	53.062	58.205
Total	**97.794**	**108.890**	**121.570**	**135.981**	**148.709**

1 Includes private-public water system demands and DWS system demands for domestic, industrial, irrigation, agriculture, military, and other municipal uses.

* 2030 projected demand interpolated from county demand projections from 2005 to 2025 provided by Fukunaga & Associates, Inc. on behalf of the County of Hawaii Department of Water Supply.

Source: Staff communication, Fukunaga & Associates, Inc., June 22, 2007.

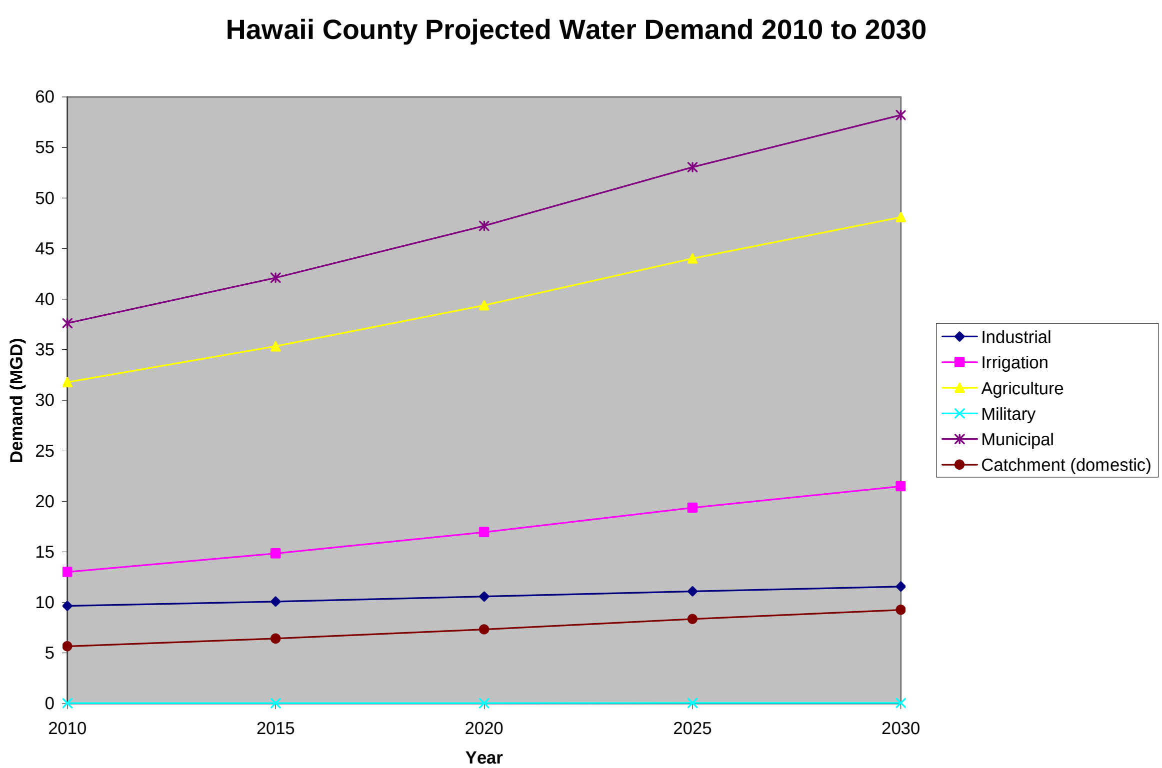

Figure 6-10. County of Hawaii Projected Water Demand 2010 to 2030

6.6. Water Planning at the County Level

One of the primary objectives of the State Water Code is the development of a program of comprehensive water resource planning to address the supply and conservation of water. A major component of this program is the Water Use and Development Plan that must be prepared by each county. The Water Code also provides for planning consistency across government levels by requiring the County WUDPs to be adopted by CWRM, and integrated into the Hawaii Water Plan.

The initial County WUDPs were prepared in 1990 to meet the deadline set by the State Water Code legislation, but the County WUDPs were adopted by the Water Commission with the condition that the plans be updated with more information on certain plan elements. In 1992, the Water Commission was briefed on draft updates to the County WUDPs, but the Water Commission deferred adoption of the updates, pending the refinement of the plans. The following describes the purpose and contents of the County WUDPs, the process for updating the plans, and the status of each county's planning efforts.

6.6.1. The County WUDP Update Process

The State Water Code requires each county to prepare and regularly update its County WUDP to address future water demands and to set forth the "allocation of water to land use in that county." It is important to note that the WUDPs are the instruments by which all other Hawaii Water Plan components are integrated, and are used to implement comprehensive water resource planning at the county level.

The County WUDP objectives include the following planning activities:

- Assess existing and future land uses and associated municipal water demands;
- Incorporate agriculture, military, private, State, and other non-municipal water demand projections; and
- Evaluate the cost and adequacy of proposed development plans and identify preferred and alternative water development plans to meet projected demands.

Requirements, recommendations, and guidance for preparing the County WUDPs are found in the State Water Code and the Statewide Framework for Updating the Hawaii Water Plan. The pertinent sections of the State Water Code and the Framework are summarized below.

6.6.1.1. State Water Code and Administrative Rule Requirements

The purpose of the County Water Use and Development Plans is to inventory all projected water demands and ensure that the future water needs of the county are met. The plans allocate water to land use, and provide additional guidance to CWRM for decision-making regarding water management area designation, water use, and water reservation requests.

The State Water Code mandates that each county update and modify its WUDP as necessary, to maintain consistency with zoning and land use policies. It also specifies that County WUDPs must be adopted by county ordinance.

HRS §174C-31(f) states that the County WUDPs must include, but are not limited to the following information:

> *(1) Status of water and related land development including an inventory of existing water uses for domestic, municipal, and industrial users, agriculture, aquaculture, hydropower development, drainage, reuse, reclamation, recharge, and resulting problems and constraints;*
> *(2) Future land uses and related water needs; and*
> *(3) Regional plans for water developments including recommended and alternative plans, costs, adequacy of plans, and relationship to the water resource protection and water quality plans.*

Hawaii Administrative Rules §13-170-32 provides additional guidelines for preparation of the County WUDPs:

> *(b) All water use and development plans shall be prepared in a manner consistent with the following conditions:*
> *(1) Each water use and development plan shall be consistent with the water resource protection plan and the water quality plan.*
> *(2) Each water use and development plan and the state water projects plan shall be consistent with the respective county land use plans and policies, including general plan and zoning as determined by each respective county.*
> *(3) Each water use and development plan shall consider a twenty-year projection period for analysis purposes.*
> *(4) The water use and development plan for each county shall also be consistent with the state land use classification and policies.*
> *(5) The cost of maintaining the water use and development plan shall be borne by the counties; state water capital improvement funds appropriated to the counties shall be deemed to satisfy Article VIII, section 5 of the State Constitution.*

6.6.1.2. Framework Requirements

The Statewide Framework for Updating the Hawaii Water Plan is intended to help integrate and update the components of the Hawaii Water Plan. With respect to the County WUDPs, several key Framework objectives are listed below:

- To achieve integration of land use and water planning efforts that are undertaken by federal, State, county, and private entities so that a consistent and coordinated plan for the protection, conservation and management of water resources is achieved;

- To recommend guidelines for the HWP update so that the plan and its component parts are useful to CWRM, other State agencies, the counties, and the general public;

- To develop a dynamic planning process that results in a “living document” for each component of the HWP which will provide county and State decision-makers with well formulated options and strategies for addressing future water resource management and development issues;

- To better define roles and responsibilities of all State and county agencies with respect to the development and updating of the HWP components; and

- To describe and outline the techniques and methodologies of integrated resource planning as the basic approach that should be utilized in developing and updating the County WUDPs.

The County WUDPs respond to the need for integration of resource development strategies at the county level. It is emphasized that the County WUDPs are required to encompass all water usage and water development plans projected throughout the county. Since the various State agencies ultimately build their projects within one of the four counties, State agency water use demands and proposals for development of various resources to meet those demands must be factored into the overall water demands and development strategies of each of the counties. The responsibility for preparation of the County WUDP rests with the specific entities charged with water planning within that county, as may be enumerated by county ordinance.

As provided by the Framework, a county-specific project description is to be prepared by each county to initiate the County WUDP update process. The project description should present specific issues, planning activities, project scope, and objectives to be met by the county in its planned update of the County WUDP. It should also include the roles and responsibilities of the various county agencies involved in the development and preparation of the WUDP, as well as the specific steps and projected timetable for updating and adopting the WUDP. The project description should be submitted for review and approval by CWRM, prior to the county’s undertaking of the update process.

6.6.2. Status of County WUDP Updates

The four counties are at various stages of their respective WUDP update processes. Since the deferral of adoption of the 1992 draft updates, the Framework was adopted in 2000 to provide guidance to agencies responsible for preparing HWP components. That same year, the Hawaii Supreme Court’s decision in the Waiahole Ditch Combined Contested Case imparted and reaffirmed the application of the Public Trust Doctrine and the precautionary principle in Hawaii’s water resource planning efforts.

Both the City and County of Honolulu and the County of Maui had begun the WUDP update process as the HWP Framework and the Waiahole case were developing. Therefore, these counties have adapted and adjusted their programs to incorporate policy developments and to formulate planning mechanisms best suited to them. The sections below provide information on the current WUDP update activities in each county, and summarize the status of planning efforts.

6.6.2.1. County of Maui WUDP Status

The County of Maui Department of Water Supply (DWS) submitted the project description for the County WUDP update for CWRM review in January 2004. The Maui DWS developed the WUDP project description in consultation with CWRM, who approved the DWS's regional planning approach in February 2004.

Maui County's regional WUDP update process incorporates planning and public input that had been accomplished since 1992 on Lanai, and to a lesser degree in West Maui. The scope involves regional planning efforts on a staggered schedule for the following districts:

- Central Maui and Upcountry
- West Maui
- East Maui
- Molokai
- Lanai

The scope of the WUDP also includes the means to resolve inter-regional issues and policy conflicts. Public and stakeholder input will be gathered through district Water Advisory Committees and possibly through surveys.

As of December 2005, Maui DWS and the Lanai Water Advisory Committee are working on finalizing the Lanai WUDP. A preliminary draft plan was distributed in August 2004, followed by an updated draft in September 2005. Maui DWS anticipates finalizing the plan as soon as possible, following the completion of district advisory committee revision and review.

Efforts in support of the Central Maui and Upcountry WUDP were initiated with an introductory public meeting held on November 30, 2004. As of December 2005, five meetings had been held in each district, and revision and review of draft sections of the WUDP was underway. Maui DWS anticipates proceeding with district committee meetings to complete a draft plan, but the project completion schedule is being revised.

In December 2005, the Maui DWS provided the following information regarding the progress of the remaining planning district WUDPs:

West Maui: The Maui DWS had completed six community meetings for the West Maui area WUDP update before efforts were put on hold after CWRM adopted the Framework. The DWS plans to re-initiate the planning process with the formation of a new community advisory committee, and the project schedule remains to be determined.

East Maui: Some preliminary research regarding demand forecasts and potential ground water contaminant sites has been completed for the East Maui district. The project schedule remains to be determined.

Molokai: As with the East Maui planning district, preliminary research has been conducted for the Molokai WUDP. The project schedule is to be determined.

6.6.2.2. City and County of Honolulu WUDP Status

To update the WUDP for the City and County of Honolulu, the Honolulu BWS proposed the development of regional "watershed management plans" that would together comprise the Oahu Water Management Plan (OWMP), which by City and County of Honolulu ordinance would also serve as the County WUDP. CWRM approved the OWMP Framework, along with the scopes of work for the first two regional watershed management plans, the Koolauloa Watershed Management Plan and the Waianae Watershed Management Plan, in March 2004.

The goal of the OWMP, via the watershed management plans, is to provide short-, mid-, and long-range guidance for the sustainable management and use of Oahu's surface and ground water resources. Such guidance will be consistent with City land use plans and State water plans. The watershed management plans for each of Oahu's eight planning districts will be developed through a planning process emphasizing:

- Community participation and consultation;
- Holistic management of watershed resources;
- Alignment with important State and City policies and programs;
- An action orientation: implementation of important watershed management programs; and
- Ahupuaa management principles.

The Honolulu BWS completed public review drafts of the Koolauloa and Waianae plans in 2007, and the schedule for the remaining plans has yet to be determined.

6.6.2.3. County of Hawaii WUDP Status

In September 2005, CWRM approved the County of Hawaii Department of Water Supply (DWS) project description for the technical approach to updating the Hawaii County Water Use and Development Plan. The County seeks to accomplish the following tasks through the technical approach:

- Take inventory of existing sources;
- Take inventory of existing uses;
- Identify existing water systems;
- Coordinate water use with land use plans and policies;
- Project future water demands;
- Identify supply-side and demand-side options; and
- Encourage public and stakeholder participation.

The relationship between land use plans, policies, infrastructure, and resource availability will be addressed with respect to the County General Plan and County zoning ordinance. The sustainability of current land use policies will be addressed by modeling the “infill” of un-developed or under-developed lands and calculating water demands. Three scenarios for water demands will be evaluated: low growth, medium growth, and high growth. Incremental water needs at 5-, 10-, 15- and 20-year intervals will be based on population and growth rate projections for the next 20 years.

The Hawaii DWS completed a public review draft of the Hawaii WUDP in 2007. The County is currently developing a long-range Water Master Plan and an implementation strategy for infrastructure upgrades that also includes a financial plan and a 5- and 20-year CIP program.

6.6.2.4. County of Kauai WUDP Status

The Kauai Department of Water (DOW) is planning to initiate work on the Water Use and Development Plan update in 2008. Infrastructure and system planning work has already been accomplished through other County plans. In 2001, the Kauai DOW and members of the Kauai Water Board completed the Water Plan 2020. The plan provides an inventory and evaluation of existing facilities, examines service standards, and includes plans for new and replacement facilities. Water Plan 2020 includes a capital improvement program, a financial plan, and a rate study and is focused on potable water for drinking and fire protection.

6.7. Recommendations for County Water Planning

The State Water Code mandates that the County WUDPs “be prepared by each separate county…setting forth the allocation of water to land use in the county.” To achieve this objective, water planning efforts related to municipal and non-municipal water demands should be coordinated and integrated at the county level. The responsible county agency will need to bring the many other water planning agencies at the State and federal levels, stakeholders, and representatives from the private sector into a collaborative process.

Water allocation planning must be accomplished in accordance with State and county policies, and be in line with county-specific strategies for sustainable development. In addition to addressing the availability of water resources, planning activities must also relate to the community's desires for development, economic growth, environmental protection, and competing uses in managing the relationship between water demand and water supply.

Demand projections for the planning horizon must account for and reflect the cumulative effects of consumptive use. Consumptive uses reduce the source water level or flow; water is not returned to its source (for example, water used for irrigation or urban supply). Typically, all water use in Hawaii is consumptive, with the exception of stream diversions for ornamental ponds or taro *loi* that return water to the stream over the course of a short period of time and at a point relatively near the initial diversion. Water loss due to evaporation, seepage, and evapotranspiration in such diversion scenarios can be considered as negligible, due to the relatively small displacement in location and limited time frame.

While the Framework provides overall guidance and recommended elements for the County WUDPs, the following list of recommendations is provided to help guide the counties in their allocation of water to land use and to encourage the assessment of cumulative impacts to the resource. Recommendations for measuring existing consumptive uses and assessing future demand are presented, along with recommendations for associated land use planning issues.

Recommendations for county water planning are as follows:

- Promote coordination and collaboration among agencies, private entities, and users to account for the cumulative effects of water use and to mitigate negative impacts to the resource.

- Establish strategies for increasing system efficiency and for managing higher water demand associated with land use and planned development.*

- Compare the total water demand projection associated with land use plans and zoning, to assess the need to evaluate/revise of land use policies (e.g., a total build-out scenario).

- Seek the optimization of infrastructure to minimize local stress on aquifers and increase confidence in ground water modeling of sustainable yields.

- Increase drought preparedness and awareness, and implement Hawaii Drought Plan recommendations for county actions.

- Implement economic incentives for resource stewardship, conservation, and reuse.

- Use alternative sources wherever possible and monitor agricultural demand for potable water and encourage the development and use of alternate non-potable agricultural water supply.

- Gather information on community values and expectations for water use.*

- Encourage local stakeholder partnerships to implement County WUDP recommendations.

* Denotes recommendations adapted from the *Guidance Notes for Planning for Water Allocation* prepared in August 2003 by Ton Snelder, NIWA and Richard Keys, Marlborough District Council for the Quality Planning Project, a partnership between the New Zealand Planning Institute, the Resource Management Law Association, Local Government New Zealand, the NZ Institute of Surveyors and the Ministry for the Environment.

Section 7

Resource Conservation and Augmentation

7. RESOURCE CONSERVATION AND AUGMENTATION

Through its review of existing demands, authorized planned uses, and hydrologic data, the CWRM has found that some areas of the State of Hawaii are approaching the limits of groundwater resource development. Nearly all of Oahu, Molokai, and part of Maui have been designated as Water Management Areas, where ground water use and development is regulated by the CWRM. From 1999 to 2001, statewide municipal water consumption increased by almost three percent with most of the increase occurring in the City and County of Honolulu. On Oahu, it is anticipated that ground water resources will be committed within 20 or 30 years, requiring the use of more expensive alternatives like reusing treated wastewater, treating surface water, and desalinating brackish or ocean water.

Estimates of ground water availability throughout the state are based on the best available, albeit limited, data. There are emerging indications of threat to our ground water sources that cannot be ignored. For example, on Molokai, ground water sustainable yield for the Kualapuu Aquifer System, which was initially estimated at seven mgd, was later revised to five mgd, and much of that water has either been allocated or reserved. On Maui, the overpumping of the Iao aquifer has threatened the island's major source of drinking water. Elsewhere in the State, there are indications that environmental effects and responses due to imposed stresses may be affecting the viability of certain aquifers, warranting closer monitoring and the implementation of management strategies to protect these aquifers from potential damage and depletion. With increasing demand for potable water and uncertainties about ground water availability, all four counties are actively promoting water conservation and are taking steps to increase the use of alternative sources of water.

There are several State and county agencies that currently implement various water conservation measures. Private businesses and organizations have also incorporated varying degrees of water conservation within their operations. Despite these efforts, the State of Hawaii lacks an overall, statewide water conservation program to provide guidance to agencies and businesses beginning a conservation program and to coordinate the various ongoing conservation efforts across the State. Water conservation planning should be an integral component of Hawaii's overall water resource management efforts.

Resource augmentation should also be embraced as an important component of sustainable water resource management. Water augmentation sources include: water that is imported from neighboring regions, water reclamation and reuse, and desalination of brackish water and seawater. Several of the county water and wastewater agencies employ reclamation techniques to process surface water and wastewater. However, as is the case with water conservation, a statewide water resource augmentation program remains to be developed.

This section reviews existing conservation and augmentation activities in Hawaii and establishes goals and priorities for statewide planning programs. The State Water Code states that CWRM shall plan and coordinate conservation and augmentation programs in cooperation with other federal, State, and county agencies, and private and public entities created for the utilization and conservation of water.[1] The State should provide leadership

[1] HRS §174C-5(12) and §174C-31(d)(4).

and guidance for the establishment, development, and implementation of statewide water conservation and augmentation programs.

7.1. Goals & Objectives

CWRM, on behalf of the State of Hawaii, establishes the following goals and objectives for water conservation and resource augmentation programs and projects statewide[2]:

- Foster the collaborative development, implementation, and update of short- and long-range plans for conserving and augmenting water supplies.
- Promote coordination and cooperation among agencies and private entities.
- Provide guidance, assistance, and oversight in the establishment, development, and implementation of statewide water conservation and augmentation programs.
- Encourage coordination between conservation activities and augmentation planning.
- Promote the utilization of the best available information and technology in planning and implementing conservation and augmentation projects.
- Provide the regulatory and planning framework for integrating resource conservation and augmentation into a comprehensive water management program.
- Support county and community-based conservation efforts by providing information resources and advisory assistance.
- Encourage water conservation and use of alternative water sources, whenever possible, through comments provided during land use planning and permitting review.

7.2. Developing a Water Conservation Program

Water supply planning and water conservation programs are closely related. Conservation programs directly affect short- and long-term water requirements and help reduce the risk of water supply deficiencies. Water conservation measures are implemented to achieve the following objectives:

- Reduce the demand for water;
- Improve efficiency in use and reduce losses and waste of water; and
- Ensure the long-term viability of the resource.

[2] HRS §174C-5(12) and §174C-31(c)(1).

Although government has taken the initiative in pursuing water conservation policies, the success of any water conservation program ultimately depends on public participation and cooperation. It is essential to the development and implementation of a good water conservation program that the community embraces and adopts a conservation ethic. Community leaders, elected officials, government agencies, private water companies, and environmental groups must be involved in the planning process. Representatives from industry, commercial associations, civic organizations, churches, labor unions, school boards, and the media can actively engage in public education and planning efforts to help formulate a cost-effective water conservation program. Public and private input will ensure that conservation measures are publicly accepted and cost-effective as compared with the design and construction of alternate water supply projects.

Water conservation programs may involve short-term and long-range conservation measures. Short-term measures may include such practices as the implementation of temporary restrictions on lawn watering and car washing. Long-range water conservation measures may include the installation of low-flush toilets, low-flow showerheads, pressure regulators, and water-efficient appliances in homes and offices. In industry, water conservation can be achieved through the recirculation of cooling water and the re-use of treated wastewater. In agriculture, drip irrigation and tailwater recovery are effective conservation measures. Surface mulches, xeriscaping, and pressure regulators can also help conserve water for landscaping applications.

Finally, a water conservation program must also include a mechanism for updating program elements. The conservation program should undergo periodic assessment to measure program effectiveness and be revised accordingly. An advisory committee is an effective forum for program review, evaluation, and update.

7.3. Water Conservation Measures

Water conservation measures may be described in four general categories:

1. Resource conservation;
2. Water system conservation;
3. Consumer conservation; and
4. Public education programs.

Resource conservation and water system conservation are primarily the functions of a water utility. As discussed below, however, the utility should also promote consumer conservation and incorporate a significant public education component in its water conservation program.

7.3.1. Resource Conservation

Resource conservation is intended to assure optimum development of sources to protect them against contamination, waste, and overdraft. In Hawaii, public control of watershed lands has long been advocated to conserve and protect ground water resources.

Watersheds are precipitation infiltration areas that are crucial to the replenishment and preservation of basal aquifers.

Rules and regulations to control the drilling of private wells and to guard against wasteful operation have long been in effect in Hawaii, particularly on the island of Oahu. The State Water Code empowers CWRM to designate Water Management Areas (WMAs) where it finds that water resources therein are in danger of overdraft. Designation of a WMA provides for CWRM jurisdiction over water use within the WMA.

An important aspect of resource conservation is the continued surveillance of hydrologic conditions to provide data, enabling long-term assessments of ground water conditions. The results of these assessments provide the basis for corrective action in the overall management of ground water resources.

The preservation of ground water resources is dependant on the effective use of all water resources. Wastewater reclamation, surface water recovery and storage, desalination, improved irrigation practices, and other means to make greater use of our total water resources all play a part in protecting ground water resources against overdraft.

7.3.2. Water System Conservation

A water utility can take various actions to affect savings by better operation and control of transmission and distribution systems. Under certain conditions, the county water departments have the authority to impose mandatory restrictions on water use. Under typical conditions, there are two primary areas where water-system conservation can be most effective: metering of water supplies and leak detection and control. To a lesser extent, reduction in water pressure can result in some degree of reduced consumption.

Some water utilities bill their customers on a flat-rate basis. Many others, especially among larger municipalities, require the installation of water meters and bill customers for metered water use and service. The practice of charging customers on the basis of water use provides a strong incentive for customers to use less water. The use of a tiered rate structure based on water use and the discouragement of master metering for large developments are two effective means for promoting conservation.

Customer use does not account for all the water passing through a water system. Water utilities must also consider the volume of unaccounted-for water. Unaccounted for water includes system leaks, unmetered water use through fire hydrants, water illegally taken from the distribution system, inoperative system controls, and water used for street cleaning and flushing water mains and sewers. On Oahu, the Honolulu BWS accounts for some of these losses by metering water used for street and sewer flushing.

A program of leak detection, meter testing and replacement, and pipe relining and replacement can appreciably reduce the amount of unaccounted for water. A good program of prevention, including proper water system design, careful installation, and effective corrosion control measures, is the best way to reduce water losses. However, each county must determine the cost-effectiveness of such a program.

Although not a major factor, reduction of water pressure can save water. The county must determine whether operating at a lower pressure is practical and if certain services, such as fire-fighting, would be negatively impacted.

7.3.3. Consumer Conservation

In general, residential water use includes more than half of the total water use from county systems. Residential water use can further be classified as water used inside and outside the house. A typical home uses between 60 and 80 gallons per capita per day (gpcd).

A 1999 study published by the American Water Works Association (AWWA) Research Foundation reported that homes with water conservation measures in place use an average of 32% less water compared to homes without water conservation measures. Inside the home, most water is used in the bathroom. Many states now require the installation of water-efficient devices in new construction. Some of the more common water-conserving fixtures are as follows:

- **Low-flush toilets:** These units use no more than 3.5 gallons per flush, approximately half the volume of water used in older toilets. Ultra low-flush toilets are also available, which use only 1.5 gallons per flush. These toilets can be more expensive than the standard models.

- **Low-flow showerheads:** Ordinary showerheads deliver from five to eight gallons per minute (gpm). A low-flow showerhead uses about 2.75 gpm, resulting in a savings of roughly 50% or more.

- **Low-flow faucets:** The AWWA reports that the savings from the use of low-flow faucets is estimated to be less than 1.0 gpcd.

- **Water-efficient dishwashers and clothes washers:** These appliances use significant amounts of water. New units on the market now make it possible to save about five gallons per load for dishwashers and about six gallons per load for clothes-washing machines.

Because of wide variations in climate and landscaping, water used outside the home may vary between 30 and well over 100 gpcd. Water used outside the home is primarily water for landscape irrigation. Water conservation measures that can be used include improved irrigation techniques, better turf preparation, and alternative landscaping designs that reduce water use. Improved irrigation techniques can save from 20 to 50% of the water applied.

The potential savings from lowering landscaping water use can be considerable. Efficient irrigation combining the appropriate sprinkler heads, uniform water application rates, automatic controllers, and the proper zoning of turf and planting beds can reduce water use substantially.

7.3.3.1. Reduction of Commercial Water Use

Water use for commercial establishments is confined mainly to sanitation and landscape irrigation. Many of the residential water-saving techniques discussed above apply to commercial establishments. Some of these are as follows:

- Installation of water-saving devices;
- Adjustment of valves on toilets and urinals;
- Use of water-efficient appliances;
- Use of low-flow shower heads;
- Elimination of leaks;
- Adoption of water-recycling practices, such as car-wash water;
- Use of low water-use landscaping; and
- Installation of automatic irrigation systems and moisture sensors.

7.3.3.2. Reduction of Industrial Water Use

Water consumed by industry is primarily used for cooling, landscape irrigation, sanitation, and production (process) water. Conservation of water used for irrigation and sanitation may be realized through the same methods recommended for residential and commercial users. Other means of reducing industrial water use are as follows:

- Conversion of once-through cooling systems to closed systems;
- Reclamation of wastewater;
- Elimination of water waste during cleanup; and
- Design of more efficient systems for process water use.

In Hawaii, the potential of reducing industrial water use is not as great as in other parts of the country. Nevertheless, opportunities for savings still exist, especially in canneries, power plants, and milk-processing plants.

7.3.3.3. Water Pricing

Water rates are designed to provide revenues for a utility to defray operating and capital expenses. Various types of rate structures have been employed by utilities to encourage water conservation. The principal types of rate structures are:

- **Uniform rates:** The uniform rate structure charges the same unit rate for all water usage. This method provides little incentive to conserve, especially to above-average per capita consumers.

- **Inclining rates:** This rate structure applies a unit charge that increases with water usage, thus making the large users responsible for the incremental cost of providing the additional water consumed. This structure encourages the large users to conserve, especially if the rate increases are significant.

- **Seasonal rates:** Under this rate structure, the unit cost of water increases during peak seasonal use periods, primarily during the summer. The seasonal rate structure is becoming more common throughout the country. The obvious objective is to provide consumers with an incentive to reduce water use during peak demand periods.

The rate structures listed above are basic concepts, and can be implemented in a number of variations and combinations. Water utilities must consider local and regional conditions when developing rate structures.

7.3.4. Public Information Programs

Public information programs are intended to foster a conservation ethic among water users. In order to achieve reductions in water use, it is essential for consumers to make a voluntary commitment to conserve water and to practice resource stewardship.

Public information programs can educate consumers on how to prevent waste by discouraging activities such as indiscriminate flushing of toilets, and running water unnecessarily while taking showers, shaving, teeth brushing, car washing, or watering lawns. The program should include educating consumers on the nature of water sources, the cost of operating a water system, the limited capacity of these sources, and the importance of water conservation.

The effectiveness of a public information program is difficult to measure. However, past programs have demonstrated that in order to be effective, a public information program must be carried out on a long-term basis.

7.4. State and County Water Conservation Programs

Under the State Water Code, CWRM is responsible for planning and coordinating of a water conservation program. CWRM has a State Drought & Water Conservation Coordinator, however, outside designated Water Management Areas or Water Emergency situations, the Water Commission does not have the authority to require the counties and other jurisdictions and interests to actually implement water conservation measures. County governments, however, have the authority to institute mandatory conservation measures, as necessary, by enacting the appropriate ordinances, rules, and regulations.

It is important for a statewide conservation program to be coordinated with the four counties, the Federal Government, and private interests. Establishing a conservation program requires extensive planning and consultation, and successful program implementation requires widespread public participation and cooperation among government agencies, water users, water purveyors, and various community and special interest groups.

The basic goal of a water conservation program is to enhance the welfare of the people of the State through proper development, protection, control, and regulation of the water resources of the State for all beneficial uses. To this end, all water utilities and water agencies are encouraged to adopt policies, principles, and practices for efficient water use through a balanced approach, combining demand management with judicious source development.

The State can provide the counties with guidance and general water conservation plan components that can be adapted to suit local conditions and needs, including policies, strategies, expected results, and guidelines for implementation. A statewide water conservation program should employ the following principles and practices:

- Ensure judicious management and efficient utilization of sources of supply.
- Employ methods and technology to accurately monitor water consumption.
- Conduct inspections of water distribution systems to detect leaks and facilitate timely repair and replacement.
- Establish water use efficiency standards for new plumbing fixtures and appliances. Retrofit existing fixtures with low-flow units.
- Improve land management practices to conserve water.
- Employ efficient irrigation methods and practices.
- Increase distribution and use of educational materials as part of a broad public information program on water conservation.
- Encourage implementation of self-administered water conservation programs for all water users.
- Encourage the use of alternative water sources for non-potable uses.
- Recommend and pursue research on more efficient water use techniques and practices.
- Explore incentives and disincentives for water conservation program compliance.

In hopes of encouraging water conservation programs that apply the principles and practices listed above, CWRM developed a prototype water conservation plan for five of the Department of Land and Natural Resources' facilities. The long-term intent of the *Prototype Water Conservation Plan for the Department of Land and Natural Resources* (February 2005) is to provide a framework for the development of water conservation plans for all State agencies, and to provide conservation program options and strategies for water purveyors throughout Hawaii. To facilitate State agency implementation of water conservation programs, CWRM developed the *Conservation Manual for State of Hawaii Facilities* (May 2007), which contains information on designing a program and water conservation guidelines for indoor domestic uses, landscaping uses, cooling and heating applications, and medical facility uses. The *Prototype Water Conservation Plan for the Department of Land and Natural Resources* and the *Water Conservation Manual for State of Hawaii Facilities* are available on CWRM's website at http://www.hawaii.gov/dlnr/cwrm/planning/conserve.htm.

7.4.1. DLNR Prototype Water Conservation Plan

The *Prototype Water Conservation Plan for the Department of Land and Natural Resources* was completed in February 2005. The plan was designed to serve as a pilot project, with potential application for the development of water conservation plans for typical government institutional facilities.

The DLNR Water Conservation Plan examines five selected facilities as models for other planning efforts. DLNR is an appropriate agency for piloting water conservation planning because the agency has multiple types of facilities and water usage characteristics (e.g., office buildings, baseyards, harbors, municipal/irrigation demands, potable/non-potable water systems). The plan addresses both potable and non-potable water demands, identifies appropriate water conservation measures, provides implementation schedules and budgets for the installation of water conservation measures, and recommends post-installation monitoring of water use.

The plan development was partially funded through the Water Conservation Field Services Program (WCFSP) administered by the U.S. Department of the Interior, Bureau of Reclamation. The WCFSP is designed to: encourage water conservation; assist water agencies to develop and implement effective water management and conservation plans, coordinate with state and other local conservation program efforts, and generally foster improved water management on a regional, statewide and watershed basis. The program emphasizes: water management planning, conservation education, demonstration of innovative technologies, and implementation of conservation measures. The Bureau of Reclamation's *Municipal and Irrigation (M&I) Conservation Plan Guidebook*, which provides methods and measures aimed at improving overall water management, assisted CWRM in the scoping of the DLNR Water Conservation Plan.

The goals of the DLNR Water Conservation Plan are summarized for each facility as follows:

- **Kalanimoku Building:** Achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Kakaako Waterfront Park:** Achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Ala Wai Harbor:** Account for all water usage at the facility, achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Honokohau Harbor:** Account for all water usage at the facility, achieve a 15% water use reduction, estimate cost savings over the long-term, and free up water supplies for additional uses.

- **Hilo Baseyard:** Achieve a 15% water use reduction, estimate cost savings over the long term, free up water supplies for additional uses.

The plan recommends monitoring all conservation measures installed pursuant to the plan through metered water use (water billings).

As stated earlier, one of the key objectives of the project was to serve as a model for developing a statewide water conservation plan. Another goal was to develop an assessment approach and planning methodology that could be used in the formulation of facility water conservation plans. The development of facility-specific water conservation plans begins with understanding each facility's water usage. Creating and adopting a consistent assessment methodology to evaluate water usage and identify possible water conservation measures is the first step in developing a facility-specific water conservation plan. The water conservation assessment methodology could be used as a template by State agencies to conduct internal evaluations of their facilities (either by their in-house staff or by consultants).

The water conservation assessment methodology consists of the following basic steps:

1. Identify current water use at the facility:
   a. Complete a water system inventory to understand the facility's current water system layout.
   b. Gather past water consumption data (e.g., water billings, and water metering records).
   c. List all water uses including domestic, irrigation, maintenance, etc.
   d. Measure water quantities used on average in each water use category. This may require the installation of sub-metering systems to determine specific water usage throughout the facility.
   e. Identify significant water uses.

2. Identify existing conservation measures:
   a. List all existing water conservation measures.
   b. Assess existing water conservation measures and any previous attempts to implement conservation measures to understand relative success or failure.
   c. Identify areas without water conservation measures.

3. Identify applicable/practical water conservation measures:
   a. List potential water conservation measures to be considered.
   b. Discuss potential water conservation measures with facility staff.

4. Complete cost benefit analysis and environmental assessment of potential water conservation measures:
   a. Develop projected water conservation plan implementation costs.
   b. Develop estimated water savings based on water conservation measures selected.

c. Evaluate water conservation plan feasibility through cost /benefit analysis.
d. Complete environmental assessment identifying resources and any possible negative impacts.
e. Develop final recommended water conservation plan based on cost/benefit and environmental analysis.

5. Create a conservation plan implementation schedule:
   a. Develop a timetable of interim and long-term conservation measures for agency implementation.

6. Develop initial steps to be taken by facility:
   a. Consider installing sub-metering systems to monitor water usage.
   b. Identify implementation costs, including labor.
   c. Identify activities for monitoring performance and results.
   d. Educate facility staff on water conservation measures.
   e. Post signs to educate water users on water conservation.
   f. Post signs identifying contacts if facility is in need of repair.

The development of facility-specific water conservation plans for State agencies is an appropriate starting point for a statewide water conservation program. Cooperative efforts between the State and counties can enhance program development and expand its application. General recommendations of the DLNR Water Conservation Plan include:

- Government agencies should pursue public/private partnerships to increase public awareness and to implement and promote water conservation efforts.

- Each State facility/site should designate a project manager to develop and implement a site-specific water conservation plan.

7.4.2. Water Conservation Manual for State of Hawaii Facilities

On January 20, 2006, Governor Linda Lingle issued Administrative Directive No. 06-01 requiring all State agencies and programs to increase their commitment towards implementing innovative and resource efficient operations and management. Examples of better management practices cited in this directive include:

- Reduced energy and water use;

- Reuse and recycle options;

- Improved construction and demolition waste management;

- Environmentally preferable purchasing;

- Efficient use of transportation fuels, especially greater use of alternative fuels; and

- Increased incorporation of sustainable building practices.

New State facilities and augmentations to existing facilities are to be designed and constructed to meet and achieve certification requirements of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards. State agencies are specifically directed to implement water and energy efficient operational practices to reduce waste and increase conservation.

The *Water Conservation Manual for State of Hawaii Facilities*, developed by CWRM in 2007, contains information and guidelines to help State agencies comply with Administrative Directive No. 06-01. The manual provides detailed information on how to implement water efficient practices at State buildings and facilities. The conversion of State buildings and facilities to water-efficient status will assist State agencies in their efforts to obtain LEED certification, as required by the Governor's directive.

7.4.3. County Conservation Programs

In general, the counties practice conservation by protecting watershed areas in order to realize dependable yields. Counties also practice conservation by reducing system leaks and losses, adopting universal metering, encouraging or requiring the installation of devices to reduce water use, implementing public education programs, adjusting water rates to influence demand, and as a last resort, rationing water use during severe shortages.

Water conservation can be beneficial to a water utility and its customers by reducing demand in dry years and prolonging short supplies during other emergency conditions. Efficient water use can also result in energy savings, particularly on hot-water use. It has been estimated that hot-water use can be reduced by almost one-third through effective water conservation measures.

Reduced water use also results in energy savings, as less water must be treated and distributed throughout the system. Moreover, water conservation within the home and in industry decreases the volume of wastewater flow. This, in turn, reduces treatment and collection system costs. In Hawaii, reductions in pumping costs could be significant, and deferred development of new water sources will postpone capital improvement costs.

In planning a water conservation program, a water utility should consider some of the potential disadvantages involved. One of these considerations is the reduction of revenues, the effect of which is felt almost immediately. Less revenue may postpone needed capital improvements, which means the utility could later face higher construction costs.

However, water conservation can also make water available to service undeveloped areas. Water conservation and land-use planning efforts should be coordinated so as to avoid inadequate water availability for future use.

Water conservation cannot be regarded as a substitute for a utility's obligation to maintain an adequate reserve capacity. Without adequate reserves, water shortages may become more frequent, and drought impacts may threaten public health.

Many states and municipalities throughout the continental United States have developed water conservation programs with varying degrees of success. Noteworthy programs have been implemented in cities such as Denver, Oakland, Los Angeles, and Washington, D.C.

The counties of Maui, Kauai, Hawaii, and the City and County of Honolulu have independently undertaken water conservation programs and strategies. Their conservation efforts are summarized below.

7.4.3.1. Maui Department of Water Supply Conservation Program

The County of Maui Department of Water Supply (DWS) provides water service via distribution systems in Central Maui, Upcountry Maui, West Maui, East Maui, and Molokai. Central Maui has the largest number of customers, and includes the areas of Wailuku, Paia, Kahului, and Kihei. The water system in Upcountry Maui covers the largest geographic area and services Kula, Pukalani, Makawao, and Haiku. The East Maui system serves the Lahaina area, and the West Maui system serves Hana. The limited areas on the island of Molokai are served by a county system. Water service on the island of Lanai is provided by a private company.

Water for most parts of Maui County comes from ground water sources. However, the Upcountry water system is supplied by surface water sources, i.e., streams and ditches in East Maui. Likewise, parts of Lahaina are supplied by surface water sources from the West Maui streams and ditches. Surface water is treated and disinfected at three treatment plants in Upcountry, two in Lahaina, and one in Wailuku before it is distributed to customers for drinking. It should be noted that Maui County also provides non-potable water from surface water sources to agricultural users.

The mission statement for the Maui Board of Water Supply is "Provide clean water efficiently." The Board's Strategic Plan includes the following goals related to water conservation:

- Develop adequate water sources, storage, and transmission for both urban and agricultural uses, including mitigation of drought.
- Systematically replace, upgrade, and improve, as needed, existing infrastructure (pumps, distribution and transmission lines, storage, and appurtenant facilities).
- Create long-term innovative and cost-effective financial management programs to accomplish the mission of the department.
- Provide programs to the public to facilitate conservation and promote greater awareness and support of the department and its activities.
- Review the feasibility of integrating the management of public and private water systems.
- Participate in watershed and well-head protection programs, and management of all of Maui County's water resources.
- Maintain a living Water Use and Development Plan through the integrated resource planning process.

The Maui DWS has implemented a water conservation program that includes a significant public outreach component. Information on consumer conservation measures, waste prevention, and general conservation information are available to the public, as well as free low-flow shower heads, faucet aerators for the kitchen and bathroom, and leak-detection dye tablets. The following are accessible from the department's website (http://mauiwater.org):

- Information on the Wellhead Protection Program to ensure ground water quality;
- Checklist of conservation ideas for the home;
- Checklist of conservation ideas for the yard;
- Checklist of conservation ideas for condominiums;
- Information about detecting leaks in faucets, toilets, and outside taps;
- Guide to fixing a leaky faucet;
- Maui planting guidelines, with an emphasis on native Hawaiian plants, describing suitable plants and planting methods for different areas of the county;
- Information on the concepts of conservation landscaping and xeriscaping;
- "25 Things You Can Do To Prevent Water Waste" (in the home) and;
- "55 Facts, Figures, and Follies of Water Conservation," including facts and simple suggestions that encourage water conservation.

The Maui DWS is developing and expanding its conservation program, which includes both supply side and demand side measures.

Supply-side measures to date include leak detection, preventive and predictive maintenance, use of reclaimed water, use of alternate system backups, and resource protective measures:

- Leak Detection: Though the Maui DWS has long practiced leak detection, due to staffing, such work has historically been primarily reactive. Leak detection staff were sent out when a leak was suspected, either based on system performance, or flow and pressure monitoring undertaken as part of hydraulic model development or other efforts. The Maui DWS is now instituting a proactive program. A preliminary water audit by district has been completed, and ten miles of distribution line have been surveyed in the first quarter of this year. Program pace is expected to increase with familiarity and additional staffing. Leak detection equipment include: digital correlating loggers, a digital correlator, a leak detector, and a line tracer.

Systematic survey and detection of leaks may be supplemented by flow and pressure monitoring as needed.

- Preventive & Predictive Maintenance: This two-pronged approach involves the regular maintenance of facilities and the periodic calibration of pumps. In the course of such maintenance, facilities are regularly checked for signs of wear. The Maui DWS also has a system inventory with age, diameter, and material of water lines and other facilities. The Maui DWS maintains a 30-year project list based upon the status and performance of system facilities and upon known inventory status and demand trends. Preventive and predictive maintenance can help reduce unaccounted-for water in the system by targeting old and substandard lines for replacement.

- Reclaimed Water Use: About 3.905 mgd is in use throughout Maui County with 1.8 mgd utilized in South Maui. As part of its Water Use & Development Plan process, the Maui DWS is currently investigating the costs and benefits of large scale capital investment to further expand reclaimed water use to offset potable use.

- Back-up Sources: In the event of a major leak, any key portion of the system can be isolated if necessary, and most areas of system can be served by other sources.

- Watershed and Resource Protection: The Maui DWS spends a million dollars annually on projects to protect and monitor water resources, including more than $600,000 on watershed protection. Staff conducts outreach and runs advertisements on the importance of watershed protection, as well as co-sponsoring events at the Maui Nui Botanical Gardens facility.

Demand-side conservation measures include fixture distribution, a tiered rate structure, educational programs, and regulations as well as resource protection. Ongoing planning efforts are evaluating the benefits and costs of increased aggressiveness in these efforts:

- Fixture Distribution: As of June 2008, Maui DWS has given out 31,671 low flow showerheads, 30,536 bathroom aerators, 18,636 kitchen aerators, 16,948 self-closing hose nozzles, and many more leak detection dye tablets, for a customer base of about 35,000 meters. Despite what would seem like high market penetration, estimated savings based on these giveaways is only about half a million gallons per day. More aggressive fixture distribution programs under consideration include audits and direct install programs, as well as rebates and incentives for larger appliances.

- Audits/Retrofits: Maui DWS co-funded its first direct install retrofits in the late 1990s with low flow toilets. However, no large scale programs were funded. More recently retrofit trials of high efficiency toilets have been started. Ongoing retrofit trials include:

- Ka Hale A Ke Ola - a homeless resource center with about 70 units and two dormitories. Seventy-four toilets, two urinals, 76 showers and 76 faucet aerators will be replaced with the most water efficient products available.

- Hale Makana O Waiale - a low income housing complex with 200 units. Two hundred showerheads, 200 bathroom and kitchen faucet aerators will be replaced with more water efficient models.

- All of Maui DWS's properties and the 5th and 9th floors of the county building will be retrofitted with 10 waterless urinals, 22 dual flush toilets.

- Maui DWS staff is working with the Maui Parks Department staff to retrofit aquatic facilities with more efficient fixtures and conserve water other ways.

The County of Maui Water Use & Development Plan update is in progress. The plan evaluates the costs and benefits of high efficiency fixture rebates and direct installation programs. Ongoing trials will help to provide some preliminary data on the effectiveness of some of these options. Longer term options for the future may also include review of various means of sub-metering multi-family units and multi-purpose buildings. Studies indicate that metering un-metered units is among the most effective of conservation measures, by billing explicitly for use rather than hiding this cost in the rent.

Conservation Pricing: Maui DWS currently has a tiered rate structure to encourage conservation. Data improvements under way could enable Maui DWS to move toward a more aggressive tier structure.

Regulation: Maui County has the following existing regulations and rules that support conservation: 1) Prohibition of discharging cooling system water into the public wastewater system; 2) Requirements that low flow fixtures are required in new development; 3) Requirements that all commercial properties within 100' of a reclaimed water line utilize reclaimed water for irrigation and other non-potable uses; 4) A water waste prohibition with provision for discontinuation of service where negligent or wasteful use of water exists; 5) A provision enabling the water director to enact special conservation measures in order to forestall water shortages. In addition, a comprehensive conservation ordinance has been drafted, and may be implemented in stages. Discussion with various consultants about how to phase such implementation is under way. Though the draft is fairly comprehensive, initial provisions enacted may focus on simple measures which have been proven effective - such as limited landscape watering days.

Education and Behavior Modification: Conservation marketing efforts include advertisements run on all local radio stations and newspapers to encourage water conservation. The permit review process is also utilized as an educational tool, with use-specific conservation tips and location-specific landscape tips included in each review. The Department participates in about 25 public events per year, such as the County Fair, Earth Day and Taro festivals. In order to provide an ongoing educational facility with demonstration and participatory learning, Maui DWS funds the operations of the Maui Nui Botanical Gardens.

Expanded education and marketing efforts under consideration include targeted marketing survey and campaign development, a hotel awards program, a building manager users group, and an agricultural users group.

Landscaping: Maui DWS co-funds operations of the Maui Nui Botanical Gardens and funded construction of its nursery and portions of other facilities and displays. This provides a resource for promoting expertise in propagating and maintaining native plant materials, helps to increase the potential marketability of appropriate plants, promotes a conservation ethic, provides training on appropriate propagation, planting, irrigation and maintenance techniques, and generally helps to increase the likelihood of successful appropriate landscapes with a "Hawaiian Sense of Place". It also helps to protect watersheds by promoting native and non-invasive plants over potentially invasive species, providing for educational opportunities on the importance of the watershed and how to protect it, and serving as a major demonstration and educational facility. The nursery is also a source of native plants for DWS outreach projects and give-aways. Maui DWS developed (with help from the arborist committee) a brochure entitled “Saving Water in your Yard, What and How to Plant in your Area”, which is distributed by the Maui Nui Botanical Garden and the DWS at events and through the permit review process. Future plans for landscape conservation include a conservation ordinance, landscape audit and retrofit program and smaller satellite demonstration projects. Maui DWS is also investigating the costs and benefits of major capital expenditure in reclaimed water transmission to offset use of potable water in South Maui landscapes. The pending conservation ordinance includes mandatory watering schedules and irrigation efficiency measures among other requirements.

Ongoing Planning Efforts: Source options considered as part of the County of Maui Water Use and Development Plan process will include consideration of extensive conservation measures as a source supply. In order to displace or delay source development, an aggressive program is required. Preliminary design of such a program is ongoing as part of the Water Use & Development Plan process. Anticipated program elements include targeted audit and direct install programs, rebates and incentives, expanded conservation requirements for landscaping and other uses, expanded marketing efforts including user groups, such as a hotel awards program, a building manager information program, agricultural user working groups/services, as well as energy production and efficiency measures, continued watershed protection and restoration, and possible major capital expenditure to support reclaimed water use.

7.4.3.2. Honolulu Board of Water Supply Conservation Program

The Honolulu BWS manages an integrated island-wide water system that serves all parts of Oahu. The system pumps an average of 150 million gallons of groundwater per day from wells, shafts, and water tunnels. To protect the long-term viability of ground water resources on Oahu, the Honolulu BWS has adopted an integrated approach to ensure a sustainable water supply, by balancing the needs of the community, the economy, and the environment.

Pursuant to the goal of sustainability, the Honolulu BWS's water conservation program seeks to foster effective water management policies and practices that reduce per capita use of potable water through resource management, supply system optimization, and consumer education. The program applies the following strategies:

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

The Honolulu BWS conducts extensive outreach and educational programs and participates in community events to promote resource protection and increase collective awareness of the importance of water. The Honolulu BWS strives to assist in the development of water awareness and implementation of conservation efforts through educational programs that can be described under four program headings:

- **Public Education Program:** This program targets both adults and children through printed materials, the Water Conservation Week Contest for elementary school children, public service announcements and television/radio/print interviews, public speaking engagements, and participation in a number of community events and activities. Group tours of watershed areas, the Halawa Xeriscape Garden, and the Honouliuli Water Recycling Facility are also offered.

- **School Education Program:** Teachers and students from preschool through high school are provided with publications, brochures, and other media explaining Oahu's water resources. Water conservation information, statistical reports, and summaries are also provided. Other publications provide students with a comprehensive understanding of water and water systems nationwide. The Honolulu BWS sponsors a Water Conservation Week Poster Contest for public and private elementary schools on Oahu, and participates in the Hawaii State Science and Engineering Fair by sponsoring water quality and water conservation awards. Classroom visits and speaking engagements are also done by BWS staff.

- **Watershed Education Program:** This program is designed to teach people in the community about the importance of healthy watersheds to replenish ground water resources. Watershed and forest protection, active stewardship of the land, and public and private partnerships are emphasized. Participants include State, City and County of Honolulu agencies, community groups, and school and environmental organizations.

