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.

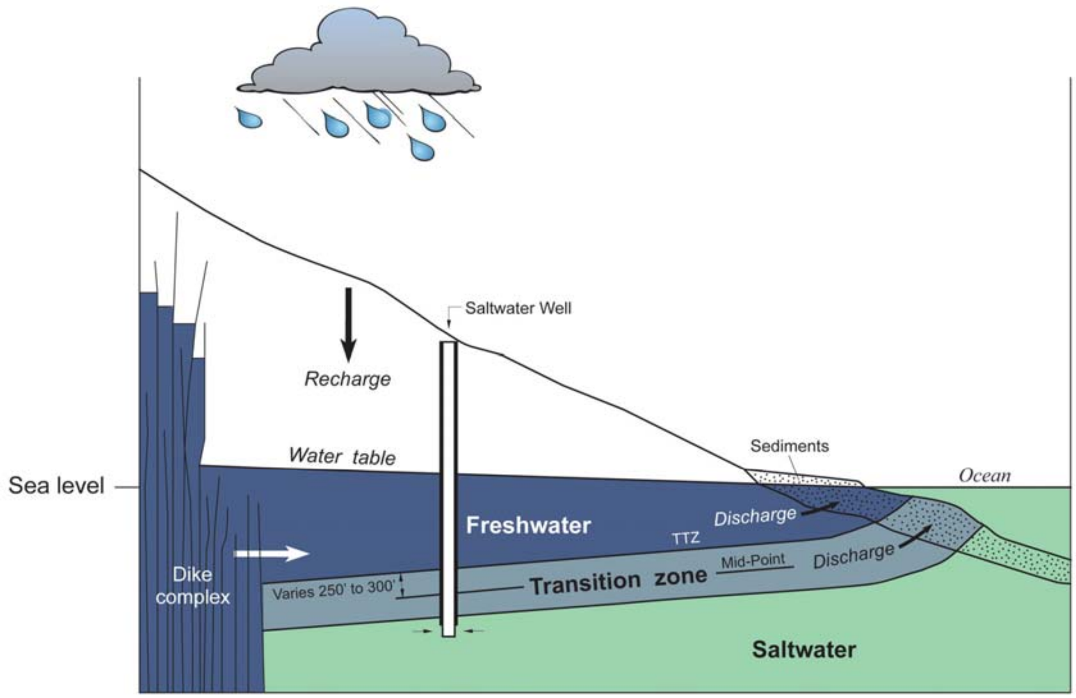

Figure 4-1. Schematic diagram of a deep monitor well. A deep monitor well penetrates through the freshwater zone and the transition zone, and terminates in the saltwater zone.

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.

