STATE OF HAWAIʻI
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
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STAFF SUBMITTAL

for the meeting of the
COMMISSION ON WATER RESOURCE MANAGEMENT

July 16, 2019
Honolulu, Oahu

Adoption of 2019 Water Resource Protection Plan Update

SUMMARY OF REQUEST:

Staff requests that the Commission on Water Resource Management (Commission) adopt an updated Water Resource Protection Plan, which is the Commission's primary contribution to the overall Hawaiʻi Water Plan.

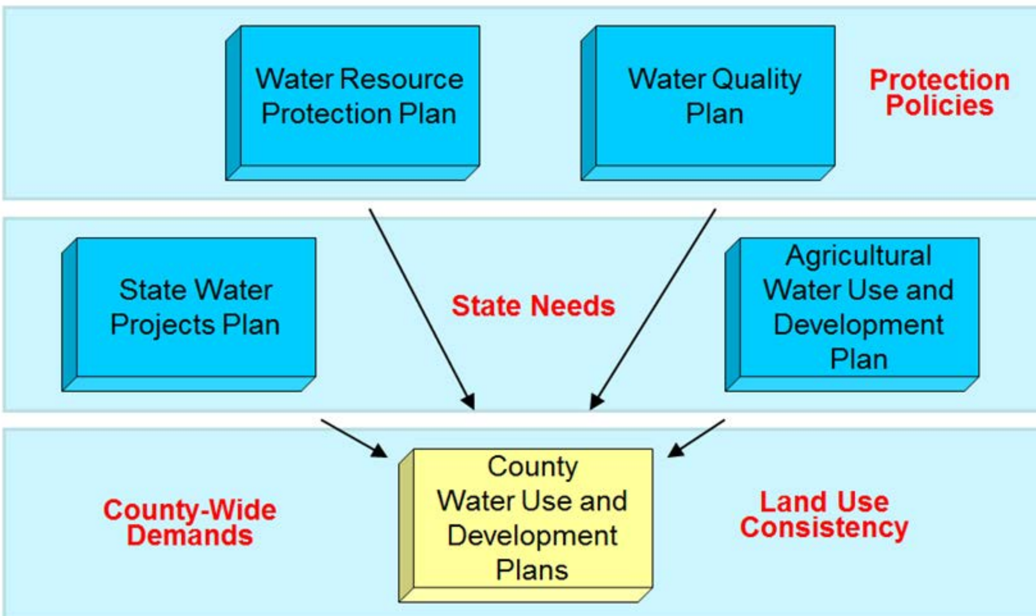
BACKGROUND:

The State Water Code, Chapter 174C, Hawaiʻi Revised Statutes, requires that the Commission implement and utilize comprehensive water resources planning in its regulation and management of our state's water resources. The Water Code sets forth the requirement for initial development and regular updating of the Hawaiʻi Water Plan (HWP) to guide the Commission in executing its general powers, duties, and responsibilities assuring economic development, good municipal services, agricultural stability, and environmental protection.

The HWP is intended to serve as a continuing long-range guide for water resource management. The HWP currently consists of five major components (plans) identified as the: 1) Water Resource Protection Plan, 2) Water Quality Plan, 3) State Water Projects Plan, 4) Agricultural Water Use and Development Plan, and 5) County Water Use and Development Plans. The Water Code mandates that these individual plans be prepared and integrated into a comprehensive "master plan" to provide for effective coordination and long-range planning between state and county agencies.

To fulfill this mandate, the components of the HWP must be reviewed and updated on a regular basis. Regular updating of the statewide components of the HWP will facilitate the counties' integration of updated information from the Water Resource Protection Plan, Water Quality Plan, State Water Projects Plan, and Agricultural Water Use and Development Plan into their respective Water Use and Development Plans (WUDPs). Absence of such information can lead to preparation of inadequate or unrealistic plans for development of existing and alternative water resources, and may result in conflicting objectives for the use and protection of our state's limited water resources.

Figure 1. Hawai‘i Water Plan Components



WATER RESOURCE PROTECTION PLAN (WRPP)

The Commission is responsible for the preparation and updating of the Water Resource Protection Plan (WRPP) component of the HWP. The major objective of the WRPP is to protect and sustain statewide ground and surface water resources, watersheds, and natural stream environments. Such protection is established through a comprehensive study of occurrence, sustainability, conservation, augmentation, and other resource management measures.

To accomplish this objective, Section 174C-31, HRS of the State Water Code mandates that the Commission undertake the following activities:

1) Study and inventory the existing water resources of the State and means and methods of conserving and augmenting such water resources.

2) Review existing and contemplated needs and uses of water including state and county land use plans and policies and study their effect on the environment, procreation of fish and wildlife, and water quality.

3) Study the quantity and quality of water needed for existing and contemplated uses, including irrigation, power development, geothermal power, and municipal uses.

4) Identify rivers and streams, or a portion of a river or stream, which appropriately may be placed within a wild and scenic rivers system, to be preserved and protected as part of the public trust.

5) Study other related matters as drainage, reclamation, flood hazards, floodplain zoning, dam safety, and selection of reservoir sites, as they relate to the protection, conservation, quantity, and quality of water.

The State Water Code also identifies the minimum requirements to be addressed in the WRPP. These minimum requirements are as follows:

1) Nature and occurrence of water resources in the State;

2) Hydrologic units and their characteristics, including the quantity and quality of available resource, requirements for beneficial instream uses and environmental protection, desirable uses worthy of preservation by permit and undesirable uses for which permits may be denied;

3) Existing and contemplated uses of water, identified in the water use and development plans of the State and the counties, their impact on the resource, and their consistency with objectives and policies established in the WRPP;

4) Programs to conserve, augment and protect the water resource; and

5) Other elements necessary or desirable for inclusion in the WRPP.

The initial WRPP was completed and adopted by the Commission in 1990. The 1990 WRPP provided the foundation to address many issues, including but not limited to, estimates of sustainable groundwater yields by island, description of aquifer sectors and aquifer systems, and an initial evaluation of current and projected water needs for the State and the counties.

The first update to the WRPP was completed in 2008 and reflected the many changes that had occurred since 1990. These included the establishment of new resource protection policies, the availability of new and better hydrologic information, the addition and expansion of resource protection programs, and changing trends in land and water use that affect resource availability.

<u>2019 WRPP UPDATE PROCESS</u>

Beginning in 2013, staff undertook the task of updating the information from the 2008 WRPP with current water resource data, management practices, and legal mandates. This includes information such as updated sustainable yield estimations, amended instream flow standards, existing and future demands, and recent court decisions that impact water resource management decisions. Near- and long-term actions identified in the 2008 WRPP that were not undertaken were also compiled.

Water resources is a very complex subject in Hawaiʻi. Major water resource management topics, and a fundamental understanding of how data and information are analyzed and assessed, informed the development of tools and programs to manage water resources across the State. These are discussed in a comprehensive and exhaustive set of appendices, listed below in Table 1:

Table 1. WRPP Appendices

Appendix	Topic
A	Acronyms
B	Planning Context
C	Legal Authorities and Guidance
D	Permit Process Diagrams
E	Stakeholder Outreach Process
F	Inventory and Assessment of Resources
G	Monitoring of Water Resources
H	Existing and Future Demands
I	CWRM Regulatory Programs
J	Resource Conservation and Augmentation
K	Drought Planning
L	Watershed Protection
M	Water Quality
N	1989 Declared Surface Water Use
O	Long-Term Tasks
P	Administrative and Civil Penalty Guideline

As part of this discussion, any program gaps, deficiencies, or issues are identified along with recommendations to address them.

Emerging issues and new initiatives undertaken since the last update were also added, including:

- Best available information on climate change impacts to Hawaiʻi's water resources
- The process for establishment and quantification of appurtenant rights
- Protection of traditional and customary rights
- Water reservations for the Department of Hawaiʻian Home Lands
- Protection of groundwater dependent ecosystems
- Occurrence of deep confined freshwater on the Island of Hawaiʻi

Concurrent with staff's review, a series of water workshops were held statewide to find out how the public perceives and understands Hawaiʻi's water resources and to solicit input on water resource issues, concerns, and potential solutions and strategies. A series of interviews were also held with individuals and small groups to obtain additional stakeholder input. These included other agencies, water experts, non-governmental organizations, cultural practitioners, professional hydrologists, and large landowners.

This input was combined with an analysis of staff updates to the information in the 2008 WRPP to identify 10 water resource issues that the 2019 WRPP needed to address:

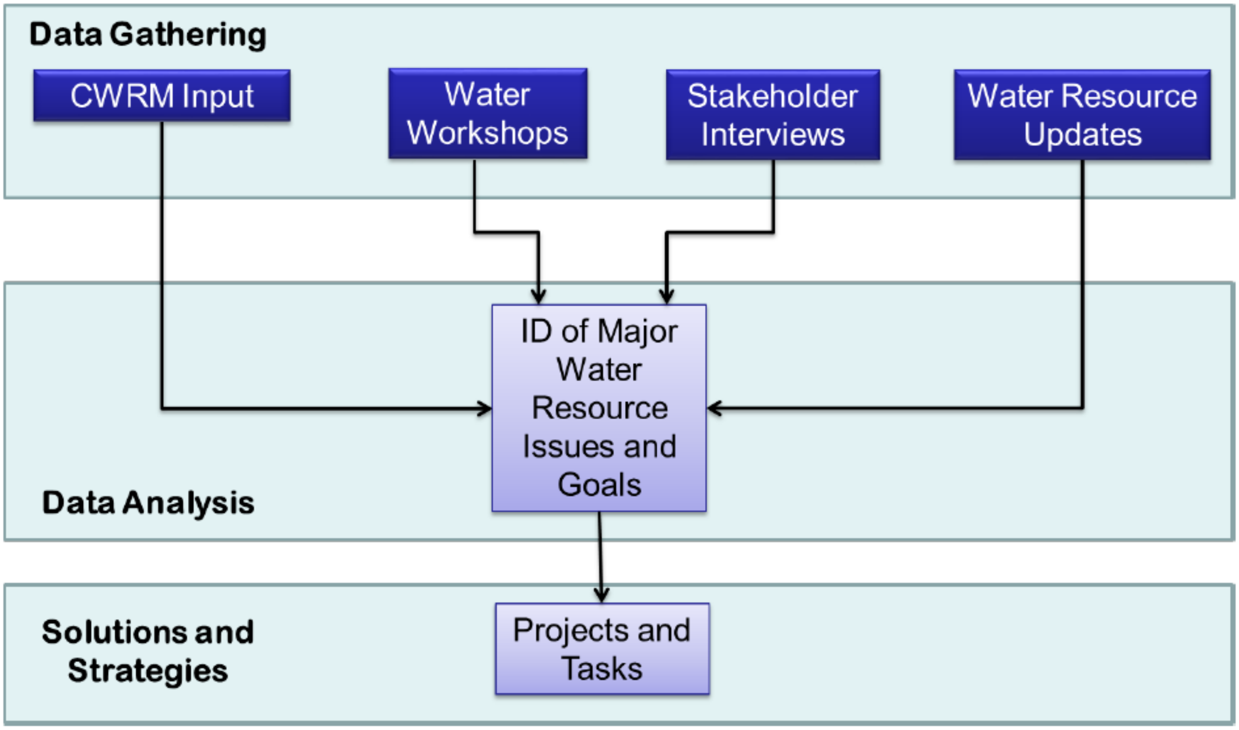
1. Reliable, long-term data is needed to make sound water-management decisions;
2. There is increasing competition for water resources in certain areas;
3. The availability of, and access to, water must be protected for public trust purposes;
4. Aging and inefficient water infrastructure could potentially waste and pollute the resource;
5. Climate change is anticipated to increase water demand and decrease water availability;
6. Man-made pollution threatens fresh water supplies;
7. Land use changes are reducing the replenishment of fresh water sources;
8. Communities feel uninformed and underrepresented in water resource management and decision-making;
9. The priorities and processes for enforcement of State Water Code violations needs to be clear, proactive, and relevant; and
10. Water resource issues are complex and require expertise and management by a diverse group of individuals and entities.

These 10 water resource issues were then grouped under three goals that would address the issues and guide the Commission in identifying and implementing management and protection actions:

1. A solid and up-to-date foundation of data on Hawaiʻi water resources, water use, and water dynamics is used to make water resource management decisions;
2. Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses; and
3. Partnerships, education, and awareness increase collaborative water resource management among government, private, and community entities and the citizens of Hawaiʻi.

A total of 135 individual tasks were identified to meet the goals and address various issues. These tasks were grouped into broader categories resulting in a total of 20 projects to achieve the 3 goals listed above. The following diagram outlines the planning process.

Figure 2. Process for Developing Projects and Tasks for WRPP Action Plan



Each of the 20 projects are included in the WRPP's 5-year Action Plan, but tasks needed to be prioritized to provide guidance to the Commission on what to focus on in the near-term. To determine which tasks the Commission will actively seek to initiate and/or implement within the next five years (when the next update of the WRPP is anticipated), tasks were put through a two-tier prioritization process where they were scored against a set of seven prioritization criteria, listed below:

1. Task is a required service or product that, (a) is mandated by the State Water Code, Administrative Rule, or Court Decision; (b) impacts core foundational Commission services or products; and/or (c) is depended on by other projects, programs, or services.
2. Task is in strategic alignment with the Commission's Vision, Mission, Goals, and Policies.
3. Task reduces or mitigates risk or negative impact on water resources and/or the public.
4. Task has value to the public.
5. Task addresses an existing or foreseeable conflict.
6. Task can be leveraged by other users or partners, adds value for external partners, increases positive collaborative efforts, or strengthens relationships with stakeholders.
7. Task costs can be shared among other government agencies, academic institutions, private individuals/entities, non-profit organizations, and/or community groups/individuals.

The 20 projects and respective priority tasks are the basis of the Action Plan (Exhibit 1, pages 60-70). This ensures that all major issues identified during the research, update, and stakeholder outreach process were addressed in some fashion. Tasks that were not included in the near-term Action Plan are still considered important and are compiled in an appendix to the WRPP, to be implemented as opportunities and funding sources arise. As with any plan, the WRPP should be regarded as a guide for future and immediate action and should not be so rigid as to not be adaptable to future conditions, new information, or opportunities.
It should also be noted that the tasks in the Action Plan are in addition to the staff's ongoing daily

activities and responsibilities, such as permitting, enforcement, resource monitoring, resource assessments, complaint and dispute resolution, document reviews, plan updates, information requests, and public outreach.

Following the development of the draft WRPP update, the staff briefed the Commission at its September 18, 2018 meeting then published a 90-day notice of public hearings on the proposed amendment to the Hawaiʻi Water Plan, as required by law. In February 2019, a total of seven public hearings were held across the state on Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, West Hawaiʻi, and East Hawaiʻi. Over 250 oral and written comments were received from 50 individual testifiers. By far, the most comments focused on the need for additional data collection, followed by concerns regarding the profiting off water by corporations and competition with private development water uses versus public rights to water, reflecting comments heard during the water workshop public outreach effort. There was also considerable testimony on the need for streamflow restoration, protection for traditional and customary practices, and concerns about water quality.

Contemporaneous water issues on certain islands were also the focus of comments gathered at the public hearings. On Kauaʻi, the Commission's proposed amendment of the interim instream flow standard for the Wailua hydrologic unit is pending, so many commenters expressed the need for restoration of flows to Waiʻaleʻale and Waikoko Streams and concern over private use of water. In Hilo, Piʻilani Partners' proposed bottling water plant, which at the time of the public hearing had a Special Management Permit pending before the Windward Planning Commission, was the focus of much of the testimony. In Kona, the proposed reduction in the sustainable yield of the Waimea Aquifer System Area (ASYA) from 24 million gallons per day (mgd) to 16 mgd generated concerns. Similarly, on Oʻahu, Honolulu Board of Water Supply (HBWS) commented that the proposed reduction of the sustainable yield for the Waiʻalae-West ASYA from 4 mgd to 2 mgd may impact their ability to meet demands. (Future implications for these latter two issues are further discussed in the following section.)

Other common themes included support for local agriculture; banning water use for certain activities such as bottled water, dairy farms, and golf courses; and strengthening protection for public trust purposes. Many comments did not request or result in changes to the draft plan. Non-substantive changes were made in response to comments requesting minor corrections to wording to provide greater clarity, or to include additional citations or references. The final draft WRPP update is available at https://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/wrpp/.

WRPP ISSUES

Should the Commission adopt the updated WRPP as currently drafted, there will be future implications resulting from the following revisions:

- Proposed reduction in the sustainable yield of the Waimea ASYA from 24 mgd to 16 mgd

  Based on the best available scientific and geohydrologic information, staff is proposing to combine the Waimea and ʻAnaehoʻomalu Aquifer System Areas into a single hydrologic unit. The analyses of recharge calculations, surficial versus subsurface geologic formation characteristics, and ground water monitoring data that culminated in this boundary modification proposal has been ongoing since 2013. At the June 18, 2019 Commission meeting, staff presented its rationale for the proposed boundary amendment. A public hearing will be held on October 3, 2019. Staff anticipates bringing the matter back to the Commission for a vote at its regular meeting on November 19, 2019. Exhibit 2 contains a draft submittal containing the staff's rationale for the proposed boundary amendment.

The WRPP is a living document that can and has been modified over time following the process laid out in the State Water Code. Staff will publish addenda to the WRPP to inform any interested persons of the current WRPP provisions pending its next review and recompilation in about 5 years.

- Proposed reduction in the sustainable yield of the Wai'alae-West ASYA from 4 mgd to 2 mgd

  Based on the staff's analysis of the best available groundwater monitoring data (Exhibit 3), staff is proposing to reduce the sustainable yield of the Wai'alae-West ASYA from 4 mgd to 2 mgd. Current permitted uses are 2.797 mgd, with all the permitted use held by HBWS, except for 0.460 mgd held by Kamehameha Schools. With the planned 0.25 mgd increase in pumpage at HBWS' Well No. 1747-005 (Primary Urban Center Watershed Management Plan, Agency Review Draft), this would bring total permitted uses in the Wai'alae-West ASYA to 3.047 mgd. Similar to what occurred in the past when sustainable yield reductions have resulted in over-allocation situations, the staff will meet with HBWS to discuss possible step-down plans or other strategies to bring permitted uses and actual pumpage to within sustainable yield levels in order to protect the long-term viability of the aquifer.

WRPP MINIMUM REQUIREMENTS

As noted above, the State Water Code outlines specific elements that must be included in the WRPP. Table 2 reiterates these minimum requirements and identifies the section in the plan that address and satisfy these requirements.

Table 2. WRPP Required Elements

WRPP Element	WRPP Appendix
Nature and occurrence of water resources in the State	F – Inventory and Assessment of Water Resources
Hydrologic units and their characteristics, including the quantity and quality of available resource, requirements for beneficial instream uses and environmental protection, desirable uses worthy of preservation by permit and undesirable uses for which permits may be denied	C – Legal Authorities and Guidance F – Inventory and Assessment of Water Resources I – CWRM Regulatory Programs M – Water Quality
Existing and contemplated uses of water, identified in the water use and development plans of the State and the counties, their impact on the resource, and their consistency with objectives and policies established in the WRPP	H – Existing and Future Demands
Programs to conserve, augment and protect the water resource	F – Inventory and Assessment of Resources G – Monitoring of Water Resources

	Resources I – CWRM Regulatory Programs J – Resource Conservation and Augmentation L – Watershed Protection M – Water Quality P – Administrative and Civil Penalty Guideline

ENVIRONMENTAL REVIEW (Chapter 343, Hawai'i Revised Statutes (HRS))

This planning study is exempt from the application of HRS Chapter 343 pursuant to HRS §343-5(b) and Hawai'i Administrative Rule §11-200-5(d). This is for a planning-level study and will not involve testing or other actions that may have a significant impact on the environment.

RECOMMENDATION

Staff recommends that the Commission adopt the updated 2019 Water Resource Protection Plan.

Ola i ka wai,

M. KALEO MANUEL
Deputy Director

Exhibit(s):
1. Updated Water Resource Protection Plan (without appendices, which are available at `https://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/wrpp/`.
2. Draft Staff Submittal for Proposed Combination of the Waimea and 'Anaeho'omalu Aquifer System Areas
3. Staff Analyses of Wai'alae-West Sustainable Yield

APPROVED FOR SUBMITTAL:

SUZANNE D. CASE
Chairperson

Hawaiʻi Water Plan

WATER RESOURCE PROTECTION PLAN

2019 UPDATE

State of Hawaiʻi
Commission on Water Resource Management

Townscape, Inc.

EXHIBIT 1

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Figures

Tables

Appendices

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1 Introduction

Ola I ka wai a ka `ōpua
There is life in the water from the clouds

-ʻŌlelo Noʻeau: Hawaiian Proverbs and Poetical Sayings,
Mary Kawena Pukui

1.1 Importance of Water in Hawaiʻi

The Hawaiian Islands are some of the most isolated islands on earth, located approximately 2,500 miles from the nearest continent. Surrounded as they are by the ocean, the six major populated Hawaiian Islands – Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, and Hawaiʻi - are solely reliant on precipitation to meet drinking water and all other freshwater needs. Unlike the continental United States, Hawaiʻi does not have the ability to transport freshwater from one county to another, thus careful and wise management is critical to sustain this most precious life-giving resource.

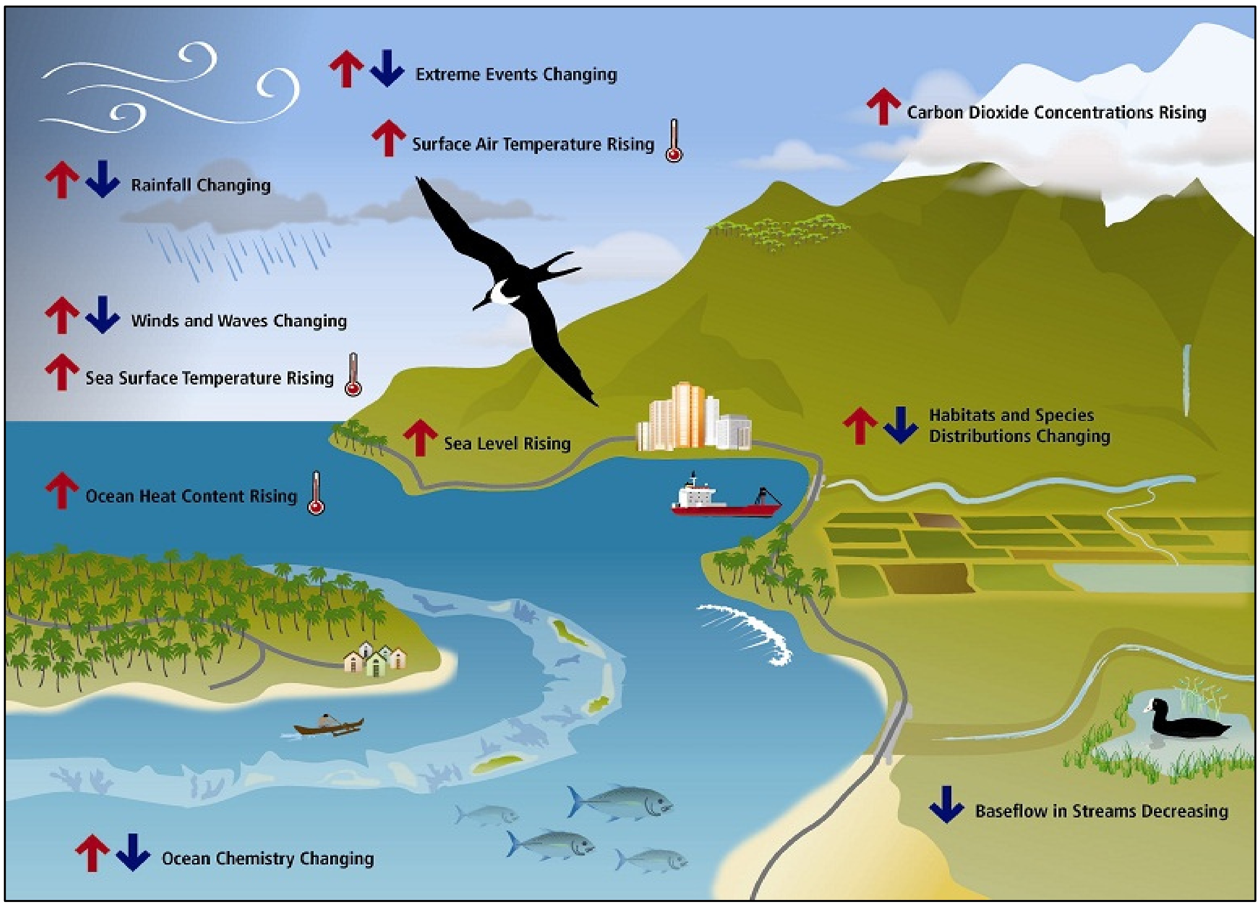
Ancient Hawaiians understood the critical importance of fresh water. According to moʻolelo (stories) passed down from generation to generation, fresh water streams and springs were created throughout Hawaiʻi by the gods Kāne and Kanaloa. This established a spiritual connection between the indigenous inhabitants of the islands and the resource that is so vital to life. The importance of water in Hawaiʻi is also evidenced in the many place names that include “wai”, as well as important words, such as those describing wealth (waiwai) and law (kānāwai). In accordance with their reverence and respect for water, land management units were organized around freshwater supplies in a traditional system known as the ahupua’a resource-management system. Water was viewed as such a critical resource to the health and well-being of the people of ancient Hawaiʻi, that the concept of private ownership did not exist. Today, our State Constitution and Water Code (**Hawaii Revised Statues Chapter 174C**) continue to reflect these traditional values by declaring that Hawaiʻi’s water resources are part of the public trust.

Photo credit:
https://douglaspooloatolentino.files.wordpress.com/2011/10/kanekanaloa.jpg,

1.2 The Need for Long-Range Water Planning

To ensure the long-term protection of the water resources trust, the State Water Code recognizes the need for a program of comprehensive water resources planning. The Hawai'i Water Plan, a multi-component, long-range plan, fulfills this need. Comprised of five component plans, each prepared by a different agency, the Hawai'i Water Plan seeks to protect, conserve, and enhance the quantity and quality of existing water resources, while providing for existing and future water demands within each county through an integrated water resource management approach.[1]

Figure 1-1 Indicators of Climate Change in the Pacific Islands Region



Source: Keener, V.W., Marra, J.J., Finucane M.L., Spooner, D., & Smith, M.H. (Eds.). (2012). Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment (PIRCA).Washington, D.C.: Island Press

[1] For more information about the Hawai'i Water Plan and its component plans, visit http://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/

The need for water resources planning and sustainable management has never been greater. Hawaiʻi's population is projected to increase by about 20% from 2010 to 2040,[2] and with it, the demand for more drinking water. Balanced against that is the growing awareness of Hawaiian water rights and the recognition of environmental needs and the critical ecosystem services that are dependent on healthy watersheds and natural water flows. Hawaiʻi's land use is in flux. The cessation of sugarcane plantation agriculture is resulting in large swaths of productive agricultural lands becoming available for new land uses, creating opportunities to rebalance instream and offstream needs and fostering greater use of alternative water sources.

The future impact of climate change on water resources is still being studied but the best available information indicates that, for the most part, the impact will be negative. Scientists have already observed decreases in rainfall over the last 30 years, along with an associated decline in stream flows. This uncertainty requires both a precautionary and adaptive approach to water management to ensure the long-term protection of our water resources while providing flexibility for revisions of prior decisions in light of new and better information.

The Water Resource Protection Plan (WRPP) is the component of the Hawaiʻi Water Plan that seeks "to protect and sustain statewide ground and surface water resources, watersheds, and natural stream environments."[3] The WRPP is prepared by the State Commission on Water Resource Management (CWRM), which is established as the primary trustee of the water resources trust under the State Water Code. Among other things, the WRPP includes:

- General water resource management principles and policies;
- The nature and occurrence of water resources in the State;
- Hydrologic units for ground and surface waters and sustainable limits for water supply (i.e., ground water sustainable yields and surface water instream flow standards);
- Existing water uses and projected future demands;
- Programs for hydrologic data collection and analyses;
- Regulatory authorities and permitting systems; and
- Studies and programs to conserve and augment water resources.

Based on a comprehensive review of the current state of water resources and management, the WRPP identifies emerging threats, unresolved issues, management gaps, and recommended actions to further sustainable water management. Initially adopted in 1990, the WRPP was last updated in 2008.

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[2] Research and Economic Analysis Division, Department of Business, Economic Development and Tourism. March 2012. *Population and Economic Projections for the State of Hawaii to 2040, DBEDT 2040 Series*.
[3] Statewide Framework for Updating the Hawaiʻi Water Plan, February 2000, p. 3-1

1.3 Vision, Mission, and Guiding Policies

Our Vision	*Flowing streams, sustainable aquifers, and functioning watersheds for the use, enjoyment, and benefit of all.*
Our Mission	*To protect and manage the waters of the State of Hawai'i for present and future generations.*

Guiding Policies

A policy is a statement that guides decision-making. As such, policies should be as clear and universally applicable as possible. CWRM's management actions and decisions are guided by policies, which are derived from statements in officially adopted documents, such as the State Constitution and State Water Code, and from CWRM and Supreme Court decisions on specific cases that laid the foundation for future decisions and actions. CWRM's guiding policies include:[4]

1. **The Public Trust Doctrine: The title to water resources is held in trust by the state for the benefit of its people.**
2. **The State recognizes four public trust purposes:**
   (a) maintenance of waters in their natural state;
   (b) domestic water use of the general public, particularly drinking water;
   (c) the exercise of Native Hawaiian traditional and customary rights; and
   (d) reservations of water for Hawaiian Home Lands.
3. **The Precautionary Principle: The State has a duty to take anticipatory action to prevent harm to public resources.**
4. **Apply adaptive management principles in the face of scientific uncertainty.**
5. **The State Water Code shall be liberally interpreted.**
6. **The State Water Code shall be applied in a manner that conforms to the intentions and land use plans of the counties.**
7. **Comprehensive water resources planning is needed for proper management and protection of the resource.**
8. **High standards of water quality shall be maintained.**
9. **Provide for public interest objectives while seeking to obtain maximum reasonable and beneficial use of waters of the state.**
10. **Quality of the water source should be matched to the quality of the water needed.**
11. **If there is a practical alternative water source available, that alternative source should be used in lieu of natural supplies.**
12. **Water use should be efficient, and waste of water is disallowed.**
13. **Appurtenant rights shall be assured.**

[4] For additional discussion on the following policies, please refer to **Appendix C Legal Authorities and Guidance**).

2 The Current State of Water Resources and Management Tools

Current and best-available information on water resources was gathered to identify technical water-related issues that need to be addressed. **Section 2.1** summarizes the water resource issues identified by the community and stakeholders during the CWRM public outreach process. **Section 2.2** describes the state of water resources in Hawai‘i and CWRM programs to manage and protect those resources. **Priority Recommendations** and the Action Plan describes the actions designed to address issues and program management gaps found in **Section 2.1** and **Section 2.2**.

2.1 Water Resource Issues

In order to find out how the public perceives and understands Hawai‘i ‘s water resources, CWRM held public meetings, and met with stakeholders and subject matter experts around the state. Ten key issues were distilled down from information gathered during these interactions. These issues are shown below in bold typeface and followed by a brief description of the issue.

Reliable, long-term data is needed to make sound water-management decisions.

To make sound decisions, water managers need reliable data. Longitudinal data provides the best information for identifying trends in water availability and use and can be helpful in predicting future scenarios to plan for. Monitoring of ground water and streams allows for an accounting of how much water there is, whether natural flows are sufficient for environmental and cultural needs, and how water is made available for human use. Despite current efforts, ground and surface water is not monitored as completely as it should be and the number of stream flow monitoring stations continues to decrease. This makes it difficult to understand long-term temporal and spatial changes in water resources and availability and the impacts of climate change on our water supplies.

In addition to monitoring of the resource itself, managers require an understanding of human water demand to be able to balance various water needs. Therefore, it is critical to have an accurate accounting of water use by various sectors, such as agriculture, domestic consumption, landscape irrigation, and industrial uses. Each owner or operator of a water source (i.e., wells or stream diversion works) is required to report their monthly water use; however, not all owners/operators are compliant. **Table 2-1** below shows the compliance rate for ground water use reporting.

Table 2-1 Water Use Reporting by Island 2016

Island	Total # of Production Wells[1]	# Wells Reporting Water Use	Compliance Rate
Kauaʻi	288	139	48.3%
Oʻahu	818	491	60.0%
Molokaʻi	89	40	44.9%
Lānaʻi	10	10	100.0%
Maui	567	240	42.3%
Hawaiʻi	927	331	35.7%
TOTAL	2,699	1,251	46.4%

1. Production Wells are defined as all wells that are not abandoned, observation, or unused wells.

Analysis of data provides critical guides for water management, such as the sustainable yield of ground water aquifers and instream flow standards for streams; whether existing regulatory controls are working; or whether additional regulation is needed. Water demand projections help to predict the amount of water needed in the future, allowing for early planning at the county level to identify the adequacy of existing resources and infrastructure, plan for the development of alternative sources, determine the need and opportunities for increased conservation and potential reallocation of water, and inform future land use plans and policies.

Water resource management needs to consider all the above considerations of demand, supply, and future water scenarios with decisions only made better with improved and long-term data and analysis. Strategic and coordinated resource monitoring, such as a network of deep monitor wells, stream flow gages, and climate stations would allow for the verification of sustainable yields, contribute to the monitoring of recharge trends in critical ground water aquifers, and provide valuable data for the understanding of ground water/surface water interactions, and the calculation of instream flow standards and surface water allocations. Such monitoring can also be used to study trends attributable to climate change and predict future needs and resources.

Improved water use reporting is another critical component to understanding water needs and availability. Reporting systems should be made as user-friendly as possible and outreach should be conducted to encourage compliance with reporting requirements. Enforcement should also be used to ensure that reporting requirements are met.

There is increasing competition for water resources in certain areas.

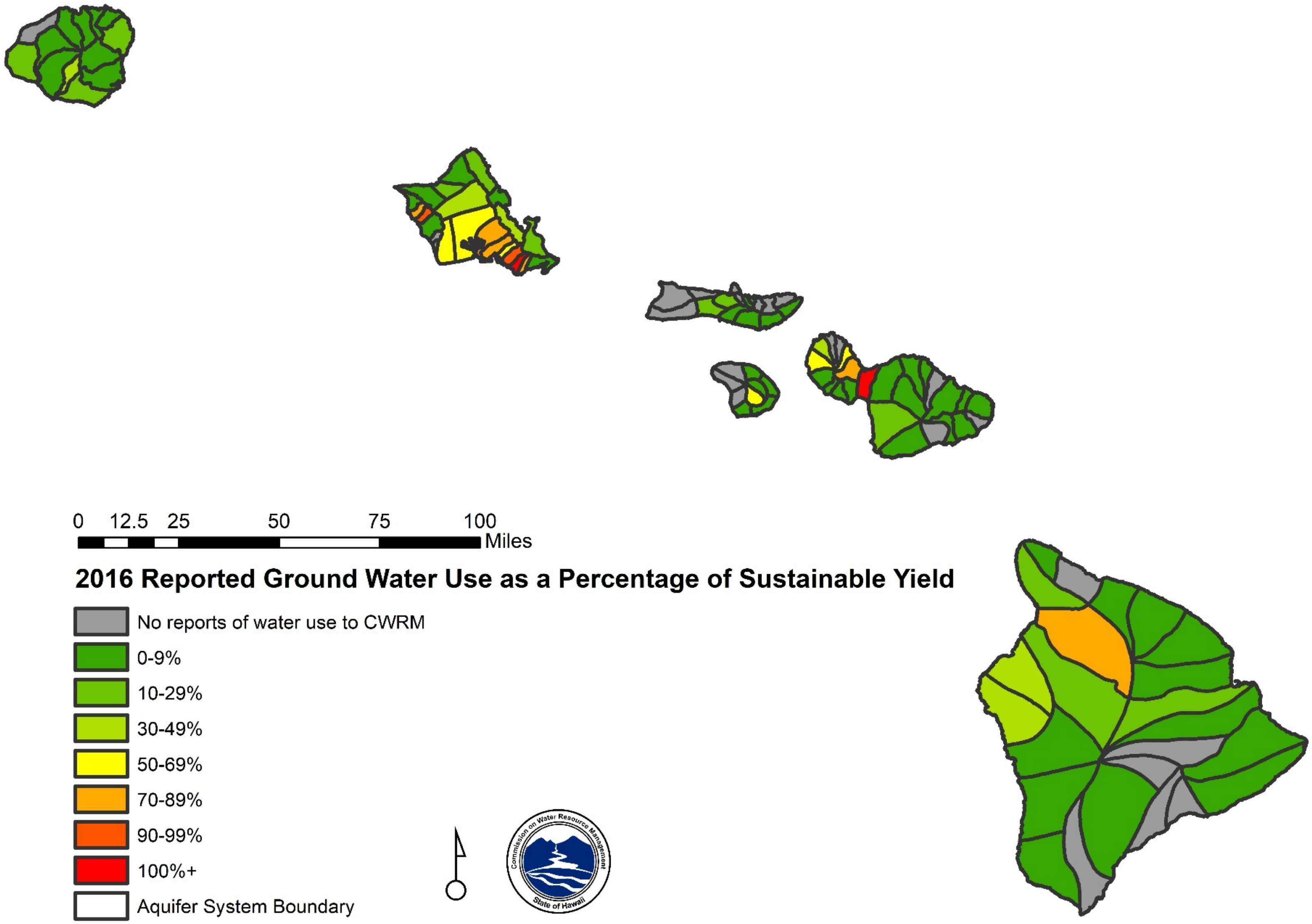
Human consumption of water resources continues to increase as Hawai'i's population grows and demand for domestic, commercial, industrial, and landscape and agricultural irrigation increases. Societal needs must be balanced against the need to maintain waters in their natural state for environmental uses and ecological health. Additionally, there has been a resurgence in traditional uses of water resources, which often rely on surface water sources and coastal springs for traditional and customary practices and subsistence activities. Such diverse uses of water may result in total demand in some areas exceeding ground water supplies, surface water supplies, or both.

Demand for water resources continues to increase as more and more users compete for both ground and surface water. The State Constitution states that "All public natural resources are held in trust by the State for the benefit of the people."[5] It is CWRM's duty to protect water resources in accordance with its public trust responsibilities. Hawai'i has recently experienced a multi-year drought and climate change is expected to increase the occurrence of drought in some areas of the state.[6] Proactive planning at the State, County, and individual user level, as well as coordination among all, is needed to minimize negative impacts to the resource, communities, and the economy.

Competition for water resources brings increased urgency for aggressive conservation measures that ensure that water is not wasted or lost. Additionally, alternative water sources, such as recycled water and storm water, offer lower quality water that can be used for non-potable needs, reserving high quality water for potable uses, such as drinking and food preparation. Desalinated could also provide high quality water to supplement potable water supplies. As emerging technologies, potential alternative water users and the public need to be educated on the benefits and actual impacts of using such sources and alternative water providers need guidance from regulators and scientists to ensure that public health and the environment are protected

[5] Constitution of the State of Hawai'i, article XI, §1.
[6] Keener, V.W., Marra, J.J., Finucane M.L., Spooner, D., & Smith, M.H. (Eds.). (2012). Climate Change and Pacific Islands: Indicators and Impacts. Report for the 2012 Pacific Islands Regional Climate Assessment (PIRCA).Washington, D.C.: Island Press

Figure 2-1 2016 Reported Ground Water Use as a Percentage of Sustainable Yield



The availability of, and access to, water must be protected for public trust purposes.