- **Community Education Program:** Community education efforts include the Honolulu BWS Neighborhood Board Liaison Program, which encourages grass roots involvement and relationships between the Honolulu BWS and Oahu communities. Volunteer neighborhood representatives have a personal Honolulu BWS contact for information, concerns, and inquiries. The Honolulu BWS participates in community events such as the Aloha Fun Run/Health and Fitness Fair, Building Industry Association Show, Food and New Products Show, Farm Fair, and City-sponsored "Sunset" events (e.g., Sunset on the Beach, Sunset on the Plain, Sunset in the Park).

The Honolulu BWS provides assistance to watershed partnerships, agencies, and organizations through the Watershed Management Partnership Program. Project proposals for grant awards are submitted to the Honolulu BWS for consideration. To be eligible for the program, projects must be located on Oahu and should be relevant to watershed studies, watershed resource protection, educational outreach for watershed management and protection, invasive species control, forest protection, or water conservation activities.

The Honolulu BWS also utilizes the agency's website for conservation education and outreach. The "Kid's Corner" page includes interactive, educational activities designed for children. The website's conservation page includes information and links for consumer conservation measures inside and around the home, information on the Ultra-Low Flush Toilet Rebate Program, xeriscaping resources and planting guide, and a registry of nurseries that grow "less thirsty" plants.

The agency also provides a Water Waste Hotline (808-748-5041) for the public to report broken water pipes, a malfunctioning irrigation sprinkler, faucets left running, or other water waste.

7.4.3.3. Kauai Department of Water Conservation Program

The Kauai Department of Water (DOW) operates 13 separate, unconnected water systems from Kekaha to Haena. Kauai DOW pumps water from 48 underground wells and tunnels and stores it in 43 tanks. Nearly 18,000 accounts are served through 400 miles of pipeline. Many of the water systems date back to the plantation era, and some pipelines are 80-100 years old. Most of the water that is provided to the department's customers is from ground water sources. Hanamaulu and Lihue receive a portion of their water from surface water sources. A new water purification facility uses a microfiltration system to treat surface water for drinking.

Information on conservation measures and other public outreach materials listed below are accessible through the Kauai DOW's website:

- Water conservation brochure, "35 Tips to Save Water";
- Table tents for restaurants, "Water served on request only";
- Free low-flow water fixtures;
- Tips for conserving water around the house and outdoors;
- Leak detection and instructions on fixing a leaky faucet;

- Xeriscape resources and information on DOW's demonstration project at the agency's Lihue office;
- Kids page with educational activities; and
- Public education programs for schools, clubs, and organizations.

7.4.3.4. Hawaii County Department of Water Supply Conservation Program

The County of Hawaii's Department of Water Supply provides domestic water service via 24 water systems and 67 sources located throughout the island. The individual water systems are not interconnected, except in the more densely populated districts of South Hilo and Kona. The Department of Water Supply services approximately 35,000 customers with about 8.5 billion gallons of water annually.

The Hawaii County water rates are designed to encourage conservation through an inverted-block rate structure, which charges higher unit costs for heavy water users. The Department of Water Supply has also published educational brochures and handouts that are available to the public. During periods of drought or low rainfall, the department may publish water conservation notices in local newspapers and include notice inserts in customer's water bills. These notices typically call for a voluntary reduction of domestic use by 10% and restrict agricultural irrigation to the hours between 8 p.m. and 6 a.m. Water conservation notices also includes tips on how to reduce water to meet the 10% voluntary reduction. If subsequent use reductions are insufficient, the department may issue notices for mandatory use reductions until the water supply situation has stabilized.

7.4.4. Recommendations for Water Conservation Programs

Several State and county agencies currently implement various water conservation program measures. Private businesses and organizations (e.g., Hawaii Green Business Program) have also incorporated water conservation in their daily operations. However, a coordinated conservation program is still lacking. The State should develop a water conservation framework for government agencies and private entities. The following are recommended:

- DLNR should implement the site-specific recommendations of the DLNR Water Conservation Plan. Funds should be sought from the Legislature and DAGS, and other financing options should be pursued, such as rebate programs, performance contracting, and public/private partnerships.
- Government agencies should pursue public/private partnerships to contribute funds, implement and promote water conservation efforts, and increase public awareness.
- The State should encourage water conservation planning efforts in all State agencies, as the State is one of the largest water users across all counties. State agencies should be encouraged to apply the water conservation planning

method described in the DLNR Water Conservation Plan and follow through with plan implementation.

- Existing and developing State agency conservation efforts should be identified in the next update of the SWPP. The SWPP should also suggest specific agency conservation goals and actions.

- Military installations should be encouraged to develop site/facility-specific water conservation plans that expand on the existing general conservation policies of the Army, Navy, and Air Force. Site/facility-specific military conservation plans should delineate conservation goals and present implementation schedules for these measures. The military should undertake conservation planning efforts with sensitivity to local, regional, and statewide water resource management issues and incorporate extensive personnel and public outreach programs to encourage a conservation and stewardship ethic in the context of Hawaii's particular water concerns.

- Water purveyors should encourage large industrial, commercial, agricultural, and institutional users to develop operational water conservation plans and introduce financial incentives to reward users who implement conservation measures and demonstrate reduced consumption.

- The State, as trustee of water resources, should promote and coordinate ongoing water conservation efforts across the state, to provide guidance for businesses lacking conservation programs. Cooperative efforts between the State and counties can enhance program development and expand program application.

- The State Water Conservation Coordinator should manage water conservation plans and initiatives at the State level, including encouraging the designation of a project manager for each facility/site and working with the project manager to develop and implement a plan for each facility.

7.5. Developing a Resource Augmentation Program

To meet future water demands throughout the State, alternative water sources should be developed to augment naturally occurring water supplies. The order in which to pursue development of alternative sources is influenced by local and county-level needs and constraints. In some areas of the state, water availability is limited by the extent and capacity of the pump and distribution system, rather than a scarcity of surface and ground water resources. In other areas, increasing water demands may only be met by augmentation and alternative water sources.

Judicious management of water resources is the primary tool for sustaining Hawaii's people, environment, economy, and lifestyle. Water can be a factor limiting growth and development, and in turn, growth and development can limit and decrease the viability of the resource. Land use planning and water resource planning are thus closely linked.

Resource augmentation must be recognized as an important component in water resource management. Alternative water supplies are renewable, drought resistant, environmentally sound, and socially responsible. Goals and priorities must be established to integrate the use of alternative water resources into daily life, and to encourage the development of these supplies in an efficient and safe manner.

It is the responsibility of the State to encourage and, when necessary, advise county and private-sector efforts to pursue safe and efficient resource augmentation. The development of alternative water resources is challenging. The planning horizon, funding, and the availability of technical resources are major considerations in developing water augmentation sources. Aside from regulatory requirements, Hawaii lacks a program to encourage innovation in augmentation methods and incentives for implementation. The State Water Code states that CWRM shall plan and coordinate conservation and augmentation programs in cooperation with other agencies and entities.[3] The following section reviews various resource augmentation methods and describes CWRM's role as an advisory agency for expansion and further development of augmentation programs statewide.

7.6. Water Supply Augmentation Resources

Hawaii's freshwater supplies have been developed thus far through traditional means, including ground water wells, stream diversion systems, and surface water reservoirs. However, current and anticipated demands for water are outpacing source development and will likely surpass the volumes of naturally occurring ground and surface water. In order to sustain Hawaii's growing population and to meet the needs of industry, the State and county governments must actively pursue alternative water supplies. Alternative water sources should be developed not only to meet certain water demands, but also to help ensure the long-term viability of our ground water aquifers and watershed areas. There are several issues to consider in exploring resource augmentation. They are:

- **Reliability considerations:** The source is vulnerable to drought conditions or seasonal variations in precipitation; there is a dependence on fuel types that are susceptible to shortages or cost inflation; the economical development of the source must have sufficient capacity to meet demand.

- **Quality considerations:** The treatment process must be capable of producing water that can meet increasingly stringent water quality standards; the source should be suitable for the production of drinking water, irrigation water, or industrial water.

- **Efficiency & economic considerations:** The cost of developing alternative water sources in comparison to that of traditional source development must be considered; cost implications of alternative source development in planned stages to meet demand is also important; long-term operation and maintenance costs must be compared.

- **Technology:** An understanding of the history and dependability of related technologies must be gained; it is beneficial to investigate foreseeable advances

[3] HRS §174C-5(12) and §174C-31(d)(4).

in technology; including specialized technology and equipment requirements; public opinions/concerns regarding the technology should be solicited.

- **Environmental Impacts:** Environmental impacts of alternative water source development should be compared to that of traditional source development; utilities need the ability to mitigate negative impacts; it would also be appropriate to compare benefits of traditional source development with alternative source development.

Several alternatives could increase or extend freshwater supplies. Reclaimed wastewater can provide for non-potable demands, including irrigation and industrial applications. Reclaimed stormwater could be used for artificial ground water recharge, environmental restoration, fish and wildlife habitat support, recreation, municipal uses, irrigation, and industrial uses. Desalinated water is well-established as a source of drinking water in other parts of the U.S. and in the Middle East, Japan, and the Caribbean. Other alternatives on the household-level, including the use of grey-water systems and rain barrels for landscape watering, can also help extend freshwater supplies.

The following sections discuss the larger scale alternatives of stormwater and wastewater reclamation and desalination methods to augment ground and surface water supplies. Each method is also briefly evaluated with regard to the issues listed above.
For clarification purposes, the following definitions are offered:

Wastewater reclamation:	*The treatment of wastewater such that it may be used for beneficial purposes.*
Recycled water:	*The useable end product of the wastewater reclamation process.*
Water reuse:	*The beneficial use of recycled water.*

7.6.1. Wastewater Reclamation

Wastewater reclamation has been practiced for decades in the continental United States and other parts of the world, especially in areas where freshwater sources are limited. Water reuse should be viewed as a key component of sustainable water resource management. Recycled water can be a drought-proof and reliable supply of water. It can replace potable water currently being used for non-potable purposes. In some instances, the availability of recycled water has stimulated Hawaii's economic development by attracting business activity. Water reuse also provides a mechanism for nutrients in wastewater to be utilized by vegetation, thereby reducing the need for fertilization. Finally, when compared to the traditional disposal methods through outfalls and injection wells, wastewater reclamation and reuse is recognized as an environmentally preferred method of effluent disposal. While water-reuse applications have grown significantly in Hawaii in recent years, recycled water is still an underutilized resource. CWRM completed the *2004 Hawaii Resource Survey and Report* as the intitial step toward development of a statewide waste-water reuse program. The information presented in this section of the WRPP has been adapted from the 2004 report.

In 1999, approximately 13% of the volume of municipal consumption in Hawaii was attributed to recycled water sources, and this figure continues to increase with the eventual implementation of planned and proposed reclamation and reuse projects. As Hawaii's population increases, wastewater volumes will increase proportionally, creating more recycled water and reuse opportunities. Integration of water reuse into the statewide water use policy will be critical as water demands increase.

Recycled water must meet strict water quality standards set by the Environmental Protection Agency (EPA) and the Department of Health. These water quality standards ensure proper treatment and disinfection, although treatment levels differ depending on the end use. The EPA and DOH regulations require wastewater treatment and encourage the availability and reuse of its by-product, recycled water. In some cases, it may be less expensive to develop recycled water distribution systems than to develop new sources of water and continually pay effluent-disposal costs. While there are significant initial capital costs for communities to develop recycled water distribution systems, the addition of recycled water to municipal water budgets will secure long-term sustainability of communities and economic growth. The typical Wastewater Treatment Plant (WWTP) is a large facility that requires significant amounts of land and operational resources, but smaller scale applications of reclamation technology are becoming more common in subdivisions, and even serve single-family homes. Small and decentralized wastewater management systems provide local solutions for wastewater collection, treatment, and reuse. Such systems also avoid costs associated with transmission of large, regional facilities.

7.6.1.1. Potential Applications for Recycled Water

There are numerous uses for recycled water. Some of the reuse applications listed below are already taking place in Hawaii on a small scale:

- Constructed Wetlands
- Ground Water Recharge
- Irrigation
- Recreational Uses
- Construction-Related Uses
- Recharge of Natural Wetlands
- In-Stream Flow Restoration
- Composting
- Toilet and Urinal Flushing
- Industrial Uses

CWRM completed the *2004 Hawaii Water Reuse Survey and Report* to monitor the utilization of recycled water in Hawaii. The report discusses the existing and potential uses of recycled water appropriate for Hawaii (see Section 7.7.1).

7.6.1.2. Guidelines for Treatment and Use of Reclaimed Water

The DOH issued the *Guidelines for the Treatment and Use of Reclaimed Water* (Guidelines) in November 1993 and updated the Guidelines in May 2002. They are now referred to as the *Guidelines for the Treatment and Use of Recycled Water*. The document identifies requirements for both purveyors and the users of recycled water. The intent of the DOH is to eventually incorporate the Guidelines into Chapter 11-62 of the Hawaii Administrative Rules (HAR).

All projects that use recycled water must first receive DOH approval. The DOH approval process has certain design and site inspection requirements. Purveyors of recycled water are required to keep operational records of the daily volumes and water quality produced by their water reclamation facilities. These records are subject to review by DOH during annual operation and maintenance inspections of each facility.

Maui County is the only county in Hawaii thus far to establish rules for recycled water use. These rules, adopted in June 1997, are referred to as *County of Maui Rules for Reclaimed Water Service.* They incorporate the *State of Hawaii Guidelines for the Treatment and Use of Recycled Water*, the *State of Hawaii Water System Standards,* and Chapter 11-62 of the HAR. The Maui County rules include sections on establishing recycled water service, design standards for on-site and off-site recycled water facilities, operational guidelines, monitoring and enforcement provisions, and fees and charges.

7.6.1.3. Recycled Water Classifications, Definitions, and Allowable Uses

Recycled water is classified as either R-1, R-2, or R-3 based on the level of treatment it has received. The first step in wastewater reclamation is primary treatment, which removes settled or floating solids. In secondary treatment, organic matter is removed, usually through “biological cleansing” using bacteria. Tertiary-treated recycled water is filtered and disinfected to remove up to 99% of impurities and suspended solids. Purveyors of recycled water must meet the treatment and water quality standards summarized below for R-1, R-2, and R-3 waters.

R-1 water is tertiary-treated recycled water that has undergone a significant reduction in viral and bacterial pathogens and meets the highest recycled water standards. R-1 water is oxidized, filtered, and exposed to disinfection processes to remove bacteria and viruses. It is of non-potable quality, but it is deemed safe for human contact. R-1 water is now approved for a number of applications including spray irrigation of golf courses, parks, athletic fields, school yards, residential properties that are managed by an irrigation supervisor, road sides and medians, and for vegetables and fruits that are eaten raw. The number of projects in Hawaii utilizing R-1 water has increased significantly in recent years.

R-2 water is disinfected, secondary-treated recycled water. R-2 water has been oxidized and disinfected; however, the disinfection criteria are not as stringent as that of R-1 water. Therefore, the reuse applications of R-2 water are limited. Spray irrigation using R-2 water is limited to evening hours, and a 500-foot buffer zone between the approved-use area and adjacent properties is required. Several golf courses in Hawaii are irrigated with R-2 water, although some are exempt from the 500-foot buffer zone requirement because they existed before the DOH established the Guidelines. Food crops that are irrigated with R-2 water must be either irrigated via a sub-surface irrigation system or, if irrigated with spray irrigation, must undergo extensive commercial, physical or chemical processing determined by the DOH to be sufficient to render it free of viable pathogenic agents, before it is suitable for human consumption.

R-3 water is undisinfected secondary-treated recycled water, and there are severe limitations on its use. Currently, the Parker Ranch pasture-irrigation project on the Big Island and the Puu O Hoku Ranch constructed-wetlands project on Molokai are the only projects in Hawaii that utilize R-3 water.

Reverse osmosis (R-O) is a method of treatment that is used in wastewater reclamation and in seawater or brackish water desalination. R-O water is wastewater that has undergone secondary treatment, followed by purification through an ultra-fine membrane that allows only water to pass. R-O water is then disinfected prior to use.

A complete list of the allowable uses of recycled water is summarized in the DOH Guidelines under Chapter III – Uses and Specific Requirements for Recycled Water.

7.6.1.4. Wastewater Reclamation Issues and Constraints

In the development of water reuse programs and projects, there are several issues that can delay progress. Certain planning and preparatory efforts must be carried out to address economic issues, legislative constraints, and public acceptance. Jurisdictional and regulatory obstacles, however, cannot be surmounted without first addressing the issue of public perception of water reuse.

To realize success, a water reuse program or project should incorporate the following elements:

1. Gain public acceptance.

2. Encourage cooperative planning among agencies.

3. Overcome regulatory hurdles.

4. Strategize on funding sources.

5. Grow a customer base and encourage demand.

The following sections provide information and strategies for achieving these program elements and for facilitating water reuse projects.

1. Gain public acceptance.

Sound and proactive communication and education programs are essential for water reuse projects and programs to succeed. Failure to educate the public early on may delay or even stop the implementation of water reuse projects or programs.

Two key concepts must be emphasized in public outreach programs:

- *Recycled water can be an important component of the community's overall water supply.* The main reason for implementing water recycling programs is to supplement limited freshwater supplies.
- *Recycled water is safe for approved uses.* The community must gain a basic understanding of how wastewater is treated and made safe through the recycling process. The community may have concerns regarding the safety of using recycled water for landscape irrigation, especially in locations such as parks, school yards, shopping centers, hotels, and condominiums. Proactive public education programs, with emphasis on disinfection, monitoring, and quality assurance, will help the community feel more comfortable with the idea of using recycled water.

Target audiences for education and outreach programs include politicians, schools, the general public, community organizations, and new and potential recycled water users. The educational outreach program described below is based on the County of Maui Department of Public Works and Environmental Management, Wastewater Reclamation Division program, and may be used as a template for other outreach programs throughout the state. The following are examples of outreach methods that are appropriate for each target audience:

Government Officials: A significant amount of time should be expended educating local government officials on the benefits and applications of recycled water through presentations at council meetings and other public meetings. Literature and testimony from local and national water reuse experts are also effective, and personal meetings allow elected officials to ask questions and broaden their knowledge of reuse.

Schools: Educating young people is the best way to establish long-term support for the concept of recycling water, and to develop behavior that will enhance sustainability within the community. Outreach programs should first notify school administration and teachers of the availability of an environmental-education program on water conservation and wastewater reclamation and reuse. Components of the program could include classroom presentations, water quality lab activities, wastewater reclamation facility tours, career-day speaker appearances, and assistance with school science projects. Desktop demonstrations, slide shows, videos, poster boards, and information booklets can be incorporated into the program, along with the distribution of promotional items such as rulers, stickers, magnets, and water conservation kits.

General Public: In addition to printed informational materials and promotional items, the general public can benefit from tours of wastewater reclamation facilities, where information can be shared on-site and face-to-face. Educational videos can be broadcast on community-cable access television, and copies of the video can be made available for loaning upon request. Additionally, press releases announcing improvements and expansions to recycled water programs and facilities and media coverage can help spotlight and reinforce the importance of recycled water.

Community Organizations: Presentations can be developed and shared with community groups such as the Rotary Club and other community associations, the local Chamber of Commerce, hotel and other business associations, and engineering, architecture, and contractor associations, which often have regular meetings and welcome guest speakers. These speaking engagements can be utilized to provide the most current information on recycled water programs, and can encourage public involvement by raising interest and identifying groups who will champion the program.

New and Potential Recycled Water Users: Educational presentations that focus on the production, safety, and proper management of recycled water can be made to the owners, managers, and employees of new and potential water reuse projects. Such presentations should emphasize water quality monitoring of the recycled product, including turbidity monitoring, automatic diversion of substandard recycled water, and fecal coliform monitoring. The presentations should also discuss best management practices and examples of successful local and national water reuse projects. Facility tours should be offered as a follow-up to these presentations, along with educational pamphlets and promotional items.

2. Encourage cooperative planning among agencies.

Water reuse provides benefits in both water supply and wastewater disposal. A common issue encountered by municipalities in the early stages of a water reuse program is the determination of which agency, the water supplier or the wastewater-services provider, will champion and administer the program. Recycled water is the link between water and wastewater. Therefore, no matter which agency takes the lead in the development and operation of a reuse program, the other agency should support the program in some capacity.

To implement recycled water use, county agencies must also coordinate permitting and management actions. For example, designing office and commercial buildings with dual water supplies for the purpose of flushing toilets and urinals with R-1 recycled water represents an excellent opportunity to displace the use of large amounts of potable water. The DOH Guidelines allow R-1 water to be used for toilet and urinal flushing, if the county plumbing code incorporates language pertaining to dual water supplies within buildings. Therefore, all counties in Hawaii should incorporate Appendix “J” of the 1997 version or later of the Uniform Plumbing Code into their respective county plumbing codes. Appendix “J” includes the provisions required to meet DOH Guidelines. Failure to update county plumbing codes for dual water supplies within buildings could result in the DOH denying projects that want to utilize recycled water for toilet and urinal flushing.

3. Overcome regulatory hurdles.

There are at least two state regulatory issues in Hawaii that restrict recycled water from use in potentially high-volume applications. Both of the issues are related to the DOH regulations and are summarized as follows:

1. The DOH Wastewater Branch does not permit the use of R-1 water for single-family lot irrigation; and

2. The DOH Clean Water Branch does not permit the discharge of recycled water into State waters.

In examining the first issue, it should be emphasized that yard and landscape irrigation consumes significant amounts of potable water, and such use can comprise up to 65% of a home’s consumption on the leeward sides of the islands. The DOH Guidelines state that R-1 water may be used for “any form of irrigation served by fixed irrigation system supplied by buried piping for turf and landscape irrigation of a residential property where managed by an irrigation supervisor.” In the past, the DOH has approved the use of R-1 water for multi-family residential developments.

However, the DOH has not approved projects proposing the use of R-1 water for irrigation in single-family residential developments. The Guidelines do not allow the use of recycled water on privately owned single-family residential lots and do not address specific requirements for dual-plumbed, recycled water facilities.

The DOH also is concerned that, even if the irrigation system for an entire single family development is managed by an irrigation supervisor, the agency cannot ensure adequate protection of public health due to insufficient staff. The agency feels that they lack personnel to properly monitor for conditions such as cross connections to the potable water system and overspray of R-1 irrigation water.

Concerns regarding monitoring and R-1 overspray can be addressed through reporting requirements and design requirements for irrigation systems. Future planned communities wishing to utilize R-1 water for irrigation could be required to provide the DOH with periodic cross connection inspection reports by a licensed plumber. Further, the development’s single-family lots should be designed and built with subsurface drip irrigation systems. Maintenance of the common-area irrigation components should be performed by one contractor, and homeowners in the development would be required to use the same contractor for any necessary irrigation system repairs within their property.

As for the second issue regarding the discharge of R-1 water to State waters, it should be noted that recycled water is commonly used on the continental U.S. and in foreign countries for recharging natural wetlands and for instream flow restoration. The U.S. Bureau of Reclamation encourages the use of recycled water for these purposes. In Hawaii, this type of application of recycled water is not permitted as it is considered an unauthorized discharge to State waters.

Chapter 11-54-04 of the HAR, which lists the basic water quality criteria, also states that all waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including substances, or conditions or combinations thereof, in concentrations which produce undesirable aquatic life. The DOH Clean Water Branch’s primary concern with the use of recycled water for recharging natural wetlands or restoring stream flows is that nutrients in the recycled water could result in excessive algal growth in the receiving waters.

The nutrient levels in recycled water can be reduced through a process called anoxic zone biological nutrient removal. Wastewater recycling facilities can be designed or retrofitted with anoxic zones that significantly reduce nitrogen and phosphorus concentrations in wastewater. Maui County has added this nutrient-removal process to the treatment at all three of the County’s wastewater reclamation facilities.

In order to move toward expanding the use of recycled water for environmental purposes, the DOH should amend HAR Chapter 11-54-04 to allow nutrient-reduced, recycled water to be discharged to natural wetlands or streams. The DOH could establish maximum nutrient levels for recycled water, as well as institute other constraints on the location, means, quantity, and frequency of discharge. In many cases on the continental U.S., recycled water has improved the water quality of wetlands and streams that have been compromised by drought, urban-stormwater runoff, and other pollutants.

4. Strategize on funding sources.

To find effective funding sources, an understanding of the economics of recycled water must be attained. An important component of implementation of water reuse programs is to determine how to pay for recycled water reuse projects. Water reuse projects in general, with the development of recycled water distribution systems in particular, are expensive to construct and operate. The revenues earned from selling recycled water are often insufficient to pay for the full capital and operating costs associated with the production and delivery of the recycled water. This is especially true if the recycled water purveyor sets the recycled water rate comparable to the user’s existing water rate. Setting recycled water rates at levels that will allow the purveyor to recover the full capital and operating costs of the recycled water system will most likely result in rates that are significantly higher than the rates paid for traditional water sources. Thus, there would be no economic incentive for a user to convert to recycled water.

Rather than laying the entire financial burden on the recycled water user, it is preferable to spread the cost of financing water reuse projects. There are four main potential sources of funds for water reuse projects:

- Recycled water users
- Potable water users
- Sewer users
- Government grants

Fees from recycled water users can be charged through recycled water rates (dollars per thousand gallons of recycled water used) or through direct, up-front payment of a portion of the project costs. These up-front payments are called assessment fees, capacity fees, connection fees, impact fees, or system-development fees, but they all basically represent a “joint venture” between the recycled water purveyor and the user to pay for all or a portion of the capital costs of the project.

Potable water users may be charged an appropriate portion of recycled water project costs, if they benefit from the implementation of the recycled water program (e.g., if water reuse results in reduced chances of potable water rationing). Similarly, sewer users may be charged a fee for water reuse projects if they receive benefits from reuse. Because future injection wells or outfall discharges of effluent in Hawaii may be limited in the future by regulatory agencies, water reuse becomes an acceptable alternate disposal method, and it is appropriate for sewer users to pay for a portion of water reuse projects.

Government grants currently represent an unlikely source of funds, due to limited state and federal budgets, but recycled water purveyors in Hawaii should be vigilant in the search for potential sources of government grants from various state and federal agencies. (Government loans are not considered sources of funds because they must be repaid. They do, however, represent a low-cost method of obtaining construction funding and are desirable for that reason.)

A good way to encourage reuse and public support of any fees associated with a reuse project is to develop the rate structure and fees with significant community input. A successful example is the County of Maui’s recycled water rate structure. The community-based committee formed to help develop the rate structure consisted of representatives from large landowners, the Maui Chamber of Commerce, the Maui Hotel Association, the Maui Realtor Association, members from the County of Maui's Wastewater Reclamation Division and Department of Finance, and the County's consultant. The committee decided upon a "composite" rate structure for its water reuse program that identified three main user classes: Major Agriculture ($0.10 per thousand gallons), Agriculture, including golf courses ($0.20 per thousand gallons) and All Other ($0.55 per thousand gallons). The recycled water rates were set to levels that were somewhat less expensive than the conventional alternative water sources used by the three user classes. Connection fees and meter fees were also developed. Because effluent disposal was an important factor driving Maui's water reuse program, sewer user rates were also slightly increased.

Maui's approach has allowed recycled water to become an attractive non-potable water source because it is less expensive than conventional alternative water sources. At the same time, sewer users help pay for the water reuse program because it is believed that they must be held responsible for not only the collection and treatment of wastewater they produce but for its ultimate disposal, whether it be through injection wells or though water reuse. It is recommended that recycled water purveyors in Hawaii attempt to recover the capital and operations cost of their respective water reuse programs by having recycled water users, sewer users and potable water users all contribute through their bimonthly user fees.

5. Grow a customer base and encourage demand.

Ordinances that require commercial properties to utilize recycled water for irrigation or other purposes have been used in several states to establish a strong customer base and maximize recycled water usage. Mandatory use ordinances are established because of a shortage of potable water resources or due to environmental problems associated with effluent disposal. Several cities in the continental U.S. have passed ordinances as part of their water reuse programs. Thus far, Maui County is the only county in Hawaii to have a mandatory use ordinance in place. The DOH Wastewater Branch attempted to establish such an ordinance in 2001, but it was not approved by the Legislature.

Maui County's mandatory use ordinance was passed in 1996, primarily as a means to reduce the use of injection wells for effluent disposal, and secondarily to proactively supplement the limited potable water supplies within the County. Although the bill was eventually passed, it faced substantial opposition from some landowners, and an extensive public education and outreach effort was required. The ordinance required commercial properties within one hundred feet of the County's recycled water distribution system to connect to the system within one year of the system's availability, and to use the recycled water for irrigation. Thus, the ordinance was successful in reducing effluent, supplementing the water supply, and building a broad customer base for recycled water.

The passage of mandatory use ordinances in the other three counties could accelerate the development of water reuse programs. The DOH could also propose a statewide, mandatory reuse ordinance to support the agency's goal of increasing Hawaii's recycled water use. For an ordinance to be passed at the State or county level, a comprehensive, educational effort should be undertaken as early as possible to convince lawmakers and the general public of the many benefits such an ordinance can provide. At a minimum, any proposed mandatory use ordinance should contain sections on connection requirements, cross-connection control measures, an inspection policy and penalties for violation, system-reliability requirements, water quality requirements, and fees and rates for recycled water service.

7.6.1.5. Evaluation of Wastewater Reclamation

Wastewater reuse in Hawaii is being aggressively implemented in some parts of the state, namely Maui County. However, wastewater recycling is not a priority in other areas. As stated earlier, the integration of water reuse into the statewide water use policy will become more critical as our potable water demands increase. CWRM completed the *2004 Hawaii Water Reuse Survey and Report* as the initial step in the development of a statewide, wastewater reuse program. The report inventories and describes existing reuse projects in the state, and more importantly, identifies opportunities for future reuse projects in Hawaii.

The program elements and strategies discussed above for developing and expanding reuse programs and the results of the *2004 Hawaii Water Reuse Survey and Report* should be incorporated into a guidance document to assist county reuse initiatives. Recycled water remains an underutilized resource with many opportunities for expansion.

7.6.2. Stormwater Reclamation

Stormwater flows are part of the urban water cycle. Stormwater consists of the runoff water from the impervious surfaces in cities and developed areas, such as streets, sidewalks, roofs, parking lots, and other areas where water cannot percolate into the subsoil.

Stormwater reclamation, sometimes referred to as rainwater harvesting, can potentially provide water for numerous uses. Non-potable water demand for uses such as irrigation and flush toilets can be supplied by reclaimed stormwater. Many communities in the southwestern region of the U.S. already incorporate stormwater reclamation and reuse into green buildings and developments. The lack of water sources in these areas has made stormwater reclamation an important component of water resource planning and management.

In addition to the various use benefits, stormwater reclamation reduces the amount of pollutants that are deposited into waterways and nearshore waters, and also provides for flood control and containment. Since most urban areas are already applying programs for flood control and the reduction of non-point source pollution, stormwater reclamation and reuse can be viewed as a sensible extension of the urban water cycle. These flood and pollution controls could help provide an alternative water source for non-potable demands.

Stormwater quality can vary dramatically depending on the rainfall amount, frequency, and collection location. Contaminants such as petroleum products, fertilizers, and animal feces are picked up by stormwater runoff. Therefore, stormwater reuse applications require different treatment levels, depending on the risk of public exposure to the recycled water. Secondary treatment with disinfection removes solids and organics, and produces recycled water of adequate quality to meet many non-potable water demands. Tertiary treatment (which removes nutrients) may be required for applications where people are more likely to come in contact with the recycled water. The risk of exposure to pathogens and contaminants is further reduced through measures such as regular pipe and system maintenance, reliable disinfection, application controls, and crop-irrigation restrictions.

County and public health agencies ensure the protection of public health through management programs that delineate risk-reducing management and monitoring actions. In addition to treatment and disinfection requirements, stormwater reuse programs provide rules and recommendations for application methods. For example, stormwater reused in irrigation may need to be applied through sub-surface drippers, rather than surface sprinkler systems. Futhermore, irrigation may be restricted to non-food crops.

Another risk-reducing management action is to provide guidelines and rules for stormwater reuse in various soil types. Soil influences the effect that nutrients, salts, heavy metals, and organic hydrocarbons may have on the environment and nearby surface water bodies. It may be necessary to implement controls to prevent excess irrigation runoff from entering nearby streams or the ocean.

7.6.2.1. Methods for Stormwater Reclamation

On the household scale, rain barrels can be used to collect, store, and distribute stormwater in landscaping. Rain gardens, or vegetated infiltration basins, constructed in the vicinity of the home to take advantage of natural site drainage patterns are another means of containing stormwater runoff that facilitates infiltration. These methods of stormwater reclamation can be classified as “source reuse” and “small lot reuse” technologies. There are five categories used by the U.S. Bureau of Reclamation (Reclamation) to classify stormwater runoff reclamation technologies. Table 7-1 lists and describes each of these technologies.

Water-impounding reservoirs, which are regulated by DLNR’s Dam Safety Program, have been used for irrigation and flood control purposes in a few areas across the state. These include Hawaii County’s Waimea Reservoir, Kauai’s Wailua and Kapahi Reservoirs, the Waikamoi and Olinda reservoirs on Maui, and the Wahiawa reservoir on Oahu.

In the past, a number of projects were envisioned to impound surface water for treatment and domestic use. Although these projects were not completed, the Kohakohau River Dam project on Hawaii and the Kokee Water Project on Kauai were two outstanding project ideas. Proposed surface water impoundment projects, however, can significantly impact the environment and ecosystem. For example, the diversion of water from its natural course or the construction of a dam would have direct and cumulative impacts on stream flows, aquatic habitats, riparian habitats, land use patterns, public health, farming operations, and other downstream and stream-related uses. However, proper planning, site selection, design, construction, and operation of an impoundment facility could be appropriate for certain areas, allowing the capture, containment, and treatment of stormwater to provide for non-potable demand. With this benefit in mind, programs for dam safety, flood control, and stormwater capture should be designed to be mutually complementary.

Table 7-1: Stormwater Reclamation Technologies

Technology	Description
Source Reuse	Use rain barrels or cisterns to collect precipitation or stormwater runoff at the source to provide water for a variety of non-potable purposes or, with treatment, potable water.
Small Lot Reuse	Manage precipitation or runoff as close to source as feasible. Examples: infiltration planter boxes, vegetated infiltration basins, eco roofs (vegetated roofs), porous pavements, depressed parking lot planter strips for biofiltration, narrowed street sections with parallel or pocket bioswales.
Stormwater Capture	Employ ditches, storm drainage system interception, dry wells, infiltration galleries, and injection wells to capture stormwater.
Stormwater Storage	Use aquifer storage and recovery, stream-bank storage, detention basins, and surface reservoirs to store stormwater.
Stormwater Distribution	Distribute stormwater via gravity ditch or pipe networks, operated/regulated ditch systems, pressure pipe networks, onsite wells.

Source: CH2MHill. *Hawaii Stormwater Reclamation Appraisal Report.* Prepared for the U.S. Bureau of Reclamation and the State of Hawaii Commission on Water Resource Management. July 2005

Related to stormwater impoundment are other types of structures used to facilitate stormwater infiltration into the subsurface. These structures are sometimes built primarily for the purpose of artificially recharging ground water aquifers. Artificial recharge is the process by which the natural infiltration of surface water or precipitation into a ground water body is supplemented by infiltration induced by man. It is typically accomplished via three methods:

- Water spreading
- Infiltration pits, shafts, or tunnels
- Injection or disposal wells (sometimes called recharge wells)

Water spreading promotes the recharge of ground water aquifers by encouraging infiltration. Water is spread over a large surface area and allowed to percolate into the ground. This can be accomplished by diverting runoff into shallow basins or depressions, ditches, or open irrigation systems. Another method of water spreading is to build dams across stream channels, in order to increase the wetted perimeter and spread the stream over a larger cross section of the stream channel and banks.

Where space is limited or in areas where impervious layers near the surface tend to restrict the infiltration of water, artificial recharge is achieved by diverting water into infiltration pits, shafts, or tunnels. These excavations are used to either penetrate the impervious layer or to provide direct access to the ground water body.

In the 1990s, numerous injection (disposal) wells were constructed throughout the state. The primary purpose of these wells is to dispose of stormwater runoff, and the amount of recharge that results from these disposal wells is uncertain.

Throughout the era of sugar and pineapple plantations, artificial recharge was incidental to irrigation practices, but in some areas contributed largely to ground water recharge. Leakage from reservoirs and ditches, together with percolation from irrigated fields, constituted a considerable amount of recharge. Some agricultural users returned excess irrigation water to the ground water sources. For example, the McBryde Sugar Company formerly recharged the ground water body beneath Kauai's Hanapepe River Valley through a system of tunnels and shafts. At one time, it was hypothesized that return irrigation water was responsible for greater than 60% of the total recharge. However, a 1987 study by Mink and Yuen indicated that the figure was closer to 40%. Since the agriculture industry has shifted from plantations to diversified agriculture and some former crop lands have been developed for non-agricultural uses, the amount of water being applied for irrigation has decreased significantly, and it remains to be determined how the change in land use has affected ground water recharge.

The disposal of stormwater in wells, pits, and tunnels currently contributes very little recharge to our ground water supply. Regulations restrict the construction and use of injection wells for storm water disposal to coastal areas to avoid potential contamination of drinking water aquifers.

Several reservoirs, such as the Waiawa reservoir, probably lose some seepage to the ground water body, but supporting hydrologic data is not available. The Honolulu BWS operates four open reservoirs in Nuuanu Valley, but it is doubtful that seepage from these reservoirs reaches the basal water body. A formal evaluation of the risks, impacts, costs, and benefits of an artificial recharge program using stormwater should be conducted before it is further considered for resource augmentation.

7.6.2.2. Urban Runoff Recycling: A Model Facility

The first full-scale, dry-weather, stormwater runoff recycling facility began operating in Santa Monica, California in December 2000. This project is truly innovative, because it contributes to the Santa Monica's Sustainable City Program goal of reducing urban runoff into the Santa Monica Bay. It also provides a significant public education opportunity that takes advantage of the plant's location in the tourist area near the Santa Monica Pier.

The Santa Monica Urban Runoff Recycling Facility (SMURRF) is an outstanding example of how a public facility can be constructed to integrate educational and art components that are responsive to the immediate neighborhood, and serve to enhance community pride. The facility is open to the public and is designed to move visitors through the plant via an elevated walkway, descending from one end of the site to the other, also providing an alternate access to the beach. Each piece of equipment is emphasized with a prominent base, dramatic lighting, and colorful tile work, and the visitor is directed past the plant components in a logical manner. Visitors are able to observe the results of the treatment process at five locations throughout the plant, and information plazas teach visitors about the workings of the facility, the local urban watershed, and the public's role in preventing stormwater pollution. By investing in architecture, landscaping, and art, the project was successfully integrated into the lively atmosphere of the Santa Monica Pier, while showing a sense of respect for the local community and achieving a positive effect on public perception in the community and among the governing bureaucracy.

SMURRF uses conventional and advanced treatment components to remove debris, sediment, oil, grease, and pathogens from stormwater collected by the city's storm drain system. The plant can treat a maximum of 500,000 gallons per day (gpd) of runoff from a 5,100-acre drainage area that produces stormwater flows averaging 265,000 gpd. The treatment processes include: coarse and fine screening to remove trash, plant material, and debris; degritting systems to remove sand and grit; dissolved-air floatation to remove oil and grease; microfiltration to remove turbidity; and ultraviolet radiation to kill pathogens. The treated product water meets the standards of the California Department of Health Services and California's Title 22 requirements. The treatment train was recommended because it was able to meet current reclaimed water requirements, while allowing for future expansion with reverse osmosis, to meet ground water recharge requirements.

The product water is distributed for landscape irrigation and flush toilets. Landscape-irrigation water is provided to street-median landscaping, city parks, and a cemetery. Dual-plumbed customers using the product water for indoor use (flush toilets) include the City of Santa Monica Public Safety Facility and the City's Water Garden.

The project was funded by the City of Santa Monica, the City of Los Angeles, the State of California Water Resources Control Board, the Metropolitan Water District, Federal Intermodal Surface Transportation Efficiency Act grant funds, and Los Angeles County Proposition "A" grant funds. Capital costs totaled $9 million: plant costs totaled $6.3 million, and distribution system costs were $2.7 million. Approximately $2 million of the plant costs are attributed to the 500,000-gallon concrete storage tank, which had to be designed and constructed for tight site considerations (with one side of the tank serving as a retaining wall for a freeway onramp). Approximately $750,000 of the plant cost can be attributed to architectural components designed to incorporate public art and education. The actual cost of the stormwater treatment system is estimated at $2.9 million ($5.80 per gallon).

7.6.2.3. Stormwater Reclamation Issues and Constraints

Stormwater reclamation is not commonly practiced in Hawaii. This section provides an overview of the broader issues related to establishing the economic, social, and technical climate to expand water reuse and develop reclaimed stormwater as an alternative water supply. The discussion below is adapted from the June 2005 *Hawaii Stormwater Reclamation Appraisal Report,* prepared by the U.S. Bureau of Reclamation in cooperation with CWRM, to investigate opportunities for stormwater reclamation in Hawaii (Section 7.7.1 provides a summary of the project).

Demand and Pricing: Reclamation and reuse of stormwater often provides opportunities for multipurpose benefits, for example, flood control and ground water recharge. In many ways, these activities have potential to mitigate impacts of development or provide water supply to maintain or increase traditional land uses such as agriculture. With the exception of some types of urban or industrial runoff, quality of reclaimed stormwater is often good and does not share the same stigmas associated with reclaimed wastewater.

For these reasons, there have not been significant obstacles identified in establishing a market for reclaimed stormwater. With a few exceptions, demand for reclaimed stormwater is primarily a function of scarcity of the resource in general, rather than any particular association with the supply. One significant exception to this finding is use of urban or industrial runoff for drinking water.

At the same time, this appearance of a commodity status for reclaimed stormwater places it more firmly in competition with more traditional methods of supply based on price alone. This must be evaluated case-by-case, but emphasis must be placed on long-term economic benefits associated with reducing the need to establish new sources of supply. In urban areas, increased development may actually increase the potential yield of reclaimed stormwater, without the need to develop new sources, based on changing land use conditions.

Needed Research and Demonstration Studies: It is necessary to establish that public health and safety are maintained with the use of reclaimed stormwater. It is also necessary to proceed in an environmentally sound manner. The areas of greatest concern regarding reuse of stormwater are: potential contamination of aquifers and other potable water supplies by poor-quality runoff, and environmental or habitat degradation resulting from diversion of surface flows from the natural hydrologic regime. From a water quality perspective, urban runoff, particularly associated with industrial processes or transportation corridors, contains the highest concentration of contaminants, often hydrocarbons or heavy metals. In more rural areas, agricultural runoff can carry high concentrations of nutrients, pesticides, and in some areas, salts. Additional research and pilot studies are needed to demonstrate economical methods of adequately treating stormwater prior to injection into aquifers or introduction in potable water systems.

Seasonality: The fundamental challenge of most methods of stormwater reuse is that stormwater is primarily available in excess during the rainy season and most needed in the dry season. Therefore, it must be stored for at least a season, in sufficient quantity to justify the cost of construction of the impoundment. This relationship informs expectations regarding the size of storage needed. The closer beneficial reuse mimics the pattern in which stormwater is available, the less storage is needed. In such a case, the opportunity is primarily one of diversion to an alternate flow path, rather than storage.

Volume: For a reuse opportunity to be successful, the runoff volume that can be consistently collected for beneficial use must be in concert with the demand for water use. In some cases, such as aquifer recharge, it has been assumed that whatever stormwater is available can be absorbed into the aquifer, given an adequately designed infiltration or injection system. In other cases, such as storage for reuse as fire suppression, the amount of collected water is likely to be very small, compared to the expected stormwater runoff. This poses no problem, unless the intent of the opportunity is, for example, to provide flood control, which is not likely to be adequately addressed by such a limited reuse demand.

On the other hand, if the purpose of the opportunity is to provide irrigation to certain crops, a cost-benefit relationship exists between the expected crop yield increase due to irrigation and the cost of opportunity construction. It is important to understand how much stormwater may be available and the related storage requirements to evaluate the efficiency of the reuse alternative.

Timing: A distinction has been made among long-term seasonality, year-to-year hydrologic variability, and large-event conditions. The latter is termed “Timing”, as flood events are, virtually by definition, difficult to adequately capture. Large volumes of excess runoff are available during these infrequent events, but often it is not cost effective to construct storage to capture all that is available. Similarly, to have a positive impact on flooding, capture of a large volume of water is often required; however, it may be difficult to revise such volumes in an efficient way.

Spatial Separation: Hawaii has a complex infrastructure of under-used old drainage and irrigation-conveyance elements that may alleviate the challenge of water transfer from capture point to use. Nevertheless, it may be a significant challenge to improve and maintain such infrastructure to provide reliable transfer water across basin boundaries. Aquifer recharge can also alleviate this challenge by using subsurface connectivity to transmit water to the point of use.

Changing Conditions: Rapid development of urban areas (or, to a lesser extent, changes in agricultural land uses) has the potential to change the stormwater runoff hydrology of a basin, as well as the expected demand for a beneficial reuse. Estimates of the potential impact are only as accurate as estimates of the expected changes.

Sediment: For ambient water quality, habitat development, or potable water use, source water quality and sediment load can be a significant issue. In addition to soil particulates, urban runoff can contain a wide variety of contaminants associated with sediments, including heavy metals and hydrocarbons.

Temperature: Ambient water quality and habitat development often have associated temperature criteria. Releases from reservoirs, which may have stratified conditions, can lead to release temperatures that do not match ambient and seasonal conditions. Alternatively, increasing base flow by infiltration and percolation through ground water can restore more natural temperature management to stream systems.

Capture Location and Mechanism: Stormwater must be captured before it enters a natural stream system. In rural areas, this can present a significant challenge. In most cases, existing irrigation systems may be used to intercept surface runoff along hill slopes. In urban areas, storm drainage systems can be intercepted before the outfalls, but cost and space constraints can make it prohibitive to retrofit facilities.

Area of Application: Some types of uses may require small volumes of water distributed over wide areas. Others may have more localized demands.

Delivery Location and Mechanism: Some uses require subsurface delivery; others may require surface systems.

7.6.2.4. Evaluation of Stormwater Reclamation Methods

In order to thoroughly evaluate the appropriateness of stormwater reclamation practices and the associated infrastructure placement within communities or urban areas, all of the opportunities and constraints described previously must be carefully considered in terms of existing and planned land uses. In Hawaii, stormwater reclamation methods that employ capture and storage technologies would have to be planned, constructed, and operated to ensure minimal impact to streams, riparian environments, conservation lands, water rights, cultural practices, and community lifestyles.

The State, with the help of the U.S. Bureau of Reclamation, has taken the initial step towards the development of recycled stormwater as a water source with the completion of the *Hawaii Stormwater Reclamation Appraisal Report* (2005). The report assesses the relationship between supply and demand of stormwater for reuse opportunities. Specific opportunities are identified, evaluated, and ranked according to considerations in the following areas.

- flood frequency
- runoff volume
- water balance
- changing conditions/land use
- crop demand
- domestic demand
- fire flow
- water quality
- aquifer storage
- aquifer firm yield
- reservoir firm yield

The contents of the report and assessment methods are discussed in more detail in Section 7.7.1.

7.6.3. Desalination

Desalination can remove dissolved minerals, including but not limited to salt, from the source water. Seawater, brackish water, or treated wastewater can be processed through several desalination methods: distillation, vacuum freezing, reverse osmosis, and electrodialysis. Distillation and reverse osmosis are the more popular methods, and significant advancements in these technologies have been made since the 1980s.

Desalination plants can process a variety of input water, or feedwater types. Seawater can be taken up through offshore intakes or wells drilled into the beach or seafloor. Brackish ground water, which is generally less costly to process, and reclaimed water are other sources of feedwater. Pretreatment and post-treatment processes are also used for disinfection and elimination of other types of pollutants, including microbes and pathogens.

A variety of pretreatment processes are used to remove materials that interfere with desalination. Biocides, usually chlorine solutions, are used to remove algae and bacteria. Ozone or ultraviolet light treatments can be used to remove marine organisms. Some distillation plants must remove metals from the feedwater to prevent system corrosion. Reverse osmosis membranes can be impaired by chlorine, suspended solids, and particles. Thus the feed water must be further pretreated with dechlorination techniques, coagulation, and filtration.

Desalination plants that produce water for domestic use have post-treatment processes to ensure that the product water meets health standards and recommended aesthetic and anti-corrosive standards. The purity of desalinated product water is usually higher than drinking water standards, and the lack of dissolved solids and minerals creates acid pH levels that are corrosive to pipes. Therefore, desalinated water for municipal use is mixed with water that contains minerals or is otherwise adjusted for hardness, alkalinity, and pH prior to distribution.

7.6.3.1. Methods for Desalination

Common desalination methods can be described in two categories: phase change (distillation) methods, and membrane separation methods. These methods are generally described below.

Thermal Separation Methods

Distillation (Evaporation): Distillation involves heating saline or brackish water until it forms water vapor. This vapor, which is largely salt-free, is condensed to liquid form for storage and distribution. Common methods of distillation are multistage flash, multiple effect distillation, and vapor condensation. Some distillation plants produce freshwater, using a hybrid production process that employs two or more of these technologies. The waste product of distillation methods is a highly concentrated brine solution.

Freezing: This phase-change method is characterized by the formation of ice crystals with the dissolved salts remaining in the solution. Fresh water is produced by separating the ice crystals from the solution and melting the crystals. This process uses much less heat than the distillation method, but it has substantially higher operating and maintenance costs.

Membrane Separation Methods

Reverse Osmosis: Osmosis occurs when water passes through a semi-permeable membrane, separating two solutions of different salt concentrations. In natural osmosis, water moves out of the diluted solution until the concentrations of the two solutions become equal, or when the pressure on the concentrated-solution side of the membrane rises to the same osmotic pressure. The osmotic pressure may be referred to as the osmotic head, or the difference of the depths of the liquid surfaces of the two solutions. When a pressure greater than the osmotic pressure is exerted on the more concentrated solution, reverse osmosis occurs. The result is the movement of water from the more concentrated side of the membrane into the more dilute solution. In the reverse osmosis process, the concentrated solution can be either seawater or brackish water. The osmotic-pressure gradient is induced to move more water into the diluted solution. This water is then collected, stored, and distributed to various users.

Electrodialysis: Salts in solution disassociate into positively and negatively charged ions called cations and anions. Electrodialysis depends on the action of semi-permeable membranes than can selectively pass either cations or anions. When stacks of alternating cation- and anion-permeable membranes are placed in a direct current electric field and feed water is passed between the membranes, the cations migrate to the negative electrode (cathode) and the anions move to the positive electrode (anode). The membranes trap the ions in cells between the membranes, and the resulting solution is removed as waste brine. Water passing through the membranes is collected and removed for use as desalted water.

7.6.3.2. Desalination Issues and Constraints

The issues and constraints associated with different desalination methods are summarized in the following paragraphs. Other issues and considerations may also be relevant depending on the particular site or application.