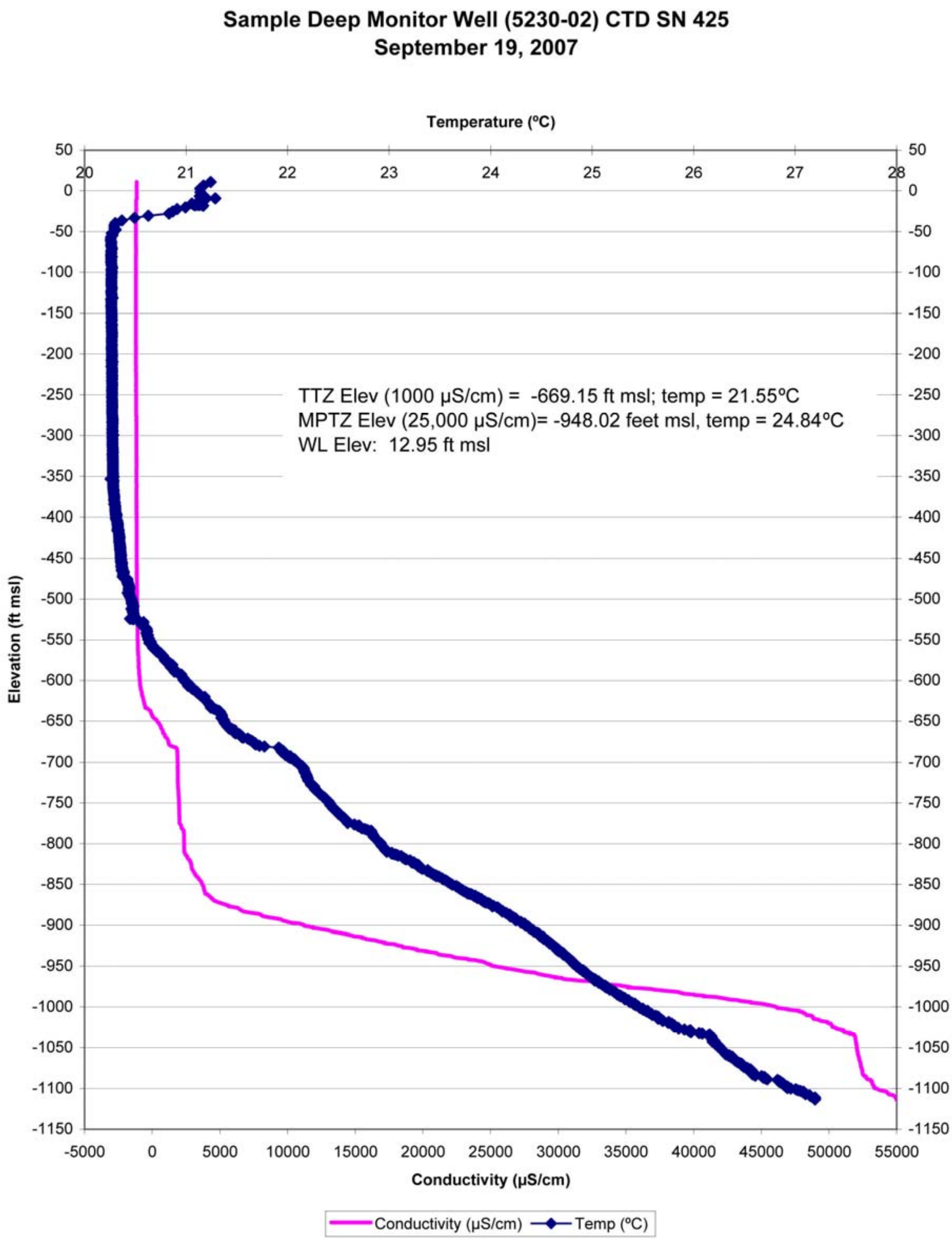

Figure 4-2. Sample Graph of CTD Data from a Deep Monitor Well.

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

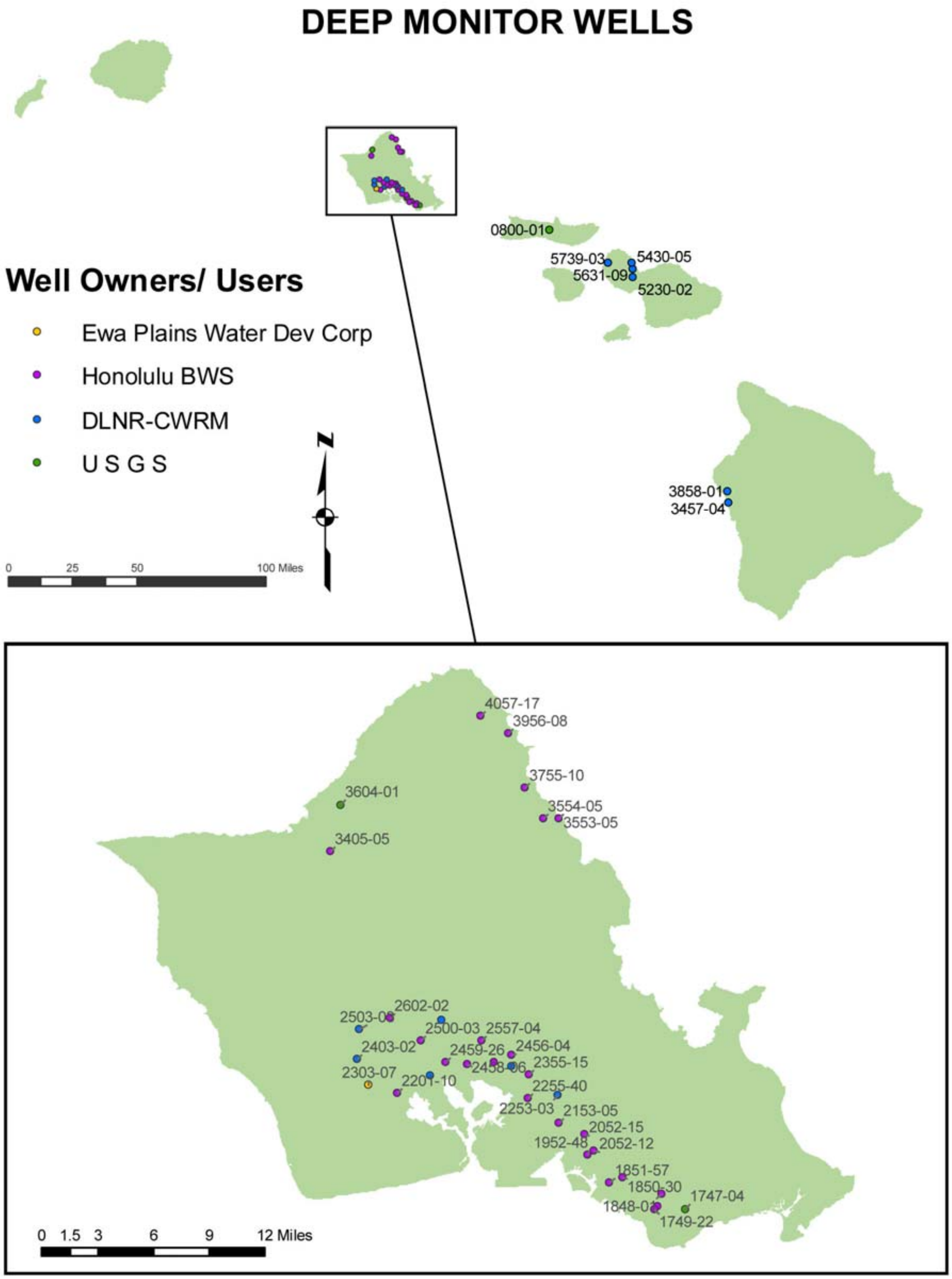

Figure 4-3. Deep monitor wells in the State of Hawaii.

