Pilot Adaptive Management Plan For (1) Protecting Groundwater Dependent Ecosystems In Kaloko-Honokōhau National Historical Park and (2) Providing Water Security and Sustainability in the Keauhou Aquifer System Area, Hawai‘i County, Hawai‘i

INTRODUCTION

This Adaptive Management Plan (Plan) is developed by the State of Hawai‘i Commission on Water Resource Management (Commission) in cooperation with the U.S. National Park Service (NPS). The Plan described herein presents a methodology for the adaptive management of groundwater withdrawals from a portion of the Keauhou Aquifer System Area (KASA) in order to protect groundwater dependent ecosystems (GDEs) at Kaloko-Honokōhau National Historical Park (National Park). The Plan also is expected to be useful in demonstrating actions that can be implemented throughout the area to help ensure water security and sustainability in the future.

The Hawai‘i Water Plan, Water Resource Protection Plan, 2019 Update (Commission 2019 – referred to as the "WRPP 2019"), states the following regarding adaptive management

- Guiding Policy No. 4: Apply adaptive management principles in the face of scientific uncertainty (p. 12).
- Table 3-1 Action Plan; Task 1.7.2: Develop a pilot adaptive management plan for protecting ground water dependent ecosystems in cooperation with the National Park, US Geological Survey (USGS), and University of Hawai‘i (p. 63).
- Based on the best available information, Commission staff should propose action triggers and develop a suite of possible management actions for consideration by the Commission. It is recommended that the Commission build on the work done by NPS to establish an adaptive management approach for the Kaloko-Honokōhau National Historical Park as a priority pilot project (Appendix F, p. 11).

The Commission acknowledges that the National Park lies within coastal portions of the historic land divisions of the Kohanaiki, Kaloko, Honokōhau, and Kealakehe ahupua‘a, and that the area proposed for this Adaptive Management Zone is within these ahupua‘a, as shown in Figure 1.

The hydrogeology of the KASA is exceedingly complex consisting of a coastal fresh-water lens system (commonly referred to as the basal aquifer, and generally brackish rather than fresh) at elevations near sea level, an inland high-level water area at elevations of several tens to several hundred or more feet above sea level, and a deep coastal confined groundwater system several hundred or more feet below sea level about which little is known (WRPP 2019, p. F 19; Oki 2021 at p. 11, and 23 to 26). In the KASA, inland high-level water flows downgradient and discharges to the coastal fresh-water lens system and also to the coastal confined groundwater system (Oki 2021)

This plan is based on the current state of scientific knowledge regarding the KASA and available data on groundwater pumping. Future advances in knowledge about the combined aquifer systems and inter-relationships between elements of the system will inform possible modifications to this Plan and adaptations made in accordance with the Plan.

PROBLEM

The Commission's "current approach for managing ground water in Hawaii does not explicitly account for the ground water discharge needs of GDEs." (WRPP 2019, Appendix F, p. 9). In particular, ground water management is based primarily on the calculation of the "sustainable yield" of each aquifer system and aquifer sector. However, currently, in the establishment of sustainable yield "no analysis of the actual needs of GDEs is conducted." (Ibid.). Moreover, in non-groundwater management designated areas, although the State has the legal authority, it currently lacks an explicit process to regulate the number and placement of wells, or the volume of groundwater extracted that addresses the impacts to GDEs, and there is no program to monitor the specific local effects of groundwater pumping on GDEs or to mitigate negative impacts on GDEs.

Climate change is expected to reduce the overall availability of surface water and groundwater in the decades to come. For example, climate change is expected to reduce recharge to aquifers in leeward areas of the Pacific Islands because the leeward areas will become drier during the dry season (WRPP 2019, p. 22 and 23). The 2012 Pacific Islands Regional Climate Assessment shows a state-wide increase in average air temperature from 1916 to 2006, a downward trend in rainfall since the beginning of the 20th century, and an even steeper negative rainfall trend since 1980 (WRPP 2019, Fig. 1-1, p. 9).

The USGS is currently evaluating effects of climate change on groundwater recharge and aquifers throughout Hawaiʻi, and in January 2022 presented preliminary results to the Commission. For the KASA, on a preliminary basis, the USGS anticipates reductions in mean annual groundwater recharge ranging between approximately 30 and 50 percent by mid-century and end-of-century, respectively, depending on the global emissions scenario modeled. As climate change brings about an overall reduction in water availability, population growth in the KASA and neighboring areas will likely result in additional demand for water supply.