Thermal Separation Methods

Distillation (Evaporation): Although distillation methods are capable of handling large quantities of saline water, there are disadvantages including, high thermal-energy requirements, high capital costs, high operating and maintenance costs, and severe scaling and corrosion problems. Scaling is a condition that results from the buildup of salt deposits on plant and pipe surfaces, and is caused by the high-salt concentration of seawater. Scaling increases in high-temperature environments, and in distillation plants it results in reduced plant efficiency and greater pipe corrosion. Scales can be removed by chemical or mechanical means and can be reduced by introducing additives to inhibit crystal growth, reducing temperatures or salt concentrations, removing scale-forming constituents, or seeding to form particles. In addition to problems with plant scaling, the intake and outfall structures and pipes can become corroded or fouled with marine organisms, and must be mechanically or chemically cleaned.

Distillation, in some cases, may not be competitive with other desalination methods. In Hawaii, the feasibility of using waste heat from a nuclear-power plant was considered by the Honolulu BWS and Hawaiian Electric Company (HECO) in the 1960s, but it was concluded at that time that the proposal was premature.

Freezing: The freezing method has limited applications, is relatively new, and is capable of producing only up to 100,000 gpd on a practical basis. Although it requires only about 15% of the energy used by the distillation process and results in minimal scaling and corrosion problems, its operating and maintenance costs are high. These costs are incurred in separating the ice from the brine, washing the ice crystals, and melting the crystals to form fresh water. As technology improves, the freezing method may have a future, especially in areas where only poor-quality water sources are available and where large quantities of product water are not required.

Membrane Separation Methods

Reverse Osmosis: Because reverse osmosis requires the use of permeable membranes, the feedwater must be pretreated to remove particles that can build up and clog the membranes. The quality of the product water depends on the pressure, the salt concentration of the feedwater, and the membrane's salt-permeation constant. Water quality can be improved by sending the product water on a second pass through the membranes.

The filters used for pretreatment of feedwater must be cleaned via backwashing, to clear accumulated particles and solids. The reverse osmosis membranes must also be cleaned several times a year with alkaline cleaners to remove organic fouling, and with acid cleaners to remove scale and inorganic precipitates. Membranes must be replaced every three to five years, and replacement procedures require partial or complete plant shut down.

Because reverse osmosis plants operate with lower temperatures, plant scaling is not as serious a problem as in distillation plants. However, reverse osmosis plant intakes and outfalls can also become corroded or fouled with marine organisms, and must be mechanically or chemically cleaned.

Electrodialysis: An electrodialysis reversal (EDR) system has been developed, which reverses the polarity of the electrodes several times an hour. This reversal process minimizes scaling and other adverse effects on the membranes. It should be noted that electrodialysis does not remove bacteria and other uncharged particles. Accordingly, it is necessary to stabilize and disinfect the product water before use.

7.6.3.3. Evaluation of Desalting Methods

Desalting methods must be compared with considerations to economics, location of area of need, availability and quality of feedwater, operational problems, energy demand, quantity and quality of product water needed, and environmental impacts. The most practical approaches for desalination in Hawaii would be electrodialysis and reverse osmosis. For the foreseeable future, we may conclude that Hawaii's municipal needs cannot be met through distillation, freezing, and ion exchange methods, although improving technology may make these methods more attractive in the future.

7.7. State and County Resource Augmentation Programs

7.7.1. CWRM Programs

The State is not a water purveyor, with the exception of small, park facilities and agricultural water systems. The county water agencies currently operate all public, municipal water systems and are responsible for developing municipal water sources. The DLNR Engineering Division is the agency that conducts source development for State facilities that are not on public water systems.

As far as resource augmentation, it is the State's responsibility to encourage the development and maximum beneficial use of alternative water resources. Therefore, the State should provide leadership and guidance to the counties and private water purveyors in the form of goals and priorities established through an integrated resource augmentation program. Such a program would ensure that the pursuit and development of alternative-water sources is executed in an efficient and sensible manner. Such a program would also encourage cooperation, development of implementation incentives, and innovative thinking among State, county, and private entities.

Planning for resource augmentation requires considerable lead-time for research and technical-resource acquisition, pilot programs and testing, and funding attainment. Resource augmentation program goals and priorities should be developed in consideration of a realistic time frame for implementation.

The State has recently completed two efforts toward the planning and development of alternative water sources. The *2004 Hawaii Water Reuse Survey and Report* was prepared to assist in planning efforts for wastewater reuse. In 2005, Reclamation, in cooperation with CWRM, completed the *Hawaii Stormwater Reclamation Appraisal Report*. These projects and the results of project efforts are described below.

7.7.1.1. 2004 Hawaii Water Reuse Survey and Report

The objective of the *2004 Hawaii Water Reuse Survey and Report* is to assist CWRM in understanding its role as a facilitator of water reclamation programs and as a proponent for the increased utilization of recycled water in Hawaii. The report is intended to help CWRM incorporate recycled water into statewide water resource management. It is the policy of CWRM to promote the viable and appropriate use of recycled water in so far as it does not compromise beneficial uses of existing water resources.

The report contains an overview of the current status of water reuse in Hawaii and descriptions of the existing water reuse projects within each respective county. Opportunities for future water reuse projects and ideas for future recycled water applications are also examined. New reuse opportunities, created through expansion of existing recycled water distribution systems, will significantly increase the volume of recycled water that is utilized, thereby improving the economies of scale for reuse program costs. The procurement of funding will determine if, and when, the existing systems will be expanded.

In addition to identifying reuse opportunities, the report discusses obstacles that restrict the growth and implementation of reuse projects, and their possible solutions. Finally, the report provides an overview of federal funding sources that may be applied to the development of reuse projects, and a directory of the existing projects in Hawaii. The report recommends regular updates every five years to inform and assist CWRM in the reuse-planning component of sustainable resource management.

7.7.1.2. Hawaii Stormwater Reclamation Appraisal Report

The *Hawaii Stormwater Reclamation Appraisal Report* was completed in June 2005 by Reclamation in consultation with CWRM. The report documents Reclamation's appraisal-level (planning-level) investigation of potential stormwater reclamation and reuse opportunities under Title XVI Program of Public Law 102-575, as expanded by Section 104(b) of the Hawaii Water Resources Act of 2000 (Public Law 106-566). Title XVI projects include reclamation water reuse and recycling, and Reclamation policy identifies the following uses as appropriate for funding under Title XVI: environmental restoration, fish and wildlife, ground water recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Within those broad categories, more specific uses, particular to stormwater capture and local needs, are identified.

In preparing the report, agency consultation meetings were conducted to collect stormwater reuse opportunity ideas, and this resulted in the identification of 31 opportunities for consideration. In this study, opportunities are specific locations where significant benefits may be gained from pairing supply and demand for reclaimed stormwater. Such opportunities must also be consistent with the goals of Title XVI and the desires of participating stakeholders.

The initial set of 31 opportunities was reduced to nine using a two-step screening process (preliminary and detailed). Preliminary screening criteria included factors such as implementability (institutional, regulatory, and land use), demand constraints, and generalized stakeholder acceptance. Detailed criteria such as operational flexibility, long-term permit compliance, flow augmentation, ground water recharge opportunities, and reuse potential were also considered.

The nine projects that came out of the screening process were evaluated and ranked on the basis of: ease of delivery and operation, dependability of water supply, simplicity of storage and water treatment, institutional considerations, the degree to which prior investment has been maximized, and cost. Specific areas of investigation included: basin land use, vegetation, soil, and slope characteristics; existing irrigation conveyance and natural stream networks; precipitation; expected demand area and size; and hydrology. Institutional factors were also assessed to identify potential direct and indirect effects on the institutional environment closest to the opportunity area. Existing knowledge and threshold-level information obtained informally during the study were used to establish the social and cultural context of the projects. Finally, preliminary cost estimates generated from rough general designs were examined and compared.

The nine candidate opportunities included locations on Molokai, Kauai, Oahu, Hawaii, and Maui. However, feasibility has not been established for all the opportunities described in the study. To move the opportunities toward funding for construction under Reclamation's Title XVI program, several key elements must be addressed:

- Congressional authorization needs to be obtained for Reclamation involvement in conducting feasibility studies.

- A project sponsor must be identified. In some cases, there is already an organization or entity that has taken responsibility for success of the project. In others, discussion with local stakeholders to date has focused on whether the project represents a "good idea" and is valuable and viable. It is vital to this process to investigate interest in ownership and market the opportunities to local groups capable of completing the funding and construction process.

- Owing to the significant nonfederal funding contribution required, additional education and outreach to local stakeholders is needed. In many cases, matching contributions for a project will be allocated by nonfederal, elected representatives. To maximize the chances of success, key constituent groups would have to be identified and approached regarding the potential benefits of the project. Such groups must be given ample opportunity to explain concerns and needs for making the project successful for all involved.

7.7.2. County Resource Augmentation Programs

The following sections describe resource augmentation programs currently administered by the counties, as well as other private projects. The County of Maui has a well-developed and successful wastewater reclamation program. In the City and County of Honolulu, wastewater reclamation and desalination are being championed by the Board of Water Supply. Wastewater reclamation is also being practiced at a smaller scale in the counties of Kauai and Hawaii.

7.7.2.1. County of Maui

Wastewater Reclamation

The County of Maui's Wastewater Reclamation Division is considered to be a water reuse leader in Hawaii. In 1990, Maui County developed a plan and embarked on a long-range program to reuse millions of gallons of a valuable resource, high-quality recycled water, which previously had been disposed into injection wells. To lay the foundation for the county's program, several key components were initiated including: water reuse feasibility studies; a community-based rate study; the creation of a Water Recycling Program Coordinator position; upgrades to the Kihei (South Maui) and Lahaina (West Maui) wastewater reclamation facilities to R-1, tertiary-treatment capability; passage of an ordinance mandating the use of recycled water at commercial properties; adoption of rules for recycled water service; and the creation of a recycled water rate structure, which recovers monies spent on distribution-system development from both recycled water and sewer users.

Program Development: The impetus behind the development of Maui County's water reuse program was a regulatory-agency belief that Maui's effluent-disposal practices were causing environmental problems. The United States Environmental Protection Agency and local environmental groups expressed a concern that injection wells may contribute nutrients that cause alga blooms in coastal waters. In 1995, the EPA placed a limitation on the amount of effluent that could be disposed into the injection wells at the county's Lahaina Wastewater Reclamation Facility (WWRF). This factor played a major role in the passage of the bill, which led to the mandatory recycled water use ordinance on Maui. Increased recycled water use on the island and the results from scientific studies, which indicated that other non-point nutrient sources might be the cause of the periodic alga blooms, have eased this concern somewhat. Nevertheless, effluent disposal will continue to be a factor driving the County of Maui's water reuse program, since most of its wastewater reclamation facilities rely on injection wells. As performance of these injection wells eventually decline, increasing the use of recycled water from the respective facilities, rather than drilling additional wells, may be required by regulatory agencies.

Potable Water Supply: Water supply is now a factor driving the County of Maui's water reuse program. The island of Maui has limited supplies of available fresh water. The island's main water source, the Iao Aquifer System Area, supplies most of Central and South Maui with potable water. Much of this water is used for landscape irrigation at parks, schools, condominiums, hotels and single-family residences. Due to increasing development in these areas, the Iao Aquifer System Area is showing signs of overpumping. Over the past several years, monitoring of the aquifer's wells has indicated that chloride levels are increasing and freshwater levels are decreasing. CWRM recently designated the Iao Aquifer System Area as a Ground Water Management Area. The nearby Waihee Aquifer System Area has also been the subject of designation concerns. CWRM designates water management areas to ensure the long-term sustainability of the resource by establishing administrative control over the withdrawal of ground water in the area.

Recycled Water Infrastructure: Wastewater Reclamation Division uses recycled water from all five of its facilities. Distribution systems have been developed in South Maui and West Maui. South Maui has the most complete distribution system at this time and as a result, the most water reuse projects. The South Maui system now provides recycled water to eighteen separate projects, with more scheduled to connect to the distribution system in the near future. Uses include landscape irrigation, agricultural irrigation, fire control, industrial cooling, composting, construction activities, and toilet and urinal flushing.

West Maui distribution is limited, due to insufficient recycled water storage, but it does service Maui County's largest water reuse project, the Kaanapali Resort. Up to 1.2 mgd is utilized by the resort for golf course and landscape irrigation. Plans are now being developed to expand this system to provide R-1 water to condominiums and hotels in the Kaanapali area. R-1 water is also pumped to Maui

Pineapple Company, but use has been limited due to above-average rainfall since the distribution system was built. Maui Pineapple Company will also phase out pineapple production in west Maui in the year 2006.

In addition to the major distribution systems described above, recycled water is utilized from Maui County's facilities on Lanai, Molokai, and in central Maui. On Lanai, wastewater is processed to R-3 quality utilizing stabilization ponds, and then the entire plant flow of approximately 0.25 mgd is sent to an auxiliary WWRF owned and operated by the Lanai Company where it is upgraded to R-1 quality and used for golf course irrigation. On Molokai, the State Department of Transportation utilizes R-2 water for landscape irrigation along the Maunaloa Highway. Finally, in central Maui, R-2 water is used to irrigate coconut trees and native Hawaiian plants at the Kanaha Cultural Park, which is adjacent to the Kahului WWRF.

Economics: Since water supply and wastewater disposal were both important factors driving Maui County's water reuse program, both recycled water users and sewer users share the costs associated with recycled water production and delivery. A portion of the sewer fees collected from all commercial and residential users of Maui County's sewer system is used to pay for the recycled water program's operation, maintenance, and infrastructure costs. Maui County officials believed that sewer users must not only pay the costs associated with wastewater collection and treatment, but must also help bear the costs of effluent disposal, whether it is through the use of injection wells or through water reuse. This approach allowed Maui County officials to set the price of recycled water at rates that encourage users to connect to the distribution system. The following user classes, with corresponding costs of recycled water, were created:

- Major Agriculture (> 3.0 mgd): $0.10/1000 gallons;
- Agriculture (including golf courses): $0.20/1000 gallons; and
- All Others: $0.55/1000 gallons.

The rates were set at levels slightly below the costs of the water sources typically used by the three recognized user classes. An "avoided cost" category was also created which allows recycled water consumers to pay the same rate for recycled water as they were paying for other non-potable water sources. Connection fees for the south and west Maui areas, where major R-1 distribution systems were developed, were also established to help pay for the recycled water program.

Public Education and Outreach: Proactive public education has played an important role in the success of Maui County's water reuse program. The Wastewater Reclamation Division's Water Recycling Program Coordinator conducts up to 100 presentations per year on water conservation, wastewater treatment, and water reuse to schools, community groups, and the general public. Tours of the County's wastewater reclamation facilities are also provided. In addition, the coordinator issues press releases announcing new projects that use recycled water and expansions to County recycled water distribution systems. Promotional items such as bumper stickers, magnets, rulers and pamphlets are also utilized.

Generally, the public has supported the concept of reusing wastewater within the community. As a result of its proactive approach to public education, the County has encountered little opposition to its water reuse program.

Most of the water reuse projects in Maui County are provided recycled water by the County of Maui's WWRD. There are also private systems, including resorts and housing developments that treat their own wastewater and utilize the recycled water for golf course irrigation. The Pukalani and Makena Golf Clubs on Maui, the Challenge at Manele on Lanai and the Kaluakoi Golf Club on Molokai blend recycled water with other non-potable sources to satisfy their respective irrigation demands.

Lanai has changed its economic base from pineapple cultivation to tourism in recent years. Two resorts, the Lodge at Koele and the Manele Bay Hotel, are located on the island and both recycle their wastewater at their respective golf courses. Water reuse is important on Lanai, because the island typically receives below-average rainfall and Maui County prohibits the use of potable water for golf-course irrigation.

Molokai is lightly populated and one of the least-visited islands in the Hawaiian chain. The bulk of the wastewater produced is treated at the County of Maui's Kaunakakai WWRF and disposed of via injection wells. A small volume is used for landscape irrigation along the Mauna Loa Highway. The Kaluakoi Resort on the west end of the island also recycles its wastewater for use on its golf course.

Puu O Hoku Ranch is located in south-central Molokai in Kaunakakai and recently commenced operation of a constructed wetlands system in the year 2004. The system is relatively small and is designed for only 3,700 gpd. Wastewater is collected from the ranch and treated to R-3 quality using septic tanks, effluent screening, and a constructed wetland. The R-3 water is used to irrigate trees and shrubs via a sub-surface drip irrigation system. The ranch benefits from the improved wastewater treatment capability and the creation of a drought-proof supply of water that satisfies much of its irrigation requirements.

Program Expansion: The County of Maui has two existing R-1 recycled water distribution systems, both of which have the potential to be expanded. The South Maui system is the most complete, as it has recycled water storage both at the Kihei WWRF and offsite at an elevated, covered storage tank. The West Maui system does not have adequate storage, and is thus limited in the number of projects that it can serve.

7.7.2.2. City and County of Honolulu

Wastewater Reclamation

In contrast to the County of Maui, where water reuse has been championed by the municipal-wastewater agency, Honolulu BWS has emerged as the lead agency for water reuse in the City and County of Honolulu. The use of recycled water has increased significantly on Oahu since the Honolulu BWS developed a comprehensive water reuse program in the late 1990s. The Honolulu BWS recognized that recycled water is a resource valuable to extending Oahu's potable water supplies.

Program Development: Most water reuse growth on the island has occurred in the arid Ewa district of southwest Oahu, where significant development has occurred in recent years. Sugar cane cultivation has given way to numerous residential, commercial, and industrial developments. The change in land use has adversely affected the region's water resources. The recharge of the region's caprock aquifer has been significantly reduced by the elimination of sugar-cane irrigation, and the construction of impermeable surfaces. Also, the amount of potable water used in the region has dramatically increased, placing a strain on Oahu's aquifers.

Development in the Ewa area includes: a number of golf courses that use brackish water from the caprock aquifer for irrigation; residential subdivisions, which use potable water for irrigation of yards, parks and median strips; and the Campbell Industrial Park that uses potable water for industrial processes.

Recycled Water Infrastructure: The City and County of Honolulu was required to build the secondary treatment facilities at the Honouliuli Wastewater Treatment Plant (WWTP) to comply with a 1993 consent order by the DOH. The main objective of the consent order was to establish secondary treatment at the plant, and to reuse portions of the treated effluent. Improvements to the facility were completed in 1996, with approximately 2.0 mgd of recycled water being used for in-plant demands. In 1995, EPA, the DOH, and the City entered into a consent decree that required the City to develop a water reuse system that would allow the City to recycle 10 mgd of water by July 2001. The Honouliuli WWTP was selected for implementation of the water reuse requirements, because of the increasing demands on the Ewa aquifer, the reduction of recharge due to the cessation of sugar cane cultivation, and the close proximity of the facility to potential users of recycled water.

The City and County of Honolulu selected Veolia Water North America (formerly U.S. Filter Corporation) to oversee construction, own, and operate the Honouliuli Water Recycling Facility (WRF). Recycled water distribution systems were built to deliver R-1 and R-O water to the potential users. CWRM adopted a policy to champion direct and indirect water reuse in the Ewa plain. Recognizing that recycled water is a valuable resource in the Ewa plain, and knowing that R-1 water would ultimately be available in the area, CWRM issued interim water use permits to the planned golf courses and other nonpotable users in the area, and conditioned these water use permits on conversion to R-1 water once it became available and acceptable for use.

The Honolulu BWS purchased the Honouliuli WRF in 2000 from Veolia Water North America, with the intent of integrating water reuse into a plan to conserve water resources through conservation and the development of new water supplies. The Honouliuli WRF receives secondary effluent from the Honouliuli WWTP and produces both R-1 and R-O grades of recycled water. R-1 water is now delivered to eight golf courses, three parks, and a median strip, where it is used for landscape irrigation. R-O water is delivered to refineries and power generation facilities in Campbell Industrial Park. Hawaiian Electric Company's Kahe power plant and the proposed Campbell peaking power plant are scheduled for connection to the RO water system within the next two years. Veolia Water North America operates and maintains the Honouliuli WRF on a contractual basis, while the Honolulu BWS operates and maintains the distribution system.

Program Economics: The Honolulu BWS has individual agreements in place with its recycled water customers. In general, golf courses and other landscape irrigation customers pay less than industrial customers. The initial rates for R-1 water were set significantly lower than what it costs the Honolulu BWS to produce and deliver the recycled water to the golf courses. Once the agreements expire, the Honolulu BWS may need to increase its recycled water rates, to recover the costs associated with production and delivery. The rate increase may place an economic hardship on the golf courses, and they may decide to revert back to less-expensive caprock wells for irrigation. Irrigation use is allowed, as long as well pumpage remains within permitted allocations and chloride levels in well water do not exceed 1,000 milligrams per liter. If the golf courses do revert back to ground water sources for irrigation, the Honolulu BWS recycled water program could be affected.

Public Education and Outreach: The Honolulu BWS's water reuse program is staffed by a recycled water program manager and three recycled water program coordinators. As in the case with the County of Maui, proactive public education has been an important component of the Honolulu BWS's water reuse program. The Honolulu BWS hired a public relations firm to develop a strategy and promotional/educational items to gain public acceptance of its program. The program's recycled water coordinators play a key role in outreach efforts. The coordinators participate in outreach efforts, conduct numerous tours of the Honouliuli WRF, and provide presentations to the community on a regular basis.

Program Expansion: Water reuse has been successfully practiced on Oahu for decades. The oldest Hawaiian reuse project is at Waialua Diversified Agriculture, where recycled water has been blended with stream water and used for irrigation of sugar cane and diversified agriculture since 1928. Other projects with successful track records include the Marine Corps Base Hawaii Kaneohe Klipper Golf Course, where R-2 water has been used to irrigate the base golf course since 1966, and Hawaii Reserves, Inc., where R-1 water has been used to irrigate diversified agriculture and the athletic fields at the Brigham Young University Hawaii campus since 1995. Most of the growth in water reuse on Oahu has taken place in the Ewa district of southwest Oahu, due to the Honolulu BWS's water recycling program. Of the City and County of Honolulu's eight WWTPs, the Honouliuli and Wahiawa WWTPs are under consideration for expansion. A third facility, the Waianae WWTP on the Leeward Coast, is under consideration for a future water reuse project.

Desalination

Desalination on a municipal scale has been considered intermittently in the past. In the 1960s, the Honolulu BWS conducted studies on the feasibility of desalination using seawater and brackish water. At that time, the estimated cost of desalting brackish water (water containing up to about 1,500 parts per million chloride) was $0.50 per 1,000 gallons, and for seawater, the cost was about $1.00 per 1,000 gallons.

In 2003, the Honolulu BWS completed construction and testing of a seawater-desalination pilot plant that could eventually produce 5 mgd of potable water. The plant is part of the BWS's strategy to diversify water sources, and it is located between Campbell Industrial Park and Barbers Point Naval Air Station in Ewa Beach. The Honolulu BWS intends the desalination plant, which employs reverse osmosis technology, to provide water for drought mitigation and to meet projected water demands for the Ewa and Kapolei areas. When completed, the $40 million facility will contain an administrative building and visitors center, a chemical storage building, a reverse osmosis building, injection and source wells, a brine pond, and parking, as well as an off-site electrical substation.

If brackish ground water is pursued for desalination, the sustainable yield of caprock-brackish water on Oahu is limited to probably not more than 15-20 mgd. For basal-brackish water, the supply is greater, but care must be exercised in the use of this source because of possible jeopardy to the basal ground water body and nearby wells.

7.7.2.3. County of Kauai

Wastewater Reclamation

The County of Kauai has not formalized its water reuse program. R-2 recycled water from three of its facilities is provided at no cost to nearby projects. For years, effluent from County wastewater reclamation facilities was used to irrigate sugarcane. Transmission systems, consisting of ditches and reservoirs, were used to transport the effluent to the sugarcane fields. These same transmission systems are still used today to deliver R-2 water to the Kauai Lagoons Resort and to Kikiaola Land Company. The County now has agreements in place with the Kauai Lagoons Resort and Kikiaola Land Company to accept effluent from the Lihue and the Waimea WWRFs, respectively. The Wailua WWRF's effluent is reused at the adjacent Wailua Municipal Golf Course. This is a convenient situation for both the Wailua WWRF and the golf course, since the County of Kauai owns both facilities. As these projects are the primary disposal sites for the effluent from the County wastewater facilities, the County has no plans at this time to charge for the recycled water.

Kauai has abundant surface water resources, and water from rivers and streams has been diverted through ditch conveyance systems to provide non-potable irrigation water for many golf courses and agricultural projects. As a result, recycled water use at most of Kauai's water reuse projects is considered more of a convenient wastewater effluent disposal option, rather than a water supply resource. A total of six projects utilize recycled water for golf course irrigation. A seventh project at Kikiaola Land Company blends R-2 recycled water from the Waimea WWRF with stream water for seed-corn irrigation.

There are no plans in place at this time to expand any of the County of Kauai's recycled water distribution systems.

7.7.2.4. County of Hawaii

Wastewater Reclamation

The County of Hawaii is developing a water reuse program, and currently provides R-2 recycled water to only one project, Swing Zone Golf Practice Facility in Kona. In this case, the owner of Swing Zone installed the recycled water distribution system from the County's Kealakehe WWRF to the practice facility at his own expense. The County's Wastewater Division is contemplating developing a distribution system to provide recycled water from its Kealakehe WWRF to a number of irrigation projects, including parks and future golf courses. Lack of available funding, however, has delayed implementation of these ideas. Technical-planning assistance has been provided to Hawaii County by Reclamation, to plan and design a proposed constructed wetlands system that will utilize recycled water from the Kealakehe WWRF. Federal authorization is being pursued in Congress for funding of this project, along with two other county water reclamation projects (on Maui and Oahu). Federal funding shall be subject to authorization and subsequent Congressional approval for appropriation of funds on a cost-shared basis.

Water reuse on the Big Island mainly takes place at five private, resort developments where wastewater is treated at resort-owned wastewater reclamation facilities, and then blended with other water sources and reused for irrigation of the resorts' golf courses. Other projects include the State Department of Transportation's Keahole International Airport, where R-1 water is used for irrigation of the airport's landscaping, and at Parker Ranch, where R-3 water is used for pasture irrigation. Swing Zone is a unique reuse project, because the owner installed a recycled water transmission system at his own expense to convey 0.06 mgd of R-2 water to the Swing Zone property, where it is used to irrigate the facility's turf grass.

The County of Hawaii's Wastewater Division is in the planning stages of developing a recycled water distribution system that will utilize recycled water from the Kealakehe WWRF. Phase one, which will satisfy the requirement of a consent decree for the County to use recycled water, involves constructing a pipeline to deliver recycled water to the Honokohau Harbor for landscape irrigation. This phase was to be completed by June 2005, and could also serve a future development by the Department of Hawaiian Home Lands. Phase two is in the design stage, and involves the development of a pipeline and reservoir system that could deliver recycled water to a possible future golf course as well as a future development. The Wastewater Division will continue to attempt to obtain federal funding for a constructed wetlands system to upgrade the Kealakehe WWRF to produce an R-1-quality water system.

7.7.3. Recommendations for Water Resource Augmentation Planning

The State Water Code states that CWRM shall plan and coordinate programs for the conservation and protection of water resources.[4] The Water Code also states that the Hawaii Water Plan shall include programs to conserve, augment and protect the water

[4] HRS §174C-5(12).

resources.[5] Therefore, it is recommended that CWRM act in an advisory capacity, guiding policies and planning efforts for augmentation projects.

The State Water Code also enables CWRM, via conditions placed on water use permits, to require the use of dual line water supply systems in new industrial and commercial developments located in designated water management areas.[6] CWRM should coordinate with county agencies to obtain regular updates for recycled-water service areas and capacities, and apply the dual line water supply system requirement to permit applications within the portions of water management areas served by recycled water distribution systems. CWRM and the DOH should also explore the use and application of gray water and gray water systems, and pursue the development of DOH use guidelines for gray water, to encourage county governments to include provisions for gray water systems in the county planning codes.

It is also recommended that CWRM explore partnerships with governmental agencies and stakeholders in order to coordinate resource augmentation planning and policies. Suggested agencies for involvement include, but are not limited to: water agencies, energy agencies, coastal-management agencies, natural-resource management agencies, economic-development agencies, and public-utility commissions. County water departments, county wastewater departments, county planning departments, DBEDT, DLNR, DOH, Coastal Zone Management program and Special Management Area program administrators, the Bureau of Reclamation, and the EPA should specifically be consulted. Environmental groups, private industry, and economic interests should also be invited to participate in creating a vision for the program. Furthermore, government agencies involved in resource augmentation planning should be encouraged to establish cooperative relationships with professional organizations like the American Water Works Association, the American Society of Civil Engineers, the American Public Works Association, the Water Environment Federation, the American Planning Association, the American Counsel of Engineering Companies of Hawaii, and other such organizations that have extensive industry expertise and skilled, knowledgeable membership bases.

The water resource augmentation planning efforts and policies must be designed to complement the water conservation program recommendations in Section 7.5, and incorporate the intent of these recommendations whenever appropriate. A long-term goal for CWRM should be to establish a resource augmentation planning program and framework to identify augmentation goals, objectives, and priorities to promote the use of alternative water resources and to encourage the development of these supplies in an efficient and sensible manner. Reiterating the assertion noted in Section 6 of the WRPP, land use planning and water resource planning should be accomplished with ongoing, mutual consultation in order to be successful and sustainable.

7.7.3.1. Recommendations for Wastewater Reclamation in Hawaii

It is recommended that the goals and strategies discussed above, as well as the results of the *2004 Hawaii Water Reuse Survey and Report,* should be used by the counties as a guidance document to assist county reuse initiatives. It is recommended that county governments examine the potential recycled water

[5] HRS §174C-31(d)(4).
[6] HRS §174C-51.5(a).

expansion and application projects identified in the *2004 Hawaii Water Reuse Survey and Report*. Counties should use the report to help strategize ways to develop and expand water reuse within their jurisdictions.

Furthermore, counties should include their current water recycling program, or strategies for program development, into subsequent updates of the County WUDPs to maintain consistency with the WRPP.[7] County recycled water rates should be published or made available upon inquiry to users, potential customers, and the general public.

It is recommended that the DOH controls and regulations for the application of recycled water address potential safety and public health concerns, including but not limited to the application of recycled water over potable water aquifers.

7.7.3.2. Recommendations for Stormwater Reclamation in Hawaii

The amount of stormwater runoff from urban areas is indeed significant, as is evidenced by existing storm drain systems and flood control installations. This water could be captured, treated, and applied to beneficial uses; however the feasibility of large-scale stormwater reclamation remains to be assessed.

State regulations are in place to ensure the protection of stormwater receiving waters. The DOH administers the National Pollution Discharge Elimination System and Total Maximum Daily Load programs that regulate the discharge of stormwater. State and county government should encourage the use of stormwater reclamation and reuse measures that could be used to meet some of these program requirements.

The *Hawaii Stormwater Reclamation Appraisal Report* identified possible sites for stormwater reclamation, but these projects may be premature. On the other hand, small-scale reclamation technologies, such as rain barrels, are easily implementable at residences and small facilities. Landscape features, such as rain gardens for infiltration, can also be incorporated into building and parking lot design.

Therefore, it is recommended that county governments encourage the use of small-lot and source-reuse technologies to manage precipitation and runoff as close to the source as feasible, and to provide water for a variety of non-potable uses. Government facilities can provide excellent demonstration sites for these simple technologies. The county could also provide incentives, in the form of water credits or speedy-permit processing, to encourage the implementation of on-site stormwater reuse.

Counties should also examine the potential stormwater reclamation opportunities described in the 2005 appraisal report for future application. Additionally, counties should look beyond the recommendations of the 2005 report in formulating potential local reclamation opportunities, and be able to contribute new or updated information to future report updates.

[7] HRS §174C-31(b)(1).

7.7.3.3. Recommendations for Desalination Programs in Hawaii

Desalination plants are in use in other parts of the country, but it is only recently that technological developments have reduced the costs and energy requirements to be comparable to that of new well construction in many coastal areas of the continental United States. Coastal communities generally lack experience in evaluating the environmental impacts or public-resource issues associated with the construction and operation of desalination plants, and this remains a matter of concern as the number of desalination plants increase.

In 2004, approximately 24 desalination facilities were being planned for various locations along the California coast. Recognizing the need to anticipate information and evaluation requirements for proposed desalination plants, the California Coastal Commission published a report in March 2004 titled *Seawater Desalination and the California Coastal Act.* The report clearly emphasizes that the "concerns about desalination are due primarily to its potential to cause adverse effects and growth that are beyond the capacity of California's coastal resources." The purpose of the report is to provide information on issues related to desalination and its possible effects on coastal resources and coastal uses, describe existing and proposed facilities, identify and discuss policies of California's Coastal Act that apply to desalination programs, and identify information required during coastal development permit review for proposed facilities.

Many of the report's primary findings may be considered in terms of their applicability to water augmentation and desalination facility planning in Hawaii. It is recommended that all proposed county and private desalination facilities evaluate the potential impact on coastal resources and uses.

7.8. Effects of Global Climate Change on Hawaii's Water Resources

The impacts of global climate change in the Hawaiian Islands can potentially devastate our considerable natural resources. Climate change causes alterations in temperature and precipitation patterns, and Hawaii's water resources are almost exclusively dependent on rainfall. This section focuses on potential impacts of climate change to the state's freshwater resources.

7.8.1. Overview

Climate is defined as the long-term average of weather conditions such as temperature, precipitation, and cloudiness.[8] Long-term trends in these weather elements are used as an indication of climate change. The most conspicuous evidence of climate change is the widespread rise in temperatures over the past century. Data has shown that the mean global temperature has increased by 1.4º F since the early 1900s and about 0.9º F of this increase occurring since around 1979.[9]

[8] The National Academies. 2005. Understanding and responding to climate change, highlights of National Academies Report. The National Academy of Sciences. 20 p.
[9] The National Academies, 2005.

Causes of climate change have been linked to human activities—mainly the increase in carbon dioxide due to the burning of fossil fuels. Increased carbon dioxide concentrations in the atmosphere are closely related to increases in global temperatures. Although some climate change can be attributed to natural causes, climate temperature model predictions closely match observed temperature changes when both natural and man-made causes are accounted for in these models.[10]

Global climate change can affect precipitation patterns, ocean temperatures, and sea levels. Scientists also have identified potential impacts to society and the environment. Generally, there may be impacts to human health, agriculture, forests, water resources, coastal areas, freshwater ecosystems, coral reefs, species diversity, and natural areas.[11] Consequently, potential impacts to Hawaii's surface and ground water resources due to global climate change need to be considered when planning for water resource protection in Hawaii.

7.8.2. Local Climate Trends

A 2004 USGS study has shown that from 1913 to 2002, there was a downward trend in annual rainfall over much of the state and an associated general downward trend in stream base flows across the state. However, the same study identified far fewer rainfall stations with a downward annual rainfall trend for the period 1893 to 2001.[12] Further study is required to determine whether the downward trends in stream base flows will continue or whether the observed pattern is part of a long-term cycle where base flows may eventually return to higher levels.

Short-term rainfall variation in Hawaii can be attributed to the El Niño/Southern Oscillation (ENSO) phenomenon, with lower winter rainfall associated with El Niño events. The recently discovered Pacific decadal oscillation (PDO) describes a low-frequency, long-term (inter-decadal) anomaly in North Pacific sea-surface temperatures and can be characterized by a PDO index. Research has shown that ENSO and PDO are interrelated and that inter-decadal Hawaiian rainfall trends are negatively related to the PDO index.[13]

While mean global temperature has increased by 1.4º F since around 1900, one paper notes that the average temperature in Honolulu has increased 4.4º F over the last century.[14]

General circulation models (GCM) can be used to predict future climate trends; however, current GCMs do not have a fine enough horizontal resolution to accurately predict climate

[10] The National Academies, 2005.
[11] National Assessment Synthesis Team. 2000. Climate change impacts on the United States: the potential consequences of climate variability and change. US Global Change Research Program, Washington DC. http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm (accessed 23 March 2006).
[12] Oki, D.S. 2004. Trends in streamflow characteristics at long-term gaging stations, Hawaii, U.S. Geological Survey Scientific Investigations Report 2004-5080. 120 p.
[13] Chu, P.S., and Chen, H. 2005. Interannual and interdecadal rainfall variations in the Hawaiian islands. Journal of Climate, v. 18, p. 4796-4813.
[14] United States Environmental Protection Agency, Office of Policy. 1998. Climate change and Hawaii, EPA 236-F98-007e. United States Environmental Protection Agency. 4 p.

changes on a regional or island scale.[15] Current models predict increased atmospheric and ocean warming based on future increases of carbon dioxide in the atmosphere.

Some climate model projections indicate more frequent El Niño events and stronger La Niña events due to a warmer climate. Some climate models also suggest more persistent El Niño conditions.[16] While future precipitation changes in Hawaii are uncertain, the frequency and variability of extreme weather such as floods and droughts may increase, although climate models differ in estimating future changes in precipitation.[17]

Finally, a warmer climate is expected to cause a rise in sea levels due to thermal expansion of the oceans and the melting of glaciers and ice caps. According to the EPA, the sea level is already rising at a rate of 6 – 14 inches per century at Honolulu, Nawiliwili, and Hilo.[18] This may have an impact on fresh and brackish water aquifers near Hawaii's shorelines.

7.8.3. Impacts to Hawaii

Although there may be multiple impacts to Hawaii due to climate change, this section focuses on any impacts to the State's freshwater resources. Since Hawaii's water resources are almost exclusively dependent on rainfall (and fog drip to a lesser degree), any changes in the frequency and duration of droughts, and rainfall patterns can affect Hawaii's ground water and surface water supplies. Increased temperatures can affect evapotranspiration and the hydrologic cycle (i.e., water balance). More frequent and intense El Niño -related drought events could reduce ground water recharge and surface runoff (stream flow). Long periods of reduced precipitation, combined with rising sea levels, may cause seawater intrusion into near shore aquifers and affect drinking water quality.

As mentioned above, a downward trend in annual rainfall and stream-base flows occurred across the state from 1913 to 2002. Long-term trends in ground water characteristics are more difficult to identify and have not been thoroughly investigated.

Issues and Unknowns

Although much progress has been recently made in climate modeling, due to improved computer technology and climate model sophistication, there are many uncertainties on how a warming climate will affect Hawaii's water resources. Current climate models cannot accurately predict precipitation changes for Hawaii, due to the coarse horizontal resolutions and the complex local topography. Clearly, any changes in rainfall patterns and trends will impact ground water and stream flows. Temperature changes will affect evapotranspiration and the hydrological water balance. Prudent water resource planning should consider the long-term impacts of global climate change and how this could affect Hawaii's water supplies, however more research is needed to determine more specifically what these impacts would include.

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[15] Chu, 2005.
[16] National Assessment Synthesis Team. 2000
[17] United States Environmental Protection Agency, 1998.
[18] United States Environmental Protection Agency, 1998.

7.8.4. Recommendations to Mitigate Impacts of Climate Trends

Given the high degree of uncertainty as to how climate change will impact Hawaii's freshwater supplies, CWRM should seek appropriate legislative funding to undertake the following investigative actions in pursuit of fulfilling CWRM's mandate for comprehensive water resource planning to address the supply and conservation of water:

- Conduct research on the impacts of global climate change to long-term precipitation patterns in Hawaii.
- Conduct research on how global climate change would impact Hawaii's hydrologic budget and water resources.
- Conduct research on how global climate change would impact Hawaii's potable and non-potable water demands.
- Develop improved El Niño forecasting tools.
- Together with the county water departments, design and implement mitigation measures to address the range of potential impacts to Hawaii's water resources due to global climate change; identify critical water sources and design mitigation alternatives that may include actions such as partial backfilling of deep wells, construction of hydraulic barriers, and relocation of wells further inland.
- Encourage sustainable water supply practices.

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Section 8

Drought Planning

8. DROUGHT PLANNING

Droughts have affected the islands throughout Hawaii's recorded history, with the most severe events occurring in the past 15 years associated with the El Niño phenomenon. Drought is a persistent and extended period of below normal precipitation where abnormal moisture deficiencies induce a variety of adverse effects. Impacts due to drought, both direct and indirect, manifest as changes in the environment, economy, public health, and long-term water supply. This chapter reviews and assesses drought mitigation planning efforts undertaken in the State of Hawaii.

8.1. Goals and Objectives

The State Water Code recognizes the need for comprehensive water resource planning to address water supply and conservation. Drought planning activities are integral to water conservation and resource protection. The State Water Code identifies the *Water Resources Protection Plan* as the document in which to include programs to conserve, augment, and protect the resource, as well as other elements necessary or desirable for inclusion. Although HRS §174C does not require drought planning, the *Statewide Framework for Updating the Hawaii Water Plan* (2000) specifically recommends drought planning to be included in the Hawaii Water Plan update, and reinforces the need for drought planning in support of water conservation and water shortage planning.

The drought from 1998 to 2003 had devastating impacts throughout the islands, including numerous wildland fires, record-low rainfall, cattle losses, and major crop damage. In mid-2000, a statewide drought declaration was issued by the Governor, and the State, together with federal and county agencies, private organizations, and affected stakeholders, identified and executed various drought response projects. Initiatives were also undertaken towards the development of a drought plan for the State to mitigate and plan for the long-term effects of drought. The Commission Water Resource Management assumed the role of lead agency in the development of the State's emerging drought program.

The Hawaii Drought Council and its subcommittees were established in 2000 to oversee drought response and mitigation efforts. The chair of CWRM and the director of the Department of Agriculture serve as co-chairs of the Hawaii Drought Council. CWRM provides administrative support to the Hawaii Drought Council and its committees, and provides coordination support to the county-level drought committees through the State Drought Coordinator, who is a CWRM staff member. The Hawaii drought program has grown considerably since its inception in 2000, resulting in the solidification of agency coordination, communication, and involvement at both the State and county levels. CWRM remains committed to drought mitigation, and has set forth the following goals for the drought program:

- Fulfill the State's responsibility, as trustee of water resources, to protect and ensure the long-term viability of resources through implementation of the drought program and regular updates of the Hawaii Drought Plan (HDP).

- Support legislative budget appropriations that strengthen the drought program and achieve the Hawaii Drought Plan priority implementation actions.

- Expand and improve outreach and public education programs, including the Hawaii Drought Monitor website and the production and distribution of drought awareness public service announcements in multiple media formats.

- Support and encourage the efforts of the Hawaii Drought Council through the efforts of the State Drought Coordinator.

- Continue to provide advisory and liaison support to county drought committees in communications with State and federal agencies, and encourage implementation of county drought mitigation strategies.

- Seek to improve drought risk assessment methods, drought impact assessment methodologies, and apply new information in developing and updating drought mitigation strategies.

- Maintain and foster positive relationships with federal agencies involved with drought hazard mitigation, response, and relief including the Federal Emergency Management Agency (FEMA), the U.S. Bureau of Reclamation (Reclamation), and the U.S. Department of Agriculture (USDA).

- Cultivate partnerships with business, agriculture, and environmental organizations and professional associations to expand participation in drought planning and mitigation activities and increase public awareness and support of drought issues.

8.2. Overview of Drought

Drought is a normal and temporary climate abnormality, but it can have profound effects on the environment and the lifestyles of affected communities. Drought diminishes natural stream flow, depletes soil and subsoil moisture, and the resultant variety of social, environmental, and economic impacts can be numerous and widespread.

8.2.1. Understanding Drought

The National Drought Mitigation Center (NDMC) uses two main types of drought definitions: conceptual and operational. Conceptual definitions of drought are general and help people understand the concept of drought. Operational definitions help to define the onset, severity, and end of a drought. Operational definitions of drought include the following:

- **Meteorological Drought:** Meteorological drought is usually an expression of the precipitation level’s departure from normal over some period of time. Meteorological measurements are the first indicators of drought.

- **Agricultural Drought:** Agricultural drought occurs when there is inadequate soil moisture to meet the needs of a particular crop at a particular time. Agriculture is usually the first economic sector to be affected by drought.

- **Hydrological Drought:** Hydrological drought refers to deficiencies in surface and subsurface water supplies, reflected in declining surface and ground water levels. There is lag time between a lack of rainfall and the observed decrease of water levels in streams, rivers, lakes, reservoirs, and aquifers; therefore, hydrological drought will not be reflected until precipitation is deficient over an extended period of time.

- **Socioeconomic Drought:** Socioeconomic drought occurs when a physical water shortage affects people such that the demand has exceeded supply, as a result of a water deficit. This can affect human and animal population and growth rates, water and fodder requirements, agricultural drought impacts, and various industries.

8.2.2. Drought Impacts

The direct impacts of drought include: reduced cropland, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat. Indirect drought impacts are the consequences of direct impacts.

Drought impacts can also be categorized by the sector that experiences the impacts. These types of impacts are economic, environmental, or social. Many of the economic impacts occur in agriculture and related sectors, due to their reliance on rainfall and on surface and ground water supplies. In addition to losses in yields to both crop and livestock production, impacts can be indicated by income loss to farmers, which has a ripple effect, impacting income to retailers and others who supply goods and services to farmers.

Environmental impacts refer to the losses incurred as direct or indirect results of drought, such as wildfire damage to plant and animal species. Direct and indirect negative impacts can include: degradation of wildlife habitat; degradation of air, water, and landscape quality; loss of biodiversity; and soil erosion. Social impacts involve public safety, health, water use conflicts, quality-of-life issues, and socio-spatial inequities in the distribution of impacts and disaster relief. Many impacts that have economic and environmental effects have social components as well.

8.2.3. Drought Response versus Mitigation

The term “drought response” refers to emergency actions that are implemented directly in response to drought conditions. In contrast, “drought mitigation” is defined as short- and long-term actions and/or programs that may be implemented prior to, during, and after drought events to reduce the degree of risk to human life, property, and the economy. Examples of response actions and corresponding examples of mitigation actions are listed in Table 8-1 below. Effective drought planning and mitigation programs can reduce the need for extensive federal, state, and county emergency response and relief expenditures to rebuild local economies and reduce competition for water during drought.

Table 8-1
Associated Drought Response and Mitigation Actions

Drought Response	Drought Mitigation
- Alert appropriate agencies of emerging rainfall deficits.	- Expand current network of rain gages to improve rainfall monitoring.
- Implement agency-coordination actions enumerated in an existing drought plan.	- Develop a drought plan to coordinate drought response between agencies.
- Alert appropriate agencies of declining ground and surface water storage.	- Establish alert procedures for declining water level conditions.
- Implement voluntary and/or mandatory water use restrictions.	- Establish conservation programs to reduce water consumption.
- Mobilize contractors to truck water to ranches without sources.	- Establish contingency water-hauling programs for livestock.
- Modify and utilize monitor wells to provide emergency sources of water.	- Seek authorization and funding for development of additional storage, alternative water sources and new water supply sources.
- Utilize models and monitoring data to assess drought recovery or escalation of drought conditions.	- Identify areas at risk to drought and plan for regional response actions and strategies.
- Release regular and timely media advisories.	- Develop and implement drought-related public awareness programs.

8.2.4. Hawaii's Need for Drought Mitigation

Drought can lead to difficult decisions regarding the allocation of water, as well as stringent water use limitations, water quality problems, and inadequate water supplies for fire suppression. In Hawaii, droughts and wildland fires threaten all islands in any given year. Also, there are additional issues such as growing conflicts between agricultural uses of surface water and instream uses, "surface and ground water" interrelationships, and the effects of growing water demands on traditional and cultural uses of water.

In the past, drought was addressed as a temporary emergency. Actions were taken in response to impacts, in a reactionary fashion. The most important lesson learned in recent years is that the best time to reduce the impacts of drought is before they occur. Therefore, it is important to develop drought planning programs that advocate a proactive management approach.

Droughts have been prevalent in the past and will continue to adversely affect the environment, economy, and the citizens of the State, due to Hawaii's strong dependency on rainfall and the lack of adequate water supply and/or infrastructure in certain areas of the State. Historical patterns indicate that Hawaii will continue to suffer damaging droughts, and the loss potential will only increase as the need for economic growth and revitalization amplify pressures upon the State's limited water supply. Aggressive planning and the utilization of alternative resources are necessary to avoid a situation where future population and economic growth cannot be sustained, due to insufficient quantity and quality of water resources. Since water is limited and precise rainfall predictions are not possible, effective water resource planning and management is critical to the long-term sustainability of our island communities.

8.3. Existing Drought Planning Context

State efforts to establish a drought plan were undertaken in recognition of and in coordination with the various federal agencies that administer drought assistance programs, including FEMA, Reclamation, the U.S.D.A. Farm Service Agency, the Natural Resources Conservation Service (NRCS), the U.S. Forest Service, and the Small Business Administration. The following sections provide background information on federal legislation and the resultant State and county actions that have contributed to the development of Hawaii's drought program.

8.3.1. Federal Disaster Management Act

Hazard mitigation is an action or number of actions taken to reduce or eliminate long-term risk to people and their property from the effects of natural hazards. The purpose of hazard mitigation is two-fold: 1) to protect people and structures from harm and destruction; and 2) to minimize the costs of disaster response and recovery. Hazard-mitigation planning is the process that analyzes a community's risk from natural hazards, coordinates available resources, and implements actions to reduce risks.

In the past, funding for hazard mitigation was typically available only following a disaster declaration, based on a percentage of the estimated damages. Since the early 1990s, FEMA and the United States Congress have witnessed large increases in disaster response and recovery costs, and as a result, they have provided funds to communities, counties, and states to reduce impacts from natural hazards through hazard mitigation. The Federal Disaster Management Act of 2000 requires each state and territory to conduct hazard mitigation planning and to implement projects to reduce hazard impacts prior to a disaster occurrence. This Act marked a fundamental shift in policy. Rather than placing primary emphasis on response and recovery, FEMA's focus broadened to incorporate mitigation as the foundation of emergency management.

8.3.2. State Hazard Mitigation Planning

Changes in federal laws have resulted in pre-disaster mitigation project funding and mitigation planning requirements. However, future funding for public assistance subsequent to disasters will be largely contingent upon mitigation plan completion. Additionally, states are required to have an approved Standard State Mitigation Plan in order to receive additional pre-disaster mitigation funds for state or local mitigation projects after November 1, 2004. Planning efforts are independent of any specific hazard event.

The Standard State Mitigation Plan will also be required for non-emergency assistance provided under the Stafford Act, including Public Assistance restoration of damaged facilities and Hazard Mitigation Grant Program funding. A state with a FEMA-approved Enhanced State Mitigation Plan at the time of a disaster declaration is eligible to receive increased funds under the Hazard Mitigation Grant Program, based on 20 percent of the total estimated eligible Stafford Act assistance. Therefore, the development of State and local hazard mitigation plans is key to maintaining eligibility for future FEMA mitigation and disaster-recovery funding.

8.3.3. Hawaii State Hazard Mitigation Plan

The Hawaii State Hazard Mitigation Forum, which is composed of county, State, and federal agency representatives, as well as private individuals with interest in hazard mitigation planning, agreed that the Hawaii State Hazard Mitigation Plan should be a multi-hazard plan. For the purpose of the plan, the term “multi-hazard” shall not be limited to discrete natural hazards, and will include anthropogenic activities that could exacerbate hazard event impacts and potentially threaten the life and safety of the citizens of Hawaii. The goal of the plan is to mitigate the impact of such potential disasters.

