Appendix C

Assessment of the Potential Impact of the Proposed Kaloko Makai Project on Water Resources
Tom Nance Water Resource Engineering
Revised July 2013

An Assessment of the
Potential Impact of the
Proposed Kaloko Makai Project
on Water Resources

Prepared for:

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INTRODUCTION

This report provides an assessment of the potential impact of the proposed Kaloko Makai project on water resources. It has been prepared to support the project's Supplemental EIS being prepared by others.

DESCRIPTION OF THE PROJECT

Project Site and Proposed Development

Location of the 1113-acre project site is shown on Figure 1. The site is on both sides of Hina Lani Drive and extends from Queen Kaahumanu Highway on its makai end to about 760-foot elevation at its highest point. The project is to be developed in three phases and would be comprised of a mix of residential, commercial, industrial, and public uses, the latter including a 150-acre dry land forest (Figure 2).

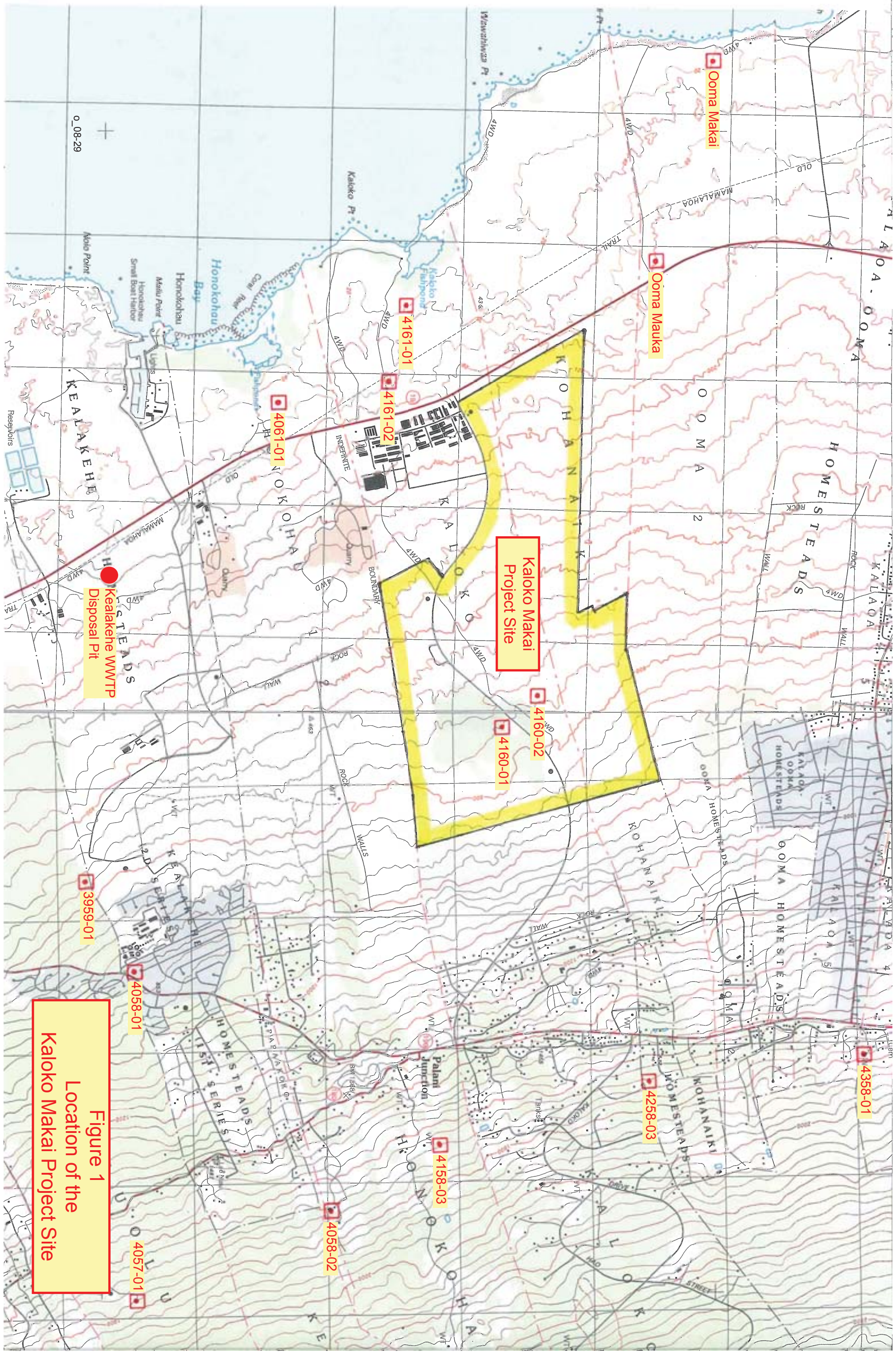
Projected Water Supply Requirements

Separate potable and non-potable systems are proposed to supply the project's water requirements. Projected supply requirements have been prepared by Wilson Okamoto Corporation (2012) and are summarized on Table 1. At full build out, projected average potable use would be 2.18 MGD. The average non-potable use would be 0.58 MGD.

Alternative Sources of Supply for the Potable System

The potable system's well pumping capacity must provide the maximum day use (defined as 1.5 times the average use) in a 24-hour pumping day. If the wells are dedicated to and incorporated into the County Department of Water Supply (DWS) system, one-third of the well capacity would be allocated to DWS and two-thirds would be allocated to the developer. Four alternative sources for potable supply are being considered: onsite wells at about 710-foot elevation at the upper end of the project; 710-foot onsite wells with desalinization; wells several miles to the south tapping the high level groundwater body; and desalinization using onsite saline groundwater as the feedwater supply. These are described in the paragraphs following.

Onsite Wells at 750-Foot Elevation Within the Project Site. The possibility of developing potable quality wells onsite at 710-foot elevation is suggested by the discoveries of two deep monitor wells (State Nos. 3858-01 and 3959-01), both of which encountered fresh groundwater under artesian pressure at depth below saline groundwater and far below and hydrologically disconnected from the basal lens. The phenomenon is discussed in detail later in this report. A deep exploratory borehole at 710-foot elevation at the upper end of the project site will be undertaken to determine if fresh groundwater can be found at depth and to determine the feasibility of its development. If successful, three production wells would be developed, each of 1150 GPM capacity and driven by 300 horsepower motors. These wells would be integrated into the DWS system, with two-thirds of their capacity allocated to supply the Kaloko Makai project.



