2010 ANNUAL

WATER QUALITY MONITORING REPORT

IN SUPPORT OF THE DEVELOPMENT AT

KA LAE MANO, NORTH KONA

Prepared For:

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EXECUTIVE SUMMARY

The Ka Lae Mano project site is just north of Kona Village in the North Kona District. This project site extends for more than 2.7 km along the coastline at Ka Lae Mano, Kaupulehu. The first phase of the Ka Lae Mano project is situated on a recent a'a lava flow (part of the Kaupulehu flow of 1800-1801) and the development is comprised of about 75 residential lots with supporting infrastructure (roads, utilities, etc.). Unlike many of the coastal developments in North Kona which occur directly adjacent to the shoreline, the Ka Lae Mano development is set back approximately 100 m inland of the shoreline with the intervening land left in a natural state to serve as a buffer. Later phases of the project may include additional residential development and a golf course which would be built at a inland site.

A marine life and water quality monitoring program has been established to insure that these resources are not impacted by the residential development at Ka Lae Mano. This monitoring program is being undertaken to insure that the development will not impact the quality of the ground, anchialine pool and near shore marine waters or the marine biota resident to waters fronting the project site. Five field surveys were carried out comprising the baseline water quality data set. These studies commenced in 1993 and continued through September 2004 after which construction (preliminary grading) commenced. At the start of construction the quarterly water quality monitoring program commenced and sampling has been carried out 31 March, 19 July, 27 September, 6 December 2005, 8 March, 1 June, 25 August, 9 November 2006, 13 April, 31 July, 25 October, 13 November 2007, 13 March, 8 May, 26 August, 24 October 2008, 5 March, 7 August and 17 November 2009 and on 20 April, 29 June and 12 November 2010. The fourth quarter 2009 and first quarter 2010 sampling were not carried out due to near-continuous surf emanating from the south-southwest through north-northwest directions starting in October 2009 and continuing through March 2010. This document presents the results of the three most recent quarterly surveys carried out in 2010 in the during construction period.

Along the Kona coast, the concentration of many nutrient parameters is usually much greater in groundwater relative to oceanic waters which establishes a concentration gradient in marine waters where groundwater enters the sea. Thus the presence of groundwater in the near shore marine environment appears to have a major influence on the quality of these near shore waters. At Ka Lae Mano when groundwater is present in the marine coastal waters, the geometric means of many parameters do not meet the state Department of Health regional water quality standards and when absent, most parameters other than turbidity and total nitrogen are in compliance. Hence the presence or absence of groundwater in the marine environment may play a pivotal role in meeting or exceeding state water quality standards at Ka Lae Mano. Local surf and wind conditions may serve to mask the presence of groundwater by increasing the mixing and dilution of effluxing groundwater in the near shore marine environment. The waters fronting Ka Lae Mano have high exposure to wind and surf relative to many other parts of the West Hawai'i coast, thus compliance of these waters to state water quality standards may be affected.

There have been twenty-seven water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last seventeen years; the tide state and local weather/surf conditions are unknown for the first four surveys (29 August 1993, 16 January 1994, 8 April 1998 and 15 April 2002) but are known for the last twenty-three surveys (20 September 2004 through 12 November 2010). The ocean conditions during the time of the first five surveys was generally rough with winds blowing from the NNW from 15 to 30 mph and the seas very choppy. These conditions serve to rapidly mix effluxing groundwater in the near shore area. The salinity data also support the hypothesis that mixing was high (i.e., having high salinities) despite favorable tide states (sampling has been carried out on falling, near zero, weakly rising tides). The ocean conditions were more favorable being calm but tides weakly falling at the time of the four 2006 surveys. Despite these favorable conditions, evidence of effluxing groundwater along the shoreline resulting in lower salinities was not particularly obvious. In the four 2007 surveys the tides were near ebb or were falling but some surge was present which served to partially mask the presence of effluxing groundwater. The 2008 surveys were carried out during falling tides (on three of four surveys) and only one had much surf and wind present. In 2009 winds created choppy conditions in the ocean on two of the three surveys and only on one was the tide strongly ebbing at the time of sampling, but groundwater signatures were not readily apparent. The April 2010 survey was undertaken under a tradewind swell and the tide was rising. The June 2010 survey occurred during calm sea conditions but the tide was gently falling and the November 2010 was done with surge on the ocean and the tide was strongly rising. In no case were the three 2010 surveys carried out under ideal conditions (strongly falling tide and totally calm seas) for the detection of effluxing groundwater adjacent to shore. The presence of winds, surf and weakly falling or rising tides increases mixing and reduces the rate of non-compliance which was the case in 2009 and 2010. In contrast, data from 2008 show high non-compliance thus the falling tides and relatively low surf reduced mixing and these conditions favored the identification of incoming groundwater and increased the rate of non-compliance among the parameters. In three of the four earlier baseline surveys (29 August 1993, 8 April 1998 and 15 April 2002) conducted by Marine Research Consultants, mean salinities were reduced and many parameters were out of compliance on those dates resulting in a high rate of noncompliance during the baseline period. It is surmised that besides tide state which is the usual driver for groundwater flow, the local wind and surf conditions play a large role in the detecting compliance/noncompliance in many water quality parameters at Ka Lae Mano.

In the preconstruction period noncompliance occurred at a frequency of 50% among the parameters/sample dates/locations while in the during construction period the frequency of noncompliance in parameters/sample dates/locations was 17% in 2005, 35% in 2006, 50% in 2007, 65% in 2008, 39% in 2009 and 32% in 2010 for the marine waters fronting the Ka Lae Mano project site. Despite focusing field sampling during periods of falling or low tides in the during construction period, it is surmised that prevailing wind and surf conditions favored more mixing thus decreasing noncompliance in the measured parameters. Furthermore, the 50% baseline noncompliance rate covers all baseline surveys carried out over an eleven year period while the subsequent during construction survey noncompliance rates are calculated for each survey. If the six-year during construction noncompliance rate is calculated as an overall mean, the rate of noncompliance among the parameters falls to 39% which is less than the rate of noncompliance during the preconstruction period.

Groundwater sampled in the five Ka Lae Mano coastal monitoring wells shows this water to have high concentrations of inorganic nutrients and relatively low salinity when considering their proximity to the coast. The high nutrient signature of this groundwater is very similar to that sampled at Kukio about 3.9 km to the southeast which suggests that the source of the high nutrient Kukio groundwater may be from Ka Lae Mano.

Statistical analyses address the question, “Has there been any significant change in quality of marine waters fronting the Ka Lae Mano project site between the preconstruction period and since the commencement of construction?” and found that the means for nitrate nitrogen, total nitrogen, orthophosphorous, silica, turbidity, temperature and pH were significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity while the changes in total phosphorus, chlorophyll-*a* and the percent saturation of dissolved oxygen were not significant. The ammonia nitrogen means are not particularly elevated (preconstruction mean = 1.67 ug/l; during construction mean = 2.19 ug/l) and the presence of well-developed fish communities (community metabolism) may be responsible for these differences. Another statistical approach is to examine the means of parameters from each sampling event, looking for chronological change. In this case the question addressed is, "has there been any significant change in the means of parameters over the 207-month period of this study?" The Kruskal-Wallis ANOVA found statistical differences among the twenty-seven sample dates for all water quality parameters. It should be noted that for many of the parameters that have their greatest mean concentrations occurring in the during construction period, these mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant.

In no case is there any evidence of a trend of increasing concentrations with time; indeed, the during construction means (2005 through 2010) are spread with no order through the range for most parameters. However the March 2009 survey means for orthophosphorous and total phosphorus were significantly greater than any other over the course of this study but by the November 2009 and subsequent 2010 surveys, these means were in the lower half of their respective ranges demonstrating the natural variability in these data. In the case of ammonia nitrogen, a statistically greater mean concentration was encountered in October 2008 but this mean is not particularly elevated. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island. (Brock 2007b).

It is virtually impossible that the development at Ka Lae Mano is having impact to ground or near shore water chemistry at this point in time. For impact to occur, two components are necessary; a source of pollutant materials applied in sufficient excess on the soil surfaces and a transport mechanism to carry these excess materials to the underlying groundwater. A potential source of impact is the application of fertilizers applied to landscaping. At this early point in this development, less than one percent of the total project site has been landscaped. Plant palettes used at Ka Lae Mano have focused on using xerophytic native species and efficient drip irrigation methods have been employed and only so until plants are established. With the groundwater lying from 10 to more than 25 m below the surface, a substantial near-continuous source of water would be necessary to transport any excess fertilizers to the underlying groundwater. Besides drip irrigation, the only other anthropogenic source of water has been for dust control purposes and only enough is used to settle dust during construction activities in a very arid, low rainfall (average = 10 inches/year) setting. Since 2009 the use of water for dust control has almost completely stopped for there are few ongoing activities that require it. Thus changes in water quality in ground and near shore marine waters measured in this study are from natural, highly variable sources.

In summary, the quality of the marine waters fronting Ka Lae Mano from the five baseline (1993-2004) and twenty-two during construction (2005-2010) surveys show them to be typical of well-flushed, West Hawai'i sites. The 2005-2010 quarterly during construction monitoring surveys have not found any evidence of materials leaching to or otherwise entering the groundwater or near shore marine waters fronting the project site. The fact that some parameters are out of compliance with the West Hawai'i regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealakekua Bay) and formerly undeveloped sites (Hokuli'a, Kukio) along the Kona coast. However, detecting the groundwater signature in the near shore marine environment fronting Ka Lae Mano is difficult than found at many other West Hawai'i sites due to the natural rapid mixing that occurs there via frequent local wind and waves.

INTRODUCTION

The Ka Lae Mano project site is just north of Kona Village in the North Kona District. This project site extends for more than 2.7 km along the coastline at Ka Lae Mano, Kaupulehu. The first phase of the Ka Lae Mano project is situated on a recent a'a lava flow (part of the Kaupulehu flow of 1800-1801, MacDonald *et al*. 1990) and the development is comprised of about 75 residential lots with supporting infrastructure (roads, utilities, etc.). Unlike many of the coastal developments in North Kona which occur directly adjacent to the shoreline, the Ka Lae Mano development is set back approximately 100 m inland of the shoreline with the intervening land left in a natural state to serve as a buffer. The overall project site is comprised of approximately 1,071 acres with 876.5 acres that could be developed and the remainder to be placed in preservation. Later phases of the development may include more residential development and a golf course which would be built in the more inland area.

A previous owner/developer had commenced on preliminary environmental work in accordance with conditions as specified in permits issued for the project site. These conditions include:

State Land Use Commission (A93-701; 18 October 2001)

"LUC 3d. Water Quality Monitoring: Petitioner shall initiate and fund a nearshore water quality monitoring program. The parameters of the monitoring program shall be approved by the State Department of Health (DOH). Petitioner shall provide regular reports and the Land Use Commission and KDMC as to the findings of this water quality monitoring program."

"LUC 21 - Groundwater Monitoring Program: Petitioner shall initiate and fund a groundwater monitoring program as determined by the State Department of Health. Mitigation measures shall be implemented by Petitioner if the results of the monitoring program warrant them. Mitigation measures shall be approved by the State Department of Health."

Besides these water quality requirements, conditions were also imposed requiring marine community monitoring as well as monitoring related to the salt pans located along the shoreline that were used by Hawaiians in the past for the making of salt. The results of these other monitoring programs will be presented separate documents.

Under the earlier land owner/developer, marine water quality monitoring was carried out in August 1993, January 1994, April 1998 and April 2002 (see Marine Research Consultants 1993, 1994, 1998 and 2002). These earlier data along with one field survey completed in September 2004 under the present program just before the commencement of construction (preliminary grading) have been used here in establishing the baseline conditions of water quality for the groundwater and marine waters fronting the project site. Construction commenced after the September 2004 survey and four quarterly field surveys were completed in 2005, 2006, 2007 and 2008 to monitor the status of marine and groundwater quality. In 2009 the first three of the four quarterly surveys were completed; the fourth quarter 2009 survey was not done because of near-continuous high surf events with waves emanating from the south-southwest through the north-northwest directions from October 2009 through March 2010. In 2010 because of the high surf early in the year, the first quarter water quality sampling was not completed. Thus the 2010 water quality sampling was carried out on 20 April, 29 June and 12 November representing the second, third and fourth quarters of the year. Near-continuous surf recommenced in late October 2010 carrying through to the present time (February 2011). The 12 November survey was undertaken during a short (3-day) lull in the surf. This document reports on the findings of the three quarterly monitoring program surveys carried out in 2010.

METHODS

1. Sample Site Locations

The Department of Health had developed regional water quality standards for the marine waters of the West Hawai'i coast. The regional criteria require that sampling in the marine environment be conducted along onshore to offshore "transects." These transects are to be established at points along the shoreline where there is greater likelihood of groundwater escaping into the sea. Along the Kona coast, these areas are usually found at the heads of bays rather than offshore of points (escaping groundwater follows the line of least resistence in its flow to the sea). Establishing sample points in an onshore-offshore transect will allow the delineation of any concentration gradients that may be present due to inputs coming via groundwater from land.

Marine Research Consultants (1993, 1994, 1998) established four onshore-offshore transects spaced roughly equidistant along the coast. These transects were sampled in August 1993, January 1994 and April 1998. A fifth transect (E) located offshore of the northern boundary of the project site was established in the 15 April 2002 survey (Marine Research Consultants 2002). Under the present monitoring program these five transects were sampled in September 2004 as well as in the 2005-2010 quarterly during construction monitoring program. The transect locations are shown in Figure 1.

Along each transect Marine Research Consultants (1993, 1994, 2002) sampled at six distances from the shoreline; these were 0.1 m from shore, 2 m, 5 m, 10 m, 50 and 100 m from the shoreline. Bottom samples (~1 m above the bottom) were collected at all stations except the 0.1 m station. The strategy for the present survey collects samples at 1, 10, 50, 100, 200, 300, and 500 m from the shoreline from the surface (within 20 cm of the air-water interface) and bottom samples (~1 m above the bottom) are taken at the 10, 50 and 100 m distances. Thus ten water quality samples are collected on each of the five marine transects located along the Ka Lae Mano shoreline in the present monitoring program. The marine surface samples and their spacing conform to the requirements of West Hawai'i Regional Water Quality Standards as delineated in HAR§11-54-06(d)(1). Samples collected at depth provide information on the *in situ* generation of some measured parameters such as ammonia nitrogen which is a product of organism metabolism.

To obtain information on the status of groundwater as it passes under the Ka Lae Mano project site on its way to the sea, five coastal monitoring wells were drilled for monitoring purposes. Two of these wells are at inland locations (no. 4 at about 1.56 km inland and no. 5 at about 1.1 km inland); these inland wells sample groundwater as it enters the inland or mauka portion of the project site and three makai (close to the shoreline) wells sample groundwater as it leaves the project site moving towards the sea. The three makai monitoring wells are located from 150 to about 225 m inland of the shoreline. Differences in parameter concentrations from the mauka wells to those measured in the makai wells provide information on possible inputs that may be occurring due to activities on the project site. Also present is a sixth well which was developed as a source of water for dust control during construction. This well is located about 528 m inland of the shoreline and it is sampled opportunistically when the pump is operating. Finally a single anchialine pool is present at Ka Lae Mano and is sampled in this program.

2. Laboratory Methods

Water quality constituents that are evaluated include the specific criteria as designated in Chapter 11-54, Section 06 State of Hawaii, Department of Health Water Quality Standards which were amended in July 2000 and reiterated again in August 2004 for West Hawai'i coastal waters. The criteria include ammonia nitrogen (NH_4), nitrate + nitrite nitrogen (NO_3 + NO_2, hereafter referred to as nitrate or NO_3), total nitrogen (TN), orthophosphorous (PO_4), total phosphorus (TP), chlorophyll-*a* (chl-*a*), turbidity, as well as the nonspecific criteria of temperature, pH, and salinity. In addition, dissolved silica (Si) is measured due to its usefulness as a conservative groundwater tracer. Total organic nitrogen (TON) is calculated as the difference between total nitrogen from ammonia nitrogen plus nitrate nitrogen and total organic phosphorus (TOP) is calculated as the difference between orthophosphorous from total phosphorus.

Marine surface water samples are collected by opening 500 ml polyethylene bottles at the desired depth. Marine samples collected at depth are done so using a Niskin bottle. Monitoring well samples are collected using a one-liter well bailer and the sample from the anchialine pool is collected from just under the water's surface. As previously stated, water samples from the dust control well (well 6) are collected opportunistically when the well pump is operational. All sample bottles are all triple rinsed using the sample water prior to sample collection. Samples are held on ice until in the laboratory where further processing occurs. Subsamples for nutrient analyses are held in 125 ml acid-washed, triple-rinsed polyethylene bottles which are stored chilled until analysis. Analysis entails filtering through Whatman glass fiber filters (GF/F, 0.7 um particle retention) with filters being retained for chlorophyll-*a* analysis. Analyses for ammonia nitrogen, orthophosphorous and nitrate are performed using a Technicon autoanalyzer following standard methods for seawater analysis (Strickland and Parsons 1972, Grasshoff 1983). Total nitrogen and total phosphorus are measured from non-filtered sample water (see Dore *et al.* 1996) and similarly analyzed following digestion using unfiltered sample water (Standard Methods 1999).