The Hawaii State Hazard Mitigation Plan encompassed the broadest possible scope of disaster occurrences, focusing on nine natural hazards: hurricanes, tsunami, earthquakes, floods, volcanic eruptions and lava flow, coastal erosion, landslides, wildfire, and drought. For each of these specific categories of disasters, additional mitigation plans or strategies targeted at these disasters will be appended to the Hawaii State Hazard Mitigation Plan. Several of these hazard categories have current advisory boards or task forces that have developed recommendations and strategies.

In September 2003, CWRM completed a statewide Drought Risk and Vulnerability Assessment. This document is referenced in the Hawaii State Hazard Mitigation Plan. The Drought Risk and Vulnerability Assessment illustrates the extent and severity of drought risk for different impact sectors throughout the islands, and will facilitate the development of drought response and mitigation strategies.

The State Hazard Mitigation Plan must highlight any gaps in data collection and analysis, as well as propose or recommend specific projects to address such gaps as well as short- and long-term drought risk reduction. Therefore, the Drought Risk and Vulnerability Assessment is an important tool for future drought hazard mitigation planning. The Hawaii Drought Plan incorporates the results of the risk and vulnerability assessment. These results provide input and context for drought response actions and drought mitigation strategies.

8.3.4. County Hazard Mitigation Plans

As noted above, the Disaster Mitigation Act of 2000 requires that each state develop a hazard mitigation plan in order to receive future funding following a disaster. This new requirement provides some funding for each state to engage in planning activities and plan preparation. Federal law also requires the development of local or county plans for that particular county to be eligible for post-disaster funding. The purpose of these requirements is to ensure that there are local programs and projects in place that will help minimize the loss of life, property, and total cost of disasters.

As is the case with the State-level plan, the county Hazard Mitigation Plans are multi-hazard plans. The initial county plans do not include specific drought mitigation projects, however pertinent elements of the Hawaii Drought Plan and the Drought Risk and

Vulnerability Assessment and GIS Mapping Project (see section 8.3.5.1) have been incorporated into the drought mitigation components of the plans. County-specific drought mitigation and response strategies were completed in 2005 through county, CWRM, and stakeholder efforts.

8.3.5. Hawaii Drought Plan, Phase I

As drought conditions emerged and continued through the late 1990s, CWRM and the Department of Agriculture, with assistance from Reclamation and cooperation from affected agencies, organizations, and stakeholders, undertook efforts to develop a statewide drought planning document.

One of the major objectives of the Hawaii Drought Plan, Phase I was to develop a planning framework in which to address a multitude of drought-related issues. The plan, completed in 2000, was structured to be dynamic in nature, utilizing a “living document” approach to address more than just response-oriented actions. Under this approach, provisions were established to accommodate changes in the drought leadership structure established by the plan, as well as to allow for periodic evaluation and revision to the plan itself.

8.3.5.1. Drought Risk and Vulnerability Assessment and GIS Mapping Project

In 2003, CWRM, on behalf of the Hawaii Drought Council and as part of the priority implementation actions recommended in Phase I of the HDP, completed a geographic and sector-based risk assessment and vulnerability analysis with applications toward statewide drought planning.

The Drought Risk and Vulnerability Assessment and GIS Mapping Project was designed to focus drought mitigation planning by delineating risk areas through the analysis of interrelated parameters. Follow-up mitigation planning would provide for protection of resources, public safety, property, and the economy by allowing for the implementing specific projects in identified risk areas.

The Drought Risk and Vulnerability Assessment and GIS Mapping Project utilizes Geographic Information System (GIS) mapping techniques to incorporate geographic, environmental, and social data to determine areas at risk to meteorological, hydrologic, and agricultural drought, as well as environmental and socioeconomic impacts that may occur due to drought conditions.

The report results include maps of drought frequency, vulnerability, and at-risk areas for each county, as well as recommendations for both mitigation actions and future studies. The maps are intended for public dissemination and use by the counties and local stakeholders in the development of mitigation strategies and projects. Recommendations for future studies and actions include:

- Develop new and improved methods for drought forecasting, tailored to Hawaii. More accurate forecasts will facilitate early identification of impending drought conditions and reduce the vulnerability of climate-sensitive activities like agriculture, water resource management, public health, and forestry.

- Conduct advanced drought frequency analysis and GIS mapping. Compile data from State and federal rain gage networks to improve accuracy and reliability of drought frequency analyses and to resolve microclimate variations.

- Conduct multi-year drought frequency and recurrence interval analyses. Study the frequency, as well as the spatial and temporal variations associated with longer-duration drought events (on the order of several years).

- Analyze drought patterns and severity during El Niño and La Niña years. Conducting such studies would help in anticipating drought patterns and severity as El Niño and La Niña events are developing. It would also be of interest to investigate the changes in drought frequency and patterns during different phases of the Pacific Decadal Oscillation, as a guide for future long-term, drought risk management.

- Conduct drought impact studies to understand how people are impacted and how best to reduce these impacts. An accurate accounting system of economic data on drought loss, including qualitative information and anecdotal reports, would be useful in quantifying, or even qualifying, the degree of drought severity from event to event.

8.3.6. Hawaii Drought Plan Update

The *Hawaii Drought Plan, Phase I* was completed in August 2000 and submitted to the U.S. Bureau of Reclamation for review. Reclamation subsequently provided comments and recommendations for refinements that would facilitate the plan's eventual submission to and acceptance by the United States Congress. CWRM, on behalf of the Hawaii Drought Council and with additional technical and financial assistance from Reclamation, revised the plan to address Reclamation's comments and well as to include additional information on drought related projects and programs that developed between 2000 and 2005.

The updated document is entitled the *Hawaii Drought Plan, 2005 Update*. It provides the most up-to-date, statewide drought response and mitigation plan for Hawaii as of its publication date. This plan strives to retain the dynamic structure and flexibility of the previous drought planning effort, while delineating program-specific actions and recommendations for planning future activities, within a document that is user-friendly and that facilitates action implementation.

Since the development of the *Hawaii Drought Plan, Phase I* in 2000, the State has completed several actions toward the implementation of the plan and further development of the drought program:

- Requested and received Emergency Drought Assistance from Reclamation under Title I of the Reclamation States Emergency Drought Relief Act of 1991, in addition to technical/planning assistance under Title II of the same Act;

- Participated as a member of the Western Governors Association's Drought Working Group, to help draft the proposed National Drought Preparedness Act of 2003 for submission to Congress;

- Established in 2002, through successful legislative authorization, a permanent State Drought Coordinator position within the Commission on Water Resource Management;

- Applied for and received a FEMA Pre-Disaster Mitigation grant to develop a Statewide Drought Risk and Vulnerability Assessment and GIS Mapping Analysis in support of the Hawaii Drought Plan and the State/County Hazard Mitigation Plans;

- Developed public outreach and education tools, including the completion of the Hawaii Drought Monitor Website and the production and distribution of drought awareness public service announcements in both radio and television;

- Established County/Local Drought Committees (CLDCs), starting with the County of Kauai in 2001 with the Kauai Department of Water in the leadership role;

- Applied for and received funding to undertake the development of the *Agricultural Water Use and* Development *Plan* component of the *Hawaii Water Plan*;

- Developed a DLNR prototype *State Agency Water Conservation Plan* with assistance from Reclamation for application across State government agencies.

CWRM continues to serve as the lead agency for the State's overall drought program and the update/implementation of the *Hawaii Drought Plan*. The drought program has grown since 2000, resulting in the solidification of agency coordination, communication, and involvement at both the State and county levels. The HDP describes: the drought program leadership structure for the State of Hawaii; the purpose, responsibilities, and involvement of agency and stakeholder representatives on various drought committees; and the communication protocol for effective drought response, monitoring, recovery, and post-drought evaluations.

8.3.7. County Drought Mitigation Strategies

In 2004 and 2005, a series of county meetings were held involving agencies and stakeholders who agreed to participate in the CLDCs. Through these meetings, county drought mitigation strategies were developed to coordinate government agency and stakeholder actions, and projects were identified for integration within the *County Hazard Mitigation Plans*. Implementation of these projects would be championed by the CLDCs. The HDP emphasizes local drought response, mitigation, and organizational efforts at the county level. While the Hawaii Drought Council and the State Drought Coordinator seek to assist local government agencies and stakeholders in coordinating drought response and mitigation, project implementation is dependent upon input and action by the CLDCs, who provide local and regional knowledge, information, and resources.

8.4. Evaluation of Current Drought Planning, Mitigation, and Response in Hawaii

Although the drought program was initiated only seven years ago, the program's expansion and execution of planning efforts, mitigation projects, and response actions have increased drought awareness and preparedness. That program committee member participate and agency contributions are voluntary makes the program's gains even more deserving of celebration.

The following sections provide brief evaluations of specific aspects of the drought program, including the leadership structure, the drought communication protocol, and drought declarations, response actions, and mitigation actions.

8.4.1. Evaluation of Drought Leadership Structure

Drought risk management encompasses human, financial, economic, social, environmental, and political aspects, which often have complex interactions. Given the range, complexity, and interaction of drought-related risks, and the potential range of decision makers involved, an integrated, interdisciplinary approach is required to provide a rounded appreciation of the problem. Close cooperation between entities with different but relevant technical specialties is required because of the occurrence of multiple ecological issues at different phases of a drought event.

The drought leadership structure described in the *Hawaii Drought Plan* addresses the need for cooperation and coordination in risk management, as well as in the implementation of response and mitigation measures. The HDP is, in essence, a framework for facilitation the timely and effective execution of drought planning, assessment, response, and mitigation actions statewide.

It should be emphasized, however, that there is no State or county statutory authority requiring the establishment of a task force or committee to address drought issues across the State. The current drought leadership structure functions on an ad-hoc volunteer basis. Implementation of any actions pursued by the Hawaii Drought Council and its committees is dependent upon public-private partnerships, interagency cooperation, and ultimately, the solidification and fortification of strong stakeholder-government relationships.

Formalization of the Hawaii Drought Council through legislation should be given appropriate consideration by government agencies and stakeholders, especially in light of federal mitigation initiatives discussed in Section 8.3.

8.4.2. Evaluation of Drought Communication Protocol and Drought Declarations

The Drought Communication Protocol described in the HDP is designed to facilitate the timely dissemination of clear and precise information to affected agencies and the public for periods before, during, and after drought events. The Drought Communication Protocol is reflected in Figure 8-1 and incorporates three elements as follows:

1. **Declaration of drought conditions**: The Hawaii Drought Council adopted three drought stage categories defined as "Normal," "Drought," and "Recovery." It was determined that this approach would effectively facilitate development and implementation of appropriate drought response actions.

2. **General communication and coordination guidelines**: The HDP provides guidelines to facilitate and coordinate drought information sharing and the release of drought status information.

3. **Specific communication and coordination responsibilities**: The Hawaii Drought Council and its committees, with the State Drought Coordinator, are the core entities for HDP implementation, and the plan sets forth actions to be undertaken by each entity under "Normal", "Drought", and "Recovery" conditions.

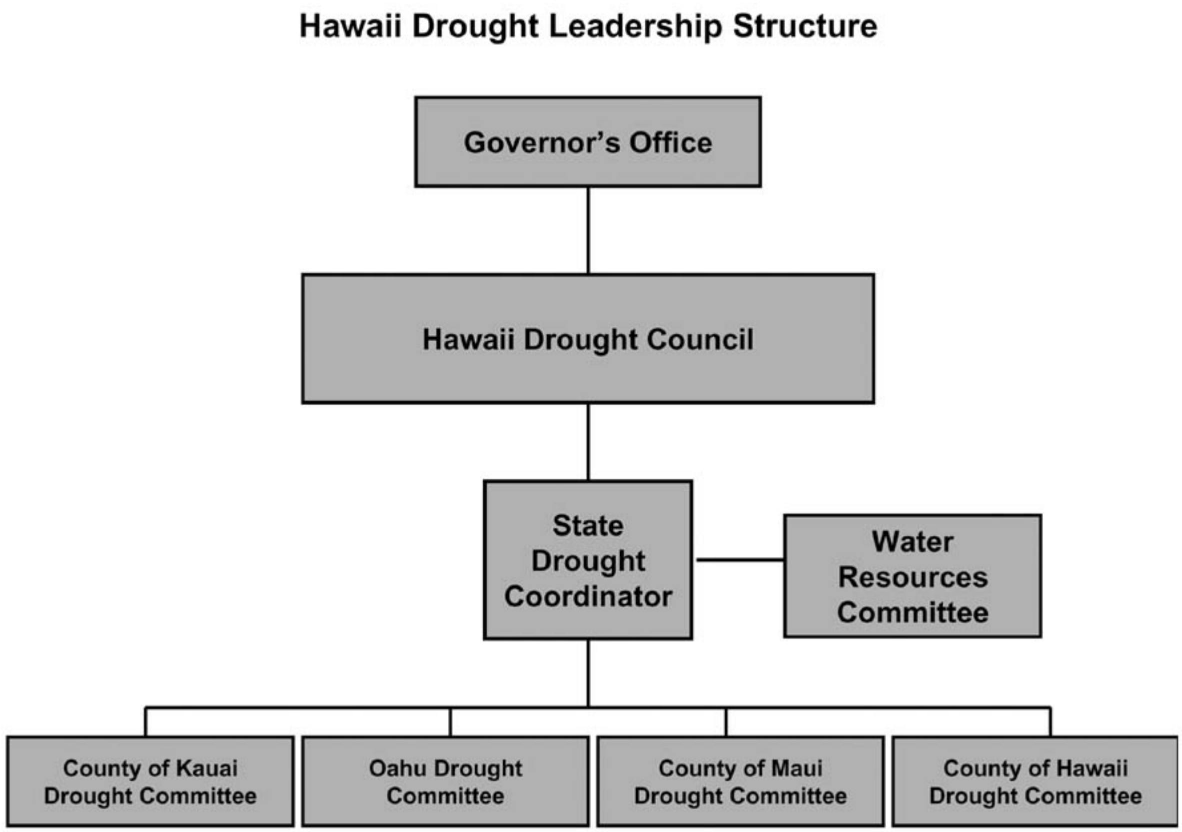

Figure 8-1. Hawaii Drought Leadership Structure

The process for declaring drought conditions, the general communication guidelines, and the specific communication responsibilities are described in the HDP. The protocol is clear and useful, but highly dependent upon volunteer commitment from the CLDCs and federal, county, State, and private entities. Formalization of the drought leadership structure should be given appropriate consideration by government agencies and stakeholders to solidify agency commitment and follow-up response actions that will address specific impacts.

8.4.3. Drought Response Actions

The HDP provides a list of actions that may be executed voluntarily by State agencies in response to drought conditions. These are emergency actions that are implemented directly in response to drought conditions, and the HDP further recommends that the agency consult and coordinate with the Hawaii Drought Council and the State Drought Coordinator.

While State actions may address some drought emergencies, it is often at the county or local level where the greater part of emergency response will occur. The establishment of the CLDCs resulted in the appropriate delineation of county roles and responsibilities, and perhaps more importantly, re-emphasized the counties' authority to pursue independent actions in response to drought. In this way, the drought leadership structure accommodates jurisdictional issues between county agencies, while maintaining coordination between the various counties and the State.

The HDP includes recommended county response actions, but the execution of these actions is within the purview and jurisdiction of the respective county agencies. County governments should consider formalizing the CLDCs and local drought programs to maintain communication with the Hawaii Drought Council and the State Drought Coordinator regarding drought stage status and response requirements. The CLDCs are key in the initial identification of the onset of drought and are best informed as to needed relief and response.

8.4.4. Drought Mitigation and Preparedness

The Hawaii Drought Plan recommends near-term and long-term State mitigation strategies. Strategies are presented in seven categories as listed below:

- Statewide water resources monitoring and impact assessments;
- Development of new or alternative water sources;
- Water conservation practices;
- Public education, awareness, and outreach;
- Watershed protection partnerships;
- Legislation; and
- Land use planning.

Additional strategies to reduce drought risk are also included as an appendix to the HDP.

As with the county drought response actions, the county drought mitigation strategies have been developed by the CLDCs, and the implementation of mitigation projects falls within the purview and jurisdiction of appropriate county agencies. Formalization of the CLDCs would help facilitate project implementation and reduce drought risk.

8.5. Recommendations for Drought Planning

The drought program in Hawaii has been successful in raising public awareness of drought hazard and in creating an effective planning framework. The HDP establishes a leadership structure to coordinate drought monitoring, mitigation, and response activities, and formalizes a protocol for communication among agencies and stakeholders. The HDP also serves as a guide for government agencies to develop mitigation and response strategies within their areas of jurisdiction and serves as a resource document for private stakeholders to develop appropriate strategies to prepare for and respond to drought.

The *Hawaii Drought Plan* delineates several State- and county-level priority implementation actions, which are included below and are incorporated herein as recommendations for statewide drought planning:

- The Water Resources Committee of the Hawaii Drought Council should continue to refine drought indices for each impact sector by correlating historical drought impact data with past drought events.

- Additional monitoring of surface water sources, including stream diversions, ditch systems, and reservoirs should be undertaken. The Water Resources Committee, the State Drought Coordinator, and the County/Local Drought Committees should discuss ways in which agencies can achieve better coordination of program activities to facilitate monitoring of these surface water resources.

- The National Weather Service Climate Prediction Center (CPC) presently provides minimal drought forecast information for the State of Hawaii. The State Drought Coordinator should work with the CPC to determine if additional drought-forecasting products can be developed for Hawaii. Similarly, the State Drought Coordinator should continue to correspond and work together with other drought-related agencies such as the National Drought Mitigation Center, Western Regional Climate Center, Western Governors' Association, University of Hawaii, National Weather Service–Honolulu Office, State Civil Defense, etc. to coordinate data collection and access to such data in a reasonable time frame and to provide real-time data where possible through the sharing of electronic databases.

- A methodology to conduct statewide drought impact assessments should be developed. The HDC, through its Water Resources Committee, the State Drought Coordinator and CLDCs should work together to develop a uniform system for the assessment of drought impacts. CLDCs should establish and implement a mechanism for conducting impact assessments on a regular basis after each drought event and report such information to the HDC.

- County/Local Drought Committees should continue their work towards developing county-level drought mitigation and response strategies. CLDCs should also continue to work with State and county civil defense agencies to incorporate additional drought mitigation projects into the *County Hazard Mitigation Plans*.

- Similarly, implementation of water conservation measures at State agency facilities (e.g., irrigation and fixture retrofits) should be encouraged. Funding for implementation of water conservation measures should be pursued, including public/private partnership financing options (i.e., performance contracting).

- Further refinement of the *Drought Risk and Vulnerability Assessment and GIS Mapping Project* (2003), should be conducted. The assessment should be updated to include data from State rain gages and analyses of multi-year drought events, recurrence intervals, drought patterns, and drought severity during El Niño and La Niña years.

- The Hawaii Drought Monitor website should be maintained and utilized to promote public education and awareness of drought-related program activities and initiatives.

8.5.1. Recommendations for Future HDP Updates and Revisions

The Hawaii Drought Plan should undergo timely updates and revisions at least every five years. Plan recommendations and the drought communication protocol should likewise be reevaluated and revised as appropriate.

The plan has been designed as a dynamic "living" document, which should be utilized and updated to reflect changing conditions, new information, and an evolving leadership structure. Additional public and private sector resources should be continually sought, and the participation of all appropriate agencies and stakeholder representatives should be expanded and fortified. The net effect of the HDP implementation will be the effective coordination of people and resources to reduce and minimize drought impacts to the State of Hawaii.

Section 9

Watershed Protection

9. WATERSHED PROTECTION

> *A watershed is the area of land where all of the water that is under it or drains off of it goes into the same place. John Wesley Powell, scientist geographer, put it best when he said that a watershed is:*
>
> > *"that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."*
>
> *Watersheds come in all shapes and sizes. They cross county, state, and national boundaries. No matter where you are, you're in a watershed!*
>
> – U.S. EPA Office of Water[1]

The public-stewardship ethic is a key component in watershed protection. The small, repetitive actions of individuals can produce detrimental, cumulative effects within the watershed. As noted by John Wesley Powell, all living things–plants, animals, microorganisms, and people–are inextricably linked in the watershed. The impacts and subsequent "ripple effect" of human activities, as demonstrated by past instances of environmental degradation, can be devastating to natural systems. In order to ensure watershed sustainability and maintain a healthy human environment, it is necessary to minimize pollution, mitigate impacts, and promote stewardship within the watershed community.

Most modern watershed protection and management programs have sprung from the Clean Water Act of 1977 and subsequent supporting legislation. The State of Hawaii has a long history of watershed protection programs. State programs were initiated specifically to ensure a sustainable water supply. This section of the WRPP describes watershed-protection resources and programs currently being implemented at the federal, State, and local levels and summarizes community efforts and partnership projects that have achieved success in Hawaii. The section concludes with recommendations that encourage more integrated watershed management by building upon existing programs to link mountain- and shoreline-area activities.

9.1. Goals and Objectives

CWRM supports watershed protection and management, including preservation of instream uses, flood control, and the conjunctive use of surface and ground water.

The term "watershed" or "watershed management" is not defined in the State Water Code, but the watershed concept and watershed management practices, based on watershed-scale programming, is integral to the protection of public trust resources. Although the State Water Code states that coastal waters are not subject to its provisions, coastal waters are very much part of the watershed system and should be addressed in State management programs. Ultimately, interagency coordination will be necessary to ensure

[1]U. S. EPA.. 2007. *What is a Watershed?* Internet, Available at: http://www.epa.gov/owow/watershed/whatis.html.

judicious and responsible management of watersheds and to maintain healthy mauka-to-makai ecosystem connections. Examples of State agencies that administer watershed programs or make decisions that affect land use in watershed areas include the DLNR Office of Conservation and Coastal Lands (OCCL), as well as the Department of Business, Economic Development and Tourism (DBEDT) Office of Planning and Land Use Commission (LUC).

Adequate management and control of watersheds is a prerequisite to sustaining water resources. An uncontrolled watershed is exposed to a wide range of potential contamination as a result of herbicide and industrial chemical use, waste material dumping, and unintentional polluting by humans and feral animals. Such situations, accompanied by wastewater treatment failures, can give rise to serious public-health emergencies.

The need to control and protect the watersheds and underlying ground water aquifers remains urgent. The encroachment of urban uses into forested watersheds decreases the land area available for infiltration, and therefore decreases the volume and rate of ground water recharge. Most watershed lands in Hawaii are owned and controlled by the State through the DLNR Division of Forestry and Wildlife (DOFAW) Watershed Protection Program. Entry into, and activities in watershed areas are governed by laws and regulations enforced by the State. Recreational, commercial, industrial, and residential developments are highly regulated or prohibited. The exclusion of activities not compatible with best public health practice has historically provided a high level of water quality protection in Hawaii.

Surface water resources must also be protected. Stormwater runoff carries significant pollutant loads of sediments, suspended material, and dissolved matter. Runoff from forested watersheds carries the least amount of pollutants, while runoff from unvegetated agricultural and urbanized areas contains high sediment and chemical loads. In altered or urbanized portions of watersheds, a greater proportion of rainfall directly becomes surface runoff that carries undesirable components to streams and receiving water bodies.

In general, further planning efforts should be based on two basic watershed-management principles: 1) watershed acreage must be large enough to ensure sufficient infiltration to recharge ground water aquifers; and 2) water quality must be protected, whether water eventually recharges ground water bodies, flows to streams and nearshore waters, or is impounded for use.

The following goals and objectives for watershed management and protection are presented to guide future State watershed-management planning efforts:

- Protect watershed health to ensure long-term sustainability of surface and ground water resources.

- Encourage integrated programs at the watershed level to address the conflicts and disconnects that currently exist between mauka- and makai-area interests, urban issues and conservation priorities, and economic goals and pollution-prevention programs. Integration of programs will help educate the public on the causal relationships between land use, sustainable water resources, and water quality.

- Encourage the integration of programs that better facilitate distribution and use of funding and resources. The existing governmental structure and jurisdictional divisions, which tend to separate land use and water resource issues, have resulted in programs that are either short-sighted in planning, or are unable to realize their full effectiveness, due to disjointed and sometimes conflicting mandates. Integrated planning and establishment of communication networks and protocols will encourage dialogue and cooperation between government agencies, community groups, private interests, and the public.

- Support integrating and applying traditional land management practices in watershed protection and management, as may be appropriate in urban, agricultural, and conservation areas.

9.2. Summary of Traditional Hawaiian Land Management Practices, and the Ahupuaa Management Model

Community responsibilities and traditional cultural practices provided a foundation for the ancient Hawaiian land-management system, which allowed Hawaiians to successfully practice integrated-resource management. This traditional system is known as the ahupuaa resource-management system, and can serve as a model for land management today.

Hawaiian society was made up of three classes: the *alii* (ruling class), the *makaainana* (commoners), and the *kaua* or *kauwa* (outcasts). Hawaiians believed that the land belonged to the *akua* (gods), not the people. They also believed that the *alii* were direct descendants of the *akua*; thus, the *alii* were the keepers of the land.[2]

At the time of European contact, Hawaiian society was an organized hierarchy with the *akua* at the top; the *alii ai moku* or *alii nui* (paramount chief of each island or district) and their cabinets of advisors were next; these advisors included a *kalaimoku* (counselor, divider of land), the *kuhina* (prime minister) and *kahuna* (priests). The various *ahupuaa* were run by *alii ai ahupuaa,* who controlled the resources of the *ahupuaa*. *Konohiki* were appointed by *alii ai ahupuaa* to manage the land and oversee production and regular payments of goods and services to the ruling class of *alii*. The *konohiki* had several roles in the *ahupuaa*, including facilitator, worker, and collector. Sometimes the *alii ai ahupuaa* also served as the *konohiki* for the *ahupuaa.*[3]

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[2]Williams, Julie Stewart. 1997. *From the Mountains to the Sea: Early Hawaiian Life*. Honolulu: Kamehameha Schools Press.
[3]Wilson Okamoto Corporation for the City and County of Honolulu Department of Design and Construction. August 2004. *Kaneohe-Kahaluu Stream Restoration and Maintenance, A Community Guidebook*.

9.2.1. Traditional Native Hawaiian Land Management System

The traditional land system in Hawaii was comprised of various subdivisions of land. The major subdivisions are:

- *Mokupuni* (island);
- *Mokuoloko* or *Moku* (district);
- *Ahupuaa* (division of land generally running from the mountain to the sea); and
- *Ili* (strip of land within an *ahupuaa*).

The *ahupuaa* was perhaps the most important of the land divisions, as it represented complete ecological and economic production systems that formed the foundation of “the Hawaiian family, social, political and religious structure…rooted in the land.”[4]

Konohiki were responsible for the conditions of the *ahupuaa*, lived within the district they ruled, and were part of the active daily life of the people. *Makaainana* were free to move between *ahupuaa* if the *konohiki* treated the people in a severe manner. Therefore, *konohiki* were concerned with the welfare of their *makaainana*; in fact, the power of a *konohiki* depended upon the welfare of their *makaainana*. The *alii nui* valued the ability to call on large numbers of men from various *ahupuaa* to support them in battle; if those numbers were not available, the *konohiki* was held accountable.[5]

The *ahupuaa* system was well balanced. The Hawaiians understood that every element within the *ahupuaa* was related to one another: that the consequences of an action would directly affect the state of the environment, the people, and their way of life. In the *ahupuaa* system, rights are balanced with expected responsibilities. For example, people had rights to water use for taro irrigation, if they fulfilled their responsibility to maintain the *auwai* (irrigation ditch). The farmer maintained the *auwai* near his farm and helped other farmers clean the main *auwai.* Based on the idea that everything within the ahupuaa was related, the Hawaiians applied a strong value system that provided them with the foundation for maintaining balance within the *ahupuaa.*

Similarly, expected responsibilities of those who live, work, and play in a watershed would enhance modern-day *ahupuaa* management and promote sustainablility. The interdependency of personal actions and the health of the watershed need to be better understood. For example, the short-term and long-term effects on water quality from polluted runoff need to be recognized and controlled, in order to maintain a balance of life in the stream, as well as on the land that is sustained by the stream.

Federal, State, and county regulations provide for the protection of native rights and cultural practices. Watershed protection and land management practices should make thoughtful

[4]Kumu Pono Accociates. 2002. An Overview of Native Hawaiian Land and Ocean Management Practices. Internet. Available online at: http://kumupono.com.
[5]Craighill Handy, E.S. 1965. *Ancient Hawaiian Civilization; a series of lectures delivered at the Kamehameha Schools*. Charles E. Tuttle Co. Publishers.

and conscious efforts to respect these rights, as well as the public trust interests of the general public.

9.2.2. Ahupuaa Management Model

An *ahupuaa* is defined as a land division extending from the uplands to the sea. The boundary was marked by a heap (*ahu*) of stones surmounted by an image of a pig (*puaa*). The image of a *puaa* head was carved out of *kukui* (*Aleurites moluccana*) wood that was often stained with *alaea* (red dirt).[6]

The typical *ahupuaa* allowed all tenants to access resources from the mountains to the sea; this is known as the *mauka-makai* (mountain-sea) concept. The ocean adjacent to the *ahupuaa* was considered an extension of the *ahupuaa*; accordingly, all ocean resources were shared in common by the people of the *ahupuaa*.

Ahupuaa varied in size, but typically included a long, narrow strip of land that ran from the mountains to the ocean. An entire valley often formed one *ahupuaa*, much like how present-day watersheds are delineated. Some *ahupuaa* were wider in inland areas, and some larger *ahupuaa* separated smaller ones from the mountains. Geographic features, such as ridgelines, depressions, streams, and stones were often used as boundary lines.[7]

Another aspect of the *ahupuaa* concept was the custom of undivided shares. For example, when a fisherman caught fish, everyone in the *ahupuaa* received a portion of the catch.[8] It has also been suggested that upland people who received a share of the catch would also share their harvest of taro with the coastal dwellers. This idea of undivided shares and the exchange of *mauka* goods for *makai* goods demonstrates the *lokahi* (balance, harmony) that existed between the people in an *ahupuaa*, and between the people and their land.

Ancient Hawaiians lived in a subsistence economy; they depended upon the land to provide them with their food, clothing, and homes. The need for exercising care in the use and management of land and water remains urgent in modern times; however, private property considerations place constraints on the equal access to and the sharing of resources. Water resources, however, remain in the public trust.

The ocean is considered an extension of the *ahupuaa*. Estuary systems are important components to the *ahupuaa*, as these *muliwai* areas provide a vital stream-to-ocean connection. Most native Hawaiian stream animals share a unique life-cycle pattern, called amphidromy, where the animals live in two different environments (diadromy) during different life stages. Adult individuals lay their eggs in streams, and upon hatching, the larvae migrate downstream and are swept out to sea. After a maturation period spent living in the ocean community, the postlarvae return to the stream habitat by migrating through the tidal and estuarine environments, often climbing numerous waterfalls. Therefore, natural flow patterns in streams and estuaries must be maintained to protect native

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[6]Pukui, Mary Kawena and Samuel H. Elbert. 1986. *Hawaiian Dictionary: Hawaiian-English, English-Hawaiian*. Honolulu: University of Hawaii Press.
[7]Craighill Handy, E.S. 1965. *Ancient Hawaiian Civilization; a series of lectures delivered at the Kamehameha Schools*. Charles E. Tuttle Co. Publishers.
[8]Devaney, Dennis M., Marion Kelly, Polly Jae Lee and Lee S. Motteler. 1982. *Kaneohe: A History of Change*. Honolulu: The Bess Press.

Hawaiian stream animals, and to ensure healthy populations of native stream flora and fauna.

Watershed protection and management should incorporate the *ahupuaa* management model, as well as other considerations, including historical and cultural context, evolving land uses, and geographic setting. Historical and cultural context provides a basis for understanding the traditional role of streams within the *ahupuaa* and lends insight into watershed protection planning efforts. Present and planned land uses act as constraints or opportunities for the restoration of the landscape and management of the stream corridor. The geographic setting of the *ahupuaa*, its natural resources, soils, and topography dictate drainage patterns and the diversity of plant and animal life.

The following sections discuss federal programs, State programs, and cooperative community-partnership programs currently underway that apply comprehensive watershed management and protection principles and aspects of the *ahupuaa*-management model.

9.3. Federal Watershed Protection and Management Programs

Federal watershed protection and management activities are primarily executed through certain programs administered by the Environmental Protection Agency, the Department of the Army, and the Department of Agriculture. These programs are described below.

9.3.1. Environmental Protection Agency Programs

Over the past 20 years, the EPA has found that the discharge of pollutants into the nation's lakes, streams, rivers, wetlands, estuaries, coastal waters, and ground water has been substantially reduced. This was achieved primarily by controlling point sources of pollution and, in the case of ground water, preventing contamination from hazardous-waste sites under the provisions of the Clean Water Act and the Safe Drinking Water Act. Environmental threats to water resources still exist, and the potential causes of pollution vary with human activities in the watershed. In addition to discharges from industrial or municipal sources, water resources may be threatened by urban, agricultural, or other forms of polluted runoff; landscape modification; depleted or contaminated ground water; changes in flow; over-harvesting of fish and other organisms; introduction of exotic species; bioaccumulation of toxics; and deposition or recycling of pollutants between air, land, and water.

Through program evaluation, the EPA has found that the federal laws addressing water resource problems have tended to focus on particular sources, pollutants, or water uses. Such laws have not enabled an integrated environmental management approach. Consequently, significant gaps exist in efforts to protect watersheds from the cumulative impacts resulting from the combination of all human activities in the watershed. However, the existing water pollution prevention and control programs, waste- and pesticide-management programs, and other related natural resource programs are excellent foundations on which to build an integrated watershed management approach.

The U.S. Environmental Protection Agency Office of Water (Office of Water) is responsible for preventing pollution wherever possible and reducing risk to people and ecosystems through implementation of the: Clean Water Act and Safe Drinking Water Act; portions of the Coastal Zone Act Reauthorization Amendments of 1990; Resource Conservation and

Recovery Act; Ocean Dumping Ban Act; Marine Protection, Research and Sanctuaries Act; Shore Protection Act; Marine Plastics Pollution Research and Control Act; London Dumping Convention; International Convention for the Prevention of Pollution from Ships; and several other statutes. Several organizations make up the Office of Water: Office of Wetlands, Oceans and Watersheds, Office of Science and Technology, Office of Wastewater Management, and the Office of Ground Water and Drinking Water. In addition, Water Divisions in all ten regional offices work with stakeholders to implement all programs.

Other federal agencies, state and local governments, Indian tribes, the regulated community, organized professional and interest groups, landowners and managers, and the public-at-large assist in program implementation. The Office of Water provides guidance, specifies scientific methods and data collection requirements, performs oversight, and facilitates communication among involved parties.

Through experienced gained over the past several decades, the Office of Water has gained valuable insight to resource regulation and management. The Office of Water notes on its website a central theme that summarizes the difficulties faced by government agencies involved in resource management:

> *"…[W]e are still working with laws and regulations that treat land, air, water and living resources as separate entities instead of as interrelated systems. This regulatory pattern makes comprehensive solutions and their implementation problematic, and complicates protection of ecosystems and habitat. The traditional command and control approach, combined with single media laws, precludes flexibility and deflects attention from developing and applying alternative solutions that include market mechanisms, economic incentives, voluntary approaches, alternative enforcement penalties, prevention, negotiation, education and land use planning."*
>
> – U.S. EPA Office of Water[9]

To remedy the existing jurisdictional and regulatory issues intrinsic in the structure of government, the Office of Water advocates supplementing the "command and control approach" with alternative techniques to allow program implementation on an integrated watershed basis, including air, land, and ecosystem relationships and related regulatory tools in water initiatives. The Office of Water seeks to apply a broad and balanced approach, utilizing regulatory enforcement, education outreach, voluntary compliance, and volunteer initiatives, particularly initiatives that prevent rather than remedy pollution. Thus, the Office of Water developed a Watershed Protection Strategy to protect water resources and public health at the overreaching watershed scale. The following sections provide information on the strategy development and the framework for implementation.

[9] U. S. EPA.. 2006. *Overview of the National Water Program.* Internet, Available at: http://www.epa.gov/water/programs/owintro.html.

9.3.1.1. EPA's Watershed Protection Approach

The Office of Water describes its Watershed Protection Approach as "a strategy for effectively protecting and restoring aquatic ecosystems and protecting human health." The approach is based on the premise that many water quality and ecosystem problems are best solved at the watershed level, rather than at the individual body of water or discharger level.

The Watershed Protection Approach includes the following actions:

- Targeting priority problems;
- Promoting a high level of stakeholder involvement;
- Using integrated solutions that employ the expertise and authority of multiple agencies; and
- Measuring success through monitoring and other data gathering.

In 1996, the EPA published its *Watershed Approach Framework*[10] to build upon the Office of Water's Watershed Protection Approach, which was endorsed by senior EPA managers in 1991. The *Watershed Approach Framework* emphasizes the role EPA envisions for states and tribes. According to the Office of Water, the Watershed Protection Approach Framework also reflects the high priority that individual Office of Water programs have put on developing and supporting comprehensive state and tribal watershed approach strategies that actively involve public and private interests at all levels to achieve environmental protection."

Increased public awareness and concern over environmental issues has invigorated community-volunteer initiatives for watershed protection nationwide. The creation of multidisciplinary and multi-jurisdictional partnerships between public and private organizations facilitates community actions to address local problems within their watershed. The Office of Water supports and encourages such partnerships for watershed restoration, maintenance, and protection. The Watershed Protection Approach Framework provides a coordinating structure for environmental management that focuses public- and private-sector efforts on the highest-priority problems within hydrologically defined geographic areas, or watersheds. The hydrologic boundaries consider both ground and surface water flow.

Guiding Principles and Benefits

The Watershed Protection Approach focuses on achieving pollution prevention, sustainable environmental improvements, and meeting community goals. The Watershed Protection Approach is flexible and its application may vary in terms of specific project objectives, priorities, elements, timing, and resources. However, the EPA recommends that projects apply the following guiding principles:

[10] U. S. EPA.. 1996. *Watershed Approach Framework*. EPA 840-S-96-001, Office of Water (4501T), U.S. EPA, Washington, DC. Available online at: http://www.epa.gov/owow/watershed/framework.html.

- **Partnerships:** The people most affected by management decisions are involved throughout and shape key decisions. This ensures that environmental objectives are well integrated with those for economic stability and other social and cultural goals. It also provides that the people who depend upon the natural resources within the watersheds are well informed of, and participate in, planning and implementation activities.

- **Geographic Focus:** Activities are directed within specific geographic areas, typically areas that drain to surface water bodies, or that recharge or overlay ground water, or a combination of both.

- **Sound Management Techniques based on Strong Science and Data:** Collectively, watershed stakeholders employ sound scientific data, tools, and techniques in an iterative decision-making process. This includes:

  - Assessing and characterizing natural resources and the communities that depend upon them;

  - Goal Setting and identifying of environmental objectives, based on the condition or vulnerability of resources, and the needs of the aquatic ecosystem and the people within the community;

  - Identifying priority problems;

  - Developing specific management options and action plans;

  - Implementing plans; and

  - Evaluating effectiveness and revising plans, as needed.

All stakeholders and involved parties provide input on the roles, priorities, and responsibilities. Collective actions are based upon shared information and a common understanding. The Office of Water notes that the iterative nature of the Watershed Protection Approach encourages partners to set goals and targets and to make maximum progress based on available information, while continuing analysis and verification in areas where information is incomplete. This is of particular importance in Hawaii, where data is lacking in many areas. The Watershed Protection Approach also accommodates concerns about environmental justice, and promotes the adoption of pollution prevention techniques.

There are numerous benefits that are derived from utilizing the EPA's Watershed Protection Approach. Active and broad involvement of citizens, agencies, and private interests fosters a sense of community, reduces conflicts, increases individual and group commitment to follow through with action items, and improves the likelihood of sustaining long-term environmental improvements. Other specific benefits include:

- Operating and coordinating programs on a watershed basis makes good sense for environmental, financial, social, and administrative reasons.

- Joint review of environmental studies and assessments (for drinking water protection, pollution control, fish and wildlife habitat protection and other aquatic resource protection programs) allows managers from all levels of government to understand the cumulative impacts of various human activities, and determine the most critical problems within each watershed.

- Shared use of environmental studies and assessments allows public and private managers to allocate limited financial and human resources to set priorities for action, and address the most critical needs.

- Establishing and monitoring environmental indicators helps guide activities toward solving high-priority problems and measuring success in real-world improvements, rather than simply fulfilling programmatic requirements.

- The emphasis on broad community involvement provides those people who depend on the aquatic resources for their health, livelihood, or quality of life a meaningful role in the management of resources.

- A cooperative approach can result in cost savings by leveraging and building upon financial resources and the willingness of individuals and concerned parties to take action.

- Improved communication and coordination reduces costly duplication of efforts and conflicting actions.

- Regarding actions that require permits, specific actions taken within a watershed context (for example, establishing of pollutant-trading schemes or wetlands mitigation banks and related streamlined permit review) enhance predictability that future actions will be permitted, and reduces costs for the private sector.

- Through resource leveraging and cost savings, the Watershed Protection Approach can help enhance local and regional economic viability in ways that are environmentally sound and consistent with watershed objectives.

- The Watershed Protection Approach strengthens teamwork between the public and private sectors at the federal, state, tribal, and local levels to achieve the greatest environmental improvements with the available resources.

Implementation through State and Local Watershed Approaches

> *"The [EPA] has both a national interest in and responsibility for supporting watershed approaches. The interest stems from the belief that the diverse sources of aquatic ecosystem impacts will best be brought under control through a combination of cooperative and mandatory measures tailored to the needs in specific watersheds with wholehearted support from watershed stakeholders. EPA's responsibility includes definition and ensured compliance with basic water programs; development of national standards and tools; funding; and national assessment of status and progress."*
>
> – EPA Office of Water, Watershed Protection Approach Framework, 1996[11]

State and local government agencies implement existing water and natural resource protection programs and are well situated to coordinate among other levels of government (e.g., local, regional, and federal). Therefore, the EPA places special emphasis on supporting state, and tribal partners in developing and implementing comprehensive watershed approaches. However, this emphasis should not be construed as a lack of support for other parties who may want to be involved in watershed management, especially local stakeholders.

The EPA recognizes that each state or tribe may approach watershed management differently. The EPA supports watershed approaches that are specifically tailored to the needs of the jurisdictions, and, therefore, the agency will not prescribe implementation actions. EPA envisions locally driven, watershed-based activities embedded in comprehensive state and tribal watershed approaches all over the United States. Between 1992 and 2002, more than 20 states adopted a statewide watershed approach to manage their water programs.

The Office of Water provides assistance to public and private water quality managers and staff in the development and implementation of watershed approaches. The four main areas of assistance include watershed management training, statewide watershed approach facilitation, watershed program scoping, and technical analysis assistance. The Office of Water has found that the training and facilitation assistance are the most actively requested services of the watershed assistance program.

9.3.1.2. Evaluation of EPA's Statewide Watershed Management Approaches

In 2002, the EPA Office of Wetlands, Oceans, and Watersheds and the Office of Wastewater Management jointly published their Final Report[12] capturing the findings of their review of eight selected state watershed management approaches. In the

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[11] U. S. EPA.. 1996. *Watershed Approach Framework*. EPA 840-S-96-001, Office of Water (4501T), U.S. EPA, Washington, DC. Available online at: http://www.epa.gov/owow/watershed/framework.html.
[12] U. S. EPA.. 2002. *A Review of Statewide Watershed Management Approaches*. Internet, available at: http://www.epa.gov/owow/watershed/approaches_fr.pdf.

decade prior to the agency review, the EPA had undertaken considerable efforts to promote state adoption of watershed management approaches by providing technical assistance, publishing communication and outreach materials, and offering facilitation and training.

The review addressed three objectives:

1. Identify and describe the different models of statewide watershed management.

2. Characterize and assess the experiences of selected states using different models for statewide watershed management.

3. Develop recommendations to improve the EPA's support and state implementation of statewide watershed management.

The report provides summaries of key findings in program management, coordination, and public involvement, and concludes with recommendations. Significant findings and recommendations are summarized below.

Key Findings

Both EPA-level and state-level program management barriers are identified in the report. The review acknowledged the following *state-level* management barriers:

- Tensions exist between programmatic requirements and statewide watershed management activities. Keeping program managers, who are comfortable with the traditional Clean Water Act programs, on board with the Watershed Protection Approach is an ongoing challenge, since their programmatic obligations often limit their involvement in watershed activities.

- States with point sources of pollution grouped unevenly throughout the state have difficulty synchronizing the issuing of National Pollutant Discharge Elimination System (NPDES) permits. In addition, situations can be further complicated by special monitoring efforts sometimes needed to address citizen complaints to collect data for Total Maximum Daily Load (TMDL) standards development.

- States lack adequate resources to hire contractors, conduct watershed assessments, provide public outreach, and carry out adult-education programs on water quality.

- Despite enormous investments some states have made in the watershed approach, they still feel vulnerable to changes in senior level commitment to the approach.

The following *EPA-level* and *federal-program level* management barriers were identified:

- EPA's oversight of state programs appears fragmented and output-oriented, rather than integrated and driven by environmental results. Although EPA policies push for environmental "progress" and long-term management, states feel that the EPA's policies and state oversight are too often focused on short-term priorities.

- Some states thought that goals and time frames for reaching goals needed to be revised or made more flexible to fit implementation schedules.

- Some states are having difficulty integrating the development of TMDLs into their statewide watershed management approaches. Some states also commented that EPA policy is too rigid, and does not allow states to be innovative with program management.

- Initiatives can result in numerous inefficiencies and redundancies that often distract staff, redirect resources, and confuse watershed partners.

- Several states felt that more visible EPA involvement in watershed planning would enhance states' watershed efforts and increase the EPA's understanding of local issues.

- Schedule requirements under the Clean Water Act for permit re-issuance, water quality standards review, and reporting requirements create difficulties in synchronizing management actions on a five-year schedule.

The report notes the following issues regarding coordination across state programs and agencies:

- Water quality and land use management authorities are distributed across numerous state agencies, commissions, departments, and agencies that have different mandates, priorities, and techniques for managing programs and interacting with local authorities and the public. Most states felt that their statewide watershed management approach had improved interagency coordination, but not to the desired and necessary extent. The challenge facing many state water programs is to convince other agencies to not only participate in the watershed process, but also to agree to common water quality goals and work to achieve them.

- Coordination elements that resulted in effective, integrated, and cooperative watershed management approaches include:

    - A firm commitment and clear direction from top agency managers.

    - Significant investments in coordination, power-sharing, and ongoing communication among state and federal partners.

- Tightly focused organizational frameworks that include statewide steering committees, dedicated basin coordinators, and multi-stakeholder teams.

- Plans that include clear responsibilities and a mechanism for tracking commitments and holding state managers accountable for achieving management goals.

The report presents the following conclusions regarding state-local coordination and public involvement:

- Some states observed significant increases in public input and involvement, while other states found that public involvement remained relatively limited. States that experienced increased public interest and involvement reported that they were not prepared for the amount of time and resources needed to effectively engage and respond to public concerns, advice, or information. However, the most successful programs have developed in watersheds with strong stakeholder groups.

- While it may be difficult for states and local entities to share agenda-setting and priority-establishing powers (and associated funding), the cooperative approach enhances local buy-in, support, and action. States are challenged to provide enough flexibility and support to local organizations to ensure their active engagement, while maintaining the ability to focus local actions on attainment of state water quality standards.

- Despite increased public involvement, statewide watershed management programs in most of the eight states have yet to build significant relationships with local government planning, zoning, or land use and management structures and their inherent authorities. Many states noted the importance of linking water-quality impacts with local land use and management practices, but admitted that state-sponsored watershed planning processes have not been as effective in the past as they could have been in helping link the two operationally.

Recommendations

As a result of the review process, the report recommends the EPA work with states to adopt a multi-pronged approach to support statewide watershed management, inclusive of the following actions:

- Promote key elements of the approach to senior management;

- Offer incentives, flexibility, and training for states that haven't adopted the approach, to initiate framework development and experimentation;

- Investigate and develop solutions to key barriers to state watershed management;

- Become more actively involved in state watershed planning and implementation;
- Review and, where necessary, revise grant evaluation criteria and resource allocation formulas to promote integrated watershed management;
- Develop performance measures to assess progress of integrated watershed management in achieving environmental results; and
- Develop organizational frameworks and partnerships at the federal, state, and local level that facilitate better integration and coordination within and between Clean Water Act and Safe Drinking Water Act programs.

The report further recommends that states consider adopting several key actions to improve their watershed approaches. Among these key actions are the following:

- Evaluate whether state watershed management frameworks have the necessary components that facilitate resource leveraging, program integration, and accountability.
- Consider developing regulations and/or legislation (with appropriate resources) that support existing basin/watershed planning processes.
- Improve the integration of more Clean Water Act and Safe Drinking Water Act programs into the state watershed approaches; and
- Effectively link state-sponsored basin planning with local planning/zoning efforts.

9.3.2. Other Federal Watershed Protection and Management Programs

The U.S. Department of the Army and the U.S. Department of Agriculture (USDA) administer certain programs that contribute to watershed protection activities. These programs are summarized below.

9.3.2.1. U.S. Army Corps of Engineers (USACE) Permitting Programs

The U.S. Army Corps of Engineers (USACE) has jurisdiction over activities in waters of the United States, and administers a regulatory program to protect aquatic resources. Waters of the United States consist of, essentially, all surface waters including all navigable waters and their tributaries, all interstate waters and their tributaries, all wetlands adjacent to these waters, and all impoundments of these waters. The USACE permit review process is intended to prevent adverse impacts to surface water resources and wetland environments, through the evaluation of proposed actions with respect to applicable laws, regulations, and policies.

The USACE derives its regulatory authority over waters of the United States from the two Federal laws. Section 10 of the Rivers and Harbors Act of 1899 applies to all navigable waters of the United States and Section 404 of the Clean Water Act applies to all waters, including wetlands, that have sufficient nexus to interstate commerce. Summaries of permit types administered by the USACE, as described on the USACE Honolulu District[13], are listed below.

Individual Permits

An Individual Permit is an authorization from the Department of the Army that has undergone a full public interest review. This includes a 30-day public notice period in which a copy of the permit drawings and a description of the project are forwarded to all interested parties, adjacent property owners, and State and federal agencies for review and comment. Processing time for these types of permits is usually 60 to 120 days from the receipt of a complete application for non-controversial projects. Controversial or larger projects, including those that require a public hearing or an Environmental Impact Statement (EIS), generally take longer to process.

Letters of Permission

The Letter of Permission (LOP) is a type of individual permit used in cases where the proposed project involves a lesser degree of impact to aquatic resources. The LOP involves a 30-day comment period or a 15-day comment period in cases where the proposed impacts are minor and non-controversial. State and federal agencies and the adjacent property owners are provided a project description and a copy of project plans. A final decision on the LOP permit application is usually reached 45 to 60 days from the date a complete application is received by the USACE office.

Nationwide Permits

Nationwide permits are general permits issued nationwide to authorize categories of minor activities. The Honolulu District has developed Regional Conditions, in order to provide additional protection for the aquatic environment within the Pacific region. All persons wishing to perform work under the nationwide permits must provide written notification to the USACE prior to the start of work. The Regional Conditions provide a list of the information necessary to submit a complete Pre-construction Notification. After a review of the project, the USACE will issue a verification letter pursuant to the applicable Nationwide Permit(s).