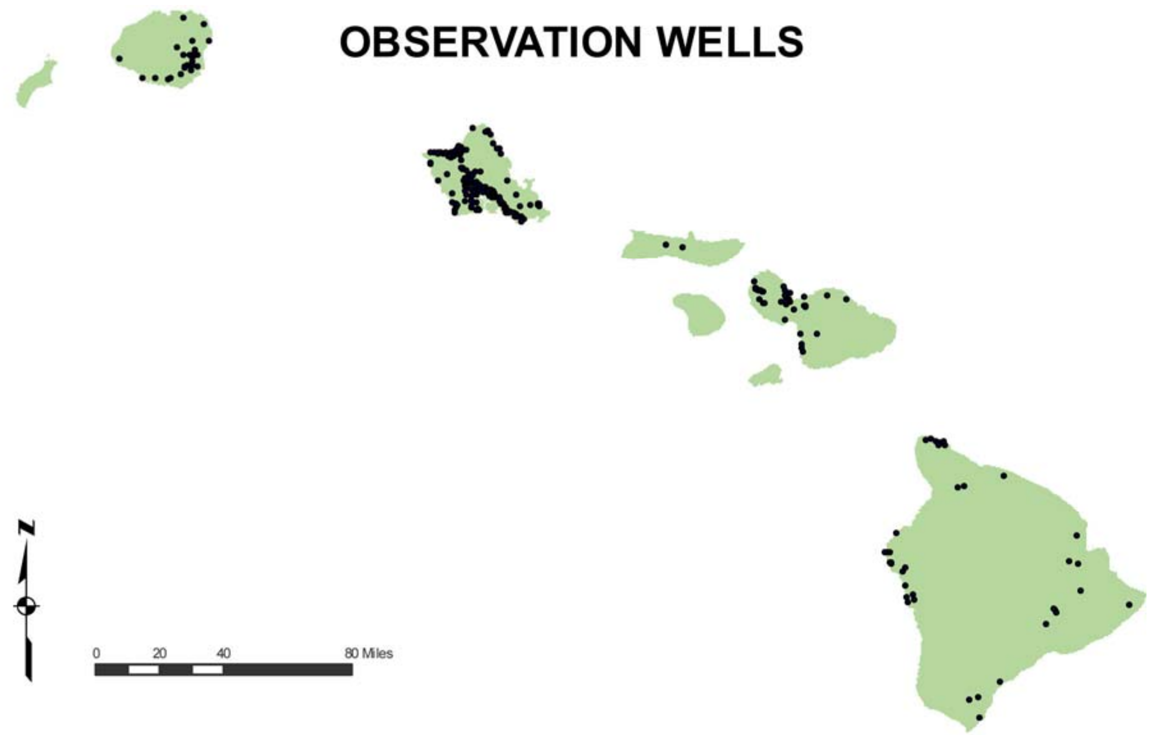

Figure 4-4: Water -level observation wells in the State of Hawaii.

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

[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.

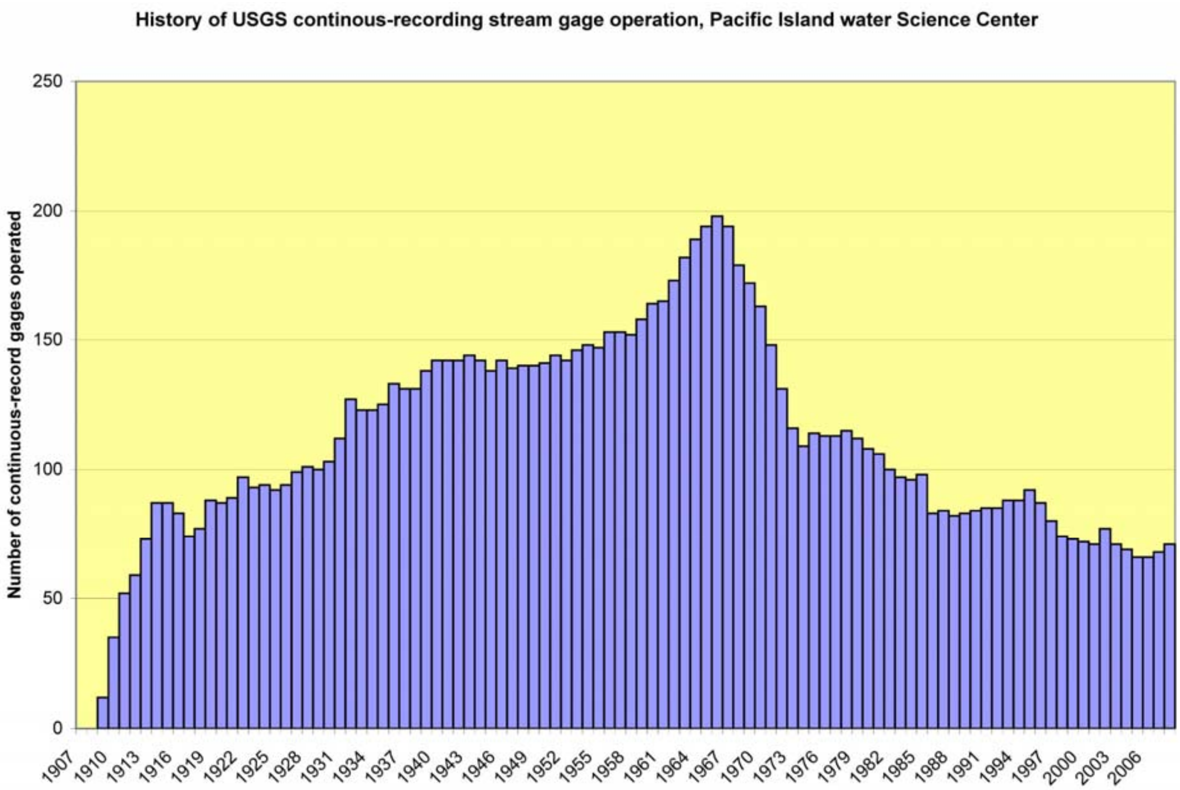

Figure 4-5. History of USGS continuous-recording stream gage operation.