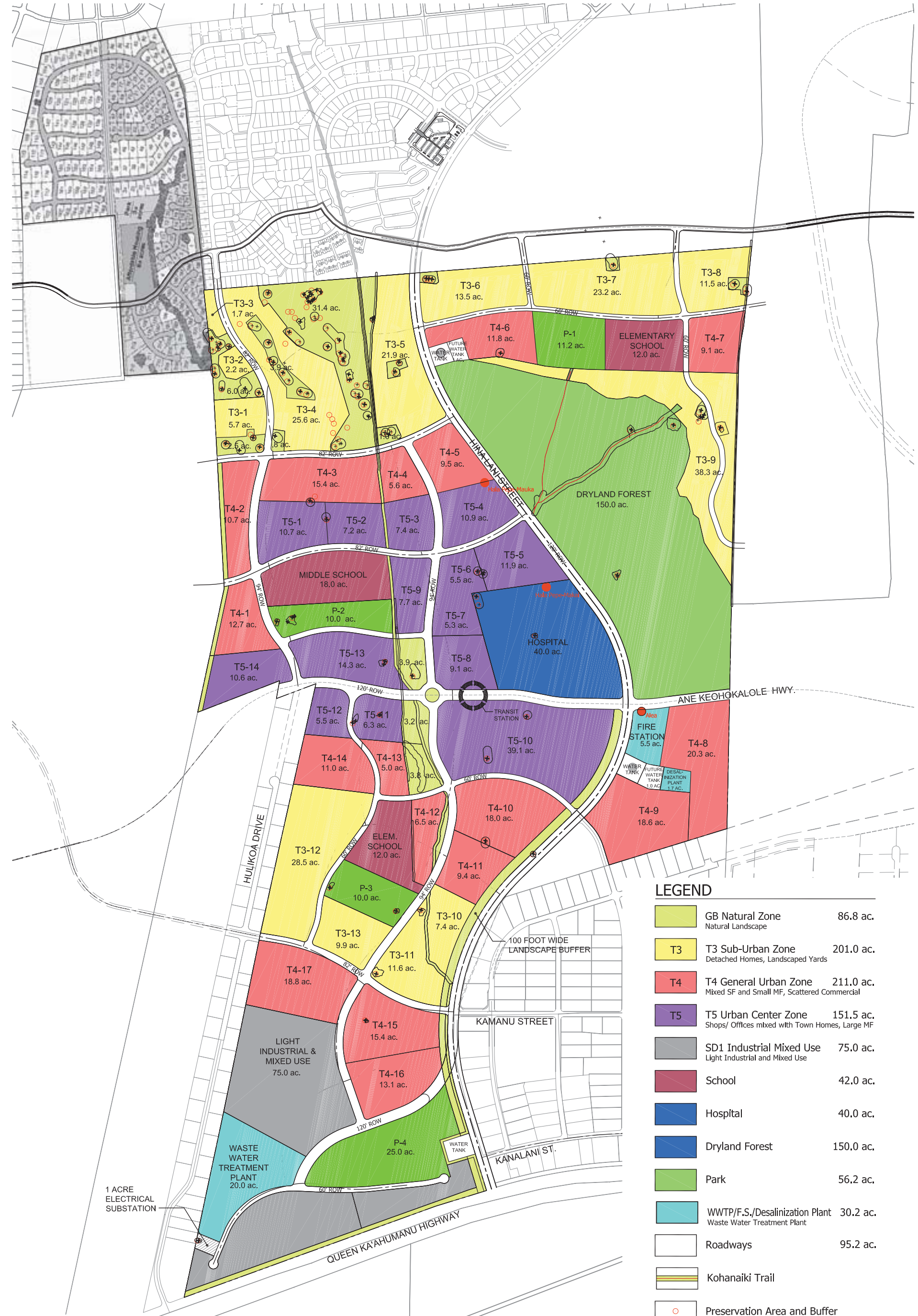


Figure 2

LAND USE PLAN

KALOKO MAKAI - VILLAGE PLAN

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SCD - TSA KALOKO MAKAI, LLC   JUNE 2012   KAILUA-KONA, HAWAII

Table 1

Modification of the Water Supply Projections With
Multi-Family Parcels Irrigated by the Non-Potable System

Development Phase	Projected Supply Requirements		Wastewater Generator for Potential Reuse (MGD)	
	Potable (MGD)	Non-Potable (MGD)	Design Amounts by Wilson Okamoto	Expected Actual Generation by TNWRE
1	0.8558	0.3044	0.8183	0.5273
2	0.7382	0.1938	0.7635	0.5288
3	0.5897	0.0856	0.6003	0.4173
Total	2.1837	0.5838	2.1821	1.4734

Note: 400 GPD/Unit water use for multi-family parcels distributed 276 GPD for potable and 124 GPD for non-potable based on Honolulu BWS Guidelines.

710-Foot Onsite Wells With Reverse Osmosis (RO) Treatment. In the event that artesian groundwater is found below saline groundwater but its salinity at projected draft rates would not meet drinking water standards, the alternative of RO treatment of this water would be considered. This treatment process would produce a wastewater stream, referred to as a concentrate, that would be disposed of injection wells located at the project's wastewater treatment plant (WWTP) at the makai end of the project site. Due to the operating costs of the RO treatment, DWS may not accept the wells and RO treatment plant for dedication. In that case, the capacity of the wells, as feedwater sources for RO treatment, would be sized to provide the project's maximum day use in a 24-hour pumping day. A product recovery from the RO process is expected to be in the range of 60 to 70 percent. As a private system, provision of standby well pumping capacity would be required. These criteria translate to four 1170 GPM well pumps, one as standby. At full build out, the disposal of concentrate would be on the order of 1.15 MGD as a year-round average.

Wells to the South of the Project Site. In the event that neither of the two onsite well alternatives described above are feasible, development of potable wells several miles to the south, would be pursued. The exact locations of these wells will depend on land acquisition costs and the costs of additions to DWS' infrastructure required to transmit this well supply north to the project site. In general, however, there are two distinctly different possibilities, wells above Mamalahoa Highway tapping the high level groundwater directly or wells in the near vicinity of the State's deep monitor well tapping the high level groundwater at depth below saline groundwater. In either case, these wells would be incorporated into DWS' system. Depending on their location, three 1120 GPM or four 840 GPM wells would be required. Improvements to DWS' transmission/distribution system would also be required for this alternative.

Desalinization of Onsite Saline Groundwater. In the event that none of the three alternatives described above are feasible, desalinization of onsite saline groundwater would be undertaken. The raw water supply wells and desalinization plant would be located next to or below DWS' existing 363-foot tank along Hina Lani Drive. The raw water supply wells would draw saline groundwater from beneath the basal lens. Tentatively, the depth from which this supply would be withdrawn would be between 250 and 350 feet below sea level, requiring total well depths on the order of 710 feet. The expectable product recovery from this saline feedwater supply is on the order of 40 to 45 percent, meaning that about 2.5 gallons of saline groundwater would be required for every gallon of fresh product water produced. As a private system with redundant capacity, this would translate to four 750 GPM treatment trains with each treatment train supplied by a 1900 GPM raw water supply well.

To reduce the RO power requirements, pressure transfer devices would be installed to recover energy from the RO's concentrate stream. The concentrate itself would be hypersaline [salinity on the order of 50 parts per thousand (PPT) compared to seawater at 35 PPT]. Its disposal, amounting to 4.9 MGD at full build out, would be in three deep wells located at the project's WWTP.

Wastewater Generation, Treatment, and Reuse or Disposal

A 20-acre site for the project's WWTP would be located at the makai end of the project site (refer to Figure 2). The WWTP would produce R-1 quality effluent which would be the source of supply for the project's non-potable system. The last two columns of Table 1 list wastewater generation amounts, both as design amounts compiled by Wilson Okamoto Corporation and as expectable average amounts compiled for this report. The expected wastewater amount substantially exceeds potential irrigation reuse in the project's non-potable system. The excess would be disposed of in injection wells at the WWTP if other uses for this water can not be found.