Regional General Permits

Regional General Permits are used to authorize activities that cause only minimal individual and cumulative environmental impacts. Regional General Permits are developed by individual districts to streamline project review by minimizing duplication of other federal, state, and local review processes, while still protecting aquatic resources. Regional General Permits may be restricted for use in areas as small as a single residential development, a county, a region of the state, or the entire district.

[13]U.S. Army Corps of Engineers. 2007. *Regulatory Branch*. Internet, available at: http://www.poh.usace.army.mil/EC-R/EC-R.htm.

9.3.2.2. USDA Natural Resource Conservation Service

In 1935, the USDA created the Natural Resource Conservation Service (NRCS), a federal-private partnership program with landowners and managers, to conserve soil, water, and other natural resources. The objectives of NRCS's natural resources conservation programs include the reduction of soil erosion, enhancement of water supplies, improvement of water quality, increase of wildlife habitat, and reduction of damages caused by floods and other natural disasters. Enhanced natural resources contribute to agricultural productivity and environmental quality, while supporting continued economic development, recreation, and scenic beauty.

The NRCS has six mission goals:

- High quality, productive soils;
- Clean and abundant water;
- Healthy plant and animal communities;
- Clean air;
- Adequate energy supply; and
- Working farms and ranchlands.

To achieve these goals, NRCS implements three strategies:

- **Cooperative conservation:** seeking and promoting cooperative efforts to achieve conservation goals.
- **Watershed approach:** providing information and assistance to encourage and enable locally led, watershed-scale conservation.
- **Market-based approach:** facilitating the growth of market-based opportunities that encourage the private sector to invest in conservation on private lands.

NRCS conservation activities include farmland protection, upstream flood prevention, emergency watershed protection, urban conservation, and local community projects designed to improve social, economic, and environmental conditions. Soil surveys, conservation needs assessments, and National Resources Inventory assessments provide the basis for resource conservation planning activities and an accurate evaluation of the condition of private lands. Local NRCS offices provide technical and financial conservation assistance to farmers and ranchers to develop conservation plans and to advise on design, layout, construction, management, operation, maintenance, and evaluation of the recommended, voluntary conservation practices.

The NRCS also provides conservation assistance through a nationwide network of conservation districts. The agency implements its "watershed approach strategy" through relationships with conservation districts and with local farmers and landowners.

9.4. State of Hawaii Watershed Protection Programs

As discussed earlier in the evaluation of the EPA's statewide watershed management approach, many state governments are structured such that water resource and land use management authorities are distributed across several state agencies, commissions, departments, and authorities. These entities all have different mandates and priorities, as well as different public education programs and relationships with the community.

The State and county governments in Hawaii are not exceptions. Although the DLNR administers most programs related to resource conservation, preservation, protection, and management, there are several other State agencies that also have responsibilities related to conservation and management. The DOH administers programs to ensure water quality. DBEDT administers the Coastal Zone Management Program, including regular updates of the agency's *Ocean Resources Management Plan*. The DOA protects and manages agricultural lands and irrigation systems to ensure the viability of the diversified agriculture industry. The DOA also administers programs to regulate the animal and plant industries in pest and disease control, quarantine, and the application of pesticides. Soil and Water Conservation Districts (SWCDs) across the state also contribute to the protection of agricultural resources. The county water departments operate and maintain water systems for municipal supply, and county planning departments administer land use zoning and permitting programs for existing and future development. Although in many cases, watershed protection may not be the ultimate purpose of these programs, the implementation of these programs results in positive impacts to watershed areas and watershed protection efforts.

In the EPA's evaluation of the agency's statewide watershed management approach implemented in various states, the agency found that most states experienced improved interagency coordination, but not to the desired and necessary extent. The challenge faced by many state water programs is to convince other agencies to not only participate in the watershed process, but also to agree to common water quality goals and work to achieve them. The same challenge, to some extent, faces Hawaii's State government; however, it should be recognized that the cooperative efforts of agencies, community groups, and private parties have been overcoming jurisdictional obstacles to improve watershed management and protection since the early 1900s.

9.4.1. DLNR Division of Forestry and Wildlife Programs

Over 100 years ago, the territorial government of Hawaii, with the active cooperation of private landowners, established Hawaii's forest reserve system to protect the islands' water supply. The upland forests are the primary recharge areas for ground water supplies and must therefore be protected to ensure healthy watersheds to sustain future ground water availability and quality. DOFAW manages the forest reserve system and all areas designated as State Watershed Areas (see Figure 9-1).

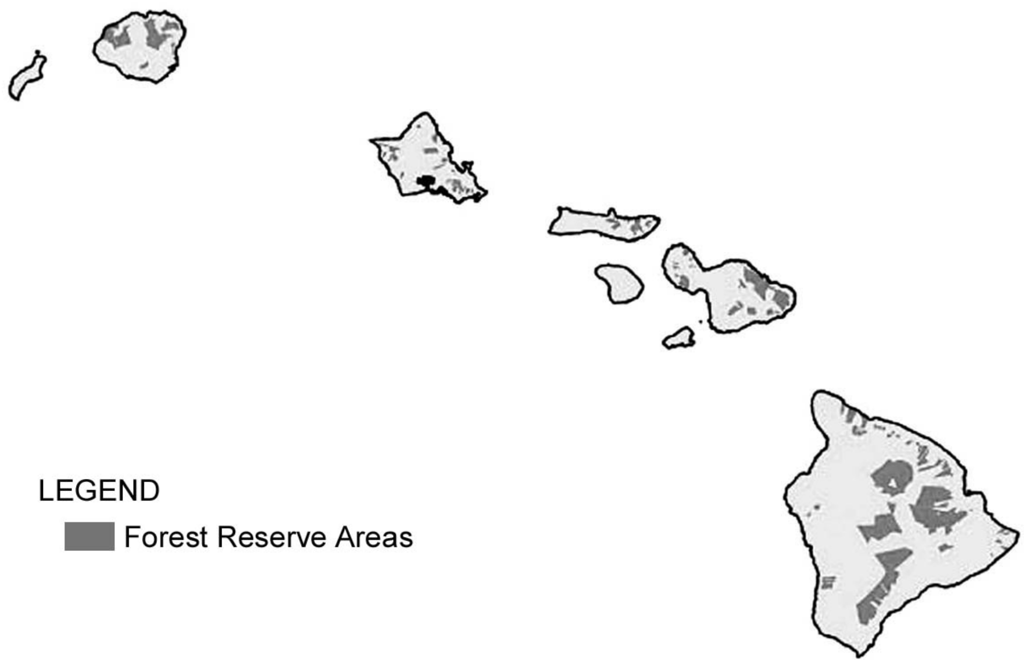

Figure 9-1. State Forest Reserve Areas

DOFAW has a legal mandate to manage public lands for social, environmental, and economic purposes. DOFAW is the largest land management entity in the State of Hawaii. Water quality, endangered species, recreation, land development, and rural economic opportunities are some of the many issues that influence forest and wildlife management strategies. Through the Division's Watershed Management Program, healthy forests will continue to capture rainfall to replenish underground aquifer systems.

The objectives of the Watershed Management Program seek to protect and improve the condition of forests that benefit our water supply:

- Help insure water quality and quantity;
- Prevent rapid run-off of storm flows and soil erosion;
- Improve water infiltration into soil; and
- Encourage forestry activities on private land.

Other DOFAW programs complement and contribute to watershed management. These programs include the Wildland Fire Protection Program, the Nursery Production Program, the Native Ecosystems Program, the Forest Pest Management Program, the Threatened and Endangered Plants and Animals Program, and the Forest Stewardship Program. The Native Ecosystems Program is especially linked to watershed management as the program administers the State's Natural Area Reserves System.

9.4.1.1. The Natural Area Reserves System and the Natural Area Partnership Program

DOFAW administers two land management programs in State Watershed Areas: the Natural Area Reserves System (NARS) and the Natural Area Partnership Program (NAPP).

NARS was established with the mandate of protecting the best remaining examples of native ecosystems and geological sites on state-managed lands. The statewide NARS currently consists of 19 reserves with a total of approximately 109,165 acres on five islands (see Figure 9-2). In addition to preserving resources, these reserves are useful in comparing and measuring changes occurring across the rest of the state. While NARS is based on the concept of protecting native ecosystems, as opposed to single species, many rare and endangered plants and animals benefit from protection efforts through NARS. Major management activities implemented according to the management plans include non-native animal control, non-native plant control, rare species protection, research, monitoring, and public education. The management plans for reserve areas, which are guided by management policies approved by the NARS Commission and the Board of Land and Natural Resources (BLNR), are regularly reviewed and updated as new management actions are identified. DOFAW participates in a number of groups to facilitate increased input by all concerned parties in plan development and revision.

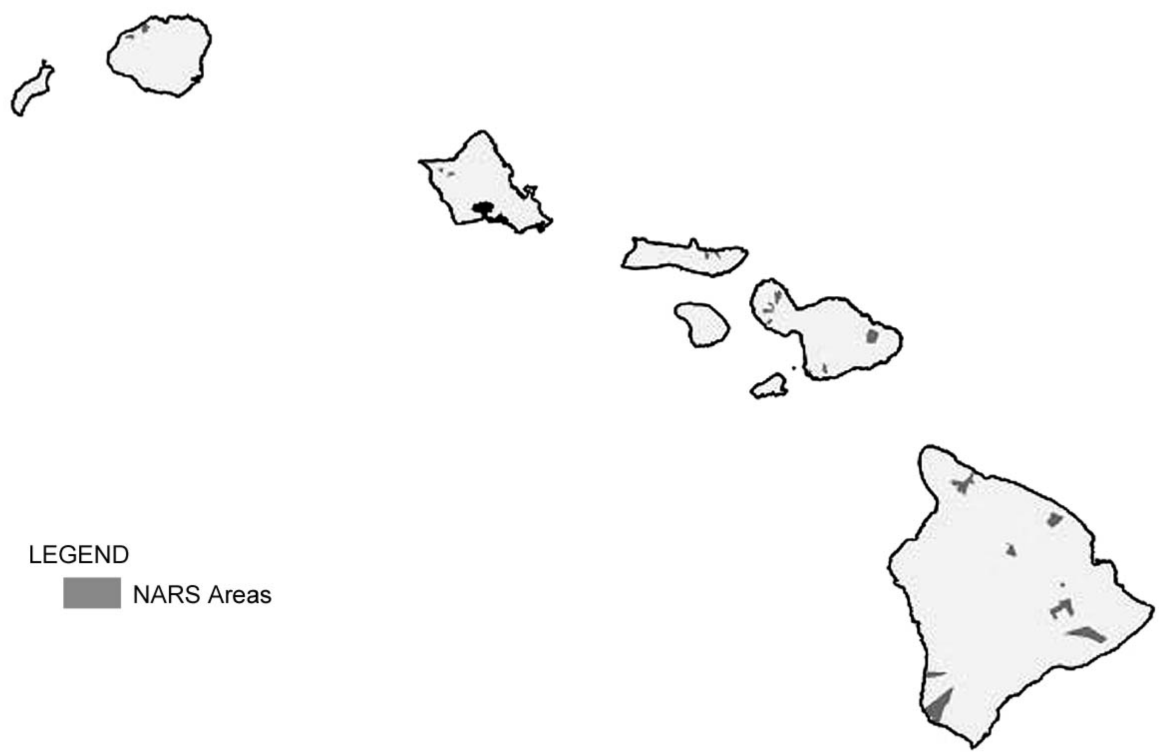

Figure 9-2. NARS Areas in Hawaii

NAPP was established by the Legislature in 1991 to complement NARS, by providing long-term protection and management of unique natural resources on private lands. Long-range management plans approved by the BLNR provide funding and direction for each NAPP preserve. Beginning in 2001, the Natural Area Reserve Special Fund was expanded to include year-to-year funding for projects undertaken in accordance with watershed management plans negotiated with private landowners (watershed partnership projects). NARS special funds are provided on a two-to-one matching basis, with private funds for the management of natural resources on private lands that have been permanently dedicated to conservation. These watershed partnerships are an efficient way to manage the natural landscape against threats to the health of the forest and to more effectively protect the water resources of the State. NAPP provides support for a full range of management activities to protect, restore, and enhance significant native resources and geological features. NARS staff administers NAPP, although the private land owner/applicant carries out all on-the-ground activities.

NARS and NAPP focus on sustained management actions conducted across land ownership boundaries, such as animal control and fire prevention. The emergence of watershed partnerships throughout the state have contributed greatly to appropriate management of forested areas. Such partnerships will continue to play an important role in the management of the reserves. Program plans and management objectives will continue to include collaboration with watershed partnerships to collectively manage areas on a landscape level.

9.4.1.2. Watershed Management Program

In 1903, the Governor of the Territory of Hawaii approved Act 44, enacted by the territorial legislature, to designate forest reserves and extend the reserve system to protect ground water supplies. Extensive cattle grazing in native forests during the 1800s had resulted in significant deforestation. Public and private concerns about water supply and quality were the impetus for placing the forests into reserves and undertaking massive reforestation projects at the turn of the century.

Through Act 44, the Territory of Hawaii established one of the first forestry agencies in the nation; the agency had the authority to establish forest reserves for the protection of springs, streams, and other water supply sources. The State's long-standing policy of watershed protection resulted in dramatic improvements from the degraded conditions due to overgrazing that prevailed at the turn of the century. Management activities such as protective zoning, fencing, removal or control of feral animals, reforestation, and fire protection have reduced excessive erosion and loss of vegetative cover.

The modern form of watershed management through public/private partnerships emerged in the early 1990s, with voluntary alliances between landowners committed to the common value of protecting large areas of forested watersheds for water recharge and other shared interests. The successful creation of the East Maui and West Maui Mountains Watershed Partnerships reinvigorated the historic cooperative partnership of public and private sectors in working together to protect essential, forested watershed recharge areas in Hawaii. In 1999, the Koolau Mountains Watershed Partnership on the Island of Oahu and the East Molokai Watershed

Partnership were formed. A watershed partnership for the island of Lanai was developed in 2001.

Act 152 and the Watershed Protection Board

In 2000, Hawaii had the 11th largest State-owned forest and natural-area reserve system in the United States. However, following the success of reforestation projects initiated at the beginning of the 20th century, invasive weeds and feral animals emerged as threats to watersheds and forest reserves. That year, the Legislature enacted and the Governor approved Act 152 to establish a seven-member Watershed Protection Board, to develop a watershed protection master plan to provide for the protection, preservation, and enhancement of important watershed areas. The board consisted of representatives from the Board of Agriculture, BLNR, the U.S. military, and each of the county water departments.

An integrated watershed and forest management program may include all of the following activities: fire control and prevention, stream monitoring, reforestation, detection and rapid response to remove invasive weeds, monitoring for pest insects and disease, maintenance of trails and access for public hunting, fencing and animal removal in priority watersheds, and public education and volunteer programs. The efforts of the Watershed Protection Board and DOFAW, pursuant to Act 152, were intended to supplement ongoing projects and explore options for a dedicated source of funding for current and future watershed protection projects.

Act 152 stipulated that a watershed protection master plan was to be completed no later than June 30, 2001. Subsequently in October 2001, the DLNR submitted its annual report to the Legislature on Act 152, the findings and recommendations of which are summarized as follows:

- Given the limitations of time and resources, a phased approach to the development of a Watershed Master Plan would be advantageous and allow the initial report to focus in on achievable targets, based on the priorities identified in Act 152. Expanding the watershed master planning effort to include the entire ahupuaa would be the focus of a subsequent planning phase. The following planning phases were identified:

Phase 1	Framework for the watershed protection program
Phase 2	Watershed assessment and prioritization (mauka areas)
Phase 3	Watershed master plan for the mauka areas
Phase 4	Watershed master plan for mauka and makai areas (ahupuaa)

- Watershed management plans must include the following components:

  - Watershed resource monitoring, including rainfall, aquatic biological data from streams, hydrological information, water quality, forest health, and species diversity;

  - Feral animal control;

- Non-native weed control;

- Polluted runoff and other pollution control;

- Management infrastructure, including roads, trails, shelters, and helicopter landing sites to do forest restoration and watershed resource monitoring work; and

- Public education and volunteer outreach, including programs to educate and train the public and communities on watershed issues and to encourage capacity-building, citizen-based watershed restoration and partnerships.

• Support the efforts of the five existing watershed partnerships located in East Maui, West Maui, East Molokai, the Koolau mountains on Oahu, and in Lanai with adequate funding.

• Develop criteria to identify the physical, social, and cultural parameters of each watershed and facilitate watershed assessment. Two basic groups of criteria can be applied to watershed management projects:

  - Significance criteria, based on resource values or conditions that impact water quality and quantity; and

  - Ability to deliver effective watershed protection programs.

• Assessment criteria should be simple and easily understood. Supporting information for watershed protection projects should suffice to demonstrate that some or all of the criteria have been met. Projects should not have to meet every criterion, but should demonstrate sufficient eligibility to be considered. Procedures for selecting watershed projects should enable sound decision-making, without creating the need for a heavy administrative structure. Selection procedures and criteria should generate sufficient data to facilitate weighing the selected parameters with confidence, without being unduly burdensome for the applicant or implementing board.

• Implementing watershed protection projects is a multimillion-dollar undertaking, justified by the value of the resources at stake. For example, in November 1997, economists at the University of Hawaii began a natural resource valuation of the Koolau Mountains watershed on Oahu. The preliminary economic analysis of the amenities provided by the Koolau Mountains watershed showed an estimated net present value (NPV) of $7.44 to $14 billion.[14]

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[14]NPV published in 1997.

- It is critical that watershed projects are supported by a combination of funding sources, including agency appropriations, grants, contributions from public and private sources, landowners, water purveyors, and other beneficiaries of watershed protection programs. A dedicated source of funding, whether it is a portion of an existing tax or a new assessment or tax on water use, should be considered. Funding through the general fund would allow a more equitable, statewide distribution of any tax burden across all water users; however, general funds are subject to changing budget priorities and are therefore not a source of dedicated funding.

- The Conveyance Tax should be considered as a source of dedicated funding for watershed management. Since 1993, the Natural Area Partnership Program and the Forest Stewardship Program have had a dedicated permanent source of state funding from 25 percent of the Conveyance Tax (HRS 247), which is levied each time real estate property is bought or sold. The revenues are deposited in the Natural Area Reserve Fund. The rationale for applying a portion of the Conveyance Tax for watershed management is that any sale, development, and improvement of real estate in Hawaii puts additional pressure on Hawaii's water resources, and increases the need and costs to protect watershed recharge areas.

- A watershed protection assessment on water users must consider policy and issues of legality and equitability. Legal issues on assessment versus taxation, equality, and the legal nexus of the assessment, and the collection of a State assessment by county agencies must be addressed prior to the imposition of any assessment. Any assessment must be fairly applied to all water users, e.g. municipal, agricultural, military, and private water systems.

- A watershed protection assessment should be based on a completed evaluation and prioritization of watershed and water resource needs and issues, as well as on an accountability plan for expending funds. In order to determine a sound basis for funding, the watershed protection master plan should be completed prior to determination of final funding needs and assessment methods.

- A commitment to funding watershed protection programs should be provided by all beneficiaries including government agencies, landowners, watershed partnerships, and the public.

Recommendations for Follow-up Actions

Act 152 expired on June 30, 2002, and the recommendations of the 2001 annual report to the Legislature did not receive funding for implementation. However, some of the recommendations for watershed protection in the mauka areas are being carried forth through the actions of the Hawaii Association of Watershed Partnerships (HAWP), which was formed in 2003 through an agreement between six existing watershed partnership organizations and the State of Hawaii (see Section 9.5). Between the October 2001 submittal of the annual report and the July

2002 expiration date of Act 152, the annual report to the Legislature listed the following potential next steps.

- The present Watershed Protection Board believes that should the Legislature desire to retain the watershed protection board and extend its expiration date or eliminate the expiration date completely, three areas need to be considered. First, the composition of the board should be reworked to include scientists, land owners, and community members. Second, the Legislature must provide funding for additional work of the board. The board cannot continue to function without the addition of staffing and other resources to properly execute activities. Third, one of the major functions of the board shall be to provide coordination between existing programs, ensuring that resources are not wasted, and to provide for the maximum coordination of different existing programs.

- Complete the list of critical watershed management areas.

- Complete the watershed data collection and prioritization assessment. More work is needed to focus or “distill” the criteria into their essential elements and complete the watershed assessment and prioritization process in a timely manner.

- Develop a list of tailored watershed protection projects. Once the prioritized list of critical watershed management areas are identified, a secondary assessment could evaluate the potential effectiveness of each type of watershed protection project, by specifically tailoring plans to the unique needs of each watershed management area. This step is critical to effectively utilize the limited available funding.

- Secure a dedicated funding source and project specific appropriations.

- Integrate various watershed efforts and programs. There is a need to integrate all of these efforts into an efficient and focused framework.

- Develop and implement a stakeholder coordination and involvement plan. A stakeholder and public participation strategy coordination and involvement plan should be completed to identify key stakeholders, whose input should be solicited early in the process and at critical stages of the watershed protection planning.

Many of these recommendations remain valid prospective actions. Perhaps the most important and resounding recommendation is captured in item six: “There is a need to integrate all of these efforts into an efficient and focused framework.” Through DOFAW’s participation in the Hawaii Association of Watershed Partnerships, DLNR continues working toward the realization and implementation of integrated watershed protection and management. The importance of integrating watershed efforts to encompass and coordinate mauka, makai, and nearshore watershed protection efforts becomes clear after examining the multitude of existing community group and partnership activities throughout the state. Section 9.5 provides descriptions of these organizations and their various objectives.

9.4.2. DLNR Office of Conservation and Coastal Lands

The OCCL is responsible for overseeing approximately 2 million acres of private and public lands that lie within the State Land Use Conservation District (see Figure 9-3). In addition to privately and publicly owned Conservation District lands, OCCL is responsible for overseeing beach and marine lands to the seaward extent of the State's jurisdiction.

The OCCL has multiple functions, such as: permit processing, prosecution of land use violations, resolution of shoreline encroachments, enactment of beach restoration projects, administration of contested cases involving Conservation District Use Permits and shoreline certifications. The OCCL provides direction and guidance to coastal landowners, concerned citizens and resource agencies on current best practices for shoreline use and management through the development, implementation, and monitoring of Coastal Management Policy and Procedures. It is a goal of OCCL to balance the conservation of our State's unique and fragile natural resources with development of these resources for the good of the State.

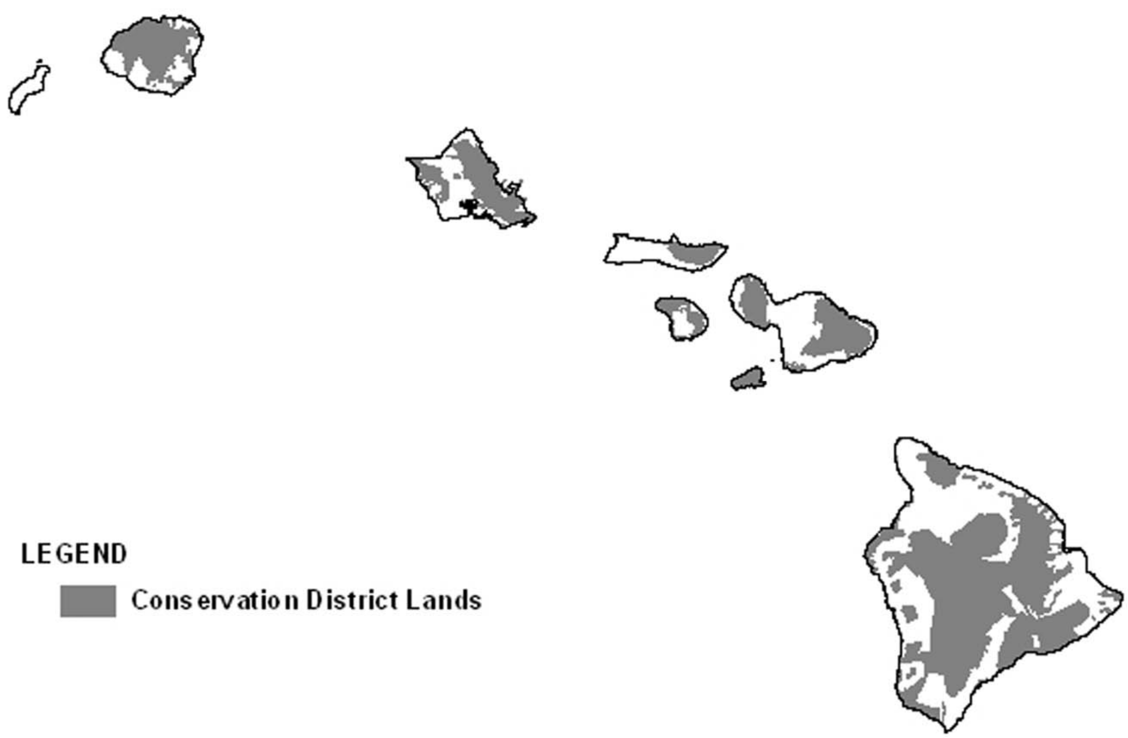

Figure 9-3. State Land Use Conservation District Lands

9.4.3. DBEDT Land Use Commission

The LUC's primary role is to ensure that areas of state concern are addressed and considered in the land use decision-making process. The LUC is administratively attached to DBEDT, and has established four land use districts: Urban District, Rural District, Agricultural District, and Conservation District.

The LUC acts on petitions for boundary changes submitted by private landowners, developers and State and county agencies. Decisions on boundary change petitions are guided by a specific set of criteria, which includes preservation or maintenance of important natural systems or habitats. Such values are generally associated with Conservation District lands.

The Conservation District is comprised primarily of lands in existing forest and water reserve zones and includes areas necessary for protecting watersheds and water sources, scenic and historic areas, parks, wilderness, open space, recreational areas, habitats of endemic plants, fish and wildlife, and all submerged lands seaward of the shoreline. The Conservation District also includes lands subject to flooding and soil erosion. Conservation Districts are administrated by the BLNR and uses are governed by rules promulgated by the State DLNR.

9.4.4. Department of Health Water Quality Programs

The DOH administers programs that contribute to watershed protection from the water quality perspective. The goals and objectives of the national Clean Water Act and Safe Drinking Water Act, among other federal laws, are embodied in the EPA's management, regulatory, and permitting programs carried out in Hawaii by the DOH.

The DOH Clean Water Branch administers the National Pollutant Discharge Elimination System (NPDES) permits to minimize discharge of pollutants to State waters. The DOH Safe Drinking Water Branch is responsible for protecting drinking water sources (surface water and ground water) from contamination and regulates owners and operators of public water systems. The DOH Wastewater Branch administers water pollution control programs and regulates municipal and private wastewater treatment works, as well as individual wastewater systems. The DOH Environmental Protection Office (EPO) administers the Water Quality Management Program, which includes setting Water Quality Standards and executing the TMDL Process and Continuing Planning Process. For more information on the DOH and water quality management, refer to Section 10 of this document.

Most of the EPO's programs are federally funded. These programs must meet federal Clean Water Act requirements, obtain EPA approval, and employ a watershed-based approach to water quality management. On the EPO's website, the office acknowledges the need for integrated watershed protection and management: "Our challenges include strengthening the connection between [water quality standards, monitoring and assessment, and long-term planning] efforts and linking them with other government functions and private actions." This statement echoes the findings of the Watershed Protection Board, with respect to Act 152, which highlighted the need to "integrate all of these [various watershed efforts and programs] into an efficient and focused framework."

9.4.5. The Hawaii Coastal Zone Management Program

Coastal zone management, or CZM, is about balancing the needs of economic development and conservation of resources in a sustainable manner. The federal Coastal Zone Management Act (CZMA) of 1972 established the voluntary program with a broad framework in order to allow flexibility among the State programs. In 1977, the Hawaii State Legislature enacted the State CZM law (codified in Chapter 205A, Hawaii Revised Statutes (HRS)) to provide a common focus for State and County actions dealing with land and water uses and activities. The Hawaii CZM Program was officially approved in 1978. The Office of Planning (OP) is responsible for the overall administration of the Hawaii CZM Program.

As the State's resource management policy umbrella, the Hawaii CZM Program is the guiding perspective for the design and implementation of allowable uses and activities. The Hawaii State Legislature charged CZM with the responsibility of encouraging agencies to look at resources from a broader ecosystem perspective.

The Hawaii CZM Program is undertaking many important initiatives, including but not limited to, the following:

- Coordinate the implementation of the Hawaii Ocean Resources Management Plan (ORMP), which was updated in 2006. The ORMP presents an innovative three-perspective framework, accompanied by concrete management goals and strategic actions for State and County agencies to implement in order to move the State of Hawaii towards comprehensive, integrated management of our coastal resources.

- Assess, consider, and control cumulative and secondary impacts of coastal growth and development, including integrated planning that builds on and better supports the stewardship efforts of community groups and organizations. The goal is to move the State towards place-, cultural-, and community-based approaches to natural and cultural resource management.

- Obtain final federal approval of the Hawaii Coastal Nonpoint Pollution Control Program (CNPCP). Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990 requires each federally-approved CZM program to develop and implement a CNPCP. The Hawaii Program plans to address remaining management measures through an integrated watershed approach by collaborating with all relevant State and County agencies to develop a Watershed Planning Process and Guidance document. The guidance document will serve as an agency and community resource for preparing watershed plans that incorporates the §6217(g) management measures. The watershed planning process will assist in addressing EPA's 9 key elements for watershed-based plans.

- Reduce hazards to life and property from coastal hazards, including tsunami, storm waves, stream-flooding erosion, and subsidence.

- Implement CZM Program compliance through Special Management Area (SMA) and Shoreline Setback Areas (SSA), which are designated for more intensive management by the Counties.

The Hawaii CZM Program focuses on complex multi-functional resource management problems, issues, concerns, and opportunities. Section 205A-2, HRS, enumerates the CZM objectives and policies which address recreational resources, historic resources, scenic and open space resources, coastal ecosystems, economic uses, coastal hazards, managing development, public participation, beach protection, and marine resources. Compliance with Chapter 205A, HRS, CZM objectives and policies ensure that appropriately designed developments along coastal areas respect economic, biological, environmental, and cultural values.

Within a network of State and County agencies, the program employs a wide variety of regulatory and non-regulatory techniques to address coastal issues and uphold environmental law. Much of CZM's work is characterized by stewardship; planning; permit administration; education and outreach; multi-functional coordination; policy development and implementation; identification of emerging issues and exploration of solutions; technical assistance to local governments and permit applicants; and assuring State and County compliance with the statutory requirements.

9.5. Watershed Protection and Conservation Partnerships

The establishment of public-private partnership organizations and their ongoing efforts contribute tremendously to watershed protection in Hawaii. These partnerships provide their member entities with specific advantages, including:

- Increased funding base and cooperative-fundraising efforts;
- Decreased duplication of efforts;
- Better application of resources;
- Combined institutional will and momentum;
- Positive public perception of cooperative efforts; and
- Grass roots input and project implementation.

Local organizations and partners, including CWRM, are encouraged to continue and expand current efforts and agency participation to promote information sharing, to leverage resources, and to encourage cooperative stewardship.

9.5.1. The Hawaii Association of Watershed Partnerships

In 2003, the Hawaii Association of Watershed Partnerships (HAWP) was established through the signing of a Memorandum of Understanding (MOU) between six existing watershed partnerships. The State of Hawaii also signed the MOU as an individual partner. The parties, through the MOU, established principles and agreed to participate in cooperative fundraising, building public and political support, and capacity building for island-based mauka watershed partnerships. The HAWP includes nine watershed partnerships on six islands, with representation from more than 50 public and private partners: Figure 9-4 shows the areas included in existing watershed partnerships statewide.

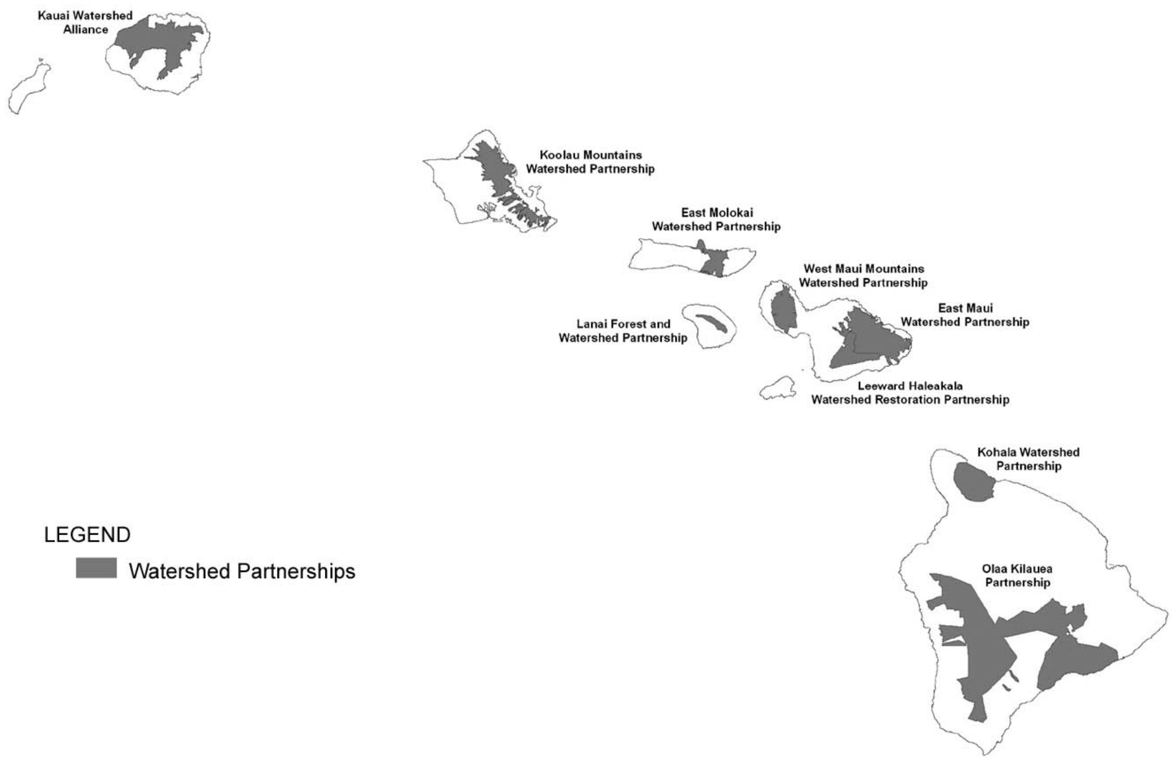

Figure 9-4. Hawaii Watershed Partnerships

Island of Kauai:

- **Kauai Watershed Alliance (130,000 acres)**
  Kamehameha Schools; Princeville Corporation; County of Kauai Department of Water; Kauai Ranch, LLC; Lihue Land Company; McBryde Sugar Company, Ltd.; DLNR; Grove Farm Company, Inc.; Ben A. Dyre Family Limited Partnership

Island of Oahu:

- **Koolau Mountain Watershed Partnership (99,000 acres)**
  Kamehameha Schools; Honolulu BWS; DLNR; Bishop Museum; DHHL; Agribusiness Development Corp.; U.S. Army; Queen Emma Foundation; Manana Valley Farm, LLC; Tiana Partners; Dole Food Co., Inc.; U.S. Fish and Wildlife Service; Hawaii Reserves, Inc.; Kualoa Ranch; Oahu Country Club; The Nature Conservancy; DOH; EPA; U.S. Forest Service; NRCS; USGS

Island of Molokai:

- **East Molokai Watershed Partnership (19,000)**
  Kamehameha Schools; Kapualei Ranch; Ke Aupuni Lokahi Enterprise Community Governance Board; DOH; DLNR; Kalaupapa National Historical Park; Maui County; Maui Board of Water Supply; MolokaI-Lanai Soil and Water Conservation District; NRCS; US Fish and Wildlife Service; USGS; EPA; The Nature Conservancy

Island of Lanai:

- **Lanaihale Watershed Partnership (20,000 acres)**
  Castle and Cooke; Maui County Board of Water Supply; Hui Malama Pono O Lanai; DLNR; U.S. Fish and Wildlife Service; NRCS, Molokai-Lanai Soil and Water Conservation District; The Nature Conservancy

Island of Maui:

- **East Maui Watershed Partnership (100,000 acres)**
  DLNR; The Nature Conservancy; Maui County Board of Water Supply; Haleakala Ranch Co.; East Maui Irrigation Co., Ltd.; Haleakala National Park; Hana Ranch; County of Maui

- **West Maui Mountains Watershed Partnership (53,000 acres)**
  Maui County Board of Water Supply; Kamehameha Schools; C. Brewer and Co., Ltd.; Amfac/JMB Hawaii, LLC; The Nature Conservancy; Maui Land and Pineapple Co., Inc.; DLNR; County of Maui

- **Leeward Haleakala Watershed Restoration Partnership (43,000 acres)**
  Department of Hawaiian Home Land (DHHL); Estate of James Campbell; Haleakala National Park; Haleakala Ranch; Kaonoulu Ranch; Nuu Mauka Ranch; DLNR; Ulupalakua Ranch; John Zwaanstra

Island of Hawaii:

- **Olaa Kilauea Partnership (420,000 acres)**
  Kamehameha Schools; DLNR; Department of Public Safety, Kulani Correctional Facility; U.S. Fish and Wildlife Service; USGS Biological Resources Division; U.S. Forest Service; The Nature Conservancy; National Park Service, Hawaii Volcanoes National Park

- **Kohala Mountain Watershed Partnership (32,000 acres)**
  Parker Ranch, Inc.; Kahua Ranch, Ltd.; Ponoholo Ranch, Ltd.; The Queen Emma Foundation; Kamehameha Schools; Laupahoehoe Nui, LLC; DLNR; DHHL; Hawaii County Department of Water Supply; The Nature Conservancy

Approximately 850,000 acres of forestlands are protected through the HAWP. In addition to continuing the efforts of existing watershed partnerships, the MOU partners also support the formation and development of new partnerships. In DOFAW's 2006 report to the

Legislature on the NARS and NAPP programs, the development of a new partnership in the Waianae area of Oahu is discussed. Community support was expressed from landowners, land managers, government agencies and interest groups for a watershed partnership focused on the mauka regions of both sides of the Waianae range. There is already a precedent set by the Waianae Kai Community Forest Partnership, which focuses on the Waianae Kai and Makaha Valley Forest Reserves, and includes participation from the Honolulu BWS, the State, and grass-roots community groups active in the Waianae region. A regional partnership that encompasses the entire Waianae range is possible, but some landowners have concerns about land encumbrances. A successful regional partnership will require collaborative efforts from landowners, conservation groups, and community members and must address mauka-to-makai relationships.

9.5.2. Ala Wai Watershed Association

In addition to the mauka watershed partnerships described in Section 9.4.1, other partnership efforts that focus more on water quality, pollution mitigation, and restoration in urban watershed areas and nearshore areas are also underway. Examples of organizations involved in these aspects of watershed protection include the Ala Wai Watershed Association (AWWA) and the Hanalei Watershed Hui (HWH). The Ala Wai Watershed Program is a community-based program spearheaded by the AWWA. The AWWA is a community group funded by the EPA and the State for the purposes of promoting watershed stewardship and improved water quality in the Ala Wai Canal. The watershed includes all of the land area that physically drains into the Ala Wai Canal, the near-shore waters, and the submerged lands extending to and including the reef.

The mission of the AWWA is to improve and maintain the water quality in the Ala Wai Canal and its watershed through a community-based effort. Goals include significantly improved water quality, increased community interaction and involvement, additional environmental education for children, and innovative stewardship partnerships between the community, the private sector, and government agencies.

The AWWA has engaged in several stream restoration projects within the Ala Wai watershed. Stream restoration is an effective means to improve public stewardship of the watershed, emphasize the environmental and scenic value of streams in urban areas, and help reduce dumping, littering, and waste disposal into storm drains and streams. The AWWA has also been involved with other community-based projects in an effort to improve the water quality in the Ala Wai Canal and its tributary waterways.

9.5.3. Hanalei Watershed Hui

The Hanalei Watershed Hui (HWH) is a 501(c)(3) non-profit environmental organization that "strives to care for the Ahupua'a of Hanalei, Waioli, Waipa, and Waikoko guided by Hawaiian and other principles of sustainability and stewardship, integrity and balance, cooperation and aloha, cultural equity and mutual respect."[15] HWH came about through the designation of the Hanalei River as an American Heritage River (AHR) on July 30, 1998. The American Heritage River Initiative is a federal program that recognizes the important traditional and modern roles of rivers in their surrounding communities, and encourages partnerships to foster environmental protection, historic and cultural preservation, and

[15] Hanalei Watershed Hui. 2004. Internet, available at: http://www.hanaleiwatershedhui.org.

economic revitalization. The University of Hawaii developed the nomination for the Hanalei River, and the U.S. Forest Service agreed to serve as the "sponsoring federal agency" and provide a "River Navigator" and related expenses for five years, as defined in the AHR initiative. The HWH is funded through grants from the U.S. Forest Service, the EPA, and the National Ocean and Atmospheric Association.

The HWH meets quarterly and implements the Hanalei Watershed Action Plan. Objectives, as described on the HWH website, include the achievement of the following:

- Natural river system that supports native ecosystems;
- Identification, conservation, and education of heritage resources;
- A fishable, swimmable, and accessible river;
- Enhanced awareness of local culture and responsible recreation;
- Educational and informational opportunities;
- Preservation of one’s working-rural character;
- Support of taro farming;
- An economy based on diversity, and local, small, shared prosperity; and
- Sharing efforts generously.

The HWH’s Action Plan was most recently revised in August 2004, and summarizes the organization’s progress on priority projects. The HWH also prepared a January 2005 Project Update Report for the EPA’s Watershed Initiative Grant. The report includes status information on several projects: residential cesspool demonstration project; beach park wastewater treatment demonstration project; wastewater strategic planning, taro loi demonstration project and study; ungulate fencing demonstration project; biological resources survey and assessment; water quality monitoring; coral recruitment, benthic habitat, and fish surveys; coral disease in Hanalei Bay; oopu (native goby fishery) monitoring; suspended sediment monitoring; and outreach activities.

As of 2006, ongoing HWH environmental programs and activities included the following:

- EPA Targeted Watershed Project
- Agriculture Non-Point Source Computer Modeling
- Coral Reef Non-Point Source Local Action Strategy
- Water Quality Investigations – Is it fishable and swimmable?
- Leptospirosis Testing Development

- Waipa Stream and Halulu Fishpond Restoration
- Okolehao Trail Restoration
- TMDL Development for Hanalei Estuary
- Environmental Education Programs

Further information on the HWH may be accessed on the organization website at http://www.hanaleiwatershedhui.org.

9.5.4. Conservation Districts

There are approximately 3,000 Conservation Districts nationwide. Conservation Districts, which are also known as “Soil and Water Conservation Districts” and “Resource Conservation Districts,” originated during the Dust Bowl era of the 1930s, after President Roosevelt urged state governors to recommend legislation that would allow the establishment of local, soil Conservation Districts. The mission of Conservation Districts is to coordinate assistance from public and private, local, state and federal sources to develop locally driven solutions to natural resource concerns.

According to the National Association of Conservation Districts, the nonprofit organization that represents the 3,000 local Conservation Districts, local residents should make conservation decisions, with technical and funding assistance from federal, state, and local governments and the private sector. Conservation Districts help accomplish the following actions:

- Implement farm conservation practices to keep soil in the fields and out of waterways;
- Conserve and restore wetlands, which purify water and provide habitat for birds, fish and numerous other animals;
- Protect ground water resources;
- Plant trees and other land cover to hold soil in place, clean the air, provide cover for wildlife, and beautify neighborhoods;
- Help developers and homeowners manage the land in an environmentally sensitive manner; and
- Reach out to communities and schools to teach the value of natural resources and encourage conservation efforts.

In Hawaii there are 16 Conservation Districts. They strive to coordinate partners and government agencies with identifying and implementing culturally sensitive projects and practices, to assure the protection of Hawaii’s environment.

Current challenges facing Conservation Districts include managing manure and fertilizer to prevent water pollution, restoring wetlands, improving irrigation efficiency and flood protection measures, and addressing urban expansion issues, including the protection of plant and animal habitats and water quality. These challenges are not unique to farmers and ranchers. Although specifics may vary, municipal, state, federal agencies, and conservation groups also deal with the same issues. albeit the specific aspect of the issue varies.

9.6. Gaps In Watershed Protection

The gaps in existing watershed protection programs are primarily communication gaps and disconnects between geographic areas, land managers, land users, water users, water purveyors, regulators, and resource providers. The level of activity observed in watershed protection projects and the high degree of public interest is encouraging, and bodes well for the ultimate preservation and stewardship of watershed resources statewide.
However, the multitude of programs and entities involved is dizzying. At some point, the momentum may become overwhelming, and effective communication may not occur between different groups. The cumulative effect will be that watershed protection activities will suffer.

It has become increasingly clear, more so since the expiration of Act 152 and the dissolving of the State Watershed Protection Board, that a coordination framework is critical to the long-term success and proliferation of watershed protection and conservation efforts. Such a framework will provide the vehicle by which funding and staffing resources can be most judiciously applied, as well as the forum through which cooperative goals can be established, strategies can be explored, and project implementation can be facilitated.

9.7. Recommendations

The State Water Code states that the CWRM, through the WRPP, shall coordinate programs to conserve, augment, and protect the resource and cooperate with other agencies and entities.[16] CWRM establishment of IFS and IIFS and assessments of water availability may be greatly influenced by the activities of the members of the existing watershed partnerships and other government agencies, such as DOH. From a water resource management perspective, watersheds are the beginning of the terrestrial water cycle and the source of all fresh water in Hawaii. From the viewpoint of program implementation and water resource management, CWRM has an important role to play in watershed management in Hawaii. Therefore, the CWRM should directly pursue, or support and cooperate in the implementation of the following recommendations:

- Take a more active role in watershed protection, watershed partnerships, and the watershed partnership association.

- Support DOFAW's watershed management activities and the division's leadership role in watershed management. Focus on the improvement of coordination between DOFAW's land management programs and CWRM's water management programs.

[16] HRS §174C-31(d)(4) and §174C-5(12).

- Study existing legislative means to protect and preserve our watersheds against contamination and encroachment of intake areas.

- Study existing government and community efforts in watershed management and protection, and encourage sharing of information and experiences.

- Study other watershed planning approaches and lessons learned, including the EPA's watershed approach and that of other state governments.

- Pursue appropriate funding to support watershed protection programs and objectives to protect water resources.

- Encourage the collaboration of federal, State, and county agencies with existing watershed partnerships and Conservation Districts to map the relationships between land management programs, land use regulations, economic and agricultural issues, and water quality and resource protection programs.

- Improve communication and encourage dialogue between watershed interests to result in the development of common goals and an integrated watershed management framework. A successful framework will acknowledge and build upon existing programs and organizations to maximize funding, staff, and volunteer resources through watershed-scale management and protection programs.

- Develop innovative public outreach methods and encourage communication between watershed entities. The development of a website for devoted to Hawaii watershed projects, organized by geographic location, should facilitate this coordination.

Section 10

Water Quality

10. WATER QUALITY

The State Water Code provides that the Department of Health (DOH) shall have primary jurisdiction and responsibility for administration of the state's water quality control programs[1].

The Hawaii Revised Statutes do not define "potable water," but the law does provide for the establishment of maximum contaminant levels for various chemicals, as well as other parameters for drinking water quality. While CWRM defers to DOH on most water quality related matters, CWRM management principles utilize operational water quality definitions based on chloride concentration as follows:

- **Fresh Water:** Chloride concentrations from 0 to 250 milligrams per liter (mg/L)
- **Brackish Water:** Chloride concentrations from 251 to 16,999 mg/L (Water for irrigation use contains 1,000 mg/L chlorides. Water for industrial and other uses contains 1,000 mg/L chlorides.)
- **Seawater:** Chloride concentrations of 17,000 mg/L and higher

The DOH's responsibilities include the formulation and regular update of a State Water Quality Plan (WQP) for all existing and potential sources of drinking water[2]. The WRPP, together with the WQP, SWPP, AWUDP, and the County WUDPs, provide the overall guidance and direction for managing Hawaii's precious water resources.

The major objective of the WQP is to protect public health and ecological systems by preserving, protecting, restoring, and enhancing the quality of ground and surface waters throughout the State of Hawaii. The initial WQP was published in 1990. Current efforts to update the WQP are described later in this chapter.

The following sections provide information on the purpose and function of the Water Quality Plan and the status of efforts to update the Water Quality Plan, and describes the current DOH programs that contribute to the plan update.

10.1. Statutory Requirements for the Water Quality Plan

HRS §174C-31(a)(4) requires the DOH to formulate a water quality plan for the State and identifies the plan as a component of the Hawaii Water Plan. The Water Code, in HRS §174C-68(a) also requires the DOH to include in the WQP criteria for use by CWRM in the designation of ground-water and surface-water management areas. HRS §174C-68(b) stipulates that, as needed, the WQP will be reviewed and revised periodically. The DOH is also required to consult with concerned federal, State, and local agencies when formulating and revising the WQP, especially county water supply agencies, and to carefully evaluate their recommendations.

[1] HRS §174C-66.
[2] HRS §174C-68 and HAR §13-170-50.

10.2. Integration of the Water Quality Plan with Other Hawaii Water Plan Components

Although different State and county agencies prepare separate components of the Hawaii Water Plan, the components must be coordinated and cohesive. The WQP and the WRPP are the two plan components that are critical to determining both water usage and strategies for developing water resources. These two components outline the regulations, standards, and resource management policies that define the availability of ground- and surface-water resources, and the quality to be maintained in these resources. In addition, the quantity of ground- and surface-water resources that can be withdrawn on a sustainable basis is determined as part of the WRPP. The WQP and WRPP therefore provide critical input to the SWPP, the AWUDP, and the County WUDPs developed by the four counties. In general, the SWPP, AWUDP, and County WUDPs must be consistent with the 1990 WRPP and WQP until subsequent updates are developed. However, statutory, rule, and policy amendments to water quality regulations since 1990 may supersede information contained in the 1990 WQP. In addition, the Commission has officially revised portions of the 1990 WRPP.