OBJECTIVE

The objective of this Plan is to provide the Commission with a process that allows for the monitoring of key components of groundwater within or near the Adaptive Management Zone (Kohanaiki, Kaloko, Honokōhau, and Kealakehe ahupuaʻa), timely assessment of data generated by that monitoring, and appropriate information from which decisions can be made in order to:

- Ensure the flow of fresh groundwater to GDEs within the National Park, and more generally along the Kona coast, so that species' full lifecycles and habitats are sustainable over time,
- Preserve flexibility to meet current and future domestic water demands in the Keauhou Aquifer,
- Provide a mechanism to incorporate advances in scientific understanding of the Keauhou Aquifer into future management decisions,
- Create opportunities for the engagement and participation of stakeholders – beyond the Commission, NPS, USGS and Hawaii County Department of Water Supply; and
- Serve as a model for incorporating adaptive management principles for the protection of GDEs elsewhere in Hawaii as well as for the protection of public trust groundwater resources generally.

BACKGROUND AND KEY CONSIDERATIONS

Background

The Commission is the primary agency implementing the State of Hawaiʻi Water Code. Hawaiʻi law recognizes the following public trust purposes for water: maintenance of waters in their natural state; domestic water uses of the general public, particularly drinking water; the exercise of Native Hawaiian traditional and customary rights; and reservations of water for the Department of Hawaiian Home Lands. Among the Guiding Policies identified in the most recent WRPP, the Commission stated that its action must be guided by "The Precautionary Principle: the State has a duty to take anticipatory action to prevent harm to public resources"; and it should "[a]pply adaptive management principles in the face of scientific uncertainty." (WRPP 2019, pp. 10, 12).

Congress established Kaloko-Honokōhau National Historical Park in 1978 "… to provide a center for the preservation, interpretation, and perpetuation of traditional Native Hawaiian activities and culture, and to demonstrate historic land use patterns as well as to provide a needed resource for the education, enjoyment, and appreciation of such traditional Native Hawaiian activities and culture by local residents and visitors." (16 U.S.C. §396d(a)). Recognizing that ongoing development posed a significant threat to the resources within the new park, Congress authorized the NPS to work directly with other governmental entities to establish adequate controls on water quality and the scenic and aesthetic values of the surrounding areas; Congress also stated that the NPS shall "… to the maximum extent feasible utilize the traditional native Hawaiian ahupuaʻ[a] concept of land and water management." (16 U.S.C. §396d(d)(4)).

The NPS administers the National Park under the mandate of the NPS Organic Act that requires the NPS "… to conserve the scenery and the natural and historic objects and the wild life [in units of the National Park System] and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."(54 U.S.C. §100101(a)).

On September 13, 2013, the NPS submitted a petition to the Commission to designate the Keauhou Aquifer System as a Water Management Area for groundwater in order to protect vital groundwater-related resources within the National Park, and to preserve and protect the spirit of Kaloko-Honokōhau for the enjoyment of residents, visitors, and future generations. Although the Commission eventually denied the petition, the information submitted during the deliberative period as well as information developed subsequently, including those presented at two symposia related to adaptive management and groundwater resources, led the Commission to identify a task for its staff to develop a pilot adaptive management plan and "to build off the work done by NPS to establish an adaptive management approach for the [National Park] as a priority pilot project." (WRPP 2019, p. 63, Appendix F, pp. 11).

On August 12, 2015, in response to a request from the Commission, the NPS submitted a report describing the quantity of groundwater needed to support the natural and cultural resources of the National Park, specifically GDEs. The report outlined the information relied upon by the NPS to determine the needed quantity of groundwater, based on traditional fishpond aquaculture methods, habitat needs for endangered waterbird species, anchialine pool habitat needs for candidate endangered native damselfly and candidate endangered pool shrimp, and threats to maintaining sufficient groundwater discharge to support these resources. The candidate species have since been listed as endangered.

Adaptive Management Principles

Effective groundwater management occurs when competing interests for groundwater resources are acknowledged and understood, and when limited available water resources are managed to pre-determined, agreed levels. Achieving this requires consideration of the social, economic, environmental, and cultural aspects of groundwater systems (Thomann et al. 2020).