The limits of detection (precision) and accuracy of nutrient determinations are as follows: total nitrogen accuracy = 0.5 uM or 7.00 ug/l, limits of detection = 0.2 uM or 2.8 ug/l; total phosphorus accuracy = 0.04 uM or 1.24 ug/l, limits of detection = 0.02 uM or 0.62 ug/l; orthophosphorous accuracy = 0.02 uM or 0.62 ug/l, limits of detection = 0.01 uM or 0.31 ug/l; nitrate+nitrite nitrogen accuracy = 0.05 uM or 0.70 ug/l, limits of detection = 0.03 uM or 0.42 ug/l; ammonia nitrogen accuracy = 0.08 uM or 1.12 ug/l, limits of detection =0.03 uM or 0.42 ug/l; and silica accuracy = 0.5 uM or 14.00 ug/l, limits of detection = 0.2 uM or 5.60 ug/l.

Turbidity samples are collected as unfiltered water and stored on ice in 125 ml polyethylene bottles until measurements are made (within 24 hours). Turbidity is measured on a Monitek Laboratory Model 21 nephalometer following the procedures as described in Standard Methods (1999). The instrument is calibrated as specified by the Environmental Protection Agency with standard formazin solutions prior to and after sample measurements. Prior to measurement, samples are throughly mixed to disperse particulate materials and measured in duplicate when all air bubbles disappear.

Chlorophyll-*a* samples are collected by filtering known volumes of sample water through glass microfiber filters (see above); filters are frozen in dark containers until laboratory analyses are carried out. Laboratory procedures follow Standard Methods (1999) and pigments are extracted in 90 percent acetone in the dark for 12 to 24 hours and fluorescence before and after acidification is measured on a Turner Designs fluorometer. Salinity samples are collected in triple-rinsed 125 ml polyethylene bottles in the field, filled completely and capped tightly until measurement on a AGE Model 2100 laboratory salinometer with a precision of 0.0001 ppt. In the field dissolved oxygen is measured using an YSI Model 58 meter with a readability of 0.01 mg/l, pH is determined using a Hanna Instruments pH meter model no. HI 9025 millivolt meter with a readability of 0.01 units and temperature is measured using a laboratory grade thermometer reading to 0.1°C.

All methods used in the Ka Lae Mano monitoring program comply with and follow those as outlined in the "West Hawaii Coastal Monitoring Program Monitoring Protocol Guidelines" as formulated and prepared by the West Hawaii Coastal Monitoring Task Force (May 1992, 30p.). Statistical and other data procedures are described where used in the text. In general to avoid assumptions of normality in the data, non-parametric methods are used (Siegel 1956, SAS Institute, Inc. 1985) for the statistical treatment of the data.

RESULTS AND DISCUSSION

Marine Research Consultants (1993, 1994 and 1998) collected water quality data at four of the five marine transect sites fronting the Ka Lae Mano project site (transects A through D, Figure 1). In the 2002 survey (Marine Research Consultants 2002) a fifth transect was added approximately offshore of the northern boundary of the project site. These data are part of the preliminary baseline and are used in the present analysis. On 20 September 2004, we sampled the five transect sites (transects A through E, Figure 1) as well as the five monitoring wells located on the project site (as shown in Figure 2) drilled specifically for that purpose. These data comprise the preconstruction baseline data set against which all subsequent data are comparatively analyzed.

The baseline data are summarized as geometric means calculated for each parameter (marine surface collected samples only) by transect and date in Table 1. It should be noted that samples were collected from all sites in the 20 September 2004 final baseline survey but the five shoreline samples (collected within ~ 1 m of the shoreline) were misplaced by the laboratory processing the water samples, thus these data are missing in the data set. Data collected from the marine sites in the 2005 "during construction" quarterly program are summarized as geometric means in Table 2; Table 3 presents these same data for 2006, Table 4 summarizes the 2007 data, Table 5 shows the data collected in 2008, Table 6 presents the summary of the data collected in 2009 and table 7 summarizes the 2010 data. All data from the years prior to 2010 are presented in their entirety in Brock (2006, 2007a, 2008, 2009, 2010). The three 2010 quarterly surveys were carried out on 20 April, 29 June and 12 November 2010 and these data are presented below in Appendices 1 - 3 and the data are summarized in Table 7. Commencing with the 20 September 2004 survey and continuing with all subsequent surveys, water quality samples were collected from five wells located on the Ka Lae Mano project site (Figure 2) and these data are summarized in Table 8 as means by survey date. The 2010 well data are given in their entirety in Appendices 1 - 3. Finally the single anchialine pool present at Ka Lae Mano is sampled during the quarterly surveys and these data are summarized in Table 9.

1. Compliance with Department of Health Criteria

The Hawai'i State Department of Health (DOH) has developed specific criteria for different classes of water in the state (e.g., as for harbors, streams and marine waters). Up to July 2000, the waters fronting Ka Lae Mano were classed as "Open Coastal Waters" and are to remain "...in their natural pristine state with an absolute minimum of pollution or alteration of water quality from any human-caused source or action" (HAR§11-54-01). The most stringent standards have been set for open coastal waters. Since July 2000, revised standards have been imposed for the West Hawai'i coastline; these standards utilize a regression approach for marine sample sites where salinity is 32 parts per thousand (ppt) or less. This regression approach is used in determining the standard for nitrate+nitrite nitrogen, total nitrogen, orthophosphorous and total phosphorus. There are no standards set for anchialine pools or coastal brackish wells (used for monitoring and/or irrigation purposes), thus the standards apply only to ocean samples. Table 10 presents the three tiers of water quality criteria developed by the Hawaii State Department of Health for the West Hawaii regional standards with the applicable criteria for the present data set. Standards for three parameters under all salinity regimes have a single not to exceed criterion; these are for ammonia nitrogen, chlorophyll-*a* and turbidity. For the remaining parameters, two situations apply: if there is no substantial groundwater flow (as evidenced by a salinity depression near the shore), a geometric mean "not to exceed" value also applies (Table 10). Where groundwater flow is evident and depressing salinity to 32 ppt or less, a straight-line mixing relationship is specified and the water quality criterion is the slope of this regression line based on surface-collected samples taken at specific points along an onshore-offshore transect.

Application of these criteria to marine samples requires that sample sites be located in a "transect" commencing at the shoreline and sampling at various distances offshore. The regional standards as given in the DOH Administrative Rules require that only samples from the surface layer (i.e., within a meter of the surface) be used in making the analysis. Thus marine sample sites that do not conform to this sampling layout with measured salinities of 32 ppt or less at one of the sites and/or are collected at depth cannot be included in this regression analysis.

A. Baseline Period Compliance

There are five transects established to monitor the waters fronting Ka Lae Mano; inspection of the salinity data from the four reports (Marine Research Consultants 1993, 1994, 1998, 2002) notes no significant salinity depression (i.e., below 32.000 ppt) along any of the five transects; significant salinity depression is also absent in the 20 September 2004 final baseline survey. With this finding, the regional water quality standards require that sample sites with no significant salinity depression (or gradient) utilize single value "not to exceed" criteria as given in Table 10. In Table 1 the "not to exceed" criteria (as given in Table 10) are applied to each of the transect geometric means (for surface samples only) sampled in each of the five baseline surveys. Geometric means out of compliance with the regional standards are underlined in Table 1. Inspection of Table 1 shows that many parameters are out of compliance on many of the transects and sample dates. Specifically, nitrate nitrogen is out of compliance at all transects on the August 1993, April 1998 and April 2002 surveys as well as at transect B in January 1994. The geometric means for total nitrogen did not meet state standards for all transects in August 1993, April 1998, April 2002 and September 2004. Ammonia nitrogen geometric means were above state standards on transects A and B in August 1993, January 1994 and April 1998. The geometric means for orthophosphorous did not meet state standards on transects C and D in August 1993, B in January 1994, A, C and D in April 1998, A, C, D and E in April 2002 and total phosphorous geometric means were out of compliance on Transects C and D in August 1993, A, B, C and D in April 1998, and A, C. and E in April 2002. The geometric means for turbidity did not meet state standards on all transects in the August 1993, January 1994, April 2002 surveys an on transects A, C and D in April 1998 as well as at transects A and E in September 2004 surveys. Finally, chlorophyll-*a* was noncompliant on transects A and C in April

1998 and on C again in the April 2002 survey.

Summarizing the compliance with state regional standards during the baseline period, there are seven parameters where compliance/non-compliance applies and four transects in the first three surveys and five transects in the last two surveys which results in 154 opportunities for non-compliance to occur. In 77 instances (or 50%) of these 154 opportunities for non-compliance, parameters were not in compliance with state standards.

It is not surprising that the geometric means for many parameters have not met regional standards for marine waters in the preconstruction period. Water quality studies carried out at Kukio (about 3.9 km south of the Ka Lae Mano project site) found over a ten-year baseline period that the geometric means for marine waters were out of compliance for ammonia nitrogen, turbidity, nitrate nitrogen, orthophosphorous, total dissolved phosphorus and chlorophyll-*a* (see Table 11). This lack of compliance spans the period from August 1990 - November 1999 (Brock 2000a) and suggests that the "baseline" noncompliance at Ka Lae Mano is not to be unexpected. Indeed, many of the grand geometric means from the Kukio baseline period are greater than those calculated in the Ka Lae Mano data set (see Tables 1 and 11).

B. "During Construction" Compliance

"During construction" surveys have been carried out quarterly since the commencement of site grading in early 2005 (with the exception of 2009 and 2010 where three surveys were done), thus there have been 22 during construction field sampling events to date. Data for the four 2005 surveys are summarized as geometric means in Table 2, Table 3 presents the geometric mean summaries for 2006, Table 4 for 2007, Table 5 for 2008, Table 6 for 2009 and Table 7 for 2010. The data from the three 2010 surveys are given in full in Appendices 1 - 3. In no cases during any of the twenty-two during construction surveys has there been a significant (i.e., 32.000 ppt or less) salinity depression at any of the five transect sites adjacent to shore thus the not to exceed regional standards as given in Table 10 apply to these data.

As given above, the 2005 data are summarized in Table 2 as geometric means for each of the five transects sampled on each of the four dates. In Tables 2 through 7, non-compliant geometric means are underlined while parameter geometric means that are in compliance with state regional standards are not. Referring to Table 2 (2005 data), the non-compliance data can be summarized: there are seven parameters sampled on each of five transects on four dates resulting in 140 opportunities for non-compliance in these during construction data. In 2005, there are 24 instances (or 17%) where these data were not in compliance with the state regional standards.

Table 3 summarizes the 2006 data in the same way, i.e., where the geometric means for each of the five transects sampled on each of four dates in 2006. Again, underlined geometric means in Table 3 are those out of compliance with state regional standards. Again summarizing the non-compliance in the 2006 data, there were 49 instances (out of a possible total of 140 or 35%)

where a parameter was out of compliance in 2006.

Table 4 summarizes the 2007 data as just above, where the geometric means for each of the five transects on the four surveys are given. Again, underlined geometric means are those out of compliance with state regional standards. Referring to Table 4, there are 70 instances where a parameter was out of compliance with state regional standards. This results in a 70/140 = 50% rate of non-compliance which is equal to the rate of non-compliance in the baseline data set.

Following the same procedure, Table 5 summarizes the geometric mean data for 2008 in the same manner as above where the underlined geometric means are those out of compliance with the West Hawai'i regional standards. In 2008 there were 91 instances of non-compliance which results in an overall non-compliance of 91/140 = 65% rate of non-compliance. The 2009 compliance/non-compliance data are given in Table 6 where there were (5 transects x 7 parameters x 3 surveys =) 105 opportunities for non-compliance to occur. There were 41 instances where the geometric means of parameters were not in compliance yielding a (41/105 =) 39% rate of non-compliance in 2009. Finally the compliance/noncompliance data for 2010 are presented in Table 7. Again there were (5 transects x 7 parameters x 3 surveys =) 105 opportunities for noncompliance to occur and there were 34 times that a parameter did not meet state standards resulting in a (34/105 =) 32% rate of noncompliance. The rate of non-compliance in the preconstruction period was 50% (above) while the grand mean during construction rate of non-compliance was 39%. These data show a decrease in non-compliance in the during construction period relative to the preconstruction period in the marine waters fronting the Ka Lae Mano project site.

Inspection of the grand geometric means derived for the transects in each sample period during the baseline period (Table 1) and comparing these to the same data from the 2005 - 2010 during construction period (Tables 2, 3, 4, 5, 6 and 7) finds that the greatest geometric means for three parameters occur in the baseline period (nitrate nitrogen, total nitrogen and turbidity) and with the four remaining parameters (ammonia nitrogen, orthophosphorous, total phosphorus and chlorophyll-*a*), the greatest geometric means have been found in the during construction period. However in total, there have been 27 surveys completed to date; five of these or (5/27 =) 19% were undertaken during the preconstruction phase and the remainder (or 81%) occurred in the during construction phase. With 81% of the surveys occurring in the during construction period and only 19% of the surveys done in the preconstruction phase one would expect that (0.81 x 7 parameters =) 5.67 of the parameters would have the greatest geometric means in the during construction period and (0.19 x 7 parameters =) 1.33 of the parameters having the greatest geometric means in the preconstruction period if the distribution of greatest geometric means were occurring randomly. The fact that three of the seven geometric means (or 43%) occurred in the preconstruction period which occupied only 19% of the surveys suggests that the concentrations of water quality parameters was as delineated by the distribution of greatest geometric means was greater in the preconstruction period relative to the during construction period. These data suggest compliance or non-compliance in parameters measured in the marine environment is not related to activities on the Ka Lae Mano project site.

There are ten samples collected on each of the five transects in the marine waters fronting the Ka Lae Mano project site. Seven samples are collected from the surface while the remaining three are taken at depth. Since freshwater is lighter than seawater, seaward flowing groundwater entering the sea will tend to "float" on the surface until wind, waves and currents mix this water, thus losing the lower salinity signature. Examining the mean salinity data for each marine sample site, only one site of all fifty routinely sampled has a small depression in salinity and this is site 1 (shoreline station) on transect KL-A (see Figure 1). Mean salinity of KL-A-1 is 34.069 ppt and at KL-A-2 (10 m seaward) is 34.189 ppt (means determined by using all data). Grand mean salinity all other surface sample sites on all transects = 34.781 ppt. In short, the only groundwater signature seen to date at the marine sample sites is located at the shoreline and 10 m offshore stations (nos. 1 and 2) on transect KL-A, otherwise all salinities measured in surface waters since the inception of this program show very little evidence of groundwater input. The presence of groundwater as manifested through lower measured salinities at stations 1 and 2 on transect KL-A is small relative to many other areas along the West Hawai'i coast (e.g., Kukio, Waikoloa, etc.) but the groundwater at Ka Lae Mano as evidenced from the mauka well data (Well sites 4 and 5, see Table 7) has extremely high natural concentrations of nitrogen and phosphorus. Since groundwater often has nitrogen and phosphorus naturally occurring in relatively high concentrations relative to seawater, the universal occurrence of high geometric means at transect KL-A is not unexpected and the high variability in non-compliance is probably related to the degree to which groundwater is or is not present at the time of sampling. To further complicate matters, groundwater may be entering the sea fronting the Ka Lae Mano project site but if winds, waves or currents are active at that time of sampling, elevation in nitrogen and phosphorus in the marine samples may not be strongly evident. Sampling at periods of calm and when the tide is falling (thus drawing groundwater in a seaward direction) will enhance the probability that groundwater signature will be present and nutrient concentrations will be elevated. Thus the physical conditions of the ocean and tide state probably play the largest role in compliance or the lack of it at Ka Lae Mano.

Finally if phosphorus and nitrogen from the use of fertilizers applied to landscaping at Ka Lae Mano were leaching to the groundwater below and traveling to the ocean thus being the source of the changes in nitrogen and phosphorus encountered in the marine samples, examination of the parameters that allow leaching to occur need to be discussed. Nitrogen in fertilizers is often applied in the ammonium form that will rapidly convert to the nitrate form (NO_3 - the form readily utilized by plants), which does not bind to the soil and readily moves down through soil horizons with water. Because of this lability, fertilizers could potentially be a source for the changes in concentrations of nitrogen measured in the ocean. However a different picture emerges with phosphorus. Once applied to soils, phosphorus is very immobile and this is related to the adsorptive capacity of soils (Taylor 1967) and the latosol soils of Hawai'i have a high fixing capacity for phosphorus (Fox 1972). In some areas, the soil competes with plants for available phosphorus and very little movement of phosphorus occurs with studies conducted on the order of years (Chang and Young 1977). More recent studies also show that leaching of applied phosphorus is unlikely because of its low solubility and high reactivity (sorption) in soils

(Green 1991, Soicher and Peterson 1997) suggesting that phosphorus encountered in groundwater at Ka Lae Mano is probably not from a fertilizer source but from completely natural sources upland of the project site.

In closing, the baseline dataset spans an eleven-year period (1993 through September 2004) while the during construction period only covers a five-year period. The baseline rate of noncompliance is a mean (here 50%) spread over eleven years but the overall during construction rate of noncompliance is 39% as given above. Thus compliance - noncompliance in parameters measured in this study does not appear to be influenced by the activities occurring on the project site.