The Framework was published by CWRM in 2000 to assist State and county agencies as they update various HWP components. The Framework offers the following recommended plan elements, interagency coordination actions, and recommended guidelines for future WQP updates:

> ***Recommended Plan Elements***
> *The current WQP was adopted in 1990 and a draft revision was prepared in December 1992. The draft revision compiles existing policies, regulations and programs at the federal, state and county levels that relate to protecting all sources of drinking water. In addition, new research needs and programs are discussed. The CWRM has not acted upon the current draft revision of the WQP. Further efforts to update the WQP have been deferred due to lack of funding. In addition, the State DOH is currently undertaking an assessment of potentially contaminating activities that may threaten existing drinking water sources, the results of which will be integrated into an updated WQP. That assessment project is described as follows.*
>
> ***Developing Effective Linkages Between Inter-Agency Programs***
> *As discussed in the preceding section, the CWRM is responsible for coordinating regular updates of the HWP, including the update of the WQP component. In fulfilling this mandate, the CWRM has actively participated with the Department of Health in its development of the SWAP project. These collaborative efforts, we believe, have led to the beginnings of more effective linkages to other water resource protection and management programs in the State. It should be reiterated that the DOH is statutorily required to update the WQP. Compliance with this mandate should be viewed as an excellent opportunity to integrate similar intra- and inter-agency water protection programs. Elements of SWAP, the Source Water Protection Strategy, and other DOH programs (e.g. UIC, Wastewater, etc.) should be compiled and coordinated as part of a comprehensive inter-agency strategy for water quality protection. Coordination and identification of program linkages and effective integration of related programs should result in a comprehensive assessment of current/foreseen problems, identification of available mitigation measures, and the development of improved management strategies.*

Program achievements that may result from such coordination include, but are not limited to:

- *Providing continual program updates and status reports;*
- *Identifying required follow-on actions by each agency;*
- *Coordinating data collection and monitoring efforts;*
- *Developing a common database and ensuring data consistency;*
- *Establishing a protocol for more effective data sharing; and*
- *Identifying relationships between regulatory and non-regulatory program efforts.*

Recommended WQP Guidelines
Procedures and program measures for coordinating and streamlining agency activities and permitting requirements of similar federal, state and county programs should be established to ensure effective linkages between agency programs. The major goals and objectives of this effort should include, but not be limited to:

- *Maximizing efficient use of agency time, staff and program resources;*
- *Identification of overlapping and/or duplicative program/statutory responsibilities;*
- *Establishment of more effective inter-agency coordination and communication;*
- *Consolidation (wherever possible) of agency review and permitting requirements; and*
- *Resolving conflicting permit approvals or other agency requirements (if any), including procedural disagreements between agencies.*

10.3. Status of the Water Quality Plan

The DOH is responsible for the preparation and update of the WQP. The DOH is moving forward with several water quality programs that will contribute to the update of the WQP. The programs include, but are not limited to, the Source Water Assessment and Protection (SWAP) Program and surface-water studies, regarding total maximum daily loads and the identification of impaired water bodies. When the programs are completed, the results will be integrated into the WQP. The current status of each program is provided in Section 10.4.

10.3.1. DOH Strategic Plan for Hawaii's Environmental Protection Programs

In 1999, the DOH completed the *Strategic Plan for Hawaii's Environmental Programs*, which describes goals, objectives and strategies for the agency's new approach to environmental management. The 1999 plan identifies improvements in environmental management to facilitate efficient resource allocation toward high-risk environmental problems.

The strategic plan examines DOH's core environmental protection programs and discusses their history, organization, mission, goals, objectives, strategies, and performance measures; the plan also sets forth targets to measure the effectiveness of programs in meeting community needs. Specifically, the plan calls for the State to improve its capability to solve serious environmental problems through risk assessment, streamlining the permitting process, and developing a priority-setting system.

In 2001, the DOH published the *Strategic Plan Update for Hawaii's Environmental Protection Programs* to update the tasks and objectives identified by the 1999 plan. The update focuses primarily on targets, objectives, strategies, and performance measures. Generally, the information on organization, mission, and goals remains appropriate and was not altered. The strategic plan and its 2001 update continue to direct the administration and implementation of the DOH environmental programs that are summarized in the sections below.

10.4. Department of Health Programs Related to the Water Quality Plan

The DOH administers several programs that provide input and guidance to the Water Quality Plan. The Environmental Planning Office, the Safe Drinking Water Branch, the Clean Water Branch, and the Wastewater Branch are the main organizational units within the DOH that administer water quality protection programs.

The Environmental Planning Office is responsible for setting the State's water quality goals, evaluating progress toward achieving those goals, and completing long-range planning for surface-water quality improvement and protection. The Safe Drinking Water Branch is responsible for safeguarding public health by protecting Hawaii's drinking water sources (surface water and ground water) from contamination and assures that owners and operators of public water systems provide safe drinking water to the community. The Clean Water Branch protects the public health and restores inland and coastal waters for marine life and wildlife, through statewide coastal water surveillance, watershed-based environmental management, permitting, monitoring, enforcement, polluted runoff control projects, and public education. The Wastewater Branch administers the statewide engineering and financial functions relating to water pollution control, municipal and private wastewater treatment works, wastewater recycling, individual wastewater systems, and the water pollution control revolving fund.

The DOH program areas that will contribute the eventual update of the WQP are described in the subsequent sections of this chapter. The summaries of program goals, status, and recommendations for future actions provided herein reflect information provided by the Department of Health.

DOH Programs Contributing to the Water Quality Plan:

- Water Quality Management Program
- Source Water Assessment and Protection Program

- Comprehensive State Groundwater Protection Program Strategy/Plan
- Underground Injection Control Program
- Groundwater Contamination Maps
- Polluted Runoff Control Program
- Beach Monitoring Program
- Wastewater Recycling Program

10.4.1. Water Quality Management Program

The Water Quality Management Program is responsible for setting the State's water quality goals (Water Quality Standards), monitoring and assessing the achievement of Water Quality Standards (assessing and listing Impaired Water Bodies), and long-range planning for surface water quality improvement and protection (Total Maximum Daily Load Process and Continuing Planning Process). Most of this work is federally-funded and must meet federal Clean Water Act requirements. Program efforts must also obtain U.S. Environmental Protection Agency (EPA) approval and employ a watershed-based approach to water quality management.

Water Quality Standards (WQS):
Federal law requires the State to complete a water quality standards review process and make necessary revisions every three years.

Program Goals:
The goal of the WQS Program is to develop scientifically based water quality standards that (a) meet federal requirements, (b) specify the uses to be protected in State waters, and (c) provide appropriate criteria and methods for evaluating the attainment of these protected uses.

Recommended Actions:
To achieve the program goals, the DOH plans to implement the following actions:

- Adopt federal bacterial indicator criteria for marine recreational uses. Develop/adopt improved pathogen/indicator criteria for all recreational uses.
- Adopt specific water column criteria for aquatic pesticide uses.
- Adopt formal guidance (WQS implementation plan) for using water quality standards to assess water quality conditions and make regulatory decisions.
- Update numeric standards for toxic pollutants and develop/adopt numeric standards for ammonia toxicity:
    - Conduct toxicity testing of native aquatic organisms.

- Revise specific water column criteria for brackish and saline waters, based on improved understanding of ecosystem dynamics and chemical variation along salinity gradients.

- Revise overall framework of waterbody types, waterbody classes, protected uses, and evaluative criteria to improve the linkage between specific uses and specific criteria and to improve the basis for specific, use-based assessment methodologies.

- Revise turbidity criteria for all waterbody types.

- Revise temperature and pH criteria for streams to remove the uncertainty in determining "ambient conditions."

  - Develop/adopt ammonia criteria for environmental uses in streams.

  - Develop/adopt biological criteria for recreational and environmental uses in streams.

- Develop/adopt biotoxicity and sediment toxicity criteria for recreational and environmental uses in all waterbody types.

Current Program Status:
The points listed below summarize the status of the WQS Program:

- Last WQS program amendments adopted 08/31/2004.

- Preparing amendments and conducting ongoing research and strategic planning to address recommended actions.

Total Maximum Daily Load (TMDL)
Federal law requires the State, every two years, to identify and prepare a list of waters that do not or are not expected to meet water quality standards after applying existing required controls (e.g. minimum sewage treatment technology). For each listed waterbody/pollutant combination, the State must (a) establish the waterbody's loading capacity (the maximum loading rate are which water quality standards are met), and (b) allocate this loading capacity among contributing point and nonpoint sources. After these TMDLs are approved by the U.S. Environmental Protection Agency, the State writes TMDL Implementation Plans that identify specific strategies and tactics that could be used to achieve the required load allocations and otherwise improve water quality and overall watershed health.

Program Goals:
The goals of the TMDL Program are as follows:

- Quantitatively assess watershed-scale water quality problems, contributing sources, and pollutant load reductions.

- Using assessment results, provide an analytical basis for planning and implementing pollution controls, land and water management practices, social/institutional changes, and restoration projects needed to improve water quality and protect public and environmental health.

Recommended Actions:
To achieve the program goals, the DOH plans to implement the following actions:

- Revise the Continuing Planning Process to refine and clarify the working relationships among DOH surface water quality protection programs (e.g., permits for point source dischargers and funding for nonpoint source controls) and with other DOH water quality protection programs.

- Follow the Water Quality Standards Program recommendations (below) to improve the scientific basis for TMDL program activities.

- Establish a State Water Quality Monitoring Council to coordinate the statewide collection, management, and use of water quality data for all water resource protection purposes.

- Develop and implement standardized Watershed and Waterbody Inventory Procedures for preparing TMDL Scoping Reports, TMDL Sampling and Analysis Plans, other DOH water pollution control and water quality management plans, and various other private and public water resource management plans:

  - Revise watershed and waterbody delineations to better represent hydrologic truth (particularly as influenced by microtopography, storm drains, and inland receiving water locations) and administrative constraints.

  - Revise watershed and waterbody codings to facilitate water quality database construction/operations, data integration, data sharing, and GIS interoperability.

- Develop and implement water quality modelling approaches that use libraries of watershed and waterbody information to reduce site-specific data requirements for TMDL development:

  - Conduct a "Know the Flow" symposium to advance knowledge of local rainfall/runoff relations and its application to streamflow prediction.

  - Create a catalog of event-based stream water quality data that links contributing area characteristics (topography, land cover, and human activity), hydroclimatic characteristics (rainfall and streamflow), pollutant-loading characteristics, and receiving water quality.

  - Use this catalog to develop pollutant washoff/loading factors across a range of contributing area and hydroclimatic characteristics.

- Join CWRM efforts to establish instream flow standards.

Current Program Status:
The points listed below summarize the status of the TMDL Program:

- 2004 List of Impaired Waters approved.
- 2006 List of Impaired Waters in preparation (incorporated into 2006 Integrated Report of Assessed Waters).
- TMDL Status Update attached.
- CPP review in progress/in preparation for revision.
- Watershed/waterbody inventory procedures in development.
- Watershed/waterbody delineation and coding revisions in progress.
- Database/GIS design and construction in progress, including DOH cross-program data integration efforts.
- Water quality data collection and modelling efforts are currently limited to site-specific TMDL development projects.
- TMDL program management and staff are members of the CWRM Stream Policy Advisory Group.

10.4.2. Source Water Assessment and Protection Program

The reauthorization of the Federal Safe Drinking Water Act included an amendment requiring states to develop a program to assess sources of drinking water, and encouraging states to establish protection programs. The drinking water source assessment is the first step in the development of a comprehensive drinking water source protection program.

Program Goals:
The goals of the SWAP Program are as follows:

- Assess the susceptibility of public drinking water sources to contamination.
- Protect public drinking water sources from contamination.
- Use source water assessment information for meeting drinking-water requirements.

Recommended Actions:
To achieve the program goals, the DOH plans to implement the following actions:

- Assess all existing drinking water sources.
- Assess new and proposed drinking water sources.

- Periodically review and update these assessments.
- Create and implement state and local source water protection workgroups.
- Work with county water and planning departments to integrate protection strategies and plans.
- Develop and implement the Wellhead Protection Financial Assistance Program.
- Work with public water systems in using assessment information as a starting point for meeting various drinking water requirements.

Current Program Status:
The points listed below summarize the status of the SWAP Program:

- Assessments have been conducted on over 475 existing drinking water sources throughout the state. In 2006, DOH completed the *Hawaii Source Water Assessment Program Report, Volume I, Approach Used For the Hawaii Source Water Assessments*.[3] Assessments will continue for all new and proposed drinking water sources.
- Preliminary approval for the Wellhead Protection Financial Assistance Program has been received from EPA.
- DOH is working with county water departments and other agencies to create workgroups.
- EPO is working with the DOH Safe Drinking Water Branch to link the source water assessments and drinking water requirements.

10.4.3. Comprehensive State Groundwater Protection Program Strategy/Plan

The overall goal of the Comprehensive State Groundwater Protection Program Strategy/Plan is to protect human health and sensitive ecosystems through the protection and enhancement of the quality of ground water throughout the State of Hawaii.

Program Goals:
The development and implementation of the program will have as its specific goals the following:

- Provide the State with greater flexibility in directing its ground-water protection activities relative to various sources of contamination across federal, State, and local programs, and geographic areas, to achieve comprehensive resource-based ground-water protection.

[3] Whittier, R.B., K. Rotzoll, S. Dhal, A.I. El-Kadi, C. Ray, G. Chen, and D. Chang. 2006. *Hawaii Source Water Assessment Program Report, Volume I, Approach Used For the Hawaii Source Water Assessments*. Hawaii Department of Health, Honolulu, Hawaii.

- Eliminate the potential for related programs to work at cross-purposes, causing ineffective expenditures of efforts and resources.

- Demonstrate the State's effectiveness in ground-water protection, thus justifying increased funding for program development and additional flexibility from the EPA and other federal agencies.

- Recognize and further delineate the appropriate roles for federal, State, and local governments as partners in ground-water protection.

- Establish a mechanism for better recognition and understanding of the relationships between ground-water quantity and quality concerns.

- Improve public understanding of ground-water protection concerns within the State, and provide a broader context for public participation.

- Build a consensus across all levels of government, regarding the need for comprehensive ground-water protection and the basic structure of comprehensive protection programs.

Recommended Actions:
The DOH plants to complete the development and implementation of a Comprehensive State Groundwater Protection Program Strategy/Plan, consisting of a set of six strategic activities that would foster more efficient and effective protection of ground water. The strategic activities are:

- Establishing a ground-water protection goal to guide all relevant federal, State, and local programs operating within the State;

- Establishing priorities, based on characterization of the resource, identification of sources of contamination, and delineation of the program's needs, to guide all relevant federal, State, and local programs and activities;

- Defining authorities, roles, responsibilities, and resources, and coordinating mechanisms across relevant federal, State, and local programs for addressing identified ground-water protection priorities;

- Implementing all necessary efforts consistent with the State's priorities;

- Coordinating information collection and management to measure progress, re-evaluate priorities, and support all ground-water related programs; and

- Improving public education and participation in all aspects of ground-water protection.

Once the Comprehensive State Groundwater Protection Program Strategy/Plan has been developed, it should be implemented as part of the SDWB Groundwater Protection Program.

Current Program Status:
An initial draft of the Comprehensive State Groundwater Protection Program Strategy/Plan was submitted to the U.S. Environmental Protection Agency, Region 9, on December 6, 2000 (the document is dated November 30, 2000). The strategy/plan represents the guiding document for the future of ground-water protection in Hawaii. Additional draft documents relating to resource assessment and ground-water quality monitoring were also prepared.

The Safe Drinking Water Branch, under the Groundwater Protection Program, is currently reviewing and updating the Comprehensive State Groundwater Protection Strategy/Plan.

10.4.4. Underground Injection Control (UIC) Program

The Underground Injection Control (UIC) Program was established to monitor and control injection well activity, in order to prevent ground-water pollution. Ground-water pollution can directly affect the quality of drinking water sources, as well as indirectly affect the quality of water in streams and near-shore waters.

Injection wells are used to dispose of wastewater from various activities, e.g., sewage treatment, industrial processes, aquaculture, and surface runoff. Each of these activities, and more, has the potential to cause groundwater pollution. For this reason, injection well activity is specifically targeted for monitoring and control because injection wells are direct, open conduits into the subsurface and are often in contact with ground-water.

Injection well activities are monitored or controlled through underground injection control (UIC) permits issued by the Department of Health. The operator of an injection well must obtain the UIC permit before the injection well can be put into service. The UIC permit stipulates discharge standards, operating conditions, and water quality testing and reporting requirements to prevent or minimize ground-water pollution. Violators of UIC permits, or of the regulations for injection wells under Hawaii Administrative Rules, Title 11, Chapter 23, can be fined and ordered to perform corrective action.

Notwithstanding the risks to Hawaii's ground-water resources, injection wells provide an important alternative method for wastewater disposal for facilities that cannot access the municipal sewer system or cannot discharge through an outfall.

Program Goals:
The function of the UIC Program is to protect the quality of Hawaii's sources of drinking water from chemical, physical, radiological, and biological contamination from injection well activity through the specific actions listed below:

- Processing permits and project reviews for new permits and renewals, modifications, and abandonment of injection wells;
- Evaluating geologic logs of soil and rock, injectivity tests, geologic maps, and groundwater-quality profiles to determine the viability of subsurface injection;
- Maintaining an inventory and database of all injection well files;

- Organizing and conducting site inspections to verify the locations and performance of injection wells, and to verify compliance with all testing or well-closure plans;

- Conducting site investigations to identify problems, such as unpermitted facilities and uncorrected deficiencies;

- Enforcing underground injection control rules and permit conditions; and

- Serving the public by providing information and technical assistance.

Recommended Actions:
To achieve the program goals, the DOH plans to implement the following actions:

- Implement and sustain an effective and efficient regulatory permitting program. Seek compliance first through voluntary and self-responsible motivations, but be ready to acquire compliance through enforcement measures.

- Constantly seek methods, techniques, and approaches that advance effectiveness and efficiency in permitting, as well as in monitoring and enforcement.

- Through our permits, processing, decision-making, and handling/servicing of applicants, agencies, consultants, and the general public, constantly aim to build a good, fair, trustworthy, and honorable reputation.

- Take steps to expand the program; that is, increase the staff, only when absolutely necessary. Never take program funding for granted. Always try to make the most of funds allocated. In private business terms, work to make a profit, even though we are government.

Current Status:
The UIC Program currently manages the UIC line, or boundary, which identifies areas where injection wells are permitted. The program also enforces Title 11, Chapter 23, Underground Injection Control (which differs from the UIC Program of the EPA), and performs the other activities identified above.

According to the DOH, the UIC program is under a 12-month backlog of permit applications and related issues. This backlog has developed over the past few years due to the State's construction surge and the federal ban on large-capacity cesspools. The permit applications are for projects for constructing new injection-wells, abandoning and backfilling injection wells and injection-well cesspools, renewing permits, and modifying permits.

In order to resolve the backlog, certain interim processing and reviewing measures are being implemented. For example, shorter application forms have been developed and are in use to hasten the review and approval/denial process. Another measure/approach being used is to have the consultant shoulder more responsibility for insuring that the UIC Program's field-work instructions are properly completed, whereby corrective action for unsatisfactory work would be the consultant's responsibility.

10.4.5. Groundwater Contamination Maps

Hawaii's Groundwater Contamination Maps are an integral part of Hawaii's Groundwater Protection Program (GWPP). The GWPP's goal is to protect human health and sensitive ecosystems by fostering protection of ground-water resources and emphasizing water quality assessment, pollution prevention and protection measures.

The Groundwater Contamination Maps illustrate the DOH's assessment of ground-water quality and trends in ground-water contamination. The Contamination Maps identify the location and amount of organic and other contaminants detected and confirmed present in public drinking water wells and select non-potable wells between January 1 and December 31 of a calendar year.

The Contamination Maps show that ground-water contamination is largely the result of human activities, and that once a ground-water source becomes contaminated, it remains so for many years. In addition, wells adjacent to contaminated wells have been found to contain the chemicals known to be present in nearby contaminated wells.

Another application of the Contamination Maps is to educate the public about ground-water contamination and the importance of protecting Hawaii's ground-water resources.

Program Goals:
DOH prepared the ground-water contamination maps in pursuit of the following goals:

- To provide maps identifying locations where certain ground-water contaminants have been detected and confirmed; and
- To provide information on the basic health effects related to the contaminants detected in ground-water wells.

Recommended Actions:
So that the maps are as useful as possible, and to ensure that those concerned with the issue of ground-water contamination have access to the maps, the DOH recommends implementation of the following actions:

- Continue to monitor ground-water quality and ground-water contamination trends.
- Periodically update the ground-water contamination maps for the State of Hawaii. Ideally, at a minimum, the maps and basic health-effects information should be updated annually.
- Make maps available to water systems, government agencies, landowners, stakeholders, the public and community, and others.

Current Program Status:
Since August 1989, ten editions of the Groundwater Contamination Maps have been published. The most current set of maps was published July 28, 2006, and represents data collected and updated between January and December 2005. Publication of the 2006 Groundwater Contamination Maps is anticipated for late 2007.

10.4.6. Polluted Runoff Control Program

The Polluted Runoff Control Program is implemented by the DOH Clean Water Branch to prevent environmental degradation due to nonpoint source pollution. Unlike pollution from industrial and sewage treatment plants, nonpoint source pollution comes from many diffuse sources. Nonpoint source pollution develops when rainfall moving over and through the ground picks up natural and manmade pollutants that are eventually deposited in streams, wetlands, coastal waters, and underground sources of drinking water. Examples of such pollutants are:

- Excess fertilizers and pesticides from fields and gardens;
- Oil, grease, and toxic chemicals from urban and industrial areas;
- Sediment from construction sites, crop and forest lands, and eroding stream banks; and
- Bacteria and nutrients from livestock, pet wastes, and faulty septic systems and cesspools.

Program Goals:
The Polluted Runoff Control Program goals are as follows:

- To ensure that Hawaii’s coastal waters are safe and healthy for people, plants and animals; and
- To protect and restore the quality of Hawaii’s streams, wetlands, estuaries, and other inland waters for fish and wildlife, recreation, aesthetic enjoyment, and other beneficial uses.

Recommended Actions:
To achieve the program goals and to implement an integrated watershed approach, the State needs to increase the amount of resources devoted to the control of polluted runoff and focus on collaborative efforts to more effectively utilize the limited resources that are devoted to controlling polluted runoff. The State’s Coastal Nonpoint Pollution Control Management Plan identifies management measures that need to be implemented by all government agencies and the public to control polluted runoff.

Current Status:
The Polluted Runoff Control Program administers grant money it receives from the EPA through Section 319(h) of the Federal Clean Water Act. The program issues grants with a dollar-for-dollar match for projects focused on the development and implementation of watershed-based plans as a means to control polluted runoff and improve water quality. Project efforts may include the development of watershed plans, as well as efforts related to the implementation of watershed management plans, other comprehensive management plans, or total maximum daily loads. These plans are intended to layout where and what the polluted runoff issues are in a particular watershed, how can the issues be addressed and by whom, and how the implementation of best management practices or activities is to be evaluated to determine success.

Specific activities considered for funding may include: implementation of measures to minimize excessive nutrients, sediment and other pollutants delivered to surface and/or coastal waters, restoration of native vegetation in critical watershed areas such as stream banks/riparian corridors, ungulate control and invasive species removal, support for a watershed coordinator, water quality monitoring and evaluation efforts, educational efforts, and refinement of watershed plans to include nonpoint source pollution elements. The program targets its efforts in specific watersheds where there may be a higher potential for CWA Section 319(h) funding to help improve water quality. These activities are consistent with Hawaii's Implementation Plan for Polluted Runoff Control (July 2000), which is a culmination of the planning that the State of Hawaii has done in past years for polluted runoff control and, at the same time, a plan for implementation of activities to be undertaken by State and County agencies, federal agencies, and Hawaii's citizens to control polluted runoff.

The program also provides outreach and education to the community through school visits and participation in community fairs. The program has partnered with Honolulu Theatre for Youth to have a "clean water message" shared with their audiences for the Little Mermaid production. The program continues to work closely with the City and County of Honolulu, Department of Land and Natural Resources, Department of Transportation and other agencies on various Earth Month activities to encourage people to keep the water clean.

10.4.7. Beach Monitoring Program

The Beach Monitoring Program is administered by the DOH Clean Water Branch to ensure that Hawaii's coastal waters are safe and healthy for people, plants, and animals. Under the DOH Beach Monitoring Program, beaches are divided into three tiers. Tier 1 beaches are Hawaii's important and threatened beaches and therefore are monitored three times a week. Tier 1 represents our core beaches and will be monitored continually until they are re-classed as Tier 2 beach.

Tier 2 beaches are beaches represented by moderate use and are sampled once or twice a week for 6 month periods. After 6 months a new set of Tier 2 beaches are monitored for another 6 months. If a Tier 2 beach shows periodic elevated counts for no obvious reason, it will be re-sampled another 6 months or be elevated to a Tier 1 status.

If a beach shows that it is not impaired or threatened and has consistently low indicator bacteria counts, then it will be given a Tier 3 status. Tier 3 beaches are for the most part, hard to access, no houses nearby, and very little anthropogenic influences. Tier 3 beaches will be sampled at least once during a 6 month period. A list will be provided in the next Annual Beach Report in June 2008.

Program Goals:
The Beach Monitoring Program goal is to maintain coastal waters for the health and safety of people, plants, and animals.

Recommendations:
To achieve the program goal, the DOH recommends that the Hawaii State Water Quality Standard for recreational waters within 1,000 feet of the shoreline be revised to the national EPA standard. The Hawaii State Water Quality Standard for recreational waters is seven enterococci colony forming units per 100 ml, while the National Standard is 35 colony forming units per 100 ml. Hawaii's standard is too strict. For tropical waters there are questions about the reliability of enterococcus as a bacterial indicator for rule-making and decision-making for control of public health risks associated with fecal contamination in coastal recreational waters.

The Hawaii State Water Quality Standard should establish the boundaries (depth) of Hawaii's Recreational Waters. Recreational scuba diving is defined as pleasure diving to a depth of 130 feet without decompression stops.

Current Status:
In 2007, 155 beaches were monitored as compared to 62 in 2004. Sampling 160 beaches per year is the limit for the DOH BEACH Monitoring Program under the current work load and manpower resources of the Monitoring & Analysis Section of the CWB.

10.4.8. Wastewater Recycling Program

The DOH's Wastewater Recycling Program is managed and implemented by the Wastewater Branch. The Wastewater Branch administers the statewide engineering and financial functions relating to water pollution control, municipal and private wastewater treatment works program, individual wastewater systems program and the water pollution control revolving fund program.

Program Goals:
The Wastewater Recycling Program seeks to promote reuse, specifically to increase wastewater reuse to about 30 million gallons per day by 2015 (which is approximately 20 percent of wastewater produced).

Recommended Actions:
To achieve the program goals, the DOH plans to implement the following actions:

- Continue to encourage the use of recycled water by working with counties and private landowners to develop water reuse plans that allow for the most efficient use of recycled water, where available.

- Continue to implement the Wastewater Branch's program for short-duration recycled water use projects, including dust control for construction sites and temporary irrigation.

Current Status:
According to the DOH, wastewater recycling has risen from roughly 20.2 million gallons per day in 2000 to nearly 23.5 million gallons per day in 2005, representing an increase of nearly 1.6 percent over a five-year period. There were no significant additions or deletions to the recycled water users in 2004 and 2005, keeping recycled water use at approximately 23.5 mgd for that period.

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Section 11

Priority Recommendations and Implementation Plan

11. Priority Recommendations and Implementation Plan

Recommendations for CWRM programs are summarized in Section 11.1 below. Recommended actions are identified for either short-term implementation (one- to five-year time frame) or long-term implementation (timeframe beyond 5-years) in Section 11.2. Cost estimates are provided for short-term implementation actions and are intended for planning purposes only.

11.1. WRPP Priority Recommendations

There are three general areas in need of CWRM program development and expansion. CWRM should seek funding and staff resources to pursue the following priority recommendations:

1. **Statewide Water Resource Monitoring and Data Collection Program Development:** An integrated, statewide CWRM resource monitoring and data collection program should be developed with equal emphasis on surface and ground water.

2. **Statewide Water Resource Investigation and Assessment Program Development:** To refine components of the hydrologic budget and improve estimates of water resource availability, a statewide investigation and assessment program should be developed. The program should include long-term investigations to evaluate recharge, sustainable yield, ground water/surface water interaction, and instream flow standards and present these in timely updates to the WRPP.

3. **Statewide Water Conservation and Water Shortage Program Development:** A statewide water conservation and water shortage program should be developed and should include provisions for the exploration of alternative water source development and for a water emergency declaration process.

Specific supporting actions for each priority recommendation are described below.

11.1.1. Priority Recommendation 1: Statewide Water Resource Monitoring and Data Collection Program Development

The statewide water resource monitoring and data collection program should be developed to coordinate and implement CWRM monitoring activities, direct the expansion of monitoring networks, and enforce regulatory requirements for water use reporting. The program should also identify funding requirements and seek federal, State, and cooperative funding to implement program actions. The program should be designed to address the following supporting actions:

A. Ground Water Resource Monitoring Actions:

1. **Increase Funding for the CWRM-USGS Cooperative Monitoring Program:** Funding for the CWRM-USGS cooperative monitoring program should be increased. The increased funding would reflect inflationary costs as well as expanding the data collection network to monitor new centers of water development.

2. **Evaluate Existing Monitoring Well Network:** The existing monitoring well network should be reviewed to: 1) identify monitor wells located in or near large pumping batteries, that are directly influenced by upconing; and 2) identify former production and/or existing water-level observation wells where it may be feasible to convert existing wells to deep monitoring wells.

3. **Resurvey All Measuring Points for Deep Monitor Wells and Water-Level Observation Wells:** Geodetic-control benchmarks in the State of Hawaii should be resurveyed to ensure consistent and accurate water level measurements. This action would include all new wells and existing wells.

4. **Conduct Additional Synoptic Water-Level Surveys:** Synoptic water level surveys should be conducted regularly in all important areas. All water-level tapes should be calibrated against the USGS reference steel tape at least once every two years to update correction factors. With the modernization of geodetic benchmarks, the synoptic water levels will provide an accurate "snapshot" into the direction of ground water movement.

5. **Drill New Deep Monitor Wells and Improve Spatial Coverage:** Deep monitor wells sites should be identified and drilled in most of the basal aquifers in Hawaii. Deep monitor wells within an aquifer should be located to provide coverage at an inland or mauka site, a middle site near withdrawal areas, and a makai site to monitor changes in the distal portion of the basal lens. As part of the evaluation of the existing monitoring network, CWRM should identify and prioritize areas and location for new deep monitor well development statewide.

6. **Drill New Water-Level Observation Wells**: Dedicated water-level monitor wells should be located or drilled in all of the aquifers in Hawaii. The primary considerations for drilling new observation wells is to better delineate the basal aquifer boundaries, to locate geological boundaries and/or structures that would affect ground water flow, and to possibly provide observation wells for new well pumping tests. New water-level observation wells or test holes should be drilled or developed in interior areas following a mauka-to-makai orientation. Priority areas and locations should be identified as part of the evaluation of the existing monitoring network.

7. **Improve Existing Data Collection Sites:** 1) Outfit all new CWRM deep monitor wells with devices that will collect water-level data on a continuous basis. 2) Add transducers (or other devices) to provide continuous water-level data collection at existing BWS and USGS deep monitor wells in the network throughout the Pearl Harbor Aquifer Sector Area. 3) Eliminate redundant data collection from some monitoring sites.

8. **Collect Data on Additional Ground Water Parameters:** Existing wells or new wells should be outfitted with nested piezometers or multiple piezometers to observe vertical flow in the aquifer system areas where such information is important. Conductivity data loggers should be lowered to depths identified in the conductivity profile logs that suggest vertical flow, and left to monitor changes in conductivity over time. Where available,

calibrated dispersion coefficients from deep monitor well data should be included in existing analytical and new 3-D solute transport ground water flow models.

9. **Map Water-Level Data in GIS Format**: Where adequate data are available, use GIS software and deep monitor well data to map the top of the transition zone, the midpoint of the transition zone, and the elevations of water-levels, to allow the illustration of actual water levels and expected water levels.

B. Well Pumpage, Water-Level, and Chloride Monitoring Actions:

1. **Complete CWRM's Water Use Reporting Database:** Completion and operation of this database is a priority. CWRM should focus on obtaining pumpage reports from all users in designated water management areas and from large users in non-designated areas. Subsequently, CWRM should pursue statewide reporting of all active pumpage, water-level, and chloride data.

2. **Integration of Databases and Public Access to Databases:** Pursue integration of any historical pumpage, chloride, and water-level data from large users beginning with the Honolulu BWS. Historical data should be integrated with CWRM and USGS database information in an appropriately managed database with the goal of public access this master database, which should be provided in a secure format. The database should eventually be expanded to include information from other county water departments and large users (military, agriculture, etc.)

3. **Application of Internet and GIS Technology:** CWRM should utilize Internet technology to facilitate water use reporting by well operators/owners and GIS software to improve spatial reporting and analysis of well pumpage, chloride, and water-level data.

C. Spring Discharge Monitoring Actions:

1. **Integration of Databases:** Secure commitments from other agencies collecting spring data to facilitate the integration of various spring discharge and chemistry databases. Explore options for data application and future studies to help understand flow dynamics of basal lenses. Use spring discharge data as calibration targets in numerical ground water models.

2. **Conduct Additional Analyses**: To provide insight on the velocity of ground water flux over time, analyze spring data for additional parameters, such as nitrate, and compare the results with that of analyses performed on well water samples.

3. **Conduct Additional Monitoring:** Use data loggers to monitor temperature and conductance at spring orifices, logging daily changes. Temperature and conductance data may provide greater insight into the movement of the basal lens.

D. Surface Water Resource Monitoring Actions:

1. **Adopt Guidelines for Surface Water Monitoring:** CWRM should adopt guidelines for surface water monitoring and develop a standardized set of methods for measuring diverted flow and water use. Surface water users and diversion works operators should be educated on the correct application of water use metering and gaging methods that are appropriate for different end uses.

2. **Streamflow Monitoring Program:** CWRM should plan and develop a streamflow monitoring program. The program should include staff training, protocol establishment, and assessment of the existing USGS stream-gaging network, and developing a schedule to measure streams at regular time intervals on a regional scale. The program should provide data to support the establishment of instream flow standards.

3. **Increase Partnership Activities:** Seek involvement from public agencies, private entities, and community organizations in watershed partnerships, alliances, and other collaborative efforts to identify water uses and assess watershed conditions. Apply collaborative approaches to planning, funding and implementation of stream-related studies and programs.

E. Water Use Reporting Actions:

1. **Require Ground Water Use Reporting of all Well Owners:** CWRM should more actively pursue all owners of wells to report monthly water usage from their ground water source. CWRM should obtain additional funding and staff resources for the water use reporting program and amend its current policy to instead require currently-exempt individual water systems using less that 1,700 gpd to report water use.

2. **Improve Ground Water Use Reporting Process:** CWRM should utilize Internet technology to provide well owners and water users the option of submitting pumpage reports online. This will be far more efficient for ground water users and should also reduce data input errors.

3. **Improve Ground Water Use Reporting Compliance:** CWRM should continue development of the ground water use database to implement an automatic notification system that will flag delinquent reports, and send notices to well owners/water users that have neglected to send in pumpage reports.

4. **Disseminate Ground Water Use Information:** CWRM should consider resurrecting the monthly newsletter (see Section 5.2) to provide up-to-date information on deep monitor well, chloride, water-level, and/or water use information currently collected by CWRM.

5. **Establish Protocols for Measuring Surface Water Use:** Due to the wide variety of existing surface water diversion structures, CWRM should develop

protocols and make equipment recommendations for the standard measurement of surface water use.

6. **Establish a Surface Water Use Reporting Program:** CWRM should complete the development of the SWIM System and begin implementing a monthly surface water use reporting program. The program should first focus on large irrigation systems and should include broad notification of water users, development of a reporting form, and the distribution of the form and information reporting via the Internet. CWRM should seek additional staff for field investigations and water use data collection and management. Funding mechanisms should be established to support the program. Upon completion of statewide field verification of surface water diversions, CWRM should utilize the information to identify key surface water users to focus implementation of surface water use reporting requirements.

7. **Revise CWRM Policies Regarding Surface Water Use Reporting:** CWRM should revise surface water use reporting policies, in conjunction with the development of a surface water use reporting program.

F. Regulatory and Administrative Actions:

1. **Examine Water Use Assessment Methods:** CWRM should further explore the use of different statistics, methods, and measures to assess water use over time, such as a 5-year moving average. If an alternative measure is identified, the State Water Code should be updated to include the assessment measure.

2. **Improve Regulatory Coordination:** CWRM should support and participate in efforts to improve regulatory coordination between government agencies that regulate water resources. CWRM should support efforts to prevent duplication of effort, excessive regulation, and unnecessary regulation.

3. **Establish Continuing Education Programs for Well Construction and Pump Installation:** CWRM should explore further education programs for well drillers in addition to DCCA licensure testing on construction standards to ensure they are knowledgeable of updated and current construction standards.

4. **Establish Funding for Well Abandondment/Sealing:** CWRM should explore available funding sources and mechanisms to immediately address priority abandoned wells that need to be sealed (list of priority abandoned wells recommended for sealing is included in Table 11-1). CWRM should secure a continuous, dedicated funding source to acquire and maintain the specialized equipment and additional staff required. Because improperly abandoned wells are largely a contamination and pollution issue, CWRM should coordinate with the DOH to identify funding sources and implement a program for sealing wells that pose existing or potential pollution concerns.

5. **Identify and Specify Follow-up Actions for Potentially Abandoned Wells:** A comprehensive, statewide survey of all potentially abandoned wells has been conducted, including estimated costs for sealing such wells if they are verified as abandoned wells. Specific follow-up actions should be identified for each well. A sample priority sealing (Table 11-1) has been developed by CWRM staff, but should include all applicable wells including prioritizing which wells need to be sealed first.

Table 11-1: Priority Well Sealings

Name	Estimated Cost[1]
BWS Punaluu VB 3453-10	$12,600
Punaluu Sproat 3453-05	$10,000
EP10 wells (select wells)	$32,300
Kailua Kona 3758-01	$8,900
Kaloko Irr I 1 4160-01	$13,300
Pahoehoe well 3657-02	$31,000
Lau Taro Farm 2356-70	$6,500
Kapahulu 1749-08	$5,900
Waipahu Yoshimura D 2459-21	$7,500
Waialae golf course 1646-02	$4,300
EP 18 2102-11, 16 to 22	$34,400
Kauai Kealia Wells 0618-03 to 07	$26,200
Waialua Sugar (96 unused wells)	$755,800
State Aiea 2256-11 210 ft. 12 in	$7,200
State WP 5 (6 wells in a shaft 2203-01 to 06)	Unknown (very expensive)
TOTAL	$955,900

[1] Note: The above cost estimates are in 2006 dollars and are based on the volume of cement required and a $3,000 contractor set-up charge. The cost estimates do not include the cost of mobilization/demobilization, which can be as much as $30,000 for a large job.

6. **Establish Enforcement Mechanisms for Well Abandondment/Sealing:** If sufficient funding cannot be obtained for CWRM to seal abandoned wells, which the landowner/well owner will not or cannot properly seal, then CWRM should consider revising the State Water Code to give CWRM clear authority to order landowners/well owners to seal abandoned wells, subject to daily fines for noncompliance.

11.1.2. Priority Recommendation 2: Statewide Water Resource Investigation and Assessment Program Development

CWRM should champion the development of a statewide investigation and assessment program to refine components of the hydrologic budget and improve estimates of water resource availability. The program should include long-term investigations to evaluate precipitation, recharge, sustainable yield, ground water/surface water interaction, and instream flow standards. Many of the action items listed below will require data from CWRM and other agency monitoring programs. To leverage staff and funding resources, it is anticipated that investigation and research activities will be executed in cooperation with other State agencies, federal agencies, county agencies, and members of the academic community. The program should address the following supporting actions:

A. Rainfall Monitoring Actions:

1. **Increase Rainfall Data Collection:** Collection additional rainfall data, especially in watershed and agricultural areas. Data collection at long-term rain-gage stations should be continued, or reestablished if station activity has been discontinued. Rainfall analysis of all types should be updated.

2. **Coordinate Rainfall Data Sharing:** Coordinate rainfall data sharing between major data collection networks. Improve data delivery and data format for public consumption (including the acquisition and review of historic plantation data kept by the Hawaii Agricultural Research Center).

3. **Update Drought Frequency Information:** Conduct regular drought frequency analyses.

4. **Update Climate Station Information:** Update the statewide, comprehensive climate station index and accompanying maps.

5. **Update Statewide Rainfall Frequency Information:** Update the statewide rainfall frequency study and maps.

6. **Update Statewide Median/Average Rainfall Information:** Update the statewide median/average rainfall maps.

7. **Investigate the Potential Impacts of Long-Term Climate Trends:** The State and counties should cooperatively undertake climate studies in support of long-term water resource planning. Investigations should explore precipitation patterns, El Niño forecasting, impacts to hydrologic cycle, impacts to potable and non-potable water demands, and potential mitigation actions.

B. Cloud Water Interception and Fog Drip Monitoring Actions:

1. **Increase Cloud Water Interception Data Collection:** Investigate cloud water interception and its contribution to the hydrologic budget, aquifer sustainable yield, and watershed hydrology, especially in important watershed areas.

2. **Develop Methods to Estimate Cloud Water Interception:** Develop regional estimates of cloud water interception.

C. Evaporation Monitoring Actions:

1. **Identify Evapotranspiration Data Sources:** Identify sources of evaporation and evapotranspiration data and improve access to this data. Historic evaporation plantation data kept by the Hawaii Agricultural Research Center should be acquired and reviewed.

2. **Establish Evapotranspiration Monitoring Stations:** Establish monitoring stations to collect evapotranspiration data and evaluate its contribution to the

hydrologic budget. Additional research should be conducted in areas where aquifer sustainable yields should be reassessed or refined.

3. **Develop Methods to Estimate Evapotranspiration:** Develop regional estimates of evapotranspiration estimates, especially in areas where aquifer sustainable yields need to be reassessed or refined.

4. **Update Statewide Pan Evaporation Maps:** Update the statewide pan evaporation maps in DLNR's *Pan Evaporation: State of Hawaii 1894-1983*, R74, 1986 based on best available information.

D. Recharge Assessment Actions:

1. **Improve Recharge Estimates:** Achieve a more standardized estimation of the rate of natural recharge through further study of relevant hydrologic processes such as precipitation, fog drip, surface runoff, soil-moisture storage, evapotranspiration, and time-steps used. Update recharge estimates statewide for complete island coverage using the general ground water recharge equation in its entirety, and consider excluding basal recharge from caprock and valley fill geology.

2. **Establish Standard Rainfall and Evaporation Data Inputs:** Identify the rainfall isohyets described in DLNR's *Rainfall Atlas*, R76, 1986 and the isopleths described in DLNR's *Pan Evaporation: State of Hawaii 1894-1983*, R74, 1986 as the standards to be used in estimating ground water recharge until more updated maps are developed.

3. **Consult Other Agencies:** Review ground water recharge components with other state and federal agencies and produce GIS coverage formats for various time-steps (annual, monthly, and if feasible, daily).

4. **Disseminate Recharge Information:** Provide recharge updates in GIS coverage format to be placed on the State GIS system.

E. Ground Water/Surface Water Interaction Assessment Actions:

1. **Conduct Seepage Runs:** Identify sites statewide where it would be appropriate to conduct seepage runs and incorporate seepage run data collection into the monitoring program.

2. **Collect Baseline Stream Data:** Ensure adequate coverage of long-term stream gage sites and identify appropriate low-flow partial record sites. Ensure adequate baseline data collection prior to new source development. Coordinate data collection based upon long-range county plans for water development.

3. **Utilize Numerical Models Appropriately:** Promote and encourage the use of calibrated local and island-scale numerical models of ground water flow in relation to aquifer system and sector areas to assess ground water/surface water interaction. Utilize data from hydrologic monitoring to calibrate and

validate numerical models of ground water/surface water interaction. This may be used as part of the well permitting process depending on the user friendliness and timeliness of getting results from such numerical models.

F. Sustainable Yield Assessment Actions:

1. **Apply Revised Recharge Estimates to Assess Sustainable Yield:** CWRM should use the revised estimates of recharge to evaluate sustainable yield statewide. CWRM should apply revised recharge estimates in all analytical and numerical models deemed appropriate by the agency, including three dimensional models, and should use the results in future sustainable yield revisions.

2. **Apply Information on Ground Water/Surface Water Interaction to Reassess Sustainable Yield:** CWRM should utilize information on ground water/surface water interactions in its evaluation of sustainable yield and in its review of well-permit applications. This would require the establishment of instream flow standards. CWRM should also consider the impacts of pumping on coastal leakage and sustainable yield estimates.

3. **Utilize New Ground Water Monitoring Data to Study Transition Zone:** CWRM should utilize salinity profiles observed at deep monitoring wells to improve estimates of the dispersion coefficient and monitor behavior of the Transition Zone. 3-D models should use deep monitor well data to justify dispersion coefficients used to estimate chloride movement within ground water.

4. **Utilize Numerical Models Appropriately:** Promote and encourage the use of calibrated local and island-scale numerical models of ground water flow in relation to aquifer system and sector areas to assess infrastructure safe yields. Spatially detailed analysis of safe yield and well infrastructure should be conducted. This would be in conjunction with selected scenarios defined in each counties water use and development plan to safeguard the public trust needs of domestic use within a municipal system. This may be used as part of the well permitting process depending on the user friendliness and timeliness of getting results from such numerical models. To support modeling efforts and sustainable yield estimates, CWRM should improve its water use reporting program statewide and explore the incorporation of adaptive management concepts where appropriate.

G. Instream Flow Standard Assessment Actions:

1. **Assess and Adopt Interim Instream Flow Standards:** CWRM should implement the agency's process for adopting interim instream flow standards.

2. **Implement Instream Use Protection Program Implementation Plan:** Continue to execute work tasks described in the CWRM Stream Protection and Management Branch, Instream Use Protection Section Program Implementation Plan, as updated.

3. **Assess Stream-Related Cultural Resources:** Develop, fund, and conduct cultural resource studies or surveys in priority areas.

4. **Inventory Stream Channel Alterations:** Fund and complete an inventory of stream channel alterations. Activities should include field verification and GIS mapping.

H. Assess Impacts of Climate Change on Statewide Water Resources:

1. **Study the Impacts of Climate Change to Hawaiian Hydrology:** CWRM should study the potential impacts of climate change on aquifer recharge, groundwater levels, stream flows, and how sea level changes may impact coastal aquifer systems.

2. **Study the Impacts of Climate Change on Long-Range Water Resource Planning:** CWRM should study how climate change will impact future supply and demand on Hawaii's water resources, taking into consideration resource protection and source development in a changing climate. CWRM should encourage county water departments to design and implement mitigation measures to address the range of potential impacts to Hawaii's water resources.

11.1.3. Priority Recommendation 3: Statewide Water Conservation and Water Shortage Program Development

Several State and county agencies currently implement various water conservation and water shortage measures. CWRM should develop a statewide water conservation and water shortage program to coordinate supply and demand management activities at the State and County level. The program should provide guidelines and recommendations for government agencies, water system operators, water use permittees, and the general public. CWRM's program should provide a planning framework for the integration of water conservation and water shortage response activities. Provisions for the exploration of alternative water source development should be included. CWRM should also identify a process for the declaration of a water emergency. Specific actions to be addressed in the statewide water conservation and water shortage program are listed below:

A. Water Conservation Planning Actions:

1. **Implement DLNR Water Conservation Plan:** DLNR should implement the site-specific recommendations of the DLNR Water Conservation Plan. Funds should be sought from the Legislature and DAGS, and other financing options should be pursued, such as rebate programs, performance contracting, and public/private partnerships.

2. **Encourage State Agency Water Conservation Planning:** All State agencies should be encouraged to apply the water conservation planning method described in the DLNR Water Conservation Plan and follow through with plan implementation. Each facility/site should designate a project manager to develop and implement a conservation plan for each facility.

Existing and developing State agency conservation efforts should be identified in the next update of the SWPP. The SWPP should also suggest specific agency conservation goals and actions.

3. **Encourage Military Water Conservation Planning:** Military installations should be encouraged to develop site/facility-specific water conservation plans that expand on the existing general conservation policies of the Army, Navy, and Air Force. Site/facility-specific military conservation plans should delineate conservation goals and present implementation schedules for these measures. The military should undertake conservation planning efforts with sensitivity to local, regional, and statewide water resource management issues and incorporate extensive personnel and public outreach programs to encourage a conservation and stewardship ethic in the context of Hawaii's particular water concerns.

4. **Encourage Water System Conservation Planning:** Water purveyors should encourage large industrial, commercial, agricultural, and institutional users to develop operational water conservation plans, introduce financial incentives to reward users who implement conservation measures and demonstrate reduced consumption, and explore greater application of tiered pricing to encourage water conservation.

5. **Encourage Business and Facility Conservation Activities:** CWRM should promote and coordinate ongoing water conservation efforts across the state, to provide guidance for businesses lacking conservation programs. A dedicated funding source for water conservation outreach should be secured. Cooperative efforts between the State and counties can enhance program development and expand program application.

6. **Identify Funding Sources to Support Conservation Activities:** Government agencies should pursue public/private partnerships to contribute funds, implement and promote water conservation efforts, and increase public awareness.

B. Water Resource Augmentation Planning Actions:

1. **Provide Guidance in Resource Augmentation:** CWRM should establish a resource augmentation planning program and framework to identify augmentation goals, objectives, and priorities to promote the use of alternative water resources and to encourage the development of these supplies in an efficient and sensible manner. CWRM should act in an advisory capacity, guiding policies and planning efforts for augmentation projects. CWRM should explore partnerships with governmental agencies and stakeholders in order to coordinate resource augmentation planning and policies. Water resource augmentation planning efforts and policies must be designed to complement the water conservation programs

2. **Promote Use of Alternative Water Sources:** CWRM should require the use of dual line water supply systems in new industrial and commercial developments located in designated water management areas where

recycled water is available. CWRM should coordinate with county agencies to obtain regular updates for recycled-water service areas and capacities, and apply the dual line water supply system requirement to permit applications within the portions of water management areas served by recycled water distribution systems. CWRM and the DOH should also explore the use and application of gray water and gray water systems, and pursue the development of DOH use guidelines for gray water, to encourage county governments to include provisions for gray water systems in the county planning codes.

C. Wastewater Reclamation Actions:

1. **Explore Potential Recycled Water Initiatives:** The results of the *2004 Hawaii Water Reuse Survey and Report* should be used by the counties as a guidance document to assist county reuse initiatives. It is recommended that county governments examine the potential recycled water expansion and application projects identified in the *2004 Hawaii Water Reuse Survey and Report* and outline strategies to develop and expand water reuse within their jurisdictions.

2. **Include Water Recycling Programs in County Water Use Planning:** Counties should include current water recycling programs, or strategies for program development, into subsequent updates of the County WUDPs to maintain consistency with the WRPP. County recycled water rates should be published or made available upon inquiry to users, potential customers, and the general public.

3. **Provide Regulatory Controls for Water Quality:** The DOH should develop controls and regulations for the application of recycled water to address potential safety and public health concerns, including but not limited to the application of recycled water over potable water aquifers.

D. Stormwater Reclamation Actions:

1. **Explore Potential Stormwater Reclamation Initiatives:** Counties should consider stormwater reclamation opportunities to provide alternative water sources for non-potable uses. County governments should encourage the use of small-lot and source-reuse technologies to manage precipitation and runoff as close to the source as feasible. The county could also provide incentives, in the form of water credits or speedy-permit processing, to encourage the implementation of on-site stormwater reuse. The feasibility of large-scale stormwater reclamation should be assessed.

2. **Explore the Use of Stormwater Reclamation to Control Non-Point Source Pollution:** The DOH administers the National Pollution Discharge Elimination System and Total Maximum Daily Load programs that regulate the discharge of stormwater. State and county governments should encourage the use of stormwater reclamation and reuse measures that could be used to meet some of these program requirements.