Adaptive management is a form of structured decision making with emphasis on iterative decision making in the face of uncertainty. Adaptive management uses ongoing monitoring, appropriate indicators, and best available information to inform management decisions (Thomann et al. 2020). Because of the diversity of aquifer systems and GDEs, thresholds for action are best determined based on site-specific conditions (WRPP 2019). Choosing appropriate indicators and developing consistent monitoring protocols are a key part of implementation. Adaptive management uses the Precautionary Approach to minimize adverse consequences to GDEs of high ecological value, such as the National Park (WRPP 2019). Water management agencies and stakeholders in the adaptive management process must identify and consider impacts on a suite of beneficial uses and users as adaptive management plans are developed by setting measurable objectives to avoid undesirable outcomes (WRPP 2019).

Adaptive management is an iterative process that promotes flexible decision making in the face of uncertainty, increases knowledge, and encourages long-term term collaboration among stakeholders (e.g., Williams et al. 2009; Rohde et al. 2017; Thomann et al. 2020). Ideal elements of an adaptive management plan (Union of Concerned Scientists 2015) include:

- defining a clear baseline,
- setting quantitative thresholds,
- developing protective triggers that require action before reaching a threshold,
- conducting regular measurement and monitoring,
- accounting for uncertainty, and
- adapting to changing conditions and new information.

Groundwater Dependent Ecosystems

In Hawaiian coastal GDEs, fresh groundwater mixes with saltwater from the ocean and discharges to fishponds, wetlands, anchialine pools, tide pools, and nearshore and submarine seeps. The mixing of fresh groundwater and seawater in the proper proportions is a critical element for maintaining healthy, sustainable GDEs.

GDEs within the National Park include culturally important and rare native species and their aquatic habitat including nursery fishpond habitat for native fish, wetland habitat for endangered native waterbirds, and anchialine pool habitat for an endangered endemic damselfly and an endangered pool shrimp. The best available information indicates that GDEs within the National Park, especially ecosystems supporting rare and threatened species, are at or near threshold conditions for water quality related to the mixing of fresh groundwater and seawater (NPS 2015). Further reductions in groundwater discharge in the National Park are expected to increase concentrations of salinity in fishponds, wetlands, and anchialine pools that has the potential to cause unacceptable injury or impairment to the Park's resources (NPS 2015). These consequences would violate the NPS Organic Act cited above.

Federally listed and culturally significant species present in the National Park that are in part or wholly dependent on GDEs at the National Park include:

Endangered Species

Hawksbill Sea Turtle (*Eretmochelys imbricata*). (35 FR 8491-8498, June 3, 1970).
Hawaiian Stilt (*Himantopus mexicanus knudseni*). (35 FR 16047-16048, October 13, 1970).
Hawaiian Coot (*Fulica americana alai*). (35 FR 16047-16048, October 13, 1970).
Orangeblack Hawaiian Damselfly (*Megalagrion xanthomelas*). (81 FR 67786-67860, September 30, 2016).
Anchialine Pool Shrimp (*Procaris hawaiana*). (81 FR 67786-67860, September 30, 2016).

Threatened Species

Green Sea Turtle (*Chelonia mydas*). (81 FR 20058-20090, April 6, 2016).

Culturally Significant Species

Limu / Algae (numerous species)
ʻOpae / Anchialine pond shrimp (numerous species)
Striped mullet / 'Ama'ama (*Mugil cephalus*)
Milkfish/Awa (*Chanos chanos*)
Hawaiian flagtail / Āhole (*Kulia sandwichensis*)

Groundwater Demand and Discharge

The reported volume of groundwater use (twelve-month moving average [12-MAV]) in the Keauhou Aquifer System as of July 2022 is 13.25 million gallons per day (Mgal/d) (from M. Kaleo Manuel, Deputy Director CWRM, meeting on July 15, 2022). Information available online from the Commission indicates that as of January 2019 the 12-MAV was 13.8 Mgal/d (Monthly Pumpage Chart, Keauhou Aquifer). Future water demand in the Keauhou Aquifer System Area is estimated to be 28 Mgal/d by about the year 2030 (DWS 2017).

The volume of fresh groundwater discharge from the National Park area to the ocean in 1978 when Congress established the National Park is estimated to have been 6.48 Mgal/d (Oki et. al. 1999). The current estimate of discharge from the National Park is 6.76 Mgal/d, based on the three-dimensional model developed by the USGS to evaluate effects of groundwater pumping and injection on groundwater salinity and discharge at the National Park (Oki 2021). The revised discharge estimate is based on data from 1984 through 2008 that the USGS (Engott 2011) used in a daily water balance model to estimate groundwater recharge to the KASA. Therefore, this Plan uses the current estimate of 6.76 Mgal/d discharge from the National Park to the ocean.