Rainfall-Runoff Generation and Disposal

According to the 2011 Rainfall Atlas of Hawaii (Giambelluca and Others, 2011), average annual rainfall across the project site varies from 15 to 25 inches a year. The land surface of the project site consists of unweathered and very permeable lavas with sparse deposits of ash soils and no defined drainageways. Essentially no rainfall runoff leaves the site in its present condition, even during intense storm events. It is either lost to evaporation or percolates to the underlying groundwater.

Development of the project will create impervious surfaces which will locally create surface runoff. All of this runoff would be directed into seepage pits and drywells such that no runoff will leave the site after it is developed.

DESCRIPTION OF THE HYDROGEOLOGIC ENVIRONMENT IN THE VICINITY OF THE KALOKO MAKAI PROJECT SITE

General Overview

The Kaloko Makai project site and the land upslope from it are comprised of unweathered lava flows with little or no soil cover and extraordinarily high permeability. Except where the natural ground has been converted to impervious surfaces by development, continuous flow of surface runoff during storm rainfalls does not occur. The rainfall percolates downward rather than flowing over the ground surface for any significant distance downslope. Because of this, the description of the hydrogeologic environment within and around the Kaloko Makai project site focuses exclusively on groundwater. Surface water resources are non-existent.

Groundwater in North Kona area occurs into two different modes. Along the coastline and for several miles inland, groundwater occurs as a brackish basal lens floating on saline groundwater beneath it and in hydraulic contact with seawater at the coastline. High level groundwater, the other mode of groundwater occurrence in North Kona, was first discovered in 1990 with a well drilled in Keauhou at 1620-foot elevation above Mamalahoa Highway. Since then, more than 20 high level wells have been developed from Kalaoa on the north and Kealakekua to the south. With only a few exceptions, all of these wells have been located above Mamalahoa Highway. Nine of the wells are currently in use, eight of which are owned and operated by the Hawaii County Department of Water Supply (DWS). DWS is about to put one more high level well (State No. 4158-03) into production in the near future.

Basal Groundwater Occurrence

Basal Water Levels. In the Keahole to Kailua area of north Kona which includes the Kaloko Makai site, basal groundwater levels near the shoreline are about one foot above sea level and slowly increase moving inland to between two and three feet above sea level at the mauka end of the project site. These water levels move up and down in response to the semi-diurnal tide with the tidal response

increasingly lagged and damped with distance inland. At the three monitor wells in the Kaloko Honokohau National Park (KAHO), which are 1500 to 3500 feet in from the shoreline, the tidal variation is about 50 percent of the ocean's tidal amplitude and is lagged by less than one hour. Further inland and within the Kaloko Makai project site at Well 4160-02, the tidal amplitude is about 15 percent and the lag is a little more than three hours (TNWRE 2002, page 10).

Figure 3 is a salinity and temperature profile through the water column of onsite Well 4160-02. It illustrates two relatively anomalous characteristics of the underlying basal groundwater, given the areal extent of the potentially contributing upland watershed. First, the 65.8º F. temperature in this top portion of the basal lens is four to six degrees colder than in upgradient wells which tap the high level groundwater. Second, the salinity is substantially higher than would otherwise be expected. These two characteristics are found in all basal wells from Keahole Point to at least as far south as the old Kona Airport. The subsurface geology which appears to be responsible for this occurrence is discussed in detail in subsequent sections.

Flowrate Through the Basal Aquifer. The most recent, sophisticated, and therefore most reliable computations of groundwater recharge for Hawaii Island are presented in Engott, 2011. The area within and around the Kaloko Makai project site is a part of the 167-square mile area delineated by the State Commission on Water Resource Management (CWRM) as the Keauhou Aquifer System. Its computed recharge in Engott, 2011 is 152 MGD. Reducing this by 14 MGD, the current groundwater pumpage from the aquifer system, leaves an average groundwater flowrate of about nine MGD per coastal mile across the aquifer's shoreline width. If all the rainfall-recharge into the high level aquifer were to discharge into the downgradient basal lens, this flowrate would create a robust basal groundwater body which could be developed for irrigation use and possibly even for potable supply.

This is decidedly not the case for the basal groundwater in the area from the Old Kona Airport to Keahole Point. Indications are that the actual basal flowrate is less than one-third of what might be expected if all of the discharge from the high level groundwater was into the inland margin of the basal lens. As noted above, the substantially lesser actual flowrate through the basal lens is reflected in water levels that are lower than otherwise expected, salinities which are too high for irrigation use, and anomalously cold temperatures.

Deep Monitor Well Results. Results of two deep monitor wells provide insight into the possible geologic feature creating the high level groundwater occurrence tapped by wells above Mamalahoa Highway and the resulting anomalous flowrate, salinity, and temperature in the basal lens. These two wells are the State's Keopu Monitor Well (No. 3858-01) and the Kamakana Monitor Well (No. 3959-01). Both were drilled through the basal lens, continued through the underlying saline groundwater, and then encountered fresh and confined groundwater at depth. Results of Well 3858-01 are described in Water Resources Associates, 2007. Since encountering fresh water at depth was unexpected at this location, the exact depth that it occurred in the borehole during drilling is not known and has not been determined with video logs and other measurements. During drilling of the Kamakana Monitor Well, salinity and temperature of the water in the borehole were closely monitored, enabling the different groundwater regimes penetrated by the borehole to be accurately documented. These are described below and illustrated on Figure 4.

Figure 3. Salinity and Temperature Profile through the Water Column of Well 4160-02 (September 14, 2012)