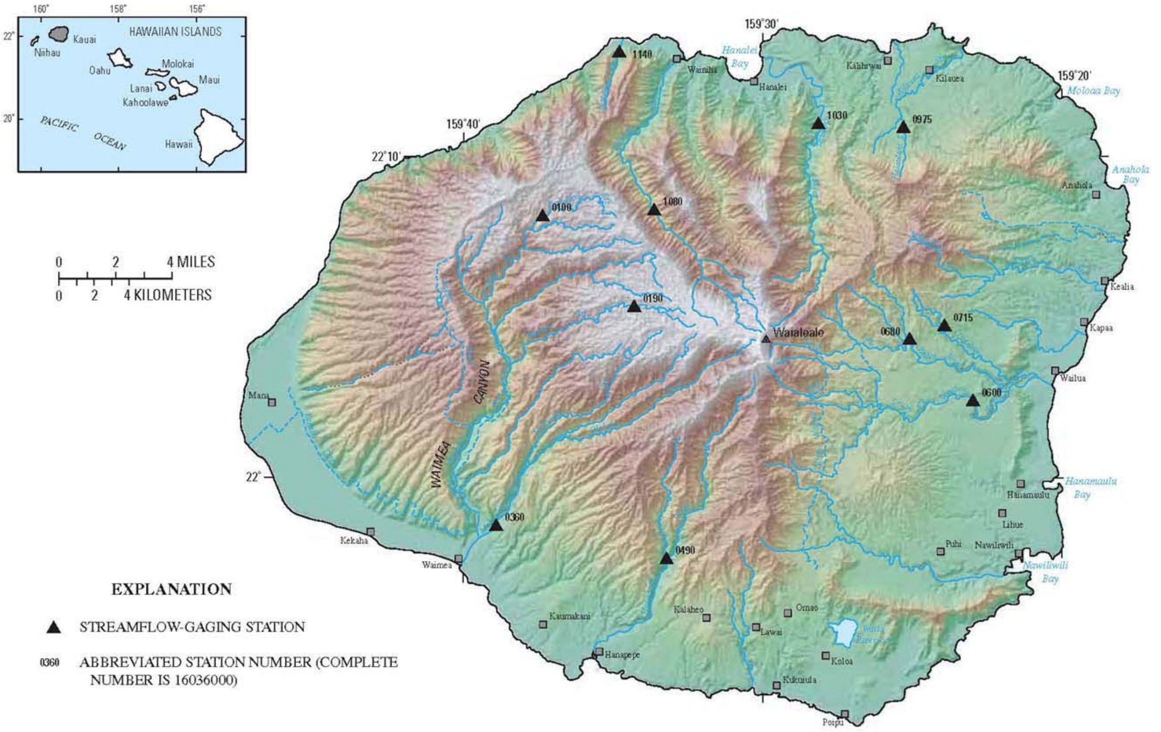

Figure 4-6. Locations of Streamflow gaging stations on Kauai (Water Year 2005).

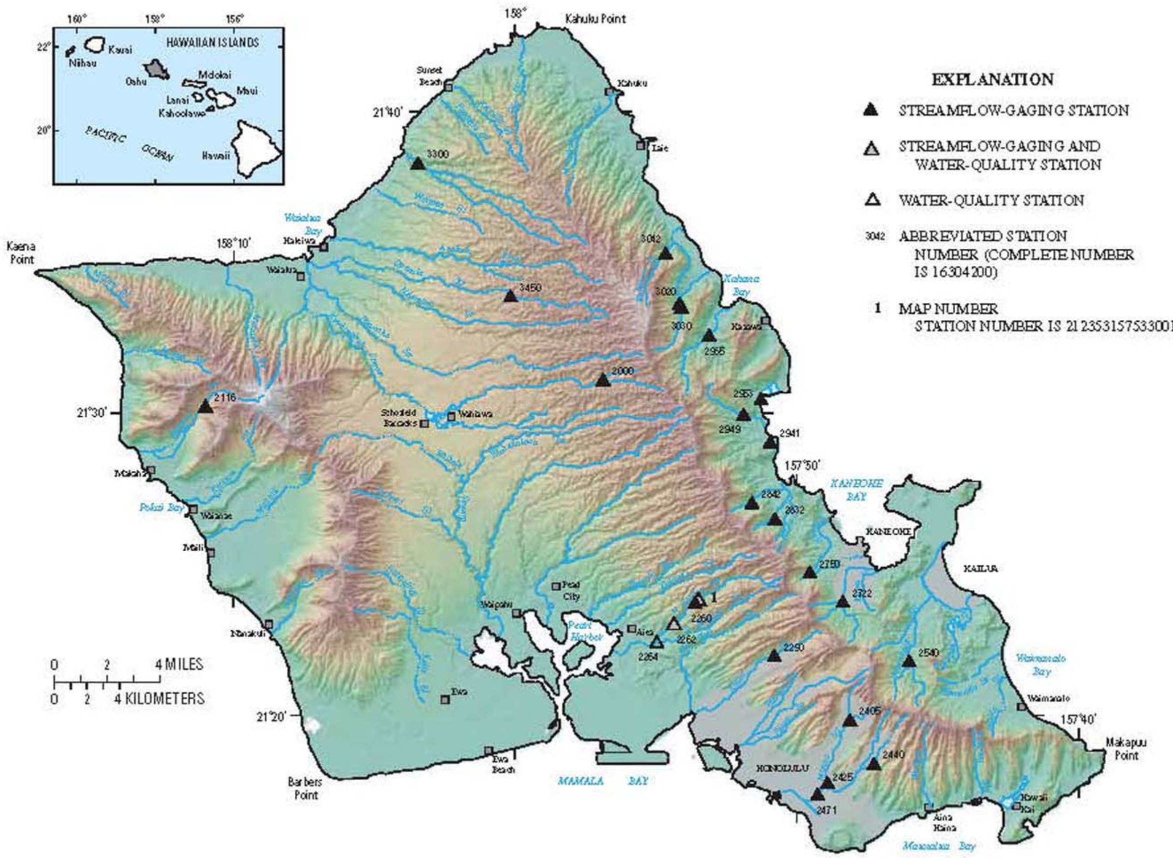

Figure 4-7. Locations of Streamflow gaging stations on Oahu (Water Year 2005).