2. Well Data

Five wells were drilled for the monitoring of groundwater at the Ka Lae Mano project site. Three wells are located along the makai portion of the project site (nos 1 - 3) to monitor the quality of water as it leaves the project site and two wells (nos. 4 and 5) are situated along the inland (mauka) boundary of the project area (Figure 2). The two mauka wells monitor the quality of the groundwater as it enters beneath the project site. These wells were completed and first sampled in the final baseline survey period (September 2004) and have been sampled on all subsequent during construction surveys. However in the March 2008 survey Well 1 (south makai well, see Figure 2) was removed due to its first placement in a roadway. It was redrilled moving it about seven meters away to the north and it has been sampled on all subsequent surveys.

Right after the commencement of grading, a dust control well was drilled (well 6, Figure 2). This well has been sampled on all surveys since its construction except in December 2005, August and November 2009, 20 April and 29 June 2010 surveys when the pump was not operational. While hand clearing vegetation (kiawe) in 2005, an anchialine pool was discovered. This pool is situated close to the shoreline mauka of a sand/coral rubble berm near the northern boundary of the project site. The pool is in an advanced state of senescence having been filled in by sand, coral rubble and plant debris thus only having water present on the highest of high tides. When water is present, native anchialine shrimp are present in high abundance. Water was present only during the December 2005 and the 9 November 2006 surveys. In early 2007, permission was obtained from kupuna whose families cared for this land in the past to place a plastic bucket with no bottom and a removable top into the mud of the pond bottom during a low tide period. The removable lid keeps leaf litter out of the bucket and water enters through the bottom of the bucket. The bucket extends about 30 cm into the mud thus has water present during all tide stages allowing the collection of a water samples at any time thus the pond has been sampled during each survey commencing in 2007.

The water quality data from these six wells and the single anchialine pool sample are summarized in Table 8 for wells and Table 9 for the anchialine pool. The well data are presented as means for each parameter by survey date. The 2010 well and anchialine pool data are given in their entirety in Appendices 1 - 3. As noted above, there are six wells present on the project site. Two of these wells are located inland and upgradient of the ongoing development (Well nos. 4 and 5, Figure 2) and sample water as it enters the project site. The remaining four wells are either in the middle of the development (Well no. 6 which is used as a source of water for dust control) or along the makai (seaward) edge of the development (Well nos. 1, 2 and 3). These latter wells sample the water as it is either beneath (Well 6) or is leaving the project site (Well nos. 1, 2, and 3, Figure 2).

A. Analysis of Well Data

The location of the six wells allows for comparative analysis of the concentrations of nutrients between sites and over time. Table 12 presents the results of these analyses using the nonparametric Wilcoxon Two-Sample Test to address questions which are given below. The first question, "Are there significant differences between the mean parameter concentrations comparing the inland (mauka) to the seaward or makai wells in the preconstruction period?" These results are given in Table 12 (Section A - top) where the analysis found no statistically significant differences in mean parameter concentrations between the mauka and makai wells in the preconstruction period. Asking the same question, "Are there significant differences in the mean concentrations of parameters in the mauka wells relative to the makai wells in the during construction period?" is addressed in Part B (Table 12) where mean nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells in the during construction period. However, mean orthophosphorous and silica are significantly greater in the mauka wells over the makai wells in the during construction period. If data from all dates (preconstruction and during construction) are considered together asking the same question, i.e., "Are there significant differences in mean parameter concentrations between mauka to makai wells?" we find the same result as seen in Part B, namely that mean orthophosphorous and silica are significantly greater in the mauka wells over the makai wells, mean nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells (Table 12, Part C). Examining the data from the mauka (inland) wells only and addressing the question, "Are there significant differences between preconstruction to during construction means in mauka wells?" finds no statistically significant differences between these two time periods (Table 12, Part D). Asking the same question, "Are there significant differences in mean parameter concentrations in makai wells comparing the preconstruction period to the during construction period?" finds that the preconstruction mean of total nitrogen is significantly greater than the during construction mean, otherwise there are no significant differences in the other parameter means (Table 12, Part E).

Summarizing the analysis of well data, there are no significant differences in parameter concentrations in the preconstruction period between mauka and makai wells (Table 11, Part A) probably because of the small sample size (only one sample period with two mauka and three makai wells). The during construction period only (Part B) as well as the all dates (Part C) analyses comparing mauka to makai wells (Table 12, Parts B and C) finds greater mean orthophosphorous and silica in mauka wells over makai wells and in the makai wells salinity, total nitrogen and nitrate nitrogen are significantly greater. Being closer to shore salinity should be higher in the makai wells over the mauka wells and silica concentrations should be greater in the mauka wells because groundwater has silica naturally occurring in high concentration and in seawater these concentrations are low. Thus mauka wells being situated further inland should have greater silica concentrations. However, significantly greater nitrate nitrogen and total nitrogen in the makai wells over the mauka wells could suggest that a anthropogenic input of nitrogen to the groundwater is occurring somewhere on the project site.

The source of nitrogen could be from the fertilization of the limited landscaping present at Ka Lae Mano. However, irrigation rates are low and the downward movement of nitrogen to the seaward flowing groundwater requires sufficient irrigation which is not likely given that much of the landscaping at Ka Lae Mano is comprised of xerophytic plant species (i.e., those that use less water).

Both nitrate nitrogen and orthophosphorous are used in fertilizing landscaping. Other than fertilizers, the only other possible source of nitrate emanating from the project site could be from explosives used in site grading. However if this were the source, a means of conveying the residues from the explosives left on the surface to the underlying groundwater which lies more than 10 m below would be needed. The only obvious transport mechanism is water but the only water used on the project site has been for dust control (where only enough is spread on the surface to prevent airborne dust) and limited irrigation. Furthermore annual rainfall totals are very low (less than 10 inches/year) for the Ka Lae Mano makai lands. Lacking an identified transport mechanism (here sufficient water), the significantly greater mean nitrogen concentration in the makai wells in the during construction period may from completely natural (unidentified) source(s) as would be the elevated orthophosphorous in mauka wells.

Further support for small groundwater efflux to the ocean in the during construction period at Ka Lae Mano may be found with the results of the statistical analysis of changes in marine water quality parameters (see next section). Albeit the differences in salinity are small, the statistical analysis found that the mean salinity was significantly greater in the during construction period relative to the preconstruction period which suggests that less groundwater is escaping to the sea in the during construction period. These data suggest that less groundwater is entering the ocean fronting the Ka Lae Mano project site now than previously.

The results from Part C (Table 12) follow those of directly above (Part B) simply because the during construction data set is significantly greater (n=126) than the preconstruction data set (n=5). The examination of mauka wells finds no significant differences between the preconstruction means from the during construction means (Part D) but the same analysis applied to the makai wells finds that the preconstruction mean for total nitrogen is significantly greater than the during construction mean in the makai wells (Part E). With no anthropogenic source present on the project site in the preconstruction period, the only logical explanation for the significantly greater mean concentration of total nitrogen is that it was from naturals source(s) which supports the contention that there is considerable variability in the concentrations of nutrients in undisturbed West Hawaii groundwater and the concentrations found in Ka Lae Mano wells despite significant changes are probably from natural sources.

3. Analysis of Marine Data

Five baseline period surveys were completed over a 121-month period prior to the commencement of construction at Ka Lae Mano. These baseline water quality data represent the natural conditions for water quality fronting the Ka Lae Mano project site. On-site construction commenced in earnest following the September 2004 survey and the quarterly water quality monitoring program began in 2005. This quarterly program has sampled in March, July, September and December 2005, March, June, August and November 2006, April, July, October and November 2007, March, May, August and October 2008, March, August and November 2009 and again in April, June and November 2010. The question, "Has there been any significant change in water quality in the ocean since the commencement of construction?" can be addressed by statistically comparing the means of parameters in the preconstruction to the during construction periods using the nonparametric Wilcoxon 2-Sample Test. The results of the Wilcoxon 2-Sample Test are given in Table 13 where the means for nitrate nitrogen, total nitrogen, orthophosphorous, silica, turbidity, temperature and pH were found to be significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity. No statistically significant differences were found for the means of total phosphorus, chlorophyll-*a*, and the percent saturation of dissolved oxygen. The concentrations of many parameters from the preconstruction period have higher mean values relative to those from the during construction period. The statistically significant differences in some parameters may be easily explained such as that for silica and salinity; groundwater usually has high silica concentrations whereas dissolved silica in seawater occurs at low concentrations. Thus higher salinity waters usually have lower silica concentrations. The significantly greater mean silica concentration in the preconstruction period is probably related to the significantly lower salinity in that period. These statistically significant changes may be related to changes in groundwater discharge to the ocean fronting the Ka Lae Mano project site. These could be due to past seasonal changes in input (mauka rainfall) or possibly to the withdrawal of low salinity groundwater on the project site used for dust control since the start of construction. However, if latter use was the reason for the significant change in salinity offshore, it should be reflected in the salinities found in the groundwater monitoring wells and it is not. The mean groundwater salinity in the coastal monitoring wells prior to the commencement of construction was 2.662 ppt and the mean salinity in these wells since the start of construction is 2.678 ppt.

Another way to statistically view the preconstruction to during construction marine water quality data is to examine the means of parameters from each sampling event, looking for chronological change. In this case the question addressed is, "Has there been any statistically significant change in the means of the parameters measuring marine water quality over 207-month period of this study encompassing five baseline field surveys and twenty-one during construction surveys?" To address this question two non-parametric tests were used; the Kruskal-Wallis analysis of variance (ANOVA) determined if significant differences did exist among the means of parameters comparing means by date and the Student-Newman-Keuls Test was used to separate which means differed significantly from others. Nonparametric statistical tests were used to avoid some of the assumptions that are requisite with use of parametric statistics (i.e., normality, homogeneity of variances, etc).

The results of the nonparametric tests are summarized in Table 14. The Kruskal-Wallis ANOVA found statistical differences among the twenty-seven sample dates for all parameters. The SNK test also found significant differences among the twenty-seven surveys for all parameters. The greatest means are found in the preconstruction (baseline) period for nitrate nitrogen and total nitrogen in April 1998, silica in April 2002 and turbidity in January 1994. All other parameters had the greatest means in the during construction period; most notable were the greatest orthophosphorous and total phosphorus means occurred in the March 2009 survey but by the end of the year (November 2009) the phosphorus means were near the bottom of the range. With respect to the parameter means found in the three most recent 2010 surveys, most were spread through the middle to lower part of their respective ranges. Indeed the November 2010 means for nitrate nitrogen and silica are the lowest to date. The lack of any chronological order to the increases or decreases in mean concentrations for all parameters suggest no relationship with the passage of time. The only parameter showing any relationship to time are the seasonally driven changes in mean temperatures which have nothing to do with development.

Thus there is no evidence of a trend of increasing concentrations with time; indeed the during construction means (2005 through 2010) are spread with no order through the range for most parameters. In the case of ammonia nitrogen, the statistically greater mean concentration found in the October 2008 survey is not particularly elevated. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island (Brock 2007b).

Finally, it should be noted for many of the parameters having their greatest mean concentrations occurring in the during construction period, that these mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant. Examples are found with temperature, pH, salinity and percent saturation of dissolved oxygen. Thus the data do not support the contention that the ongoing grading, landscaping and limited residential construction activities at Ka Lae Mano are having an impact on the quality of the ground- and/or nearshore marine waters. At a minimum, the fact that there is statistically significant separation among the means for all parameters in the marine waters fronting this project site over the preconstruction and during construction periods supports the contention that variability in these water quality parameters is the norm and this variability is natural and must be considered in any analysis of data, particularly during the construction phase of the project.

Finally, change to the quality of the marine waters fronting the Ka Lae Mano project site due to the development is not expected at this early point in the development process. As noted above, the project site encompasses approximately 1,071 acres, 876.6 acres of which could be developed and ~200 acres are to be preserved. This first phase of the development includes roadways, about 75 house lots situated in the makai portion of the project site and limited infrastructure including a cultural center with a landscaped buffer. Some landscaping has been developed in the buffers along some of the roadways. In the context of the entire project site, the landscaping and construction activities comprise an extremely small part of the total project site. Thus at this juncture, preliminary grading of raw lava has comprised the majority of the activities. The landscaping that has been planted is made up of a palette of hardy largely native xerophytic species. This landscaping has been developed in the makai portions of the project site alongside of some roadways and has been watered by drip irrigation. Once the vegetation is established, the irrigation schedules have been greatly reduced or terminated because water is a precious commodity and is not wasted which leaves little chance for its escapement to the underlying watertable (Kauhane Morton, personal communication). Some low-salinity groundwater has been withdrawn and used for the purpose of dust control, however the method of application (surface spray to control dust) does not allow much, if any escapement of water to the underlying groundwater because volumes used per unit area are small and evaporation is high. Furthermore in recent months, much of the dust control activities have ceased. The only activity occurring during grading that could result in a change to ground- and/or near shore marine waters would be an increase in nitrate due to the use of explosives. Nitrate may occur as a residue following the use of dynamite. However, the usual mechanism to transport materials from the surface to the groundwater table is sufficient water to cause the leaching of materials from the surface to down to the underlying seaward-flowing groundwater. In the absence of high rainfall on the project site, the opportunity for sufficient water to be available is remote if just dust-control applications and limited drip irrigation (which has been largely terminated) are the only identified sources. As noted above, annual rainfall at Ka Lae Mano is less than 10 inches per year. If they are to occur, possible changes to ground- and near shore marine water chemistry due to the development would not manifest themselves until landscaping has encumbered a much larger portion of the project site than it presently occupies and only if the use of plant palettes change to less drought-tolerant species requiring much greater use of irrigation water. Since the Ka Lae Mano development fosters a sustainable focus, greater use of irrigation water would probably not occur. Thus it is unlikely that the activities occurring on the Ka Lae Mano project site will result in changes to the ground and near shore marine water chemistry in the foreseeable future.

CONCLUSIONS

The concentration of many nutrient parameters is usually much greater in groundwater relative to oceanic waters which establishes a concentration gradient in marine waters where groundwater enters the sea. Thus the presence of groundwater in the near shore marine environment appears to have a major influence on the quality of these near shore waters. When groundwater is present, the geometric means of many parameters do not meet the state Department of Health regional water quality standards and when absent, most parameters other than turbidity, total nitrogen and sometimes ammonia nitrogen are in compliance. Hence the presence or absence of groundwater in the marine environment may play a pivotal role in meeting or exceeding state water quality standards. Usually along the relatively porous lavas of the Kona coast, groundwater is more evident in the coastal marine environment on falling tides due to its increased seaward flow and conversely, this flow is impeded by rising tides. However, local surf and wind conditions may serve to mask the presence of groundwater by increasing the mixing and dilution of effluxing groundwater in the near shore marine environment. The waters fronting Ka Lae Mano have high exposure to wind and surf relative to many other parts of the West Hawai'i coast thus compliance of these waters to state water quality standards may be affected by the local weather at the time of sample collection.

There have been twenty-seven water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last seventeen years; the tide state and local weather/surf conditions are unknown for the first four surveys (29 August 1993, 16 January 1994, 8 April 1998 and 15 April 2002) but are known for the last twenty-three surveys (20 September 2004 through 12 November 2010). The ocean conditions during the time of the first five surveys (20 September 2004, 31 March, 19 July, 27 September and 6 December 2005 were generally rough, with winds blowing from the NNW from 15 to 30 mph and the seas very choppy. These conditions serve to rapidly mix effluxing groundwater in the near shore area. The salinity data as given in the 2005 annual survey (Brock 2006) also support the hypothesis that mixing was high (i.e., having high salinities) despite favorable tide states (sampling has been carried out on falling, near zero, weakly rising tides). In the 2006 surveys, the tides were either dropping or were showing little change during the time that samples were collected. Winds were somewhat less during all four surveys and only in the November 2006 survey was there any surge. Again the salinity data suggest little evidence of groundwater (Brock 2007a) along the shoreline. On all four of the 2007 surveys, there was some surge present but almost no surf. On the first three 2007 surveys the tide was at or near ebb and on the last (November) 2007 survey the tide was falling. Because of generally low tides and little to no surf present (but some surge), conditions for all of the 2007 surveys would be expected to show some reasonable salinity depression close to shore but again did not. In the four 2008 surveys there was some surge in the March, August and October surveys but the May survey was carried out during a period of calm and clear ocean conditions. The tide state in the 2008 surveys ranged from being favorable (i.e., relatively low or falling for the March and May surveys) but was rising steeply in the August survey and much less so in the October 2008 survey and once again the shoreline salinity data show little evidence of groundwater efflux.

Brisk northerly winds were present during the March and November 2009 surveys which resulted in choppy seas that would tend to mix and mask any effluxing groundwater. In the August 2009 survey, the seas were calm which would assist in identifying any groundwater entering the sea. Tide states in 2009 rising slightly in the March survey, ebbing slightly in the August survey and steeply falling in the November survey. In general the weather conditions in 2009 were not favorable for encountering groundwater offshore of Ka Lae Mano. On the 20 April 2010 survey there was a small tradewind swell present but the water conditions adjacent to shore were relatively calm. Tide at the time of sampling was gently rising which would impede groundwater flow to the sea. In the 29 June 2010 survey the water was calm and the tide was gently falling which should assist in detecting groundwater flow. On the 12 November 2010 survey some surge was present along the shoreline and the tide was strongly rising at the time of sampling which, again, serve to impede the flow of groundwater to the ocean.