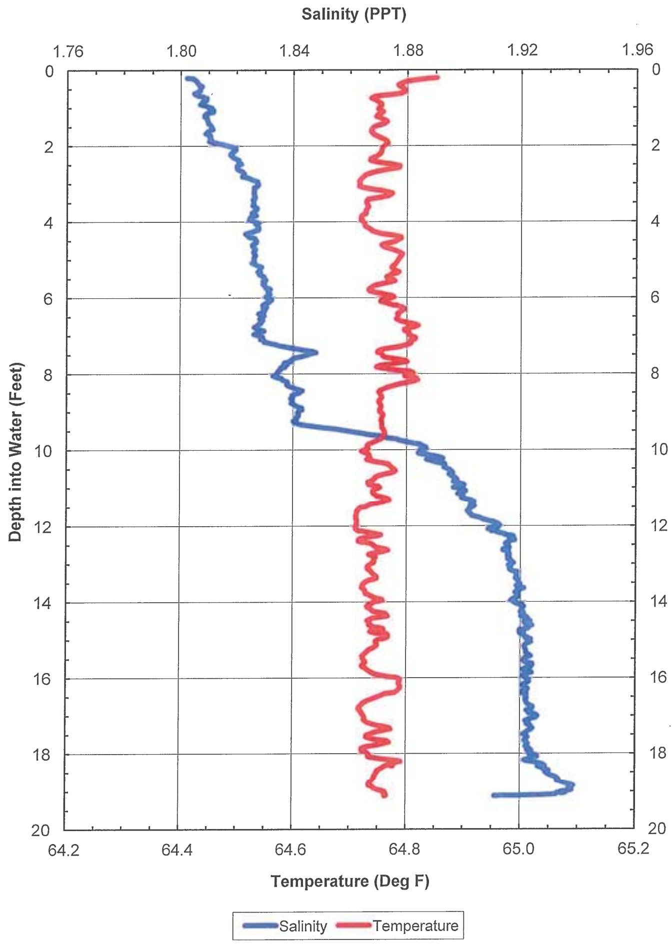
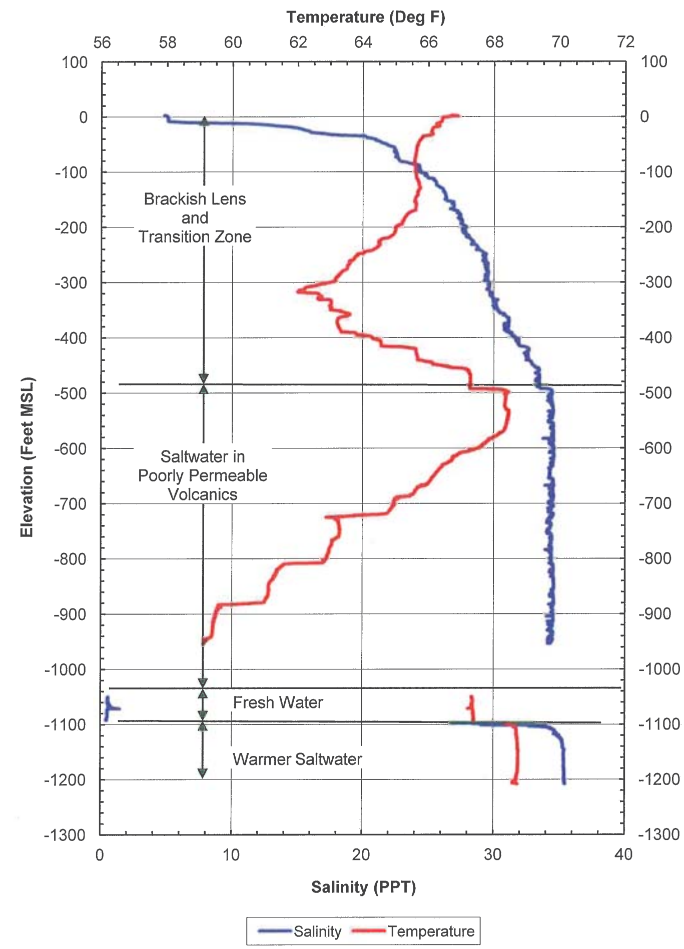


Figure 4. Composite Profile through the Water Column of the Kamakana Borehole (Profiles of 4/12/10, 5/12/10, and 8/18/10)



- Initially, a thin, relatively saline (5 PPT) and cool (66° F.) basal lens was encountered. The water level was typically about 2.5 feet (MSL) according to the available surveyed elevation. However, the mid-point of the transition zone of this basal lens is between 35 and 40 feet into water, suggesting that the actual water level relative to sea level may actually be less than two feet.

- Below the brackish basal lens is a thick transition zone which extends to a depth of 490 feet below sea level. In this transition zone, the water temperature steadily declines to 62° F. at 320 feet below sea level and then the temperature trend reverses, increasing to 67° F. at 490 feet below sea level.

- Below this thick transition zone, extending from 490 to more than 1020 feet below sea level, the salinity is essentially that of seawater and the temperature steadily declines with depth to about 59° F.

- At 1060 feet below sea level, fresh water was encountered. It was about eight degrees warmer than the saline groundwater immediately above it and had a piezometric head subsequently determined to be about 32 feet above sea level. The fresh water rushed up the borehole, mixing with the saltwater above for the first 150 feet, moving up the borehole for the next 720 feet with little or no mixing, and then mixing into the transition zone above that (Figure 5).

- The freshwater zone turned out to be less than 40 feet thick. At 1100 feet below sea level, warmer (70° F.) and slightly hypersaline (35.4 PPT) groundwater was encountered. Drilling was continued for another 120 feet with no salinity or temperature change.

Using inflatable packers to isolate the fresh water zone from the saline groundwater above and below it, short term air lift pumping was done to see if this narrow stratum containing fresh water could provide a developable supply. At low rates of pumping (120 GPM), however, the salinity of the pumped water became brackish and did not stabilize. Somewhat surprisingly, the freshwater zone had a substantial response to ocean tidal variations (Figures 6 and 7), significantly greater than the tidal response in the basal lens directly above. Comparative tidal lags and amplitudes for the respective periods of recording were as tabulated below.

Groundwater Zone	Tidal Lag (Hours)	Tidal Amplitude (% of Ocean Tide)
Fresh Water Zone	1.0	48
Brackish Basal Lens	3.0	25

Results of the two deep monitor wells provide insight on the relationship between high level and basal groundwater and the anomalies in the basal water body, at least in the near vicinity of these two monitor wells. These conclusions are:

Figure 5. Profile through the Water Column of the Kamakana Borehole After Fresh Water was Encountered (May 12, 2010)

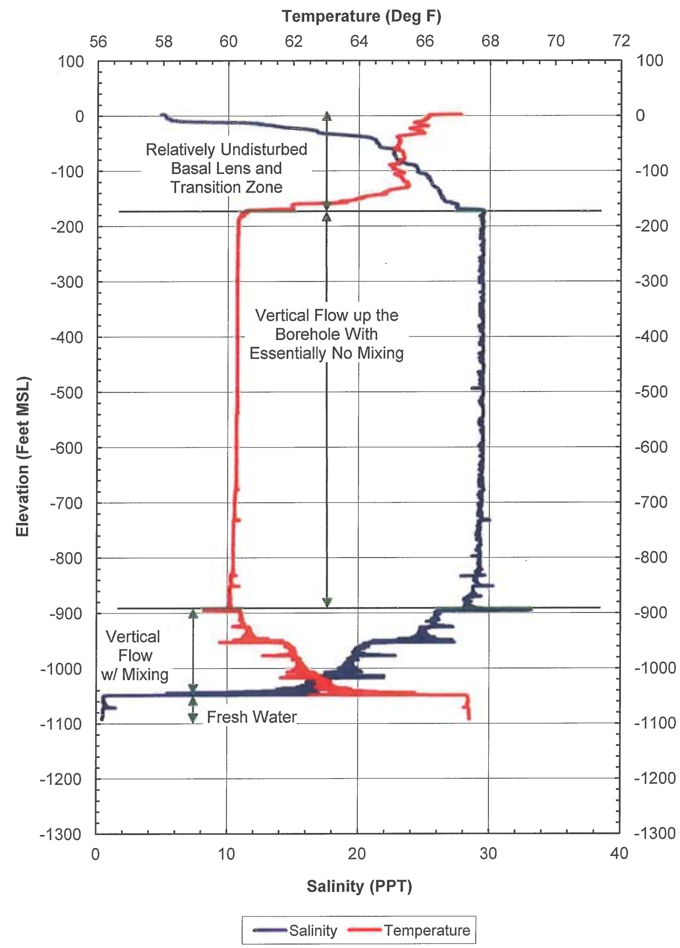


Figure 6. Tidal Variation in the Fresh Water Zone of the Kamakana Monitor Well in December 27 to 28, 2010