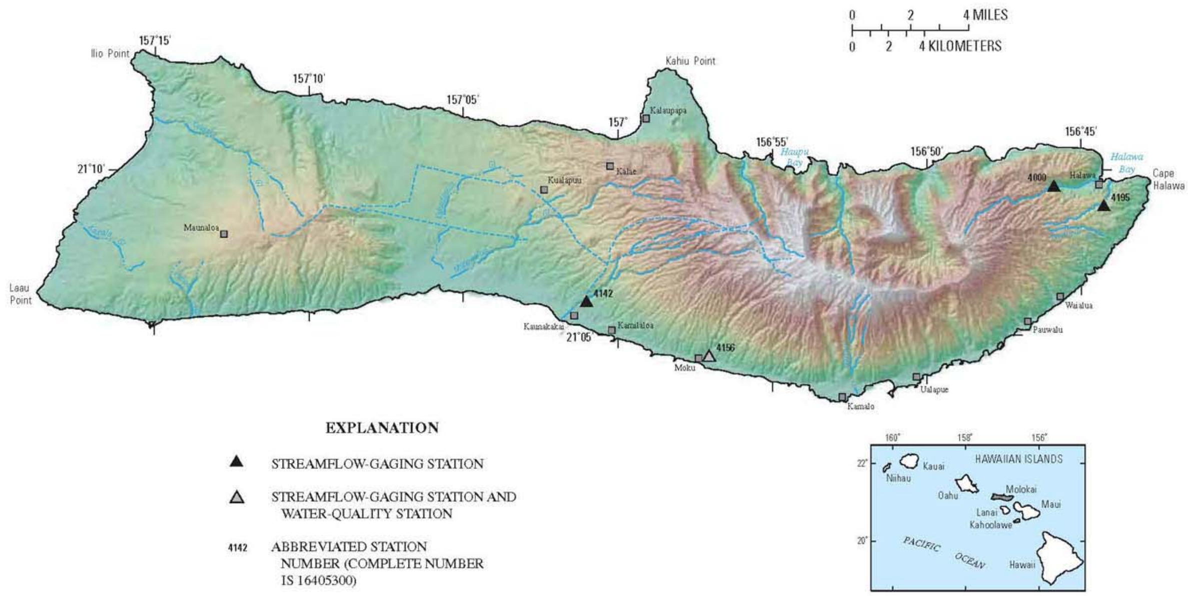

Figure 4-8. Locations of Streamflow gaging stations on Molokai (Water Year 2005).

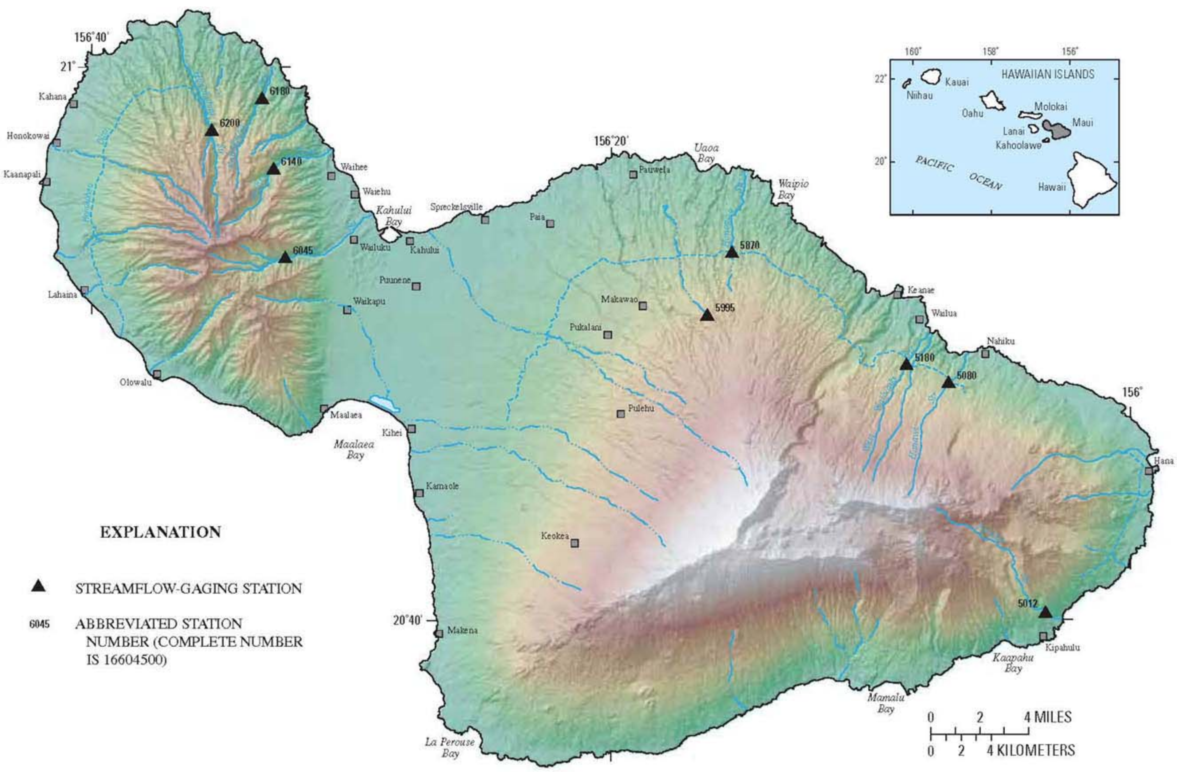

Figure 4-9. Locations of Streamflow gaging stations on Maui (Water Year 2005).