The Hawai'i State Constitution recognizes that water resources are part of the public trust. The Hawai'i Supreme Court further established the following four public trust purposes: (1) maintenance of waters in their natural state; (2) domestic water use of the public, particularly drinking water; (3) the exercise of Native Hawaiian and traditional and customary rights, including appurtenant rights; and (4) reservations of water for Hawaiian Home Land allotments.[7]

It has been especially difficult to plan for traditional and customary rights, as practices are site specific, there are no databases of practices from which to plan for, and many practices are not shared publicly. Nonetheless, the State has an obligation to protect traditional and customary practices and should account for them in any natural resource planning effort. To do so, there needs to be a better understanding of the public trust purposes, guidance on how to incorporate public trust needs into decision-making, and education and outreach to water users and managers to understand those needs and management considerations.

Aging and inefficient water infrastructure could potentially waste and impact the quality of the resource.

Much of Hawai'i's water infrastructure was constructed decades ago. There are many ground water wells that are no longer in use and have not been properly sealed, providing potential conduits for contamination of ground water aquifers. Some older wells also do not have flow control devices that manage pumpage volumes and measure flow, making it difficult to monitor usage and minimize waste. Similarly, some stream diversions and large-scale agricultural irrigation systems are no longer used for their original purpose, are leaking and inefficient, and do not have flow control devices.

Water use reporting may be used to identify unused water infrastructure and prioritize wells and diversions for sealing and removal. Large agricultural irrigation systems are inventoried by the State Agricultural Water Use and Development Plan, which provides information on the current rehabilitation and maintenance needs for each system. This agricultural water needs assessment should include in their analyses important agricultural lands and the volumes of water needed, as well as the parties responsible for maintenance of these legacy irrigation systems.

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[7] The Supreme Court decision No. 21309 *In the Matter of the Water Use Permit Applications, Petitions for Interim Instream Flow Standard Amendments, and Petitions for Water Reservations for the Waiāhole Ditch Combined Contested Case Hearing* ("Waiāhole I"), *Section III. Discussion, B. The Public Trust Doctrine, 3. The State Water Resources Trust, b. Substance of the Trust, i. Purposes of the Trust* (2000) established the first three public trust purposes. The Supreme Court decision No. *22250 In the Matter of the Contested Case Hearing on Water Use, Well Construction, and Pump Installation Permit Applications, Filed By WAI'OLA O MOLOKA'I, INC. and MOLOKA'I RANCH, LIMITED, Section III. Discussion, A. The Commission's Decision Violated DHHL's Reservation Rights As Guaranteed by the HHCA, The Hawai'i Constitution, The Code, And The Public Trust Doctrine, 3. Reservations of water constitute a public trust purpose, which the commission has a duty to protect in balancing the competing interests for a water use permit application* (2004) established the fourth public trust purpose.

Climate change is anticipated to increase water demand and decrease water availability.

Climate change is expected to result in many water resource changes, including intensified flooding and drought, reduced recharge to ground water aquifers in leeward areas, elevation of basal aquifers due to sea level rise, and higher water use. In general, researchers expect wet areas in Hawaiʻi to get wetter and dry areas to get drier. However, there is considerable uncertainty in future predictions of climate. This will change water demands and supplies in some areas and require adaptation in demand management, water infrastructure, and distribution.

Proactive planning is needed for such climate change scenarios, including projected water demands and expected water availability in localized areas. Continued research is needed to refine climate change predictions for Hawaiʻi as new information is made available and our understanding of this phenomenon is improved.

Man-made pollution threatens fresh water supplies.

The availability of water for human use and consumption is affected not only by the amount of water that is in our ground water aquifers and in our streams; the quality of our water resources also impacts what is available for use. In general, Hawaiʻi's water quality is very good, with ground water requiring little treatment before being distributed for consumption. However, over the years, land uses have intensified and encroached over aquifers, increasing the potential for ground water contamination. Similarly, some land uses may increase the potential for erosion and surface runoff that transports sediment and other pollutants into streams and nearshore waters.

The State Department of Health oversees programs that protect the quality of surface and drinking water, County water departments are responsible for the quality of the drinking water they provide their customers, County environmental services departments manage polluted runoff control, and County planning departments have jurisdiction over land uses. Coordination among these entities and CWRM will ensure clean, healthy waters for drinking and public and environmental health.

Land uses changes are reducing the replenishment of fresh water sources.

To manage our water resources and ensure supplies for cultural needs, human consumption, and ecological sustainability, we need to understand the dynamics of hydrology, ecosystem function, and the impacts of land use and human water use on the resource. Some land uses impact water resources not only in their demands for water, but also in how water supplies are replenished. For example, urban development increases the impervious surfaces (hard surfaces that water cannot seep through). In these areas, less water can soak into the ground replenishing ground water aquifers, and more water runs off into streams. Some land uses also divert or hold back surface water, making it unavailable for uses downstream.

Continued understanding of hydrologic patterns and functions can inform strategies for source water replenishment. Long-range planning that seeks to minimize impacts on the natural flow of water should be used as a tool to protect critical water sources. Low impact development has also been identified as one way to restore some pre-development hydrologic functions by allowing storm water to infiltrate into the ground, rather than run off into drainages.

Communities feel uninformed and underrepresented in water resource management and decision-making.

Water resource management has often been left to government, scientific researchers, and other "experts." As communities become more informed about water resources, they are calling for more information on sources, uses, and water resource health and for the ability to participate in managing their water resources.

As beneficiaries of the public trust and direct users of water resources, the public can and should have a significant role in understanding water resources and its management. But for this to occur, there must be opportunities for information exchange and participation in the decision-making process. Opportunities must exist for government to share water resource and user data and to receive information on uses, users, needs, and observations from those who are affected by management decisions. At the same time, the public also needs to be receptive to the decision-making process, to the multiple demands that must be weighed, the tradeoffs that must be made, and to legal obligations and judicial precedent.

The priorities and processes for enforcement of State Water Code violations need to be clear, proactive, and relevant.

Effective management of any resource requires clear, thoughtful guidance and timely and fair penalties for violations. Many violations go unchecked due to the sheer number of water sources and permits in existence throughout the state and the limited number of staff, none of which are dedicated solely to investigating and correcting violations. Additionally, penalties have been criticized as arbitrary and not fitting of the severity of the violation. Compliance with water management permits and policies, such as reporting of water use or constructing a well or diversion, could benefit from developing enforcement priorities and processes. Updates and refinements to the regulatory process, enforcement policy, and penalty system could also address these concerns.

Water resource issues are complex and require expertise and management by a diverse group of individuals and entities.

Water is a complex resource that touches many facets of daily life and each person in unique ways. While we continue to learn more about the science of water, we have even more to learn about the ecology and cultural and spiritual links of people to water. With water's importance to everyone and with so much to understand, it is necessary that many sources of knowledge and perspectives are accounted for. All levels of government need to partner with private entities, scholars, and communities to monitor the resource, bring forth information and perspectives, and to plan for the future.

Water does not exist in isolation. It cannot be managed in a vacuum, separate from what is going on around it. Therefore, water must be planned for in a holistic way, considering ecological needs and land uses, as well as human needs.

2.2 Current Knowledge of Water Resources and Available Management Tools

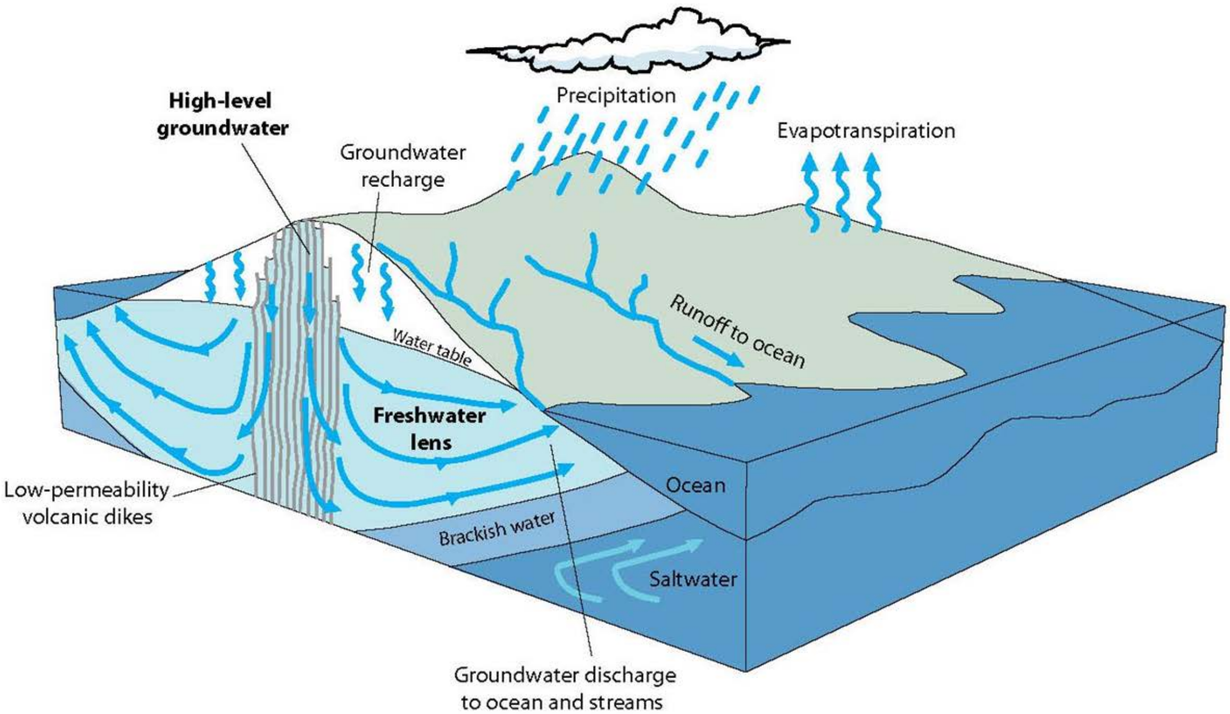
Water resources is a very complex subject in Hawai‘i. This section summarizes major water resource management topics and related issues to provide readers a fundamental understanding of how CWRM assesses and analyzes data and information – and how these analyses inform the development of tools and implementation of programs to manage water resources across the State of Hawai‘i. As part of this discussion, any program gaps, deficiencies, or issues are identified along with recommendations to address them.

The following sub-sections follow the order of the topical information contained in the appendices of the WRPP Update

2.2.1 The Hydrologic Cycle

The hydrologic cycle refers to the constant movement of water between the ocean, the atmosphere, and the Earth, and includes precipitation, infiltration and recharge, runoff, and evapotranspiration (**Figure 2-2**). **Evapotranspiration** is the loss of water from soils, canopy, and open water bodies through evaporation and the transfer of water from plants to the air through transpiration. Moisture in the air is carried by trade winds up mountain sides, where it cools and condenses, and finally falls to the land surface as **precipitation** (i.e., rain or fog drip). Plants immediately absorb and use some of the rain and fog drip, but the remaining volume of water **infiltrates** through the ground surface, **runs off** to the ocean or streams, **evaporates** into the atmosphere, or ends up **recharging** the ground water aquifers. Additional explanation of the hydrologic cycle may be found in **Appendix F**.

Figure 2-2 Hydrology of Ocean Islands



Source: USGS Pacific Islands Water Science Center (http://hi.water.usgs.gov/studies/GWRP/islhydro.html)

As rainwater wets the land surface, shallow infiltration saturates the uppermost soil layer and replaces soil moisture used by plants. Thereafter, excess water percolates slowly downward to recharge ground water bodies and support stream flow in perennial sections. However, human activities can alter infiltration and runoff patterns by changing the permeability of ground surfaces, thus encouraging or inhibiting infiltration of water into ground water aquifers.

Program Issues: To quantify and make accurate estimates of water availability, it is important to collect data and observations of individual hydrologic cycle processes over a long period of time. This includes observations of precipitation (rainfall), evapotranspiration, runoff (stream flows) and the ground water column.

Recommended Projects: Project 1.1, Project 1.2, and Project 1.4

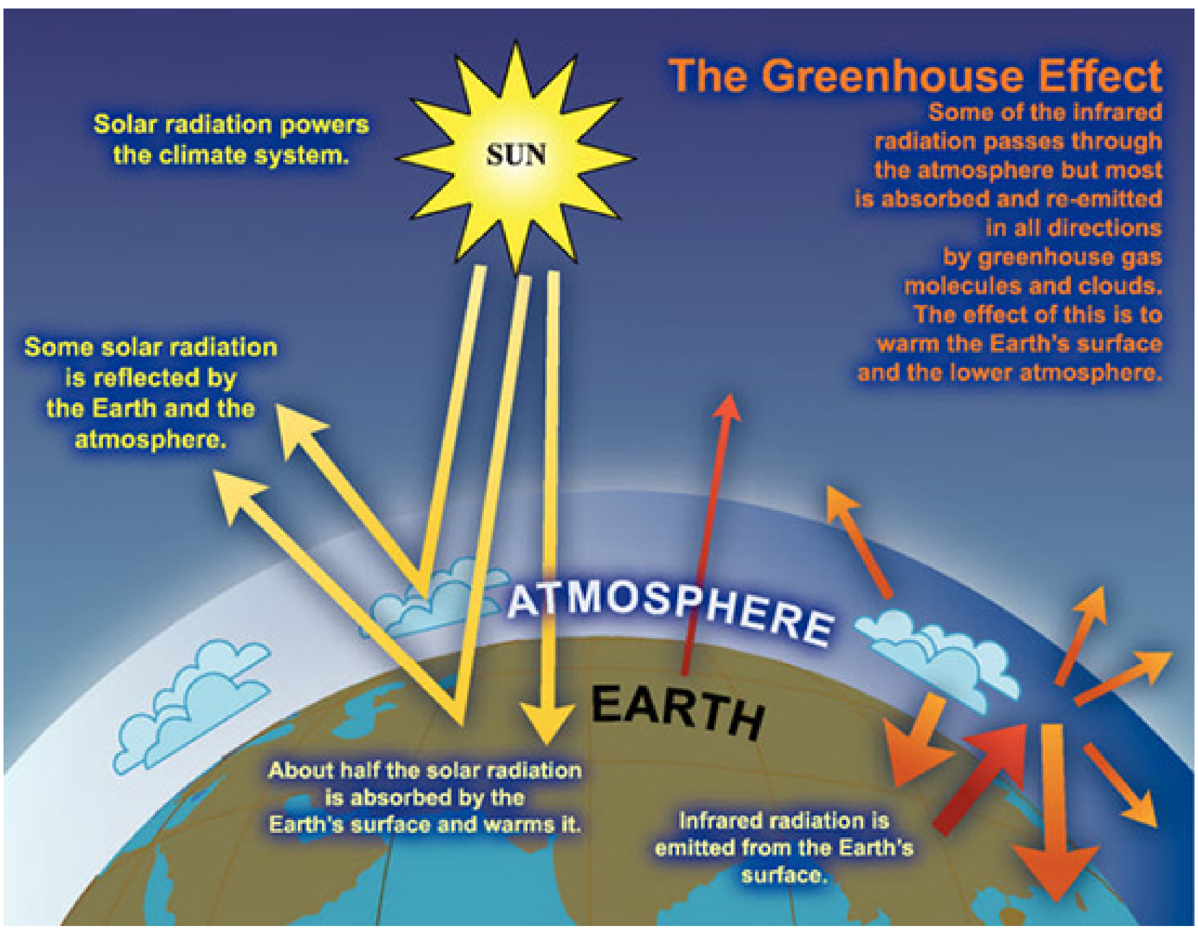
2.2.2 Climate Change

Climate change is "a change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity."

-United Nations Intergovernmental Panel on Climate Change (IPCC, 2007)

Greenhouse gases such as carbon dioxide (CO_2) absorb heat, or infrared radiation, from the Earth's surface, trapping heat in the atmosphere that would otherwise escape into space. While these gases occur naturally, the industrial age resulted in an increase in the burning of fossil fuels and deforestation, which increased their concentrations in the atmosphere. Results of greenhouse gas increases are warming of the Earth's oceans and air, changing precipitation patterns, melting snow cover and ice sheets, ocean acidification, and rising sea levels, which in turn lead to further impacts on natural processes.

Figure 2-3 An Idealized Model of the Natural Greenhouse Effect



Source: *Intergovernmental Panel on Climate Change, 2007, IPCC Fourth Assessment Report: Climate Change 2007. Ch.1*

Locally, Hawai‘i has experienced changes in measured precipitation and stream flows[8] and is expected to also experience the following water-resource-related impacts from climate change:

- **Decrease/increase in potable water supplies across the region, changing frequency and intensity of climatic extremes.** Drought has been more frequent and prolonged, and there have been fewer tropical cyclones. Over the past century rainfall has decreased across the region. Average surface air temperatures are rising, especially at high altitudes. Ground water discharge to streams has significantly decreased over the past 100 years. This trend indicates a decrease in ground water storage[9]. However windward sides will become wetter during the wet season and leeward sides are expected to become drier in the dry season;[10]

- **Increase in potable and non-potable water demand** for municipal and agricultural uses may result from increases in air temperatures,[11] increases in evapotranspiration and longer and more frequent droughts;

- **Decrease in ground water discharge to streams** due to decreases in rainfall and decreases in fair weather flows from springs and seeps from high level aquifers;[12]

- **Impacts on water supply infrastructure** due to sea level rise and associated inland and coastal flooding, increasing corrosion of metallic pipelines resulting in more main breaks and higher repair and replacement costs;

- **Large increases in the costs of water supply infrastructure and flood mitigation measures** due to this complex array of climate change impacts on the water systems of Hawai‘i.

Program Issues: It is important to establish and maintain long-term climate monitoring stations to track changes in Hawai‘i’s climate elements over time.

Recommended Projects: Project 1.1, Project 1.5

[8] University of Hawai‘i at Mānoa Sea Grant College Program. June 2014 Climate Change Impacts in Hawai‘i - A summary of climate change and its impacts to Hawai‘i’s ecosystems and communities
[9] Keener, et.al. (2012)
[10] USGS Open File Report 2016-1102
[11] Keener, et.al. (2012)
[12] Ibid

2.2.3 Inventory and Assessment of Resources

To meaningfully plan for and manage water resources, it is important to understand the inventory of water resources statewide; the human impact on those resources; and the issues, challenges, and opportunities for improving management and protection practices. Concerns related to water supply, water quality, and degradation of aquatic environments are frequently at the forefront of water management issues.

> *"Effective policies and management practices must be built on a foundation that recognizes that surface water and ground water are simply two manifestations of a single integrated resource."*
>
> - USGS Circular 1139: Ground Water and Surface Water: A Single Resource

A major issue with water resource management is balancing existing water needs with the availability of water for future generations and environmental needs. Over and above actual water withdrawals, other issues include environmental and safety concerns with the siting and maintenance of water infrastructure, such as reservoirs for storage.

The cumulative effects of land use changes, other human activities, and short- and long-term climate change can shift the natural balance of the hydrologic cycle, having profound social, environmental, and economic impacts within our island communities. CWRM has developed goals to guide sustainable water planning and management activities that seek to continually improve the understanding of water resources, collaborate with stakeholders and other water resource professionals, and apply updated information and best practices toward the management of water resources. Further description of CWRM's goals may be found in **Appendix C**.

Additionally, the interaction of ground water and surface water has been, and continues to be, a significant area of focus and deliberation. Most potable water is drawn from ground water aquifers, potentially having impacts on surface water and coastal leakage, the ecosystems dependent upon them, and associated traditional and customary rights. The interaction between ground and surface water also means that there is the potential for each to impact the water quality of the other. Despite this, typical management of water resources separates ground and surface water resources and the limited understanding of their localized interactions make it difficult to characterize actual processes. However, where interaction exists, monitoring and appropriate ground and surface water management programs are integrated and implemented. Further description of these issues may be found in **Appendix F: Inventory and Assessment of Water Resources**.

2.2.3.1 Nature and Occurrence of Ground Water

Ground water in Hawaiʻi is stored in several different types of aquifers: basal, dike impounded, perched, caprock, brackish, deep confined freshwater. Descriptions of each type of aquifer may be found in **Appendix F: Inventory and Assessment of Resources**. Basal aquifers are the primary source for municipal water in Hawaiʻi. There is a brackish transition zone where the freshwater basal lens meets seawater, with salinity gradually increasing with depth. The upward movement of this transition zone presents a constant potential danger of saline contamination to the freshwater aquifer. Interestingly, previous conceptual ground water models are being modified in response to recent discoveries of freshwater aquifers beneath the salt water underlying basal aquifers on Hawaiʻi Island.

> "Aquifer - *a geologic formation(s) that is water bearing…Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses."*
>
> - USGS Water Science Glossary of Terms
> http://ga.water.usgs.gov/edu/dictionary.html

CWRM established ground water hydrologic units, or aquifers, and assigned each one a unique code to provide a standard method by which to reference and describe ground water resources, facilitate consistent collection and sharing of information amongst diverse governmental and non-governmental entities, optimize ground water development, and implement resource protection measures. Aquifer boundary lines should be recognized as management lines and not strict hydrologic boundaries where ground water flow does not cross. There are 114 aquifers delineated across the islands of Kauaʻi, Oʻahu, Molokaʻi, Lānaʻi, Maui, and Hawaiʻi. Tables of all units by island and accompanying maps of ground water hydrologic unit boundaries may be found in **Appendix F**.

The availability of ground water resources is dependent upon recharge, or the replenishment of fresh ground water, and ground and surface water interactions. However, ground water flow can be difficult to understand and predict because scientists must infer and interpolate its status and characteristics from limited data and modeling tools. CWRM, researchers, and others are constantly working to improve the understanding of ground water flow and the ability to assess the availability of ground water for human consumption.

> *"'Sustainable yield' means the maximum rate at which water may be withdrawn from a water source without impairing the utility or quality of the water source as determined by the commission."*
>
> \- Hawaiʻi Revised Statutes §174C-3

The amount of ground water that can be developed in any aquifer is limited by the amount of natural recharge and aquifer outflow that must be maintained to prevent seawater intrusion, to maintain perennial streamflow, and to sustain the ecosystems dependent upon ground water discharge. CWRM first adopted **sustainable yield** estimates in the WRPP in 1990 and has revised them based on management approaches, new information and modeling techniques, and the identification of errors in previous models or studies. Explanations of how sustainable yields are estimated, as well as maps of hydrologic units and associated sustainable yields, may be found in **Appendix F**.

2.2.3.2 Nature and Occurrence of Surface Water

Surface water generally occurs in areas that contribute to drainage systems that are confined by topographic divides and are referred to as **watersheds**, drainage basins, or catchments. Streams, springs, ditches and canals, and reservoirs are the most common surface water settings in Hawaiʻi. Descriptions of each type of surface water body may be found in **Appendix F: Inventory and Assessment of Resources**.

In 2005, CWRM adopted surface water hydrologic units to provide the same consistency and benefits provided by the establishment of ground water aquifers. There are 558 Surface Water Hydrologic Units statewide. Tables of all units by island and accompanying maps of surface water hydrologic units may be found in **Appendix F**.

> *"Instream flow standard means 'a quantity or flow of water or depth of water which is required to be present at a specific location in a stream system at certain specified times of the year to protect fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses.'"*
>
> \- Hawaiʻi Revised Statutes §174C-3

The State Water Code directs CWRM to "*establish instream flow standards on a stream-by-stream basis wherever necessary to protect the public interest in waters of the State*," and that "*in formulating the proposed standard, the commission shall weigh the importance of the present or potential uses of water from the stream for non-instream purposes, including the economic impact of restriction of such use*." CWRM developed a methodology for establishing measurable interim instream flow standards (interim IFS) based upon best available information, along with input from interested parties and agencies.

Interim instream flow standards are "*a temporary instream flow standard of immediate applicability, adopted by the Commission without the necessity of a public hearing, and terminating upon the establishment of an instream flow standard*." [13] Generally, the interim IFS for all streams in a given region were adopted by CWRM and defined as the "*amount of water flowing in each stream on the effective date of this standard, and as that flow may naturally vary throughout the year and from year to year without further amounts of water being diverted offstream through new or expanded diversions*."[14]

The interim IFS of certain individual streams have subsequently been amended as a direct result of petitions to amend the IFS, contested case hearings, other regulatory actions, and staff initiatives. Interim IFS may be amended by CWRM based on a petition and does not require a formal hearing process. On the other hand, an amendment to an Instream Flow Standard can only be initiated by CWRM. For a discussion of the regulatory process for setting instream flow standards, and references to specific actions amending the interim instream flow standard of specific streams, see **Appendix F**. An inventory of surface water resources, including surface water hydrologic unit codes, unit names, area, number of diversions, number of gages, number of active gages, and interim IFS may be found in **Table F-21 in Appendix F**.

Program Issues: Accurate and timely estimates of water availability require: (1) robust data sets; (2) careful analysis and study of the system; and (3) reports and results that are understandable and usable for resource managers and decision makers.

Recommended Projects: Project 1.2, Project 1.3, Project 1.4, Project 1.7, Project 1.8, Project 2.1

2.2.4 Monitoring of Water Resources

Continuous and consistent water data collection is critical to CWRM's ability to protect water resources. CWRM collects, analyzes, and verifies hydrologic data to provide an understanding of water within a particular area. Ground water data are used to observe empirical trends for changes in water levels, pumpage, salinity and the thickness of the transition zone, and to calibrate computer models that will refine conceptual models and sustainable yield estimates, and surface water data are used in the development of instream flow standards. Under the State Water Code, CWRM is primarily responsible for assessing the quantity issues of ground and surface water resources while the Department of Health (DOH) oversees ground and surface water quality issues with respect to public and environmental health. Please refer to **Appendix M: Water Quality** for more information about DOH programs and plans. CWRM's goals, policies, and objectives that guide and focus water resource monitoring programs and the use of resultant monitoring data may be found in **Appendix G: Monitoring of Water Resources**.

[13] Hawai'i Revised Statutes §§ 174C-3.
[14] Hawai'i Administrative Rules § 13-169-49.1

2.2.4.1 Monitoring of Ground Water Resources

Since ground water provides much of the municipal and drinking water supply statewide and demand for high-quality ground water continues to increase, long-term monitoring data is needed to identify emerging trends and problems, provide a basis for comparison, measure the impacts of water development, detect ground water threats, and determine the best management and corrective measures. On O‘ahu, CWRM, the USGS, and the Honolulu BWS have robust monitoring networks; however, monitoring networks in other counties are not as expansive and data is lacking in many areas.

Ground water monitoring activities in Hawai‘i include deep monitoring wells; water-level observation wells; spring discharge; conductivity; rainfall data; and data from well owners including pumpage, salinity (measured as chlorides or conductivity), water-level, and temperature data. Required, regular reporting by well owners is facilitated through the use of an online water use reporting database, the Water Resource Information Management System (WRIMS), which is able to provide reports on water use and other time-series data by aquifer system area, island, user, type of use (e.g., domestic, municipal, and agricultural), and other source information and documentation.

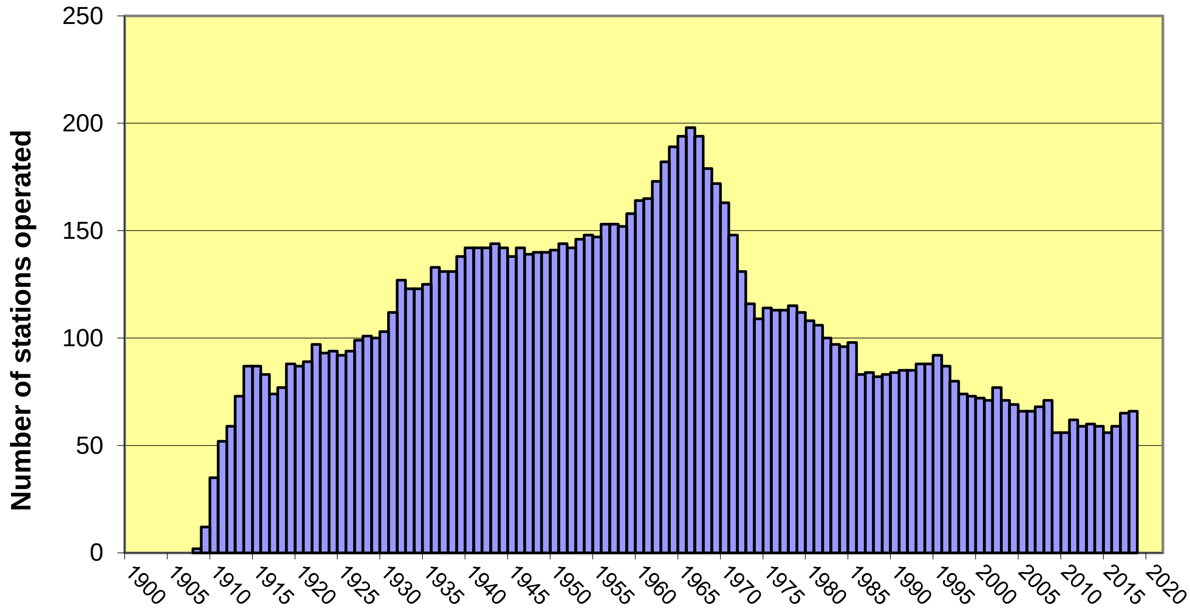
CWRM utilizes several tools to manage information on ground water including: a well index database, verifications of ground water well sources, a digital library of published Hawai‘i related hydrologic reports, and water use reports submitted by individual well owners or operators. These tools, as well as descriptions of monitoring programs, including a complete list of registered observation and deep monitor wells, and the identification of gaps in ground water monitoring activities and recommendations for improving the monitoring of ground water resources, are described in **Appendix G**.

2.2.4.2 Monitoring of Surface Water Resources

Similar to ground water resources, long-term monitoring information is critical to developing appropriate management strategies for surface water resources. Monitoring stream flow, along with appropriate climate and physical data, can provide valuable information on stream health and integrity. Important considerations for surface water monitoring include streamflow, rainfall, diversions, irrigation systems, end uses, biology, and water quality. Descriptions of each of these considerations are provided in **Appendix G**.

CWRM enters into cooperative agreements with the USGS to operate and maintain a statewide network of surface water gaging stations that gather stream, spring flow, water level, and rainfall data, which supports a wide range of statewide studies (e.g., flood analysis, water quality, ground/surface water interaction, biology, etc.). However, as plantation-supported gages were retired, the number of long-term gaging stations has decreased since its peak in 1966 when there were 197 continuous-record gages in the state. CWRM establishes surface water gaging stations in streams where IFS are established and where IFS establishment is anticipated.

Figure 2-4 History of USGS Continuous-Recording Stream Gage Operations



CWRM has a comprehensive information management system to track and maintain data for water use reports, stream channel alterations, and stream diversion works. This Surface Water Information Management (SWIM) System is integrated into CWRM's WRIMS and will facilitate the setting of IFS by helping CWRM to track and manage water use data, location and type of alterations to stream channels, and water use for various off-stream purposes, allowing CWRM to assess impacts upon instream uses and to develop appropriate management scenarios at the watershed level. Additionally, CWRM is working to verify and update diversion information and advance the water use reporting process. Descriptions of these management efforts, as well as an identification of gaps in surface water monitoring activities and recommendations for improving surface water monitoring, are described in **Appendix G**.

2.2.4.3 Rainfall Monitoring

Rainfall is the primary natural source of fresh water for streams, springs, and underground aquifers, and long-term rainfall data is important in analyzing the effects of climate changes; decadal and shorter-term atmospheric fluctuations, such as the Pacific Decadal Oscillation, El Niño, and La Niña events; and the effects of extreme weather events, such as floods and droughts, on water resources. Rainfall data has been collected in Hawai‘i since the mid-1800s by sugar and pineapple plantations and ranches. There are currently several principal rainfall data collection networks in Hawai‘i operated by the National Weather Service (NWS), USGS, University of Hawai‘i, and private entities.

CWRM supported the Hawaiʻi Rainfall Atlas project which enhances estimates of normal rainfall across the state. The locations of all the historic and active rain gages as of 2013, a description of the available rainfall data, gaps in rainfall data and analysis, and recommendations for rainfall monitoring may be found in **Appendix G**.

Rain gages provide much-needed monitoring of rainfall.

2.2.4.4 Cloud Water Interception and Fog Drip Monitoring Activities

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 Hawaiʻi's forested areas frequently enveloped in clouds, especially when there is little or no precipitation occurring. Although this subject has been studied to some degree in Hawaiʻi 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. Descriptions of fog drip monitoring programs, analyses, gaps, and recommendations for improvement may be found in **Appendix G**.

Cloud water monitoring.

2.2.4.5 Evaporation Data

Evaporation data was used extensively in Hawai‘i to assist in developing plantation irrigation practices. It is also an important tool in determining an area's hydrologic budget by contributing to estimates of **evapotranspiration** (the water evaporated from the soil and other surfaces combined with the transpiration from plants in a vegetated area). Very few pan evaporation stations remain now that the large plantations have shut down. Descriptions of evaporation monitoring programs, analyses, gaps, and recommendations for improvement may be found in **Appendix G**.

Program Issues: Hydrologic and climatic data collection networks must be sustained and expanded to maintain and improve water resource management in Hawai‘i.

Recommended Projects: Project 1.1, Project 1.2, Project 1.8

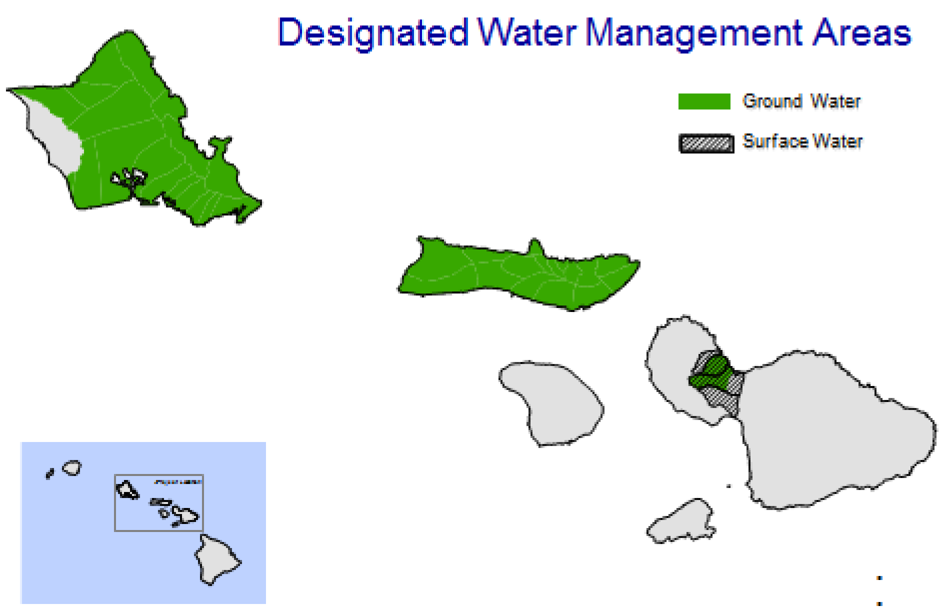
2.2.5 CWRM Regulatory Programs

CWRM uses regulatory controls to protect and conserve water resources, optimize water availability, protect public rights, and obtain maximum reasonable-beneficial uses. Permit systems are used to implement regulations concerning source development and water use. CWRM decisions on permit applications are guided by the Hawai‘i Water Plan, thus implementing the counties' long-range plans and policies regarding land and water use. The regulations also promote hydrologic data-gathering by requiring specific data to be collected and submitted to CWRM. In turn, this helps to assure informed decision-making in the future based on new and better information.

2.2.5.1 Designation of a Water Management Area

When the water resources of an area are determined to be threatened by existing or proposed withdrawals of water, CWRM shall designate the area as a water management area. This establishes greater administrative control over the withdrawals and diversions of ground and surface waters to ensure reasonable-beneficial use of the water resources in the public interest while protecting those resources. The State Water Code provides eight criteria for CWRM to consider in designating an area for regulation of ground water use (HRS §174C-44) and three criteria for surface water (HRS §174C-45) that are further discussed in **Appendix I**. **Figure 2-5** below shows the location of designated ground and surface water management areas.

Figure 2-5 Designated Water Management Areas



2.2.5.2 Regulatory Permits

There are five main types of permits regulated by CWRM: Water Use Permits, Well Construction Permits, Pump Installation Permits, Stream Channel Alteration Permits, and Stream Diversion Works Permits. These permits are described in **Table 2-2** below.

2.2.5.3 Penalties and Enforcement

CWRM has the authority to assess penalties for any violation of HRS Chapter 174C or HAR Title 13 for failure to comply with CWRM rules and orders, and for any violation of permit conditions.[15] To provide a logical and consistent means to assess penalties and guide the settlement of enforcement cases, CWRM adopted an Administrative and Civil Penalty Guideline with the objectives of deterring violations, removing the economic benefit of violations, providing fair treatment of the regulated community, and offering the violator a chance to undertake a beneficial alternative, under proper conditions, in a partial or total substitution of monetary fines (see **Appendix I**).

[15] HRS §174C-15 and HAR §13-167-10.

Table 2-2 Regulatory Permits

Regulatory Permit	Description
Water Use Permits (WUP)	Water Use Permits are required in designated ground and surface water management areas for both existing uses and prior to commencing any new water uses (HRS §174C-48). WUPs provide for the protection of public trust purposes and allow for maximum reasonable-beneficial use of water resources, while ensuring that the integrity of the resource is not threatened. CWRM is obligated to consider, protect, and advance public trust rights to the resource and make a presumption in their favor over other interests that seek water use permits.
Well Construction and Pump Installation Permits	Well Construction Permits are required statewide prior to the construction, modification, or decommissioning and sealing of any well that will explore for development, recharge (*injection wells are regulated by the State Department of Health's Underground Injection Control Program, environmental wells are regulated under the Department of Health's Underground Storage Tank and the Office of Hazard Evaluation and Emergency Response Programs, and geothermal wells are regulated by the Department of Land and Natural Resources' Engineering Division*), or permanently monitor ground water aquifers. Pump Installation Permits are required prior to the installation or replacement of well pumps (HRS §174C-84). Both permits are done in accordance with the Hawai'i Well Construction and Pump Installation Standards (HWCPIS).
Stream Channel Alteration Permits (SCAP)	Stream Channel Alteration Permits protect streams from alteration, whenever practicable, to provide for fishery, wildlife, recreational, aesthetic, scenic, and other beneficial instream uses. Generally, SCAPs are required for projects that are in the streambed itself or on the banks of the stream and are issued for all projects that alter a stream channel.
Stream Diversion Works Permit (SDWP)	Stream Diversion Works Permit are required for any structure placed within a stream for the purpose of diverting stream water. Any new stream diversion, or expansion of an existing stream diversion, may require a petition to amend the interim instream flow standard.

CWRM has prioritized enforcement of violations in water management areas and in response to complaints. CWRM staff plans to more rigorously enforce Water Code provisions and permit conditions, particularly the water use reporting requirement, with two newly-developed tools: (1) the online Water Resource Information Management System water use reporting system, and (2) DLNR's Civil Resource Violation System (CRVS),[16] which will be implemented to bring administrative enforcement actions for resource violations of a civil, rather than criminal, nature, especially minor, routine violation cases, such as failure to submit required monthly water use reports.

In addition to these enforcement tools, CWRM is also presently conducting outreach and education to facilitate voluntary compliance. One outreach effort focuses on agricultural irrigation system water use reporting to educate users in simple, yet reasonably accurate, methods for measuring diverted surface water flow, which will help to improve surface water use data collection and help agricultural operators to better manage their water use.