Despite little salinity depression along the shoreline in many of the surveys, groundwater is effluxing along the Ka Lae Mano coastline is the probable sole source of the often elevated measured nutrient concentrations. Examination of the nutrient chemistry of the Ka Lae Mano groundwater as given in the well data shows that the natural nutrient concentrations are among the highest found anywhere along the West Hawai'i coast. Thus, in the case of Ka Lae Mano, the amount of groundwater entering the ocean does not need to be a high volume flow because its signature is readily identifiable by the natural elevation of inorganic nutrients.

It is surmised that when mixing is high in the coastal waters as occurs during period of surf, winds and in particular on rising tides, the effluxing groundwater is rapidly mixed and diluted such that its signature is quickly "lost"resulting in a lower rate of noncompliance in water quality parameters. However, when the tide is rapidly falling, winds are light and surf is near absent, the effluxing groundwater is less rapidly mixed and the resulting rate of noncompliance is greater. The Ka Lae Mano environmental monitoring program attempts to focus sampling during periods when surf, wind and tides favor the sampling of effluxing groundwater but the exposed nature of the Ka Lae Mano coastline often results in less than perfect sampling conditions. These weather conditions are reflected in the rate of noncompliance with state water quality standards; in the preconstruction period (1993 through September 2004), the overall rate of noncompliance was 50%; in 2005 it was 17% (a year with poor or rough weather conditions), in 2006 the rate of noncompliance increased to 35% (slightly better weather conditions during most surveys), in 2007 the rate of noncompliance was 50% which is equal to the overall noncompliance found during the eleven-year baseline period and the weather conditions were better for water quality sampling than in 2006. In 2008 the annual rate of noncompliance had increased to 65% and the weather and tides were generally favorable suggesting a better sampling of effluxing groundwater because mixing was less. In 2009 the rate of non-compliance was 39% and in 2010 the overall rate of noncompliance was 32% suggesting that mixing was higher due to weather and tide states, thus the lower rate of noncompliance. In summary, besides tide state which is the usual driver for groundwater flow, the local wind and surf conditions play a large role in the detecting compliance/noncompliance in many water quality parameters at Ka Lae Mano. Furthermore, when the conditions are absolutely calm coupled with a strongly falling tide, effluxing groundwater will be greatest and most obvious at the surface along the shoreline and under these conditions, more parameters will not meet state regional water quality standards.

Groundwater sampled in the five Ka Lae Mano coastal monitoring wells plus the one dust control well shows this water to be high in inorganic nutrients and relatively low salinity when considering the proximity of these sample sites to the coast. The high nutrient signature of this groundwater is very similar to that sampled at Kukio about 3.9 km to the southeast which suggests that the source of the high nutrient Kukio groundwater may be from the lands mauka of Ka Lae Mano. Examination of the groundwater sampled in these wells found many of the parameters at higher concentrations in the makai wells relative to the mauka wells. One might infer that these higher concentrations are due to activities occurring on the construction site, however they are present in the baseline data suggesting that other natural factors are responsible for the differences in measured concentrations. Secondly, examination of well data over time shows considerable variability at given sites, a finding that has been encountered at many other well sites in West Hawai'i. As a consequence of these two findings, the few statistically significant differences seen in parameters measured in mauka and makai wells are probably not related to inputs coming from the construction site but are related to the high natural variability.

Nutrient concentrations are often naturally elevated in groundwater relative to marine waters. Thus effluxing groundwater may be a source for some nutrient species in near shore marine settings. Statistical analyses addressing the question, "Has there been any significant change in quality of marine waters fronting the Ka Lae Mano project site since the commencement of construction?" found that the means for nitrate nitrogen, total nitrogen, orthophosphorous, silica, turbidity, temperature and pH were significantly greater in the preconstruction period relative to the during construction period. During construction means that were significantly greater include ammonia nitrogen and salinity. The ammonia nitrogen means are not particularly elevated (preconstruction = 1.67 ug/l and during construction = 2.19 ug/l) and the presence of well-developed fish communities (i.e., via community metabolism) may be responsible for these differences.

Another statistical approach is to examine the means of marine water quality parameters from each sampling event, looking for chronological change. In this case the question addressed is, "has there been any significant change in the means of parameters over the 207-month period of this study?" The Kruskal-Wallis ANOVA found statistical differences among the twenty-seven sample dates for all water quality parameters. It should be noted that for many of the parameters that have their greatest mean concentrations occurring in the during construction period, their mean concentrations are typical of Hawaiian coastal waters and at these concentrations are biologically insignificant despite their being statistically greater.

Furthermore examination of marine survey means by date in the during construction period finds no evidence of a trend of increasing concentrations with time; indeed, the during construction means (2005 through 2010) are spread with no order through the range for most parameters. The highest marine survey means for orthophosphorous and total phosphorus were encountered in the March 2009 survey but by the November 2009 survey these means were both near the bottom of the range. The November 2009 survey mean for salinity was significantly greater than all others to date but the difference between this mean (35.192 ppt) relative to the lowest survey mean (August 1993 = 33.894 ppt) is trivial and has no biological significance.

In the case of ammonia nitrogen, the statistically greatest mean concentration occurred in the October 2008 during construction sample period (mean = 6.03 ug/l) is not particularly elevated. Ammonia nitrogen is a product of organism metabolism (excretion) and can be an indicator of sewage input if concurrent measurements of nitrate nitrogen, silica and orthophosphorous are likewise high and salinity significantly less which has not been the case at Ka Lae Mano. Ammonia nitrogen is frequently out of compliance with state water quality standards along undeveloped coastlines and this may be due to excretion by locally abundant fish (Brock and Kam 2000) as has been encountered over the last twenty years along much of the undeveloped coastline of Lana'i Island. (Brock 2007b).

It is virtually impossible that the development at Ka Lae Mano is having impact to ground or near shore water chemistry at this point in time. For impact to occur, two components are necessary; a source of pollutant materials applied in sufficient excess on the soil surfaces and a transport mechanism to carry these excess materials to the underlying groundwater. A potential source of impact is the application of fertilizers applied to landscaping. Less than one percent of the total project site has been landscaped. Plant palettes used at Ka Lae Mano have focused on using xerophytic native species and efficient drip irrigation methods have been employed and only so until plants are established. With the groundwater lying from 10 to more than 25 m below the surface, a substantial near-continuous source of water would be necessary to transport any excess fertilizers to the underlying groundwater. Besides drip irrigation, the only other anthropogenic source of water has been for dust control purposes and only enough is used to settle dust during construction activities in a very arid, low rainfall (average = 10 inches/year) setting. Since the latter part of 2009, the use of water for dust control has largely ceased. Thus changes in water quality in ground and near shore marine waters measured in this study are from natural, highly variable sources.

In summary, the quality of the marine waters fronting Ka Lae Mano from the five baseline (1993-2004) and twenty-two (2005-2010) during construction surveys show them to be typical of well-flushed, West Hawaii sites. The quarterly during construction monitoring surveys have not found any evidence of materials leaching to or otherwise entering the groundwater or near shore marine waters fronting the project site. The fact that some parameters are out of compliance with the regional West Hawai'i regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealakekua Bay - Brock 2000b, 2001) and formerly undeveloped sites (Hokuli'a - Brock 1999, Kukio - Brock 2000a) along the Kona coast. However, detecting the groundwater signature in the near shore marine environment fronting Ka Lae Mano is difficult due to the natural rapid mixing that occurs there via frequent local wind and waves.

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TABLE 1. Summary of the water quality parameters as geometric means from samples collected along four of 5 transects in the preconstruction period on 29 August 1993, 16 January 1994, and 8 April 1998 and 5 transects on 15 April 2002 and 20 September 2004 in the ocean fronting Ka Lae Mano for surface samples only; also given are the grand surface sample geometric means for each date. These data summarize the baseline water quality conditions of the Ka Lae Mano project site. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
29-Aug-93														
KL-A	48.62	3.24	142.88	4.95	11.32	720.74	74.64	5.70	33.165	0.16	0.159	27.3		8.24
KL-B	31.96	3.13	144.41	4.62	11.30	463.28	98.81	6.35	33.895	0.11	0.119	27.3		8.18
KL-C	36.89	1.91	141.99	6.82	13.20	542.80	86.64	5.61	33.642	0.12	0.138	27.3		8.18
KL-D	35.41	1.06	146.09	5.86	17.88	596.81	94.26	11.46	33.622	0.11	0.124	27.1		8.18
Geometric Mean	37.75	2.13	143.83	5.50	13.18	573.49	88.10	6.95	33.580	0.12	0.134	27.2		8.19
16-Jan-94														
KL-A	2.81	3.19	85.84	3.42	8.13	96.52	79.55	4.62	34.859	0.23	0.264	24.9		
KL-B	7.56	2.92	89.39	6.31	11.43	199.89	77.01	5.03	34.760	0.28	0.286	24.8		
KL-C	2.85	1.79	83.71	4.70	9.81	100.91	78.84	5.05	34.840	0.22	0.196	24.9		
KL-D	2.63	1.12	80.61	3.89	9.34	73.15	76.76	5.39	34.834	0.21	0.259	24.8		
Geometric Mean	3.55	2.08	84.83	4.46	9.61	109.24	78.03	5.02	34.823	0.23	0.249	24.8		
08-Apr-98														
KL-A	86.28	4.18	264.30	7.17	21.19	1183.90	163.82	14.34	33.430	0.13	0.384	24.8		8.18
KL-B	17.17	3.11	158.66	4.36	17.79	319.27	125.08	13.31	34.281	0.08	0.256	24.7		8.17
KL-C	49.52	2.16	213.41	7.41	20.76	760.66	145.76	12.96	33.682	0.10	0.305	24.8		8.17
KL-D	44.17	0.61	201.91	8.02	21.52	739.24	136.93	12.56	33.615	0.10	0.210	24.7		8.15
Geometric Mean	42.43	2.03	206.17	6.57	20.26	678.99	142.21	13.28	33.751	0.10	0.282	24.7		8.17
15-Apr-02														
KL-A	50.85	1.00	197.62	8.43	13.80	957.85	110.89	5.05	33.121	0.35	0.294	26.2		8.19
KL-B	6.81	0.41	131.89	3.75	8.44	267.62	119.64	4.13	34.314	0.14	0.282	26.1		8.15
KL-C	43.04	0.51	189.43	8.41	14.96	856.00	124.46	6.21	33.479	0.17	0.327	25.9		8.16
KL-D	21.18	0.29	174.83	5.77	11.45	513.05	145.51	5.55	34.046	0.13	0.240	26.2		8.18
KL-E	69.56	0.56	173.02	12.06	19.21	1087.76	93.66	6.72	33.172	0.13	0.236	26.1		8.15
Geometric Mean	29.40	0.51	171.73	7.14	13.08	657.05	117.61	5.46	33.623	0.17	0.274	26.1		8.17
20-Sep-04														
KL-A	1.74	0.35	118.62	2.09	7.78	91.16	115.56	5.41	34.707	0.11	0.164	28.8	100	8.15
KL-B	1.54	0.13	130.73	1.54	9.13	85.58	128.49	7.07	34.708	0.08	0.142	28.8	100	8.17
KL-C	1.27	1.36	118.98	0.91	8.43	82.80	117.37	7.38	34.719	0.07	0.169	28.5	99	8.20
KL-D	1.41	0.28	129.18	0.38	9.26	75.15	127.64	8.81	34.719	0.09	0.179	29.5	100	8.18
KL-E	1.62	1.29	139.72	1.21	10.97	80.29	136.08	9.68	34.701	0.10	0.179	29.5	100	8.12
Geometric Mean	1.51	0.47	127.20	1.06	9.05	82.82	124.80	7.52	34.711	0.09	0.166	29.0	100	8.17

TABLE 2. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2005 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
31-Mar-05														
KL-A	9.17	0.21	122.55	5.55	11.93	137.02	97.81	4.99	34.336	0.13	0.101	25.2	101	8.13
KL-B	2.64	0.25	114.52	4.87	12.39	110.23	107.82	7.48	34.504	0.08	0.113	24.9	101	8.16
KL-C	1.22	0.14	98.43	5.05	12.49	113.04	88.66	7.25	34.441	0.05	0.088	24.9	102	8.16
KL-D	0.36	0.16	92.22	4.46	10.77	75.61	91.08	6.25	34.582	0.08	0.077	24.7	102	8.16
KL-E	0.38	0.27	95.54	4.62	10.75	82.71	93.63	6.09	34.566	0.04	0.063	24.9	101	8.16
Geometric Mean	1.32	0.20	104.01	4.89	11.64	101.32	95.57	6.35	34.486	0.07	0.087	24.9	101	8.16
19-Jul-05														
KL-A	1.25	1.85	80.37	3.72	10.55	141.29	75.78	6.72	34.612	0.12	0.307	27.4	100	8.19
KL-B	1.16	1.40	81.98	3.19	10.32	127.81	78.77	7.11	34.620	0.09	0.264	27.5	101	8.20
KL-C	0.85	1.87	98.73	3.16	10.18	107.88	94.95	7.02	34.630	0.07	0.367	27.6	101	8.22
KL-D	0.86	0.62	82.64	2.71	9.87	109.63	80.26	7.12	34.631	0.07	0.301	28.0	101	8.21
KL-E	0.85	0.62	98.41	2.49	9.25	100.89	95.54	6.73	34.633	0.06	0.292	28.3	101	8.22
Geometric Mean	0.98	1.13	88.05	3.03	10.02	116.60	84.65	6.93	34.625	0.08	0.304	27.8	101	8.21
27-Sep-05														
KL-A	2.65	1.29	115.36	4.36	9.36	125.62	104.15	4.26	34.764	0.12	0.205	26.5	101	8.08
KL-B	1.18	1.07	117.21	3.34	9.24	106.37	111.89	5.74	34.824	0.12	0.174	27.0	102	8.09
KL-C	0.91	1.34	117.27	3.21	9.07	98.86	111.66	5.65	34.826	0.12	0.193	27.0	102	8.12
KL-D	0.55	1.69	98.03	3.11	8.70	89.54	94.03	5.47	34.855	0.10	0.185	27.2	102	8.11
KL-E	1.04	1.91	81.28	3.38	8.12	101.95	76.15	4.59	34.846	0.08	0.232	26.9	102	8.12
Geometric Mean	1.10	1.43	104.79	3.45	8.88	103.82	98.59	5.10	34.823	0.10	0.197	26.9	102	8.10
06-Dec-05														
KL-A	3.61	0.84	110.74	4.31	7.69	145.89	103.14	1.27	34.846	0.22	0.260	24.7	102	8.06
KL-B	3.42	0.67	113.56	3.61	8.23	116.51	107.61	4.36	34.862	0.14	0.187	24.6	102	8.09
KL-C	2.57	0.39	147.46	3.27	9.65	96.49	142.61	5.64	34.889	0.09	0.197	24.2	102	8.11
KL-D	3.10	0.51	93.37	3.37	6.43	88.59	88.45	2.75	34.860	0.11	0.230	24.0	102	8.09
KL-E	1.78	0.57	100.31	3.14	6.54	71.75	97.04	3.14	34.876	0.08	0.222	23.9	102	8.11
Geometric Mean	2.81	0.58	111.67	3.52	7.62	100.83	106.32	3.06	34.866	0.12	0.218	24.3	102	8.09