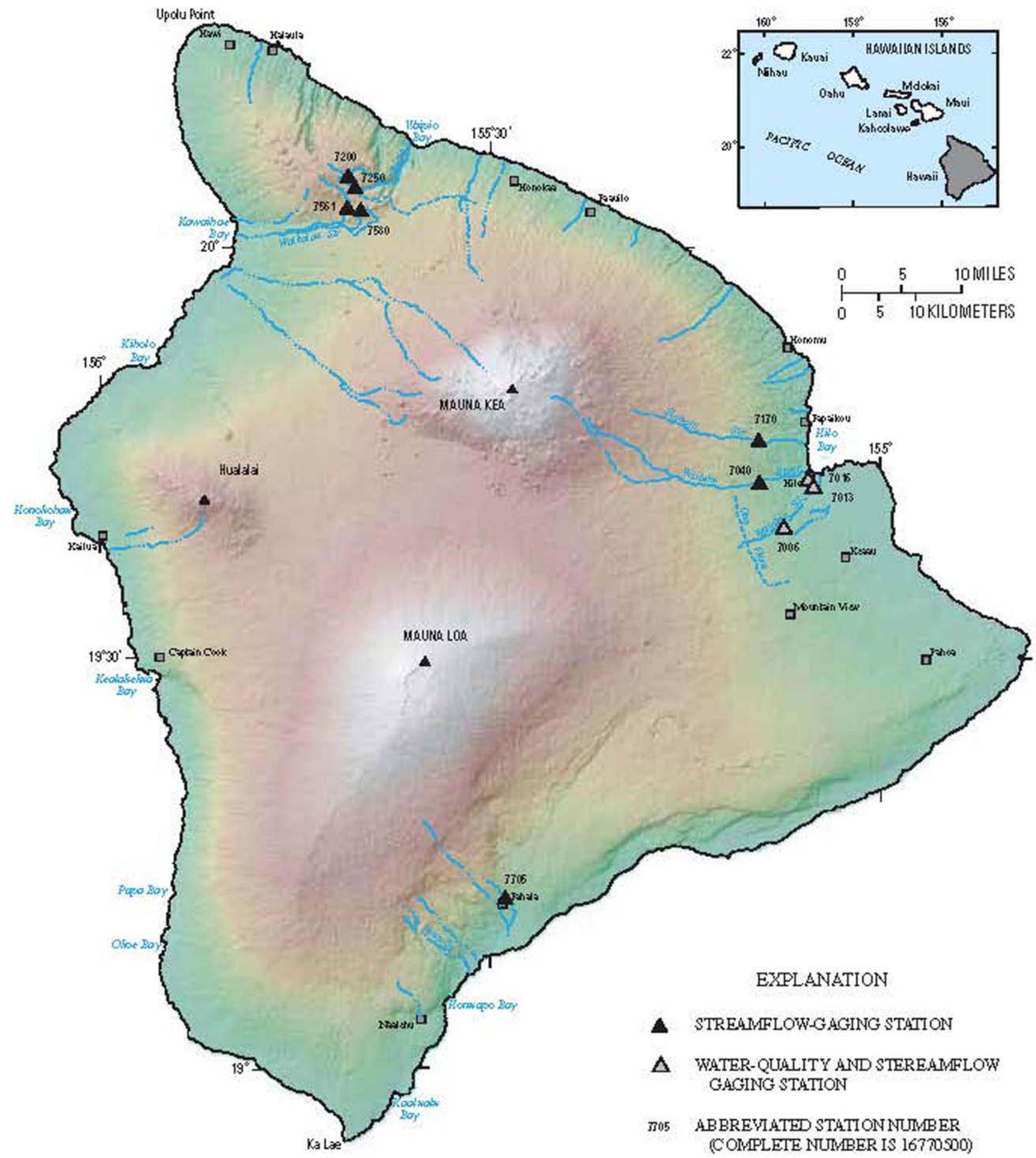

Figure 4-10. Locations of Streamflow gaging stations on Hawaii (Water Year 2005).

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.

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[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]

[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

[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.*

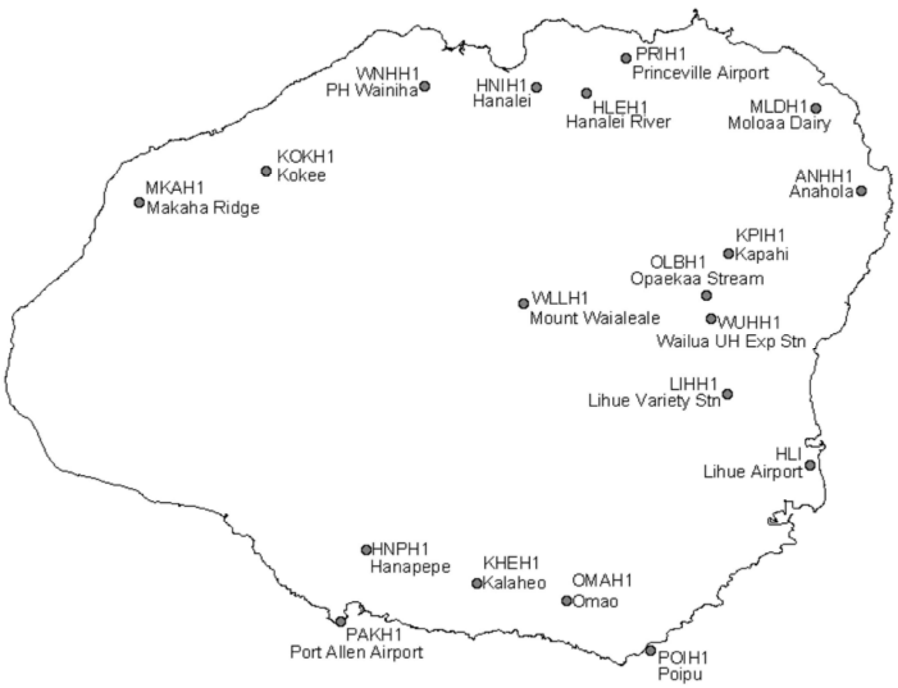

Figure 4-11. NWS Hydronet rain gages on Kauai.