E. Drought Planning Actions:

1. **Continue Implementing 2005 Hawaii Drought Plan Update:** CWRM should continue implementation of the 2005 Hawaii Drought Plan Update, including recommendations summarized in Section 8 of the WRPP.

2. **Complete Regular Updates of the Hawaii Drought Plan:** CWRM should secure funding and contracts to execute the timely update and revision of the Hawaii Drought Plan every five years. Plan recommendations and the drought communication protocol should likewise be reevaluated and revised as appropriate.

F. Watershed Protection Actions:

1. **Support DOFAW's Watershed Protection Initiatives:** CWRM should become more active and support DOFAW's watershed management activities and the division's leadership role in watershed management. CWRM should focus on improving coordination between DOFAW's land management programs and CWRM's water management programs. CWRM and DOFAW should pursue appropriate funding to support and implement watershed protection programs and objectives to protect water resources.

2. **Assess Watershed Protection Policies:** Agencies should become familiar with legislative means to protect and preserve our watersheds against contamination and encroachment of intake areas. Federal, State, and county agencies should collaborate with existing watershed partnerships and Conservation Districts to map the relationships between land management programs, land use regulations, economic and agricultural issues, and water quality and resource protection programs. Existing policies should be assessed and amended as appropriate to improve watershed protection.

3. **Improve Communication between Watershed Interests:** CWRM should work with DOH and CZM to improve communication and encourage dialogue between watershed interests. Agencies should support the recommendation of the Hawaii Ocean Resources Management Plan to create a watershed coordinating committee, as such a body could facilitate the development of common goals and an integrated watershed management framework. Agencies should cooperatively develop a watershed planning process and guidance document to be overseen and informed by the watershed coordinating committee. This effort should include the development of innovative public outreach methods and the acknowledgement of existing programs and organizations to maximize funding, staff, and volunteer resources through watershed-scale management and protection programs.

4. **Explore Potential Watershed Protection Initiatives:** Agencies should study existing government and community efforts in watershed management and protection, watershed planning approaches, and lessons learned, and encourage sharing of information and experiences. Agencies should explore means to expand and improve watershed protection statewide, including

opportunities to coordinate with the CZM and DOH in the Coastal Nonpoint Pollution Control Program.

G. Water Shortage Planning Actions:

1. **Develop Water Shortage Plans for All Water Management Areas:** CWRM should pursue the development and adoption of Water Shortage Plans for all designated water management areas, in coordination with drought, conservation, and resource augmentation plans and programs. CWRM should seek legislation to provide for formulation and implementation of the Water Shortage Plan and plan provisions, including funding and the mechanism for timely enforcement of the penalty policy for non-compliance with water shortage restrictions, which will be developed as part of the plan. CWRM should formulate and adopt rules to streamline the public hearing process for the water shortage declarations.

2. **Require Water Shortage Plans From All Water Use Permittees:** Water shortage plans are and shall continue to be required from all water use permittees. Plans shall be submitted as part of the permit application so that CWRM can perform actions on the water use permits and updates to the regional plan simultaneously. HRS §174C-51(8) and HRS §174C-62(a) & (c) of the State Water Code provide the authority for CWRM to implement this recommendation. Permittees whose individual water shortage plan indicates a 0% reduction in water use shall be required to provide supporting justification. CWRM shall conduct site visits as necessary to verify the permittee's inability to reduce water use during shortage conditions. If it is determined that the permittee has the ability to reduce water use during water shortage conditions, CWRM shall modify the permittee's individual water shortage plan. CWRM should consider requiring all artesian wells and other free-flowing sources to be outfitted with a flow control device such as a valve. Permittees of sources which are not required to have flow control devices shall be exempt from water shortage plan provisions.

3. **Monitor Water Use for Compliance:** CWRM shall review and compare the current monthly water usage data of all permittees with their permitted allocation in order to determine if there are any permittees whose monthly pumpage is greater than their permitted allocation. For those permittees whose water usage exceeds their allocation, CWRM shall proceed with enforcement of permit restrictions.

4. **Identify Domestic Water Use from Public Water Systems:** CWRM shall request all large water users (e.g., BWS, United States military) to separate out and make known any of their permitted water uses or users that fall within the domestic water use class, which is an identified public trust purpose.

5. **Evaluate Unused Water Allocations:** CWRM should field verify all water use permits who either have sources out of service or not in use (for a period of four years or longer), and CWRM shall consider revoking the water use permits of such permittees.

H. Water Emergency Planning Actions:

1. **Develop Water Emergency Declaration Process:** CWRM, in consultation with county water agencies and other public/private water system purveyors who operate systems, should formulate and adopt rules specifically for the issuance of a water emergency declaration. Such rules should detail:

    - Criteria for determining when a water emergency exists;
    - A streamlined process for emergency declaration, notification, public comment processes;
    - Extent of the regulatory authority of a water emergency declaration;
    - Restrictions that may be imposed by CWRM under a water emergency declaration; and
    - Suggested relief measures to be taken by county water agencies and water system operators.

11.2. WRPP Implementation Plan

Table 11-2 illustrates the implementation plan for the WRPP priority recommendations. Actions identified for short-term phasing are anticipated to be implemented within five years. Long-term actions are anticipated for implementation beyond 5-years. As noted earlier in Section 11.1, CWRM should seek funding and staff resources to pursue these priority recommendations. Cost estimates are provided for the initial implementation of short-term actions, and do not reflect additional annual operating costs to CWRM. Cost estimates should be refined based upon scope of implementation and related studies that may be required. Long-term actions, especially those requiring the participation and cooperation of other agencies and entities, should be re-examined upon progress of CWRM program development.

Table 11-2:
WRPP Implementation Plan

Action Item	Phasing	Cost Estimate ($1000)
Priority Recommendation		
1. Statewide Water Resource Monitoring and Data Collection Program Development		
A. Ground Water Resource Monitoring Actions:		
1. Increase Funding for the CWRM-USGS Cooperative Monitoring Program.	Short-Term	$400
2. Evaluate Existing Monitoring Well Network.	Short-Term	$50
3. Resurvey All Measuring Points for Deep Monitor Wells and Water-Level Observation Wells.	Short-Term	$350
4. Conduct Additional Synoptic Water-Level Surveys.	Short-Term	$150
5. Drill New Deep Monitor Wells and Improve Spatial Coverage.	Long-Term	TBD
6. Drill New Water-Level Observation Wells.	Long-Term	TBD
7. Improve Data Collection.	Short-Term	$250
8. Collect Data on Additional Ground Water Parameters.	Short-Term	$250
9. Map Water-Level Data in GIS Format.	Short-Term	$75
B. Well Pumpage, Water-Level, and Chloride Monitoring Actions:		
1. Complete CWRM's Water Use Reporting Database.	Short-Term	$50
2. Integration of Databases and Public Access to Databases.	Long-Term	TBD
3. Application of Internet and GIS Technology.	Short-Term	$40
C. Spring Discharge Monitoring Actions:		
1. Integration of Databases.	Short-Term	$20
2. Conduct Additional Analyses.	Short-Term	$250
3. Conduct Additional Monitoring.	Short-Term	$75
D. Surface Water Resource Monitoring Actions:		
1. Adopt Guidelines for Surface Water Monitoring.	Short-Term	$50
2. Streamflow Monitoring Program.	Long-Term	TBD
3. Increase Partnership Activities.	Long-Term	TBD
E. Water Use Reporting Actions		
1. Require Ground Water Use Reporting of All Well Owners.	Short-Term	$20
2. Improve Ground Water Use Reporting Process.	Short-Term	$40
3. Improve Ground Water Use Reporting Compliance.	Short-Term	$10
4. Disseminate Ground Water Use Information.	Short-Term	$10
5. Establish Protocols for Measuring Surface Water Use.	Short-Term	$100
6. Establish a Surface Water Use Reporting Program.	Short-Term	$500
7. Revise CWRM Policies Regarding Surface Water Use Reporting.	Short-Term	$40
F. Regulatory and Administrative Actions:		
1. Examine Water Use Assessment Methods.	Long-Term	TBD
2. Improve Regulatory Coordination.	Long-Term	TBD
3. Establish Continuing Education Programs for Well Construction and Pump Installation.	Short-Term	$50
4. Establish Funding for Well Abandondment/Sealing.	Long-Term	TBD
5. Identify and Specify Follow-up Actions for Potentially Abandoned Wells.	Long-Term	TBD
6. Establish Enforcement Mechanisms for Well Abandondment/Sealing.	Long-Term	TBD

Table 11-2: (continued)
WRPP Implementation Plan

Priority Recommendation		
Action Item	**Phasing**	**Cost Estimate ($1000)**
2. Statewide Water Resource Investigation and Assessment Program Development		
A. Rainfall Monitoring Actions:		
1. Increase Rainfall Data Collection.	Long-Term	TBD
2. Coordinate Rainfall Data Sharing.	Long-Term	TBD
3. Update Drought Frequency Information.	Long-Term	TBD
4. Update Climate Station Information.	Short-Term	$50
5. Update Statewide Rainfall Frequency Information.	Long-Term	TBD
6. Update Statewide Median/Average Rainfall Information.	Long-Term	TBD
7. Investigate the Potential Impacts of Long-Term Climate Trends.	Long-Term	TBD
B. Cloud Water Interception and Fog Drip Monitoring Actions:		
1. Increase Cloud Water Interception Data Collection.	Long-Term	TBD
2. Develop Methods to Estimate Cloud Water Interception.	Long-Term	TBD
C. Evaporation Monitoring Actions:		
1. Identify Evapotranspiration Data Sources.	Long-Term	TBD
2. Establish Evapotranspiration Monitoring Stations.	Long-Term	TBD
3. Develop Methods to Estimate Evapotranspiration.	Long-Term	TBD
4. Update Pan Evaporation Maps	Long-Term	TBD
D. Recharge Assessment Actions:		
1. Improve Recharge Estimates.	Long-Term	TBD
2. Establish Standard Rainfall and Evaporation Data Inputs.	Short-Term	$75
3. Consult Other Agencies.	Short-Term	$75
4. Disseminate Recharge Information.	Short-Term	$10
E. Ground Water/Surface Water Interaction Assessment Actions:		
1. Conduct Seepage Runs.	Short-Term	$600
2. Collect Baseline Stream Data.	Short-Term	$500
3. Utilize Numerical Models Appropriately.	Long-Term	TBD
F. Sustainable Yield Assessment Actions:		
1. Apply Revised Recharge Estimates to Assess Sustainable Yield.	Short-Term	$250
2. Apply Information on Ground Water/Surface Water Interaction to Reassess Sustainable Yield.	Short-Term	$50
3. Utilize New Ground Water Monitoring Data to Study Transition Zone.	Short-Term	$500
4. Utilize Numerical Models Appropriately.	Long-Term	TBD
G. Instream Flow Standard Assessment Actions:		
1. Assess and Adopt Interim Instream Flow Standards.	Long-Term	TBD
2. Implement Instream Use Protection Program Implementation Plan.	Short-Term	$750
3. Assess Stream-Related Cultural Resources.	Short-Term	$800
4. Inventory Stream Channel Alterations.	Short-Term	$250
H. Assess Impacts of Climate Change on Statewide Water Resources:		
1. Study the Impacts of Climate Change to Hawaiian Hydrology	Long-Term	TBD
2. Study the Impacts of Climate Change on Long-Range Water Resource Planning.	Long-Term	TBD

Table 11-2: (continued)
WRPP Implementation Plan

Priority Recommendation		
Action Item	**Phasing**	**Cost Estimate ($1000)**
3. Statewide Water Conservation and Water Shortage Program Development		
A. Water Conservation Planning Actions:		
1. Implement DLNR Water Conservation Plan.	Short-Term	$1,500
2. Encourage State Agency Water Conservation Planning.	Long-Term	TBD
3. Encourage Military Water Conservation Planning.	Long-Term	TBD
4. Encourage Water System Conservation Planning.	Short-Term	$75
5. Encourage Business and Facility Conservation Activities.	Short-Term	$100
6. Identify Funding Sources to Support Conservation Activities.	Long-Term	TBD
B. Water Resource Augmentation Planning Actions:		
1. Provide Guidance in Resource Augmentation.	Long-Term	TBD
2. Promote Use of Alternative Water Sources.	Long-Term	TBD
C. Wastewater Reclamation Actions:		
1. Explore Potential Recycled Water Initiatives.	Long-Term	TBD
2. Include Water Recycling Programs in County Water Use Planning.	Long-Term	TBD
3. Provide Regulatory Controls for Water Quality.	Long-Term	TBD
D. Stormwater Reclamation Actions:		
1. Explore Potential Stormwater Reclamation Initiatives.	Long-Term	TBD
2. Explore the Use of Stormwater Reclamation to Control Non-Point Source Pollution.	Long-Term	TBD
E. Drought Planning Actions:		
1. Continue Implementing 2005 Hawaii Drought Plan Update	Short-Term	$400
2. Complete Regular Updates of the Hawaii Drought Plan	Short-Term	$75
F. Watershed Protection Actions:		
1. Support DOFAW's Watershed Protection Initiatives.	Long-Term	TBD
2. Assess Watershed Protection Policies.	Long-Term	TBD
3. Improve Communication between Watershed Interests.	Long-Term	TBD
4. Explore Potential Watershed Protection Initiatives.	Long-Term	TBD
G. Water Shortage Planning Actions:		
1. Develop Water Shortage Plans for All Water Management Areas.	Long-Term Short-Term	TBD $100
2. Require Water Shortage Plans From All Water Use Permittees.	Short-Term	$50
3. Monitor Water Use for Compliance.	Short-Term	$50
4. Identify Domestic Water Use from Public Water Systems.	Short-Term	$75
5. Evaluate Unused Water Allocations.		
H. Water Emergency Planning Actions:		
1. Develop Water Emergency Declaration Process.	Long-Term	TBD

Note: "TBD" indicates cost estimates to be determined.

Section 12

References

12. REFERENCES

Alley, W.M., T.E. Reilly, and O.L. Franke, 1999, Sustainability of Ground-Water Resources: U.S. Geological Survey Circular 1186, 79 p. Available online at http://pubs.usgs.gov/circ/circ1186/html/gw_effect.html.

American Water Works Association, Research Foundation, 1999, Residential End Uses of Water.

Anderson, M.P., Woessner, W.W., 1992, Applied Groundwater Modeling – Simulation of Flow and Advective Transport, 381 p.

Anthony, Stephen S., 1997, Evaluation of the U.S. Geological Survey Ground-Water Data-Collection Program in Hawaii, 1992: U.S. Geological Survey Water-Resources Investigations Report 97-4232, 76 p.

Carter, R.W. and Davidian, J., 1968, Chapter A6, General procedure for gaging streams, Book 3, Applications of Hydraulics, Techniques of Water Resources Investigations of the U.S. Geological Survey. Available online at http://pubs.usgs.gov/twri/twri3-A6/html/pdf.html.

Chu, P.S., and Chen, H, 2005, Interannual and interdecadal rainfall variations in the Hawaiian islands: Journal of Climate, v. 18, pp. 4796-4813.

Chu, P.S., 2006 (unpublished report), Rainfall Station Index and Atlas for Kauai County: County of Kauai Department of Water and State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, 30 p.

Climate Change Science Program and the Subcommittee on Global Change Research, 2005, Our Changing Planet, The U.S. Climate Change Science Program for Fiscal Year 2006: U.S. Climate Change Science Program, Washington, DC, 216 p.

Craighill Handy, E.S., 1965, Ancient Hawaiian Civilization; a series of lectures delivered at the Kamehameha Schools. Charles E. Tuttle Co. Publishers.

Dale, R.H., and Takasaki, K.J., 1976, Probable effects of increasing pumpage from the Schofield ground-water body, Island of Oahu, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 76-47.

Devaney, Dennis M., Marion Kelly, Polly Jae Lee and Lee S. Motteler, Kaneohe: A History of Change: Honolulu, The Bess Press, 1982.

Ekern, P.C., and Chang, J.H., 1985, Pan Evaporation: State of Hawaii, 1894-1983: State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Report R74, 172 p.

Englund, R., 1998, Biological assessment and the effects of water withdrawls on Waikele Stream, Oahu, Aquatic biota: Prepared for Belt-Collins Hawaii, 31 p.

Engott, John A., and Vana, Thomas T. 2007, Effects of agricultural land-use changes and rainfall on ground-water recharge in central and west Maui, Hawaii, 1926-2004: U.S. Geological Survey Scientific Investigations Report 2007-5103, 56 p. Available online at http://pubs.usgs.gov/sir/2007/5103/.

Essaid, H. I., 1986, A comparison of the coupled fresh water-salt water flow and the Ghyben-Herzberg sharp interface approaches to modeling of transient behavior in coastal aquifer systems: Journal of Hydrology, 86: pp. 169–193.

Essaid, H.I., 1990, SHARP--A quasi-three-dimensional finite-difference simulation model for freshwater and saltwater flow in layered coastal aquifer systems: U.S. Geological Survey Water-Resources Investigations Report 90-4130, 181 p.

Fontaine, R.A., Wong, M.F., and Matsuoka, Iwao, 1992, Estimation of median streamflows at perennial stream sites in Hawaii: U.S. Geological Survey Water-Resources Investigations Report 92-4099, 37 p.

Fontaine, R.A., 1996, Evaluation of the surface-water quantity, surface-water quality, and rainfall data-collection programs in Hawaii: U.S. Geological Survey Water-Resources Investigations Report 95-4212, prepared in cooperation with the State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, 125 p.

Fontaine, R.A., 2003, Availability and distribution of base flow in lower Honokohau Stream, Island of Maui, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 03-4060, 37 p.

Fontaine, R.A., 2006, Water Resources Data, Hawaii and other Pacific Islands, Water Year 2005, Volume 1. Hawaii: U.S. Geological Survey Water-Data Report HI-05-1, 344p.

Foote, D. E. et al., 1972, Soil Surveys of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii: United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C. 232 pp., 130 map sheets.

Galloway, Devin L., Alley, William M., Barlow Paul M., Reilly, Thomas E., and Tucci, Patrick, Evolving issues and practices in managing ground water-resources: case studies on the role of science: U.S. Geological Survey Circular 1247, 83 p.

Gelhar, L. W., Welty, C., and Rehfeldt, K. R., 1992, A critical review of data on field-scale dispersion in aquifer: Water Resources Research, 28(7): pp. 1955-1974.

Giambelluca, T.W., 1983, Water balance of the Pearl Harbor-Honolulu Basins, Hawaii, 1946-1975, Technical Report No.151: Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii.

Giambelluca, T.W., DeLay, J.K., Nullet, M.A., Scholl, M.A., and Gingerich, S.B. Interpreting canopy water balance and fog screen observations: Separating cloud water from wind-blown rainfall at two contrasting forest sites in Bruijnzeel, L.A., Juvik, J., Scatena, F.N., Hamilton, L.S., and Bubb, P., Mountains in the Mist: Science for Conserving and Managing Tropical Montane Cloud Forests, Honolulu, HI, University of Hawaii Press.

Giambelluca, T.W., Nullet, M.A., and Schroeder, T.A., 1986, Rainfall atlas of Hawaii: State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, Report R76, 267 p.

Gingerich, S.B. and Voss, C.I., 2005, Three-dimensional variable-density flow simulation of a coastal aquifer in Southern Oahu, Hawaii, USA: Hydrogeology, 13:436-450.

Hanalei Watershed Hui, 2004, Internet, Available at: http://www.hanaleiwatershedhui.org.

Hirsch, Robert M., Winter, Thomas C., Harvey, Judson W., Franke, O. Lehn, and Alley, William M., Ground water and surface water: a single resource: U.S. Geological Survey Circular 1139, 79 pp, Available on line at: http://water.usgs.gov/ogw/gwsw.html.

Hunt, C.D., Jr., 1996, Geohydrology of the island of Oahu, Hawaii Professional Paper 1412-B, U.S. Geological Survey.

Hunt, C. D., and DeCarlo, E. H., 2000, Hydrology and water and sediment quality at James Campbell National Wildlife Refuge near Kahuku, Island of Oahu, Hawaii: prepared in cooperation with the U. S. Fish and Wildlife Service, Department of Interior: U. S. Geological Survey Water-Resources Investigations Report 99-4171, 85 p.

Intergovernmental Panel on Climate Change, 1998, The regional impacts of climate change, an assessment of vulnerability: Cambridge University Press, 517 p.

Intergovernmental Panel on Climate Change, 2001, Summary for policymakers, a report of working group I of the intergovernmental panel on climate change: climate change 2001: synthesis report, April 4, 2006, http://www.ipcc.ch/pub/spm22-01.pdf.

Izuka, S. K., 1992, Geology and stream infiltration of North Halawa Valley, Oahu, Hawaii: prepared in cooperation with the Department of Transportation, State of Hawaii: U. S. Geological Survey Water Resources Investigations Report 91-4197, 21 p.

Izuka, S.K., and Gingerich, S.B., 1998, Ground water in the southern Lihue basin, Kauai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 98-4031, 71 p.

Izuka, S.K., and Oki, D.S., 2001, Numerical simulation of groundwater withdrawals in the Southern Lihue Basin: U.S. Geological Survey Water-Resources Investigations Report 01-4200.

Jenkins, C. T., 1970, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey, Technical Water-Resources Investigations, Ch. D1, Book 4, Hydrological Analysis Interpretation, 17 pp.; Glover, R. E., 1974, Transient ground water hydraulics: Dept. of Civil Engineering, Colorado State University, Fort Collins, Colorado, 413 p.

Juvik, J. O. and Ekern, P. C., 1978, A climatology of mountain fog on Mauna Loa, Hawaii Island, Technical Report No. 118, Project Completion Report for fog precipitation along topo-climatic gradients on the Island of Hawaii, OWRT Project No. A-041-HI, Grant Agreement No. 14-34-0001-5011, Project Period: 1 July 1974 to 31 December 1975.

Juvik, J. O, and Nullet, D., 1994, A climate transect through tropical montane rain forest in Hawaii: Journal of Applied Meteorology, v. 33, No.11, p. 1304.

Juvik, J. O, and Nullet, D., 1995, Comments on "A Proposed Standard Fog Collector for Use in High Elevation Regions": Journal of Applied Meteorology, v. 34, No.9, p. 2108-2110.

Koch, Linda, Harrigan-Lum, June, and Henderson, Katina, 2004, Final 2004 List of Impaired Waters in Hawaii, Prepared Under Clean Water Act §303 (d): Hawaii State Department of Health, Environmental Planning Office.

Konikow, L.F., and Bredehoeft, J.D., 1978, Computer model of two-dimensional solute transport and dispersion in groundwater, USGS Techniques of water resources investigation, book 7, Chapter 2, Washington, DC.

Kumu Pono Associates, 2002, An Overview of Native Hawaiian Land and Ocean Management Practices. Internet. Available online at: http://kumupono.com.

Langenheim, V.A.M., and Clague, D.A., 1987, The Hawaiian-Emperor volcanic chain, part II, stratigraphic framework of volcanic rocks of the Hawaiian islands, volcanism in Hawaii: U.S. Geological Survey Professional Paper 1350. pp. 55-84.

Lau, L. Stephen and Mink, J.F., 2006, Hydrology of the Hawaiian Islands: University of Hawaii Press: Honolulu.

Liu, C.C.K., Green, R.E., Lee, C.C. and Williams, M.K., 1983, Modeling Analysis of Pesticide DBCP Transport and Transformation in Soils of Kunia Area in Central Oahu, Hawaii, Phase I Completion Report To U.S. Environmental Protection Agency, Pacific Biomedical Research Center, University of Hawaii, Honolulu.

Liu, C.C.K., Lau, L.S. and Mink, J.F., 1983, Groundwater Model for a Thick Freshwater Lens, Ground Water, 21(3):293-300.

Liu, C.C.K., Ewart, C. and Huang, Q., 1991, Response of a Basal Water-Body to Forced Draft, In ASCE Book: Ground Water in the Pacific Rim Countries, J. Peters (ed.), American Society of Civil Engineers (ASCE), pp. 36-42.

Liu, C.C.K., Loague, K.M. and Feng, J.S., 1991, Fluid Flow and Solute Transport in Unsaturated Heterogeneous Soils: Numerical Experiments: Journal of Contaminant Hydrology 7, pp. 261-283.

Liu, C.C.K., 2006, Analytical groundwater flow and transport modeling for the estimation of the sustainable yield of Pearl Harbor Aquifer, Project Report PR-2006-06, Water Resources Research Center, University of Hawaii, 53 p.

Liu, C.C.K., 2007, Testing and Application of RAM2 for Determining Sustainable Yield of Hawaii Basal Aquifers, Project Report PR-2007-00, Water Resources Research Center, University of Hawaii (in preparation).

Loague, K.T., Giambelluca, T.W., Green, R.E., Liu, C.C.K, Liang, T.C., and Oki, D.S., 1989, Simulation of organic chemical movement in Hawaii soils with PRZM: 2. Predicting deep penetration of DBCP, EDB, and TCP: Pacific Science, 43, pp. 362-383.

Macdonald, Gordon A., Abbott, Agatin T., and Peterson Frank L., 1970, Volcanoes in the Sea, The Geology of Hawaii: Honolulu, University of Hawaii Press.

McKnight, J. H. and Juvik, J. O., 1975, Methodological approaches in Hawaiian fog research, Technical Report No. 85, Project Completion Report for fog precipitation along topo-climatic gradients on the Island of Hawaii, OWRT Project No. A-041-HI, Grant Agreement No. 14-31-0001-4011, Project Period: July 1, 1972 to June 30, 1975.

Meyer, W. and Todd, K. P., 2001, The Response of the Iao Aquifer to Groundwater Development, Rainfall, and Land-Use Practices Between 1940 and 1998, Island of Maui, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 00-4223.

Meyers, C.K., Kleinecke, D.C., Todd, D.K., and Ewing, L.E., 1974, Mathematical modeling of fresh water aquifers having salt water bottoms, Tech. Rep. GE74 TEM-43, Center for Advanced Studies, TEMPO, General Electric Co.: Report to Office of Water Resources Research, U.S. Dept. of the Interior.

Miike, Lawrence H., 2004, Water and the Law in Hawaii: Honolulu, University of Hawaii Press.

Mink, J.F., 1980, State of the groundwater resources of Southern Oahu, Honolulu: Board of Water Supply, Honolulu, Hawaii.

Mink, J.F., 1981, Determination of Sustainable Yields in Basal Aquifer, in: Groundwater in Hawaii-A Century of Progress, Book published by the Water Resources Research Center, University of Hawaii at Manoa, pp.101-116.

Mink, J.F., and Lau, L.S., 1990, Aquifer identification and classification for Maui: groundwater protection strategy for Hawaii: Honolulu, Hawaii, University of Hawaii Water Resources Research Center, Technical Report no. 185, 47 p.

Mink, J. F., 1996, Stream flow-well interaction in lower Punaluu Valley. Lack of effect of pumpage at Makalii wells on Punaluu Stream flow: letter and memorandum dated August 12, 1996 to Deputy Director Rae Loui, 3 p.

National Assessment Synthesis Team, 2000, Climate change impacts on the United States: the potential consequences of climate variability and change, US Global Change Research Program, Washington DC, March 23, 2006, available online at http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm.

National Weather Service Forecast Office, Honolulu, HI, nd, Hydrology in Hawaii, Additional Hydrology Resources, Rainfall Summary Gage Location Maps, September 7, 2007, http://www.prh.noaa.gov/hnl/pages/hydrology.php.

Neuman, S.P., and Di Federico, V., 2003, Multifaceted nature of hydrogeologic scaling and its interpretation: Reviews of Geophysics, 41(3), 1014 p.

Nichols, W.D., Shade, P.J., and Hunt, Jr., C.D., 1996, Summary of the Oahu, Hawaii Regional Aquifer-System Analysis, U.S. Geological Survey Professional Paper 1412-A.

Oki, D.S., 1997, Geohydrology and numerical simulation of the ground-water flow system of Molokai, Hawaii: U.S. Geological Survey, Water-Resources Investigations Report 97-4176.

Oki, D. S., 1998, Geohydrology of the Central Oahu, Hawaii, ground-water flow system and numerical simulation of the effects of additional pumpage: U. S. Geological Survey Water-Resources Investigations Report 97-4276, prepared in cooperation with the Honolulu Board of Water Supply, 132 p.

Oki, D.S., 2000, Site selection for a deep monitoring well, Kualapuu, Molokai, Hawaii, U.S. Geological Survey Water Resources Investigation Report 99-4291.

Oki, D. S. and Meyer, W., 2001, Analytical Versus Numerical Estimates of Water Level Declines Caused by Pumping, and a Case Study of the Iao Aquifer, Maui, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 00-4244.

Oki, Delwyn S. and Brasher, Anne M.D., 2003, Environmental Setting and the Effects of Natural and Human-Related Factors on Water Quality and Aquatic Biota, Oahu, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 03-4156, 98 p. Available online at http://pubs.usgs.gov/wri/wri034156.

Oki, D.S., 2004, Trends in streamflow characteristics at long-term gaging stations, Hawaii, U.S. Geological Survey Scientific Investigations Report 2004-5080, 120 p.

Oki, D.S., 2005, Numerical Simulation of the Effects of Low-Permeability Valley-Fill Barriers and Redistribution of Ground-Water Withdrawals in the Pearl Harbor Area, Oahu, Hawaii: U.S .Geological Survey Water-Resources Investigations Report 05-5253.

Oki, D. S., Wolff, R. H., and Perreault, J. A., 2006, Effects of surface-diversion and ground-water withdrawal on streamflow and habitat, Punaluu Stream, Oahu, Hawaii: U.S. Geological Survey Scientific Investigations Report 2006-5153, prepared in cooperation with the Honolulu Board of Water Supply, 104 p.

Orr, Shlomo, and Lau, L.S., 1987, Trace organic (DBCP) transport simulation of Pearl Harbor aquifer, Oahu, Hawaii—Multiple mixing-cell model, Phase I: Honolulu, University of Hawaii Water Resources Research Center Technical Report No. 174, 60 p.

Pukui, Mary Kawena and Samuel H. Elbert, 1986, Hawaiian Dictionary: Hawaiian-English, English-Hawaiian: Honolulu, University of Hawaii Press.

Rantz, S. E. and others, 1982, Measurement and computation of streamflow: volume 1. measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, 284 p.

Riggs, H.C., 1972, Chapter B1, Low-Flow Investigations, Book 4, Hydrologic Analysis and Interpretation, Techniques of Water Resources Investigations of the U.S. Geological Survey, Available online at http://pubs.usgs.gov/twri/twri4b1/pdf/twri_4-B1_a.pdf.

Sato, H. et al., 1973, Soil Survey of the Island of Hawaii, State of Hawaii: United States Department of Agriculture, Soil Conservation Service, U.S. Government Printing Office, Washington, D.C. 115 pp., 195 map sheets.

Scholl, M., T. W. Giambelluca, S. B. Gingerich, M. A. Nullett, and L. L. Loope (2007), Cloud water in windward and leeward mountain forests: The stable isotope signature of orographic cloud water, Water Resour. Res., doi:10.1029/2007WR006011, in press. http://www.agu.org/journals/pip/wr/ 2007WR006011-pip.pdf" (accepted 31 August 2007).

Scholl, M.A., Gingerich, S.B., and Tribble, G.W., 2002, The influence of microclimates and fog on stable isotope signatures used in interpretation of regional hydrology: East Maui, Hawaii: Journal of Hydrology, v. 264, p. 170-184.

Searcy, J.K., 1959, Flow-duration curves: U.S. Geological Survey Water-Supply Paper 1542-A, 33p.

Shade, P.J., 1997, Water budget for the Island of Molokai, State of Hawaii, Department of Hawaiian Home Lands: U.S. Geological Survey Water-Resources Investigations report: 97-4155.

Shade, P.J., 1997, Water Budget for the Iao area, Island of Maui, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 97-4244.

Shade, P.J., and Nichols, W.D., 1997, Water Budget and the Effects of Land-Use Changes on Ground-Water Recharge, Oahu, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 97-4244.

Snelder, Ton, , NIWA and Keys, Richard, Guidance Notes for Planning for Water Allocation prepared in August 2003 by Ton a partnership between the New Zealand Planning Institute, the Resource Management Law Association, Local Government New Zealand, the NZ Institute of Surveyors and the Ministry for the Environment. http://www.qualityplanning.org.nz/plan-topics/water-allocation.php.

Sophocleous, M., Koussis, A., Martin, J. L., and Perkins, S. P., 1995, Evaluation of simplified stream-aquifer depletion models for water rights administration: Ground Water, vol. 33, pp. 579-588.

Souza, W.R., and Voss, C.I., 1987, Analysis of an anisotropic coastal aquifer system using variable-density flow and transport simulation, Journal of Hydrology, 92, pp. 17-41.

Souza, W.R., and Meyer, William, 1995, Numerical simulation of regional changes in ground-water levels and in the freshwater-saltwater interface induced by increased pumpage at Barbers Point shaft, Oahu, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 95-4206, 47 p.

State of Hawaii, Department of Business, Economic Development and Tourism's Office of Planning–Coastal Zone Management and Department of Health's Clean Water Branch Polluted Runoff Control Program, 2000, Hawaii's Implementation Plan for Polluted Runoff Control.

State of Hawaii Department of Land and Natural Resources, Commission on Water Resource Management, 1990, Hawaii Water Plan, Water Resources Protection Plan: Honolulu, Hawaii.

State of Hawaii Department of Land and Natural Resources, Commission on Water Resource Management, 2000, Statewide Framework for Updating the Hawaii Water Plan: Honolulu, Hawaii. Available online at:

http://www.hawaii.gov/dlnr/cwrm/planning/plans/framewrk.pdf.

State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, 2003, Drought Risk and Vulnerability Assessment: Honolulu, Hawaii.

State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, 2004, Hawaii Water Reuse Survey and Report: Honolulu, Hawaii.

State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, 2005, Hawaii Drought Plan 2005 Update, Prepared by Wilson Okamoto Corporation.

State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, May 2007, Conservation Manual for State of Hawaii Facilities: Honolulu, Hawaii.

State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management, Prototype Water Conservation Plan for the Department of Land and Natural Resources and the Water Conservation Manual for State of Hawaii Facilities, http://www.hawaii.gov/dlnr/cwrm/planning/conserve.htm.

Stearns, H.T. and Macdonald, G.A., 1942, Geology and groundwater resources of the island of Maui, Hawaii: Hawaii Division of Hydrography Bulletin 7, 344 p.

Taylor, Charles J. and Alley, William M., Ground-water-level monitoring and the importance of long-term water-level data: U.S. Geological Survey Circular 1217, 68 p.

Takasaki, K. J., Hirashima, G. T., and Lubke, E. R., 1969, Water resources of windward Oahu, Hawaii: U. S. Geological Survey Water-Supply Paper 1894, prepared in cooperation with State of Hawaii, Department of Land and Natural Resource, 119 p.

Takasaki, K. J. and Mink, J. F., 1982, Water resources of southeastern Oahu, Hawaii: U. S. Geological WRI 82-628, prepared in cooperation with the Honolulu Board of Water Supply, City and County of Honolulu, 89 p.

Takasaki, K. J. and Mink, J. F., 1985, Evaluation of major dike-impounded ground-water reservoirs, Island of Oahu: U. S. Geological Survey Water-Supply Paper 2217, prepared in cooperation with the Honolulu Board of Water Supply, City and County of Honolulu, 77 p.

Taylor, Charles J. and Alley, William M., 2001, Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data: U.S. Geological Survey Circular 1217, Internet, available online at http://pubs.usgs.gov/circ/circ1217/html/pdf.html.

The National Academies, 2005, Understanding and responding to climate change, highlights of National Academies Report: The National Academy of Sciences, 20 p.

Todd, D.K., 1980, Groundwater Hydrology: New York, John Wiley & Sons.

Todd Engineers, 2005, Development of a Groundwater Management Model, Honolulu Area of the Southern Oahu Groundwater System, Prepared for the City and County of Honolulu Board of Water Supply, Honolulu, Hawaii.

U.S. Army Corps of Engineers, 2007, Regulatory Branch. Internet, available at: http://www.poh.usace.army.mil/EC-R/EC-R.htm.

U.S. Bureau of Reclamation, July 2005, Hawaii Stormwater Reclamation Appraisal Report: prepared in cooperation with the State of Hawaii, Department of Land and Natural Resources, Commission on Water Resource Management and CH2M Hill.

U. S. Environmental Protection Agency, 1996, Watershed Approach Framework, EPA 840-S-96-001, Office of Water (4501T), U.S. EPA, Washington, DC. Available online at: http://www.epa.gov/owow/watershed/framework.html.

U.S. Environmental Protection Agency, Office of Policy, 1998, Climate change and Hawaii, EPA 236-F98-007e: United States Environmental Protection Agency, 4 p.

U. S. Environmental Protection Agency, 2002, A Review of Statewide Watershed Management Approaches. Internet, available at: http://www.epa.gov/owow/watershed/approaches_fr.pdf.

U. S. Environmental Protection Agency, 2006, Overview of the National Water Program. Internet, available at: http://www.epa.gov/water/programs/owintro.html.

U. S. Environmental Protection Agency, 2007, What is a Watershed? Internet, available at: http://www.epa.gov/owow/watershed/whatis.html.

U.S. Geological Survey Water Science Glossary of Terms, June 22, 2007, http://ga.water.usgs.gov/edu/dictionary.html.

Visher, F. N. and Mink, J. F., 1964, Ground-water resources in Southern Oahu, Hawaii: U. S. Geological Survey Water-Supply Paper 1778: Prepared in cooperation with the Division of Land and Water Development, Department of Land and Natural Resources, State of Hawaii, 133 p.

Voss, C.J., 1984, A finite-element Simulation Model for Saturated-unsaturated, Fluid-density-dependent Groundwater Flow and Transport Flow with Energy Transport or Chemically Reactive Single-species Solute Transport: U.S. Geological Survey Water-Resources Investigations Report 84-4369.

Wahl, K.L., and Wahl, T.L., 1995, Determining the flow of Comal Springs at New Braunfels, Texas: Proceedings of Texas Water '95, A Component Conference of the First International Conference on Water Resources Engineering, American Society of Civil Engineers, August 16-17, 1995, San Antonio, Tex., 77-86.

WASY, 2005, FEFLOW Finite Element Subsurface Flow and Transport Simulation, System, Version 5.0, Institute for Water Resources Planning and System Research LTD, Berlin, Germany.

Wentworth, C.K., 1938, Geology and ground water resources of the Palolo-Waialae District, Honolulu, Hawaii: Honolulu Board of Water Supply.

Whittier, R.B., K. Rotzoll, S. Dhal, A.I. El-Kadi, C. Ray, G. Chen, and D. Chang, 2006, Hawaii Source Water Assessment Program Report, Volume I, Approach Used For the Hawaii Source Water Assessments: Hawaii Department of Health, State of Hawaii, Honolulu, Hawaii.

Williams, Julie Stewart, From the Mountains to the Sea: Early Hawaiian Life, Honolulu: Kamehameha Schools Press, 1997.

Wilson Okamoto Corporation, 2004, Kaneohe-Kahaluu Stream Restoration and Maintenance, A Community Guidebook, City and County of Honolulu Department of Design and Construction, State of Hawaii, Honolulu, Hawaii.

Yeung, C.W., and Fontaine, R.A., 2007, Natural and diverted low-flow duration discharges for streams affected by the Waiahole Ditch System, windward O'ahu, Hawai'i: U.S. Geological Survey Scientific Investigations Report 2006-5285. Available online at http://pubs.usgs.gov/sir/2006/5285/.

Ziegler, Alan C., 2002, Hawaiian Natural History, Ecology, and Evolution: Honolulu, University of Hawaii Press.

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Appendix A

Planning Context for the WRPP

APPENDIX A

WRPP SUPPLEMENTAL INFORMATION
PLANNING CONTEXT

Water resource issues in Hawaii are constantly evolving, as they are increasingly subject to socio-cultural, economic, and political developments. Water resource management and the planning process must, therefore, be flexible and adaptable to changing parameters. The purpose of this appendix is to provide the reader with an informed examination of the legislative requirements and administrative influences that have contributed to the planning context for the current update to the WRPP. The following sections are intended to provide a historical review of the development of current water planning infrastructure and to demonstrate how legislation and regulation have contributed to contemporary water planning.

Background information is presented in two parts:

- **Legislative Context**. This section provides a chronological account of the development and scope of major legislation related to water resource planning in Hawaii. Such legislation has constructed legal constraints and obligations for specific government agencies. The intent and objectives of legislative actions are discussed, as well as the atmosphere in which such legislation was conceived.

- **Administrative Context**. This section provides a summary of statewide water planning efforts that preceded the WRPP, and indicates how past planning efforts have ultimately impacted and encouraged the development of this document.

An understanding of related events and themes will give the reader a more comprehensive perspective on the WRPP. The sections below provide ancillary information to supplement chapters one and two of the WRPP.

1.1. Legislative Context: A Historical Perspective of Water Regulation in Hawaii

1.1.1. Territorial Legislation and Early State Water Laws

Historically, governmental regulation of water development and use throughout the state was largely confined to Oahu, mainly the Honolulu area, due to the rapid urbanization and industrialization of the island, the expansion of sugar and pineapple cultivation, the establishment of military activities and facilities, and the emergence of Honolulu as a transportation hub in the Pacific. During the early years of the territorial government, uncontrolled development and use of ground water resources gave rise to public concern over the steadily declining flow from artesian wells in Honolulu. In 1925, the Territorial Legislature created the Honolulu Sewer and Water Commission. This commission's responsibility included the investigation of water resources on Oahu.

Public outcry for better management and operation of water systems continued until 1929, when the legislature created the Honolulu BWS. The Honolulu BWS was provided with complete responsibility for management, operation, and regulation of water works and artesian water development in Honolulu. In 1959, the Honolulu Board of Supervisors transferred the Suburban Water System to the Board of Water Supply. With this transfer, all water functions for the island were finally vested in the semi-autonomous Honolulu BWS. Water resources management for the remainder of the Territory was the responsibility of the Territorial Division of Hydrography.

The Hawaii Irrigation Authority was created by the Territorial Legislature in 1953 to construct and operate small irrigation systems throughout the islands. The Hawaii Water Authority replaced the Hawaii Irrigation Authority in 1959 and was made responsible for the collection and correlation of all water resource data in the Territory. Following statehood in 1959, water resource management became a function of the DLNR. The DLNR's Division of Water and Land Development, now the Engineering Division, became responsible for carrying out the Water Development Program. "Under this program, the division investigates and develops traditional and alternative water sources to meet increasing demands of urban development, agriculture and other uses. Finite water resources and limited funding effects a closer look at alternative water sources. This program also promotes partnerships and cost sharing in the development of water projects to meet the goals of otherwise competing entities."[1]

Under the leadership of the Honolulu BWS, water resource management on Oahu appeared to be under control. However, by the late 1970s, increasing public apprehension over the condition of the state's water resources prompted the State to review the situation on Oahu. At the time, Chapters 177 and 178 HRS 1975 governed ground water resources. Chapter 177 was the Groundwater Use Act, which provided for the regulation of ground water resources in designated areas. Chapter 178 was the Artesian Well Law, which provided for the control of waste, notification of intent to drill, and transfer of a flowing artesian well from an individual to the county. Chapter 176 was the Water Resources Act, which provided the responsibilities and duties of the board of land and natural resources with regard to the compilation, inventorying, studying, and publication of statewide water resource information. Chapter 176D HRS, entitled Protection of Instream Uses of Water, directed the board of land and natural resources to establish and administer an instream use protection program to protect and enhance, where practicable, beneficial instream uses of water.

In 1977, a State Water Commission was appointed by the Governor to assess the state's water resources following a prolonged drought, during which Oahu's ground water levels fell to record lows and hardship befell farmers and ranchers on other islands. In its report, submitted in early 1979, this commission made a number of recommendations, including the following:

1. Regulate the Pearl Harbor ground water resources through Chapter 177;
2. Establish a permit system for water development and use; and
3. Formulate a State Water Code.

[1] Report to the Governor 1992-93, DLNR, State of Hawaii.

In accordance with the Groundwater Use Act, the first designation of a water control area was made in 1979 when the Board of Land and Natural Resources designated the Ewa-Pearl Harbor and Wahiawa Districts.

Meanwhile, the State was taking steps to address water resources through a comprehensive, statewide approach. In 1978, the State of Hawaii Constitutional Convention identified the State's "obligation to protect, control and regulate the use of Hawaii's water resources for the benefit of its people." Under Article XI, Section 7, of the State Constitution:

> "The legislature shall provide for a water resources agency which, as provided by law, shall set overall water conservation, quality and use policies; define beneficial and reasonable uses; protect ground and surface water resources, watersheds and natural stream environments; establish criteria for water use priorities while assuring appurtenant rights and existing correlative and riparian uses and establish procedures for regulating all uses of Hawaii's water resources."

Thus, the initiative for the Commission on Water Resource Management emerged from the Constitutional Convention of 1978. However, CWRM was not established until 1987, when the Legislature enacted the State Water Code, Chapter 174C HRS. HRS Chapters 177 and 178, Groundwater Use Act and the Artesian Well Law, respectively, were repealed and superseded by the State Water Code. HRS Chapter 176 Water Resources and Chapter 176D Protection of Instream Uses of Water were also repealed and replaced by the State Water Code.

1.1.2. CWRM Administration

The State Water Code provides the legal basis for the establishment of CWRM and delineates the agency's authority and responsibilities. CWRM's primary responsibility is to administer the State Water Code. CWRM's general mission is to protect and enhance the water resources of the State of Hawaii through wise and responsible management. As specified in the HRS §174C-2, the State Water Code "shall be liberally interpreted to obtain maximum beneficial use of the waters of the State for purposes declared to be in the public interest, such as domestic uses, aquaculture uses, irrigation and other agricultural uses, power development, and commercial and industrial uses." The State Water Code also specifies that, "adequate provision shall be made for the protection of traditional and customary Hawaiian rights, the protection and procreation of fish and wildlife, the maintenance of proper ecological balance and scenic beauty, and the preservation and enhancement of waters of the State for municipal uses, public recreation, public water supply, agriculture, and navigation."

In conjunction with the State Water Code, CWRM also needed to enact new administrative rules within a two-year time period, as required by HRS §174C-8. Accordingly, chapters 13-167 to 13-171 of the Hawaii Administrative Rules were adopted in 1988 to state and clarify definitions, rules, procedures, and provisions required by, but not specified in the State Water Code. CWRM operates under these rules through periodic updating and public participation based on the experience of implementing the State Water Code.

Several major amendments to the State Water Code occurred over the next 16 years as CWRM's experience broadened and more hydrologic information became available. Significant amendments to HRS §174C and the associated HAR are listed below:

Amendments to the State Water Code, HRS §174C**:**

- **Act 101 (AWUDP, 174C-31(e)):** The 1998 Legislature added the AWUDP as a fifth component to the HWP to ensure that the plantation irrigation systems affected by plantation closures would be rehabilitated and maintained for future agricultural use. The major objective of the AWUDP is to develop a long-range management plan that assesses state and private agricultural water use, supply and irrigation water systems.

- **Water resource management fund (174C-5.5):** This section was added to the State Water Code to provide a consistent source of funding to allow CWRM to implement monitoring, management, resource protection programs/activities, and enforcement necessary to sustain the State's resources. The funds would also allow the development and regular updating of the HWP using state-of-the art methods such as integrated resource planning.

- **Dual line systems (174C-51.5):** This measure was added to the State Water Code in 2000 to allow CWRM to require the use of dual line water supply systems in new industrial and commercial developments in designated water management areas. This new section helps to further CWRM's policy favoring the use of alternate water sources, such as reclaimed water, as a measure to conserve higher quality water for higher uses.

- **Administrative violation system (174C-15.5):** The 2004 Legislature added this section to allow CWRM to use the DLNR's civil natural resource violations system with the mutual consent of both CWRM and DLNR. Also in 2004, the Legislature increased the maximum fine under 174C-15(b) HRS from $1,000 to $5,000.

Amendments to the associated HAR:

- HAR Chapter 13-169 was amended in 1988 and 1989 to establish interim instream flow standards for perennial streams statewide.

- HAR Chapter 13-171 was amended in 1993 and 1994 to effectuate the following: (1) authorize CWRM to adopt specific water reservations in water management areas as necessary for purposes consistent with public interests, including current and foreseeable development and use of Hawaiian Home Lands; (2) delineate the procedure by which water reservations would be established; and (3) establish water reservations for Hawaiian Home Lands in Honolulu, Leeward and Windward Oahu, and in Kualapuu, Molokai.

- HAR Chapter 13-168 was amended in 1997 and 2004 to establish and revise the State standards for well construction and pump installation.

The State Water Code and the administrative rules represent the culmination of intense efforts by the Legislature, State and county agencies, community and professional organizations, and various private interests. The State Water Code contains the collective input of many entities and attempts to address various competing interests.

In addition to the State Water Code, other laws may contribute to water resource management and related issues. The Legislature, during the 2007 session, passed Senate Bill 1853 toward the creation of an Aha Moku Council System. The Aha Moku Council System will enable another means for CWRM and other agencies to gain public input and feedback on water resource management issues.

Act 212, Session Laws of Hawaii, enacted on July 1, 2007, created a framework for the establishment of an Aha Moku council. The purpose of Act 212 is “to initiate the process to create a system of best practices that is based upon the indigenous resource management practices of moku (regional) boundaries, which acknowledges the natural contours of land, the specific resources located within those areas, and the methodology necessary to sustain resources and the community. Pursuant to the Act, the Aha Kiole Advisory Committee members were appointed on November 1, 2007. According to the Report to the Twenty-Fourth Legislature, 2008 Regular Session, Interim Report, Aha Kiole Advisory Committee, dated December 28, 2007, the Aha Kiole Advisory Committee determined a schedule of meetings and events to be held in each moku during 2008. The purpose of these meetings is to engage in discussion with the community to develop consensus on establishing an Aha Moku Council System and Aha Moku Council Commission. It is anticipated that the future Aha Moku Councils will provide government agencies and other organizations with input on regional natural resource management methods and practices.

1.1.3. State Water Code Implementation and the Hawaii Water Plan

CWRM implements and utilizes comprehensive water resource planning to regulate and manage the State's ground and surface water resources. The State Water Code sets forth the requirements for the development of the HWP, described in Section 1.1 of the WRPP, to guide CWRM in executing its general powers, duties, and responsibilities to assure economic development, good municipal water service, agricultural stability, and environmental protection.

The State Water Code imposed a December 31, 1989 deadline for adoption of the HWP. The responsible State and county agencies were able to publish the HWP components in 1990; however, the deadline did not allow for the construction of a truly comprehensive plan. As reflected in the recommendations of the 1990 plan components, more information and additional study would be required to achieve a document that addresses the full extent of the State Water Code requirements.

As agencies struggled to execute an earlier effort to update the HWP in 1992, a consensus arose among State and county agencies that a comprehensive water resource planning process was needed to address the problems of supply, demand, and conservation of water. Accordingly, CWRM developed a framework document to guide the updating process.