TABLE 3. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2006 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
08-Mar-06														
KL-A	9.81	1.88	88.89	<u>6.35</u>	11.20	458.09	56.47	4.20	34.441	<u>0.23</u>	<u>0.321</u>	25.2	101	8.15
KL-B	2.31	1.84	<u>100.15</u>	<u>5.13</u>	10.78	267.77	88.41	5.40	34.686	<u>0.13</u>	0.205	26.4	101	8.19
KL-C	4.24	1.50	<u>133.44</u>	<u>5.93</u>	12.03	259.65	110.92	5.94	34.466	<u>0.13</u>	0.228	25.8	101	8.20
KL-D	0.53	0.73	<u>112.11</u>	4.32	9.41	161.81	110.31	5.02	34.825	<u>0.10</u>	0.187	25.8	101	8.20
KL-E	0.89	0.91	<u>126.29</u>	4.37	8.69	171.04	121.78	4.25	34.781	<u>0.11</u>	0.233	25.5	101	8.19
Geometric Mear	2.14	1.28	<u>110.96</u>	<u>5.16</u>	10.35	244.93	94.26	4.92	34.639	<u>0.13</u>	0.231	25.7	101	8.19
01-Jun-06														
KL-A	1.25	1.85	80.37	3.72	10.55	141.29	75.78	6.72	34.612	<u>0.12</u>	<u>0.307</u>	27.4	100	8.19
KL-B	1.16	1.40	81.98	3.19	10.32	127.81	78.77	7.11	34.620	0.09	0.264	27.5	101	8.20
KL-C	0.85	1.87	98.73	3.16	10.18	107.88	94.95	7.02	34.630	0.07	<u>0.367</u>	27.6	101	8.22
KL-D	0.86	0.62	82.64	2.71	9.87	109.63	80.26	7.12	34.631	0.07	<u>0.301</u>	28.0	101	8.21
KL-E	0.85	0.62	98.41	2.49	9.25	100.89	95.54	6.73	34.633	0.06	0.292	28.3	101	8.22
Geometric Mear	0.98	1.13	88.05	3.03	10.02	116.60	84.65	6.93	34.625	0.08	<u>0.304</u>	27.8	101	8.21
25-Aug-06														
KL-A	<u>7.06</u>	<u>2.92</u>	<u>153.00</u>	<u>7.80</u>	<u>15.20</u>	241.69	120.40	7.24	34.300	<u>0.16</u>	<u>0.345</u>	27.7	100	8.00
KL-B	1.35	1.61	<u>135.11</u>	<u>6.24</u>	<u>13.44</u>	122.87	123.22	7.09	34.606	0.08	0.236	27.2	100	8.06
KL-C	<u>6.21</u>	1.26	<u>110.20</u>	<u>6.41</u>	<u>14.13</u>	191.66	86.84	7.40	34.521	0.08	0.173	27.1	100	8.09
KL-D	<u>5.03</u>	0.45	<u>119.89</u>	<u>5.18</u>	<u>13.05</u>	89.23	113.94	7.85	34.758	0.06	0.167	27.5	100	8.11
KL-E	<u>9.67</u>	1.07	<u>122.85</u>	<u>5.39</u>	<u>14.23</u>	97.58	111.49	8.81	34.737	0.07	0.188	27.3	100	8.10
Geometric Mear	<u>4.92</u>	1.23	<u>127.39</u>	<u>6.14</u>	<u>13.99</u>	137.73	110.36	7.66	34.584	0.09	0.213	27.4	100	8.07
09-Nov-06														
KL-A	1.71	2.27	<u>133.33</u>	<u>5.08</u>	8.71	156.94	127.47	3.26	34.762	<u>0.13</u>	0.295	26.7	100	8.12
KL-B	0.69	1.90	<u>132.38</u>	4.56	9.17	211.74	127.97	4.49	34.760	<u>0.10</u>	0.258	26.4	100	8.16
KL-C	0.41	1.00	<u>128.50</u>	4.56	8.75	117.92	126.56	4.09	34.804	0.09	0.208	26.4	100	8.16
KL-D	0.28	0.69	<u>118.20</u>	4.23	8.88	107.35	116.89	4.56	34.806	0.08	0.213	26.2	100	8.18
KL-E	1.05	0.86	<u>107.32</u>	4.18	8.39	98.72	104.58	4.11	34.817	0.08	0.216	25.9	100	8.18
Geometric Mear	0.68	1.21	<u>123.54</u>	4.51	8.77	132.94	120.34	4.08	34.790	<u>0.10</u>	0.236	26.3	100	8.16

TABLE 4. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2007 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
13-Apr-07														
KL-A	27.27	2.75	184.85	7.14	15.17	443.23	140.94	7.98	34.151	0.12	0.244	26.0	100	8.12
KL-B	13.77	0.87	188.56	5.41	14.18	182.88	162.30	8.38	34.490	0.07	0.199	26.0	100	8.13
KL-C	21.19	1.49	191.69	6.97	15.20	223.82	154.57	8.20	34.332	0.07	0.221	25.4	100	8.10
KL-D	10.66	1.18	169.25	6.76	13.83	173.37	155.09	7.03	34.560	0.06	0.173	25.1	100	8.08
KL-E	9.31	1.16	155.99	6.52	12.25	146.28	145.02	5.71	34.621	0.06	0.162	25.0	100	8.10
Geometric Mean	15.12	1.37	177.54	6.53	14.08	215.06	151.39	7.39	34.430	0.08	0.198	25.5	100	8.11
31-Jul-07														
KL-A	9.31	2.68	151.64	5.87	12.73	257.06	122.01	6.81	34.511	0.11	0.303	27.1	100	8.26
KL-B	2.14	2.55	158.70	4.97	11.92	161.40	134.76	6.83	34.637	0.10	0.306	26.8	100	8.27
KL-C	2.96	2.76	171.05	5.87	13.72	249.56	138.93	7.71	34.514	0.10	0.340	26.8	100	8.24
KL-D	0.76	1.31	130.72	3.73	10.23	92.39	126.83	6.47	34.891	0.09	0.237	26.4	100	8.23
KL-E	3.44	2.32	136.03	4.68	11.44	156.52	121.07	6.64	34.703	0.09	0.227	26.3	100	8.20
Geometric Mean	2.74	2.25	148.90	4.95	11.95	171.82	128.53	6.88	34.651	0.10	0.279	26.7	100	8.24
25-Oct-07														
KL-A	5.65	2.03	136.47	6.86	16.27	243.17	99.93	9.11	34.376	0.28	0.440	26.4	99	8.08
KL-B	1.96	1.28	129.06	5.05	13.52	113.15	114.17	8.28	34.819	0.15	0.322	27.0	100	8.12
KL-C	0.31	0.86	136.95	4.08	12.40	75.41	130.13	8.31	34.924	0.12	0.332	26.6	100	8.12
KL-D	0.14	0.97	123.32	3.58	10.96	77.64	121.30	7.28	35.002	0.13	0.270	27.0	100	8.11
KL-E	0.27	1.07	112.03	3.98	10.15	116.64	109.78	6.16	34.997	0.10	0.198	27.0	100	8.14
Geometric Mean	0.66	1.18	127.22	4.58	12.48	113.45	114.61	7.76	34.823	0.15	0.302	26.8	100	8.11
13-Nov-07														
KL-A	6.60	3.97	113.62	5.02	11.61	123.51	95.55	6.55	34.819	0.18	0.165	26.7	99	8.16
KL-B	3.69	2.18	113.34	4.08	11.15	81.76	103.36	7.00	34.904	0.12	0.142	26.1	100	8.12
KL-C	1.67	2.51	114.92	3.56	10.31	45.73	110.12	6.73	34.933	0.09	0.149	26.4	100	8.17
KL-D	1.78	2.32	106.96	3.75	11.01	53.84	102.29	7.21	34.967	0.09	0.132	25.9	100	8.18
KL-E	1.82	2.73	113.27	3.64	11.88	78.01	107.42	8.19	34.966	0.10	0.140	26.0	100	8.19
Geometric Mean	2.65	2.68	112.39	3.98	11.18	72.03	103.63	7.11	34.918	0.11	0.145	26.2	100	8.16

TABLE 5. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2008 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
13-Mar-08														
KL-A	<u>13.39</u>	<u>3.44</u>	<u>133.64</u>	<u>5.70</u>	<u>14.27</u>	352.73	113.53	8.44	34.634	<u>0.21</u>	<u>0.312</u>	25.5	100	8.09
KL-B	<u>13.73</u>	<u>2.55</u>	<u>126.06</u>	<u>5.36</u>	<u>13.60</u>	291.10	102.16	8.19	34.706	<u>0.16</u>	<u>0.305</u>	25.5	101	8.12
KL-C	3.12	2.32	<u>112.49</u>	3.73	11.83	117.35	105.30	8.05	34.896	<u>0.10</u>	0.230	24.9	100	8.13
KL-D	1.89	1.27	<u>111.39</u>	3.72	11.14	95.76	107.42	7.40	34.928	<u>0.11</u>	0.202	25.0	101	8.14
KL-E	1.44	<u>3.26</u>	<u>111.93</u>	4.15	11.37	110.77	106.22	7.16	34.915	<u>0.10</u>	0.211	24.5	101	8.14
Geometric Mean	4.35	2.43	<u>118.76</u>	4.46	12.38	166.46	106.86	7.83	34.815	<u>0.13</u>	0.248	25.1	101	8.13
08-May-08														
KL-A	<u>11.37</u>	0.75	<u>124.29</u>	<u>6.27</u>	<u>14.02</u>	338.30	92.76	7.40	34.377	<u>0.14</u>	0.215	25.8	99	8.06
KL-B	<u>7.42</u>	1.40	<u>110.83</u>	<u>5.64</u>	<u>14.77</u>	219.37	92.58	8.70	34.596	<u>0.15</u>	0.229	25.3	100	8.09
KL-C	<u>12.98</u>	1.39	<u>124.76</u>	<u>6.37</u>	<u>12.83</u>	271.98	93.52	6.07	34.421	0.09	0.213	25.7	100	8.09
KL-D	<u>4.85</u>	1.31	<u>102.91</u>	<u>5.26</u>	10.70	147.57	95.03	5.18	34.710	<u>0.10</u>	0.173	25.5	100	8.09
KL-E	<u>8.10</u>	1.42	<u>117.14</u>	<u>5.99</u>	12.04	208.99	102.69	5.69	34.479	<u>0.10</u>	0.182	25.1	100	8.11
Geometric Mean	<u>8.45</u>	1.22	<u>115.68</u>	<u>5.89</u>	<u>12.79</u>	228.47	95.24	6.49	34.516	<u>0.11</u>	0.201	25.5	100	8.09
26-Aug-08														
KL-A	<u>20.73</u>	2.12	<u>132.01</u>	<u>5.16</u>	<u>13.06</u>	280.90	107.20	7.83	34.603	<u>0.16</u>	0.251	26.5	100	8.10
KL-B	<u>14.63</u>	1.38	<u>131.60</u>	4.00	<u>13.80</u>	193.22	110.49	9.56	34.646	<u>0.13</u>	0.254	26.7	100	8.14
KL-C	<u>14.97</u>	0.78	<u>133.88</u>	<u>6.28</u>	<u>14.24</u>	224.37	111.52	7.93	34.616	0.09	0.219	26.4	100	8.14
KL-D	<u>10.08</u>	1.86	<u>129.16</u>	<u>6.45</u>	<u>13.92</u>	210.14	116.99	7.45	34.748	<u>0.11</u>	0.237	26.8	100	8.13
KL-E	<u>12.84</u>	1.71	<u>144.68</u>	<u>6.94</u>	<u>14.53</u>	222.71	128.62	7.55	34.636	<u>0.11</u>	0.290	26.1	100	8.13
Geometric Mean	<u>14.25</u>	1.49	<u>134.16</u>	<u>5.66</u>	<u>13.90</u>	224.47	114.72	8.03	34.650	<u>0.12</u>	0.249	26.5	100	8.13
24-Oct-08														
KL-A	<u>8.46</u>	<u>5.66</u>	<u>165.58</u>	<u>7.34</u>	<u>15.47</u>	182.85	138.21	7.91	34.551	<u>0.14</u>	0.239	25.5	101	8.11
KL-B	<u>5.90</u>	<u>3.40</u>	<u>145.25</u>	<u>6.26</u>	<u>13.98</u>	141.13	130.77	7.64	34.774	<u>0.10</u>	0.203	25.7	101	8.14
KL-C	<u>6.06</u>	<u>3.65</u>	<u>137.89</u>	<u>6.07</u>	<u>13.68</u>	159.49	114.76	7.41	34.750	0.09	0.218	25.2	100	8.16
KL-D	4.03	<u>3.30</u>	<u>144.89</u>	<u>5.43</u>	<u>13.06</u>	74.01	136.24	7.60	34.861	<u>0.10</u>	0.160	25.3	101	8.15
KL-E	1.82	<u>2.73</u>	<u>113.27</u>	3.64	11.88	78.01	107.42	8.19	34.966	<u>0.10</u>	0.140	26.0	100	8.19
Geometric Mean	<u>4.67</u>	<u>3.63</u>	<u>140.33</u>	<u>5.60</u>	<u>13.57</u>	118.90	124.87	7.75	34.780	<u>0.10</u>	0.188	25.5	101	8.15

TABLE 6. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2009 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
05-Mar-09														
KL-A	10.52	1.60	108.64	14.30	30.73	343.09	82.69	14.99	34.738	0.13	0.259	21.4	101	8.18
KL-B	6.28	0.57	106.13	8.93	20.91	216.41	93.62	11.94	35.013	0.07	0.188	20.9	101	8.22
KL-C	2.77	0.81	145.89	3.56	12.42	145.95	137.57	8.70	35.013	0.06	0.183	20.9	101	8.22
KL-D	1.98	0.86	148.14	4.31	16.39	140.50	143.13	11.80	35.244	0.05	0.180	20.7	101	8.22
KL-E	1.28	1.02	126.04	2.22	10.19	119.51	118.59	7.68	34.990	0.06	0.180	20.6	101	8.23
Geometric Mean	3.41	0.92	125.72	5.35	16.79	178.65	112.57	10.71	34.999	0.07	0.196	20.9	101	8.21
07-Aug-09														
KL-A	12.02	3.42	114.14	7.73	16.35	600.54	90.55	8.40	34.674	0.10	0.162	26.2	100	8.10
KL-B	7.77	2.46	121.37	7.05	16.04	262.19	102.91	8.90	34.765	0.09	0.186	26.2	100	8.13
KL-C	7.71	1.92	118.14	6.78	14.74	203.69	100.82	7.88	34.742	0.07	0.200	26.4	100	8.12
KL-D	3.19	1.72	115.37	5.99	13.85	109.33	109.95	7.85	34.905	0.08	0.197	26.4	101	8.14
KL-E	4.01	2.17	112.56	6.30	13.48	159.34	105.16	7.12	34.900	0.08	0.171	25.7	101	8.13
Geometric Mean	6.21	2.27	116.28	6.75	14.85	223.58	101.67	8.01	34.797	0.08	0.183	26.2	100	8.12
17-Nov-09														
KL-A	6.76	1.06	145.86	4.76	10.26	222.79	117.99	5.02	34.888	0.11	0.204	25.9	100	8.12
KL-B	1.39	0.64	118.91	2.73	8.53	111.31	115.23	5.65	35.238	0.09	0.179	25.3	101	8.15
KL-C	1.36	0.56	126.35	3.13	9.56	130.20	119.75	6.18	35.174	0.09	0.190	25.7	101	8.12
KL-D	0.42	1.05	115.08	1.98	8.61	100.00	112.83	6.57	35.268	0.09	0.158	25.4	101	8.15
KL-E	0.37	0.47	107.97	1.93	8.08	87.84	107.02	6.11	35.270	0.11	0.192	25.6	101	8.15
Geometric Mean	1.14	0.71	122.18	2.74	8.97	123.18	114.48	5.88	35.167	0.10	0.184	25.6	101	8.14

TABLE 7. Summary of the water quality parameters as geometric means from samples collected along five transects in the ocean fronting Ka Lae Mano in the 2010 during construction period. Geometric means are given for each of the transects on each of the survey dates for surface samples only; also given are the grand surface geometric means for each date. Underlined geometric means exceed Department of Health West Hawaii regional water quality standards. All values are in ug/l unless otherwise indicated; ND = below limits of detection.

Transect No.	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [ppt]	Turbidity [NTU]	Chl-a	Temperature [`C]	Oxygen [%]	pH
20-Apr-10														
KL-A	21.00	2.48	176.27	9.42	16.99	363.63	136.24	5.39	34.543	0.15	0.219	23.3	99	8.07
KL-B	8.19	1.27	162.93	5.20	11.82	168.84	152.43	6.59	34.902	0.08	0.185	23.2	100	8.11
KL-C	6.37	2.27	179.12	6.00	13.50	170.12	163.90	7.41	34.826	0.08	0.228	23.3	100	8.13
KL-D	2.12	1.06	154.25	4.63	11.42	93.89	150.05	6.77	34.975	0.08	0.145	23.5	100	8.13
KL-E	2.15	1.29	137.99	5.11	11.06	100.61	132.46	5.92	34.946	0.09	0.138	22.9	100	8.14
Geometric Mean	5.49	1.58	161.39	5.87	12.79	158.07	146.57	6.38	34.838	0.09	0.179	23.2	100	8.12
29-Jun-10														
KL-A	12.11	1.03	161.57	6.37	12.15	516.17	127.55	5.29	34.410	0.12	0.209	25.3	99	8.05
KL-B	3.00	0.79	133.45	4.95	11.47	191.91	120.94	6.37	34.818	0.10	0.186	25.3	100	8.09
KL-C	3.30	0.87	136.18	5.05	9.71	211.40	123.34	4.55	34.783	0.09	0.263	25.6	100	8.10
KL-D	2.17	0.64	118.43	4.24	7.64	175.37	115.18	3.38	34.988	0.09	0.244	25.0	100	8.11
KL-E	2.55	0.61	117.10	3.35	7.64	119.91	113.51	3.60	34.986	0.10	0.240	24.9	100	8.11
Geometric Mean	3.67	0.77	132.42	4.69	9.54	213.19	119.99	4.51	34.796	0.10	0.227	25.2	100	8.09
12-Nov-10														
KL-A	3.14	2.44	91.73	2.85	9.87	104.58	84.44	6.88	34.967	0.19	0.180	25.6	100	8.06
KL-B	1.05	1.84	92.26	2.16	8.76	64.14	89.01	6.55	35.042	0.17	0.149	25.7	100	8.12
KL-C	0.57	2.07	107.14	2.30	9.60	55.34	104.13	7.19	35.051	0.12	0.170	25.3	100	8.13
KL-D	0.37	2.11	100.74	2.25	9.63	47.29	98.31	7.34	35.056	0.10	0.119	25.0	100	8.15
KL-E	0.39	2.71	127.49	2.89	9.99	53.80	123.75	6.94	35.047	0.09	0.143	24.9	100	8.14
Geometric Mean	0.77	2.21	103.09	2.47	9.56	62.38	99.02	6.98	35.033	0.13	0.150	25.3	100	8.12

TABLE 8. Parameter means by date from the five monitoring wells drilled at Ka Lae Mano sampled once during the baseline period and on each of the 2005 - 2010 quarterly surveys. Note that a dust control well (Well 6) was developed at the start of construction but was not sampled in December 2005, August and November 2009, April and June 2010 (pump off). Otherwise Well 6 data are include in the means below. All values in ug/l unless otherwise noted.