The USGS (Engott 2011) estimated recharge to the KASA at 106 Mgal/d, based on the 1984 through 2008 period. This compares to the Commission's current planning and management estimate of 87 Mgal/d recharge. Engott (2011) further estimated that of the 106 Mgal/d, 67 Mgal/d recharges the inland high-level water area, and 39 Mgal/d recharges the coastal fresh-water lens system.

In addition, Engott (2011) estimated that recharge to the KASA during periods of drought is approximately 65 Mgal/d. The NPS believes it would be prudent for the Commission to consider this recharge value as a within the range of probable common future conditions, based on anticipated impacts from climate change.

Sea Level Rise

Fishponds, anchialine ponds, and the species that depend on them and other GDEs in the National Park will be affected by climate change-induced sea level rise in addition to impacts from groundwater management actions that may be implemented in the KASA.

The Hawaiʻi Climate Change Mitigation and Adaptation Commission (2017) review of Intergovernmental Panel on Climate Change and US Global Change Research Program literature suggests that global mean sea level rise is expected to be 0.3 to 0.6 feet by 2030, 0.5 to 1.2 feet by 2050, and 1.0 to 4.3 feet by 2100. There is very high confidence in lower bounds, medium confidence in upper bounds for 2030 and 2050, and low confidence in upper bounds for 2100. Sea level observations and trends in the latest scientific literature suggest that 1.1 feet of sea level rise could be reached intermittently in Hawaiʻi over the next few decades and sustained before mid-century (Hawaiʻi Climate Change Mitigation and Adaptation Commission 2017). In addition to sea level rise, the island of Hawaiʻi is subsiding, and therefore sea level rise could be relatively greater than at other locations.

Current monitoring at ʻAimakapā Fishpond, the three monitoring wells, and anchialine pools will capture sea level rise and its effects. Anchialine pools form in natural fissures and depressions in the basaltic lava in the National Park, and elsewhere, and it is possible that some associated fauna may be able to colonize pools forming further inland in response to sea level rise, however, the timeframe for full biological development of the anchialine habitat necessary to support species is unknown. It is possible that new wetlands may be created further inland; however, within the existing topography of the National Park, no new fishponds comparable to Kaloko and ʻAimakapā will be formed. All aquatic habitats in the National Park are vulnerable both to rising sea level and capture of discharge caused by groundwater pumping.

ADAPTIVE MANAGEMENT

I. MONITORING

Monitoring changes in the quantity of freshwater discharging from the National Park and effects of seawater intrusion caused by groundwater withdrawal (and sea level rise) are important for water-resource managers. Therefore, several Indicator Wells have been identified for this Plan, as shown in Figures 1 and 2.

- Kohanaiki MW401 (Well No. 4161-011), located very near the north boundary of the National Park.
- Kohanaiki wells 4162-05 and 4162-07, located nearer the coast than MW401 and also very near the north boundary of the National Park.
- Kaloko Monitor Well (Well No. 4161-013), located at a DWS property across Queen Kaʻahumanu Highway east from the northeast corner of the National Park.
- Kamakana Well (Well No. 3959-001), located just over 2 miles southeast from the southeast corner of the National Park.

It is possible that additional Indicator Wells, such as the deep Kaloko monitoring well (Well No. 4159-001) east of the National Park, could be included in the future. The Indicator Wells are completed in the coastal fresh-water lens system within the KASA, and each intersects saltwater underlying the freshwater lens. Monitoring will focus on evaluating changes in the thickness of the freshwater lens at the location of each Indicator Well. The midpoint depth (depth at which salinity is 50% that of salt water, where the specific conductance of groundwater equals 25,000 microsiemens per centimeter) of the transition zone between freshwater and salt water is an indicator of the thickness of the freshwater lens (Rotzoll et al. 2010). Monitoring the midpoint of the transition-zone (MPTZ) between freshwater and salt water over time can explain changes in the freshwater lens caused by fluctuations in groundwater withdrawals, changes in recharge, and changes in sea level, and should be used to identify depletion of freshwater resources caused by regional withdrawals and changes in recharge (Rotzoll et al. 2010).

The Commission requires each owner or operator of a pumping well to report their monthly water use. These data are summarized in updates to the Water Resources Protection Plan available at http://dlnr.hawaii.gov/cwrm/planning/hiwaterplan/wrpp/ and will be used to evaluate the volume of pumping from active production wells in the adaptive management zone on a 12-month moving average basis.