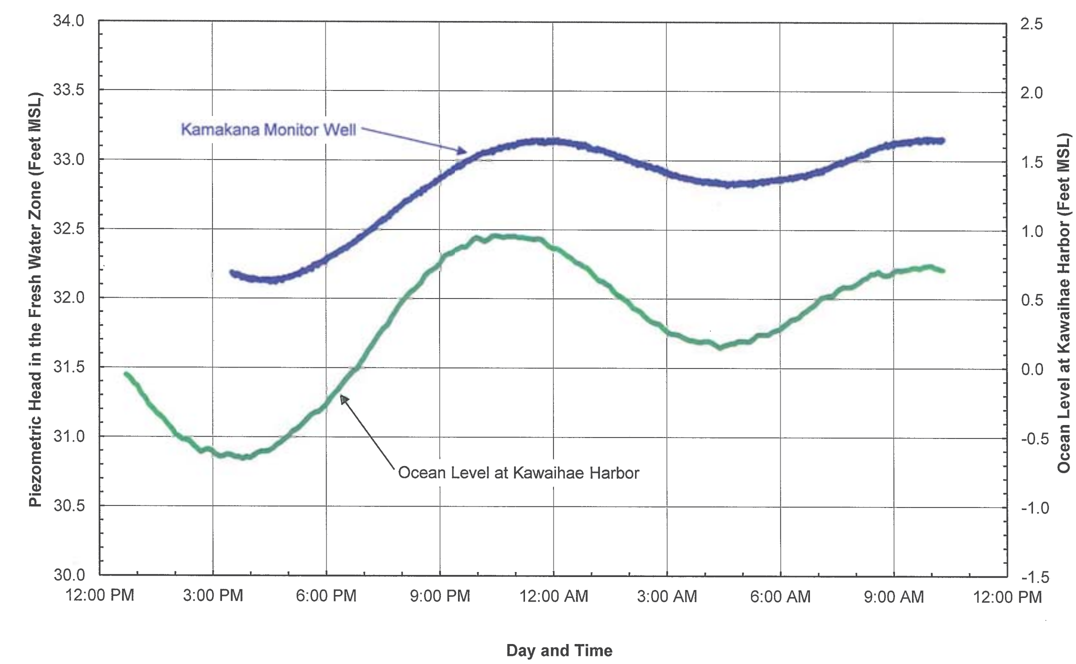
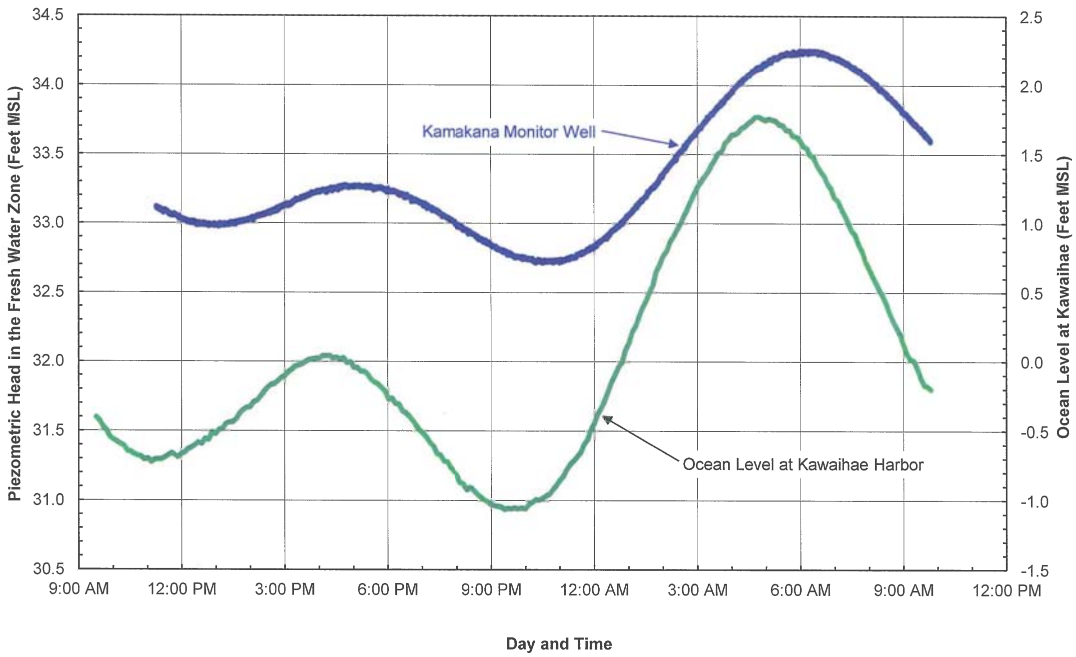


Figure 7. Tidal Variation in the Fresh Water Zone of the Kamakana Monitor Well in January 4 to 5, 2011



- The feature confining the fresh water at depth is a thick sequence of poorly permeable lava flows, in the aggregate hundreds of feet thick (the zone of vertical flow in the Kamakana borehole with essentially no mixing identified on Figure 5).

- That poorly permeable lava flows are the mechanism creating the high level groundwater in Kona is also supported by the results of two high level wells located above Mamalahoa Highway (Hualalai, State No. 4258-03 and Keopu, State No. 3957-05). During the construction and testing of both wells, water levels rose and yields were increased by drilling deeper.

- The confined fresh groundwater at depth, with an apparent hydraulic connection to seawater at depth offshore, suggests that at least some of the inland high level groundwater may discharge at depth offshore rather than flow into the basal lens at its inland margin.

- With limited amounts of warmer, high level groundwater flowing into the inland margin of the basal lens, the source of the colder temperatures in the basal lens is seawater at depth moving inland in a saltwater circulation pattern beneath the basal lens. Figure 8 compares the temperature profile through the water column of the Kamakana borehole with the ocean water directly offshore. Temperatures in the Kamakana borehole to a depth of 320 feet below sea level reflect the movement of saline groundwater below the basal lens which originated as seawater from more than 600-foot depth offshore. Deeper than 500 feet below sea level in the Kamakana borehole, the zone of poorly permeable lava with little groundwater movement on Figure 4, the temperature appear to be simply the result of cooling by the ocean water at similar depths offshore.

Groundwater Quality

Water quality analyses of samples from wells, anchialine ponds, and other locations within and near to the Kaloko Makai mauka-makai corridor are compiled in Table 2. Samples from high level groundwater wells, with very low salinity levels and nutrient concentrations reflecting only natural, rather than man-made input, are at the top of the table. Below that are samples from basal wells with significantly higher salinities and widely varying nutrient concentrations. Toward the bottom of the table are samples from the upper end of Honokohau Harbor and the discharge of the R-2 quality wastewater effluent from the Kealakehe Wastewater Treatment Plant (WWTP). The effluent discharge occurs into an excavated pit which is located on the mauka side of Queen Kaahumanu Highway and about 3700 feet nominally upgradient of Honokohau Harbor (its location is shown on Figure 1). Nutrient removal from the WWTP effluent as it moves to and discharges into upper end of Honokohau Harbor is quantified in section following.