DATE	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	SILICA	SALINITY [ppt]	TURBIDITY [NTU]	TEMP [`C]	OXYGEN [%]	pH
Baseline											
20-Sep-04	2372.30	4.88	5455.13	200.94	243.16	26751.56	2.662	4.87	20.7	62	8.07
During Construction											
31-Mar-05	2495.06	3.03	4602.71	194.73	329.53	28420.37	2.526	1.55	22.5		7.93
19-Jul-05	2441.89	4.03	3451.00	180.67	286.80	27291.80	4.530	0.91	22.5	38	7.65
27-Sep-05	2499.44	1.38	3621.73	178.82	229.97	26915.56	2.559	0.75	24.6	44	7.87
06-Dec-05	2504.95	1.11	3609.82	193.36	254.14	29754.13	2.720	0.85	24.9	48	7.87
08-Mar-06	2279.01	1.31	5169.73	163.99	236.32	28679.42	2.642	0.39	23.5	65	8.01
01-Jun-06	2466.81	0.68	3763.60	184.48	222.74	27184.32	2.529	0.62	25.6	50	7.86
25-Aug-06	2506.52	0.88	3685.66	179.14	238.70	26337.72	2.711	0.21	25.6	52	7.89
09-Nov-06	2544.42	125.41	3978.19	194.52	291.40	26619.77	2.719	1.46	24.0	59	7.94
13-Apr-07	2469.16	0.23	6741.98	166.35	503.29	26588.96	2.603	0.43	23.2	62	7.89
31-Jul-07	882.66	1.04	4957.77	69.21	308.45	10350.52	2.696	0.50	24.8	79	8.29
25-Oct-07	2415.79	1.04	3204.39	195.22	266.55	27060.19	2.665	0.56	23.7	76	7.92
13-Nov-07	2479.85	0.24	3222.15	223.96	327.57	26856.07	2.717	0.28	23.7	77	7.93
13-Mar-08	2723.85	4.35	3964.55	239.92	352.16	25633.26	2.201	0.28	23.3	67	7.87
08-May-08	2625.12	2.60	3356.73	217.44	278.28	26361.74	2.394	0.90	24.4	74	7.91
26-Aug-08	2672.21	7.04	3841.02	209.04	250.27	26714.57	2.538	2.19	24.1	76	7.98
24-Oct-08	2593.06	13.82	5085.13	211.27	282.51	23315.79	2.527	3.20	25.0	72	8.20
05-Mar-09	2323.28	7.25	4340.72	204.98	284.99	27445.98	2.509	2.89	22.0	73	8.01
07-Aug-09	2688.17	0.25	2915.02	205.84	224.44	27346.22	2.699	1.34	24.9	76	8.08
17-Nov-09	2600.43	0.32	2920.79	199.54	205.32	26912.54	2.673	0.35	23.2	64	7.92
20-Apr-10	2459.91	3.42	4335.30	224.94	254.26	26989.09	2.489	0.56	22.8	62	7.95
29-Jun-10	2448.88	2.02	3862.29	178.87	290.84	20101.20	2.600	0.72	23.6	59	7.71
12-Nov-10	2572.15	93.68	3221.00	161.72	229.14	27365.47	2.677	0.38	23.1	71	8.11

TABLE 9. Water quality data and dates of collection for the single anchialine pond present at Ka Lae Mano. All data in ug/l unless otherwise noted.

DATE	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	SILICA	SALINITY [ppt]	TURBIDITY [NTU]	TEMP [`C]	OXYGEN [%]	CHL-a	pH
06-Dec-05	1423.95	27.74	2947.56	147.93	221.96	29558.81	2.941	0.34	0.177	24.9	62	7.36
09-Nov-06	1657.00	175.23	3333.33	181.54	282.88	25932.35	2.942	0.43	0.171	24.1	91	7.55
13-Apr-07	739.73	47.74	4086.74	185.82	544.67	27613.06	3.311	0.25	0.025	24.1	78	7.40
31-Jul-07	483.71	180.45	3268.86	206.57	338.83	28346.80	3.247	0.26	0.082	25.5	70	7.77
25-Oct-07	640.36	193.99	1341.48	204.75	284.58	28007.50	2.991	0.45	0.369	24.3	86	7.44
13-Nov-07	1392.32	6.99	1913.66	179.68	272.18	26995.36	2.985	0.28	0.252	24.9	85	7.71
13-Mar-08	628.75	108.68	1664.46	300.65	421.29	26764.68	3.049	0.30	0.117	24.1	76	7.53
08-May-08	846.61	53.17	1835.54	191.38	240.87	28290.51	3.194	0.41	0.429	25.3	81	7.48
26-Aug-08	437.94	46.54	3060.12	228.46	524.21	13201.29	3.095	0.31	1.690	25.2	80	7.65
24-Oct-08	335.88	52.20	2817.36	264.18	312.79	27580.09	2.992	0.35	0.232	26.2	81	7.77
05-Mar-09	878.55	67.96	2265.62	294.07	364.56	28462.09	3.304	0.30	0.116	22.0	88	7.61
07-Aug-09	397.46	23.24	782.88	178.51	199.02	29175.47	3.273	0.36	0.182	25.6	77	7.68
17-Nov-09	455.10	36.48	1282.68	248.77	269.70	28725.05	3.293	0.55	0.684	24.9	82	7.57
20-Apr-10	187.74	66.08	1955.94	198.40	319.30	29315.44	3.323	0.53	4.207	23.1	54	7.30
29-Jun-10	1317.96	16.10	2212.28	147.87	230.02	17364.20	3.240	0.47	0.014	24.9	71	7.60
12-Nov-10	209.30	307.16	1664.18	438.34	510.26	29219.40	3.197	1.55	2.209	23.6	65	7.45

TABLE 10. Three tiers of water quality criteria developed by the Department of Health for the Kona or West Hawaii coast. Also included are the regional criteria for three parameters under all salinity regimes as well as those for sites with no significant groundwater discharge as has been the case with all samples collected since the 20 September 2004 survey of marine sites fronting the Ka Lae Mano project site.

All Salinity Regimes:	Single Value "Not To Exceed" Criterion For: Ammonia Nitrogen - Criterion = 2.5 ug/l Chlorophyll-*a* - Criterion = 0.3 ug/l Turbidity - Criterion = 0.1 N.T.U.
No Salinity Gradient Observed:	Single Value "Not To Exceed" Criterion For: Total Nitrogen - Criterion = 100.0 ug/l Total Phosphorus - Criterion = 12.5 ug/l Nitrate+Nitrite Nitrogen - Criterion = 4.5 ug/l Orthophosphorous - Criterion = 5.0 ug/l
Salinity Gradient Observed:	Regression Coefficient (Slope) Criterion For: Total Nitrogen Total Phosphorus Nitrate+Nitrite Nitrogen Orthophosphorous

NOTE: Salinities measured in the marine waters fronting the Ka Lae Mano project site in September 2004, the four 2005, 2006, 2007, 2008 as well as the three 2009 and 2010 surveys were all above 32 ppt, so no regression analysis was required to determine compliance with the regional water quality standards.

TABLE 11. Summary of the geometric means for water quality parameters (ug/l unless otherwise noted) as measured at marine stations fronting the Kukio development during the 111-month baseline study period (August 1990 through November 1999). Underlined values exceed the Department of Health regional standards.

Site No.	No. of Samples	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	DON	DOP
3	17	31.13	9.08	147.99	7.77	16.31	592.05	70.02	7.42
4	17	9.98	3.67	92.06	4.04	12.01	195.05	70.32	7.79
5	17	6.55	3.92	98.68	3.70	12.24	182.42	84.15	8.36
6	17	4.25	3.71	93.39	3.64	10.66	108.82	82.34	6.84
14	35	68.23	12.69	170.11	8.46	14.50	1214.79	84.76	5.67
15	34	19.27	7.36	114.40	5.61	12.09	395.32	77.50	6.02
16	20	8.05	5.53	101.32	4.11	11.23	211.43	77.80	6.48
17	17	3.86	3.69	86.75	3.31	10.70	127.38	76.15	6.96
18	17	236.11	25.49	399.33	15.47	22.57	3254.21	77.29	4.76
19	11	66.50	11.36	223.43	7.45	15.51	959.04	104.22	7.07
Grand Geometric Means		17.14	7.03	132.68	5.32	14.18	372.39	79.15	7.38

Site No.	Turbidity (NTU)	Chl-*a*	Salinity (°/oo)	Oxygen (%)	Temp. (°C)	pH
3	0.16	0.365	32.947	103	26.0	8.03
4	0.10	0.172	34.144	102	26.0	8.11
5	0.11	0.140	34.197	103	26.0	8.11
6	0.10	0.144	34.261	102	26.0	8.13
14	0.17	0.325	32.733	103	26.3	8.16
15	0.13	0.180	33.867	102	26.3	8.14
16	0.11	0.135	34.126	102	26.6	8.13
17	0.10	0.136	34.258	102	26.5	8.15
18	0.44	0.670	29.017	102	27.0	8.09
19	0.17	0.415	31.578	103	26.4	8.09
Grand Geometric Means	0.14	0.220	33.120	102	26.2	8.11

TABLE 12. Statistical summary of seven parameters from well data collected to date using the nonparametric Wilcoxon Two Sample Test. Wells are examined in two groups: Makai Wells are numbers 1, 2, 3 and 6 and Mauka Wells are numbers 4 and 5; data are also examined in the preconstruction period only, during construction period as well as all dates together. Means and sample sizes (n) are given for each group. All data in ug/l except salinity which is in ppt.

A. Preconstruction Period Only: Are there significant differences between mauka and makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2190.02	(2)	2493.82	(3)	No
Ammonia-N	1.66		7.02		No
Total-N	4888.03		5833.19		No
Ortho-P	208.49		195.91		No
Total-P	239.01		245.93		No
Silica	27127.93		26500.65		No
Salinity	2.131		3.017		No

B. During Construction Period Only: Are there significant differences between mauka and makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2261.49	(44)	2527.12	(82)	YES ($P<0.0001$)
Interpretation: Nitrate is significantly greater in makai wells.					
Ammonia-N	12.94		13.05		No
Total-N	3776.57		4138.18		YES ($P<0.02$)
Interpretation: Total nitrogen is significantly greater in makai wells.					
Ortho-P	198.13		184.24		YES ($P<0.0004$)
Interpretation: Ortho-P is significantly greater in mauka wells.					
Total-P	280.97		279.78		No
Silica	26684.07		25495.52		YES ($P<0.02$)
Interpretation: Silica is significantly greater in the mauka wells.					
Salinity	2.374		2.850		YES ($P<0.0001$)
Interpretation: Salinity is significantly greater in makai wells.					

TABLE 12. Continued

C. All Dates: Are there significant differences between mauka to makai wells?

Analyte	Mauka Wells Means	(n)	Makai Wells Means	(n)	Significantly Different?
Nitrate-N	2258.38	(46)	2525.95	(85)	YES (P<0.0001)
Interpretation: Nitrate is significantly greater in makai wells.					
Ammonia-N	12.45		12.83		No
Total-N	3824.89		4198.01		YES (P<0.02)
Interpretation: Total nitrogen is significantly greater in makai wells.					
Ortho-P	198.58		184.65		YES (P<0.0003)
Interpretation: Ortho-P is significantly greater in mauka wells.					
Total-P	279.15		278.59		No
Silica	26703.36		25530.99		YES (P<0.01)
Interpretation: Silica is significantly greater in mauka wells.					
Salinity	2.363		2.856		YES (P<0.0001)
Interpretation: Salinity is significantly greater in the makai wells.					

D. Mauka Wells Only: Are there significant differences between preconstruction to during construction means?

Analyte	Preconstruction Means	(n)	During Construction Means	(n)	Significantly Different?
Nitrate-N	2190.02	(2)	2261.49	(44)	No
Ammonia-N	1.66		12.94		No
Total-N	4888.03		3776.57		No
Ortho-P	208.49		198.13		No
Total-P	239.01		280.97		No
Silica	27127.93		26684.07		No
Salinity	2.131		2.374		No

TABLE 12. Continued

E. Makai Wells Only: Are there significant differences between preconstruction to during construction means?

Analyte	Preconstruction Means	(n)	During Construction Means	(n)	Significantly Different?
Nitrate-N	2493.82	(3)	2527.12	(82)	No
Ammonia-N	7.02		13.05		No
Total-N	5833.19		4138.18		YES (P<0.01)
Interpretation: Preconstruction mean is significantly greater.					
Ortho-P	195.91		184.24		No
Total-P	245.93		279.78		No
Silica	26500.65		25495.52		No
Salinity	3.017		2.850		No

TABLE 13. Results of the Wilcoxon 2-Sample Test applied to the means of parameters from the pre-construction (n= 215 samples) and during construction (n= 1098 samples) period a Ka Lae Mano addressing the question. "Has there been any significant change in the means of marine water quality parameters since the commencement of construction?" All means in the body of the table are ug/l unless otherwise noted.

Parameter	Preconstruction Mean	During construction Mean	Significantly Different?	
Nitrate N	26.33	9.68	**YES**	P < 0.0001
	Preconstruction mean significantly greater			
Ammonia N	1.67	2.19	**YES**	P > 0.002
	During construction is significantly greater			
Total N	142.36	126.13	**YES**	P > 0.04
	Preconstruction mean significantly greater			
Ortho P	4.91	5.28	**YES**	P > 0.003
	Preconstruction mean significantly greater			
Total P	12.59	12.23	NO	
Silica	425.45	205.6	**YES**	P < 0.0001
	Preconstruction mean significantly greater			
Salinity (o/oo)	34.299	34.781	**YES**	P < 0.0001
	During construction mean is significantly greater			
Turbidity (NTU)	0.14	0.12	**YES**	P < 0.0001
	Preconstruction mean significantly greater			
Chlorophyll-a	0.216	0.222	NO	
Temp (`C)	26.4	25.6	**YES**	P < 0.0001
	Preconstruction mean significantly greater			
Oxygen (% Sat)	99.9	100.1	NO	
pH (Units)	8.17	8.14	**YES**	P < 0.0001
	Preconstruction mean significantly greater			

TABLE 14. Summary of statistical comparisons of parameters by date using the Kruskal-Wallis Anova and the Student-Neuman-Keuls (SNK) Test addressing the question "Has there been any statistically significant changes in parameters through time at stations in the ocean fronting the Ka Lae Mano project site?" In the body of the table are given the SNK results which the sample date and arithematic mean for a given parameter on that date. Means are expressed in ug/l unless otherwise noted. In the SNK Test, letters with the same designation show means and sample dates are related; changes in letter designation show where significant differences exist. Overlaps in letters indicate a lack of significant differences. In such cases, only the extremes may be significantly different.

Nitrate Nitrogen (P<0.0001)

Date	Mean			
Apr-98	43.83	A		
Aug-93	41.45	A		
Apr-02	39.97	A		
Apr-07	20.87		B	
Jun-06	17.22		B	C
May-08	17.18		B	C
Jul-07	15.71		B	C
Aug-08	14.51		B	C
Aug-06	13.28		B	C
Oct-07	12.06		B	C
Jun-10	10.95		B	C
Mar-09	10.45		B	C
Oct-08	10.34		B	C
Aug-09	10.22		B	C
Apr-10	10.16		B	C
Mar-06	10.07		B	C
Mar-08	8.36		B	C
Mar-05	7.18		B	C
Nov-09	7.15		B	C
Nov-07	4.53			C
Sep-05	4.06			C
Dec-05	3.93			C
Jan-94	3.86			C
Sep-04	2.15			C
Jul-05	1.82			C
Nov-06	1.50			C
Nov-10	1.46			C

Interpretation: Mean nitate at marine stations is significantly greater on 3 preconstruction surveys relative to all other surveys.

Ammonia Nitrogen (P<0.0001)

Date	Mean					
Oct-08	6.03	A				
Nov-07	3.72		B			
Mar-08	3.52		B	C		
Jul-07	3.44		B	C	D	
Jun-06	3.36		B	C	D	
Apr-98	2.63			C	D	E
Aug-09	2.60			C	D	E
Aug-93	2.46			C	D	E
Nov-10	2.44			C	D	E
Jan-94	2.39	F			D	E
Jul-05	1.92	F	G			E
Aug-08	1.88	F	G			E
Aug-06	1.88	F	G			E
Apr-10	1.83	F	G	H		E
Mar-09	1.77	F	G	H		E
Sep-05	1.77	F	G	H		E
Apr-07	1.76	F	G	H		E
Nov-06	1.72	F	G	H		E
May-08	1.68	F	G	H		E
Oct-07	1.64	F	G	H		E
Mar-06	1.57	F	G	H	I	E
Dec-05	1.19	F	G	H	I	
Nov-09	0.93		G	H	I	
Jun-10	0.82		G	H	I	
Apr-02	0.72		G	H	I	
Mar-05	0.63			H	I	
Sep-04	0.52				I	

Interpretation: Ammonia nitrogen is significantly greater in the October 2008 period over all others whose means show considerable overlap.