In addition to the Indicator Wells for the Plan, the USGS will continue to monitor the elevation and specific conductance of groundwater at four locations within the National Park: KAHO Well 1 (8-4061-01), KAHO Well 2 (8-4161-02), KAHO Well 3 (8-4161-01), and ʻAimakapā Fishpond. These data are available at https://irma.nps.gov/aqwebportal/ and will supplement data collected from the Indicator Wells.

In the past, the NPS has obtained periodic measurements of salinity in Kaloko Fishpond (NPS 2015). Monitoring in Kaloko Fishpond for water salinity and temperature, and possibly water elevation, could assist the Commission in meeting the goals of this Plan. The response of Kaloko Fishpond to tides, storm-generated waves, sea level rise, and change in freshwater discharge is important in understanding how the system is adapting to changing conditions. Because the pond is connected directly to the ocean, several sites or transects may need to be monitored to understand differences in salinity and temperature throughout the pond, especially those conditions important for pool biota. The Commission will evaluate the feasibility of developing a Kaloko Fishpond monitoring plan in coordination with the NPS. The Commission will also seek the input of the Native Hawaiian community, the USGS, and other stakeholders. The Native Hawaiian perspective is important because of the significant cultural connections with the area that now constitutes the National Park and because the Community's knowledge base and oral histories are important datasets for understanding how conditions at Kaloko Fishpond have changed over time, and how the fishpond may respond to future environmental changes.

The NPS Inventory and Monitoring program also monitors benthic marine communities, faunal communities in anchialine pools, and water quality in anchialine pools, monitoring wells, and marine waters within the National Park. These data can be available for use with the Plan.

II. ASSESSMENT AND MANAGEMENT ACTIONS

A. Groundwater Flux-Based Assessment

Although data are not yet available for the 12-MAV of pumping in the KASA between January 2019 and June 2022, it appears that the pumping volume has varied between approximate 13 and 14 Mgal/d since March 2017, based on published data. These pumping volumes are in accordance with volumes acceptable to the NPS, based on previous information provided to the Commission (NPS 2015).

The current methodology used by the Commission for determining the sustainable yield of the Keauhou Aquifer System Area assumes that the rate of groundwater discharge equals the rate of groundwater recharge under pre-development conditions and limits withdrawals to forty-four percent (44%) of this rate. Therefore, under this Plan, <u>the 12-MAV of pumpage within the Adaptive Management Zone should not exceed a volume of 3.00 Mgal/d</u>, based on retaining 56 percent of the current estimate of discharge from the National Park of 6.76 Mgal/d. The volume of 3.0 Mgal/d includes the combined total of pumping from both the coastal fresh-water lens and the inland high-level water area.

However, Commission data from March 2021 indicate that total pumping is increasing through time and the average pumping volume from 2010 through 2020 is 3.1 Mgal/d, with pumping in the period from 2019 to March 2021 approximately 4 Mgal/d. Furthermore, the permitted pumping capacity in the Adaptive Management Zone is 8 Mgal/day.

The Commission will post on its website the 12-MAV of pumping within both the KASA and the Adaptive Management Zone on a monthly basis.

B. Salinity-Based Assessment

The current elevations (baseline) of the MPTZ at the locations of the Indicator Wells will be documented using quality control and quality assurance procedures designed to ensure data quality and developed in consultation with the NPS and USGS. The basic procedure is to measure the MPTZ, then place a transducer at that depth and collect salinity data. An increase in salinity indicates the MPTZ is rising because of saltwater intrusion. A decline in salinity indicates the MPTZ is lowering because the thickness of the fresher water column above is increasing. For this Plan, the NPS recommends that the baseline MPTZ be established based on 90-days of continuous measurement at each Indicator Well.

During ongoing monitoring, the elevations of the MPTZ will be measured at the locations of the Indicator Wells at a frequency acceptable to Commission and NPS, in consultation with the USGS. This is expected to be at intervals of every 10 minutes, as is conducted in the National Park monitoring wells.

The Commission will post on its website all the MPTZ data from each Indicator Well on a monthly basis.

Data regarding changes in MPTZ in the KASA are very sparse. However, the following table provides an example of the sensitivity of the MPTZ to changes in water level (feet). The table presents statistics (variance, standard deviation, and multiples of the standard deviation) developed from calculating the 14-day running average of water level data in KAHO Well 2 using the period of record dataset from July 2007 through August 2021. The 14-day running average smooths the data to remove some of artifacts of tidal fluctuation in the dataset.