Nutrient Removal by Natural Processes in the Groundwater Environment

The ongoing discharge of 1.3 to 1.7 MGD Kealakehe WWTP effluent into a pit which is nominally upgradient of Honokohau Harbor and the groundwater discharged into the back end of Honokohau Harbor provide an opportunity to quantify natural nutrient removal in the groundwater environment. The inland excavation of the harbor acts as a point sink for groundwater discharge, including the addition of the WWTP effluent into the groundwater. Travel from the pit disposal to the upper end of the harbor

Figure 8. Temperature Profile Comparison, Kamakana Borehole and the Ocean Offshore (Profiles of April 3, 2010 and December 9, 2011, Respectively)

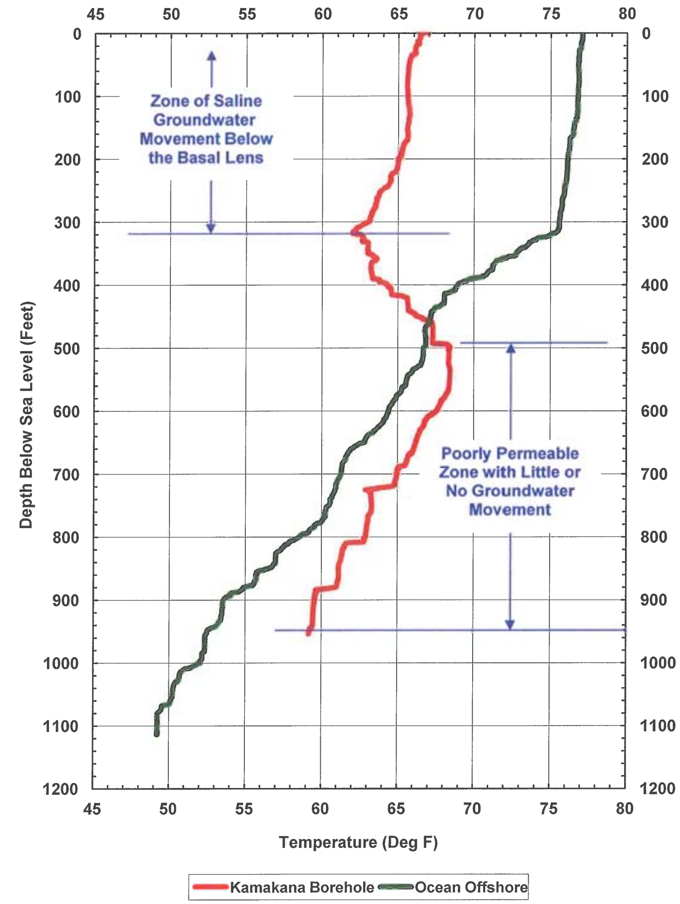


Table 2

Groundwater Quality Within and Near to the Kaloko Makai Corridor

Sampling Site	Date Sampled	Salinity (PPT)	Silica (µM)	Forms of Nitrogen (µM)				Forms of Phosphorus (µM)		
				NO_3	NH_4	TON	Total N	PO_4	TOP	Total P
High Level Potable Quality Wells										
3857-04 DWS Waiaha	11-02-11	0.129	752	74.1	1.5	20.6	96.2	4.24	0.24	4.48
	11-09-11	0.105	749	78.9	1.5	12.6	93.0	4.32	0.88	5.20
	11-25-11	0.119	750	75.9	0.9	13.1	89.9	4.30	0.60	4.90
4057-01 DWS QLT	5-26-00	0.109	801	86.0	0.0	14.7	100.7	3.76	0.08	3.84
	7-20-01	0.079	776	85.1	0.0	35.1	120.2	3.83	3.16	6.99
	11-02-11	0.116	776	87.1	1.1	22.1	110.3	4.00	0.24	4.24
	11-09-11	0.113	771	93.2	1.2	7.7	102.1	4.08	0.80	4.88
	11-25-11	0.130	746	85.4	1.1	11.7	98.2	4.00	0.50	4.50
4158-03 DWS Honokohau	5-26-00	0.144	844	80.1	0.0	14.5	94.6	3.64	0.20	3.84
	11-02-11	0.159	819	79.7	1.0	20.8	101.5	3.84	0.32	4.16
	11-09-11	0.152	804	85.0	2.6	16.6	104.2	4.24	0.80	5.04
	11-25-11	0.158	796	76.8	0.7	2.5	80.0	4.20	0.60	4.80
Basal Wells										
3959-01 Kamakana	11-02-11	5.390	578	160.4	0.7	9.7	170.8	3.84	0.88	4.72
	11-25-11	4.916	598	141.8	1.0	3.6	146.4	3.80	0.40	4.20
3960-01 QLT	10-23-94	25.543	318	28.1	0.3	4.9	33.3	1.49	0.02	1.15
	6-02-00	25.698	356	30.5	1.6	22.5	54.6	1.40	0.70	2.10
4061-01 KAHO 1	5-26-00	9.464	334	55.0	0.3	24.8	80.2	1.84	0.20	2.04
	6-10-00	9.463	304	56.2	3.5	32.1	91.8	1.44	2.96	4.40
	12-19-01	8.657	40	38.4	5.7	20.4	64.5	0.20	0.45	0.65
	11-14-07	10.015	301	67.1	2.7	33.2	103.0	1.65	0.60	2.25
	1-24-12	9.497	482	78.4	2.2	33.6	114.2	4.52	1.56	6.08
	10-29-12	9.317	518	86.3	8.6	68.0	162.9	2.00	0.90	2.90
4161-01 KAHO 3	5-26-00	6.259	672	75.0	0.2	14.8	90.0	4.36	0.04	4.40
	6-10-00	6.325	701	76.9	1.6	43.2	121.7	4.64	2.64	7.28
	12-19-01	6.305	652	79.4	4.2	0.1	83.7	4.35	0.07	4.42
	11-14-07	6.854	666	76.7	1.4	27.2	105.3	3.70	0.50	4.20
	1-24-12	6.387	589	81.4	1.2	11.9	94.5	4.32	0.16	4.48
	10-29-12	6.243	637	81.8	1.3	24.3	107.4	4.50	0.10	4.60
4161-02 KAHO 2	5-26-00	5.399	653	87.2	0.5	22.8	110.4	4.08	0.56	4.64
	6-10-00	5.361	691	104.3	5.1	42.2	151.6	9.04	2.88	11.92
	12-19-01	5.401	616	86.5	1.9	2.0	90.4	4.30	0.05	4.35
	11-14-07	5.382	651	100.4	1.9	31.6	133.9	3.20	1.15	4.35
	1-24-12	5.043	589	95.8	1.4	14.5	111.7	4.52	0.24	4.76
	10-29-12	5.009	653	107.7	2.7	32.9	143.3	5.20	0.00	5.20
4160-02 Kaloko Irrig.	5-15-94	1.734	670	68.6	0.3	2.9	71.8	5.89	0.03	5.92
	3-22-96	1.773	671	78.1	0.3	8.2	86.6	4.42	0.70	5.12
	9-14-12	1.837	633	70.0	1.1	14.4	85.5	4.70	0.60	5.30
	9-14-12	1.917	642	68.2	0.8	14.4	83.4	4.60	0.60	5.20
Ooma Mauka Monitor Well	3-15-96	7.962	661	81.8	0.2	15.8	97.8	3.08	0.16	3.24
	6-02-00	7.783	672	89.7	1.5	26.6	117.8	5.30	0.75	6.05
	6-10-00	7.850	741	91.4	1.0	35.8	128.2	3.60	0.72	4.32
	11-03-06	7.293	640	81.2	3.5	24.8	109.5	2.32	1.28	3.60
	10-29-12	7.067	644	89.5	1.8	9.6	100.9	4.00	0.20	4.20
Ooma Makai Monitor Well	11-03-06	9.945	577	67.0	2.5	22.8	99.2	2.64	1.04	3.68
	10-29-12	10.208	600	94.7	2.2	30.6	127.5	3.70	0.40	4.10
Groundwater Discharge into Honokohau Harbor										
Honokohau Harbor	6-03-00	20.987	373	39.7	0.0	4.2	43.9	2.30	0.07	2.37
	7-20-01	20.431	380	40.4	0.3	10.7	51.4	2.31	2.25	4.56
	9-03-01	20.362	341	38.1	0.3	2.7	41.1	2.05	0.27	2.32
	11-09-11	20.750	305	48.1	0.3	0.2	48.6	2.51	0.17	2.68
	11-09-11	23.216	278	38.0	0.5	1.5	40.0	2.05	0.19	2.24
	11-21-11	19.556	314	51.8	0.1	5.3	57.2	2.93	0.13	3.06
	11-21-11	21.074	318	42.8	0.1	3.6	46.5	2.71	0.09	2.80
Kealakehe WWTP Effluent										
	11-09-11	1.816	450	1037.4	26.2	1.90	1065.5	166.88	7.84	174.72
	12-09-11	1.869	762	1480.6	25.0	35.4	1541.0	193.00	4.80	197.80