Figure 4-12. NWS Hydronet rain gages on Oahu.

Figure 4-13. NWS Hydronet rain gages on Molokai and Lanai.

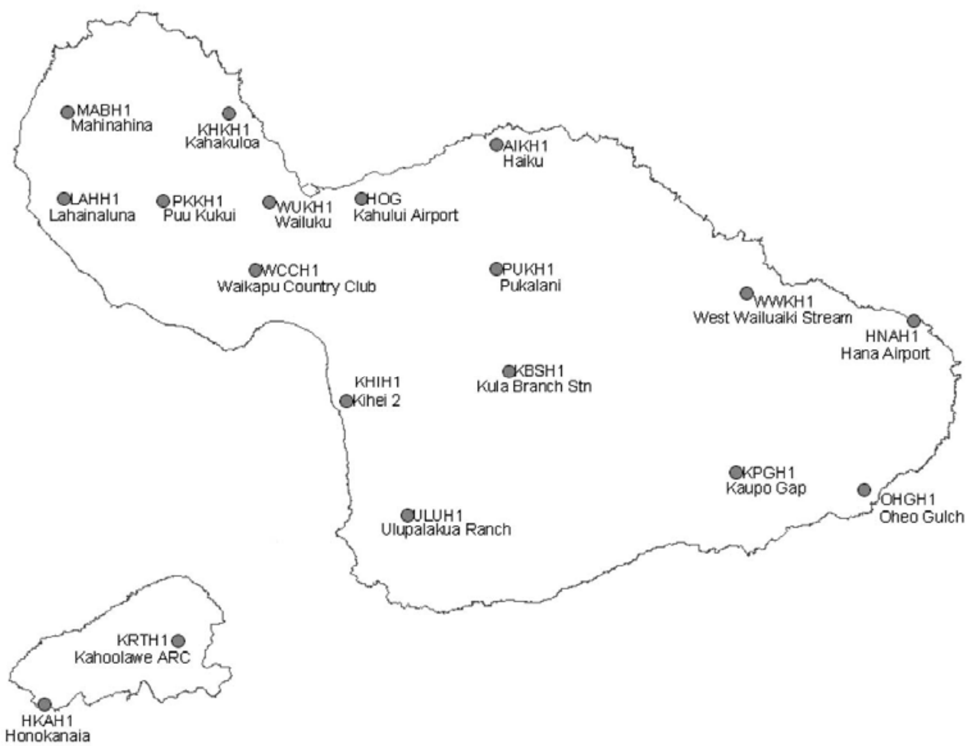

Figure 4-14. NWS Hydronet rain gages on Maui and Kahoolawe.