KAHO Well 2: 14-Day Running Average water level; Jul 2007 - Aug 2021					
Avg EL	Variance	St. Dev	2 St. Dev	3 St. Dev	4 St. Dev
1.620	0.035	0.188	0.377	0.565	0.754
Δ MPTZ	1.420	7.536	15.072	22.608	30.144

In accordance with ideal Ghyben-Herzberg principles, a decline in average (smoothed) water level elevation equal to the Variance of 0.035 feet would result in a rise in the MPTZ of 1.42 feet. A decline in water level elevation equal to the Standard Deviation of 0.188 feet would result in a rise of the MPTZ of 7.536 feet, and so on. As a result, long-term monitoring of the MPTZ provides water managers with an excellent understanding of trends in the thickness of the coastal fresh-water lens system in the Adaptive Management Zone, the KASA, and elsewhere.

The National Park suggests that for wells completed in the coastal fresh-water lens system, a significant change in the MPTZ occurs when that change is equal to or greater than the variance of smoothed water level data. As MPTZ data are collected for this plan, the data can be evaluated to determine if a single MPTZ value is used to trigger management actions, or if multiple MPTZ values need to be established. For example, one value may be appropriate for Indicator Wells completed in the coastal fresh-water lens system in close proximity to the National Park, and another value will likely be needed to evaluate the significance of the MPTZ in deep wells such as the Kamakana Well (Well No. 8-3959-001).

C. Assessment-Based Management Actions

The Commission will take management actions if either of the following flux-based or salinity-based criteria are exceeded:

- The 12-MAV of pumping is greater than 3.0 Mgal/d in the Adaptive Management Zone over a 120-day period, or
- A rise in the elevation of the MPTZ greater than the variance of smoothed water level data (estimated to be between 1.2 and 1.7 feet) over a 120-day period.

If the either criterion are exceeded for 60 days, the Commission shall notify public and commercial entities that are withdrawing groundwater in the Adaptive Management Zone that reductions in pumping volume will be required if the trend continues for another 60 days. The Commission may choose to implement a process for public review and comment regarding proposed reductions in groundwater pumping.

The Commission shall not approve any new Pump Installation Permits within the Adaptive Management Zone until both criteria are met.

Reductions in pumping will be focused on locations that provide the greatest benefit to GDEs. In general, reduction in pumping from the coastal fresh-water lens system will have greater benefits than reducing pumping from the inland high-level water area because the coastal fresh-water lens system receives less recharge, has a thin fresh-water lens, and is more susceptible to saltwater intrusion. For example, assume that during a 120-day period, pumping from the Adaptive Management Zone shows a 12-MAV of 5.0 Mgal/d, of which 3.5 Mgal/d is pumped from the inland high-level water area and 1.5 Mgal/d is pumped from the coastal fresh-water lens system. Pumping from the coastal fresh-water lens system could be reduced by 85% to a volume of 0.2 Mgal/d and pumping from the inland high-level water area could be reduced by 20% to a volume of 2.8 Mgal/d. This would continue to provide groundwater for public trust resources throughout the KASA while reducing non-public trust water uses.

If pumping from the inland high-water level area is directly upgradient from the National Park, that pumping will capture a proportion of groundwater that would eventually discharge through the National Park to the ocean and reduction in pumping at that location could take precedent over pumping from the coastal fresh-water lens system at distances greater than 2 to 3 miles from the National Park. Using the above example, reduction of pumping in the Adaptive Management Zone could be achieved by transferring the excess pumping to other areas of the KASA (or other aquifer systems) outside the Adaptive Management Zone. A transfer of pumping quantity is most feasible in the inland high-level water area because many of the high-capacity wells are part of the freshwater distribution system managed by DWS.

If the elevation of the MPTZ in any individual Indicator Well does not meet the above criteria after 180 days, the Commission shall work with the NPS, USGS, the well owner, and other partners if required to determine why the MPTZ is not recovering to baseline. Even if the criteria of 3.0 Mgal/d pumping in the Adaptive Management Zone is met, additional restrictions in pumping, or injection of brine, may be required. The USGS three-dimensional groundwater flow model (Oki 2021) indicates that injection of brine into the coastal fresh-water lens system at concentrations 140% of sea water reduces salinity in National Park anchialine pools unless the injection occurs approximately 3 miles or more from the park. This is not an intuitive response, and is the result of complex aquifer system dynamics with variable density waters.