2.2.5.4 Complaints and Dispute Resolution

The State Water Code provides CWRM with the authority to process citizen complaints[17] and statewide jurisdiction to hear any dispute regarding water use, resource protection and management, water rights and competing uses, or other water issues, regardless of whether the area involved has been designated as a water management area.[18] Water quality complaints are referred to the DOH.[19] Complaints concerning flooding and flooding-related maintenance of stream banks are referred to the respective county authorities.[20] A person with standing may petition CWRM to establish a water management area or amend an interim instream flow standard.

2.2.5.5 Declaration of Water Shortage

The State Water Code (HRS §174C-62) mandates that CWRM formulate a plan to be implemented during periods of water shortage within a water management area. The water shortage plan must set forth provisions and guidelines for imposing use restrictions on different classes of permits as may be necessary to protect the resource. While CWRM has never moved toward the declaration of a water shortage in any part of the state, the Hawai'i Administrative Rules

> *"The commission, by rule, may declare a that a water shortage exists within all or part of an area when insufficient water is available to meet the requirements of the permit system or when conditions are such as to require a temporary reduction in total water use within the area to protect water resources from serious harm."*
>
> \- HRS §174C-62

16 HAR § 13-1, Subchapter 7
17 HRS §174C-13
18 HRS §174C-10
19 HAR §13-167-82
20 HRS §46-11.5

include provisions for emergency rulemaking that can be invoked if CWRM "finds that an imminent peril to public health, safety, or morals requires adoption, amendment, or repeal of a rule upon less than twenty days' notice of hearing."[21]

2.2.5.6 Declaration of Water Emergency

The State Water Code provides CWRM with emergency powers that can be exercised statewide during periods of water emergency, including non-water management areas and despite permitted water use allocations. Thus far, CWRM has never issued a water emergency declaration. CWRM has broad powers to order the "apportioning, rotating, limiting, or prohibiting the use of water resources" in any area if it declares an emergency condition.

Program Issues: Regulatory programs allow CWRM to manage the extent of water resource use and protection through permits and other means. These programs should be refined as needed to meet CWRM objectives as management priorities change. This could involve new or modified statutes, administrative rules, or regulatory programs.

Recommended Projects: Project 1.2, Project 2.3, Project 2.4, Project 2.7, Project 2.8

2.2.6 CWRM Water Use Reporting Program

CWRM collects information on existing water use and projected future water demand through the Water Use Reporting Program and the Water Use and Development Plan process in order to plan for and manage water resources. In particular, water use and demand data are used to foster comprehensive and sustainable resource planning for the development, use, protection, and conservation of water; facilitate integrated water and land use planning and policies; provide a regulatory and internal framework for efficient ground and surface water management; and promote coordination and collaboration among agencies, private entities, and communities.

> *"Any person making use of water from a well or stream diversion works… shall file a declaration of the person's use with the commission…and shall contain information including, but not limited to, the location of the water sources and all usage-related facts, or information within his knowledge or possession…the manner, purposes, and time in which the water source is being used and operated, the rate and volume of water being withdrawn or diverted therefrom, and the method or means of measuring and controlling the water taken or used."*
>
> \- Hawaiʻi Administrative Rules, §13-168-5

[21] HAR §13-167-45.

2.2.6.1 CWRM Water Use Reporting Requirements

Operators of wells and stream diversion works are required to measure their water use and submit regular monthly reports of their use to CWRM, but salt water wells are exempt from the monthly reporting requirement and may instead report annually. Under the Hawaiʻi Well Construction and Pump Installation Standards (HWCPIS 2004), all well owners are required to install flowmeters to measure ground water withdrawals. To facilitate surface water use reporting, CWRM produced a handbook with guidelines for appropriate devices and means of measuring water use that would not be unduly burdensome on water users.[22] Additionally, in 2012, CWRM's Water Resource Management Information System went live, allowing water users to file their reports on-line and monitor their historical use from each source via the internet. This new tool was developed to facilitate reporting by water users and to enable CWRM staff to more efficiently enforce compliance with the reporting requirement. See **Appendix G** for a more detailed discussion of WRIMS and the online reporting features.

2.2.6.2 Water Use Reporting for Ground Water Sources

Table 2-3 below summarizes reported total ground water use during the calendar year of 2016 by ground water use category. Based on reported water use, Oʻahu uses the most ground water, withdrawing over 177 MGD, primarily for municipal purposes. Municipal uses account for about 56% of total reported water use statewide. This is partly a reflection of the high reporting compliance rate of the municipalities, relative to other ground water users. Statewide, total reported ground water use exceeds 395 MGD.

Table 2-3 Summary of 2016 Reported Ground Water Use

Island	Use Category (MGD)						Island Total
	Agriculture	Domestic	Industrial	Irrigation	Military	Municipal	
Kauaʻi	9.17	0.02	0.18	0.30	0.25	13.13	23.06
Oʻahu	9.32	3.00	1.72	4.81	21.22	137.78	177.85
Molokaʻi	0.43	0.00	0.00	0.04	0.00	2.00	2.47
Lānaʻi	0.00	0.00	0.00	0.70	0.00	1.08	1.78
Maui	14.57	0.03	35.96	5.01	0.00	27.83	83.39
Hawaiʻi	0.68	0.06	49.18	16.08	0.00	41.42	107.41
Use Total	**34.16**	**3.11**	**87.03**	**26.94**	**21.48**	**223.23**	**395.96**

Notes: Includes all fresh ground water sources, excluding wells categorized as "other," saltwater, and caprock sources.
This analysis does not include DHHL ground water reservations

[22] Commission on Water Resource Management. (2009). Stream Diversion Measurement Methods. Honolulu, HI. Prepared by Element Environmental LLC.

2.2.6.3 Water Use Reporting for Surface Water Sources

The number of reporters of large irrigation systems continues to increase. CWRM staff are continuing to improve the accessibility and ease of water use reporting so that more surface water use data can be collected.
Table 2-4 summarizes reported surface water use as of December 2016, by island.

CWRM stores and manages surface water data in WRIMS. At the same time, CWRM is continuing to work with landowners and system operators statewide to get more surface water gaging and water use reporting data into its information management system.[23] To facilitate this, CWRM compiled a handbook to inform users of the various types of methods that are available. Additionally, CWRM contracted with the USGS to conduct on-site training workshops statewide for measuring water flow and reporting water use for large-scale stream diversion ditch systems to aid current ditch operators and owners in meeting the mandate for surface water use reporting. CWRM continues to work closely with diversion works owners both with reporting water use date and installing of gaging equipment.

Table 2-4 Summary of Reported Surface Water Use (2016)

Island	Total (MGD)[1]
Kaua‘i	186.907
O‘ahu	13.811
Moloka‘i	0.000
Lāna‘i	0.000
Maui[2]	117.508
Hawai‘i	56.340

1 Total of computed 12-month moving average for January 1, 2016 to December 31, 2016.
2 Includes Wailuku Water Company and Launiupoko Water Company

Stream diversion works declared in the 1990 registration process were not completely field verified. CWRM continues to regularly work with stream diversion works owners, update its stream diversion records, and expand water use reporting.

Program Issues: CWRM must continue to improve its collection of water use reports through a combination of outreach, training, and enforcement actions.

Recommended Projects: Project 1.2, Project 1.4

[23] Commission on Water Resource Management. (2009). Stream Diversion Measurement Methods. Honolulu, HI. Prepared by Element Environmental LLC.

2.2.7 Assessing Existing Water Demands

Existing water demands are recorded and archived to varying degrees by several entities statewide. CWRM relies on reported water use data to quantify both ground water and surface water demands and uses a twelve-month moving average to assess water use.

2.2.7.1 CWRM Assessment of Existing Ground Water Demands

As discussed in **Appendix H: Existing and Future Demands**, when actual ground water withdrawals or authorized planned uses may cause the maximum rate of withdrawal to exceed 90% of the aquifer's sustainable yield, CWRM may designate the area as a water management area and regulate water use through the issuance of water use permits. Once an area has been designated, CWRM continues to monitor water use for compliance with allocation limits.

Table 2-5 indicates water availability by summarizing existing water demands in relation to the aquifer system area sustainable yields for each of six major Hawai'i Islands. Water use is based on reported pumpage as of December 31, 2016 unless otherwise noted. Because caprock and salt water withdrawals do not count against aquifer sustainable yields, water withdrawn from caprock and salt water sources are excluded from the tables. For the islands of O'ahu and Moloka'i, where most or all of the aquifer system areas have been designated as ground water management areas, a comparison of total allocations to sustainable yields is also presented.

Table 2-5 Existing Demands and Water Allocations by Island Compared to Sustainable Yield, December 2016

Island	Sustainable Yield (SY) (MGD)	Existing Permit Allocation (MGD)	Unallocated SY (MGD)	Existing Water Use[5] (12 MAV, MGD)	SY minus pumpage (MGD)	Existing Water Use as a Percent of SY
Kaua'i[1]	328	N/A	N/A	26.009	301.991	7.9%
O'ahu	393	292.351	100.65	177.84	215.16	45.3%
Maui[2]	357	N/A	N/A	86.89	270.11	24.3%
Moloka'i	79	7.130	71.87	2.46	76.54	3.1%
Lāna'i[3]	6	N/A	N/A	1.847	4.153	30.8%
Hawai'i [4]	2,393	N/A	N/A	114.71	2278.29	4.8%
STATE-WIDE	**3,556**	**N/A**	**N/A**	**409.75**	**3,146.25**	**11.5%**

1 Kaua'i aquifers are not designated ground water management areas; therefore withdrawals do not require water use permits.

2 Only the 'Īao ASYA is a designated ground water management area; therefore withdrawals from the remaining ASYAs do not require water use permits.

3 Lāna'i aquifers are not designated ground water management areas; therefore withdrawals do not require water use permits.

4 Hawai'i island aquifers are not designated ground water management areas; therefore withdrawals do not require water use permits.

5 Includes DHHL ground water reservations

Table 2-5 shows that at an island-wide scale, total reported pumpage on all islands is within the sustainable yield, although O'ahu and Maui have a few aquifer system areas where pumpage has exceeded sustainable yield. For more detailed information on aquifer SY, WUP allocations, and existing water use, please see **Appendix H: Existing and Future Demands**.

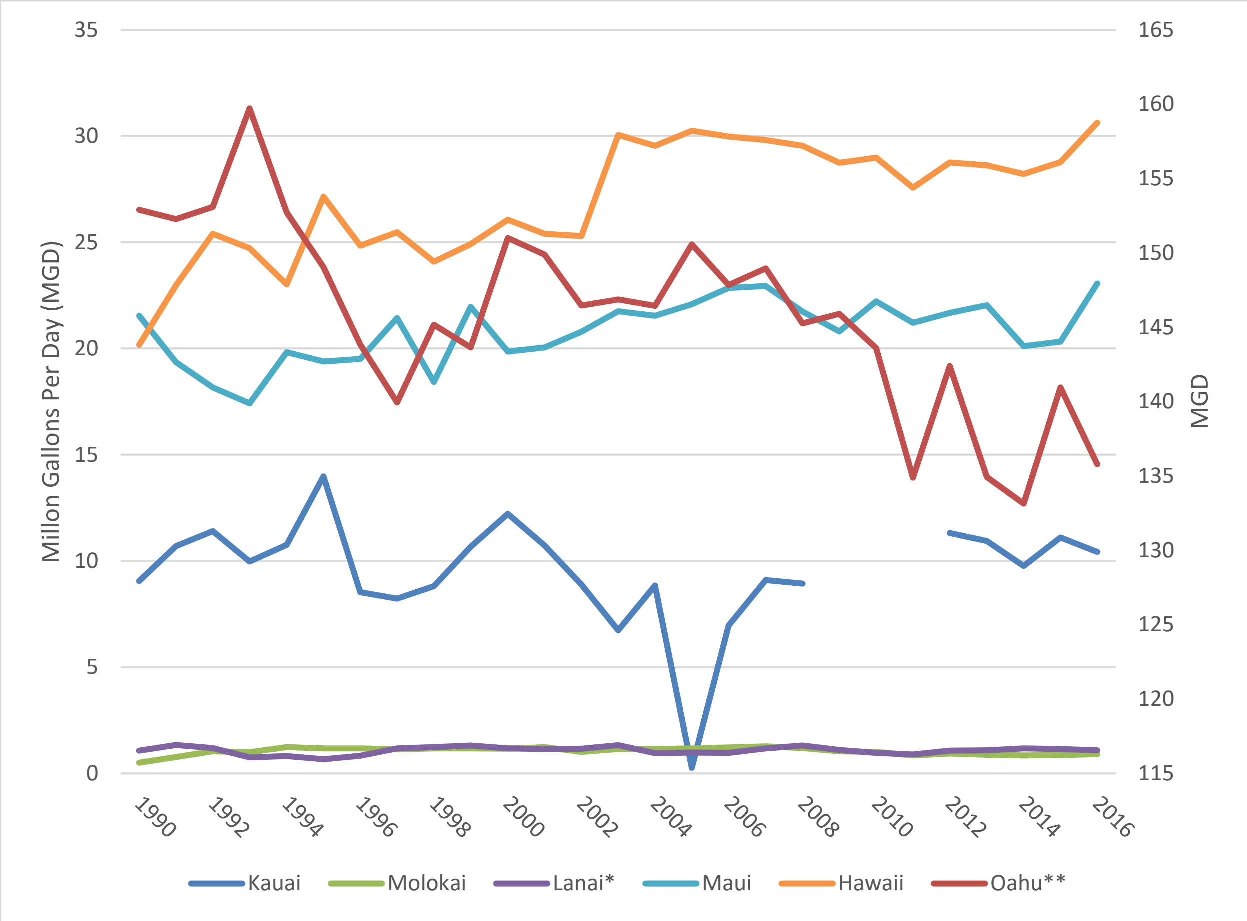
2.2.7.2 CWRM Assessment of Existing Surface Water Demands

CWRM staff is working to improve the understanding and collection of surface water use data with current resources. Efforts have been focused on the large legacy plantation irrigation systems. The current lack of understanding is due to past water use reporting exemptions, little information on stream diversions (field verification information), changes in water use by large-scale agricultural systems, and the difficulties associated with measuring diverted flow. A summary of the 1989 declared surface water use for each Surface Water Hydrologic Unit may be found in **Appendix N,** but it is mostly unverified. Thus, much of the information in **Appendix N** is only included in this document for reference purposes.

2.2.7.3 County Water Department Assessments of Existing Water Demands

With the exception of Lānaʻi, the county water departments provide the majority of the drinking water for each island. They also report their water use to CWRM in accordance with the requirements of the State Water Code. The table below summarizes their reported ground water use to CWRM from 1990 to 2016.

Figure 2-6 Reported County Municipal Water Use 1990-2016



* Data for Lānaʻi from Lānaʻi Water Company

**Data for Oʻahu is shown on right axis

The county water departments also provided municipal water use data to CWRM that characterizes existing water demands in terms of the agency's customer billing categories. This data in **Table 2-6** below represents existing water use only from county water systems and is intended to provide information on the relative distribution of demands across various use categories.

Table 2-6 2012 Water Use by County Water Departments (MGD)

County Water Department Customer Category	Kaua'i[1]	O'ahu[2]	Maui[3]	Hawai'i[4]
Agriculture	0.291	3.40	1.649	2.424
Domestic – Residential	7.326	73.41	21.055	15.206
Domestic – Non-Residential	2.818	34.33	8.14	6.598
Industrial	0.040	2.51	0.884	0.024
Irrigation	0.071	7.59	- - -	0.35
Military	0.020	2.87	- - -	- - -
Municipal	0.917	4.85	- - -	3.927
Other	- - -	0.03	- - -	- - -
Total	11.483	128.99	31.728	28.527

1 Consumption data for Fiscal Year 2011-2012. Source: Kaua'i Department of Water, November 22, 2013 Letter and January 9, 2104 Email.
2 Source: Honolulu Board of Water Supply, May 21, 2014 Email.
3 Source: Maui Department of Water Supply, November 26, 2013 Email.
4 Source: Hawai'i Department of Water Supply, December 13, 2013 Email.

In general, domestic residential water demand represents the highest use category for county municipal water systems, followed by domestic non-residential and agricultural and landscape irrigation. Municipal water demands also use a significant amount of water.

Program Issues: CWRM should continue to work with water use reporters, county water departments, and other large water users to improve water use reporting accuracy and to refine our understanding of water use and water availability.

Recommended Projects: Project 1.2 Project 1.4

2.2.8 Estimating Future Water Demands

The accuracy of future projections in water use over the long term is subject to many influences, including economic conditions, population growth, land use policies, and conservation practices. Several methods are used to derive water demand projections, including land use-based and population growth-based methods. These projections provide estimates over planning horizon increments of 5, 10, 15, or 20 years. Multiple growth scenarios are usually evaluated for each time increment to provide a range of projected demand. Demand projections can be refined using information contained in other State and county plans, information on federal and private water systems, and historical water use data.

2.2.8.1 Projected Future Department of Hawaiian Home Lands Water Demands

Department of Hawaiian Home Lands (DHHL) water needs are identified as a public trust purpose and are thus given high priority under the Hawaiʻi State Constitution and the Water Code. Please refer to **Appendix C: Legal Authorities and Guidance** for a discussion of DHHL's rights under the State Constitution, Water Code, and Section 221 of the Hawaiian Homes Commission Act.

As a State agency, the current and future water needs of DHHL are identified in the State Water Projects Plan (SWPP). In 2017, the SWPP was updated to reflect DHHL's potable and non-potable water needs, broken down by island, to 2031. These projected water demands may be found in **Appendix H: Existing and Future Water Demand**.

In order to ensure that DHHL's foreseeable future needs are provided for, CWRM has established water reservations by rule, pursuant to HRS §174C-49(d), in designated water management areas on Oʻahu and Molokaʻi, and by regular CWRM action in non-designated areas. These reservations are counted against available sustainable yields and may not be used by other parties. The existing water needs and future demands of DHHL protected through water reservations, as well as those identified in the SWPP, must be incorporated and recognized in the components of the Hawaiʻi Water Plan. Additional reservations for DHHL are planned based on the 2017 SWPP future demands.

Table 2-7 Current DHHL Water Reservations

Island	Hydrologic Unit	Quantity of Water Reserved (MGD)	Effective Date
O‘ahu	Waipahu-Waiawa	1.358[24]	February 18, 1994
O‘ahu	Waimānalo	0.124[25]	February 18, 1994
Moloka‘i	Kualapu‘u	2.905[26]	June 10, 1995
Hawai‘i	Keauhou	3.398	August 17, 2015
Kaua‘i	Waimea River	6.903	June 20, 2017
Kaua‘i	Wailua	0.708	September 18, 2018
Kaua‘i	Anahola	1.470	September 18, 2018
Kaua‘i	Kekaha	0.336	September 18, 2018
Kaua‘i	Makaweli	0.405	September 18, 2018
Lāna‘i	Leeward	0.067	September 18, 2018
Maui	Honokōwai	0.770	September 18, 2018
Maui	Kama‘ole	2.547	September 18, 2018
Maui	Ke‘anae	0.003	September 18, 2018
Maui	Kawaipapa	0.118	September 18, 2018
Maui	Luala‘ilua	0.063	September 18, 2018
Hawai‘i	Hāwī	0.148	September 18, 2018
Hawai‘i	Māhukona	3.014	September 18, 2018
Hawai‘i	Honoka‘a	0.396	September 18, 2018
Hawai‘i	Hakalau	0.083	September 18, 2018
Hawai‘i	Onomea	0.250	September 18, 2018
Hawai‘i	Hilo	0.492	September 18, 2018
Hawai‘i	Kea‘au	1.336	September 18, 2018
Hawai‘i	‘Ōla‘a	0.025	September 18, 2018
Hawai‘i	Nā‘ālehu	0.185	September 18, 2018
Hawai‘i	Pāhoa	0.660	September 18, 2018

2.2.8.2 Projected Future County Water Demands

According to county water agency projections, by the year 2035, water demands will approach 268 MGD statewide. This translates to an approximate 12% increase in demand from year 2020 to year 2035. Table 2-8 summarizes the water demands projected by the county water agencies through 2035. **Appendix H** also provides a breakdown by water demand categories or billing classes (as designated by the water departments), which is useful in comparing demands associated with potable and non-potable water uses. Demand forecasts were prepared independently by each county; therefore, assumptions and forecast methods vary.

[24] HAR 13-171-61 reserves 1.724 MGD, of which 0.366 MGD has been converted to water use permits.
[25] HAR 13-171-62
[26] HAR 13-171-63

Table 2-8 Projected Water Demand for All Counties, 2020 to 2035 (MGD)

County	2020	2025	2030	2035
Kaua'i[1]	17.795	18.744	19.696	20.526[6]
Honolulu[2]	144.8	144.3	147.2	150
Maui[3] **(DWS system – includes Maui & Moloka'i)** **Lāna'i (private system)** [4]	39.945	42.913	45.856	48.808[6]
Hawai'i[5]	36.941	40.786	45.031	49.718
Total	**239.481**	**246.743**	**257.783**	**268.852**

1 Source: Kaua'i Department of Water, November 22, 2013 Letter.
2 Source: Honolulu Board of Water Supply, June 20, 2018 Email.
3 Source: Maui Department of Water Supply, January 7, 2014 Email.
4 Lāna'i water demand information was not available at the time of this writing.
5 Source: Hawai'i Department of Water Supply, December 13, 2013 Email
6 Data interpolated from county demand projections from 2015 to 2030.

2.2.8.3 Water Planning at the County Level

The State Water Code requires each county to prepare and regularly update its County Water Use and Development Plan (WUDP) to address future water demands and to set forth the "allocation of water to land use in that county."[27] County WUDPs (1) assess existing and future land uses and associated municipal water demands; (2) incorporate agriculture, military, private, State, and other non-municipal water demand projections; and (3) evaluate the cost and adequacy of proposed development plans and identify preferred and alternative water development strategies to meet projected demands. It is adopted by CWRM and integrates all other Hawai'i Water Plan components, as emphasized through the adoption of the WUDP as County ordinances. Requirements, recommendations, and guidance for preparing the County WUDPs are found in the State Water Code and the Statewide Framework for Updating the Hawai'i Water Plan, and are summarized in **Appendix H.**

The status of each of the County updates are shown in **Table 2-9**. A summary of the findings of each WUDP, in terms of existing and future water demands, resource options and strategies, and the implications for natural supplies, may be found in **Appendix H**.

[27] HRS §174C-31

Table 2-9 Status of County Water Use and Development Plans

County, Island or District	Current WUDP Adoption Date	Status of WUDP Update	Strategies to Meet Future Water Needs
Kaua'i	February 1990	In progress	
O'ahu			
Central O'ahu	March 1990	In progress	
East Honolulu	March 1990	In progress	
'Ewa	March 1990	In progress	
Ko'olau Loa	March 2011	Current	• Ground water development • Water reuse expansion • Conservation
Ko'olau Poko	September 2012	Current	• Ground water development • Water reuse expansion • Surface water for kalo expansion • Conservation
North Shore	December 2016	Current	• Current supplies sufficient
Primary Urban Center	March 1990	In progress	
Wai'anae	March 2011	Current	• Decrease ground water development • Increase import from Pearl Harbor ASYA • Conservation
Maui			
Maui	March 1990	In progress	
Moloka'i	March 1990	Awaiting completion of Maui Island WUDP update	
Lāna'i	August 2012	Current	• Ground water development • Water reuse expansion • Desalination • Conservation
Hawai'i	December 2011	Current	• Extend ground water system service areas • Water transfers • Alternative source development • Demand-side management
Keauhou		In progress	

Program Issues: CWRM should continue to work with the counties and others who prepare the Hawai'i Water Plan components to refine estimates of future water use. CWRM should also continue to encourage coordination between land-use and water planners.

Recommended Projects: Project 2.3, Project 3.1.

2.2.9 Resource Conservation and Augmentation

As an island state, Hawaiʻi has limited access to natural fresh water supplies. Competition for fresh water, increasing population and development pressures, the rising awareness of environmental and cultural water needs, and the impacts of global climate change require that Hawaiʻi become as efficient as possible in its uses of limited fresh water supplies, and plan for natural water resource alternatives. In fact, some areas of the State of Hawaiʻi are approaching the limits of water resource development: nearly all of Oʻahu and Molokaʻi, and part of Maui have been designated as ground water management areas, where ground water use and development is regulated by CWRM. Additionally, North Central Maui (Nā Wai ʻEhā) has been designated as a surface water management area, having similar regulations.

The State Water Code mandates that CWRM plan for and coordinate conservation and augmentation programs in cooperation with other federal, State, and county agencies, and private and public entities created for the utilization and conservation of water.[28] CWRM is moving forward in providing leadership and guidance for the establishment, development, and implementation of statewide water conservation and augmentation programs.

2.2.9.1 Water Conservation Programs

CWRM serves as a coordinator, funding source, and clearing house for information on water conservation. It also offers technical assistance and leads by example, but because CWRM is not a water purveyor, it cannot directly implement water efficiency programs. CWRM depends on water purveyors and users in Hawaiʻi to participate in and implement the measures outlined in its water conservation plans. State and county agencies and private businesses and organizations have incorporated varying degrees of water conservation within their operations. CWRM water conservation plans and programs are in **Table 2-10** below.

[28] HRS §174C-5(12) and §174C-31(d)(4)

Table 2-10 CWRM Water Conservation Plans and Programs

Program/Report	Purpose
Hawai‘i Water Conservation Plan (CWRM, February 2013) http://files.Hawai‘i .gov/dlnr/cwrm/planning/hwcp2013.pdf	Coordinate various state agencies’ and muncipalities’ individual water conservation programs and provide for collaboration toward a common goal.
Prototype Water Conservation Plan for the Department of Land and Natural Resources (CWRM, February 2005) http://files.Hawai‘i .gov/dlnr/cwrm/planning/pwcp2005.pdf	Provide a framework for water conservation plans for all State agencies, and conservation program options and strategies for water purveyors throughout Hawai‘i.
Conservation Manual for State of Hawai‘i Facilities (CWRM, May 2007) http://files.Hawai‘i .gov/dlnr/cwrm/planning/wcmshf2007.pdf	Facilitate State agency implementation of water conservation programs.
Water Loss Audit Program (2016)	Establishes a water loss audit program for public water systems, including technical assistance. Annual validated audits are required by affected systems.
Water Security Grant Program (2016)	Establishes a two-year pilot program to enable public-private partnerships that increase water security.

In general, the counties practice conservation by reducing system leaks and losses, adopting universal metering, customer water conservation programs, public education programs, adjusting water rates to influence demand, and as a last resort, rationing water use during severe shortages as provided by county rules and ordinances. Counties also practice conservation by protecting watershed areas to realize dependable yields. Each of the counties have independently undertaken water conservation programs and strategies, summarized in **Appendix J: Resource Conservation and Augmentation**.

2.2.9.2 Water-Energy Nexus

In modern society, water is used to produce energy and energy is used to develop and deliver drinking water and to treat wastewater. This water-energy connection is referred to as the water-energy nexus. While water in Hawai‘i is relatively inexpensive, energy is not. The substantial amount of energy used by water and wastewater utilities and the volume of water used for energy production presents opportunities for utilities to find ways for conserving both water and energy by improving efficiencies in their production and delivery processes. High energy prices in Hawai‘i provide powerful incentives to improve water efficiency. Water and wastewater utilities should conduct energy and water audits to inform their decision making.

CWRM's 2016 **Hawai'i Water Energy Nexus Report** found that utilities and agencies often pursue water conservation programs independently with dispersed results, and that greater collaboration between utilities and government agencies is necessary to develop effective and mutually beneficial conservation initiatives and programs, including partnerships and collaboration between energy and water utilities. There are very few programs targeting combined water-energy conservation in Hawai'i. For a short description of the known programs, please refer to **Appendix J**.

2.2.9.3 Developing a Resource Augmentation Program

Resource augmentation, including rainwater/stormwater capture, wastewater reclamation and reuse, and desalination of brackish water and seawater, should also be embraced as an important component of sustainable water resource management. In general, alternative water supplies should be renewable, drought resistant, environmentally sound, and socially responsible. Several county water and wastewater agencies employ reclamation techniques to process surface water and wastewater. However, there is no statewide water resource augmentation program.

It is the State's policy to encourage the development and maximum beneficial use of alternative water resources to augment the water development programs of each county. The State is providing leadership and guidance to counties and private water purveyors in the form of goals and priorities established through an integrated resource augmentation program that ensures that the pursuit and development of alternative-water sources is executed in an efficient and sensible manner, and encourages cooperation, development of implementation incentives, and innovative thinking among State, county, and private entities.

Existing CWRM programs that promote the use of alternative sources include water use regulation, instream flow standard assessment, and long-range planning. In designated water management areas, applicants for water use permits must show that no alternative water sources are available to meet their needs. If an alternative source is available, CWRM will deny requests for use of public trust resources in favor of the available alternative. In setting instream flow standards, the Water Code directs CWRM to consider alternative sources, and other physical solutions, to minimize the impacts of streamflow restoration on existing uses.[29] Finally, CWRM's Statewide Framework for Updating the Hawai'i Water Plan[30] advocates the use of an integrated resource planning (IRP) approach, a comprehensive form of planning that considers direct and indirect costs and benefits of demand-side and supply-side management, in addition to supply augmentation, for updating the County Water Use and Development Plan components of the Hawai'i Water Plan.

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[29] HRS §174C-71(1)(E)
[30] Commission on Water Resource Management. (2000). *Statewide Framework for Updating the Hawai'i Water Plan*

2.2.9.4 Water Supply Augmentation

Current and anticipated demands for fresh water are outpacing conventional source development and will likely surpass the volumes of naturally occurring ground and surface water at some point. State and county governments must actively pursue alternative water supplies to sustain Hawai'i's growing population, meet the needs of industry, and help ensure the long-term viability of our ground water aquifers and watershed areas. Common alternative water supplies may be found in **Table 2-11**.

Table 2-11 Alternative Water Supplies

Alternative Water Supply	Potential Uses/Benefits
Gray Water Reuse Definition: wastewater discharged from showers and bathtubs; hand-washing lavatories; wastewater that has not contacted toilet waste; sinks (not used for disposal of hazardous, toxic materials, food preparation, or food disposal); and clothes-washing machines (excluding wash water with human excreta e.g., diapers).[31]	• Landscape irrigation • Toilet and urinal flushing • Freshwater conservation • Increased environmental flows • Reduced wastewater flows • Reduced energy consumption • Landscape enhancement • Nutrient reuse • Ground water recharge
Wastewater Reclamation Definition: The treatment of wastewater such that it may be used for beneficial purposes	• Constructed wetlands • Ground water recharge • Irrigation • Recreational uses • Construction-related uses • Recharge of natural wetlands • In-stream flow restoration • Composting • Toilet and urinal flushing • Industrial uses • Aesthetic uses • Freshwater conservation • Increased environmental flows • Landscape enhancement • Nutrient reuse • Pollution reduction and prevention • Drought-proof supply

[31] Hawai'i Department of Health, June 22, 2009, Guidelines for the Reuse of Gray Water.

Table 2-11 Alternative Water Supplies (continued)

Alternative Water Supply	Potential Uses/Benefits
Stormwater Reclamation (i.e., Rainwater Harvesting) Definition: Runoff water from the impervious surfaces in cities and developed areas, such as streets, sidewalks, roofs, parking lots, and other areas where water cannot percolate into the subsoil.	• Domestic uses (washing bathing, drinking, toilet and urinal flushing, etc) • Ground water recharge • Irrigation • Construction-related uses • Industrial uses • Aesthetic uses (ponds and water features) • Freshwater conservation • Ground water recharge • Landscape enhancement • Pollution reduction and prevention • Erosion reduction • Flood control and containment • Clean Water Act compliance
Desalination Definition: removal of dissolved minerals, including but not limited to salt, from seawater, brackish ground water, or treated wastewater.	• Domestic use • Industrial uses • Freshwater conservation • Drought-proof supply

Note: Water conservation, through the implementation of effective demand- or supply-side measures, may also be viewed as a strategy to meet future water needs.

Major challenges related to successful resource augmentation include reliability, quality, efficiency and economics, technology, and environmental impacts. Further discussion and descriptions of resource augmentation methods, issues, constraints, reports/studies, and programs may be found in **Appendix J: Resource Conservation and Augmentation**.

Program Issues: CWRM should continue to promote water delivery and use efficiency, alternative water supplies where appropriate, and to facilitate planning and discussions among stakeholders who are interested in implementing these practices. Other regulatory agencies should also review their policies and programs to reduce barriers to alternative water supplies

Recommended Projects: Project 2.5, Project 2.6, Project 3.1, Project 3.2

2.2.10 Drought Planning

Drought is a persistent and extended period of below normal precipitation that induces a variety of adverse effects. Direct and indirect impacts of drought manifest as changes in the environment, economy, public health, and long-term water supply and may be exacerbated by climate change. Drought can lead to difficult decisions regarding the allocation of water, stringent water use limitations, water quality problems, and inadequate water supplies for fire suppression. CWRM has assumed the role of lead agency in the development of the State's drought program, which is described in **Appendix K: Drought Planning.**

> **Drought Response vs. Mitigation**
>
> **Drought Response:**
> Emergency actions that are implemented directly in response to drought conditions.
>
> **Drought Mitigation**
> Short- and long-term actions and/or programs that may be implemented prior to, during, and after drought events to reduce the degree of risk to human life, property, and the economy.

According to the U.S. Drought Monitor, Hawai'i has frequently experienced severe drought conditions somewhere in the state since June 2008.[32] The 2012 Pacific Islands Regional Climate Assessment (PIRCA) shows a statewide increase in average air temperature from 1916-2006, a downward trend in rainfall since the beginning of the 20th century, and an even steeper negative rainfall trend since 1980 (**Figure 2-7**). The data also show a decrease in stream base-flow across the state since the early 1900s, which indicate a decrease in ground water recharge and storage, coinciding with the trend of decreasing rainfall. Furthermore, research projections of future rainfall in the Hawaiian Islands suggest that Hawai'i should be prepared for a future with a warmer climate, diminishing rainfall, and declining stream base flows.

In recent years, planning has shifted from responding to drought impacts to proactively reducing its impacts before they occur. Federal legislation and the resultant State and county actions that have contributed to the development of Hawai'i's drought program are listed in **Table 2-12**. Further discussion and descriptions of drought resources, as well as recommendations for drought planning, may be found in **Appendix K**.

[32] National Drought Mitigation Center, U.S. Drought Monitor, accessed February 28, 2014, http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx

Figure 2-7 Interannual and Interdecadal Rainfall Variations in the Hawaiian Islands[33]

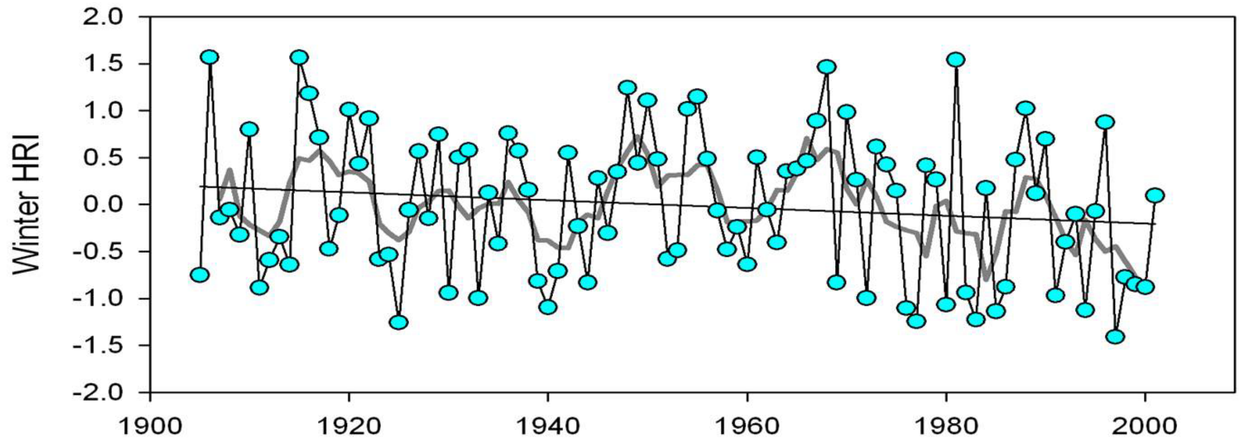

Table 2-12 Drought Planning-Related Federal Legislation and State and County Actions

Action	Need/Purpose
Federal Disaster Management Act of 2000 (FEMA)	Requires each state and territory to conduct hazard mitigation planning and to implement projects to reduce hazard impacts prior to a disaster occurrence
Hawai'i State Multi-Hazard Mitigation Plan (Hawai'i Emergency Management Agency, 2013)	Assesses risk and vulnerability to multiple hazards, reviews current mitigation actions and capabilities, and develops a mitigation strategy for each hazard including mitigation projects and actions. Required to receive public assistance subsequent to disasters, additional pre-disaster mitigation funds for state or local mitigation projects, and non-emergency assistance such as Public Assistance restoration of damaged facilities and Hazard Mitigation Grant Program funding.
County Hazard Mitigation Plans • Kaua'i (August 2015) • Honolulu (September 2017) • Hawai'i (October 2015) • Maui (October 2015)	Required for a county to be eligible for post-disaster federal funding. The counties prepare multi-hazard plans and have a five-year update cycle
Hawai'i Drought Plan (CWRM, 2017)	Develops coordinated emergency response mechanisms, while outlining steps toward mitigating the effects of future drought occurrences at a statewide level.

[33] Chu, P.-S., and Chen, H. 2005. Interannual and interdecadal rainfall variations in the Hawaiian Islands. Journal of Climate 18: 4796-4813.

Table 2-12 Drought Planning-Related Federal Legislation and State and County Actions (continued)

Action	Need/Purpose
Drought Risk and Vulnerability Assessment and Geographic Information System (GIS) Mapping Project (CWRM, 2003)	Illustrates the extent and severity of drought risk for different impact sectors throughout the islands and facilitates the development of drought response and mitigation strategies.
County Drought Mitigation Strategies	Coordinates government agency and stakeholder actions and identifies projects for integration within the *County Hazard Mitigation Plans*. Implementation of these projects is championed by County/Local Drought Committees.

Program Issues: CWRM should continue to coordinate drought mitigation and planning activities among impacted stakeholder sectors, conduct regular updates of the Hawaiʻi Drought Plan and develop water shortage plans for priority water management areas.

Recommended Project: Project 2.8

2.2.11 Watershed Protection

The USGS simply defines a watershed as the divide separating one drainage basin from another.[34] However, healthy watersheds provide Hawaiʻi communities with valuable water-related services such as flood mitigation, streamflow, healthy nearshore waters, and healthy ground water supplies. Watershed management seeks to maintain and restore the continuing functioning of these and other ecosystem services. CWRM's goals toward watershed protection encourage integrated efforts, good data, and collaboration across all levels of government, communities, and the private sector. Further discussion may be found in **Appendix L: Watershed Protection**.

> *"(DLNR) shall 'devise ways and means of protecting, extending, increasing, and utilizing the forests and forest reserves, more particularly for protecting and developing the springs, streams, and sources of water supply to increase and make that water supply available for use.'"*
>
> -Hawaiʻi Revised Statutes § 183-31

[34] USGS Water Science Center http://water.usgs.gov/wsc/glossary.html#W

The State of Hawai‘i has a long history of watershed protection and management programs, which were initiated to ensure a sustainable water supply. Additionally, many modern watershed protection and management programs have sprung from the requirements of the Clean Water Act of 1977, subsequent supporting legislation, a resurgence in Hawaiian culture, and a newfound appreciation for traditional land and water management principles. In the face of a changing climate, these programs and principles have become even more critical as a means to ensure the sustainability of clean and plentiful water resources for our island communities. Initiatives in Hawai‘i that engage in and support watershed protection, include public/private Watershed Partnerships and the Hawai‘i Association of Watershed Partnerships, various State DLNR Division of Forestry and Wildlife (DOFAW) watershed protection initiatives, Honolulu Board of Water Supply's watershed prioritization, the County of Maui Department of Water Supply's grant program, the Hawai‘i Coastal Zone Management Program, the Department of Health water quality programs, and other State watershed protection programs. Additional information on each of these programs and initiatives may be found in **Appendix L: Watershed Protection**.