Total Nitrogen (P<0.0001)

Date	Mean					
Apr-98	191.81	A				
Apr-07	174.86		B			
Apr-10	162.93		B	C		
Apr-02	162.54		B	C		
Oct-08	150.58			C	D	
Jul-07	148.30			C	D	E
Sep-04	137.27		F		D	E
Oct-07	134.23		F	G	D	E
Aug-08	133.98		F	G	D	E
Jun-10	132.80		F	G	D	E
Aug-93	131.06		F	G	D	E
Aug-06	130.58		F	G	D	E
Mar-09	129.08		F	G	H	E
Nov-06	126.40		F	G	H	
Nov-09	125.19		F	G	H	
Mar-08	118.50		F	G	H	
Aug-09	116.23		F	G	H	
May-08	115.85		F	G	H	
Dec-05	115.68		F	G	H	
Mar-06	115.18		F	G	H	
Nov-07	115.12		F	G	H	
Jun-06	112.69			G	H	
Nov-10	108.76				H	I
Sep-05	107.80				H	I
Mar-05	107.36				H	I
Jul-05	92.85	J				I
Jan-94	84.69	J				

Interpretation: Significantly greater mean TN found in one baseline period. No evidence of chronological order.

Orthophosphorus (P<0.0001)

Date	Mean					
Mar-09	13.06	A				
Apr-02	7.10		B			
Aug-09	6.69		B	C		
Apr-07	6.51		B	C		
Apr-10	6.49		B	C		
Aug-06	6.28		B	C		
Oct-08	6.21		B	C	D	
May-08	5.97		B	C	D	
Apr-98	5.85		B	C	D	
Aug-08	5.59		B	C	D	
Mar-06	5.26		B	C	D	
Aug-93	5.25		B	C	D	
Jul-07	5.16		B	C	D	
Mar-05	5.02		B	C	D	
Oct-07	4.93		B	C	D	
Jun-10	4.81		B	C	D	E
Jan-94	4.60		B	C	D	E
Jun-06	4.59		B	C	D	E
Nov-06	4.56		B	C	D	E
Mar-08	4.53		B	C	D	E
Nov-07	4.12		B	C	D	E
Dec-05	3.72		B	C	D	E
Sep-05	3.69		B	C	D	E
Nov-09	3.14			C	D	E
Jul-05	3.13			C	D	E
Nov-10	2.63				D	E
Sep-04	1.55					E

Interpretation: Greater mean concentration in the baseline period. No evidence of increasing concentration due to construction activities on the project site.

TABLE 14. Continued.

Total Phosphorus (P<0.0001)

Date	Mean			
Mar-09	30.27	A		
Apr-98	18.93		B	
Aug-09	14.72		B	C
Aug-06	14.11		B	C
Oct-08	13.86		B	C
Apr-07	13.74		B	C
Aug-08	13.65		B	C
Apr-10	13.06		B	C
Apr-02	12.94		B	C
May-08	12.92		B	C
Oct-07	12.80		B	C
Aug-93	12.54		B	C
Mar-08	12.41		B	C
Jul-07	11.88			C
Mar-05	11.57			C
Nov-07	11.20			C
Mar-06	10.46			C
Jul-05	10.11			C
Nov-10	9.69			C
Jan-94	9.61			C
Jun-10	9.56			C
Sep-04	9.19			C
Nov-09	9.07			C
Sep-05	8.92			C
Nov-06	8.66			C
Jun-06	8.57			C
Dec-05	7.78			C

Interpretation: No evidence of increasing concentration due to construction activities on the project site.

Silicate (P<0.0001)

Date	Mean			
Apr-02	686.98	A		
Apr-98	632.15	A		
Aug-93	582.72	A		
Jun-06	350.38		B	
Apr-07	289.73		B	C
Mar-06	287.39		B	C
May-08	285.20		B	C
Aug-09	279.92		B	C
Jun-10	271.01		B	C
Mar-09	263.22		B	C
Jul-07	249.05		B	C
Oct-07	223.57		B	C
Aug-08	214.99		B	C
Aug-06	210.78		B	C
Mar-08	204.67		B	C
Apr-10	193.29		B	C
Oct-08	176.52		B	C
Nov-09	172.64		B	C
Mar-05	150.79		B	C
Nov-06	147.27		B	C
Jul-05	134.56			C
Sep-05	133.91			C
Dec-05	112.63			C
Jan-94	112.50			C
Nov-07	96.23			C
Sep-04	89.52			C
Nov-10	75.10			C

Interpretation: Significantly greater concentration in baseline period. No evidence of increasing concentration due to construction activities on the project site. Silica shows an inverse relatonship with salinity.

Salinity (P<0.0001)

Date	Mean					
Nov-09	35.192	A				
Nov-10	35.034		B			
Mar-09	35.011		B	C		
Nov-07	34.931		B	C	D	
Jan-94	34.909		B	C	D	E
Jun-10	34.881		B	C	D	E
Dec-05	34.872		B	C	D	E
Oct-07	34.867		B	C	D	E
Apr-10	34.859	F	B	C	D	E
Sep-05	34.839	F	BG	C	D	E
Mar-08	34.834	F	BG	C	D	E
Aug-09	34.827	F	BG	C	D	E
Nov-06	34.792	F	G	CH	D	E
Oct-08	34.773	F	G	H	D	E
Jul-07	34.714	F	G	H	DI	E
Sep-04	34.708	F	G	H	DI	E
Aug-08	34.698	F	G	H	I	E
Mar-06	34.673	F	G	H	I	
Jul-05	34.631		G	H	I	
Aug-06	34.626		G	H	I	
May-08	34.586			H	I	
Jun-06	34.523				I	
Mar-05	34.517				I	
Apr-07	34.502				I	
Apr-98	34.106					J
Apr-02	33.922				K	
Aug-93	33.894				K	

Interpretation: Salinity is related to groundwater input both fronting the project site as well as away from it. There is no evidence of changes in salinity related to the development.

Turbidity (NTU) P<0.0001

Date	Mean					
Jan-94	0.23	A				
Apr-02	0.18		B			
Oct-07	0.17		B			
Dec-05	0.17		B	C		
Nov-10	0.15		B	C	D	
Mar-08	0.14		B	C	D	
Mar-06	0.14		B	C	D	
Oct-08	0.13		B	C	D	E
Nov-07	0.12			C	D	E
Aug-93	0.12			C	D	E
Aug-08	0.12			C	D	E
May-08	0.12				D	E
Sep-05	0.12				D	E
Nov-06	0.11				D	E
Jun-10	0.11				D	E
Nov-09	0.10				D	E
Jul-07	0.10				D	E
Apr-10	0.10				D	E
Jun-06	0.10				D	E
Apr-98	0.10				D	E
Aug-06	0.10				D	E
Jul-05	0.10				D	E
Mar-05	0.10				D	E
Sep-04	0.10				D	E
Aug-09	0.09					E
Apr-07	0.08					E
Mar-09	0.08					E

Interpretation: Turbidity shows no relationship with the during construction period; highest turbidity value is during the baseline period. Turbidity is probably related to surf causing resuspension of materials in situ.

TABLE 14. Continued.

Chlorophyll-a (P<0.0001)

Date	Mean					
Oct-07	0.315	A				
Jul-05	0.315	A				
Jul-07	0.296	A	B			
Apr-98	0.271	A	B	C		
Mar-08	0.262	A	B	C	D	
Apr-02	0.259	A	B	C	D	
Nov-06	0.250	A	B	C	D	E
Jan-94	0.246	AF	B	C	D	E
Aug-06	0.245	AF	B	C	D	E
Aug-08	0.245	AF	B	C	D	E
Mar-06	0.239	F	B	C	D	E
Jun-10	0.235	F	B	C	D	E
Dec-05	0.230	F	B	C	D	E
Oct-08	0.215	F	G	C	D	E
Jun-06	0.212	F	G	C	D	E
Mar-09	0.212	F	G	C	D	E
Apr-07	0.207	F	G	C	D	E
May-08	0.204	F	G	C	D	E
Sep-05	0.201	F	G	C	D	E
Nov-09	0.186	F	G		D	E
Apr-10	0.186	F	G		D	E
Nov-10	0.179	F	G			E
Aug-09	0.184	F	G	H		
Sep-04	0.169	F	G	H		
Nov-07	0.148		G	H	I	
Aug-93	0.128			H	I	
Mar-05	0.107				I	

Interpretation: No evidence of increase in chlorophyll-a with time and considerable overlap masks any real significant changes.

% Oxygen Saturation (P<0.0001)

Date	Mean					
Dec-05	101.3	A				
Sep-05	101.1	A	B			
Mar-05	100.8		B	C		
Oct-08	100.5			C		
Mar-06	100.5			C	D	
Mar-09	100.4			C	D	E
Jul-05	100.2		F		D	E
Nov-09	100.2		F		D	E
Mar-08	100.1		F		D	E
Aug-08	100.1		F		D	E
Aug-06	100.0		F	G	D	E
Jul-07	99.9		F	G	DH	E
Apr-07	99.9		F	G	DH	E
Jun-06	99.9		F	G	H	E
Sep-04	99.9		F	G	H	E
Aug-09	99.9		F	G	H	E
May-08	99.8		F	G	H	EI
Nov-06	99.8		F	G	H	I
Nov-07	99.7		F	G	H	I
Nov-10	99.4			G	H	I
Apr-10	99.4				H	I
Oct-07	99.4				H	I
Jun-10	99.3					I

Interpretation: Note that dissolved oxygen was not measured in most preconstruction surveys. Dissolved oxygen concentrations are probably related to time of day of sampling and local surf.

Temperature ('C) P<0.0001

Date	Mean					
Sep-04	29.0	A				
Jul-05	27.8		B			
Aug-06	27.4			C		
Aug-93	27.3			C		
Sep-05	26.9				D	
Oct-07	26.8				D	
Jul-07	26.6					E
Aug-08	26.5					E
Nov-06	26.3	F				
Nov-07	26.2	F	G			
Aug-09	26.2	F	G			
Apr-02	26.0		G			
Jun-06	25.7			H		
Mar-06	25.7			H	I	
Nov-09	25.6			H	I	J
Apr-07	25.5	K			I	J
May-08	25.5	K				J
Oct-08	25.3	K	L			
Nov-10	25.1		L			
Jun-10	25.1		L	M		
Mar-08	25.1			M		
Mar-05	24.9				N	
Jan-94	24.8				N	
Apr-98	24.8				N	
Dec-05	24.2					O
Apr-10	24.2				P	
Mar-09	24.2					Q

Interpretation: Significant differences in means are related to seasonal influences.

pH (units) P<0.0001

Date	Mean					
Jul-07	8.24	A				
Mar-09	8.21		B			
Jul-05	8.20		B	C		
Aug-93	8.19			C	D	
Mar-06	8.19				D	
Apr-98	8.17					E
Sep-04	8.16	F				E
Apr-02	8.16	F				E
Nov-07	8.16	F				E
Mar-05	8.16	F	G			E
Nov-06	8.16	F	G			E
Jun-06	8.15	F	G	H		
Oct-08	8.14		G	H		
Nov-09	8.14			H	I	
Aug-08	8.13			H	I	J
Mar-08	8.13				I	J
Aug-09	8.12	K				J
Nov-10	8.12	K	L			J
Apr-10	8.12	K	L			J
Oct-07	8.11	K	L			J
Apr-07	8.11	K	L	M		
Sep-05	8.10		L	M	N	
Jun-10	8.09			M	N	
Dec-05	8.09			M	N	
May-08	8.09				N	
Aug-06	8.07					O

Interpretation: Significant differences in means are not related to the development, the differences are small, in the normal range and are biologically insignificant.

FIGURE 1. Outline map of the coastal portion of the Ka Lae Mano project site showing the approximate locations of the five water quality monitoring transects (A through E) with ten sampling stations on each (adopted from Marine Research Consultants 1993).

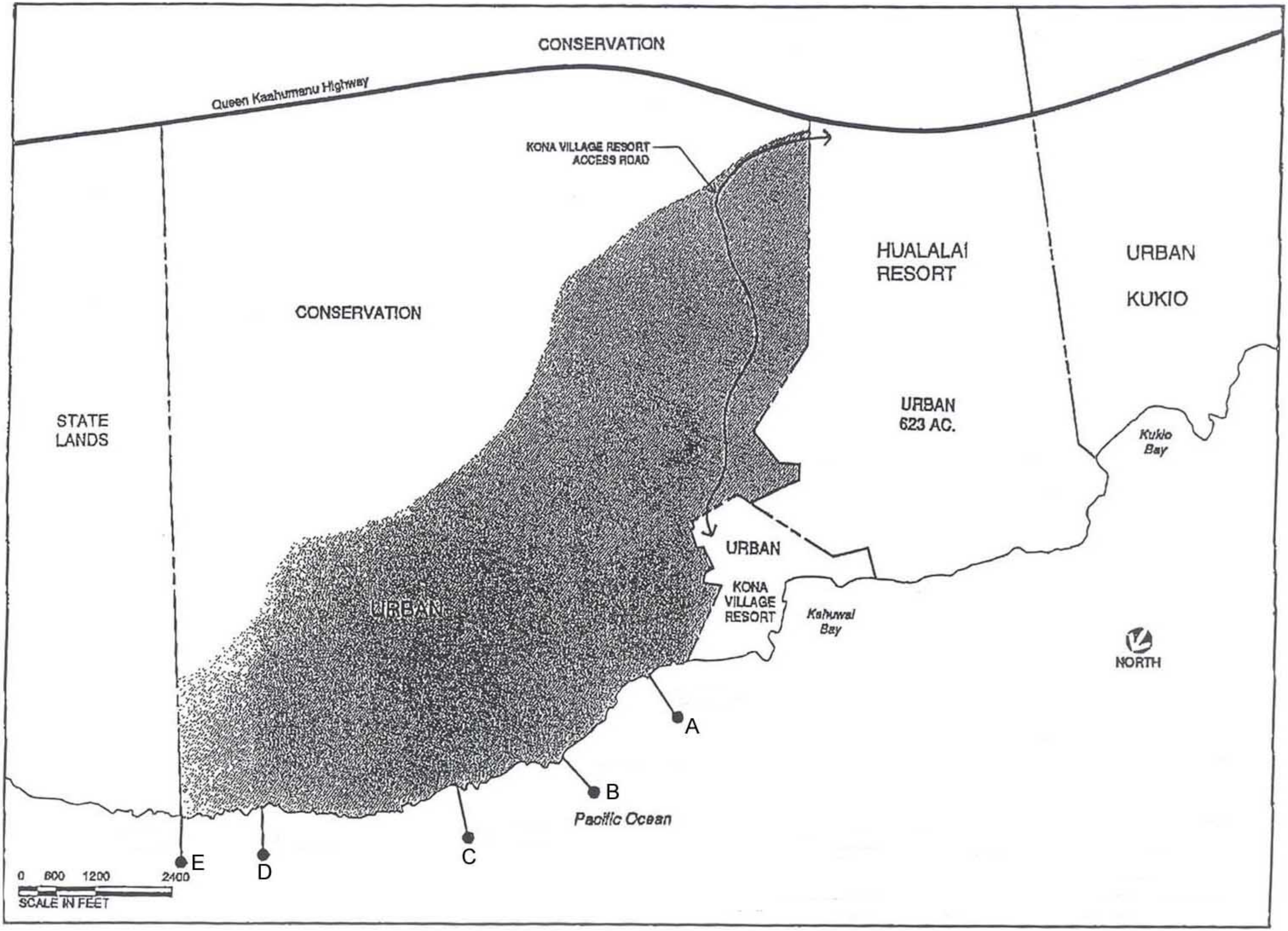
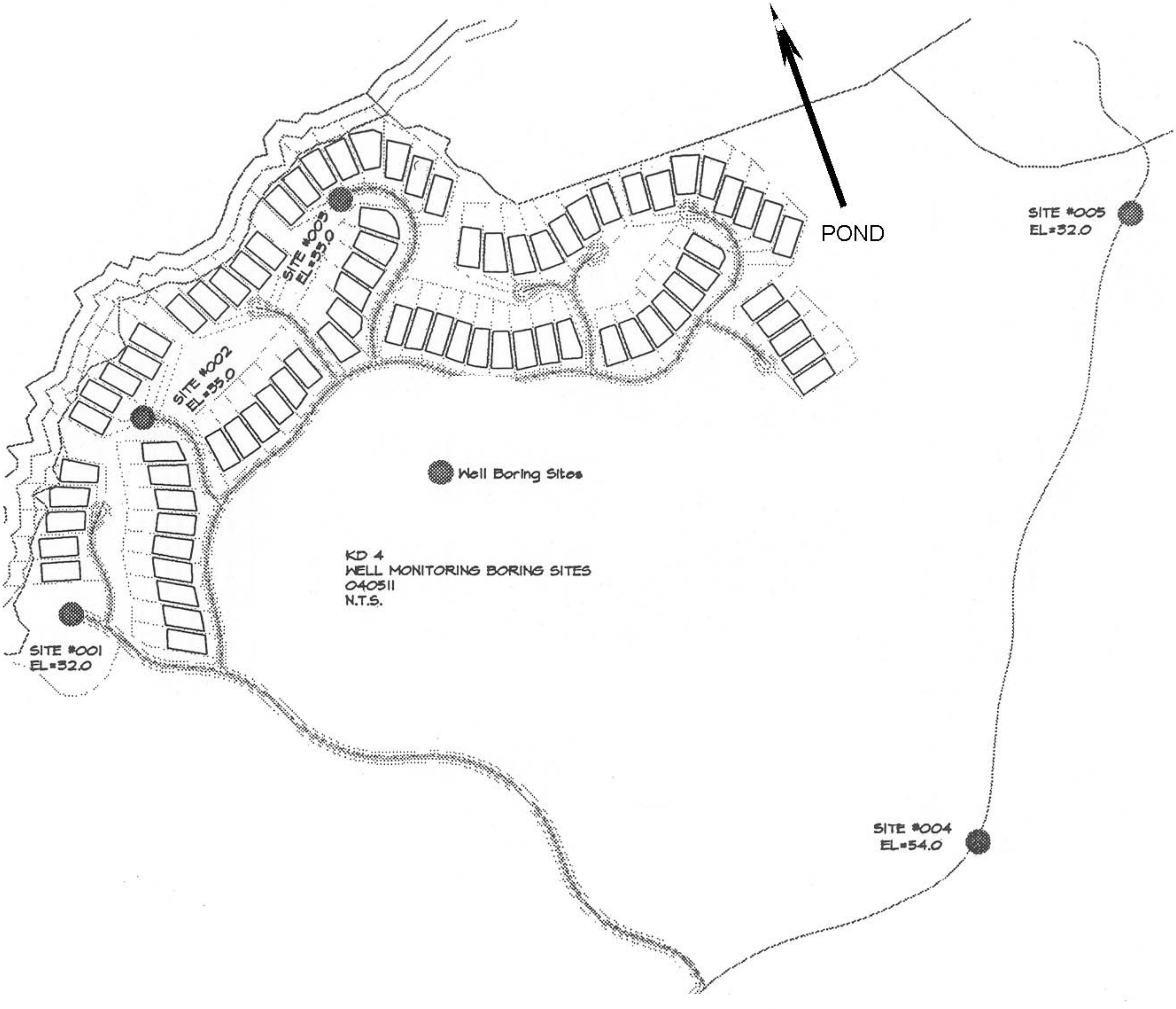