Note: All samples collected by Tom Nance Water Resource Engineering (Tom Nance) and/or Marine Research Consultants (Steve Dollar) and analyzed by Marine Analytical Specialists.

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consists of a 60-foot drop through the vadose zone and 3700 feet of travel with groundwater to the upper end of the harbor. Samples collected from two visually obvious groundwater discharge locations at the upper end of the harbor are a mix of: (1) the WWTP treated effluent that has undergone natural nutrient removal to the harbor; (2) the ambient groundwater; and (3) seawater. The amount of nutrient removal from the effluent can be approximated in the following steps:

- Assume a ratio of ambient groundwater to treated effluent in the discharge into the harbor;
- Using a salinity balance, solve for the amount of seawater in the mix; and then
- With the ratios of the three sources in the samples collected at the upper end of the harbor, solve for the remaining nitrogen and phosphorus that was originally in the WWTP effluent dumped into the pit.

If the groundwater to WWTP effluent ratio is selected to cover the plausible extremes of this mix, the ensuing nutrient balance calculations would bracket the probable nutrient removal rates from the WWTP effluent. In the resulting removal tabulations below, calculations were done as if only effluent is discharged into the upper end of the harbor and for a 4:1, groundwater to effluent mix. For this plausible range of effluent mixed with groundwater discharging into the upper end of Honokohau Harbor, rates of removal of nitrogen are 89 to 92 percent. For phosphorus, the removal rates are 93 to 98 percent. Several other aspects of the calculation results are worth noting:

- The calculations used the November 9, 2011 sample of the Kealakehe WWTP effluent being discharged into the pit. Had the second, December 9, 2011 sample been used instead, its higher nutrient levels would have resulted in even greater calculated removal rates.
- If it is argued that the WWTP effluent discharges to the shoreline south of Honokohau Harbor rather than into the upper end of the harbor, the nutrients in Kealakehe shoreline samples in Nance (2002) and the Keahuolu shoreline samples (TNWRE data not yet published) could be used for a similar set of calculations. Using these data results in similar, very high natural nutrient removal rates (Table 3).

ESTIMATES OF THE PROJECT'S POTENTIAL IMPACT ON BASAL GROUNDWATER

Assumptions Incorporated Into the Calculations

Relationship of Basal to High Level Groundwater. For the calculations herein, it is assumed that no high level groundwater leaks into the basal lens beneath the project site, meaning that the flow in the basal lens is entirely due to local recharge on the area between Mamalahoa Highway and the shoreline. That flowrate is estimated to be 1.7 MGD per coastal mile. Across the 1.2-mile width of the project site, the basal flowrate is estimated to be 2.0 MGD. It should be pointed out that if some or most of the high level groundwater is flowing into the basal lens, the project's relative impact on this greater basal flowrate would be less than calculated herein.

Table 3

Computed Removal Rates of Nitrogen and Phosphorus From Kealakekua WWTP Effluent Arriving at the Upper End of Honokohau Harbor

Sample Station in Honokohau Harbor	Sample Date	Computed Nutrient Removal Rates (%)			
		All WWTP Effluent		4:1, Groundwater:Effluent	
		Nitrogen	Phosphorus	Nitrogen	Phosphorus
Station 1	11-09-11	90.2	96.8	91.8	93.4
	11-21-11	89.2	96.6	87.7	97.8
Station 2	11-09-11	90.6	96.9	93.4	93.4
	11-21-11	90.5	96.6	93.0	93.1

Notes:
1. Salinity, nitrogen, and phosphorus values for Kealakehe WWTP effluent from the November 9, 2011 sample (bottom of Table 1).
2. Ambient groundwater salinity of nutrient concentrations based on Well 4061-01 in Table 1.
3. Seawater mixed in the sample assumed to be 35.0 PPT salinity; total nitrogen of 7.0 μM, and total phosphorus of 0.50 μM.
4. Discharge into the upper end of Honokohau Harbor based samples of Stations 1 and 2 in Table 2.

Ambient Quality of the Underlying Basal Groundwater. The salinity and nutrient levels in samples taken from onsite Well 4160-02 (Table 2) are assumed to represent the ambient quality of the underlying basal groundwater. These averages are: salinity of 1.75 PPT; total nitrogen of 80 μM or 1.12 mg/l; and total phosphorus of 5.5 μM or 0.17 mg/l.

Potable Supply Alternatives. Two of the four potable supply alternatives would drill wells at the inland end of the project site. If successful, wells for these two alternatives would tap fresh artesian groundwater which exists at depth below the basal lens and saline groundwater. One or the other of these options would only be pursued if it can be demonstrated, initially by testing in the exploratory borehole and subsequently by testing in the finished production wells, that pumping this water will have no impact on the basal lens above. Rather, it would simply be tapping groundwater than flows beneath the basal lens and does not leak into it.

The third potable alternative being considered would tap the high level groundwater at locations several miles or more to the south of the project site. For the purposes of this assessment, it is assumed that these offsite locations would either be to the north and south of DWS' existing Waiaha well (State No. 3857-04) or just north of the State's Keopu deep monitor well (State No. 3858-01). These locations are four and three miles to the south of the Kaloko Makai project site, respectively.

The fourth alternative, desalinization of saline groundwater, would utilize onsite wells designed to draw water from a substantial distance below the basal lens where the salinity may be on the order of 30 PPT. Extensive testing would be undertaken in the development of these wells to affirmatively demonstrate that such pumping can be done without adversely impacting the overlying basal lens.

A key requirement of all four of the supply alternatives being considered is that none would utilize water from the brackish basal lens flowing beneath the project site. Of the three alternatives that would draw from the high level groundwater body, none would impact basal groundwater in the project's mauka-to-makai corridor or elsewhere in North Kona. However, all three of these alternatives would result in a 1:1 reduction of fresh groundwater ultimately discharged into the marine environment offshore.