Although current watershed management efforts favor a comprehensive approach, watershed management in Hawai‘i tends to have either a water quality (DOH, Environmental Protection Agency (EPA), and the Coastal Zone Management Program) or water quantity (Honolulu BWS, Maui DWS, the Watershed Partnerships, and DOFAW) improvement focus. The Natural Resources Conservation Service (NRCS) and the Soil and Water Conservation Districts address both water quality and quantity, and entities such as the State Office of Conservation and Coastal Lands (OCCL), the Land Use Commission (LUC), and U.S. Army Corps of Engineers (USACE) address water as part of a system, but do not have water resource protection as a main focus. Further discussion of watershed issues, programs, and recommendations may be found in **Appendix L**.

Fencing protects vegetation (left side of photo) from feral ungulates.

Program Issues: CWRM should continue to collaborate with watershed partnerships, county water departments, and large landowners to support watershed studies, protection and restoration.

Recommended Projects: Project 1.7, Project 3.2, Project 3.3

2.2.12 Water Quality

The State Water Code provides that the Department of Health shall have primary jurisdiction and responsibility for administration of the state's water quality control programs.[35] The *Hawai'i Administrative Rules, Title 11, Chapter 20, Rules Relating to Public Water Systems*, identifies the maximum contaminant levels for various chemicals, as well as other parameters for drinking water quality. Water quality standards for state waters are found under HAR §11-54. CWRM defers to DOH on most water quality related matters. DOH plans and strategies for ensuring water quality are listed below and described in **Appendix M: Water Quality**.

- **DOH Strategic Plan: The Five Foundations for Healthy Generations**

  Examines DOH's core environmental protection programs and discusses their history, organization, mission, goals, strategies, and performance measures, and sets forth targets to measure the effectiveness of programs in meeting community needs.

- **Environmental Health Management Report**

  Provides an overview of all of the activities of the Environmental Health Administration, not just those involved in water quality, and clarifies the environmental goals and objectives of the DOH.

- **Water Quality Plan (WQP)**

  The DOH is responsible for formulating and updating the State Water Quality Plan, a component of the Hawai'i Water Plan, for all existing and potential sources of drinking water.[36] The major objective of the WQP is to protect public health and ecological systems by preserving, protecting, restoring, and enhancing the quality of ground and surface waters throughout the State of Hawai'i.

The Safe Drinking Water, Clean Water and Wastewater programs provide input and guidance to the WQP. Major initiatives are listed below and described in **Appendix M**.

- Surface Water Quality Management Program
- Source Water Assessment and Protection Program
- Comprehensive State Groundwater Protection Program Strategy/Plan
- Underground Injection Control (UIC) Program
- Groundwater Contamination Maps
- Wastewater Recycling Program

Program Issues: DOH should update their Water Quality Plan. CWRM should continue to work with DOH and other stakeholders to monitor, protect and improve water quality.

Recommended Projects: Project 2.2, Project 2.6, Project 2.7, Project 3.2

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[35] HRS §174C-66
[36] HRS §174C-68 and HAR §13-170-50.

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3 Priority Recommendations and the Action Plan

3.1 Planning for the Future

CWRM underwent a multi-part process to identify issues and needs, projects and tasks to address those issues and needs, and priorities for near-term action. This section briefly describes that process.

3.1.1 Goals for the WRPP Update

From the information received through the stakeholder input process and the analysis of current water resource information and management tools, three broad goals were developed to focus the actions that would be put into a near-term Action Plan. Goals are ideal future end-states that reflect the values of a community or institution. The following goals will guide CWRM in its actions to further the protection and management of the water resources trust.

Goal 1: A solid and up-to-date foundation of data on Hawaiʻi water resources, water use, and water dynamics is used to make water resource management decisions.

Goal 2: Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.

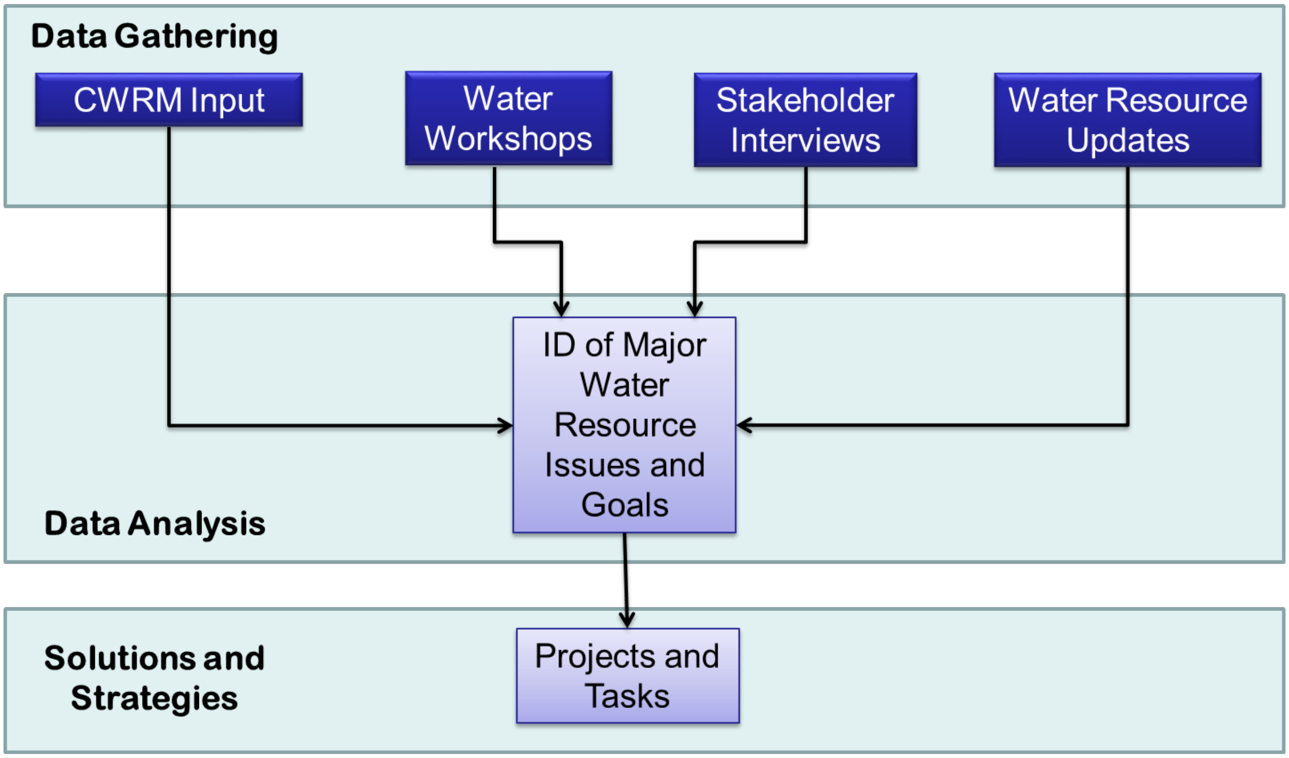
Goal 3: Partnerships, education, and awareness increase collaborative water resource management among government, private, and community entities and the citizens of Hawaiʻi.

3.1.2 Identification of Issues, Tasks, and Projects

This update of the WRPP began with a thorough evaluation of the implementation of the 2008 WRPP - what actions and programs were implemented, what issues or management needs remain outstanding, what new information was generated through monitoring or studies to better inform management going forward? The next step involved a series of meetings, interviews, and workshops to gather additional input. Initially, the input of CWRM staff was sought. This was followed by a series of interviews and small group meetings with stakeholders having a special interest in water resource management or use, such as federal, state, and county agencies; non-governmental organizations; cultural practitioners; large landowners; and professional hydrologists. CWRM then conducted a series of workshops statewide to gather input from the general public (see **Appendix E** for the stakeholder input process and summary). In addition, actions, directives and policies established by CWRM at its monthly meeting and decisions of the Supreme Court in its review of contested case hearing decisions were also compiled.

Through the update process, several hundred possible tasks were identified to address various issues. These tasks were then refined by CWRM and grouped into broader categories resulting in a total of 20 projects to achieve the three goals listed above. The following diagram outlines the planning process.

Figure 3-1 Process for Identifying WRPP Projects and Tasks



3.1.3 Prioritization of Projects and Tasks

Each of the 20 projects are included in an Action Plan, but tasks needed to be prioritized to provide guidance to CWRM on what to focus on in the near-term. In order to determine which tasks CWRM will actively seek to initiate and/or implement within the next five years, tasks were put through a two-tier prioritization process where they were scored against a set of seven prioritization criteria, listed below.

PRIORITIZATION CRITERIA

1. Task is a required service or product that, (a) is mandated by the State Water Code, Administrative Rule, or Court Decision; (b) impacts core foundational CWRM services or products; and/or (c) is depended on by other projects, programs, or services.

2. Task is in strategic alignment with CWRM's Vision, Mission, Goals, and Policies.

3. Task reduces or mitigates risk or negative impact on water resources and/or the public.

4. Task has value to the public.

5. Task addresses an existing or foreseeable conflict.

6. Task can be leveraged by other users or partners, adds value for external partners, increases positive collaborative efforts, or strengthens relationships with stakeholders.

7. Task costs can be shared among other government agencies, academic institutions, private individuals / entities, non-profit organizations, and / or community groups / individuals.

The 20 projects and respective priority tasks are the basis of this Action Plan. This ensures that all major issues identified during the research, update, and stakeholder outreach process were addressed in some fashion. Tasks that were not included in the near-term Action Plan are still considered important and are compiled in **Appendix O,** to be implemented as opportunities and funding sources arise.

3.2 Action Plan

Table 3-1 Table 3-1 lists those tasks that CWRM will seek to initiate or implement within the next five years as a part of its Action Plan. Included in the Action Plan table are the project title, lead CWRM Branch and partnering agency or entity, estimated cost range, and status to enable CWRM to track the progress and performance of its Action Plan. Tasks listed in the table are presented as they correspond to the three goals of CWRM and not necessarily how they ranked during the prioritization process. The cost ranges for each task are estimations of the cost for CWRM. Total project costs would be determined through detailed scoping and development of the activity.

The Action Plan Table shall be treated as a living document to allow CWRM to track the progress of meeting the goals identified in the Action Plan. The "Task Status" column will be populated with the information needed to determine the status, progress, and/or results for the corresponding task.

Table 3-1 Action Plan

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 1:	**A solid and up-to-date foundation of data on Hawai'i water resources, water use, and water dynamics is used to make water resource management decisions**			
Project 1.1	**Collect and analyze climatic data to determine trends in water resource health and anticipate future issues and problems.**			
Task 1.1.1	Identify the adequate level of hydrologic and climatic data collection needed statewide to enable effective decision-making about water security.	CWRM/ University of Hawai'i (UH)/ USGS/ Counties	$155,000	In progress
Task 1.1.2	Develop implementation plan based on recommendations from Task 1.1.1	CWRM/ USGS/UH/ Counties	$100,000*	
Task 1.1.3	Coordinate climate data sharing by establishing a common data portal or shared public data resource.	Ike Wai CWRM/NWS/ USGS	Internal	In progress
Project 1.2	**Improve the reporting and analysis of ground and surface water use.**			
Task 1.2.1	Maintain and improve the ease of use and utility of CWRM's WRIMS database on a continuous basis.	CWRM	$375,000*	In progress
Task 1.2.2	Increase participation of stream diversion and well owners in online reporting through outreach, education, and ultimately, enforcement.	Ground Water/Stream Branches	$250,000/ Internal	In progress
Task 1.2.3	Develop standards for surface water use reporting to improve consistent reporting.	Stream Branch	Internal	In progress

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with "in progress" or "completed"

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

DESCRIPTION		LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
Goal 1	**A solid and up-to-date foundation of data on Hawai'i water resources, water use, and water dynamics is used to make water resource management decisions**			
Project 1.3	**Update estimates of aquifer sustainable yields with new and best information available using the 2008 precautionary approach.**			
Task 1.3.1	Improve recharge estimates to include the best available information on climate change impacts.	Ground Water Branch/USGS	$250,000	
Project 1.4	**Develop and implement a strategic surface water monitoring plan.**			
Task 1.4.1	Improve estimates of stream flow characteristics, particularly during low-flow conditions (USGS StreamStats).	Stream Branch	$1,500,000	In progress
Task 1.4.2	Verify diversion use and amounts for large/legacy irrigation systems	Stream Branch	Internal	In progress

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with "in progress" or "completed"

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
Goal 1	**A solid and up-to-date foundation of data on Hawai‘i water resources, water use, and water dynamics is used to make water resource management decisions**			
Project 1.5	**Understand how climate change will impact water resources.**			
Task 1.5.1	Partner and coordinate with other entities who are researching the potential impacts of climate change.	Planning Branch	Internal	
Task 1.5.2	Integrate the best available information on the impacts of climate change on long-range water resources planning.	Planning Branch/Counti es/DOA/DLNR/ DOH	Internal	
Task 1.5.3	Encourage long-range planning at the Federal/State/County levels to include climate change adaptation plans.	Planning Branch /Counties/ Federal	Internal	
Project 1.6	**Improve the understanding of appurtenant water rights.**			
Task 1.6.1	Develop an efficient process to determine and quantify appurtenant water rights to guide CWRM staff and the public.	CWRM	Internal	In progress
Task 1.6.2	Develop and implement a process to catalog and inventory appurtenant water rights. Incorporate known and anticipated appurtenant claims into instream flow standards and surface water permitting.	CWRM	$100,000	

*May require additional recurring costs for operation and maintenance
**This column will be populated as CWRM implements tasks listed with “in progress” or “completed”
Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
Goal 1	**A solid and up-to-date foundation of data on Hawai'i water resources, water use, and water dynamics is used to make water resource management decisions**			
Project 1.7	**Understand the impacts of land use on hydrology, ecosystem function, and water resources needed for human consumption.**			
Task 1.7.1	Understand the impacts of native vs. nonnative plant species on water resources and watersheds by supporting research and long-term hydrologic monitoring programs.	CWRM/USGS/ UH/DLNR/ Counties	$100,000*	In progress
Task 1.7.2	Develop a pilot adaptive management plan for protecting ground water dependent ecosystems	CWRM/USGS/ UH/National Park Service (NPS)/ Cultural Practitioners	$175,000 *	In progress
Project 1.8	**Develop and implement a comprehensive statewide ground water monitoring plan.**			
Task 1.8.1	Construct new deep monitoring wells in critical aquifers to gather and utilize data to identify impacts from pumpage and climate and land use changes, verify fresh water sustainable yields, and monitor recharge trends.	Ground Water Branch	$5,000,000/ 1 Full-Time or Equivalent staff (FTE)	In progress
Task 1.8.2	Resurvey geodetic-control benchmarks in the State for deep monitor wells and water –level observation wells to ensure consistent and accurate water level measurements.	USGS	TBD	

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with "in progress" or "completed"

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
Goal 1	**A solid and up-to-date foundation of data on Hawai‘i water resources, water use, and water dynamics is used to make water resource management decisions**			
Project 1.9	**Establish Sustainable Funding sources.**			
Task 1.9.1	Increase permit fees to amounts sufficient to defray administrative costs of permit systems	CWRM	Internal	In progress
Task 1.9.2	Establish and implement water source registration fees for the purpose of supporting CWRM core activities and programs.	CWRM	1 FTE	
GOAL 2:	**Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.**			
Project 2.1	**Manage instream and non-instream uses to provide for reasonable beneficial use while protecting public trust uses.**			
Task 2.1.1	Prioritize streams for developing measurable IFS.	Stream Branch	Internal	In progress
Task 2.1.2	Continue to develop measurable instream flow standards by reviewing instream needs and current non-instream uses.	Stream Branch	Internal	In progress
Task 2.1.3	Implement and enforce measurable instream flow standards.	Stream Branch	Internal	In progress

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with “in progress” or “completed”

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 2	**Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.**			
Project 2.2	**Protect water quality from land use impacts.**			
Task 2.2.1	Implement source water protection programs.	DOH/Office of Planning/CZM/ Counties	TBD	
Task 2.2.2	Develop standards and guidelines for stormwater reclamation and reuse.	DOH/EPA	TBD	
Task 2.2.3	Address the impacts of leaking underground storage tanks on water quality.	DOH/EPA	TBD	
Task 2.2.4	Address impacts of byproducts of desalination process injected below the UIC line.	DOH/EPA	TBD	
Task 2.2.5	Develop guidelines and incentives for on-site water reclamation and reuse.	DOH/EPA/ Counties	TBD	

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with “in progress” or “completed”

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 2	**Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.**			
Project 2.3	**Provide clear guidance on criteria used to make water resource management decisions, including, but not limited to, the precautionary principle, the protection of public trust purposes, including traditional and customary practices, and economic considerations.**			
Task 2.3.1	Develop a process and policy for regulatory and planning purposes, for identifying the presence of traditional and customary practices in a particular area and the water needs associated with those practices.	CWRM/AMAC	Internal	In progress
Task 2.3.2	Continue to refine the application of the precautionary principle and public trust doctrine to water resource management (app X).	CWRM	Internal	In progress
Task 2.3.3	Update model/methodology for estimating irrigation water demands to ensure the most efficient use of water.	Ground Water/ Stream Branches	$100,000	
Task 2.3.4	Establish additional water reservations for DHHL	Planning Branch	Internal	In progress

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with "in progress" or "completed"

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 2	**Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.**			
Project 2.4	**Update CWRM's policies on enforcement and penalties, and modernize and streamline the regulatory process.**			
Task 2.4.1	Develop formal enforcement policies.	Ground Water/ Stream Branches	Internal	
Task 2.4.2	Implement the Civil Resource Violation System already being utilized by other DLNR divisions.	Ground Water/ Stream Branches	Internal	
Task 2.4.3	Update CWRM's Administrative Rules to reflect updated penalties and streamline the regulatory process.	Ground Water /Stream Branches	Internal	In progress
Project 2.5	**Develop, update, and implement water conservation tools, techniques, and plans.**			
Task 2.5.1	Study how energy conservation can be used as an incentive for, and complement to, water conservation.	Planning Branch	$200,000	
Task 2.5.2	Conduct water audits of public water systems to verify use and aid water providers in identifying water losses.	Planning Branch/ DOH/EPA	$700,000 0.5 FTE	In progress
Task 2.5.3	Seek funding for a water conservation rebate program	Planning Branch	$500,000 0.5 FTE	
Project 2.6	**Plan for and provide guidance on the use of alternative water sources.**			
Task 2.6.1	Appraise opportunities for aquifer storage and recharge/recovery in Hawaiʻi.	Planning Branch/ DOH/Counties	$500,000	
Task 2.6.2	Inventory current and planned resource augmentation projects and efforts in the State.	Planning Branch/DOH	$300,000	
Task 2.6.3	Undertake a statewide stormwater recharge study	Planning Branch/ DOH/EPA/OP/ CZM/ Counties	$300,000	

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 2	**Water resources, public trust uses, and water rights are protected and balanced against reasonable beneficial uses.**			
Project 2.7	**Protect ground water sources by updating well standards and sealing abandoned wells.**			
Task 2.7.1	Develop an abandoned well sealing program in coordination with DOH and the Counties, including staff and funding resources, in order to eliminate potential conduits for ground water contamination.	Ground Water Branch/DOH/ Counties	2 FTE	
Task 2.7.2	Identify and prioritize abandoned and unused wells for sealing.	Ground Water Branch/DOH/ Counties	Internal	In progress
Task 2.7.3	Update the Hawai‘i well construction and pump installation standards to address free-flowing tunnels and artesian wells.	Ground Water Branch	Internal	
Project 2.8	**Prepare for water shortages and drought.**			
Task 2.8.1	Coordinate statewide drought planning efforts and resources through regular meetings of the County drought committees and Hawai‘i Drought Council.	Planning Branch	Internal	In progress
Task 2.8.2	Complete regular updates to the Hawai‘i Drought Plan. Evaluate and revise Plan recommendations and drought communication protocol as necessary and appropriate.	Planning Branch	$75,000	Completed
Task 2.8.3	Develop water shortage plans for priority water management areas.	Planning Branch	$200,000	

*May require additional recurring costs for operation and maintenance
**This column will be populated as CWRM implements tasks listed with “in progress” or “completed”
Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 3:	**Partnerships, education, and awareness increase collaborative water resource management among government, private, and community entities and the citizens of Hawai‘i.**			
Project 3.1	**Update the Hawai‘i Water Plan.**			
Task 3.1.1	Update the Statewide Framework for Updating the Hawai‘i Water Plan to reflect new issues and data, improved methodologies, and current priorities.	Planning Branch/DOA/ DLNR/ Counties/DOH/ Stakeholders	$300,000	
Task 3.1.2	Ensure incorporation of recent issues and insights, e.g., climate change, reuse, DHHL needs, and traditional and customary practices, into Hawai‘i Water Plan components.	Planning Branch	Internal	In progress
Task 3.1.3	Promote coordination and collaboration among agencies, private entities, and water users when developing Hawai‘i Water Plan components	Planning Branch/ Counties/ DLNR/DOA/ DOH/ Stakeholders	Internal	In progress
Task 3.1.4	Conduct regular updates of the WRPP	Planning Branch	$300,000	
Project 3.2	**Support multi-sectoral based management of water resources.**			
Task 3.2.1	Collaborate with the State Department of Health to protect water resources by the further integration of water quality and water quantity programs.	Planning Branch/DOH	Internal	In progress
Task 3.2.2	Engage and collaborate with other agencies having an interest in water resources to address inter-agency issues and increase coordination.	CWRM/DOH/ CZM/LUC/ Counties/ Federal Partners	Internal	

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with “in progress” or “completed”

Internal: CWRM staff will accomplish task with existing resources

Table 3-1 Action Plan (continued)

	DESCRIPTION	LEAD CWRM BRANCH AND PARTNERS	COST RANGE	TASK STATUS**
GOAL 3	**Partnerships, education, and awareness increase collaborative water resource management among government, private, and community entities and the citizens of Hawai'i.**			
Project 3.3	**Increase CWRM community involvement, participation, outreach, and education.**			
Task 3.3.1	Hold regular CWRM meetings on the neighbor islands to allow CWRM members and staff to learn about and understand issues throughout the State and to increase opportunities for neighbor island communities to participate in CWRM processes.	CWRM	Internal	In progress
Task 3.3.2	Publish water use and monitoring data on CWRM's website.	Ground Water/Stream Branch	Internal	In progress
Task 3.3.3	Assess the development of a pilot community-based surface water data collection program.	Stream Branch	Internal	

*May require additional recurring costs for operation and maintenance

**This column will be populated as CWRM implements tasks listed with "in progress" or "completed"

Internal: CWRM staff will accomplish task with existing resources

3.3 Long-Term Projects

All of the projects, programs, and associated tasks that were identified as a result of this WRPP update process are considered important to managing the use and protection of water resources. Following the task prioritization process, those tasks that were found to be of lower priority are captured in this WRPP as tasks that should be revisited in future planning and updates to the WRPP or those that may be initiated should funds become available or should priorities change. As with any plan, the Water Resource Protection Plan should be regarded as a guide for future and immediate action and should not be so rigid as to not be adaptable to future conditions, new information, or opportunities. A complete list of the long-term tasks may be found in **Appendix O**.

3.4 Implementation and Next Steps

In the past five years during this plan update process, CWRM initiated and/or completed five of the fifty-six tasks in the Action Plan requiring funding. Many of the tasks that will be accomplished using existing staff resources have already been initiated and are ongoing. All tasks are retained in the Action Plan to show the full panoply of tasks that address the issues raised through the stakeholder outreach process.

To complete the remaining tasks in the next five years, it is estimated that an additional $5,000,000 and five full-time staff positions will be required. This $5,000,000 shortfall is equivalent to Capital Improvement Projects (CIP) funds needed for new deep monitor well construction (**Task 1.8.1**). CIP funds are not part of the Commission's operating expenses but will be requested as part of the Department's CIP request during the annual legislative budgeting process.

Should the CIP requests be denied or should a shortfall in the budget occur due to unanticipated executive, judicial, or legislative directives that supersede the priorities outlined in this WRPP, some of these tasks may need to proceed in phases, allowing the actual cost to be spread out beyond the five-year planning period. Phasing will be determined based on available funding at the time and subject to contract negotiations. While some tasks are a critical path and must be implemented before others, in general, any of the tasks in the Action Plan may be selected for implementation in any given year given the needs and grant and partnership opportunities available at that time. Where CWRM is identified as lead agency, it is CWRM's goal to initiate or implement each task in the Action Plan within the next five years.

Currently, CWRM's main source of funding is through annual legislative appropriations. CWRM seeks opportunities to leverage these funds with federal matching funds, other cost-sharing opportunities, and grants. Unfortunately, obtaining cost-share commitments in advance is difficult. The federal agencies that CWRM partners with are also subject to annual budgets, and so commitments for cost-sharing cannot be made in advance of the start of each federal fiscal year. Non-profit organizations occasionally express interest in investing in water resource management, but they often have their own specific interests that may not align with the priorities of CWRM. Finally, executive, judicial, and legislative mandates have in the past and will in the future require CWRM to deviate from its pre-determined priorities. Lack of inclusion in the current Action Plan should not preclude undertaking these new tasks, should the need and opportunity arise. Therefore, some flexibility is needed in plan implementation. CWRM staff will use the Action Plan as a guide for identifying priority tasks, and the Action Plan will be implemented through internal workplans developed by CWRM staff and annual budget requests.

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Waialae-West Aquifer System Area (WWASA)

The current WWASA sustainable yield is 4 million gallons per month with a proposed 2019 decrease to 2 million gallons per month based on the most recent USGS recharge numbers. This short report reviews the historical observed data to support the proposed reduction.

The ground water response to pumpage in the WWASA is well documented. There are 16 registered wells, including five lost, five unused, five observation wells, one golf course irrigation well, two municipal wells, and two recently added Kaimukī Middle Scholl wells (see attached listing & map) with a historical pumpage record since 1947 (see attached WWASA pumpage graph). Currently, only three wells are pumping (see attached Water Use Permit table). The CWRM is currently receiving chloride data from the two municipal wells, and quarterly Conductivity-Temperature-Depth profiles from a deep monitor well collected by the Honolulu Board of Water Supply. The Commission does not have its own deep monitor well in the area but has started monitoring two observation wells at Kaimukī Middle School.

During the period between April 2015 and January 2017, when pumpage from the WWASA was at its highest levels averaging 1.7 MGD, chloride trends increased and measurements peaked at the two active municipal wells, Ainakoa (3-1746-001) and Aina Koa II (3-1746-004) (see attached). During this period, the Ainakoa Well chloride measurements averaged 166 ppm, with the highest measurement at 176 ppm, compared to an average of 132 ppm over its entire reporting period since 1970 (see attached). Likewise, the Aina Koa II Well, the chloride measurements averaged 101 ppm, with the highest measurement at 112 ppm (occurring twice), compared to an average of 91 ppm over the entire reporting period since 2006 (see attached). Clearly these wells were sensitive to pumpage less than 2 mgd throughout the WWASA.

At the Waialae Shaft Deep Monitor Well (3-1747-004), Conductivity-Temperature-Depth Profiles during the period between June 2000 through December 2018, the resulting declining trendline for the water table and rising top and mid-points of the transition zone with larger increases noted during the months with higher pumping volumes (see attached).

Given these observations, the updated USGS recharge estimates, and historical pumpage barely exceeding 2.0 mgd it seems prudent to leave update the sustainable yield for the WWASA to 2 mgd. Setting the sustainable yield to 2.5 mgd gives a false sense of accuracy and such pumpage has not been tried in the past while showing stable trends.

Commission on Water Resource Management
Information Management System

STATE OF HAWAII / DEPARTMENT OF LAND AND NATURAL RESOURCES / COMMISSION ON WATER RESOURCE MANAGEMENT GROUND WATER WELL INDEX / SUMMARY

Friday, June 28, 2019

Wells Reviewed in Report

Island:	Oahu
Well Owner:	All
Well Reporter:	All
Land Owner:	All
Aquifer Sector:	All
Aquifer:	30105 Waialae-West
Aquifer Type:	Alluvial, Basal, Caprock, Dike, Perched, Not Specified
TMK:	All
PWS:	All
Water Quality:	Fresh;Brackish;Salt;other
Well Use:	All

Island: Oahu

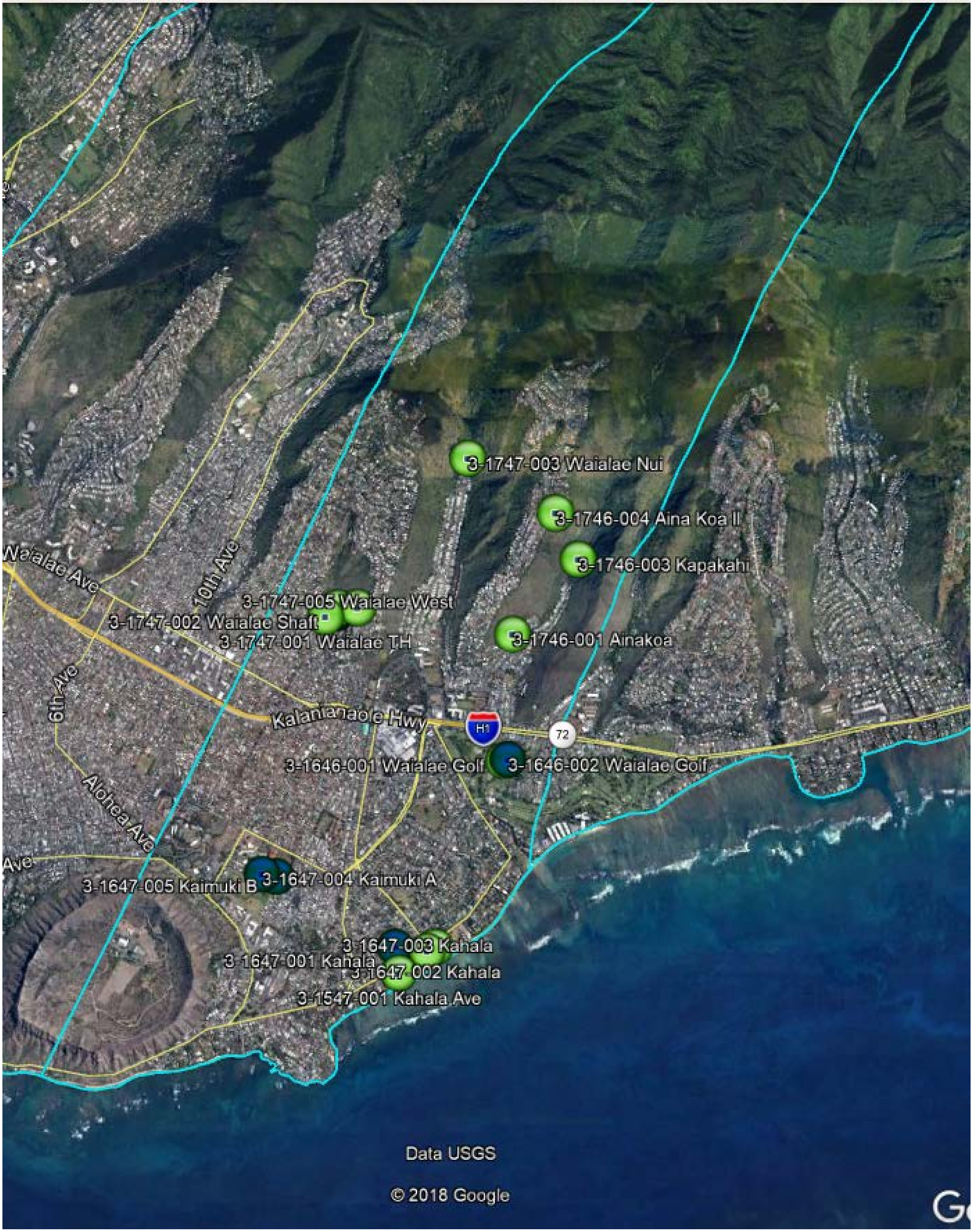
30105 Waialae-West

					Coordinates(NAD83)		Physical Data			Elevations in feet (msl)				Initial				Pump Test Result		
Well No	Well Name	Aquifer	Well Owner/Operator	Year Drilled	Latitude DD	Longitude DD	Type	Casing Dia in.	Total Depth ft.	Ground	Bottom Solid Casing	Bottom Perf Casing	Bottom of Hole	Static Head	Cl	Temp	Spec Cap	T ft²/d	Installed Capacity mgd	Use
3-1547-001	Kahala Ave	30105	WF Coastal Properties, LLC	1956	21.262222	-157.786389		8	70											ABNLOS
3-1646-001	Waialae Golf	30105	Waialae Country Club	1881	21.275826	-157.779191		8	120	18	-25		-102	8.20					0.864	IRRGC
3-1646-002	Waialae Golf	30105	Kamehameha Schools, KS	1881	21.275882	-157.778913		4	131	18	-82		-113	8.50	164					OBS
3-1647-001	Kahala	30105	D. Cromwell	1937	21.263889	-157.786667		6	70	8			-62							OBS
3-1647-002	Kahala	30105	4607 Kahala LLC	1954	21.263889	-157.783889		8	60					5.75						ABNLOS
3-1647-003	Kahala	30105	Estates of Kahala LLC, Oahu	1955	21.263611	-157.784444		8	70											ABNLOS
3-1647-004	Kaimuki A	30105	State of Hawaii, DLNR, Engineering Division	2001	21.268583	-157.795778	ROT	12	65	55	5	-10	-10	1.09	505		174	36,778		OBS
3-1647-005	Kaimuki B	30105	State of Hawaii, DLNR, Engineering Division	2001	21.268417	-157.794778	ROT	12	65	50	5	-15	-15	1.60	600		363	347,859		OBS
3-1746-001	Ainakoa	30105	Honolulu Board of Water Supply, BWS	1968	21.283889	-157.778611	PER	12	305	156	-7	-37	-149	9.00	0		3640		0.504	MUNCO
3-1746-003	Kapakahi	30105	Honolulu Board of Water Supply, BWS	1992	21.288611	-157.774167	PER	14	320	267	7	-53	-53	8.00			161			UNU
3-1746-004	Aina Koa II	30105	Honolulu Board of Water Supply, BWS	1993	21.291389	-157.775833	PER	15	920	850	-20		-70	9.70			81		1.353	MUNCO
3-1747-001	Waialae TH	30105	Honolulu Board of Water Supply, BWS	1935	21.285000	-157.791389		1	171	152	-6	-16	-19	10.30						UNU
3-1747-002	Waialae Shaft	30105	Honolulu Board of Water Supply, BWS	1937	21.285556	-157.790556	SHF	96	157	160			3	10.20	73		868		2.923	UNU
3-1747-003	Waialae Nui	30105	Honolulu Board of Water Supply, BWS	1983	21.295000	-157.781667	PER	14	410	310	-17	-57	-100	11.40	48		128			UNU
3-1747-004	Waialae SH Deep Monitor	30105	Honolulu Board of Water Supply, BWS	1996	21.285278	-157.790556	ROT	10	805	161	14		-644	9.90						OBSDM

					Coordinates(NAD83)		Physical Data			Elevations in feet (msl)				Initial				Pump Test Result		
Well No	Well Name	Aquifer	Well Owner/Operator	Year Drilled	Latitude DD	Longitude DD	Type	Casing Dia in.	Total Depth ft.	Ground	Bottom Solid Casing	Bottom Perf Casing	Bottom of Hole	Static Head	Cl	Temp	Spec Cap	T ft²/d	Installed Capacity mgd	Use
3-1747-005	Waialae West	30105	Honolulu Board of Water Supply, BWS	1999	21.285556	-157.789167		10	217	188	-15		-29	8.93	98					UNU

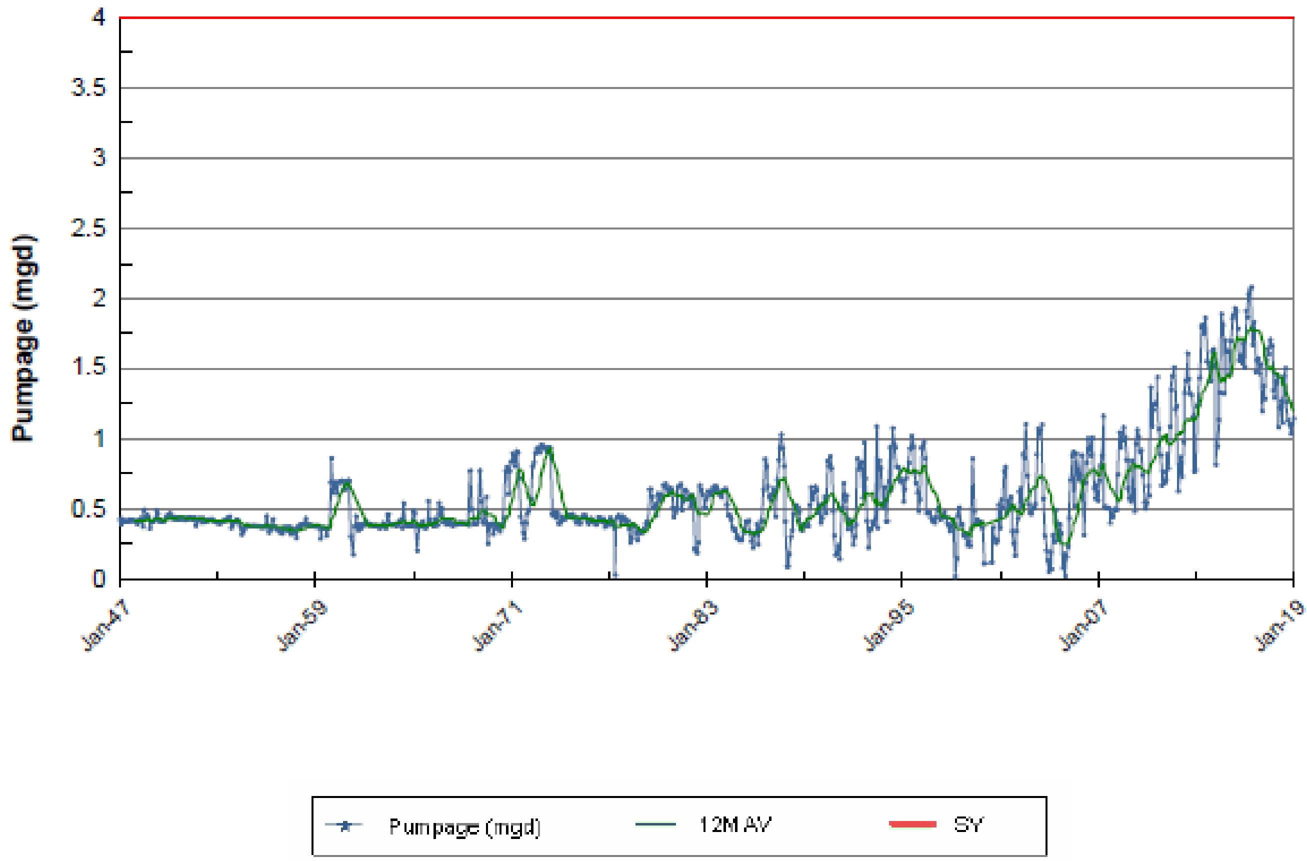
Total Installed Pump Capacity in Aquifer in mgd: 5.644