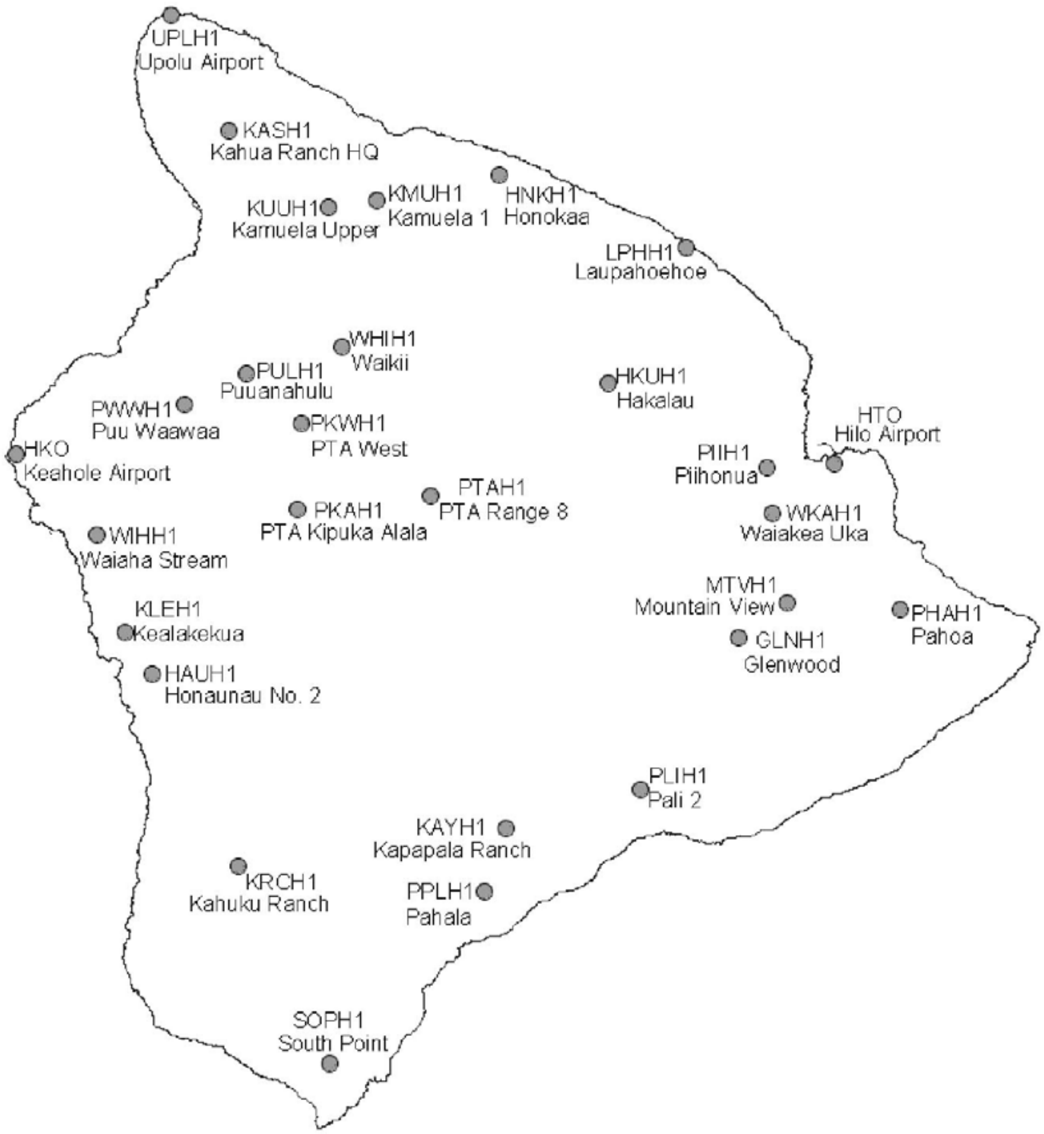

Figure 4-15. NWS Hydronet rain gages on Hawaii.

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.

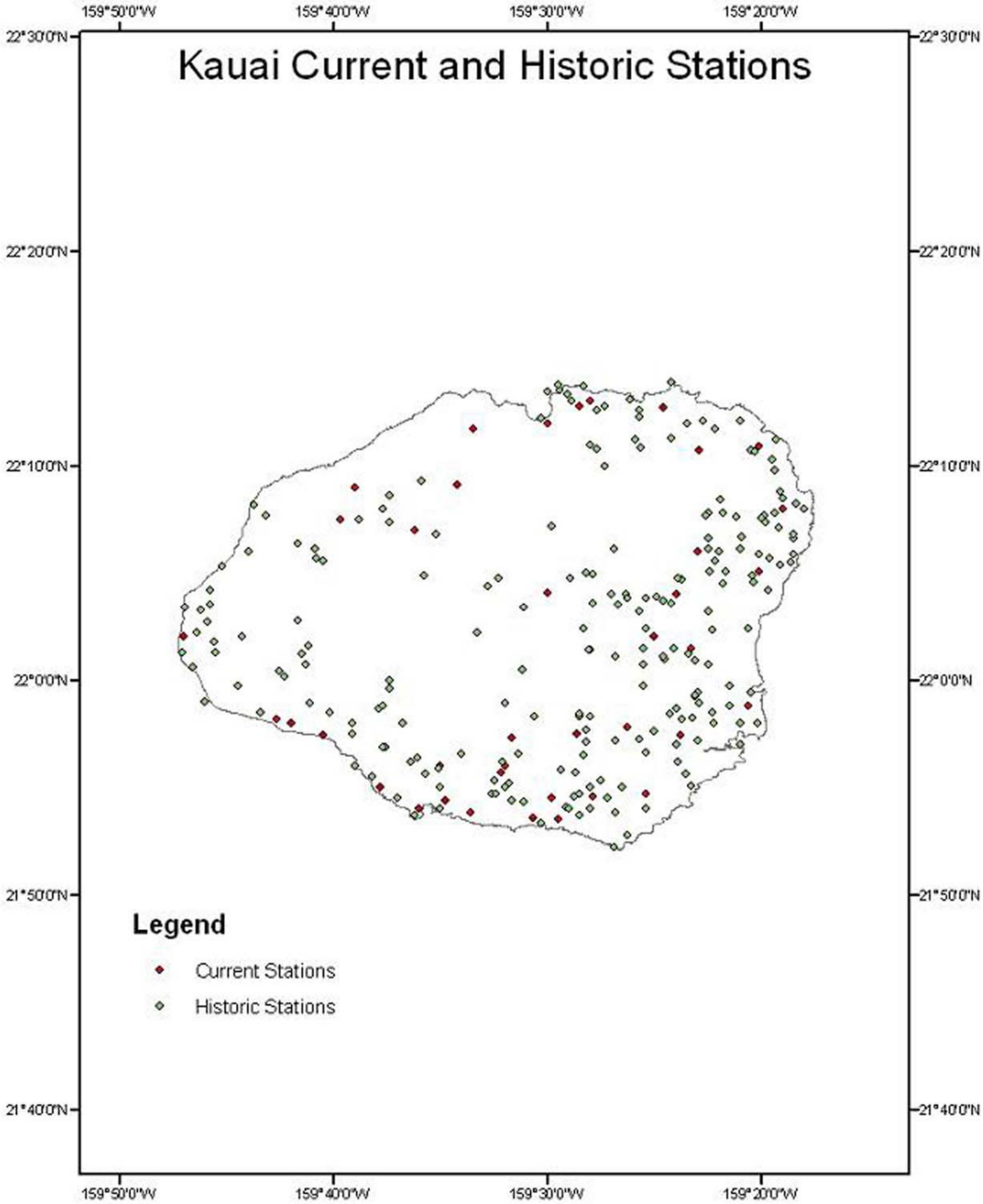

Figure 4-16: Current and historic rainfall monitoring stations on Kauai. Historic stations are not active.

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

[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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