Landscape Irrigation Return Flow. Landscape irrigation will be supplied by both the potable and non-potable systems, the former occurring primarily in single family residential areas which will not be supplied by the non-potable system. The use of potable water for this purpose at full build out is estimated to be 0.46 MGD, calculated as an average of 4000 GPD/acre on 115 acres throughout the project site. Irrigation using R-1 effluent as the source of supply is estimated to be 0.58 MGD (Table 1). That means the excess of R-1 for disposal in injection wells at the project's WWTP site would be about 0.90 MGD as a year-round average at full build out. For the calculations herein regarding the percolation of excess applied irrigation water to the underlying basal lens, three assumptions are made. First, 12 percent of the water applied for irrigation will be in excess of crop requirements and percolate to the basal groundwater below. Second, total nitrogen and total phosphorus in the R-1 effluent are assumed to be 1500 and 200 μM, respectively, based on levels of these nutrients in the effluent from the County's Kealakehe WWTP (Table 2). Third, fertilizer levels where landscape irrigation is supplied by R-1 effluent will be far less than where the supply is the potable system. Assumed fertilizer applications are:

- In areas irrigated with potable water, nitrogen and phosphorus in fertilizers will be applied at 3.0 and 0.5 pounds/year/1000 ft^2, respectively.

- In areas irrigated where R-1 effluent, nitrogen and phosphorus in fertilizers would be applied at 10 percent of the rate applied in areas with potable water irrigation.

- Ten (10) percent of the applied nitrogen and two (2) percent of the applied phosphorus will be carried in the excess applied irrigation water below the plant root zone.

Onsite Rainfall-Recharge. As an approximation, it is assumed that 60 percent of the project site's 20 inches of average annual rainfall percolates to and becomes groundwater recharge. Over the 1113-acre site, this amounts to an average of 1.0 MGD. Drainage features of the development will capture surface runoff and direct it to seepage basins and drywells, resulting, as a first order approximation, in no change in the amount of onsite rainfall ultimately becoming groundwater recharge. However, it is also assumed that nutrient levels in the post-development rainfall percolating to groundwater will be increased by 20 μM and 2 μM for nitrogen and phosphorus, respectively.

Natural Removal of Nutrients Originating From the Project Site. Earlier in this report, computed nitrogen and phosphorus removal from Kealakehe WWTP effluent disposed of in a pit 3700 feet nominally upgradient of Honokohau Harbor were given. Selecting values slightly lower values than these computed rates, removal rates of 88 and 92 percent of nitrogen and phosphorus are assumed for the calculations herein.

Calculated Changes to Basal Groundwater Flowing Beneath the Kaloko Makai Project Site

Table 4 incorporates all of the foregoing assumptions to approximate possible changes to the brackish basal lens flowing beneath the project site as a result of its proposed development. The resulting approximations are: a 6.2 percent increase in the flowrate; a 5.1 percent reduction in salinity; and nitrogen and phosphorus increases of 5.2 and 2.1 percent, respectively.

OTHER CHANGES TO THE GROUNDWATER DISCHARGE INTO THE MARINE ENVIRONMENT

All of the foregoing calculations were for estimated changes to the brackish basal groundwater flowing directly beneath the project site. Three other aspects of the project's development, although not having an impact on this basal lens, will affect the ultimate discharge of groundwater into the marine environment. Each of these is described and quantified below.

Consumptive Use of Potable Quality Groundwater

Three of the project's four potable supply alternatives under consideration would draw water from what is referred to as the high level groundwater, either as it exists at depth below the basal lens at the inland end of the project site or at a location to the south where it can be accessed directly. The project's ultimate potable water use would be 2.18 MGD as a year-round average. Wells developed for such use would actually draw 3.27 MGD, one-third of which would be used by DWS to serve other customers in its service area. If RO treatment is necessary (Alternative 2), the draft would be slightly greater at about 3.33 MGD.

Table 4

Approximated Changes to the Brackish Basal Groundwater Flowing
Beneath the Kaloko Makai Project Site

I t e m	Flowrate (MGD)	Salinity (PPT)	Nitrogen (lbs / day)	Phosphorus (lbs / day)
Present Groundwater Flow	2.0	1.75	18.66	2.83
Excess Applied Irrigation				
• As Potable Water + Fertilizer	0.055	0.15	0.502	0.011
• As R-1 Treated Wastewater + Fertilizer	0.070	0.30	0.210	0.007
Change in Local Rainfall-Recharge	No Change	No Change	0.280	0.041
Post-Development Totals : Amount	2.125	1.661	19.652	2.889
: % Change	+ 6.2	- 5.1	+ 5.2	+ 2.1

Notes: 1. The area irrigated with potable water is 115 acres. The amount of water used for this purpose is 0.46 MGD.

2. The area irrigated with R-1 effluent is 165 acres. The amount of R-1 used for this purpose is 0.58 MGD.

Based on the Keauhou Aquifer recharge calculations in Engott (2011), this total draft for the project and DWS would represent a two to three percent reduction of the total groundwater discharge into the marine environment offshore of the aquifer. Essentially all of this change would be occurring at substantial depth and distance offshore with no significant impact.

Disposal of Excess R-1 Treated Effluent in Onsite Injection Wells

As a long-term average, it appears that the amount of R-1 treated wastewater effluent will exceed its onsite irrigation reuse by about 0.90 MGD. If other uses can not be found for this water, this excess would be disposed of in injection wells located at the project's WWTP. That excess could amount to about half the present disposal by the County's Kealakehe WWTP into a pit inland of Honokohau Harbor. The disposal wells would be designed to deliver the excess effluent at depth below the basal lens so as not to impact the lens itself. To accomplish this, disposal would be at and below where the receiving groundwater salinity is 30 PPT or greater and below poorly permeable lava flows identified in the process of drilling. This may require the injection wells to deliver the water at depths of 300 feet or more below sea level. However, the extraordinary disposal depth is warranted to avoid having a significant impact on basal groundwater moving through the Kaloko-Honokohau National Historical Park or to the Park's nearshore waters. The effluent disposed of would be significantly less dense than the receiving basal groundwater. The tendency for the disposed of effluent to rise up due to its lesser density would be offset by several factors: (1) disposal beneath one or more poorly permeable lava flows; (2) the substantial vertical to horizontal anisotropy in the lava flows; and (3) progressive mixing of the effluent into the receiving groundwater, causing its density to increase. Wastewater disposal in this manner is being done at the Mauna Lani Resort without adverse impact.

Potential Disposal of RO Concentrate

Two of the four drinking water supply alternatives being considered would involve desalinization. An inevitable part of this process is the production of a wastewater stream, referred to as the concentrate. For the desalinization alternative using slightly brackish water extracted at depth below the basal lens, the expected concentrate amount product recovery would be about 1.15 MGD, assuming that the product recovery rate would be in the range of 60 to 70 percent. If it is assumed that the salinity of the feedwater supply is between 2.0 and 3.0 PPT, the salinity of the concentrate would be in the range of 5.3 to 8.2 PPT. This would be too salty for irrigation reuse and would require disposal in wells located on the project's WWTP site. The disposal wells would be designed to deliver the concentrate to below the midpoint of the transition zone between brackish basal water above and saline groundwater below in order to avoid impacting the overlying basal lens.

For the desalinization alternative using onsite saline groundwater as the feedwater source, the hypersaline (50 PPT) concentrate would amount to an average of 3.33 MGD at the project's full development. Disposal will be at the project's WWTP site and utilize the wells also used for excess R-1 disposal. Mixing the hypersaline concentrate with the excess R-1 will assist in ensuring that the less dense R-1 does not rise up into the overlying basal lens.

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