Total Number of wells in Aquifer: 16


3-1747-003 Waialae Nui
3-1746-004 Aina Koa II
3-1746-003 Kapakahi
3-1747-005 Waialae West
3-1747-002 Waialae Shaft
3-1747-001 Waialae TH
3-1746-001 Ainakoa
Waialae Ave
10th Ave
6th Ave
Alohea Ave
Kalanianaole Hwy
H1
72
3-1646-001 Waialae Golf
3-1646-002 Waialae Golf
3-1647-005 Kaimuki B
3-1647-004 Kaimuki A
3-1647-003 Kahala
3-1647-001 Kahala
3-1647-002 Kahala
3-1547-001 Kahala Ave
Data USGS
© 2018 Google

Commission on Water Resource Management
Information Management System

Monthly Pumpage Chart
12 Month Moving Average



Report Parameters

Date:	01/01/1947 - 01/01/2019
Island:	Oahu
Well Owner:	All
Well Reporter:	All
Well # Prefix:	All
Aquifer Sector:	All
Aquifer:	30105 Waialae-West
Potable/Non-Potable:	All
TMK:	All
PWS:	All
Aquifer Type:	Alluvial, Basal, Caprock, Dike, Perched, Not Specified
Pump Capacity:	All
Well Use:	All

Commission on Water Resource Management
Information Management System

Water Use Permit

Report Parameters

WUP Type:	Water Use Permit, Administrative Modification, Reservation, Transfer, CWRM Decision and Orders, Court Orders, Other
Island:	Oahu
Applicant:	All
Well # Prefix:	All
Date:	All
Issued Date:	All
Date Accepted:	All
Aquifer Sector:	All
Aquifer:	30105 Waialae-West
Source or End Use TMK:	All
Aquifer Type:	Alluvial, Basal, Dike, Perched, Not Specified
Water Quality:	Fresh, Brackish, Potable, Non-Potable, Not Specified
Not:	Salt
Proposed Use:	All

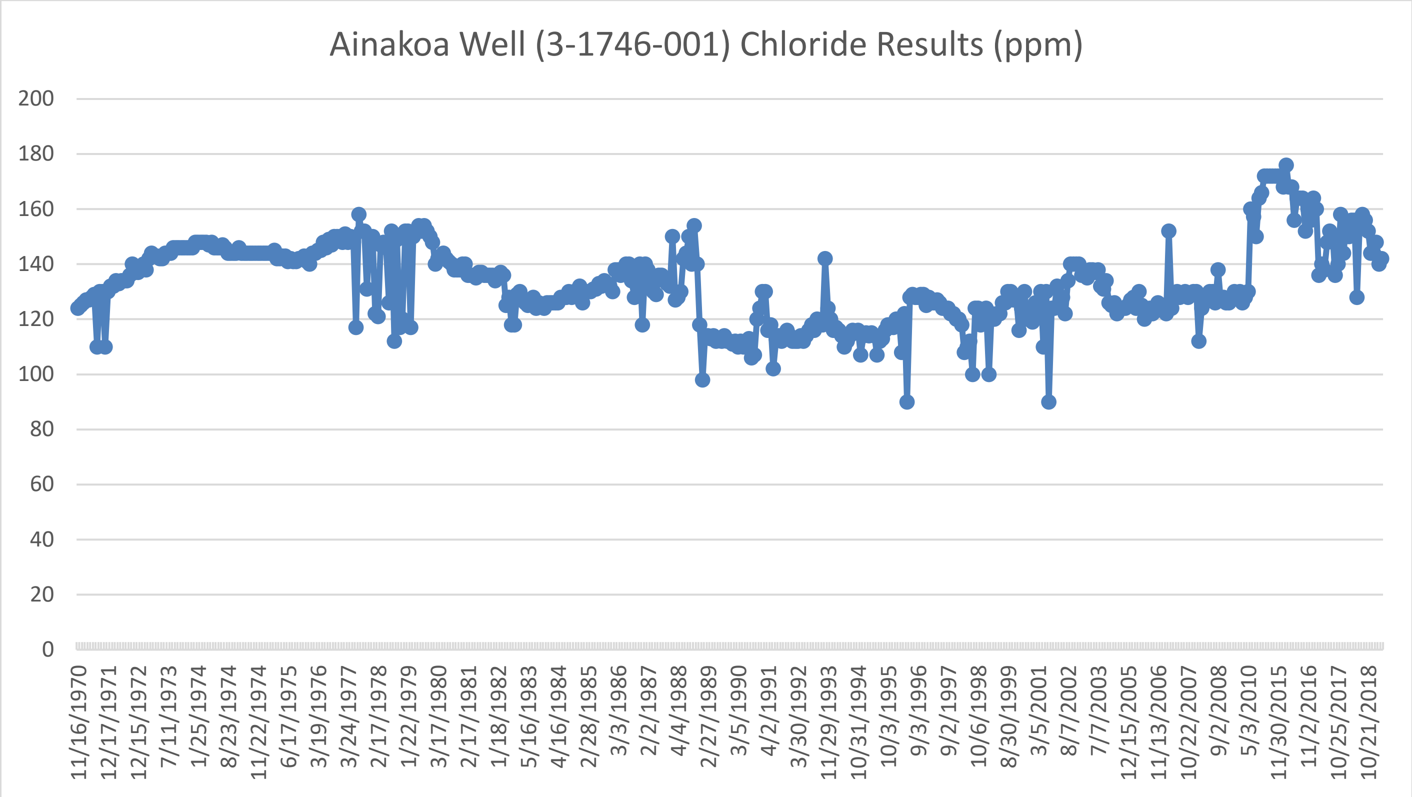
WUP = Water Use Permit, 12-MAV = 12 month moving average, Diff = WUP-12-MAV, mgd = million gallons per day

Island of Oahu

Aquifer System Ground Water Management Area: 30105 Waialae-West

Sustainable Yield (mgd): 4

Wup No	Approved	Permittee	Well No	Well Name	WUP (mgd)	12-MAV (mgd)	Diff (mgd)	Date Last Reported
00150	09/11/1981	Kamehameha Schools, KS	3-1646-001	Waialae Golf	0.460	0.239	0.221	06/03/2019
00475	10/22/1997	Honolulu Board of Water Supply, BWS	3-1746-001	Ainakoa	0.480	0.185	0.295	02/28/2019
00609	10/22/1997	Honolulu Board of Water Supply, BWS	3-1747-005	Waialae West	0.160	0.000	0.160	02/28/2019
00705	06/22/1984	Honolulu Board of Water Supply, BWS	3-1747-003	Waialae Nui	0.700	0.000	0.700	02/28/2019
00830	05/20/1998	Honolulu Board of Water Supply, BWS	3-1746-004	Aina Koa II	0.997	0.780	0.217	02/28/2019
Summary for Waialae-West (5 detail records)				Total:	2.797	1.204	1.593	
				SY Available:	1.203			
Sustainable Yield: 422				SY Available:	419.20			


Ainakoa Well (3-1746-001) Chloride Results (ppm)
200
180
160
140
120
100
80
60
40
20
0
11/16/1970
12/17/1971
12/15/1972
7/11/1973
1/25/1974
8/23/1974
11/22/1974
6/17/1975
3/19/1976
3/24/1977
2/17/1978
1/22/1979
3/17/1980
2/17/1981
1/18/1982
5/16/1983
4/16/1984
2/28/1985
3/3/1986
2/2/1987
4/4/1988
2/27/1989
3/5/1990
4/2/1991
3/30/1992
11/29/1993
10/31/1994
10/3/1995
9/3/1996
9/2/1997
10/6/1998
8/30/1999
3/5/2001
8/7/2002
7/7/2003
12/15/2005
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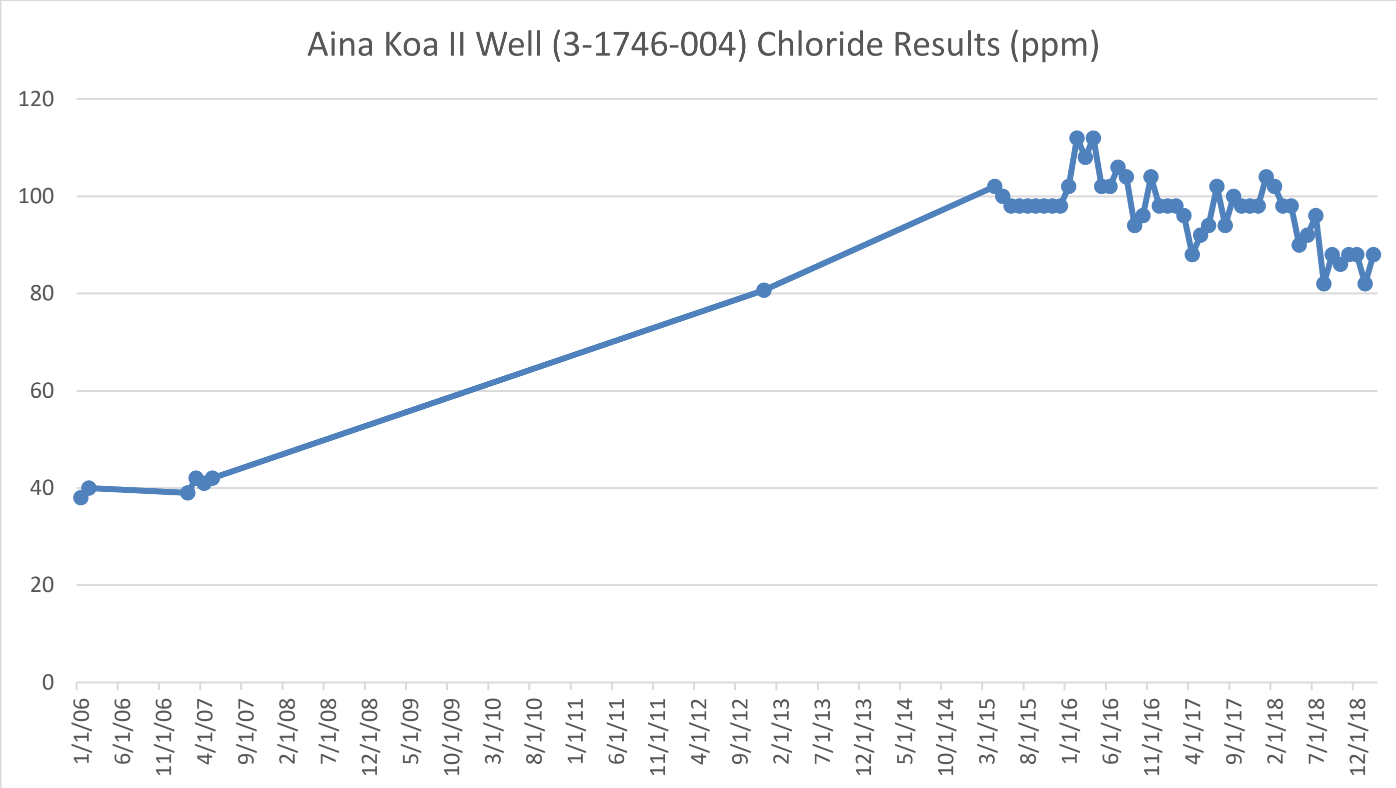
11/30/2015
11/2/2016
10/25/2017
10/21/2018


Aina Koa II Well (3-1746-004) Chloride Results (ppm)
120
100
80
60
40
20
0
1/1/06
6/1/06
11/1/06
4/1/07
9/1/07
2/1/08
7/1/08
12/1/08
5/1/09
10/1/09
3/1/10
8/1/10
1/1/11
6/1/11
11/1/11
4/1/12
9/1/12
2/1/13
7/1/13
12/1/13
5/1/14
10/1/14
3/1/15
8/1/15
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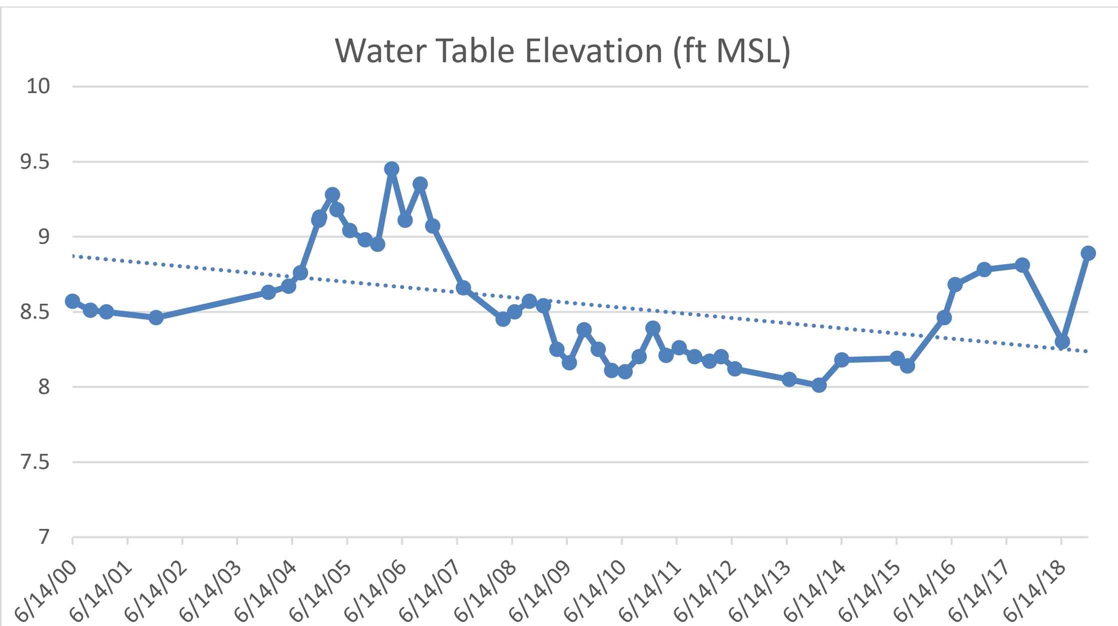
7/1/18
12/1/18


Water Table Elevation (ft MSL)
10
9.5
9
8.5
8
7.5
7
6/14/00
6/14/01
6/14/02
6/14/03
6/14/04
6/14/05
6/14/06
6/14/07
6/14/08
6/14/09
6/14/10
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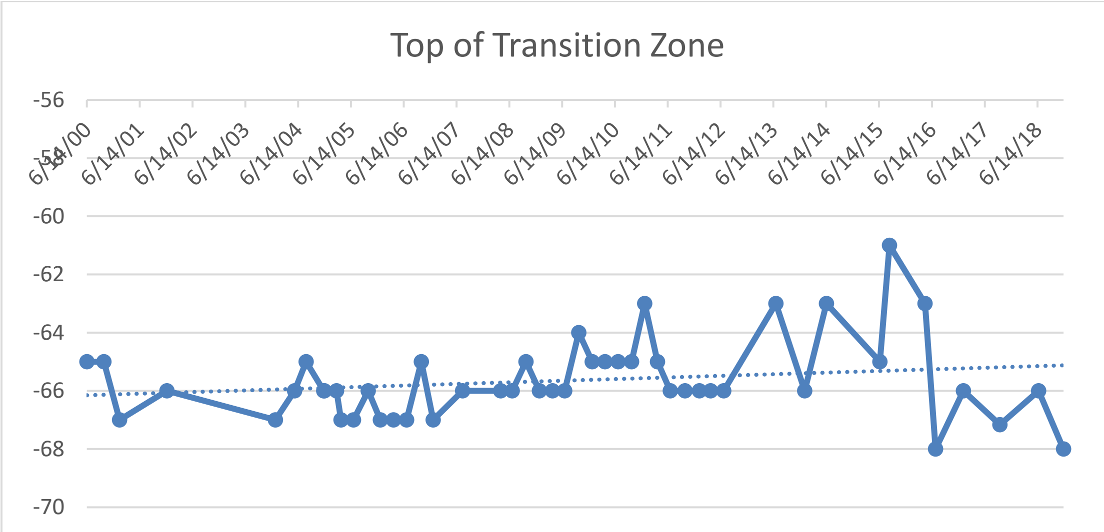
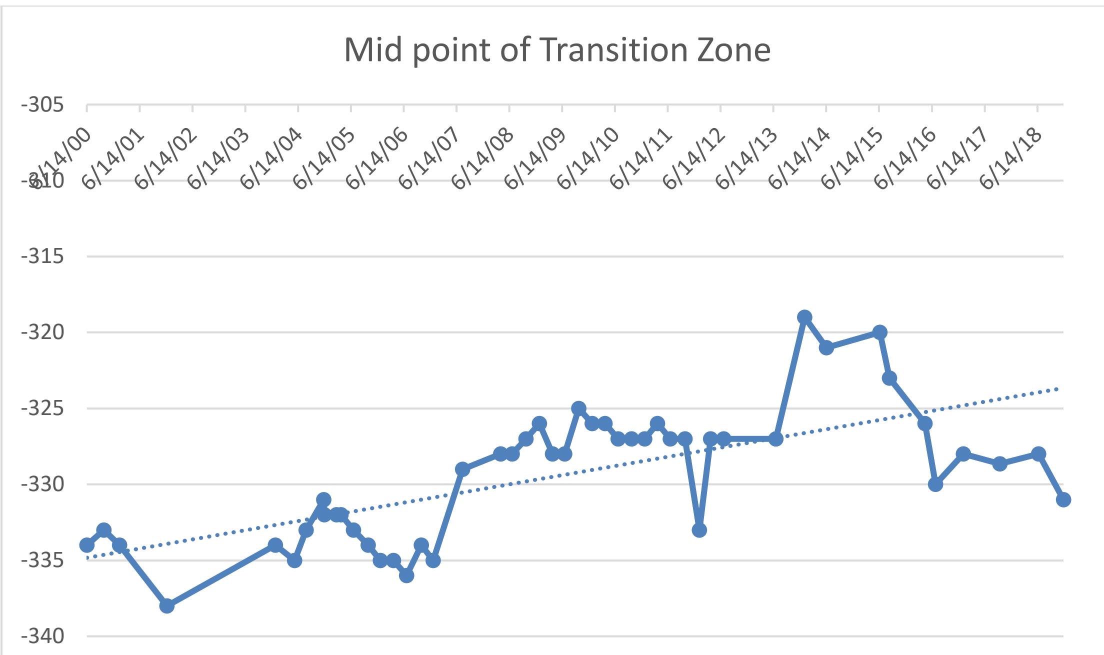
6/14/16
6/14/17
6/14/18


Top of Transition Zone
-56
-58
-60
-62
-64
-66
-68
-70
6/14/00 6/14/01 6/14/02 6/14/03 6/14/04 6/14/05 6/14/06 6/14/07 6/14/08 6/14/09 6/14/10 6/14/11 6/14/12 6/14/13 6/14/14 6/14/15 6/14/16 6/14/17 6/14/18


Mid point of Transition Zone
-305
-310
-315
-320
-325
-330
-335
-340
6/14/00 6/14/01 6/14/02 6/14/03 6/14/04 6/14/05 6/14/06 6/14/07 6/14/08 6/14/09 6/14/10 6/14/11 6/14/12 6/14/13 6/14/14 6/14/15 6/14/16 6/14/17 6/14/18

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT
P.O. BOX 621
HONOLULU, HAWAII 96809

DRAFT STAFF SUBMITTAL

for the meeting of the
COMMISSION ON WATER RESOURCE MANAGEMENT

December 17, 2019 (Tentative)
Honolulu, Hawai‘i

Proposed Amendment and Update
to the Water Resource Protection Plan of the Hawai‘i Water Plan
to Combine the Waimea (80301) and ‘Anaeho‘omalu (80701) Aquifer System Areas (ASA)
Into the Waimea-‘Anaeho‘omalu System/Sector Area (80302)

SUMMARY OF REQUEST

Authorize staff to initiate a public hearing for an aquifer boundary change to combine the ‘Anaeho’omalu (80701) and Waimea (80301) Aquifer System Areas (ASA), by removing the boundary that divides them, and combine them into a single Aquifer System Area to be called the Waimea-‘Anaeho’omalu System Area (80302) (Exhibit 1, Proposed Boundary Change). The resulting Waimea-‘Anaeho‘omalu System Area will also cause the combining of the existing W. Mauna Kea and N. W. Mauna Loa Aquifer Sector Areas into the W. Mauna Kea-N. W. Mauna Loa Aquifer Sector Area (803).

BACKGROUND

Ground water sustainable yields (SY) and hydrologic units called Aquifer System Areas (ASA) are established by the Commission through the Water Resource Protection Plan (WRPP) of the Hawai‘i Water Plan as established by the State Water Code, HRS 174C. The WRPP was last updated in 2008 and the 2019 WRPP update will be coming before the Commission for approval in July 2019.

In 2011 the Waimea ASA came under consideration for a sustainable yield (SY) reduction from 24 million gallons per day (mgd) to 16 mgd, based upon the new recharge estimate made by the U.S. Geological Survey (USGS) in Scientific Investigations Report 2011-5078 (Engott 2011). This was part of the overall effort to update to the 2008 Water Resource Protection Plan (WRPP) of the Hawai‘i Water Plan originally targeted for 2013.

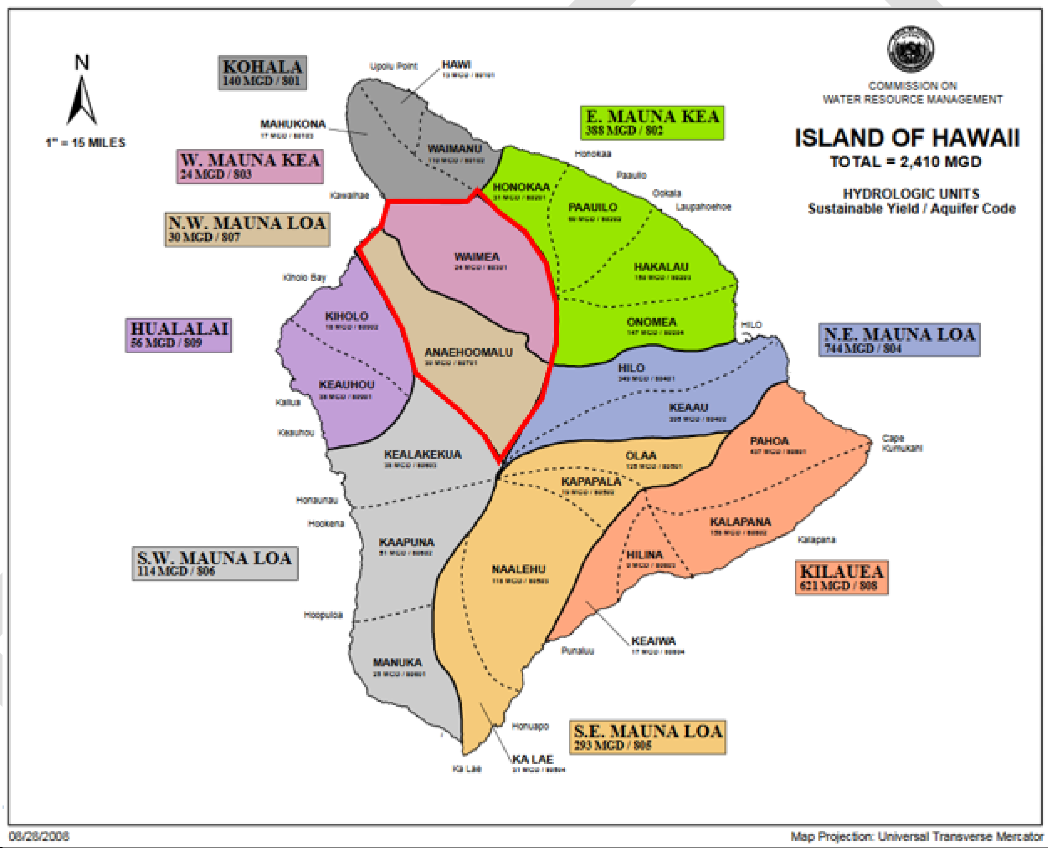
On December 17, 2013, staff met its water professional group composed of Private Sector Professionals, Commission on Water Resource Management (CWRM), Hawai‘i Department of Water Supply (HDWS), National Park Service (NPS), University of Hawai‘i Mānoa, and United States Geological Survey (USGS) to solicit comments on the overall proposed SY updates based on Engott’s 2011 recharge updates. Meeting notes were taken and compiled by Townscape, Inc. (Exhibit 2). It was evident back then there was much concern about the proposed lowering of sustainable yields and aquifer system area boundaries between ‘Anaeho‘omalu to Hāwī.

In 2015, Tom Nance Water Resource Engineering (TNWRE) and HDWS, with experience in the Waimea ASA further responded to the proposed SY reduction with additional written concerns (Exhibit 3 - letters from TNWRE and HDWS) that a reduction of the Waimea ASA SY did not reflect observed conditions from pumping and monitor wells.

In 2019, staff completed the public hearings on the draft of the 2019 Water Resource Protection Plan Additional comments on the proposed SY reduction to the Waimea ASA were received (Exhibit 4).

DISCUSSION

The current Waimea and 'Anaeho'omalu ASAs are shown in Figure 1, and the relevant comparative data is tabulated below:



	Area		Millions of gallons per day (mgd)			
ASA	miles^2	meters^2	2008 SY	2019 Recharge Range	2019 SY Range	Proposed 2019 SY
Waimea	299.97	776,907,632	24	36.62-54.0	16-24	16
'Anaeho'omalu	319.2	826,734,124	30	69.0-176.0	30-77	30

Figure 1. Current Waimea and 'Anaeho'omalu ASA Boundaries

After discussions on the WRPP update commencing in 2013, three main issues on the sustainable yield for the Waimea ASA have been raised and investigated: 1) an apparent discrepancy between recharge as a percentage of hydrologic inputs for Waimea ASA and Kohala Aquifer Sector Area and the rest of the island; 2) the aquifer area boundaries of the Waimea ASA; and 3) ground water monitoring behavior.

Waimea Recharge Issue

As raised by Nance (Exhibit 3), the Waimea ASA recharge percentage compared to overall hydrologic inputs in Engott (USGS 2011) seemed unreasonably low compared with neighboring ASAs.

Table 1

Summary Comparison of Results in Engott (2011) for
Aquifer Systems from Waimea to Keauhou in West Hawaii

Aquifer System				
• Name	Waimea	Anaehoomalu	Kiholo	Keauhou
• Number	80301	807.01	80902	809.01
• Area (Square Miles)	300.0	319.2	147.4	164.4
• Shoreline Length (Miles)	3.55	5.29	12.3	19.4
Sources Contributing to Evapotranspiration				
• Rainfall (MGD)	286.02	315.68	176.04	339.01
• Fog Drip (MGD)	13.52	11.64	7.75	13.76
• Irrigation (MGD)	6.59	7.00	3.44	3.50
• Total (MGD)	312.13	334.32	187.23	356.29
Amount of ET and Evapotranspiration				
• Evapotranspiration (MGD)	255.83	145.34	99.21	158.64
• Canopy Evaporation (MGD)	12.50	4.07	7.96	40.13
• Total (MGD)	268.33	149.41	107.17	198.77
• % of Contributing Sources	86.0	44.7	57.2	55.7
Contributing Sources Versus Recharge				
• Total of Contributing Sources (MGD)	312.65	334.43	187.31	358.46
• Calculated Recharge (MGD)	35.62	181.69	76.19	151.62
• Recharge as a % of Contributing Sources	11.4	54.3	40.7	42.3

Table 1 from TNWRE 11/27/2015 letter (Exhibit 3)

Staff reviewed this relationship for the rest of the Big Island and found this very low ratio to be isolated to other aquifer system areas within the Kohala Sector Area. The ASAs of Māhukona (11.0%), Hāwī (13.3%), and Waimea (11.6%)) are much lower compared to the rest of the island's 21 other aquifer system areas. Figure 2 below is a map showing the recharge percentage compared to overall hydrologic inputs from Engott (USGS 2011).

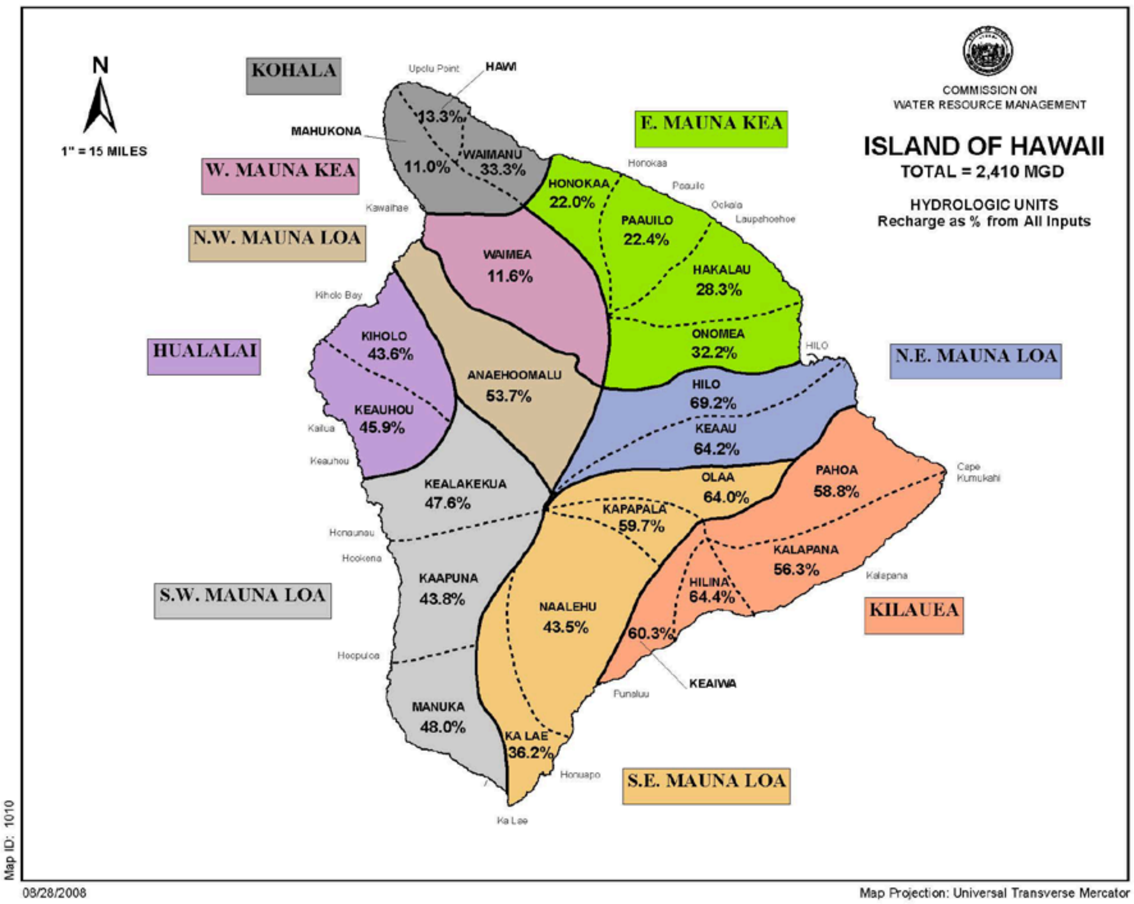


Figure 2. Recharge as % of All Inputs Map based on USGS Engott 2011 Climate II scenario

In discussions with Engott, he explained recharge values are most likely low due to the thicker soil coverage differences and clarified that losing stream effects across ASAs were also not included. TNWRE calculated that the surface and subsurface recharge from "offsite" could amount to as much as 10 to 20 mgd being discounted from calculations for recharge in the Waimea ASA alone (Exhibit 3). For these reasons, the Waimea ASA recharge estimate appears to be underestimated in Engott (USGS 2011).

Waimea-‘Anaeho‘omalu Aquifer System Area Boundaries

As currently delineated, the lateral boundaries of these two ASAs are surface contacts rather than geologic rift or valley fills that normally govern other aquifer sector boundaries. The Waimea ASA lateral boundaries are the surface contacts between the Kohala and Mauna Kea lavas on the north side, the ridge on the northwest flank of Mauna Kea on the northeast side, and the surface contact between Mauna Kea and Mauna Loa lavas on the south side. Likewise, the lateral boundaries of the Anaeho’omalu ASA are the surface contacts of the Mauna Kea and Mauna Loa lavas on the north side, the Humu‘ula Saddle between Mauna Kea and Mauna Loa on the east side, and the surface contact between Hualālai and Mauna Loa lavas on the south side. In the case of the ‘Anaeho‘omalu ASA northern boundary we know that this contact reflects the northern most extent of Mauna Loa's encroachment onto older Mauna Kea lavas and that water infiltrating into the Mauna Kea slope above the Saddle Road area flows directly beneath that surface contact and below the Mauna Loa surface lavas. Therefore, the water within the ‘Anaeho‘omalu ASA is derived from recharge infiltration entering both the southern flank of Mauna Kea as well as the northern flank of Mauna Loa.

From geologic information gathered to date in the area, and in the opinion of the water providers and professionals familiar with Hawaii Island geology, the buried physical aquifer boundaries associated with changes in the characteristics of the geologic formations governing groundwater flow and changes in the hydraulic conductivity of the rocks that affect or impede the transport of water are not clear in the area. Clearly there are no valley fills in the area, and a rift zone (where dense intrusive rocks are present), which are the predominant effective barriers to groundwater flow, has not been identified near the current Waimea/’Anaeho’omalu boundary. There has been speculation regarding Mauna Kea's rift zones for several decades. Figure 2, below, is an interpreted rift zones map (USGS SIR 2015-5164, Figure 45), that suggested western-trending rift zones from the summit of Mauna Kea. However, these interpretations were from studies conducted from 1946 through 1987.

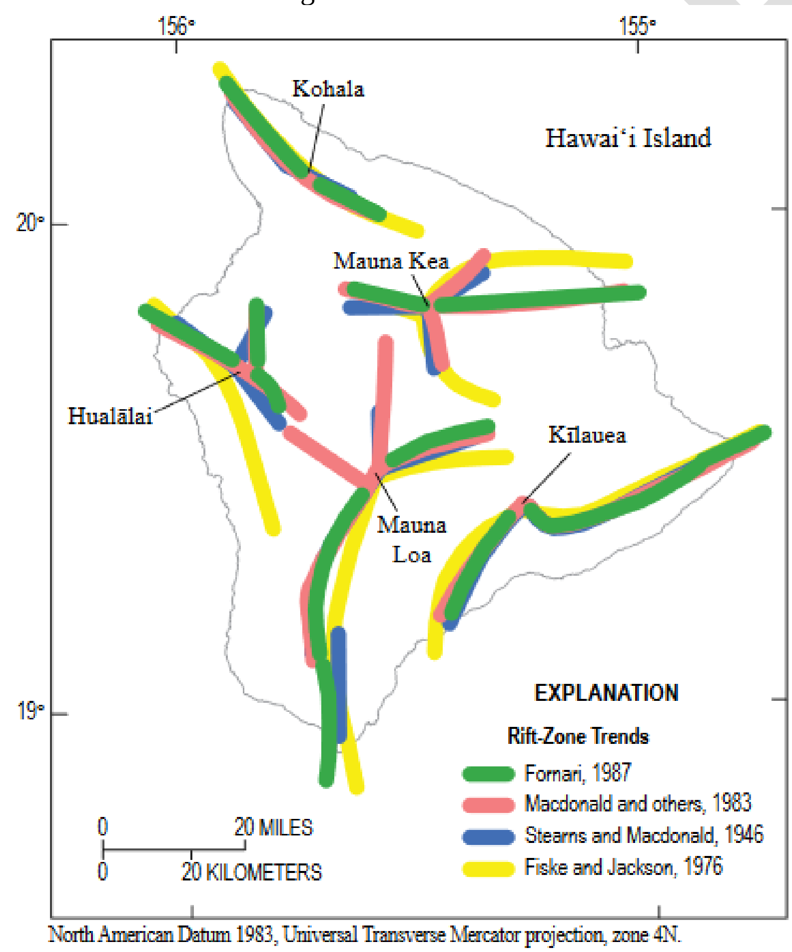


Figure 45. Interpretations of rift-zone trends on Hawai‘i Island.

Figure 3. USGS Rift Zone Map (from 1946 to 1987 Studies)

A more recent analysis indicates that an east and a west rift zone that had previously been proposed (with sufficient density to serve as an effective barrier to groundwater flow), has not been geophysically confirmed, (GSA, Morgan, 2010). A current map of Hawaii Island rift zones (highlighted in yellow) from the 2010 Morgan study is shown in Figure 4 below.

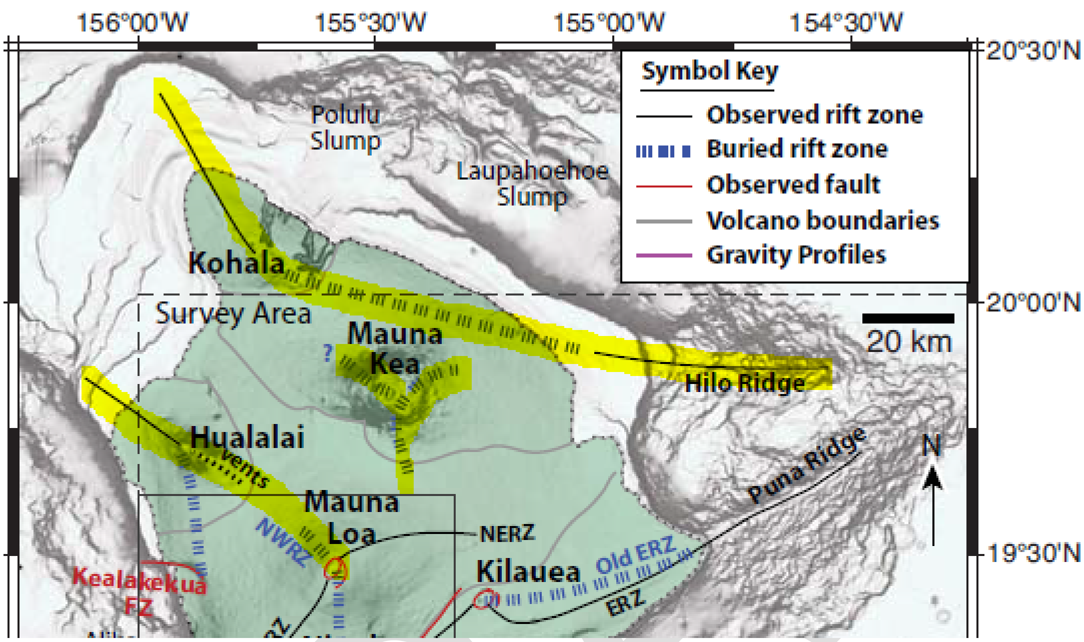


Figure 4. Section from 2010 Morgan Rift Zone Map

The presence of the rift zones identified by the Morgan report would further support the Waimea-‘Anaeho‘omalu hydrologic unit concept, bounded by rift zones to the southwest and north.

Recent drilling projects in the area have provided additional geologic evidence that the Mauna Kea and Mauna Loa lavas interfinger within the ground water basin comprised of the Waimea and ‘Anaeho’omalu aquifer systems (D. Thomas, 2019 Exhibit 5). Results also indicate that the ground waters flowing from Mauna Kea and Mauna Loa mix in this basin; and are not separate ground water bodies.

Waimea/‘Anaeho‘omalu Ground Water Monitoring

There is a limited amount of observed well ground water data in these ASAs, but enough to suggest that the Waimea Aquifer Area is not near sustainable yield as suggested by the proposed 2019 WRPP update. There are no deep monitor wells in the area; however, the Commission staff and private consultants have been monitoring the existing well pumpage, water levels and chlorides. In addition to the Keauhou Aquifer System Area, staff had established a water-level monitoring network in the area beginning in 1993, or 26 years ago. Basal ground water levels have been measured quarterly in 4 selected wells in the Waimea and ‘Anaeho‘omalu ASAs and are updated on the Commission’s website (see https://dlnr.hawaii.gov/cwrm/groundwater/monitoring/). Figure 5 below is a compilation of the data provided on the website for the area and shows stable water levels between 1993 to the present.