Further modeling and field documentation of the MPTZ at various locations is required to determine if injection of brine will affect the MPTZ. If the MPTZ does not revert to baseline or begin to decline after 240 days, additional pumping restrictions will be implemented even if average pumping in the Adaptive Management Zone is less than or equal to 3.0 Mgal/d. Initial pumping restrictions would occur in the coastal fresh-water lens system and would be implemented based on the results of USGS modeling. It is anticipated that initial reductions would be 10% of the existing pumping volume in the coastal fresh-water lens system and 5% of the 12-MAV in the inland high-level water area. Reductions would remain in place for a minimum of 180 days or until evidence is observed that the MPTZ is very close to or has reverted to baseline.

D. Additional Assessment and Actions

In addition to the actions discussed above, other assessment and management actions may be incorporated into this Plan or future revisions of the Plan. Many of these concepts are also valid for groundwater management in the KASA and other aquifer systems in west Hawaiʻi Island, and could provide for long-term water security and sustainability. For example,

- Implementing changes to the well permitting process would help the Commission preserve and protect public trust resources. In any groundwater system, all pumping from wells is balanced by a loss of water somewhere - almost always a capture of groundwater that would have discharged to support vegetation evapotranspiration or to a spring, river, lake, or the ocean. Ultimately, a well pumping 1 Mgal/d in the coastal fresh-water lens system upgradient from the National Park will reduce discharge at the Park by 1 Mgal/d. It does not matter if overall pumping from the aquifer is 10% of sustainable yield or 90% of sustainable yield. It does not matter if aquifer recharge is 50 Mgal/d or 100 Mgal/d. A well pumping 1 Mgal/d, located within the zone that provides freshwater discharge to the National Park, will reduce discharge from the National Park by 1 Mgal/d. It is somewhat different if that well is in the inland high-level water area because a portion of the groundwater in the high-level area discharges to the deep coastal confined groundwater system (Oki 2021). However, the proportion of water that would have discharged to the coastal fresh-water lens system will no longer do so and therefore discharge to the ocean will be reduced.

  The USGS three-dimensional groundwater flow model (Oki 2021) can be used during the permitting process to evaluate capture of discharge from proposed wells in areas of the Adaptive Management Zone and KASA.

Changes to the permitting process would allow the Commission to explicitly consider where and how much discharge would be captured before new wells are permitted. Identifying where discharge is most likely to be captured is critical in evaluating the effects of pumping on GDEs. Therefore, the Commission could require an applicant to evaluate if reduced discharge caused by their proposed pumping would impact GDEs and the probable magnitude of the impact.

As part of the permitting process, the Commission would be able to allow the public to offer comments regarding any concerns, or support, for permitting a new well and the potential impacts to GDEs.

- Additional Indicator Wells could be added if the currently identified wells do not provide sufficient early-warning information or to enhance the overall knowledge of the groundwater system and effectiveness of a monitoring network.
- The USGS (Oki 2021) suggests that the deep coastal confined groundwater system discharges some groundwater to the coastal fresh-water lens system, based on salinity profiles and differentials between aquifer water levels. As more research is conducted into the hydrologic connections between the inland high-level water area, coastal fresh-water lens system, and coastal confined groundwater system, that research will likely become more relevant to effective management of the overall groundwater system.
- The results of monitoring well installation and geophysical testing in the inland high-level water area, and aquifer testing in the high-level and coastal confined groundwater systems could be used to better quantify the quantity of groundwater, volumes and locations of discharge, and how the aquifer systems are changing with time. As above, this information will assist in developing and implementing more effective management actions.
- Technologies such as treatment and reuse of water can be implemented throughout Hawaiʻi so that fresh potable water is used for high-value activities related directly to public trust uses and the health of individuals and the community. Capturing and treating gray water could be effective for activities such as landscape irrigation, washing vehicles, washing seawater off boats, and other non-potable uses, and would reduce demands on potable water.
- Protocols for monitoring of listed or culturally significant species could be incorporated formally into the Plan. In addition, new data on the groundwater needs of these species, or other GDEs, or important thresholds could be formally added to the Plan.
- A new groundwater model could be developed that incorporates knowledge of the high-level and deep confined groundwater systems.