1.1.4. Adoption of the Statewide Framework for Updating the Hawaii Water Plan

CWRM adopted the Statewide Framework for Updating the Hawaii Water Plan in 2000, under the authority of HRS 174C-31 which provides that CWRM may add to the HWP any other information, directions, or objectives it feels necessary or desirable for the guidance of the counties in the administration and enforcement of code provisions. As such, the Framework is intended to provide focus and additional "guidance" to each agency responsible for updating specific components of the plan. The Framework should be viewed as a long-term vision to preparation of a "living document" which over several plan iterations will result in a truly comprehensive water resource plan.

The Framework incorporates techniques to address current complexities associated with planning, regulation, and management of water resources. The integrated resource planning (IRP) approach described in the Framework was used to identify nexuses between HWP components and develop strategies to manage these relationships.

The objectives of the Framework are as follows:

- To achieve integration of land use and water planning efforts that are undertaken by federal, State, county, and private entities so that a consistent and coordinated plan for the protection, conservation and management of our water resources is achieved;
- To recommend guidelines for the HWP update so that the plan and its component parts are useful to CWRM, other State agencies, the counties, and the general public;
- To develop a dynamic planning process that results in a "living document" for each component of the HWP, which will provide county and State decision-makers with well-formulated options and strategies for addressing future water resource management and development issues;
- To better define roles and responsibilities of all State and county agencies with respect to the development and updating of the HWP components;
- To describe and outline the techniques and methodologies of integrated resource planning as the basic approach that should be utilized in developing and updating the County WUDPs;
- To facilitate permitting and to identify potential critical resource areas where increased monitoring or baseline data gathering should proceed;
- To establish an overall schedule for phased updating of the HWP; and
- To outline an implementation plan for near-term and long-term actions.

The framework document is organized into four sections. Section I briefly outlines the objectives of establishing a statewide framework for updating the HWP and its various component plans. Section II discusses the overall framework for the HWP, including the IRP approach, elements of the IRP process, relationships between HWP components, and the importance of implementing management strategies at the county level. Section III describes the roles and responsibilities of those agencies charged with preparing/updating the various components of the HWP. This section also identifies the minimum requirements of each component plan and the recommended elements that should be included within an IRP approach. Lastly, Section IV outlines a schedule and preliminary implementation plan for the phased updating of the HWP components.

1.2. Administrative Context: A Historical Perspective of Water Resource Planning in Hawaii

In light of the legislative context described earlier in Section 1.1, it should be emphasized that the State Water Code is a relatively young chapter of the HRS that seeks to address an ambitious spectrum of water management issues and resource protection goals. Of the HWP components, the WQP and the WRPP are critical to balancing use and resource protection. The development of the WRPP is itself an evolving process. Despite the ways popular issues can shift from year to year, and public perception can be persuaded by politics and other influences, the challenge remains to sustain flexibility in the document and encourage a planning process that acknowledges and embraces issues, as they arise without compromising the intent of the State Water Code. This section describes the previous efforts toward statewide water resource planning that have contributed to the overall planning context surrounding the current WRPP update.

1.2.1. The 1979 Hawaii Water Resources Plan

The Hawaii Water Resources Plan, published in 1979, was the product of regional water planning efforts that began in the mid-1960s. During a period in U.S. history when nationwide public awareness of environmental degradation rapidly escalated, the Water Resources Planning Act of 1965 created a national policy to encourage the conservation, development, and utilization of water and related land resources on all levels of government and by private entities. The act established the groundwork for comprehensive studies designed to facilitate water resources planning and created a coordinating agency called the U.S. Water Resources Council. In 1968, the Council designated the State of Hawaii Department of Land and Natural Resources as chair to an *ad hoc* committee of government agencies charged with the preparation of a preliminary plan of study for a regional plan of Hawaii water resources.

The Hawaii Water Resources Plan is conceptually broad and represents the first coordinated multi-agency water planning effort. The plan is noteworthy and timely considering the multiplicity of plans and planning agencies that sprouted nationwide during the 1960s and 1970s in reaction to increasing environmental pollution. "The need to coordinate water planning, management, protection, and use at all levels of government has become increasingly apparent," notes the plan's introduction.

In 1973, the *ad hoc* Hawaii Water Resources Coordinating Committee's study was funded with $580,000 appropriated by the Hawaii State Legislature and $200,000 authorized by Congress. The Hawaii Water Resources Regional Study was supported by a total budget of $1.78 million over a period of three and one-half years. A review draft of the Hawaii Water Resources Plan was published in 1977, followed by publication of the final document in 1979.

Nearly 50 agencies from all levels of government, numerous private entities, and the interested public participated in the planning process, which, according to the plan's executive summary, contributed to a "comprehensive plan of action to achieve the balanced conservation, development, and use of Hawaii's water resources and related land resources." The planning period encompassed the decade from 1990 to 2000, and the study was designed to suggest solutions to long-range problems and needs on a coordinated basis by federal, State and county governments and the private sector.

The overall goal of the Hawaii Water Resources Regional Study was to promote and enhance the quality of life, despite a growing population within a limited land area with limited resources. The study sought to address these issues by:

- Identifying the water and related land resource problems and needs;
- Reflecting public attitudes and preferences in the measures or alternatives proposed to satisfy those problems and needs; and
- Suggesting a schedule to implement recommended actions.

The study was organized to cover 15 subjects, or elements, and a study team was assigned to each planning subject. The planning process and results are captured in 19-study element reports and supplements that were prepared for use by the plan-formulation team, the general public, and participating agencies. Preliminary drafts of the Hawaii Water Resources Plan allowed participants to identify major planning concerns and formulate specific water resource planning objectives. Management alternatives were identified with respect to planning objectives, and these alternatives were subsequently assembled into three plans: the economic development plan; the environmental quality plan; and the balanced plan, which included compatible actions that contributed significantly to both economic and environmental objectives. The relative social, economic, environmental, and regional development impacts were evaluated, and conflicts were resolved to the extent practicable to arrive at a comprehensive list of recommendations and specific actions.

The plan concludes with an implementation schedule, cost estimates, and a suggested institutional arrangement for implementing, revising, and updating the plan. Priority recommendations are highlighted, as well as cost-sharing opportunities.

Many of the Hawaii Water Resources Plan's priority recommendations and specific actions regarding water management legislation have been gradually implemented through the emergence of the initiative for the Water Commission through the Hawaii Constitutional Convention of 1978, and through the enactment of the State Water Code and the formal establishment of the Water Commission in 1987. The intents of other plan recommendations are captured within the HWP Framework and amendments to the Water

Code and Hawaii Administrative Rules. Still, other recommendations retain their validity and contribute to the objectives of the WRPP.

1.2.2. The 1990 Hawaii Water Plan and Water Resource Protection Plan

The objectives of the HWP and CWRM's responsibilities in preparing the HWP and the WRPP, as set forth in the State Water Code, are listed below.

Objectives of the HWP:

The Hawaii water plan shall be directed toward the achievement of the following objectives:

(1) The attainment of maximum reasonable-beneficial use of water for such purposes as those referred to in subsection (a);
(2) The proper conservation and development of the waters of the State;
(3) The control of the waters of the State for such public purposes as navigation, drainage, sanitation, and flood control;
(4) The attainment of adequate water quality as expressed in the water resource protection and water quality plans; and
(5) *The implementation of the water resources policies expressed in section 174C-2.* (§174C-31(g))

CWRM Responsibilities in the Preparation of the HWP:

The Hawaii water plan shall divide each county into sections which shall each conform as nearly as practicable to a hydrologic unit. The commission shall describe and inventory:

(1) All water resources and systems in each hydrologic unit;
(2) All presently exercised uses;
(3) The quantity of water not presently used within that hydrologic unit; and
(4) Potential threats to water resources, both current and future. (§174C-31(h))

Within each hydrologic unit the commission shall establish the following:

(1) An instream use and protection program for the surface watercourses in the area; and
(2) Sustainable yield. The sustainable yield shall be determined by the commission using the best information available and shall be reviewed periodically. Where appropriate the sustainable yield may be determined to reflect seasonal variation. (§174C-31(i))

The commission may add to the Hawaii water plan any other information, directions, or objectives it feels necessary or desirable for the guidance of the counties in the administration and enforcement of this chapter. (§174C-31(n))

> *In formulating or revising the plans, each county and the commission shall consult with and carefully evaluate the recommendations of concerned federal, state, and county agencies.* (§174C-31(o))
>
> *The commission shall not adopt, approve, or modify any portion of the Hawaii water plan which affects a county or any portion thereof without first holding a public hearing on the matter on the island on which the water resources are located. At least 90 days in advance of such hearing, the commission shall notify the affected county and shall give notice of such hearing by publication within the affected region and statewide.* (§174C-31(p))
>
> *In formulating or revising each county's water use and development plan, the state water projects plan, the water resource protection plan and the water quality plan, each county and the commission shall incorporate the current and foreseeable development and use needs of the department of Hawaiian home lands for water as provided in section 221 of the Hawaii Homes Commission Act.* (§174C-31(q))
>
> *Respective portions of the water resource protection and water quality plans, and the water use and development plans of each county, shall be developed together to achieve maximum coordination.* (§174C-32)
>
> *The development of the Hawaii water plan or any portion thereof shall proceed in coordination with and with attention to the Hawaii state plan described in chapter 226.* (§174C-32)
>
> *The Hawaii water plan and its constituent parts, except for the water quality plan, shall be adopted by the commission not later than three years from July 1, 1987. The commission shall receive the water quality plan from the department of health and incorporate this part in the Hawaii water plan.* (§174C-32)

The initial HWP, including the WRPP, was prepared by various State and county agencies and formally adopted by CWRM in 1990. The preparation of the 1990 WRPP was an enormous undertaking, since the plan sought to address all ground water and surface water resource issues in the State.

In order to complete the HWP by the December 31, 1989 deadline imposed by the State Water Code, CWRM had to rely on incomplete information and estimates. The Legislature likely realized the uncertainty of the data, as evidenced by the discussion of the crucial item of sustainable yields; the law provides that the "sustainable yield shall be determined by the Water Commission using the best information available and shall be reviewed periodically." The Legislature wisely provided the means for CWRM to further develop, review, adjust, and fine-tune sustainable yields based on experience and availability of additional information and findings.

CWRM adoption of the 1992 update to the WRPP was deferred pending further refinement of plan components. While it may be argued that the current WRPP and other HWP components fall short of their intended objectives, sufficient provisions established in the 1990 plan, together with policies subsequently adopted by CWRM, provide for appreciable guidance to the CWRM in carrying out its duties and responsibilities. However, this is not to say that the current plan should not be updated or that specific elements do not require further revision and/or modification.

Specific plan recommendations that emanated from the initial preparation of the HWP clearly identified the need for further studies, assessments, and follow-on actions that should be undertaken by each responsible agency. This inherent need to improve upon the existing plans formed the basis for the HWP Framework, adopted by CWRM in 2000. In the interim, the existing HWP and WRPP comprised the first steps toward “comprehensive water resource planning.” More importantly, the 1990 WRPP remains a valid planning and resource-management tool until more recent updates can be adopted.

1.2.3. Integration of the Water Resource Protection Plan with other Hawaii Water Plan Components

Because different State and county agencies prepare the separate components of the HWP, it is critical that the components are interrelated in order for the overall result to be cohesive. The relationships between the various component plans are described below.

The WQP and the WRPP are the two plan components that are critical to determining both water usage and water development strategies. These two plans outline the regulations, standards, and resource management policies that define the availability of ground and surface water resources and the quality to be maintained in these resources. In addition, the quantity of ground and surface water resources that can be withdrawn on a sustainable basis is determined as part of the WRPP. The WQP and WRPP therefore provide critical inputs to the SWPP, the AWUDP, and the County WUDPs developed by the four counties. The SWPP, AWUDP, and County WUDPs must be consistent with the 1990 WRPP and WQP until subsequent updates are developed.

The relationships between the plans prepared by the State and the WUDPs prepared by the four counties are best understood by noting that the County WUDP must, by statute, encompass *all* water usage and planned water development plans projected throughout the county. Since the various state agencies ultimately build their projects within one of the four counties, their water use demands and their proposals for developing various resources to meet those demands must be factored into the overall water demands and development strategies of each of the counties. This relationship is depicted in Section 1, Figure 1-2 as input from the state level to the county level. In practice, the relationship should be more in the nature of a cooperative dialogue and joint planning effort, if a cohesive HWP is to be achieved.

The Framework principally guides the updating of the various County WUDPs. As part of each county’s WUDP update, a county-specific project description shall be prepared by each county and submitted to CWRM. The County WUDP project description should present specific issues, planning activities, a schedule, and objectives to be met by the county in its update of the plan. Integration of the State-level planning effort will be achieved by bringing the results of the State planning into the county planning process.

In addition to the coordination of Hawaii Water Plan Components described in the Framework, inter-agency collaboration on water-related planning is promoted through other agency programs. The Department of Land and Natural Resources participates in the policy and working groups established in the CZM's Ocean Resource Management Plan (ORMP). The ORMP is an integrated, place-based approach to management of ocean resources based on land-sea links, the role of human activities, and improved collaboration in governance. Since the ORMP is a living document to be updated every five years, there is great flexibility to coordinate appropriate aspects of the Water Resource Protection Plan and other Hawaii Water Plan components.

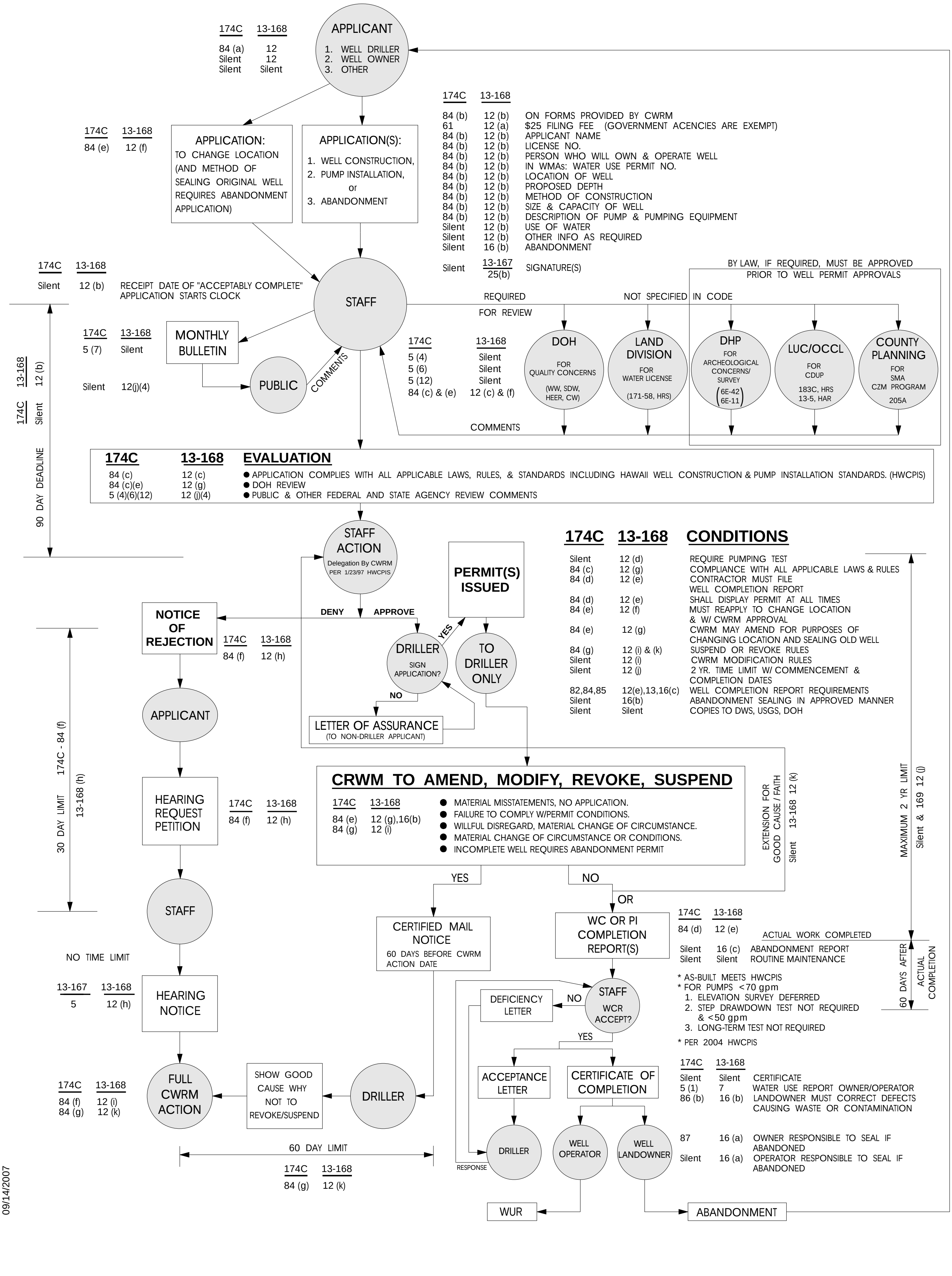
1.3. Conclusion

The collective effect of the legislative and administrative history described above is the emergence of a dynamic planning context for water resource management—one that the current update to the WRPP acknowledges and strives to address to the fullest extent possible.

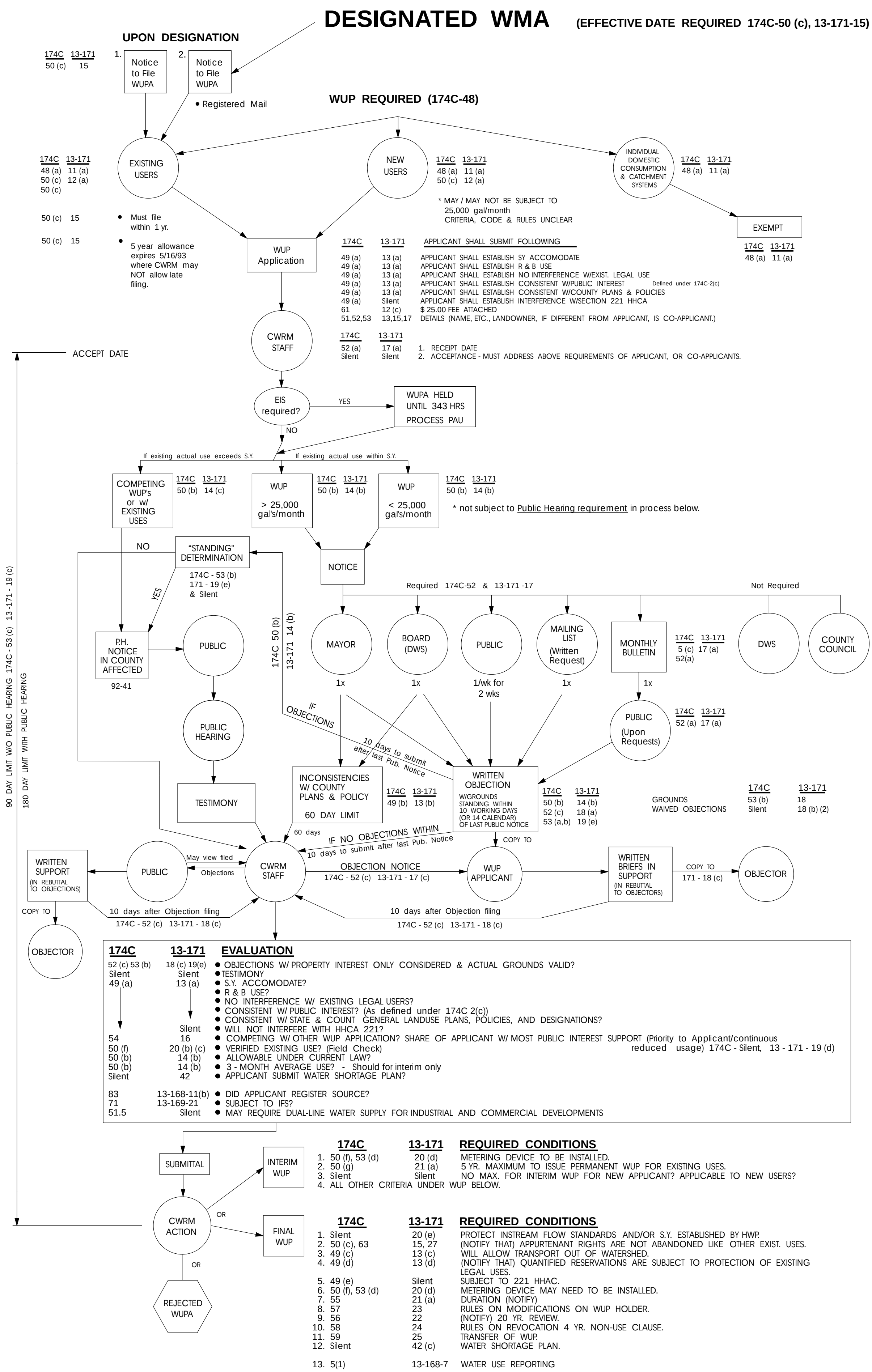
A p p e n d i x B

CWRM Permit Process Diagrams

WELL CONSTRUCTION / PUMP INSTALLATION PERMIT PROCESS



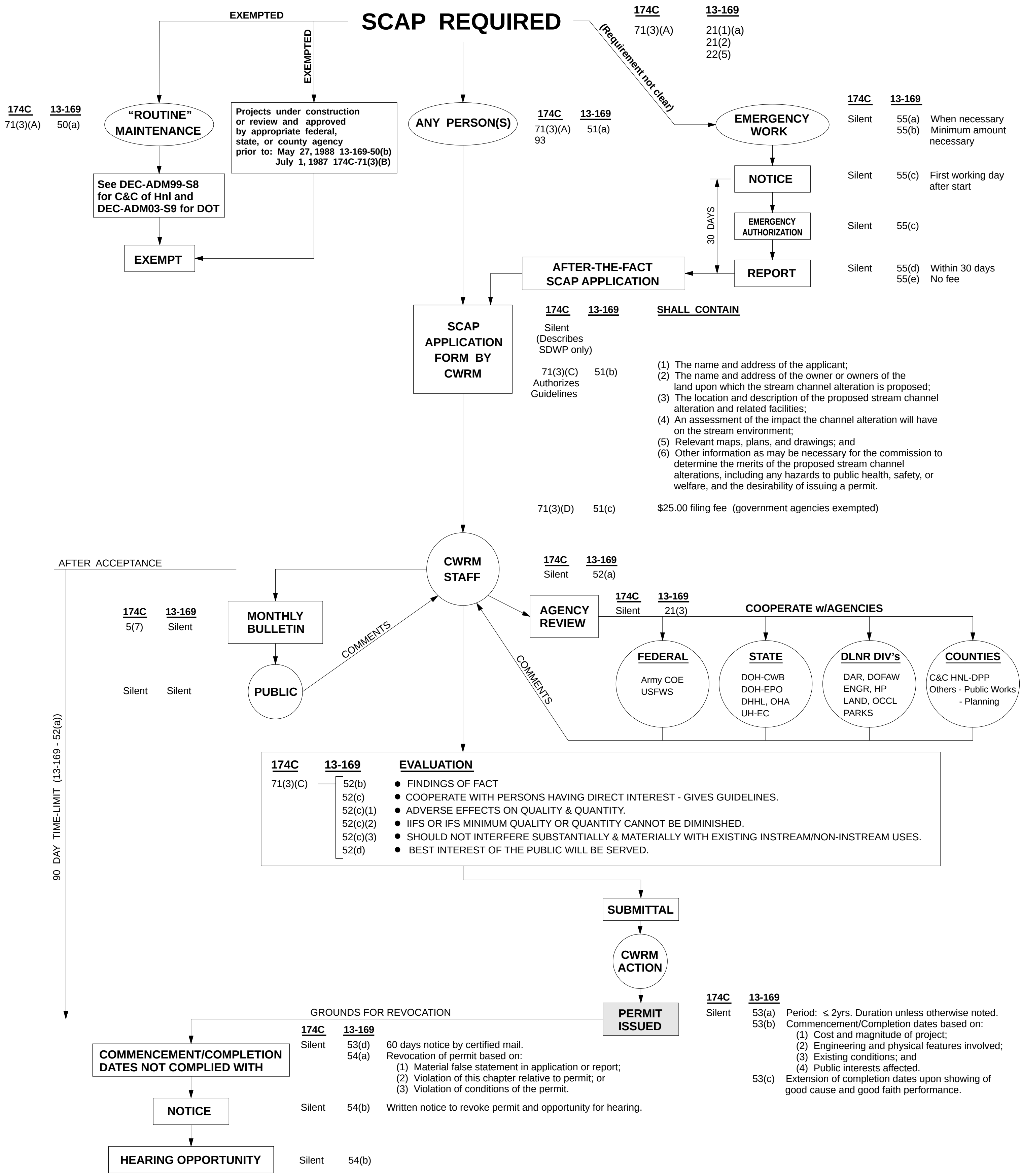
WATER USE PERMIT PROCESS



6/03/2004

SCAP PROCESS 174C-71(3)(C) & 13-169-50

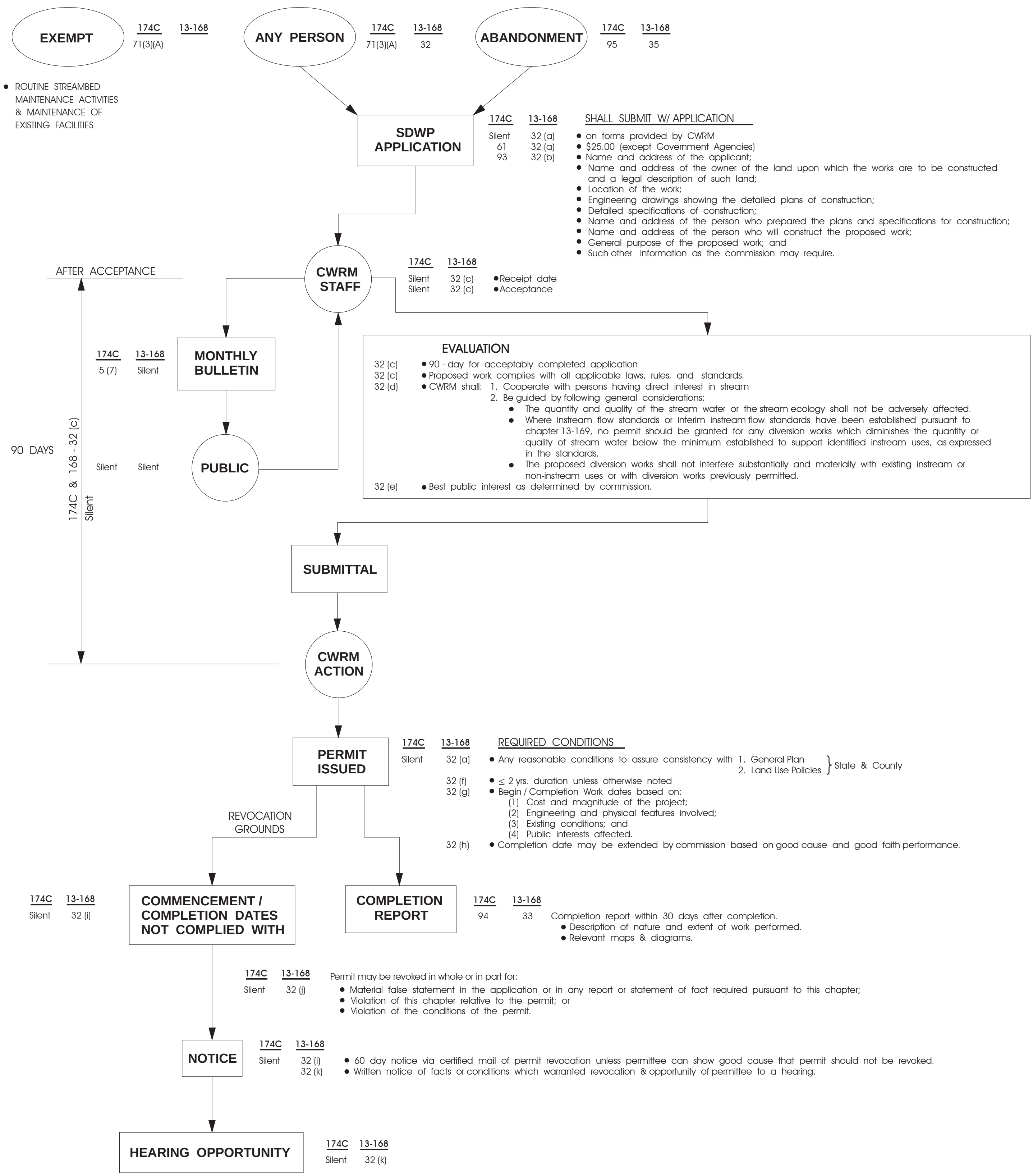
PURPOSE	174C	13-169	
	5(3)&71(3),(4)	1	**Protect, enhance, and reestablish, where practical, beneficial instream uses of water including the creation of a permit system to regulate the alteration of stream channels.**



4/9/2007

STREAM DIVERSION WORKS PERMIT (SDWP) 174C & 13-168

PURPOSE	174C	13-168	
	2(c)	Silent	• Adequate provision for protection and procreation of fish & wildlife, the maintenance of proper ecological balance and scenic beauty (in Public Interest)
	2(c)	1	• Maximum beneficial use



4/9/2007

INSTREAM FLOW STANDARD (IFS) PROCESS (174C-5,71(2) & 13-169-21(1))

PURPOSE	174C 5,71(4)	13-169 1	To provide for the establishment of a statewide program to protect, enhance, and reestablish, where practical, beneficial instream uses of water, including the development for instream flows.

174C 3 **13-169 2**

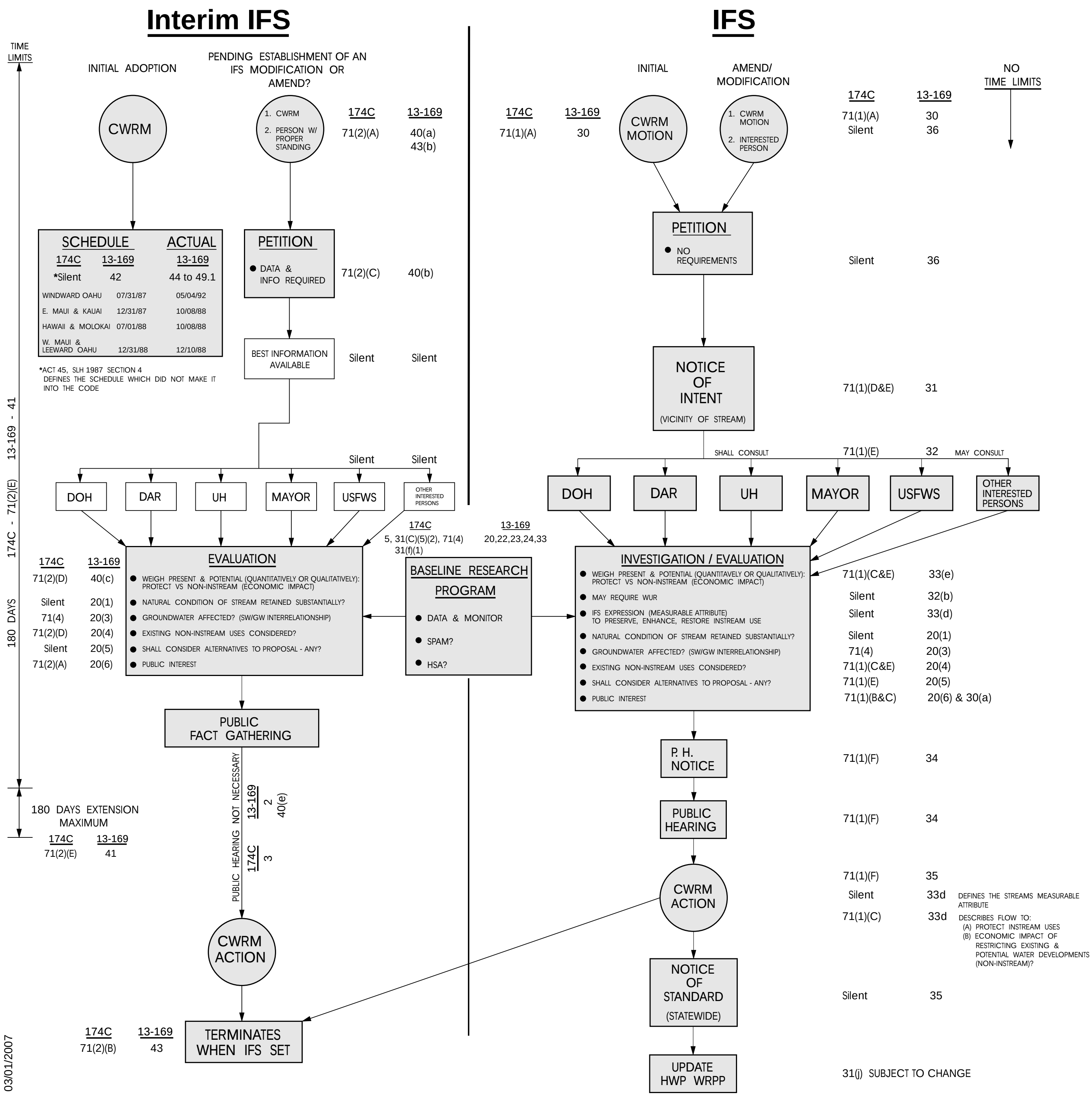
INSTREAM USES:

(1) MAINTENANCE OF FISH & WILDLIFE HABITAT;
(2) OUTDOOR RECREATIONAL ACTIVITIES;
(3) MAINTENANCE OF ECOSYSTEMS SUCH AS ESTUARIES, WETLANDS, AND STREAM VEGETATION;
(4) AESTHETIC VALUES SUCH AS WATERFALLS AND SCENIC WATERWAYS;
(5) NAVIGATION;
(6) INSTREAM HYDROPOWER GENERATION;
(7) MAINTENANCE OF WATER QUALITY;
(8) THE CONVEYANCE OF IRRIGATION AND DOMESTIC WATER SUPPLIES TO DOWNSTREAM POINTS OF DIVERSION; AND
(9) THE PROTECTION OF TRADITIONAL AND CUSTOMARY HAWAIIAN RIGHTS.

NON-INSTREAM USES:

- DOMESTIC
- AGRICULTURAL
- INDUSTRIAL

OUTSIDE OF STREAM CHANNEL



03/01/2007

Appendix C

1989 Declared Surface Water Use

Appendix C: 1989 Declared Surface Water Use

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Kauai					
2001	Awaawapuhi	0.000	2038	Moikeha	0.053
2002	Honopu	0.000	2039	Waikaea	0.100
2003	Nakeikionaiwi	0.000	2040	Wailua	7.564
2004	Kalalau	0.000	2041	Kawailoa	0.000
2005	Pohakuao	0.000	2042	Hanamaulu	0.004
2006	Waiolaa	0.000	2043	Lihue Airport	0.000
2007	Hanakoa	0.000	2044	Nawiliwili	0.004
2008	Waiahuakua	0.000	2045	Puali	1.637
2009	Hoolulu	0.000	2046	Huleia	5.228
2010	Hanakapiai	0.000	2047	Kipu Kai	0.018
2011	Maunapuluo	0.000	2048	Mahaulepu	0.000
2012	Limahuli	0.649	2049	Waikomo	1.000
2013	Manoa	0.000	2050	Aepo	0.000
2014	Wainiha	0.000	2051	Lawai	1.739
2015	Lumahai	0.000	2052	Kalaheo	0.000
2016	Waikoko	0.000	2053	Wahiawa	7.175
2017	Waipa	0.000	2054	Hanapepe	19.820
2018	Waioli	0.000	2055	Kukamahu	0.000
2019	Hanalei	0.026	2056	Kaumakani	0.000
2020	Waileia	0.000	2057	Mahinauli	0.000
2021	Anini	0.092	2058	Aakukui	0.216
2022	Kalihikai West	0.000	2059	Waipao	0.000
2023	Kalihikai Center	0.000	2060	Waimea	17.693
2024	Kalihikai East	0.000	2061	Kapilimao	32.847
2025	Kalihiwai	0.000	2062	Paua	0.000
2026	Puukumu	0.002	2063	Hoea	0.000
2027	Kauapea	0.000	2064	Niu	0.000
2028	Kilauea	0.000	2065	Kaawaloa	0.000
2029	Kulihaili	0.000	2066	Nahomalu	0.000
2030	Pilaa	0.159	2067	Kaulaula	0.000
2031	Waipake	0.164	2068	Haeleele	0.000
2032	Moloaa	0.001	2069	Hikimoe	0.000
2033	Papaa	0.013	2070	Kaaweiki	0.000
2034	Aliomanu	0.000	2071	Kauhao	19.010
2035	Anahola	0.001	2072	Makaha	0.000
2036	Kumukumu	0.000	2073	Milolii	0.000
2037	Kapaa	2.793	2074	Nualolo	0.000
				Kauai Total Declared Surface Water Use	**118.007**
Island of Oahu					
3001	Kalunawaikaala	0.000	3010	Kaipapau	0.000
3002	Pakulena	0.000	3011	Maakua	0.000
3003	Paumalu	0.022	3012	Waipuhi	0.006
3004	Kawela	0.000	3013	Kaluanui	0.000
3005	Oio	0.000	3014	Papaakoko	0.000
3006	Malaekahana	0.000	3015	Halehaa	0.000
3007	Kahawainui	0.000	3016	Punaluu	14.242
3008	Wailele	0.000	3017	Kahana	0.000
3009	Koloa	0.000	3018	Makaua	0.000

Appendix C: 1989 Declared Surface Water Use (continued)

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Oahu (continued)					
3019	Kaaawa	0.064	3054	Keehi	0.000
3020	Kualoa	0.000	3055	Manuwai	0.000
3021	Hakipuu	0.000	3056	Salt Lake	0.000
3022	Waikane	0.001	3057	Halawa	0.000
3023	Waianu	0.000	3058	Aiea	0.000
3024	Waiahole	0.000	3059	Kalauao	0.000
3025	Kaalaea	0.000	3060	Waimalu	0.000
3026	Haiamoa	0.000	3061	Waiawa	0.020
3027	Kahaluu	0.008	3062	Waipio	0.000
3028	Heeia	33.532	3063	Kapakahi	0.292
3029	Keaahala	0.000	3064	Waikele	4.701
3030	Kaneohe	0.000	3065	Honouliuli	0.000
3031	Kawa	0.000	3066	Kaloi	0.000
3032	Puu Hawaiiloa	0.000	3067	Makaiwa	0.000
3033	Kawainui	0.936	3068	Nanakuli	0.000
3034	Kaelepulu	0.000	3069	Ulehawa	0.000
3035	Waimanalo	0.006	3070	Mailiili	0.000
3036	Kahawai	0.000	3071	Kaupuni	0.144
3037	Makapuu	0.000	3072	Kamaileunu	0.000
3038	Koko Crater	0.000	3073	Makaha	0.000
3039	Hanauma	0.000	3074	Keaau	0.000
3040	Portlock	0.000	3075	Makua	0.000
3041	Kamiloiki	0.000	3076	Kaluakauila	0.000
3042	Kamilonui	0.000	3077	Manini	0.000
3043	Hahaione	0.000	3078	Kawaihapai	0.000
3044	Kuliouou	0.000	3079	Pahole	0.000
3045	Niu	0.000	3080	Makaleha	0.006
3046	Wailupe	0.000	3081	Waialua	0.000
3047	Waialaenui	0.000	3082	Kiikii	25.543
3048	Diamond Head	0.000	3083	Paukauila	0.000
3049	Ala Wai	2.801	3084	Anahulu	0.530
3050	Nuuanu	0.156	3085	Loko Ea	0.000
3051	Kapalama	0.200	3086	Keamanea	0.000
3052	Kalihi	0.002	3087	Waimea	0.000
3053	Moanalua	0.000			
		Oahu Total Declared Surface Water Use			**83.211**
Island of Molokai					
4001	Waihanau	0.274	4012	Oloupena	0.000
4002	Waialeia	0.000	4013	Puukaoku	0.000
4003	Waikolu	0.130	4014	Wailele	0.000
4004	Wainene	0.000	4015	Wailau	0.004
4005	Anapuhi	0.000	4016	Kalaemilo	0.000
4006	Waiohookalo	0.000	4017	Waiahookalo	0.000
4007	Keawanui	0.000	4018	Kahiwa	0.000
4008	Kailiili	0.000	4019	Kawainui	0.000
4009	Pelekunu	0.000	4020	Pipiwai	0.000
4010	Waipu	0.000	4021	Halawa	0.002
4011	Haloku	0.000	4022	Papio	0.007

Appendix C: 1989 Declared Surface Water Use (continued)

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Molokai (continued)					
4023	Honowewe	0.000	4037	Kawela	0.716
4024	Pohakupili	0.000	4038	Kamiloloa	0.000
4025	Honoulimaloo	0.139	4039	Kaunakakai	0.000
4026	Honouliwai	0.250	4040	Kalamaula	0.000
4027	Waialua	0.000	4041	Manawainui	0.071
4028	Kainalu	0.000	4042	Kaluapeelua	0.000
4029	Honomuni	0.018	4043	Waiahewahewa	0.000
4030	Ahaino	0.000	4044	Kolo	0.000
4031	Mapulehu	0.000	4045	Hakina	0.000
4032	Kaluaaha	0.000	4046	Kaunala	0.000
4033	Kahananui	0.000	4047	Papohaku	0.000
4034	Ohia	0.000	4048	Kaa	0.000
4035	Wawaia	0.000	4049	Moomomi	0.000
4036	Kamalo	0.000	4050	Maneopapa	0.000
		Molokai Total Declared Surface Water Use			**1.610**
Island of Maui					
6001	Waikapu	2.507	6033	Kakipi	0.155
6002	Pohakea	0.000	6034	Honopou	1.327
6003	Papalaua	0.000	6035	Hoolawa	0.133
6004	Ukumehame	4.888	6036	Waipio	0.050
6005	Olowalu	4.556	6037	Hanehoi	0.007
6006	Launiupoko	0.728	6038	Hoalua	0.000
6007	Kauaula	6.008	6039	Hanawana	0.000
6008	Kahoma	5.626	6040	Kailua	0.000
6009	Wahikuli	0.000	6041	Nailiilihaele	0.000
6010	Honokowai	0.000	6042	Puehu	0.000
6011	Kahana	1.099	6043	Oopuola	0.000
6012	Honokahua	0.000	6044	Kaaiea	0.000
6013	Honolua	0.000	6045	Punaluu	0.000
6014	Honokohau	0.011	6046	Kolea	0.000
6015	Anakaluahine	0.000	6047	Waikamoi	0.000
6016	Poelua	0.000	6048	Puohokamoa	0.000
6017	Honanana	0.006	6049	Haipuaena	0.000
6018	Kahakuloa	0.004	6050	Punalau	0.000
6019	Waipili	0.027	6051	Honomanu	0.017
6020	Waiolai	0.000	6052	Nuaailua	0.000
6021	Makamakaole	0.007	6053	Piinaau	0.378
6022	Waihee	9.727	6054	Ohia	0.000
6023	Waiehu	0.105	6055	Waiokamilo	0.023
6024	Iao	22.833	6056	Wailuanui	0.002
6025	Kalialinui	0.000	6057	W. Wailuaiki	0.000
6026	Kailua Gulch	0.000	6058	E. Wailuaiki	0.000
6027	Maliko	0.014	6059	Kopiliula	0.000
6028	Kuiaha	0.002	6060	Waiohue	0.000
6029	Kaupakulua	0.012	6061	Paakea	0.000
6030	Manawaiiao	0.000	6062	Waiaaka	0.000
6031	Uaoa	0.000	6063	Kapaula	0.000
6032	Kealii	0.001	6064	Hanawi	0.303

Appendix C: 1989 Declared Surface Water Use (continued)

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Maui (continued)					
6065	Makapipi	0.000	6089	Oheo	0.000
6066	Kuhiwa	0.000	6090	Kalena	0.000
6067	Waihole	0.001	6091	Koukouai	0.000
6068	Manawaikeae	0.000	6092	Opelu	0.000
6069	Kahawaihapapa	0.000	6093	Kukuiula	0.000
6070	Keaaiki	0.000	6094	Kaapahu	0.000
6071	Waioni	0.000	6095	Lelekea	0.000
6072	Lanikele	0.000	6096	Alelele	0.000
6073	Heleleikeoha	0.001	6097	Kalepa	0.018
6074	Kawakoe	0.002	6098	Nuanuaaloa	0.000
6075	Honomaele	0.000	6099	Manawainui	0.004
6076	Kawaipapa	0.000	6100	Kaupo	0.000
6077	Moomoonui	0.000	6101	Nuu	0.000
6078	Haneoo	0.000	6102	Pahihi	0.000
6079	Kapia	0.002	6103	Waiopai	0.000
6080	Waiohonu	0.000	6104	Poopoo	0.000
6081	Papahawahawa	0.000	6105	Manawainui Gulch	0.000
6082	Alaalaula	0.007	6106	Kipapa	0.000
6083	Wailua	0.101	6107	Kanaio	0.000
6084	Honolewa	0.000	6108	Ahihi Kinau	0.000
6085	Waieli	0.000	6109	Mooloa	0.000
6086	Kakiweka	0.000	6110	Wailea	0.000
6087	Hahalawe	0.000	6111	Hapapa	0.000
6088	Puaaluu	0.112	6112	Waiakoa	0.000
				Maui Total Declared Surface Water Use	**60.803**
Island of Hawaii					
8001	Kealahewa	0.000	8022	Honopue	0.000
8002	Hualua	0.000	8023	Kolealiilii	0.000
8003	Kumakua	0.000	8024	Ohiahuea	0.000
8004	Kapua	0.000	8025	Nakooko	0.000
8005	Ohanaula	0.000	8026	Waiapuka	0.000
8006	Hanaula	0.000	8027	Waikaloa	0.000
8007	Hapahapai	0.000	8028	Waimaile	0.000
8008	Pali Akamoa	0.000	8029	Kukui	0.000
8009	Wainaia	2.259	8030	Paopao	0.000
8010	Halelua	0.000	8031	Waiaalala	0.000
8011	Halawa	0.000	8032	Punalulu	0.000
8012	Aamakao	0.100	8033	Kaimu	0.000
8013	Niulii	9.199	8034	Pae	0.000
8014	Waikama	0.002	8035	Waimanu	0.000
8015	Pololu	2.001	8036	Pukoa	0.000
8016	Honokane Nui	3.502	8037	Manuwaikaalio	0.000
8017	Honokane Iki	0.000	8038	Naluea	0.000
8018	Kalele	0.000	8039	Kahoopuu	0.000
8019	Waipahi	0.000	8040	Waipahoehoe	0.000
8020	Honokea	0.000	8041	Wailoa/Waipio	0.776
8021	Kailikaula	0.000	8042	Kaluahine Falls	0.000

Appendix C: 1989 Declared Surface Water Use (continued)

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Hawaii (continued)					
8043	Waiulili	0.000	8089	Kihalani	0.000
8044	Waikoekoe	0.000	8090	Kaiwilahilahi	0.000
8045	Waipunahoe	0.000	8091	Haakoa	0.000
8046	Waialeale	0.000	8092	Pahale	0.000
8047	Waikoloa	0.000	8093	Kapehu Camp	0.000
8048	Kapulena	0.000	8094	Paeohe	0.000
8049	Kawaikalia	0.000	8095	Maulua	0.000
8050	Malanahae	0.000	8096	Pohakupuka	0.000
8051	Honokaia	0.000	8097	Kulanakii	0.000
8052	Kawela	0.000	8098	Ahole	0.000
8053	Keaakaukau	0.000	8099	Poupou	0.000
8054	Kainapahoa	0.000	8100	Manoloa	0.000
8055	Nienie	0.000	8101	Ninole	0.000
8056	Papuaa	0.000	8102	Kaaheiki	0.000
8057	Ouhi	0.000	8103	Waikolu	0.020
8058	Kahaupu	0.000	8104	Waikaumalo	0.000
8059	Kahawailiili	0.000	8105	Waiehu	0.000
8060	Keahua	0.000	8106	Nanue	0.000
8061	Kalopa	0.000	8107	Opea	0.000
8062	Waikaalulu	0.000	8108	Peleau	0.012
8063	Kukuilamalamahii	0.000	8109	Umauma	0.000
8064	Alilipali	0.000	8110	Hakalau	0.000
8065	Kaumoali	0.000	8111	Kolekole	0.096
8066	Pohakuhaku	0.000	8112	Paheehee	0.000
8067	Waipunahina	0.000	8113	Honomu	0.000
8068	Waipunalau	0.000	8114	Laimi	0.000
8069	Paauilo	0.000	8115	Kapehu	0.000
8070	Aamanu	0.000	8116	Makea	7.422
8071	Koholalele	0.000	8117	Alia	3.014
8072	Kalapahapuu	0.000	8118	Makahanaloa	0.000
8073	Kukaiau	0.000	8119	Waimaauou	1.808
8074	Puumaile	0.000	8120	Waiaama	2.835
8075	Kekualele	0.000	8121	Kawainui	3.014
8076	Kaala	0.000	8122	Onomea	0.025
8077	Kealakaha	0.000	8123	Alakahi	0.000
8078	Keehia	0.000	8124	Hanawi	0.000
8079	Kupapaulua	0.000	8125	Kalaoa	0.001
8080	Kaiwiki	0.000	8126	Aleamai	0.000
8081	Kaula	0.000	8127	Kaieie	0.000
8082	Kaohaoha	0.000	8128	Puuokalepa	0.030
8083	Kaawalii	0.000	8129	Kaapoko	0.000
8084	Waipunalei	0.000	8130	Papaikou	0.000
8085	Laupahoehoe	0.000	8131	Kapue	0.000
8086	Kilau	0.000	8132	Pahoehoe	0.000
8087	Manowaiopae	0.194	8133	Paukaa	0.000
8088	Kuwaikahi	0.010	8134	Honolii	0.000

Appendix C: 1989 Declared Surface Water Use (continued)

Unit Code	Unit Name	Demand (mgd)	Unit Code	Unit Name	Demand (mgd)
Island of Hawaii (continued)					
8135	Maili	0.145	8151	Kiilae	0.001
8136	Wainaku	0.000	8152	Kealakekua	0.000
8137	Pukihae	0.000	8153	Waiaha	0.014
8138	Wailuku	47.343	8154	Honokohau	0.000
8139	Wailoa	0.000	8155	Keahole	0.000
8140	Kaahakini	0.000	8156	Kiholo	0.000
8141	Kilauea	0.000	8157	Pohakuloa	0.000
8142	Keauhou Point	0.000	8158	Kamakoa	0.000
8143	Kilauea Crater	0.000	8159	Haloa	0.000
8144	Kapapala	0.000	8160	Lamimaumau	0.000
8145	Pahala	0.000	8161	Waikoloa	37.155
8146	Hilea	0.001	8162	Kawaihae	0.000
8147	Naalehu	0.001	8163	Honokoa	5.184
8148	Kiolakaa	0.000	8164	Keawanui	0.350
8149	South Point	0.000	8165	Lapakahi	0.000
8150	Kauna	0.000	8166	Mahukona	0.000
				Hawaii Total Declared Surface Water Use	**126.515**