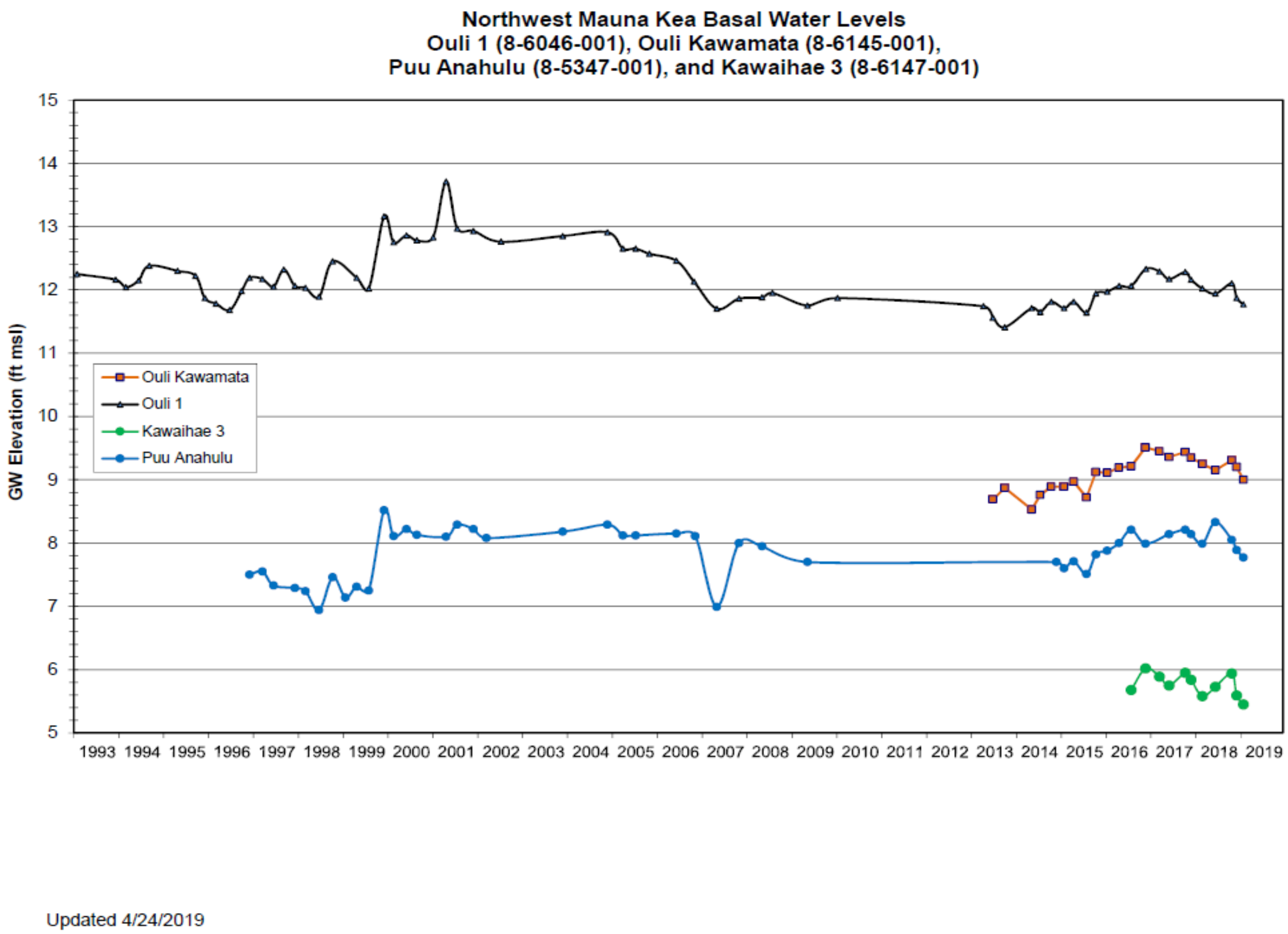
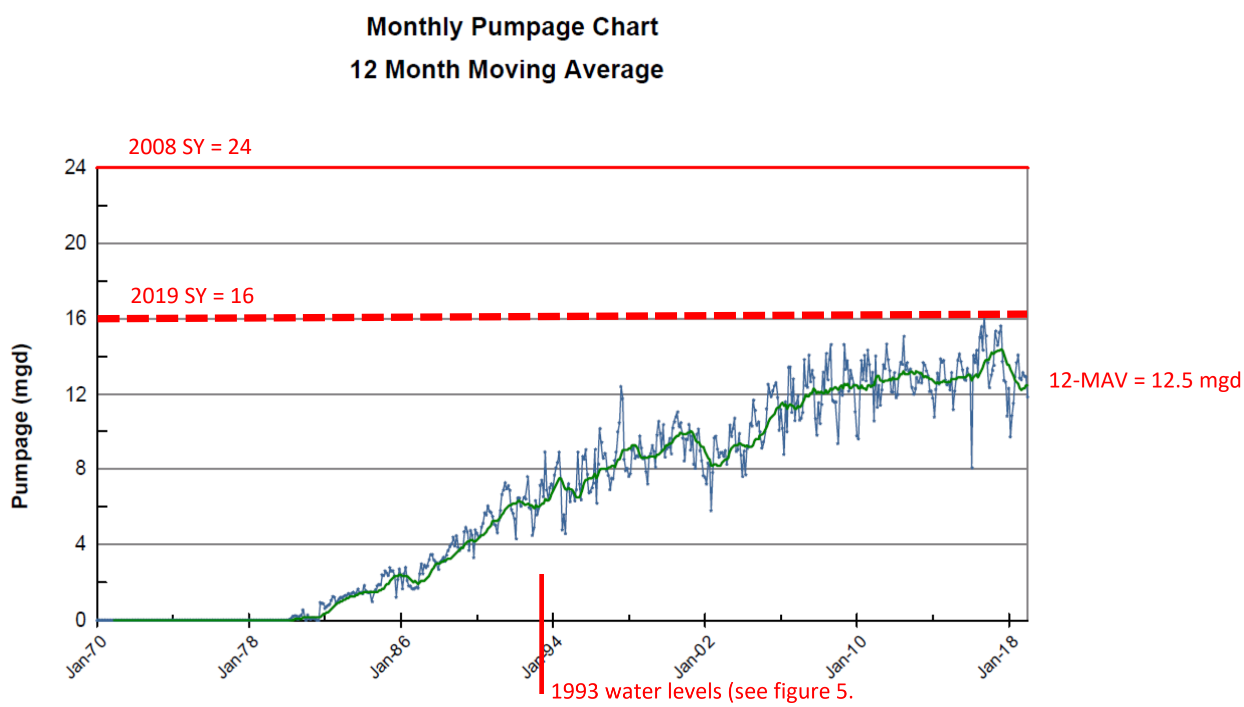
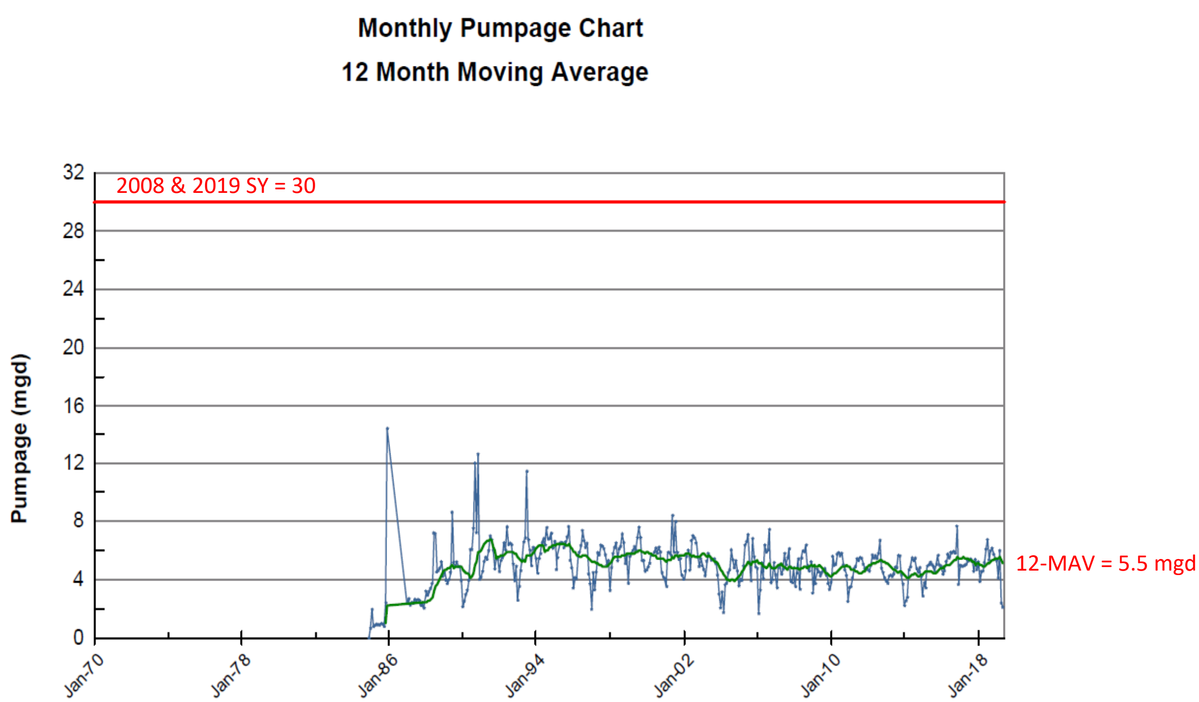


Figure 5. Monitoring network basal water-levels within the Waimea-'Anaeho'omalu ASAs

As can be seen, water level data from these monitor wells away from the local influences of pumpage show steady water-levels despite increased reported pumpage since 1993, which is shown in Figures 6 & 7. These data and observations show that the aquifers' reaction to the stresses of pumpage since 1993 has been unchanged and suggests that it may not be near sustainable yield.





Figures 6 & 7. Waimea and ‘Anaeho‘omalu ASA Pumpage

Figures 6 & 7 show the pumpage for the Waimea and ‘Anaeho‘omalu ASAs. Waimea is the main ASA of concern. Combining both ASAs would form a new ASA with a total 12-month moving average (12-MAV) of 17.5 mgd and a 2019 sustainable yield 46 mgd. All wells within the two ASAs are shown in Figure 8.

Staff has been reviewing reported water-levels and chlorides data from production wells in the Waimea and ‘Anaeho‘omalu ASAs. Reporting has been varied depending on owner, but in general chlorides have been better reported than water-levels. In the Waimea ASA, basal chlorides show steady and good quality chlorides that improve moving from north to south and makai to mauka through the various well fields of Hapuna, Lalamilo, Parker Ranch, and Waikoloa. High-level wells of Waiki‘i Ranch show very low chloride content as well.

Additionally, though data is limited and not definitive, recent isotopic sample analyses further indicate that the ground waters flowing from Mauna Kea and Moana Loa mix in this basin; and are not separate ground water bodies. Figure 8 (Courtesy R. Whittier) illustrates the similarity of isotopic content in ground water samples collected from within the Waimea/‘Anaeho‘omalu ASAs. More isotopic sample analyses would be helpful to confirm this observation and staff is working with other scientists and Ike Wai to obtain more isotopic information.

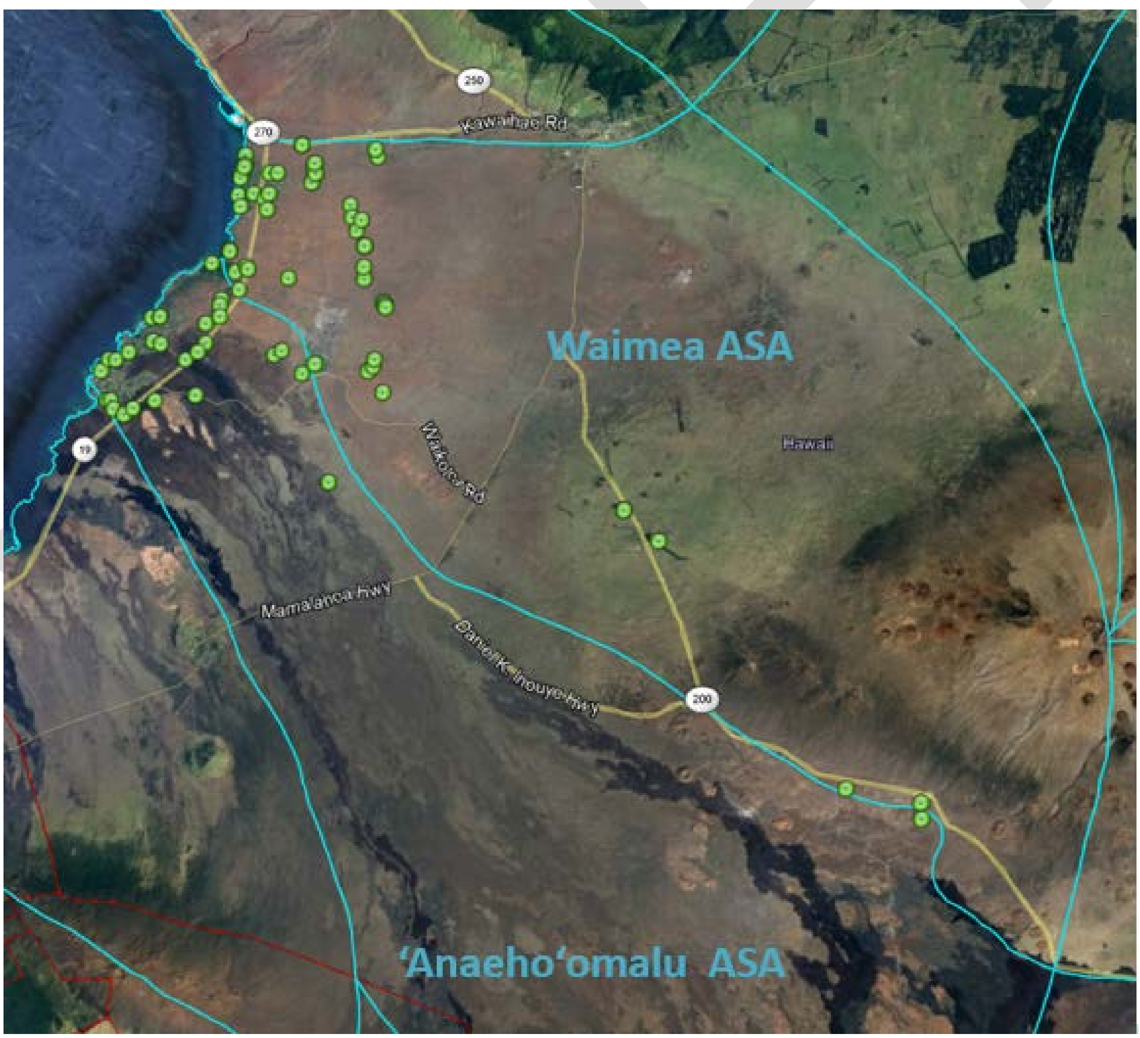


Figure 8. Well Locations within Waimea and ‘Anaeho‘omalu ASAs

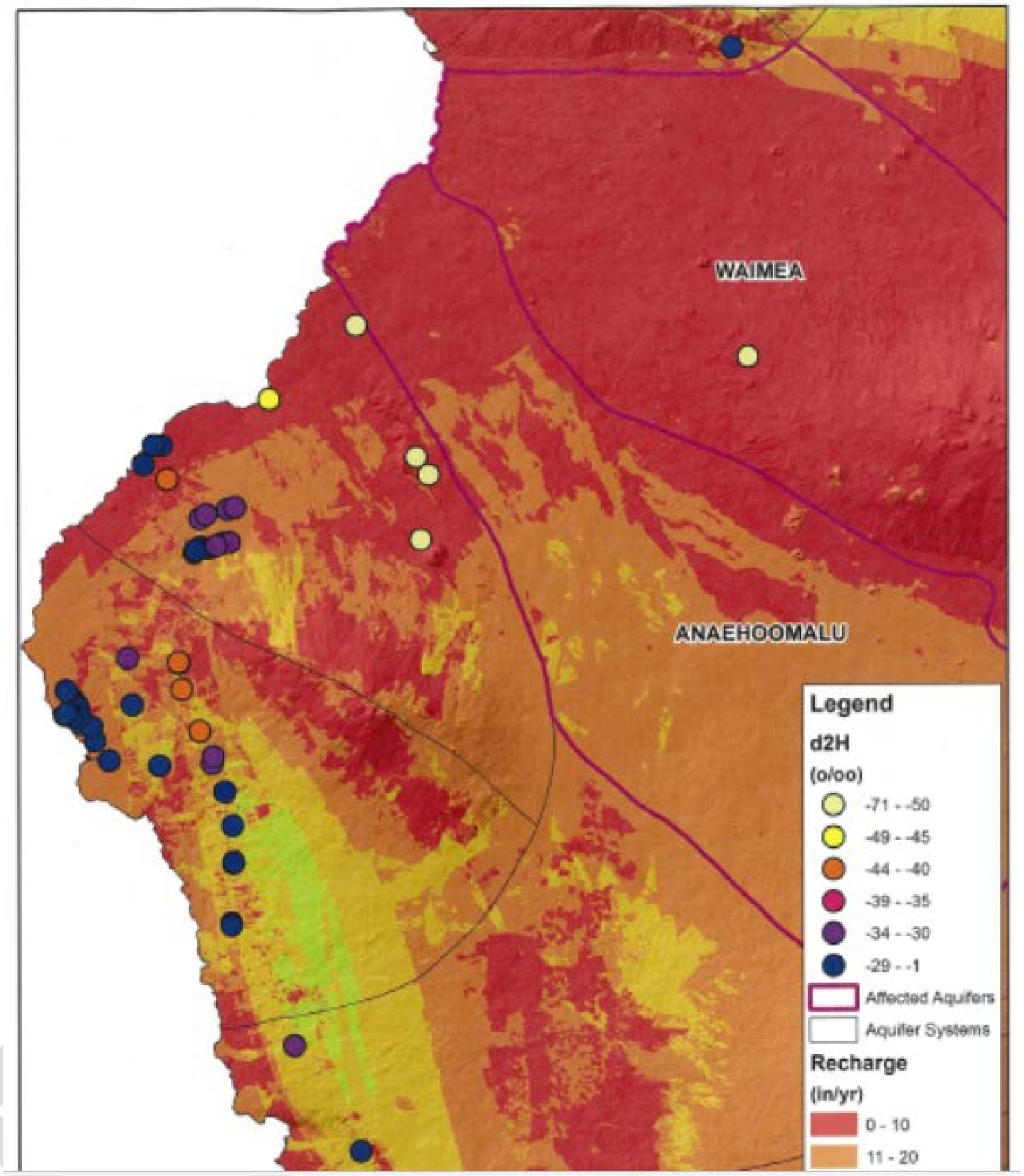


Figure 9. Results of Ground Water Isotope Sampling Analyses (Whittier, 2019)

Some professional group comments were made to adjust the Waimea ASA boundaries to account for recharge/underflow from the adjacent Māhukona ASA and other changes in the Waimea and ‘Anaeho‘omalu ASAs in addition to the missing imported surface water flows from Māhukona ASA (see Exhibit 3). These boundary changes have merit; however, from a ground water resource management perspective, the simplest and most expeditious approach to addressing the concerns of the proposed decrease in SY in the Waimea ASA is to combine the ‘Anaeho‘omalu and Waimea ASAs, and manage the described ground water basin as one ASA. Alternatively, keeping the ASA boundaries intact but including the importation of surface water and a re-review of the considerations towards the high evapotranspiration for the Kohala area could be done, but this would take some time to reassess with the U.S. Geological Survey.

PROPOSED BOUNDARY MODIFICATION

Based on the overall information from monitoring, recent drilling projects & studies, and comments from the professional group and public from the Water Resource Protection Plan public hearings, staff is proposing to combine the current Waimea and ‘Anaeho‘omalu ASAs into the Waimea-‘Anaeho‘omalu Aquifer System (80302) of the West Mauna Kea/Northwest Mauna Loa Aquifer Sector Area (803), Exhibit 1. Note that this figure incorporates the proposed 2019 sustainable yield SY figures of 16 mgd (reduced from 24 mgd) for Waimea, and 30 mgd (unchanged minimum) for ‘Anaeho‘omalu, yielding 46 mgd for the new Waimea-‘Anaeho‘omalu ASA. This is a reasonable management approach that does not require recalculation of system areas and the resulting corresponding changes in recharge.

Given the geologic setting, a contiguous ground water basin comprised of interfingered lavas from Mauna Loa and Mauna Kea, containing co-mingled ground water from both mountains, the concept of combining the two hydrologic units into one is logical, is supported by the available data, addresses the concerns of the public and water professionals, and can be accomplished with simple arithmetic without additional modifications to areal and recharge calculations as shown in Table 2.

Table 2 – Waimea-‘Anaeho‘omalu Aquifer System Area (ASA) Area & Sustainable Yield Values

	Area		Millions of gallons per day (mgd)			
ASA	miles^2	meters^2	2008 SY	2019 Recharge Range	2019 SY Range	Proposed 2019 SY
Waimea	299.97	776,907,632	24	36.62-54.0	16-24	16
‘Anaeho‘omalu	319.2	826,734,124	30	69.0-176.0	30-77	30
Waimea-‘Anaeho‘omalu	**619.17**	**1,603,641,756**	**-**	**105.62-230.0**	**46-101**	**46**

Moreover, this proposed change is not precedent setting; in March 1993 to address similar concerns, on O‘ahu, the ‘Ewa and Kunia ASAs were combined into the Ewa-Kunia ASA, and the Waipahu and Waiawa ASAs were similarly combined into the Waipahu-Waiawa ASA.

This approach has been recirculated to the water professionals group for further comment and the public hearing will provide additional opportunity to comment on this management approach.

LEGAL AUTHORITY

Legal authority to modify the Hawai‘i Water Plan is established in the Hawai‘i Water Code under HRS 174C Part III, Sections 31 & 21.

Additionally, under its general powers and duties, the Commission has the authority to plan and coordinate programs for the conservation of water and to contract with private persons to assist with these programs. Under section §174C-5 (4), HRS, the Commission "*[m]ay contract and cooperate with the various agencies of the federal government and with state and local administrative and governmental agencies or private persons*". Section §174C-5 (13), HRS, further provides that the Commission "*[s]hall plan and coordinate programs for the development, conservation, protection, control, and regulation of water resources based upon the best available information, and in cooperation with federal agencies, other state agencies, county or other local governmental organizations and other public and private agencies created for the utilization and conservation of water*".

The Code defines a "Hydrologic Unit" as: *"a surface drainage area or a ground water basin or a combination of the two."*. This would indicate that there is a great amount of flexibility afforded to the Commission in setting boundaries by which to manage. Surface drainage boundaries are rarely equivalent to ground water basin barriers yet the State Water Code clearly allows the Commission to combine them if there is some advantage to be gained above and beyond actual physical boundaries. In most cases, the sector boundaries are the best *"estimate"* of the actual geophysical boundaries of an aquifer. However, the Code clearly allows the Commission to manage using boundaries other than actual physical boundaries if there is some advantage to be gained. Therefore, the Commission can define boundaries which are most advantageous and helpful towards fulfilling its management objectives.

SCHEDULE

Updates to the Water Resource Protection Plan (WRPP) require 90-day notice prior to the public hearing on any update. Therefore, a public notice on June 28, 2019 will allow for a September 26, 2019 public hearing in Waimea with an October 28, 2019 deadline for written comments. This would allow for Commission action at its scheduled November 19, 2019 meeting.

ENVIRONMENTAL REVIEW CHAPTER 343, HAWAII REVISED STATUTES

This planning study is exempt from the application of HRS Chapter 343 pursuant to HRS §343-5(b) and Hawaii Administrative Rule §11-200-5(d). This is for a planning-level study and will not involve testing or other actions that may have a significant impact on the environment.

RECOMMENDATION

Staff recommends that the Commission:

1. Amend the 2019 Water Resources Protection Plan of the Hawai'i Water Plan by modifying the Waimea (80301) and 'Anaeho'omalu (80701) Aquifer System Areas (ASA) boundaries by removing their shared boundary as specified in this submittal. The name of this new hydrologic unit would be the Waimea-'Anaeho'omalu Aquifer System Area (80302) of the West Mauna Kea/Northwest Mauna Loa Aquifer Sector Area (803).

Ola i ka wai,

M. KALEO MANUEL
Deputy Director

Figures:
1. Current Hydrologic Units, Hawaii Island
2. Recharge as % of All Inputs Map based on USGS Engott 2011
3. USGS Rift Zone Map (from 1946 to 1987 Studies)
4. Section from 2010 Morgan Rift Zone Map
5. Monitoring network basal water-levels within the Waimea-'Anaeho'omalu ASAs
6. Waimea ASA pumpage
7. 'Anaeho'omalu ASA pumpage
8. Well Locations within Waimea and 'Anaeho'omalu ASAs
9. Results of Ground Water Isotope Sampling Analyses (Whittier, 2019)

Exhibits:

1. Proposed Hydrologic Units, Hawaii Island
2. Townscape, Inc. notes from 12/17/2013 CWRM/Water Professionals meeting
3. TNWRE letters (11/27/2015 and 7/6/2016)
   HDWS letters (11/27/2015 and 3/28/2019)
4. WRPP Public Hearing comments
5. Don Thomas, PhD Memo May 13, 2019
6. Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

APPROVED FOR SUBMITTAL:

SUZANNE D. CASE
Chairperson

REFERENCES

Morgan, J.K., J. Park, and C. A. Zelt, 2010, Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone, Geology, v. 38, no. 5, pp. 471-474.

Pierce, Herbert A. and Thomas, Donald M., 2009. Magnetotelluric and audiomagnetotelluric groundwater survey along the Humu'ula portion of Saddle Road near and around the Pohakuloa Training Area, Hawaii. USGS Open-File Report 2009-1135.

Thomas, D., Pierce, H. A., and Lautze, N., 2017, Integrated Geophysical and Drilling Results for Mauna Kea Volcano: Hydrologic Implications, GSA Annual Meeting in Seattle, WA, Geological Society of America Abstracts with Programs. Vol. 49, No. 6. doi: 10.1130/abs/2017AM-308419

Thomas, D., and Haskins E., 2017, Reconsidering Hawaii's Hydrologic Conditions in Light of Recent Exploration Results, Abstract Presented at Cordilleran Section - 113th Annual Meeting – 2017, Geological Society of America *Abstracts with Programs.* Vol. 49, No. 4, doi: 10.1130/abs/2017CD-292772.

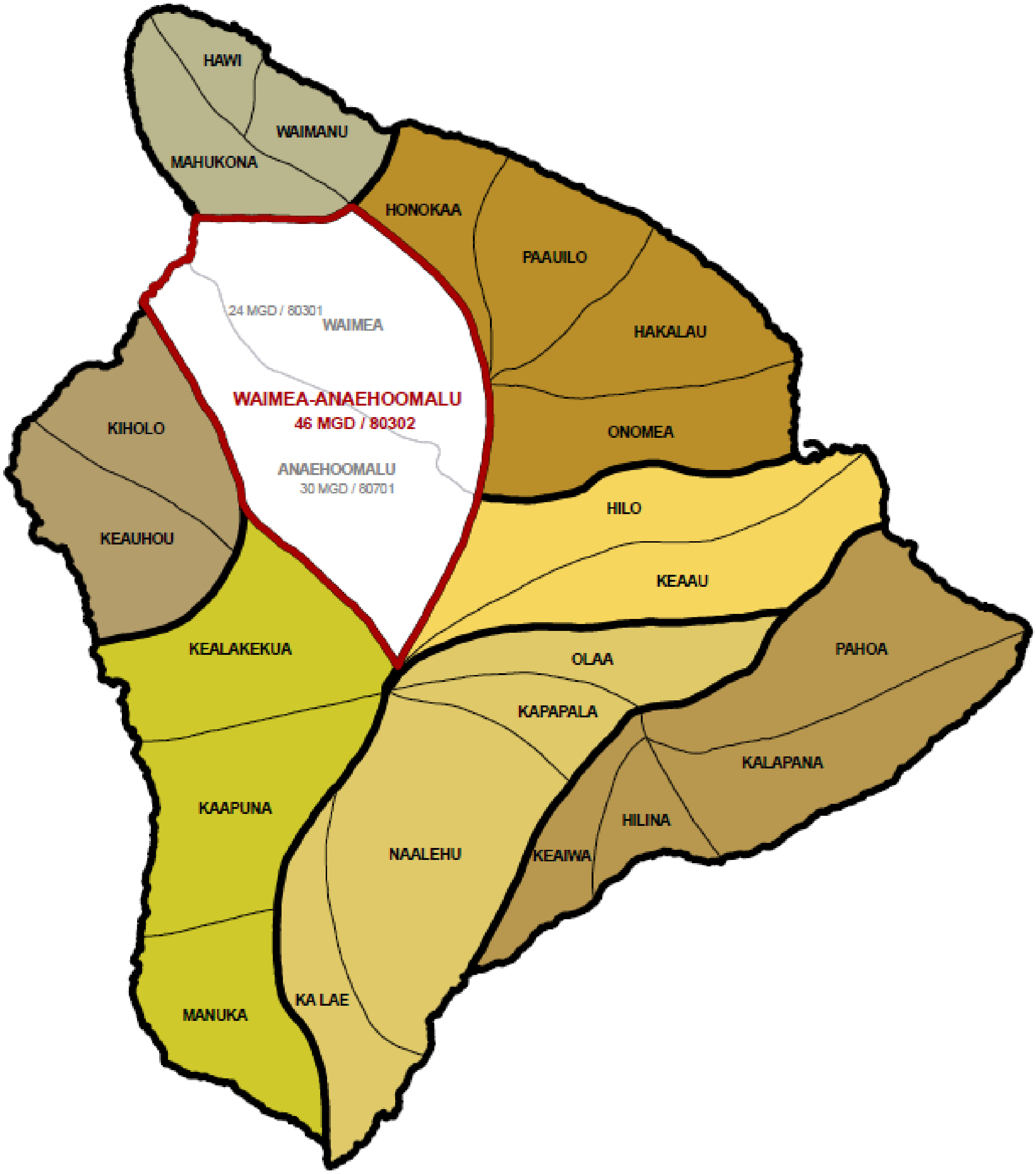
Thomas, D.M., 2016, Deep Geologic Structures and Groundwater Occurrence in Hawaii, Invited Talk at the 8th Jeju Water Forum, Nov. 16, 2016, Jeju, S. Korea.

Thomas, D.M. and Haskins, E., 2015, New Insights into the Influence of Structural Controls Affecting Groundwater Flow and Storage Within an Ocean Island Volcano, Mauna Kea, Hawaii, Abstract H31D-1446 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Thomas, D.M., Lienert, B.R., 2015, Three-dimensional Magnetotelluric Modeling of the Pohukuloa Training Area, Hawaii Island, Abstract GP13A-1281, presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

USGS, 2011 (Engott). Scientific Investigations Report 2011-5078, A Water-Budget Model and Assessment of Groundwater Recharge for the Island of Hawaii

USGS, 2018. Scientific Investigations Report 2015-5164. Volcanic Aquifers of Hawai'i – Hydrogeology, Water Budgets, and Conceptual Models



Note: The SY of 46 mgd for the new Waimea-'Anaeho'omalu ASA reflects the proposed 16 mgd for the Waimea ASA, and 30 mgd for the 'Anaeho'omalu ASA.

EXHIBIT 1. Proposed Boundary Change

TOWNSCAPE, INC.

ENVIRONMENTAL AND COMMUNITY PLANNING

900 Fort Street Mall, Suite 1160, Honolulu, HI 96813
Telephone (808) 536-6999 Facsimile (808) 524-4998 email address: mail@townscapeinc.com

WATER RESOURCES PROTECTION PLAN (WRPP) UPDATE
MEMORANDUM NO. 18

Date: December 17, 2013
To: Project Files
From: Townscape, Inc.
RE: Water Professionals Group Meeting

Meeting Participants:

Private Sector Professionals
- David Barnes, Waimea Water Services (WWS)
- Stephen Bowles, Waimea Water Services (WWS)
- Dan Lum, Water Resource Associates
- Tom Nance Water Resource Engineering
- Glenn Bauer (retired)

Commission on Water Resource Management (CWRM)
- Roy Hardy, Ground Water Regulation Branch
- Patrick Casey, Ground Water Regulation Branch
- Paul Eyre, Ground Water Regulation Branch
- Lenore Ohye, Planning Branch
- Jeremy Kimura, Planning Branch
- Neal Fujii, Planning Branch

County of Hawai'i Department of Water Supply
- Larry Beck (*phone*)

National Park Service (NPS)
- Paula Cutillo

UH Manoa
- Clark Liu, Civil & Environmental Engineering, Water Resources Research Center
- Tom Giambelluca, Geography
- Craig Glenn, Geology & Geophysics
- Joseph Fackrell, Geology & Geophysics
- Aly El-Kadi, Geology & Geophysics, Water Resources Research Center
- Donald Thomas, Hawaii Institute of Geophysics & Planetology

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group Meeting
December 17, 2013

Meeting Participants (continued)

U.S. Geological Survey (USGS)
- Stephen Anthony
- Delwyn Oki
- John Engott (*phone*)

Jeremy opened the meeting and reviewed its purpose: to present proposed revisions to the sustainable yield (SY) for Hawai'i Island and to discuss concerns with the revisions and the methodology that was used to develop them. After a brief background on the Hawaii Water Plan and Water Resource Protection Plan (WRRP) Update process, Roy provided background on SY, the model used to develop the revised SYs, basic caveats associated with the numbers, and proposed SYs for Hawai'i island (see attached slideshow)

Water Budget Model and Assessment of Groundwater Recharge for the Island of Hawai'i (2011).
John Engott then presented the results of the USGS study (*31:16 in audio file*)
- Report available on-line at: http://pubs.usgs.gov/sir/2011/5078/
- In forested areas, two reservoirs were used: forest canopy and soil. In unforested areas, only one reservoir was used:soil.
- The model calculated the water budget for each sub-area and aggregated theresults. Hawaii Island had over 467,000 subareas.
- The estimated recharge distribution was based on:
    - Land cover (2008)
    - Mean rainfall from 1986 Rainfall Atlas of Hawaii (1916-1983rainfall)
    - Mean Pan Evaporation 1985 study
- Differences in recharge between 2008 WRPP numbers and the new estimates: some were lower, some higher, and some over 100% higher. The new model:
    - Used a daily time step vs. an annual time step (2008 WRPP)
    - Included fog interception
    - Subtracted runoff from baseflow
    - Used a more rigorous approach to calculate evapotranspiration (ET)
- 2011 water budget report
    - Is a transient recharge model
    - Identified four aquifer systems in Kona: Kiholo, Keahou, Kealakekua, Kaapuna
    - Ran the model in 5-year increments
    - Used estimated rainfall from the time period: 1984-2008
    - The 1984-2008 rainfall estimates are presented in terms of the percent of the 1916- 1983 rainfall mean presented in the 1986 Rainfall Atlas of Hawai'i.
    - Shows that using more current rainfall could make a substantial difference in recharge estimates, particularly in the Kona area.

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group Meeting
December 17, 2013

- New datasets being incorporated into the water budget studies:
  - 2011 Rainfall Atlas (1978-2007 rainfall data)
  - Updated historical rainfall – monthly rainfall (1920 – 2007, to be extended to 2010)
  - New ET datasets being finalized by T. Giambelluca (UH)
  - Updated methods for calculating runoff
  - New climate data
  - Estimating runoff in ungaged basins
  - Updated how canopy interception is calculated
- Ongoing recharge projects:
  - Kauai 1978-2007 recharge estimate (uses 2011 Rainfall Atlas) : long-term average for a given area
  - 2010-2011 recharge estimates; Cooperator: USGS Ground Water Resources Program; expected in 2015
  - Oahu 1870: predevelopment condition
  - Oahu long term average 2010-2011
  - Oahu future scenario: incorporates climate change estimates
  - Oahu 1900-2010 transient study in 10 –year periods; Cooperators: CWRM, BWS, USGS GWRP; expect incremental reports from mid-2014 to early 2015
  - Maui 1978-2007 recharge estimates
  - Maui 2001-2010 drought scenario; Cooperators: GWRP, CWRM, Maui DWS; expected 2014-2015
  - Molokai 1940 – 2010 transient study in ten year period; Cooperators: USGS, Office of Hawaiian Affairs, Department of Hawaiian Home Lands, Maui Department of Water Supply; expected late 2014
- Would like to update Hawaii Island with new datasets but currently no funding

PROPOSED 2014 WRPP HAWAI'I ISLAND SY (*44:40 in audio file*)

- Generally affected upper range of SY; did not affect lower range of SY as much
- Yellow: lower ranges affected (*slide 19 of presentation*)
- Red: upper ranges affected (*slide 19 of presentation*)

DISCUSSION

- Hawi SY is too low
  - The original pumping numbers from sugar plantation days are a good starting point in determining more realistic numbers.
  - Water is being imported from Honokane and probably accounts for 50% of SY.
- Waimea and 'Anaeho'omalu aquifers – best available data is not being used
  - The table shows over 176 mgd recharge in 'Anaeho'omalu, but only about 20 percent of that in Waimea.

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group Meeting
December 17, 2013

- We are currently pumping 14 mgd out of Waimea (nearing the lower end of the SY range) and only 4.3 mgd out of 'Anaeho'omalu, but sampling of shoreline discharge shows that there is at least an order of magnitude greater flow coming out of Waimea than 'Anaeho'omalu.
- The aquifer boundaries here do not make sense.
- The implication of recharge study is that there is more water in 'Anaeho'omalu, but on the ground observations contradict that. All wells drilled in 'Anaeho'omalu have been less productive and higher salinity than on the Waimea side ofboundary.
- Northern side (Waimea) wells are tapping water from the Kohala Mountains. There are wells close to the boundary on both sides of Wai'ula'ula Gulch at the 700' elevation that are drinking-water fresh.
- **Starting with the recharge numbers is misleading. We need to start by redrawing the aquifer boundaries.**
  - The north boundary is far more important than the south.
  - This would shortchange the Mahukona aquifer, but a portion of the Kohala Mountains in the Mahukona aquifer above Waimea Town is a source ofrecharge to the Waimea aquifer.
- **Would not use the subsurface boundary as the aquifer boundary, but would move the aquifer boundary to the north to include the top of the Kohala Mountains.**
- Recharge for 'Anaeho'omalu would suggest that there is an average of 20 mgd coming out at the shoreline, but it's not coming out.
- There may be subsurface paths where groundwater is moving, which would explain the lack of coastal discharge from 'Anaeho'omalu, but there is actually a small fraction of that coming out. The water was never there.
- This area will become a hot spot in the future because it is slated for development.
- **Suggest new deep monitor wells in the Waimea/'Anaeho'omalu AquiferSystem Area (ASYA)**
- Pu'uanahulu State well (drilled but not cased) on the south boundary of 'Anaeho'omalu area. The open-hole pump test at the 1500-1600-foot well elevation yielded <100 Cl and eight-foot water level.