III. LONGER TERM MANAGEMENT ADAPTATIONS

The Commission, with the assistance of the NPS, USGS, well owners such as the County of Hawaiʻi Department of Water Supply and Kohanaiki Shores LLC, and other partners and community voices could evaluate the effectiveness of the management strategy described in this Plan based on the status of resources, and new information (data and studies) about groundwater resources within the Adaptive Management Zone and, more generally within the KASA. For example, the frequency of monitoring or the criteria for designation may be adjusted based upon analysis of the data collected as part of this Plan. Any such evaluations or proposed modifications to this Plan would be presented to the Commission for review at a regularly scheduled public meeting of the Commission and that would include appropriate public review and comment.

The Commission may recommend adjustments to the management strategy related to groundwater through the processes that have been established for updating the Hawaiʻi County Water Use and

Development Plan, for updating the State of Hawaiʻi Water Resource Protection Plan, and for evaluating Well Construction/Pump Installation and Water Use Permits.

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Figure 1. Map of the boundaries of the Adaptive Management Zone relative to the Keauhou Aquifer System Area, Kaloko-Honokōhau National Historical Park, and the Indicator Wells.

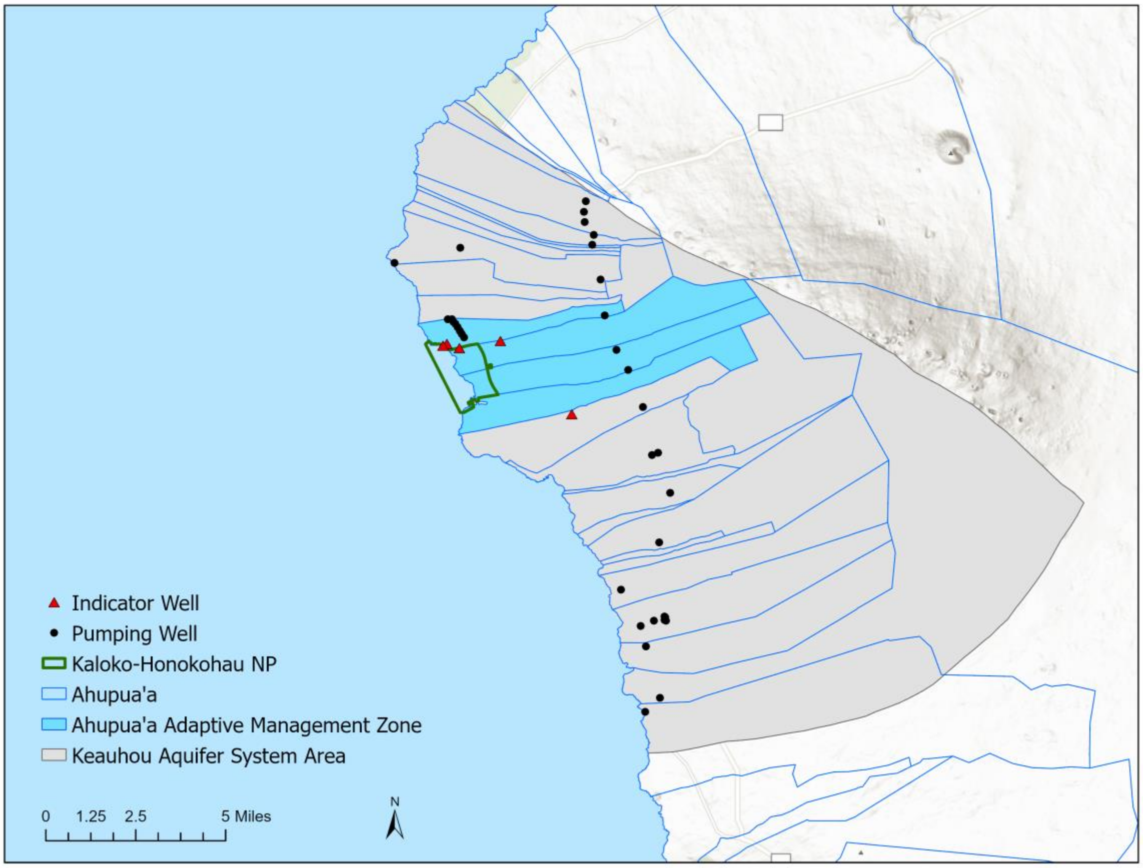

Figure 2. Map of Indicator Well locations. Base map courtesy USGS Scientific Investigations Report 2021-5004, Figure 2, p. 3