- **SY should be ranges, rather than a single number, but how should we determine the minimum and maximum?**

1:10:06 in the audio file – break for move

4

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group Meeting
December 17, 2013

- Basal vs. High Level Aquifers (*1:18:55 in audiofile*)
  - Hawai'i Island is expected to develop both basal and high level water.
  - The RAM model only works for basal aquifers, so how do we determine SY for high- level aquifers?
    - For high level water, we make a conservative estimate. Is the 0.44 draft/recharge (D/I) ratio in the table (*slide 19 of the presentation*) a conservative estimate?
    - The 0.44 D/I ratio is from J. Mink's suggestion for basal aquifers, but it's the best we have for high level water.
  - Hilo borehole hit water at 10,000 feet below msl
  - Schofield SY was left at the status quo; no additional pumping is allowed. Not sure how much water is going to Pearl Harbor vs. North Aquifer Sector Area(ASA)
  - "Water budgeting" is problematic in that it suggests that we know all of the other parameters and are trying to figure out one "left-over" number, but in reality,there are two or three parameters subject to uncertainty.
  - For water budgeting, a daily time step may not make sense because the other data is averaged.
  - There are other methods to estimate recharge beyond the water budget method.
  - Numerical modeling is not ready to replace RAM or RAM2 models for estimating SY, but it is still valuable for other roles, such as delineating boundaries, testing conceptual models, etc.
  - **Recommendations for more study:**
    - Delineate boundaries between basal and high-level aquifers
    - How to evaluate high level SY; D/I estimation
    - How to utilize the RAM2 model in basal aquifer evaluation, which requires monitor well data (RAM does not require monitoring data)
    - In the long-term, we need to investigate other methods beyond hydrological budgeting and investigate the underlying physics more: recharge vs. how much infiltration actually takes place under different scenarios.
    - More research on water budget estimation
- Water budget models are useful in that they provide recharge data to be used in determining SY estimates, which is what the State needs.
- Suggest using SY as a starting point. Come up with a reasonable SY with an "easy" methodology that people can understand and agree on. Assuming there is a reasonable SY, what is the process for determining when things are ok or not ok, so we know when/where to enforce management? How do you know where there's a problem? Is there an alternative method other than SY to manage water resources?
  - **We need to simplify water resource management – use direct observation as a tool.**
  - **Monitor measurable elements: rainfall and water levels + pumpage + salinity + streamflow**

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

- **Need to monitor in the high level area**
- **Need to monitor on a regular basis to be able to see changes**
- If we use SY as a starting point, how often and under what circumstances should we be revisiting SY? When data show evidence of some change in factors affecting SY.

- Professional vs. casual/citizen observer. CWRM is using technology to allow for each user to report use. Is it sufficient to have "non-professional" monitoring at a monthly interval?
  - Take advantage of data we can get, but have some quality assurance/quality control (QA/QC) for monitoring – how good is the data collected?
  - **Provide periodic training to those providing the data to check calibration methods and ensure that the data being used to make decisions (water levels, pumpage, etc.) is good data.**
  - CWRM is planning to hire a consultant to help get users on board with reporting and to verify that the older wells have a meter. New wells after 1997 are supposed to have meters, based on construction standards.
  - **It might it be better to get a good representation of wells across a given area, rather than try to get 100% compliance in reporting? Water professionals could agree to a set of key monitorwells.**
  - Kiholo USGS well had good data in real time, but it was discontinued due to vandalism.
  - Honolulu BWS collected island-wide water level data which was readily available, but CWRM doesn't have this kind of data set.
  - Due to limited resources and personnel, CWRM began its groundwater data collection program in "hot spot" areas. Complicating factors: collecting data on neighbor islands and on private property, large sampling areas. Resources will limit the amount of data that an organization is able to collect.
  - **Develop better collaboration between private and public partners to maintain a useful monitoring network.**
- CWRM will build off of existing data and analysis – e.g., Kona area.
  - Kona high-level wells are responsive to rainfall, so we should **concentrate on the high level aquifers** (e.g., Keopu). Look at where water is coming out from high- level to the basal. If water is coming out, identify where it is coming out.
  - Need to both get additional data and analyze existing data to find out what is happening in the high-level Keauhou-Kona area
  - Some high level well trends are inconclusive – there are large changes, +/-10 feet
  - **Need to re-establish the "Bauer-era" monitor well network**
- **In areas where the SY range is changing, CWRM should look at monitoring data and identify how to correlate monitoring efforts with management, then bring that up for discussion.**

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

  - Water budgets and recharge estimates can be a starting point to revising SY, but there should be multiple lines of evidence for getting at SY, e.g., operational data. How do we incorporate operational data in the setting of SY?
  - How are we going to address high level data if RAM does not provide that? Especially now that we've found high level water in the Keahou area, there is uncertainty as to how we are going to manage that resource.
- Results of the isotope study may help to ascertain the elevation that water is recharging and the path of ground water, but there are uncertainties.
  - Preliminary results suggest that recharge may be coming from high elevation rainfall and that water may not be going where most people think it is going.
  - Isotope analysis is complicated by mixing with seawater.
- Role of geologic data (i.e., deep borehole, gravity survey, data) in explaining ground water occurrence, aquifer boundaries, water movement and barriers (inferred dike systems, etc.) (*2:01:45 in audio file*)
  - Modeled gravity data and inferred substantial diking
  - Geologic structure is a major player in where groundwater is moving, but we do not understand the geologic structure.
  - Future expansion of magnetotelluric groundwater (MT) surveys could indicate where fresh water is and where the transition is between fresh and saltwater. There may be sharp boundaries in the ground water system. Study areas include Waimea region and the Hualalai transect.
  - Land access and permission are challenges to MT research projects.
  - Data expected hopefully by 2015.
- To model high elevation water, we need to know aquifer thickness.
  - Beyond a certain depth we assume that water will be stagnant.
  - Based on what we see at the Saddle borehole, porosity is maintained for about one kilometer. Beyond that, things "pancake."
  - At 5,000 feet, we can see the flow boundaries but they are "pancaked." Do not see the same loose formations we see at 2,000 feet.
  - Saddle borehole cores can help to determine porosity and find barriers. This type of analysis was not included in the current study, but the cores are available to others for analysis.
- Purpose of the borehole was to determine the elevation ground water is at and what is its water quality because the Army is interested in it as a potential water supply.
  - The first 2,900 feet of the hole is unstable and experienced a lot of caving. The team needed to install casing to 2,918 feet to stabilize the hole. Will be perforating the casing and doing a pump test in spring 2014.

- The hole diameter is about 4-1/2-inched (casing) to the 2,918 foot depth, then HQ coring size from there to 5,786-foot depth. The only water that could be sampled is 1,100-feet below the surface of what appears to be the stable water table.
- At about 3,000' to 4,000 feet below the surface, the rocks lose permeability.
- The Waiki'i pump well went to 3,700 feet.

- At what depth is an aquifer non-water bearing or impermeable?
  - Hilo borehole saw different results from the Saddle borehole.
  - Hilo borehole drilled to 3,600 feet and found fractures that are much more open.
  - Started at about 25 feet above msl, drilled through 2,760 feet of lava before hitting submarine haloclastites, but even those were open.
  - Saw a flat temperature gradient until 4,500 feet, then saw conducted gradient. Core got mineralized and compacted. This seemed to happen sooner in Saddle borehole.
  - The Saddle borehole hit the first perched water at 500 feet depth to about 540 feet, hit another perched aquifer at 700 feet to 1200 feet, then hit a sequence of unsaturated zones. All standing water in the borehole was lost at around 1,500 feet, then the final water table was hit at 1,800 feet and the borehole never lost water after that. The bottom of the hole is at 600 feet above msl.
  - Large scale perching formations will affect water flow.
- Traditional and Customary (T&C) Practices (*2:16:00 in audio file*)
  - Is how we currently define sustainable yield enough? We currently allow for 56% of recharge to flow into the ocean?
  - Do we need a monitoring for outflow? Is that an end-use?
- Climate Change Impacts
  - There is a current study on climate change impacts (sea level rise) on O'ahu aquifers
  - Climate change (sea level rise) will affect anchialine ponds
    - Rising sea level will make the ponds more saline
    - It will occur faster on Big Island since it is sinking
    - Impacts depend on how sea level rise interacts with nearshore topography
  - Change in storage boundaries due to rising sea level
  - Changes in rainfall will also affect recharge. Has there been an analysis in rainfall patterns in Kona area (there are still a number of active gages)?
- Volcanic Eruption Impacts
  - Rainfall decrease of about 30% in Kona due to vog (data shows this in downwind rain gages).
  - Rainfall is corrosive due to atmospheric sulphur from volcanic emissions (acid rain)
  - Possible increased sulphur in rainfall, and thus in the groundwater?
  - Really high concentrations of pollutants in the rift zone area – Ka'upulehu wells are enriched in every dissolved constituent. The water becomes semi carbonated and fouls up the R-O filters at Four Seasons resort.

EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group
Meeting December 17, 2013

- Is the decline in rainfall in Kona exacerbated by volcanic activity (vog)? There is a correlation between decreased rainfall and vog, but there are no known studies that show causation. There are papers on polluted cities (where there are more particulates in the air) getthing reduced rainfall Water does not rain out of the atmosphere, but there tends to be more fog. There may be more fog interception in the upland Kona area.

- Is Kona high-level water moving into the basal aquifer – spillover vs. throughflow. The actual mechanism will affect management.
  Are the water bodies separate? How should we be treating this? Isotope studies are crucial so we can determine this.
  - Is basal water really just high level water just coming down? This is how we have been treating it. If not, how do we treat it?
  - If high level water is spilled over from the high level aquifer, then drawdown will have a more drastic effect than if we have throughflow, which would be driven by hydrostatic head. Drawdown of a few percent would affect throughflow by a few percent.
  - **Monitoring is essential. It will inform our understanding of how the systems work and we can then adjust our management.**
- Do we need something in Kona similar as the Pearl Harbor Monitoring Working Group that agreed on a monitoring network and triggers were proposed for management actions?
  - If we do not have a proactive approach, we will permit a lot of wells and development will occur, and we would have to pullback.
  - O'ahu was developed and had to cut back, but we should be able to plan for it better now.
  - What is the best management philosophy?
- **We need to have better monitoring. We need to identify the most critical data points, and get data in a timely manner.**
- How do we factor T&C into the SY? How much is sufficient? Is leaving a certain percentage of the water in the ground enough?
  - **Begin with SY as a starting point. Do not modify SY, but take that and other things into consideration when evaluating T&C impacts: well location, drilling, site specific studies on ecosystems, and other factors which may impact T&C practices.**
  - T&C is very site specific but SY is over a broad area.
  - Ascertain T&C practices through the permitting process (Ka Pa'akai analysis).

Water Resources Protection Plan Update
Memo No. 18 – Water Professionals Group Meeting
December 17, 2013

Next Steps

- There are areas where SY numbers are in question: CWRM staff should take a look at those and re-send the table out to the group.
- D. Thomas to send Flinders, et.al., paper to CWRM.
- Bowles and Nance to propose boundary changes on aquifer map.
- Isotope study analysis may help to identify aquifer boundaries, but data will not come out until after the WRPP.
  - New sampling point: Pace's Ranch well (hit water 1,000 feet above msl) – for isotope study.
- University group to identify relevant academic research in the area.
- Group should suggest new research projects in the area to improve knowledge inthe area.
- Locations for new deep monitor wells, particularly in Kona
- Potential to meet again, if needed.

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EXHIBIT 2. Water Professionals meeting notes 12-17-2013 WRPP Update

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March 28, 2019

Commission on Water Resource Management
Attention: Lenore N. Ohye and Roy Hardy, P.E.
Kalanimoku Building
1151 Punchbowl Street, Room 227
Honolulu, HI 96813

Dear Sirs:

Subject: Water Resource Protection Plan Update - Sustainable Yield Numbers and Aquifer Boundaries; Hawaiʻi Island

The Department of Water Supply (DWS) respectfully requests, that until the aquifer boundary changes under consideration are resolved, and ready to be adopted, the Commission on Water Resource Management (CWRM) refrain from adopting the proposed changes to the aquifer sustainable yield numbers found in the *draft* update [Public Review Draft October 2018] to the Water Resource Protection Plan (WRPP).

DWS recognizes that boundary changes could have a significant impact on the application of the sustainable yield (SY) numbers. DWS believes that adopting new SY numbers without incorporating potential boundary changes at the same time could result in an unnecessarily misleading outlook on resource capacity and that it would be better to include all the pertinent information available to provide the most accurate determinations for sustainable yield. Doing so will help ensure the public's trust and support for the WRPP Update. Once the boundary changes have been appropriately addressed and those boundary changes can then be reflected in the determination of sustainable yield, then both the boundary changes and new sustainable yield numbers should be adopted.

Following are some additional comments and questions regarding some of the specific information found in the draft WRPP Update document.

SY Table – 201810 – The bottom of this page refers to Appendix F, however, if this table may sometimes be viewed as a stand-alone document, then the SY Table, itself, should include the footnotes that are found in Appendix F.

Appendix E – Memorandum No. 18: What is being done to consider the water professionals group's input on the Waimea and Anaehoomalu Aquifers in Memorandum No. 18, drafted December 17, 2013 by Townscape, Inc.?

Appendix F – Table F-10: Although the reference to Note 29 follows the SY (2019) estimates for the Waimea, Anaehoomalu and Mahukona Aquifer Systems, there should be a clear indication within the

EXHIBIT 3. – HDWS (5/28/19)

table that these numbers are under special consideration and are preliminary in order to avoid potential misconceptions.

Appendix F – Table F-11: Same as above. In addition to the comments in the column following, it should be made clear that this number is "preliminary until further confirmation."

Appendix H – Table H-10: This table does not indicate in any way, the intention of the 16 MGD being preliminary until further confirmation, nor does it indicate any potential aquifer boundary changes. This should be made clear as this is definitely a source of information that could be misleading.

Appendix H, Section 6.3.6 – County of Hawai'i WUDP 2010: This section addresses the WUDP as is and does not take into account the 2019 SY numbers. There should be some reference to the 2019 SY numbers and the potential aquifer boundary changes. It should also make it clear that the 2019 SY for the Waimea Aquifer in particular, is only preliminary until further confirmation and that the aquifer boundary changes are being considered based on the input of the water professionals' memorandum in Appendix E.

Appendix J, Section J.6.3.1: Reference to the County of Hawai'i, Waimea Reservoir. Please note that this is not intended to mean DWS' Waikoloa Reservoirs.

Should there be any questions or concerns, please contact Mr. Larry Beck of our Water Resources and Planning Branch at 961-8070, extension 260.

Sincerely yours,

Keith K. Okamoto, P.E.
Manager-Chief Engineer

LEB:dfg

copy – Fukunaga and Associates
Ms. Bethany Morrison, Planning Department

EXHIBIT 3. – HDWS (5/28/19)

TNWRE
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Original ☐ will ☑ will not be mailed to you.

November 27, 2015
15-239 | 15-63

MEMORANDUM

To: Bob Chenet and Roy Hardy – Commission on Water Resource Management

From: Tom Nance

Subject: Comments on the Proposed Reduction of the Sustainable Yield of the Waimea Aquifer System (Code 80301) from 24 to 16 MGD

Introduction

This memo and its attachments provide comments on the proposal to reduce the sustainable yield of the Waimea Aquifer System from 24 to 16 MGD solely on the basis of a recharge estimate in USGS Scientific Investigations Report 2011-5078 (Engott 2011). I have been working on well development, monitoring well performance, and have been involved in other aspects of groundwater movement and its shoreline discharge in the Waimea Aquifer and elsewhere in West Hawaii continuously since the early 1970s. I believe my 40 plus years of experience puts me in a unique position to comment on the merits of the proposed reduction.

In my view, the proposed reduction is not warranted and would unnecessarily lead to the aquifer's near term designation as a groundwater management area. To demonstrate that, I will focus on the following three areas: recharge into the aquifer from beyond its currently delineated boundaries that is not included in Engott (2011); the unrealistic evapotranspiration amount in the Waimea Aquifer calculated in Engott (2011); and the field reality of conditions in the Waimea Aquifer itself and in comparison to other aquifers in West Hawaii. It is important that this unwarranted reduction not be enacted. Since January 2010, pumpage in the Waimea Aquifer has averaged about 13 MGD (Figure 1). Planned increases in groundwater use, particularly in Waikoloa (served by the Hawaii Water Service Company System), at the Mauna Kea Resort (potable and non-potable uses), and in DWS' Lalamilo System would trigger designation proceedings in the near future without any field evidence that such designation would be warranted.

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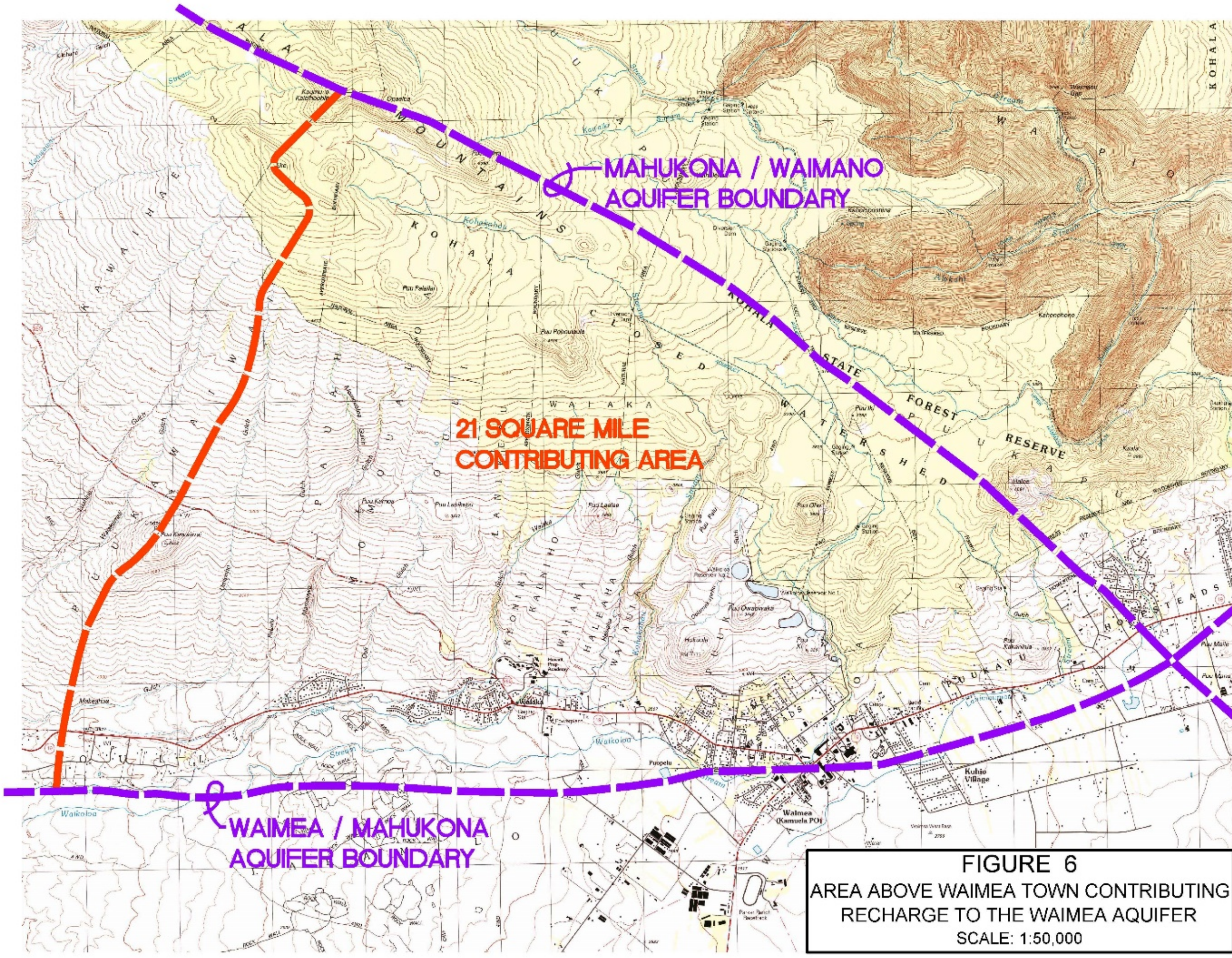

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Table 1

Summary Comparison of Results in Engott (2011) for
Aquifer Systems from Waimea to Keauhou in West Hawaii

Aquifer System				
• Name	Waimea	Anaehoomalu	Kiholo	Keauhou
• Number	80301	807.01	80902	809.01
• Area (Square Miles)	300.0	319.2	147.4	164.4
• Shoreline Length (Miles)	3.55	5.29	12.3	19.4
Sources Contributing to Evapotranspiration				
• Rainfall (MGD)	286.02	315.68	176.04	339.01
• Fog Drip (MGD)	13.52	11.64	7.75	13.76
• Irrigation (MGD)	6.59	7.00	3.44	3.50
• Total (MGD)	312.13	334.32	187.23	356.29
Amount of ET and Evapotranspiration				
• Evapotranspiration (MGD)	255.83	145.34	99.21	158.64
• Canopy Evaporation (MGD)	12.50	4.07	7.96	40.13
• Total (MGD)	268.33	149.41	107.17	198.77
• % of Contributing Sources	86.0	44.7	57.2	55.7
Contributing Sources Versus Recharge				
• Total of Contributing Sources (MGD)	312.65	334.43	187.31	358.46
• Calculated Recharge (MGD)	35.62	181.69	76.19	151.62
• Recharge as a % of Contributing Sources	11.4	54.3	40.7	42.3

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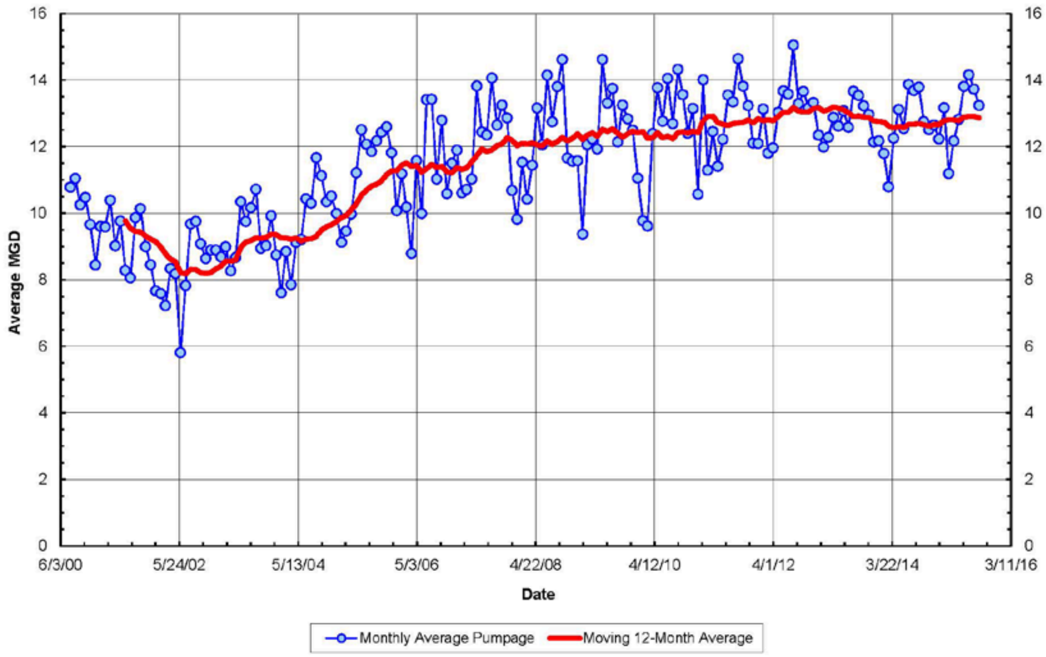
Figure 1. Monthly Pumpage of the Waimea Aquifer (Data from the CWRM)



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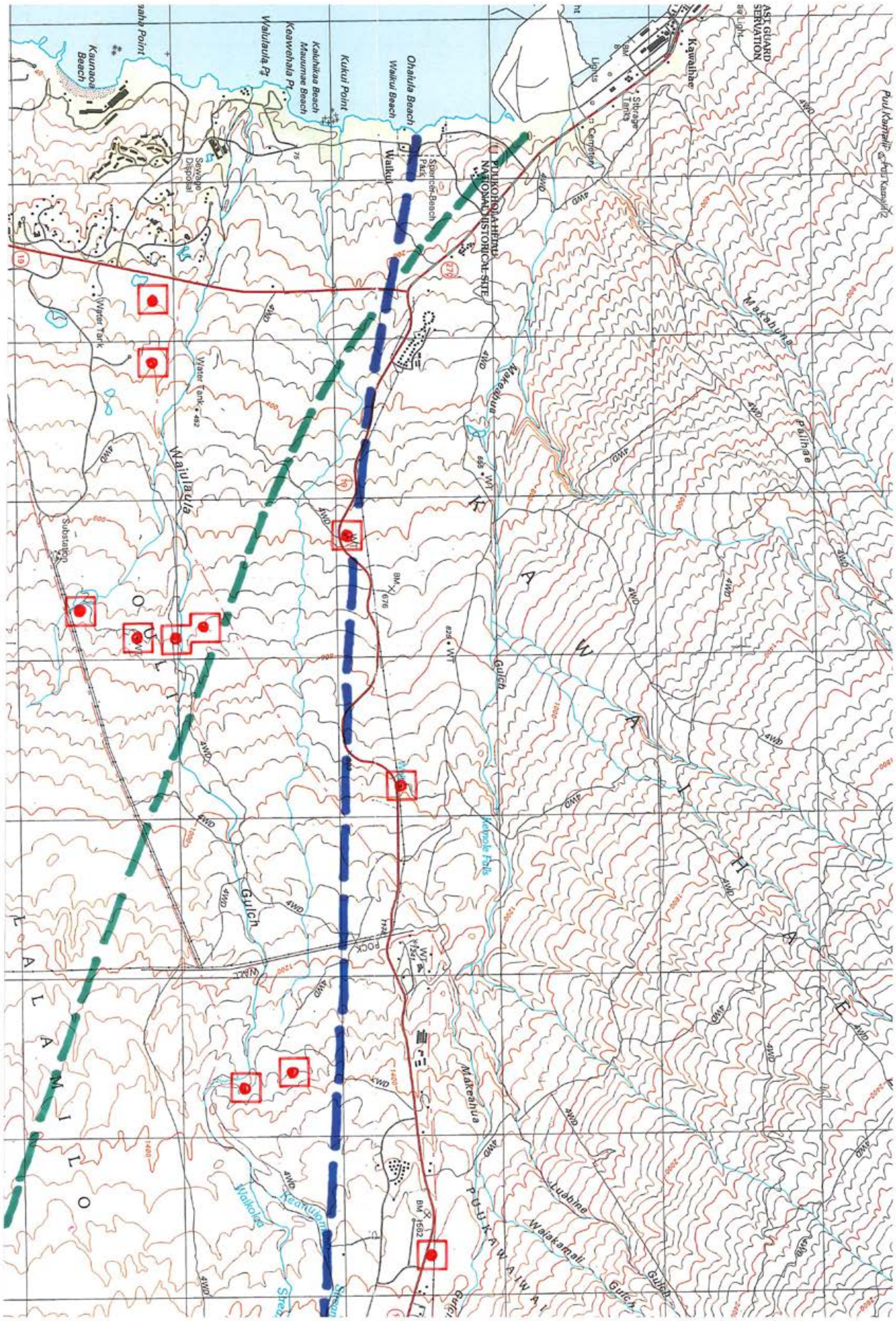

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Figure 3. Adjusted Flowrate at USGS Gage 7580 on Waikoloa Stream

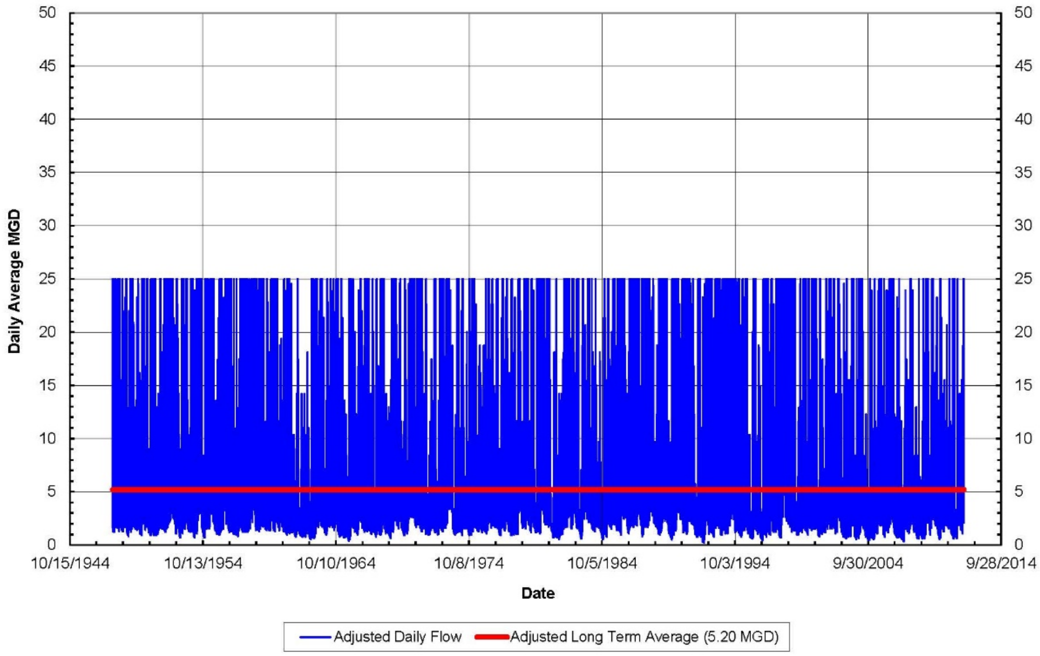

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Figure 4. Adjusted Flowrate at USGS Gage 7565 on Keanuiomano Stream

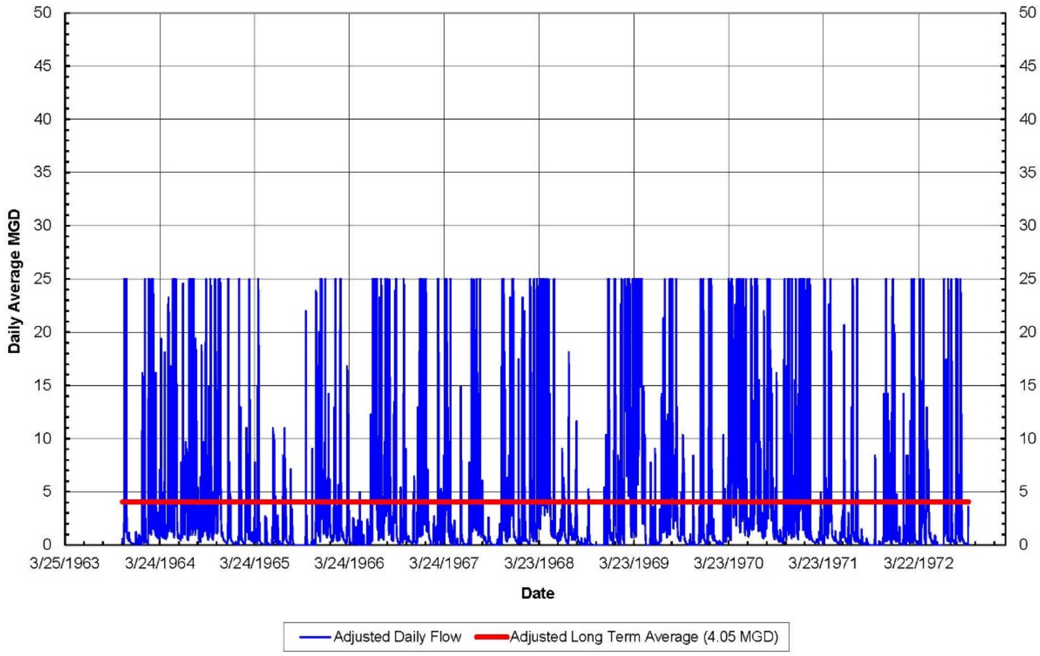

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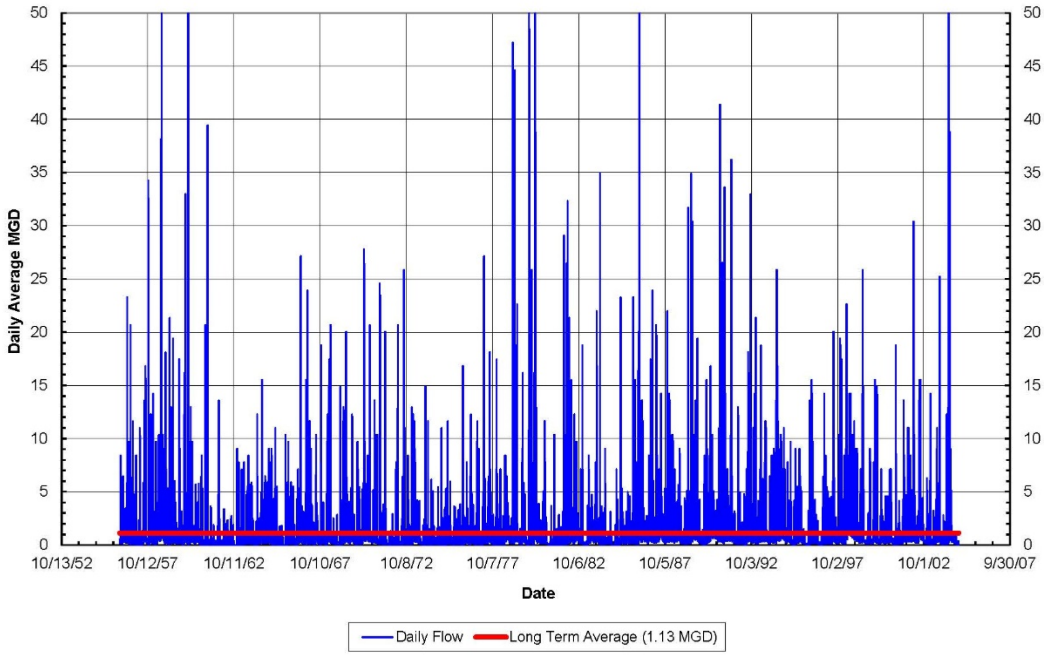
Figure 5. Flowrate at USGS Gage 7590 on Hauani Stream



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Lateral Boundaries of the Waimea Aquifer and the Recharge from Beyond these Boundaries into the Waimea Aquifer

As currently delineated, the lateral boundaries of the Waimea Aquifer are the surface contacts of Kohala and Mauna Kea lavas on the north side and the Mauna Kea and Mauna Loa lavas on the south side. The reality is that neither of these surface contacts functions as a hydrologic boundary. From the perspective of the Waimea Aquifer's sustainable yield, the most egregious of these boundary delineations is on the north side. Without question, substantial recharge as surface runoff and as subsurface flow moves from the Kohala Mountain into the Waimea Aquifer. This very substantial contribution to the Waimea Aquifer's recharge, which is not included in Engott 2011, is described below:

- A projection of the Kohala Mountain lavas to sea level (Figure 2) is a way of illustrating a long known fact that a number of wells in the Waimea Aquifer actually draw water from the Kohala Mountain lavas. Further, a contact surface between the Kohala and Mauna Kea lavas that might impede the flow of groundwater between the two lava formations has never been encountered in the drilling of any of these wells.
- A substantial amount of surface runoff which originates on the slopes of the Kohala Mountain flows out onto the Waimea Aquifer, most of which never reaches the ocean and becomes groundwater recharge. The incredibly low salinity in the Hapuna 3 and 4 wells (State Nos. 6047-04 and -05) is attributable to this occurrence. An approximation of this contribution can be made with USGS gaging station data. By eliminating flowrates above 25 MGD as being lost to shoreline discharge(Figures 3, 4, and 5), the recharge to the Waimea Aquifer via surface water originating on the Kohala Mountain is on the order of 10 MGD (tally below which assumes a cancelling of flow diverted from Waikoloa Stream by DWS with runoff in ungagged streams and from below the USGS gages on gaged streams):

Approximation of Surface Runoff from the Kohala Mountain Into the Waimea Aquifer

Stream	Average MGD
Waikoloa	4
Keanuiomano	4
Hauani	1
Other	0.5
Total	10+

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- If the subsurface inflow from the Kohala Mountain into the Waimea Aquifer is conservatively limited to the 21 square mile area above Waimea Town shown on Figure 6, its contribution to the Waimea Aquifer's recharges is on the order of 10 MGD (approximated as 20% of its 47 inches per year of rainfall and 3 to 5 MGD of fog drip).

In short, by not including the indisputable subsurface and surface water sources of recharge from the Kohala Mountain into the Waimea Aquifer, the recharge amount in Engott (2011) has not included about 20 MGD of "offsite" recharge.

Unrealistic Evapotranspiration Calculation for the Waimea Aquifer in Engott (2011)

The information in attached Table 1 has been extracted from Table 7 of Engott (2011) to highlight the anomalous numbers calculated for the Waimea Aquifer. The tally in Table 1 compares the aquifer systems along West Hawaii from Waimea to Keauhou. Two calculated amounts for the Waimea Aquifer jump out as being unrealistic. First, evapotranspiration and canopy evaporation are calculated to be 86 percent of its potential sources (rainfall, fog drip, and irrigation). This is far higher than for the other three aquifer systems and is not realistic.

Second, groundwater recharge as a percentage of its contributing sources (rainfall, fog drip, irrigation, and direct recharge) is just 11.4 percent for the Waimea Aquifer. For the other three aquifer systems, the recharge percentages vary from 40.7 (Kiholo) to 54.3 (Anaehoomalu), an almost absurd contrast of numbers.

Field Reality versus a Desk Top Exercise

As indicated previously, my professional work in the Waimea Aquifer and elsewhere in West Hawaii spans 40 plus years. During this time, I have been responsible for the construction and pump testing of most of the currently active wells in the Waimea and adjacent Anaehoomalu aquifer systems. I have and continue to monitor the pumped salinity of the wells. In addition to work on the wells, I have made about forty assessments of groundwater conditions as required for proposed projects in various stages of land use entitlement processes. These assessments have included extensive and repeated sampling of groundwater discharge along the shoreline, done exclusively at low tide in the early morning when groundwater discharges are easiest to locate. The totality of this work translates to an extensive knowledge of field conditions in West Hawaii. From the perspective of this field experience, I have the following additional reactions to some of the calculations in Engott (2011):

- The computed recharge in Engott (2011) less ongoing pumpage should presumably reflect the balance of groundwater flow discharging along the shoreline. For the Waimea Aquifer, this would amount to 6.37 MGD per coastal mile (35.62 MGD recharge less 13 MGD pumpage over 3.55 coastal miles). For Anaehoomalu, it would be 33.4 MGD per coastal mile (181.69 MGD recharge less 5 MGD current pumpage over 5.29 coastal miles). The contrast is completely unrealistic. The Waimea shoreline discharge rate is too low and the Anaehoomalu shoreline rate is absurdly higher than reality.
- The Kiholo Aquifer (147.4 square miles) is less than half the size of the Waimea Aquifer (300.0 square miles), yet its computed recharge is more than double (76.19 versus 35.62 MGD). As someone how has been responsible for developing most of the active pumping wells in the Kiholo Aquifer and has continued to track their pumped water salinity, I can state unequivocally that the flowrate through the Waimea Aquifer is far greater than it is through the Kiholo Aquifer. The Engott (2011) calculations simply do not come close to reflecting field reality.
- Present pumpage of 13 MGD in the Waimea Aquifer amounts to about 80 percent of its proposed reduced sustainable yield. If the proposed sustainable yield is actually accurate, some indication of increasing salinity trends in the nearshore brackish irrigation wells or in the more inland freshwater wells is likely to have occurred. No such trend is evident in any of the actively pumped wells.

Summary Recommendations

1. To reflect reality, the CWRM must consider the indisputable contribution to the Waimea Aquifer's recharge from the Kohala Mountain either as a revision to the aquifer's lateral boundaries (both north and south) or simply as an adjustment to the mathematical accounting.
2. To accept the Engott (2011) calculations for the Waimea Aquifer as the sole basis for reducing its sustainable yield is to endorse its unrealistic results which are contrary to existing field conditions. Engott (2011) may have been peer reviewed within the USGS, but it was not by individuals such as myself who, through years of experience, can immediately identify its unrealistic results. The shoreline discharge rate from the Anaehoomalu Aquifer being more than five times the discharge rate from the adjacent Waimea Aquifer does not reflect reality. Recharge in the Kiholo Aquifer being more than double the recharge in the Waimea Aquifer is not at all realistic.
3. There is no distress due to overdraft anywhere in the Waimea Aquifer. The anticipated growth in groundwater use will be slow and can and will be carefully monitored. Given actual conditions in the aquifer, there is absolutely no reason to reduce its sustainable yield at this time.

EXHIBIT 3. – TNWRE (03/27/17)

Attachments

ec: Greg Fukumitsu and Todd Yonamine – TNWRE, Inc.

EXHIBIT 3. – TNWRE (03/27/17)

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Original ☐ will ☑ will not
be mailed to you.

July 6, 2016
16-122 | 15-63

MEMORANDUM

To: Roy Hardy, Bob Chenet, and Patrick Casey – Commission on Water Resource Management

From: Tom Nance

Subject: Suggested Revisions of the Boundaries of the Waimea Aquifer System

As a follow up to my November 27, 2015 memo commenting on the proposed reduction of the sustainable yield of the Waimea Aquifer, this memo has an accompanying figure with recommended revisions to the boundaries of the Waimea Aquifer. The most significant revision is on the north side to add that portion of the Kohala Mountain which augments recharge to the Waimea Aquifer in two ways: as surface runoff onto the South Kohala plain which sinks into the ground rather than traveling all the way to shoreline discharge; and as subsurface underflow. The additional area is more than 20 square miles (essentially identical to Figure 6 attached to my November 27th memo) and adds on the order of 20 MGD of recharge to the Waimea Aquifer.

The suggested revision to the south boundary of the Waimea Aquifer is quite modest and limited to the nearshore area. The revision aligns the boundary to be parallel to the direction of groundwater flow toward shoreline discharge. Although the inland portion of the southern boundary may also ultimately need to be revised, I don't believe sufficient information exists to confidently suggest changes at this time.

Attachment

ec: Steve Green – Hawaii Water Service Company
Greg Fukumitsu and Todd Yonamine – TNWRE, Inc.

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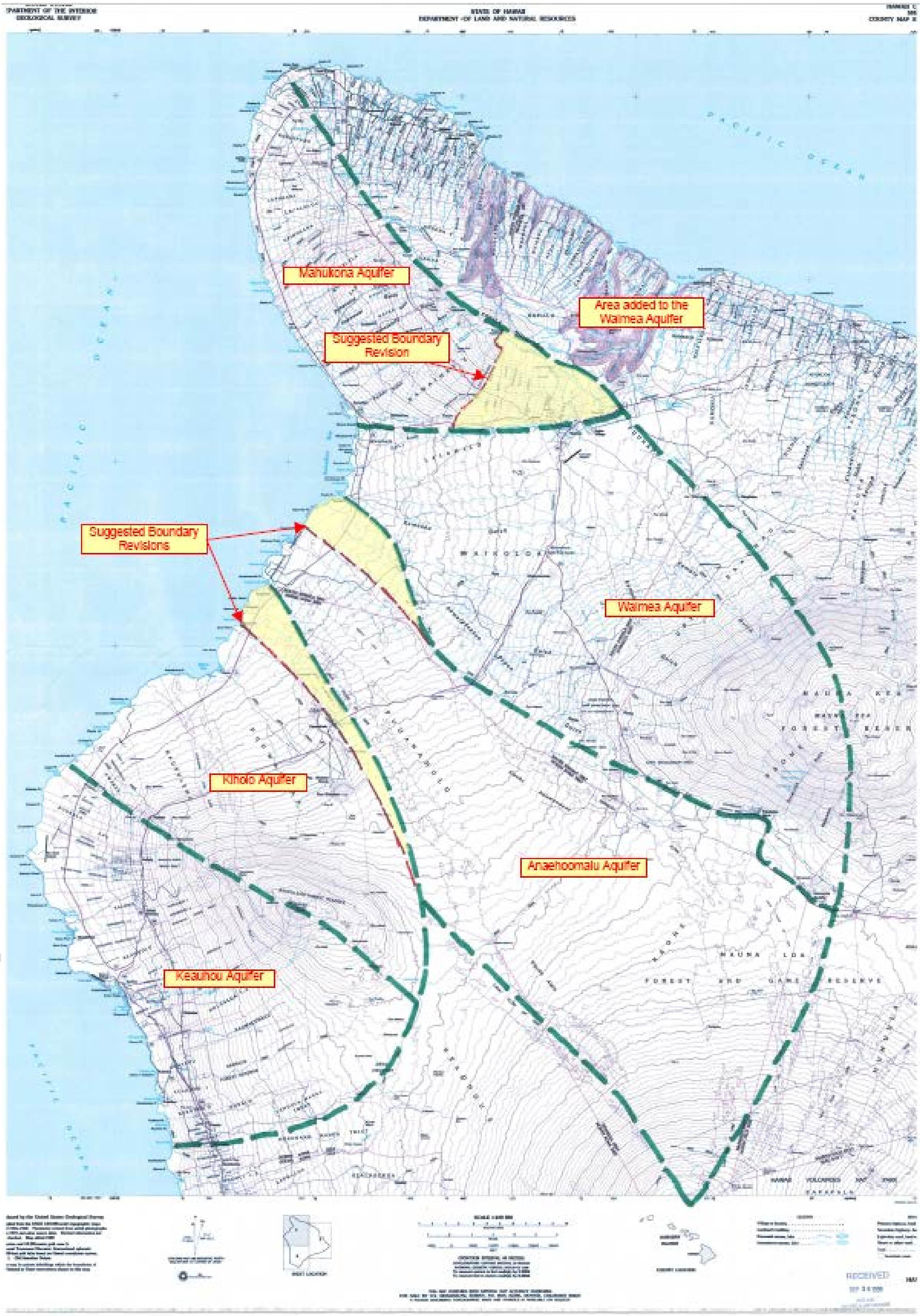

EXHIBIT 3. – TNWRE (07/06/16)

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November 27, 2015

Mr. Robert F. Chenet
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Commission on Water Resource Management
1151 Punchbowl Street, Room 227
Honolulu, HI 96813

Dear Mr. Chenet:

Subject: Proposed Changes to Sustainable Yields
2016 Update to the Water Resource Protection Plan

We have received your email regarding the request for comments from the Water Professionals Group with respect to proposed changes in the 2016 Update to the Water Resource Protection Plan (WRPP). We strongly support CWRM's careful consideration of their comments and data before seriously contemplating any changes to Sustainable Yield numbers in the 2016 Update to the Water Resource Protection Plan (WRPP).

While the Department of Water Supply (DWS) does not have any hydrologists on staff, we rely on consultants with the appropriate expertise, including critical field experience in Hawai'i, such as Tom Nance Water Resource Engineering (TNWRE). We have received a copy of the TNWRE letter dated November 27, 2015, regarding the proposed change in the Sustainable Yield (SY) for the Waimea Aquifer. Upon review of this letter and the facts presented in the TNWRE letter, we request that the SY for the Waimea Aquifer remain at 24 mgd until additional studies or information become available and are analyzed for this aquifer. The proposed SY (16 mgd) is significantly lower than the existing SY (24 mgd), and a premature reduction could cause unnecessary concerns. The TNWRE letter points out discrepancies in the USGS sir2011-5078 study (Engott) and asserts that obvious subsurface and surface flow transferring from one aquifer to another is not considered at all in the study and that the SY numbers need to reflect this approximate 20 mgd of recharge, or the aquifer boundaries should be adjusted accordingly. It is extremely important to realistically evaluate the limitations of model parameters and the input data and to fully understand what critical factors may not be taken into account by any particular methodology. Thus, the DWS asks that the TNWRE information be strongly considered as Mr. Tom Nance had had been intimately involved with the development of most of the wells within the Waimea Aquifer. In addition, his data collection and evaluation of groundwater sources in this aquifer has spanned over 40 years, and continues currently.

. . .Water, Our Most Precious Resource . . . Ka Wai A Kāne . . .
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EXHIBIT 3. – TNWRE (11/27/15)

Mr. Robert F. Chenet
Page 2
November 27, 2015

We believe that we both share the same concerns to protect our resources as it is as much our responsibility as it is yours and that is why we are asking you to consider not only the best available, but more importantly, the most complete and reliable information prior to deciding on any changes to the proposed SY numbers.

Should you have any questions, please feel free to contact Mr. Kurt Inaba of our staff at 961-8070, extension 238.

Sincerely yours,

for Keith K. Okamoto, P.E.
Manager-Chief Engineer

KYI:dmj

Enc.

copy – (w/enc.) Mr. Roy Hardy, Commission of Water Resource Management

EXHIBIT 3. – TNWRE (11/27/15)

WATER RESOURCE PROTECTION PLAN
PUBLIC HEARING COMMENTS AND RESPONSES

EXHIBIT 4 WRPP Hearing Comments

NAME/ENTITY	COMMENT	SECTION	EMAIL	LETTER	COMMENT SHEET	Testimony
Tom Schnell, PBR Hawaii (14 min 0 sec)	App F: Table F-10. W. Mauna Kea ASA, Waimea ASYA. Proposed SY = 16 MGD. Clarification on how staff will resolve footnote 29 re: amending the boundaries of Māhukona, Waimea, and Anaehoomalu ASYA and subsequently, SY estimates.					2/19/19, O'ahu
Tom Schnell, PBR Hawaii (16 min, 45 sec)	So if the WRPP is adopted with the current SY, there is a process to amend the SY in the future?					2/19/19, O'ahu
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	The Department of Water Supply (DWS) respectfully requests, that until the aquifer boundary changes under consideration are resolved, and ready to be adopted, the Commission on Water Resource Management (CWRM) refrain from adopting the proposed changes to the aquifer sustainable yield numbers found in the draft update [Public Review Draft October 2018] to the Water Resource Protection Plan (WRPP). DWS recognizes that boundary changes could have a significant impact on the application of the sustainable yield (SY) numbers. DWS believes that adopting new SY numbers without incorporating potential boundary changes at the same time could result in an unnecessarily misleading outlook on resource capacity and that it would be better to include all the pertinent information available to provide the most accurate determinations for sustainable yield. Doing so will help ensure the public's trust and support for the WRPP Update. Once the boundary changes have been appropriately addressed and those boundary changes can then be reflected in the determination of sustainable yield, then both the boundary changes and new sustainable yield numbers should be adopted.			3/28/19		
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	SY Table - 201810 - The bottom of this page refers to Appendix F, however, if this table may sometimes be viewed as a stand-alone document, then the SY Table, itself, should include the footnotes that are found in Appendix F.			3/28/19		
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	Appendix E - Memorandum No. 18: What is being done to consider the water professionals group's input on the Waimea and Anaehoomalu Aquifers in Memorandum No. 18, drafted December 17, 2013 by Townscape, Inc.?			3/28/19		
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	Appendix F - Table F-10: Although the reference to Note 29 follows the SY (2019) estimates for the Waimea, Anaehoomalu and Mahukona Aquifer Systems, there should be a clear indication within the table that these numbers are under special consideration and are preliminary in order to avoid potential misconceptions.			3/28/19		

page 1 of 2

WATER RESOURCE PROTECTION PLAN
PUBLIC HEARING COMMENTS AND RESPONSES

EXHIBIT 4 WRPP Hearing Comments

NAME/ENTITY	COMMENT	SECTION	EMAIL	LETTER	COMMENT SHEET	Testimony
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	Appendix F - Table F-11: Same as above. In addition to the comments in the column following, it should be made clear that this number is "preliminary until further confirmation."			3/28/19		
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	Appendix H - Table H-10: This table does not indicate in any way, the intention of the 16 MGD being preliminary until further confirmation, nor does it indicate any potential aquifer boundary changes. This should be made clear as this is definitely a source of information that could be misleading.			3/28/19		
Keith K. Okamoto, P.E., Manager-Chief Engineer, Department of Water Supply, County of Hawai'i (see "Notes" for follow-up contact info)	Appendix H, Section 6.3.6 - County ofHawai' i WUDP 2010: This section addresses the WUDP as is and does not take into account the 2019 SY numbers. There should be some reference to the 2019 SY numbers and the potential aquifer boundary changes. It should also make it clear that the 2019 SY for the Waimea Aquifer in particular, is only preliminary until further confirmation and that the aquifer boundary changes are being considered based on the input of the water professionals' memorandum in Appendix E.			3/28/19		
Bill Hobbs	The sustainable yield for the Waimea Aquifer needs to be clarified. Would like to buy a workforce home at some point and it would involve projects in the Waimea Waikoloa area. We've heard there's plenty of water in the Waimea aquifer and the aquifer next to it. There is a need to clarify this in the report for the county, the community, and the developers.					2/28/2019
Greg Brown, Resident	Appendix F: Sustainable Yield of Waimea Aquifer, specifically, Footnote 29. Extremely important to the community that footnote 29 is cleared up before the WRPP is adopted and not after because it reduces the SY from 24 MGD to 16 MGD. Workforce housing advocate. Waimea-Waikoloa area is growing faster than anywhere else on the island and the Big Island is growing faster than anywhere else in the State. Without clarity, this could impact the ability for housing. The County has a project called Kamakoa that was shut down because of unexploded ordnance and has a good chance of being resurrected very soon, but with this uncertainty, it's unlikely that this will happen. There are also other big projects in the area and housing is drastically needed so it would not be wise to defer this.					2/26/2019

page 2 of 2

EXHIBIT 4. WRPP Public Hearing Comments

Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

Julia K. Morgan, Jaewoo Park*, and Colin A. Zelt
Department of Earth Science, Rice University, 6100 Main Street, Houston, Texas 77005, USA

ABSTRACT

A new onshore-offshore three-dimensional seismic velocity model for the Island of Hawaii reveals a massive buried rift zone within Mauna Loa's southeast flank, introduced here as the Ninole rift zone. This feature extends more than 60 km south of Mauna Loa's summit, spans a depth range of ~2–14 km below sea level, and is the probable source of the 100–200 ka Ninole volcanics in several prominent erosional hills. The ancient rift zone may stabilize Mauna Loa's southeast flank, focusing recent volcanic activity and deformation onto the unbuttressed west flank. The upper portion of the Ninole rift zone appears to have migrated westward over time, possibly triggered by landsliding, causing its eventual abandonment in preference to Mauna Loa's present-day southwest rift zone. Subsequently, the lower southwest rift zone broke away, tracking rift intrusions along the trace of the Kahuku detachment fault. Similar rift zone migration is thought to be under way at Kilauea volcano, and may one day lead to the abandonment of the east rift zone. Such rift zone reconfiguration is a reflection of changing stress conditions within growing volcanoes; it is probably much more common than previously assumed, and may enable the growth of large volcanic edifices such as Mauna Loa.

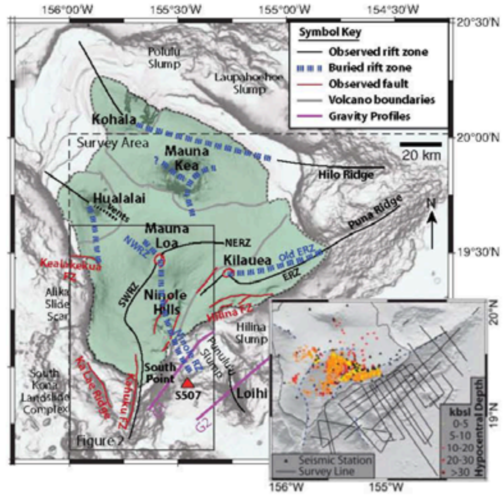

Figure 1. Present-day morphology of Island of Hawaii, showing active volcanic rift zones (solid black lines), buried rift zones (wide dashed blue lines) inferred from gravity and seismic velocity models (Hill and Zucca, 1987; Kauahikaua et al., 2000; Park et al., 2009), major fault scarps (red lines), and tracks of gravity profiles (purple lines) shown in Figure 4. Location of Shinkai Dive S507 is indicated by red triangle. Solid box shows area of Figure 2; dashed box is model domain (Park et al., 2009). SWRZ—Mauna Loa's southwest rift zone; NWRZ—Mauna Loa's northwest rift zone; ERZ—Kilauea's east rift zone. Bathymetry is from Eakins et al. (2003). Inset: Survey geometry showing locations of on-land seismic stations operated by U.S. Geological Survey Hawaii Volcanoes Observatory (black triangles) and 1998 R/V *Ewing* seismic survey lines, and earthquakes used in this study.

INTRODUCTION

Large oceanic volcanoes commonly develop elongate rift zones that disperse viscous magmas to the distal reaches of the edifice. The origins of such rift zones vary with location, but accompanying dike intrusions are thought to occur during extension perpendicular to the rift zones (Fiske and Jackson, 1972; Rubin and Pollard, 1987). Extension can be induced by gravitational loading and sagging of an elastic medium (e.g., Fiske and Jackson, 1972), spreading of the rift flanks on weak layers or detachments (Dieterich, 1988; Borgia, 1994), or slope failure (Walter et al., 2005). Topographic buttressing or resistance to basal sliding, however, can alter the axial stress regime, trapping intrusions at depth or blocking their lateral propagation (Dieterich, 1988). Thus, as volcanoes grow and interact, the controlling stress fields will change, potentially altering the orientations and activities of rift zones (e.g., Fiske and Jackson, 1972). The reconfiguration of volcanic rift zones has been documented along the boundaries of shallow slope failures (Walter and Schmincke, 2002; Walter et al., 2005), and in response to volcano superposition and flank buttressing (Carracedo et al., 1999; Day et al., 1999). This phenomenon may be common, and can produce complex internal structures that influence the evolution of a volcano and its neighbors. However, little direct evidence for such rift zone reconfiguration exists, primarily due to poor preservation or recognition of earlier volcanic configurations.

One setting in which major rift zone reconfiguration has been interpreted is Mauna Loa volcano, Hawaii (Fig. 1). With a lateral extent of more than 120 km, and a vertical height of 16–18 km above the downbowed ocean floor, Mauna Loa is the oldest and largest of three active volcanoes that overlie the vigorous Hawaiian hotspot. Two active rift zones dominate the edifice today: the northeast rift zone trends toward Kilauea volcano and the southwest rift zone bends sharply to the south ~30 km from the summit, entering the ocean at South Point (Fig. 1). However, asymmetric gravity anomalies along the upper southwest rift zone (Lipman, 1980), further constrained by three-dimensional (3-D) gravity modeling (Kauahikaua et al., 2000), hint of buried intrusive rocks east of the active rift zone. Lipman (1980) interpreted an older rift zone left behind as the southwest rift zone migrated westward, possibly precipitated by catastrophic landsliding of Mauna Loa's west flank (Lipman et al., 1990).

Further evidence for past rift zone geometries comes from submersible surveys along the submarine Kahuku fault zone and Ka Lae ridge to the south (Fig. 1), where thick exposures of intrusive dikes are found (Garcia et al., 1995; Garcia and Davis, 2001). Either the southwest rift zone was unusually wide, or the Ka Lae exposures were emplaced by landsliding (Garcia and Davis, 2001). Until recently, few data existed to probe these hypotheses further, although each has significant implications for the evolution of large basaltic edifices in Hawaii and elsewhere.

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Geology, May 2010; v. 38; no. 5; p. 471–474; doi: 10.1130/G30626.1; 5 figures. 471

EXHIBIT 5. - Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

MAUNA LOA VELOCITY STRUCTURE

We carried out a joint seismic tomographic inversion for the 3-D P-wave velocity structure of the southeastern part of the Island of Hawaii and adjacent offshore areas, using an offshore airgun shot–onshore receiver geometry, as well as earthquake sources beneath the subaerial edifice (Fig. 1, inset). The methodology and a more complete description of our preferred velocity model were presented by Park et al. (2009). The data were inverted for 3-D P-wave velocity structure using the regularized first-arrival-time seismic tomography method of Zelt and Barton (1998), modified to simultaneously relocate the hypocentral parameters, i.e., location and origin time (Ramachandran et al., 2005). The final velocity model is parameterized on a 1 km grid spacing. Based on checkerboard tests, we estimated the lateral resolution to be better than 10 km down to ~20 km depth beneath Mauna Loa's southeastern flank (Park et al., 2009).

Based on this preferred velocity model, the occurrence of high velocities of 6.5–7.5 km/s beneath the summits and major rift zones of the island's volcanoes was demonstrated by Park et al. (2009), consistent with intrusive complexes composed of dense intrusive dikes, gabbros, and olivine cumulates (Hill and Zucca, 1987; Okubo et al., 1997). In addition, several buried rift zones extending away from the major volcano summits (Fig. 1) were identified by Park et al. (2009), showing that Hawaiian volcanoes looked very different in the past. We take this effort one step further, exploring one such feature within Mauna Loa's southern reaches, previously recognized by Okubo et al. (1997), to understand the evolution of this massive edifice and implications for the future.

Figure 2 shows three depth slices through our velocity model at 3, 5, and 7 km below sea level (kbsl). Seismic velocities as high as 7.0–7.5 km/s occur in all three sections. At 3 kbsl (Fig. 2A), the high-velocity zone trends southwest of Mauna Loa's summit. At 5 kbsl (Fig. 2B), high velocities occur in an elongate zone that extends ~40 km due south of the summit. A marked step down in velocities also occurs just seaward of the bend in the southwest rift zone (arrow in Fig. 2B). By 7 kbsl (Fig. 2C), the high-velocity region has broadened, and a second one is revealed within the lower southwest rift zone. A prong of lower, but still anomalous velocities (5.5–6.2 km/s) continues another 20 km onto the submarine flank (Fig. 2C). A vertical section along the length of the anomaly (Fig. 3A) shows that the anomalous body extends to ~14 kbsl, where it merges with high velocities in the upper mantle. The highest velocities occur between 4 and 8 kbsl, and are sharply truncated at their southern end. A transverse profile (Fig. 3B) reveals the high velocity feature to be ~10–15 km wide, with a sharp velocity boundary on its northeastern side and smaller velocity step adjacent to the southwest rift zone (arrow in Fig. 3B).

The great length and thickness of the velocity anomaly in Mauna Loa's southeastern flank, along with its elongate geometry and unusually high

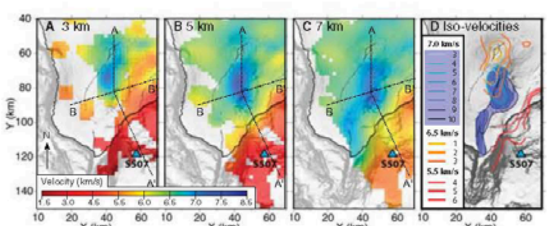

Figure 2. Depth slices through three-dimensional velocity model in vicinity of Mauna Loa volcano overlain by morphology; plotted region shown in Figure 1. Unsampled regions of velocity model are white. Dotted lines show locations of vertical cross sections shown in Figure 3. A: Velocity slice for 3 km below sea level (kbsl). B: Velocity slice for 5 kbsl. C: Velocity slices for 7 kbsl. D: Isovelocity contours for 5.5, 6.5, and 7.0 km/s between 1 and 10 kbsl.

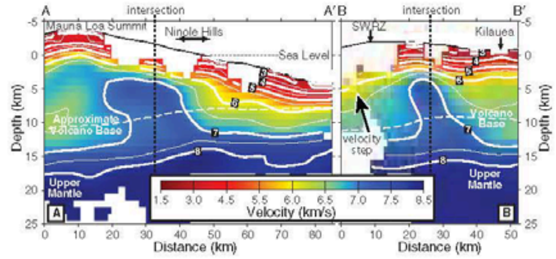

Figure 3. Vertical cross sections along line segments shown in Figure 2. Unsampled regions of slices are white. A: Profile A-A′ parallels long axis of interpreted rift zone within Mauna Loa's south flank. B: Profile B-B′ crosses Mauna Loa's buried rift zone. Dashed lines indicate base of volcanic edifice. Velocity contours in km/s. SWRZ—Mauna Loa's southwest rift zone.

seismic velocities, indicate that this feature is a buried rift zone, which does not correlate with any recent volcanic activity (Park et al., 2009). Based on its location beneath the prominent Ninole Hills (Fig. 1), we introduce this feature here as the Ninole rift zone.

To better constrain the 3-D geometry of the enormous Ninole rift zone, we plot velocity contours for several depth slices (Fig. 2D). Contours for 6.5 km/s from 1 to 3 kbsl show that the velocity anomaly aligns with the present-day southwest rift zone at shallow depths. The most prominent high-velocity anomaly is resolved by 7.0 km/s contours (Fig. 2D). At 3 kbsl, the 7.0 km/s contour outlines a small region trending south-southwest of the summit, just east of the present-day upper southwest rift zone. By 5 kbsl and deeper, the 7.0 km/s contour defines a broad north-south–trending body, which terminates along a high-angle velocity boundary beneath the Ninole Hills. The continuation of the high velocity feature into the submarine flank is indicated by seaward deflection of the 5.5 km/s contours (Fig. 2D).

A smaller region of high velocity is along the lower southwest rift zone between 8 and 10 kbsl (Fig. 2D). In contrast, there is a distinct lack of high velocities beneath the central southwest rift zone. It is significant that the large south-trending anomaly attributed to the Ninole rift zone is distinct from the high-velocity regions beneath the southwest rift zone throughout most of the edifice (Fig. 2D), and appears to be unrelated to the present-day active rift zones.

NINOLE RIFT ZONE

The recognition of a voluminous south-trending rift zone in Mauna Loa's southeast flank confirms and refines the interpretations for intrusive rocks to the east of the southwest rift zone based on gravity anomalies (Lipman, 1980; Kauahikaua et al., 2000), and also helps to explain several puzzles in Hawaiian geology. The origin of the highly eroded Ninole Hills on Mauna Loa's southeastern flank has been a subject of continuing debate. Their prominence and noncomformable east-dipping layers suggested that the hills were remnants of an older volcano underlying Mauna Loa (Stearns and Clark, 1930; Wright, 1971). Subsequent geochemical analyses, however, support a Mauna Loa origin for the Ninole volcanics, albeit quite old, 100–200 ka (Lipman et al., 1990). Lipman et al. (1990) suggested that the hills represented blocks entrained within the large Punulu'u landslide responsible for stepped lobate terraces on the submarine flank (Fig. 1).

We now believe that the high Ninole Hills are remnants of surface flows erupted from the ancient Ninole rift zone buried beneath them, and although breached by normal faults, are nearly in situ. The north-south trend of the Ninole rift zone is consistent with several north-south dikes

EXHIBIT 5. - Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

that dissect the ancient hills (Lipman, 1980; Lipman et al., 1990). The east-dipping layering within the Ninole Hills can be explained by draping flows along the eastern flank of the rift zone. At the scale of our model, the steep frontal scarps of the Ninole Hills (Fig. 1) coincide with the sharp velocity boundary at the south edge of the high velocity anomaly (Fig. 3A), suggesting that past landsliding disrupted the downslope portions of the hills.

The offshore flank may preserve evidence for such landsliding (Lipman et al., 1990), but the geology and morphology are also consistent with a submarine rift zone (e.g., Smith, 1996), which we argue extends from Mauna Loa's summit. Two additional pieces of evidence support this interpretation: (1) a Bouguer gravity anomaly above the interpreted rift zone (G1, Fig. 4), comparable in magnitude to that over Loihi seamount (G2, Fig. 4), which is also underlain by a high-velocity body at a similar depth to the Ninole rift zone (Park et al., 2007); and (2) geochemical evidence for submarine erupted Mauna Loa pillow flows and massive basalt units (Lipman et al., 2002, Table A5), recovered during JAMSTEC (Japan Marine Science and Technology Center) Shinkai Dive S507 (Fig. 1). Relatively high sulfur contents of 400–600 ppm in these rocks indicate that these flows erupted from a submarine vent (Moore and Fabbi, 1971), likely along the Ninole rift zone. Future studies of this submarine flank could investigate these findings further.

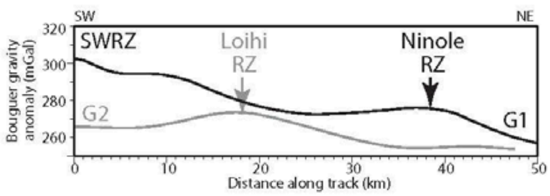

Figure 4. Bouguer gravity anomalies for tracks denoted in Figure 1; data sources and processing explained in Park (2008). Black line crosses interpreted Ninole rift zone (RZ), showing elevated anomaly relative to regional slope. Bouguer anomaly increases to southwest, where track approaches shallow intrusives in Mauna Loa's younger southwest rift zone (SWRZ). Gray line traverses Loihi seamount, and shows similar Bouguer anomaly associated with high-velocity body at similar depth to Ninole anomaly (Park et al., 2007).

New evidence for the truncation of the original southwest rift zone now suggests a second episode of rift zone reconfiguration that provides insight into the first. The seaward decrease in velocities observed parallel to the bend in the central southwest rift zone (Figs. 2B and 3B) suggests a buried extension of the Kahuku fault zone. The offshore Ka Lae ridge, with its detached intrusive rift complex (Garcia and Davis, 2001) could have originated along this scarp (Fig. 5). Consistent with this model, high-velocity features within the southwest flank of Mauna Loa hint of buried landslide blocks (Park et al., 2009). The incision and detachment of the old southwest rift zone would have directed subsequent intrusions along the fault scarp toward South Point (Fig. 5).

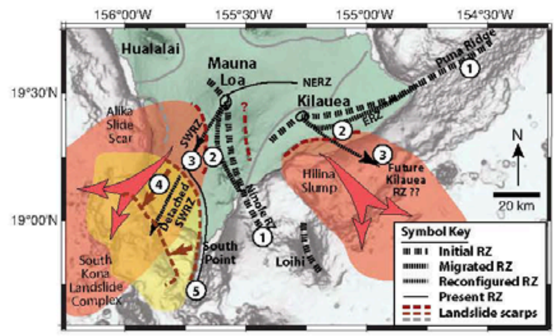

Figure 5. Interpretation of rift zone (RZ) evolution for Mauna Loa and Kilauea volcanoes. For each edifice, the oldest rift zone is indicated by wide dashed line, and younger rift zone configurations by progressively decreasing line widths. Landslide scarps are dashed, with probable regions affected by their debris fields noted by color shading. Circled numbers indicate sequence or events for a given volcano. 1: Buried rift zones, i.e., Kilauea's east rift zone (ERZ) and Mauna Loa's Ninole rift zone, extend onto submarine ridges. 2: Upper rift zones migrate seaward, introducing bends. Nearby landslides may unload rift zones. 3: New rift zones cut across landslide scars and onto submarine slopes; configuration of future Kilauea rift zone is hypothetical. 4: Mauna Loa's lower southwest rift zone (SWRZ) detaches along extension of Kahuku fault. (5) SWRZ follows trace of detachment fault, entering ocean at South Point.

RIFT ZONE RECONFIGURATION IN HAWAII

Our data offer general support for past rift zone migration and rotation on Mauna Loa (e.g., Lipman et al., 1990), but we also confirm large-scale rift zone abandonment on a scale never before documented. What could have caused the Ninole rift zone to shut down in favor of the younger southwest rift zone ? Catastrophic landsliding may have triggered rift zone migration. Any failure surface along the west flank would now be deeply buried, but could account for the low velocities across this area (Fig. 2). Alternatively, increasing curvature of the upper rift zone reduced magma supply to the lower Ninole rift zone, causing the gradual abandonment of the original rift zone. There is no direct evidence from our velocity model showing that this transition was sudden or catastrophic.

Abandonment of the Ninole rift zone would also favor the asymmetric growth of Mauna Loa documented by others (Lipman, 1980; Lipman et al., 1990). As the new southwest rift zone grew across the former west flank, it was buttressed on the east by the great Ninole rift zone. The west flank, however, was free to deform, as demonstrated by submarine landsliding, uplift, and accretion (Morgan and Clague, 2003). Ongoing deformation of the west flank created accommodation space for in-filling lava flows, favoring west-directed flows over east-directed ones (Lipman et al., 1990).

Large oceanic volcanoes around the world likely hide similarly complex structures and histories, unnoticed due to a lack of data. Of great interest is the potential for younger volcanoes to undergo similar transformations in the future. In particular, Kilauea volcano appears to be in an early stage of rift zone reconfiguration. The upper east rift zone exhibits a nearly 90° bend (Fig. 1), and high gravity anomalies north of the present rift zone trace suggest the seaward migration of the rift zone over time (Swanson et al., 1976), possibly precipitated by past submarine slope failure (Morgan et al., 2003). One can see how continued rift zone migration could lead to the abandonment of Kilauea's lower east rift zone, allowing a new rift zone to propagate across the volcano's south flank (Fig. 5). If a new rift zone formed in this vicinity, the old east rift zone would serve as an upslope buttress, leading to asymmetric growth and flank spreading as documented on Mauna Loa.

Rift zone orientations are governed by regional and local stress fields, but these will change as volcanoes evolve, deform, and collapse. Thus, rift zone growth, abandonment, and reconfiguration may be the norm rather than the exception for large basaltic shield volcanoes, the formation of new rift zones opening easier pathways for magmas to reach the surface. Thus, rift zone reconfiguration can breathe new life into old edifices, potentially allowing volcanoes to grow to large size, as exemplified by Mauna Loa.

EXHIBIT 5. - Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

Typically, this complex history is hidden from view, beneath the deceptive exterior of an active volcano, and can only be reconstructed when tools exist to look deep within the volcanic edifice, as has been achieved here.

ACKNOWLEDGMENTS

We thank Paul Okubo for help with extraction of the active source data and for sharing the earthquake data that made this joint inversion possible. Ongoing discussions with many investigators of Hawaiian geology have advanced our thinking about complex volcanotectonic evolution. We thank the reviewers, including Marco Neri, for their thoughtful comments on an earlier draft. Funding for this study was provided through National Science Foundation grants OCE-0221953 and OCE-0551750.

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EXHIBIT 5. - Rift zone abandonment and reconfiguration in Hawaii: Mauna Loa's Ninole rift zone

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May 12, 2019

Memo To: Roy Hardy
Commission on Water resources Management

From: Donald Thomas

Subject: Findings of the Humu'ula Saddle drilling project of relevance to determination of Aquifer System boundaries

The research program that was undertaken in the Humu'ula Saddle was intended to better characterize the hydrologic conditions within the interior of the Island of Hawaii where relatively little hydrologic data were previously available. The project conducted geophysical resistivity surveys across the Saddle region, both east-west and north-south, to determine the deep electrical resistivity of the subsurface (as a means of identifying areas likely to have groundwater), and drilled two boreholes to depths of approximately 1.5 km.

Very briefly stated, the findings of that research were as follows:

Geophysical surveys: The east-west electrical resistivity data showed a fairly complicated structure that included a broad conductive feature at an elevation of a little more than 1 km above sea level that extended from a vertical resistive feature, located a short distance west of the Mauna Kea access road, westward beneath the Pohakuloa Training area lands toward the west flank of the Saddle. The top of the conductive feature is at a nearly constant elevation, except for a narrow (1 – 2 km wide) ridge immediately beneath the PTA cantonment. As the western flank of the Saddle is approached, the top of the conductor begins to descend to lower elevations at about the same rate as the slope of the ground surface. The conductive formations were interpreted to represent water saturated basalts, an aquifer, that was later confirmed to be present by drilling.

The north-south trending geophysical surveys extend across the exposed Mauna Kea surface onto younger lavas produced by Mauna Loa. Those surveys likewise show conductors at about the same depth as those shown in the E-W surveys but also show a shallow lowered resistivity layer that slopes toward the south that is interpreted to reflect the now-buried Mauna Kea slope that has been encroached upon by Mauna Loa lavas. That lowered resistivity is interpreted to be the result of soil and ash accumulated on the exposed Mauna Kea surface before Mauna Loa lavas were deposited: we believe that that layer is intercepting infiltrating rainfall and partially retaining it to allow lowered resistivity.

Drilling Results:
We selected as our primary drilling target the above-noted ridge in the conductive feature present in the E-W resistivity surveys. Our borehole at that location encountered a perched groundwater

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table at a depth of about 700' below ground surface, an elevation of ~5700' amsl, that extended to a depth of about 1200' below ground surface. At the latter depth, the perching aquifer was penetrated and water levels in the hole dropped to below the bit. Drilling continued and a second aquifer was encountered at a depth of ~1800' (about 4600' amsl). That aquifer was continuous to the total depth drilled, 5786' depth or about 630' amsl, and we believe that aquifer is the continuous regional aquifer extending to sea level and below. The second borehole was located on the western flank of the Saddle, about 1 km beyond where the elevation of the top of the cross-Saddle conductive feature begins to descend in elevation. Our drilling at that location encountered a much different hydrologic environment: a series of confined aquifers was penetrated beginning at a depth of ~1050' below the surface (~4000' amsl). Many of the confined aquifers showed substantial hydrostatic head above the depth of entry: water levels within the drill string (which were sensed each time the core tube was lowered to the bit) would rise by several hundred to several thousand feet above the depth of entry into the confined aquifer.

To date, we have only been able to conduct testing of the deep regional aquifer in the first test hole located in the PTA cantonment. We conducted a short pump test and sampled the water from the formation at a depth of ~2000' below ground surface. The water there showed an isotopic composition consistent with rainfall at an elevation of ~10,000' amsl. The apparent age of that water was ~10,000 years before present, although that age may be somewhat impacted by the presence of magmatic carbon dioxide produced by an underlying geothermal system present in Mauna Kea.

The significance of these findings to the aquifer boundary between the Waimea and Anaehoomalu aquifer boundaries is as follows;
1. The presence of perched and confined (pressurized) aquifers in these boreholes demonstrates that buried ash/soil/clay layers within Mauna Kea's slopes exert a strong control over water flow and storage within the mountain.
2. The presence of high elevation recharge in the regional aquifer encountered in the PTA cantonment test hole, which is located south of the Anaehoomalu/Waimea aquifer boundary, indicates that recharge into the upper elevations of Mauna Kea is flowing toward the southwest into Mauna Kea formations that are now covered by more recent Mauna Loa flows.
3. The Anaehoomalu/Waimea aquifer boundary is, more or less, drawn along the surface contact of the recent Mauna Loa lavas where they have encroached onto the older Mauna Kea surface but has no further geologic basis that would affect groundwater flow within Mauna Kea or Mauna Loa.

Hence, I don't believe that the subject aquifer boundary, as currently configured, is useful for, or relevant to, its intended purpose. I don't believe that the observations made in the Humu'ula Saddle are unique and am strongly of the opinion that water flow across currently designated aquifer boundaries is far more common than has generally been recognized: this would include the Kohala/Waimea aquifer boundary as well as Anaehoomalu/Hualalai boundary and many others where aquifer boundaries reflect the intersection of volcanic deposits of younger volcanoes covering those of their older sister volcanoes. I would strongly advocate a program of re-evaluating all aquifer boundaries to better align them with geologic conditions and features that do have a substantial effect on groundwater flow – both in a horizontal direction as well as in a vertical direction. The current consideration of the Waimea/Anaehoomalu aquifer boundary is one obvious example, where we have data to demonstrate that cross boundary flow is occurring.

If I can provide further data of relevance to the present discussion, please contact me at your convenience.

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