CONSERVATION
Queen Kaahumanu Highway
KONA VILLAGE RESORT
ACCESS ROAD
HUALALAI
RESORT
URBAN
KUKIO
CONSERVATION
STATE
LANDS
URBAN
623 AC.
Kukio
Bay
URBAN
KONA
VILLAGE
RESORT
Kahuwai
Bay
URBAN
NORTH
A
B
Pacific Ocean
C
D
E
0 600 1200 2400
SCALE IN FEET

FIGURE 2. Map showing the first phase of the development at Ka Lae Mano with roads and residential lots (under construction). Also shown are the five coastal monitoring wells (1 through 5) along with a dust control well (site 6) and anchialine pool. Map courtesy of W.B. Kukio, LLC.


POND
SITE #005
EL=32.0
SITE #003
EL=35.0
SITE #002
EL=35.0
Well Boring Sites
KD 4
WELL MONITORING BORING SITES
040511
N.T.S.
SITE #001
EL=32.0
SITE #004
EL=54.0

APPENDIX 1. Summary of the water quality parameters as measured at 57 sites for the KaLaeMano project on 20 April 2010. One sample is from an anchialine pool, five from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No	DFS [m]	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [`C]	Oxygen [%]	pH
KL-A	1-S	0	68.04	4.48	167.86	25.73	28.52	920.92	95.34	2.79	34.034	0.34	0.215	23.0	98	8.00
	2-S	10	76.72	3.36	163.80	39.68	42.78	1045.52	83.72	3.10	33.950	0.29	0.330	23.5	99	8.02
	3-B	10	10.22	1.68	99.82	9.61	14.88	207.48	87.92	5.27	34.890	0.15	0.198	23.2	97	8.07
	4-S	50	40.46	2.66	203.98	7.75	14.26	615.72	160.86	6.51	34.402	0.14	0.247	23.4	99	8.08
	5-B	50	4.06	1.26	178.50	4.96	13.02	200.76	173.18	8.06	35.001	0.10	0.165	23.4	98	8.11
	6-S	100	23.24	1.82	180.46	6.20	12.40	373.80	155.40	6.20	34.678	0.13	0.207	23.4	100	8.05
	7-B	100	4.06	1.12	162.96	4.65	11.47	126.00	157.78	6.82	34.969	0.10	0.177	23.3	99	8.10
	8-S	200	13.58	2.38	181.72	6.20	13.64	234.64	165.76	7.44	34.845	0.09	0.188	23.3	100	8.11
	9-S	300	4.20	1.40	169.54	4.65	11.78	117.60	163.94	7.13	34.958	0.09	0.150	23.4	100	8.12
	10-S	500	6.44	2.38	169.54	4.65	11.78	137.48	160.72	7.13	34.948	0.10	0.234	23.4	100	8.11
KL-B	11-S	0	15.68	2.10	168.84	5.89	12.09	278.04	151.06	6.20	34.778	0.11	0.238	23.2	100	8.10
	12-S	10	4.76	2.10	172.90	4.96	11.78	131.32	166.04	6.82	34.970	0.10	0.241	23.3	100	8.07
	13-B	10	5.18	2.10	162.68	6.20	12.09	112.84	155.40	5.89	34.976	0.09	0.200	23.4	99	8.10
	14-S	50	13.44	2.10	152.60	6.20	12.09	253.40	137.06	5.89	34.817	0.09	0.192	23.3	100	8.10
	15-B	50	2.80	1.40	162.68	4.96	11.78	112.84	158.48	6.82	35.006	0.08	0.178	23.1	100	8.12
	16-S	100	4.62	0.84	159.32	4.65	11.47	114.52	153.86	6.82	34.968	0.08	0.159	23.1	100	8.12
	17-B	100	2.10	0.70	167.30	4.96	12.09	96.32	164.50	7.13	35.002	0.07	0.166	23.0	100	8.13
	18-S	200	6.86	0.84	164.64	4.96	11.78	144.20	156.94	6.82	34.936	0.07	0.175	23.4	100	8.14
	19-S	300	9.10	0.84	161.84	4.96	11.78	162.12	151.90	6.82	34.919	0.07	0.163	23.2	101	8.13
	20-S	500	8.54	0.98	161.14	4.96	11.78	157.92	151.62	6.82	34.925	0.08	0.149	23.1	100	8.13
KL-C	21-S	0	29.40	2.66	192.64	7.13	13.95	455.00	160.58	6.82	34.535	0.11	0.293	23.0	99	8.12
	22-S	10	28.42	2.94	196.00	7.13	13.95	448.84	164.64	6.82	34.558	0.11	0.255	23.2	99	8.11
	23-B	10	7.70	2.24	174.44	5.89	12.71	131.60	164.50	6.82	34.955	0.10	0.257	23.2	99	8.11
	24-S	50	20.72	2.66	168.42	6.51	12.71	332.08	145.04	6.20	34.693	0.09	0.270	23.3	100	8.10
	25-B	50	6.72	1.54	161.70	4.96	12.09	151.20	153.44	7.13	34.938	0.10	0.195	23.4	99	8.11
	26-S	100	2.52	1.68	154.84	5.27	12.09	94.92	150.64	6.82	34.989	0.06	0.161	23.5	100	8.13
	27-B	100	2.10	1.54	168.28	5.58	13.33	92.68	164.64	7.75	35.004	0.08	0.163	23.4	99	8.14
	28-S	200	2.52	1.12	181.72	4.65	12.40	92.68	178.08	7.75	34.997	0.08	0.210	23.4	100	8.15
	29-S	300	2.52	0.98	150.78	4.65	11.47	90.44	147.28	6.82	34.996	0.06	0.155	23.3	100	8.15
	30-S	500	1.54	7.98	219.24	7.44	19.22	76.44	209.72	11.78	35.018	0.09	0.303	23.4	100	8.12
KL-D	31-S	0	5.60	2.38	168.84	5.58	12.09	164.36	160.86	6.51	34.900	0.11	0.271	23.0	99	8.10
	32-S	10	5.60	1.96	154.70	4.96	11.47	138.04	147.14	6.51	34.922	0.10	0.216	23.1	99	8.11
	33-B	10	4.20	1.54	181.58	4.96	11.78	106.12	175.84	6.82	34.981	0.10	0.181	23.5	98	8.13
	34-S	50	4.20	1.54	171.50	4.65	11.78	107.80	165.76	7.13	34.972	0.09	0.169	23.4	99	8.13
	35-B	50	3.64	1.12	167.44	4.96	11.47	101.64	162.68	6.51	34.977	0.06	0.172	23.3	98	8.14
	36-S	100	4.20	1.40	163.94	4.65	11.47	109.48	158.34	6.82	34.966	0.07	0.156	23.6	100	8.13
	37-B	100	2.24	2.10	148.54	4.65	11.47	89.32	144.20	6.82	34.990	0.09	0.160	23.6	98	8.14
	38-S	200	1.96	0.84	141.82	4.34	11.16	89.32	139.02	6.82	34.997	0.06	0.131	23.5	100	8.13
	39-S	300	0.00	0.42	134.40	4.03	10.85	49.00	133.98	6.82	35.040	0.05	0.079	23.8	100	8.13
	40-S	500	0.00	0.42	148.40	4.34	11.16	54.88	147.98	6.82	35.029	0.07	0.086	24.0	101	8.16
KL-E	41-S	0	13.86	3.08	195.44	6.51	12.71	245.00	178.50	6.20	34.797	0.10	0.198	22.9	99	8.13
	42-S	10	12.46	2.38	182.70	6.20	12.40	224.84	167.86	6.20	34.822	0.09	0.245	22.5	99	8.11
	43-B	10	5.32	2.10	206.78	5.58	12.40	98.56	199.36	6.82	34.993	0.12	0.159	23.0	99	8.12
	44-S	50	8.54	2.24	165.06	5.89	11.78	158.48	154.28	5.89	34.912	0.13	0.173	22.8	100	8.11
	45-B	50	4.06	1.40	165.76	4.96	11.16	108.36	160.30	6.20	34.979	0.07	0.136	22.8	98	8.13
	46-S	100	1.96	1.54	146.86	4.65	11.16	84.28	143.36	6.51	34.994	0.10	0.111	22.8	100	8.13
	47-B	100	1.68	1.12	112.56	4.65	9.92	68.04	109.76	5.27	35.013	0.07	0.092	22.8	99	8.15
	48-S	200	0.00	0.56	98.42	4.34	9.92	47.88	97.86	5.58	35.031	0.09	0.120	23.0	100	8.17
	49-S	300	0.00	0.42	107.80	4.34	9.92	61.88	107.38	5.58	35.034	0.09	0.105	22.9	100	8.17
	50-S	500	0.00	0.98	103.74	4.34	9.92	47.88	102.76	5.58	35.036	0.05	0.082	23.1	100	8.17
Geometric Means			5.49	1.58	161.39	5.87	12.79	158.07	146.57	6.38	34.838	0.09	0.179	23.2	100	8.12
Anchialine Pool and Well Samples																
Well 1	W		2335.20	3.22	4137.00	260.09	304.42	22092.28	1798.58	44.33	2.483	0.70	*	23.0	60	7.91
Well 2	W		2711.24	0.42	4459.28	202.43	230.33	27754.72	1747.62	27.90	2.836	0.39	*	22.9	60	7.95
Well 3	W		2601.20	3.22	4479.02	218.86	246.14	28012.88	1874.60	27.28	2.811	1.17	*	22.7	68	8.00
Well 4	W		2547.86	6.86	4592.98	224.44	245.83	29324.96	2038.26	21.39	1.911	0.35	*	22.6	60	7.89
Well 5	W		2104.06	3.36	4008.20	218.86	244.59	27760.60	1900.78	25.73	2.403	0.19	*	22.8	60	7.99
Pond 1	A		187.74	66.08	1955.94	198.40	319.30	29315.44	1702.12	120.90	3.323	0.53	4.207	23.1	54	7.30

APPENDIX 2. Summary of the water quality parameters as measured at 56 sites for the KaLaeMano project on 29 June 2010. One sample is from an anchialine pool, five from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No	DFS [m]	Nitrate N	Ammonia N	TN	Ortho P	TP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [`C]	Oxygen [%]	pH
KL-A	1-S	0	111.16	2.80	253.40	12.09	16.43	1387.40	139.44	4.34	33.434	0.17	0.256	25.3	99	7.97
	2-S	10	69.16	2.80	208.74	9.30	14.26	1065.40	136.78	4.96	33.952	0.19	0.270	25.1	99	8.01
	3-B	10	9.94	1.96	189.00	5.27	12.09	308.84	177.10	6.82	34.764	0.18	0.369	25.3	97	8.03
	4-S	50	64.12	2.24	221.48	8.68	12.40	1037.40	155.12	3.72	34.023	0.14	0.230	25.2	99	8.05
	5-B	50	3.78	0.70	120.68	4.34	9.92	152.88	116.20	5.58	34.971	0.10	0.270	25.4	98	8.06
	6-S	100	25.06	1.40	153.86	6.20	13.02	526.40	127.40	6.82	34.560	0.12	0.161	25.4	100	8.07
	7-B	100	1.82	0.28	107.94	4.03	9.61	156.52	105.84	5.58	35.025	0.15	0.183	25.4	99	8.08
	8-S	200	3.50	0.28	127.12	4.03	9.61	136.08	123.34	5.58	34.993	0.09	0.171	25.1	100	8.09
	9-S	300	6.30	0.42	117.60	4.34	9.92	183.68	110.88	5.58	34.907	0.08	0.172	25.3	100	8.09
	10-S	500	0.14	0.00	106.68	4.03	10.85	483.84	106.54	6.82	35.038	0.08	0.231	25.5	99	8.09
KL-B	11-S	0	37.38	2.52	175.70	7.75	13.02	610.68	135.80	5.27	34.451	0.13	0.060	24.8	99	8.08
	12-S	10	29.68	1.68	150.08	6.51	13.02	515.48	118.72	6.51	34.500	0.11	0.222	24.9	99	8.07
	13-B	10	3.50	1.12	159.74	4.65	9.92	146.72	155.12	5.27	34.967	0.16	0.229	24.7	99	8.07
	14-S	50	21.14	1.40	145.04	6.51	14.57	780.36	122.50	8.06	34.662	0.14	0.188	25.1	100	8.07
	15-B	50	4.76	0.56	120.82	4.34	8.37	183.12	115.50	4.03	34.949	0.16	0.165	25.4	99	8.07
	16-S	100	0.84	0.00	106.82	3.41	9.61	71.68	105.98	6.20	35.045	0.10	0.202	25.7	100	8.09
	17-B	100	0.14	0.00	106.12	3.72	9.92	63.28	105.98	6.20	35.053	0.10	0.213	24.9	99	8.10
	18-S	200	0.28	0.00	125.86	3.72	9.92	70.84	125.58	6.20	35.032	0.07	0.217	25.3	100	8.11
	19-S	300	0.28	0.42	131.04	4.34	10.23	71.68	130.34	5.89	35.045	0.07	0.230	25.5	100	8.10
	20-S	500	1.40	0.00	111.86	4.03	10.85	107.24	110.46	6.82	34.994	0.09	0.310	26.0	100	8.10
KL-C	21-S	0	58.24	2.38	201.32	8.99	14.57	831.32	140.70	5.58	34.095	0.12	0.428	25.4	99	8.08
	22-S	10	19.88	1.54	140.70	5.89	11.16	352.80	119.28	5.27	34.658	0.12	0.337	25.5	99	8.08
	23-B	10	2.66	0.98	108.78	4.34	9.92	127.96	105.14	5.58	34.983	0.13	0.230	25.3	98	8.08
	24-S	50	16.94	1.26	157.92	5.58	10.23	330.68	139.72	4.65	34.688	0.10	0.225	25.1	99	8.08
	25-B	50	0.84	0.42	126.70	4.34	10.54	106.40	125.44	6.20	35.040	0.08	0.208	25.9	99	8.09
	26-S	100	2.80	0.84	133.70	4.34	10.23	123.20	130.06	5.89	34.979	0.08	0.177	25.4	100	8.10
	27-B	100	0.14	0.00	111.30	3.72	8.99	70.56	111.16	5.27	35.056	0.11	0.217	25.1	99	8.11
	28-S	200	0.56	0.56	114.52	4.34	7.13	73.64	113.40	2.79	35.045	0.08	0.234	25.6	100	8.11
	29-S	300	0.98	0.00	111.30	4.03	7.44	213.36	110.32	3.41	34.987	0.07	0.237	25.9	100	8.11
	30-S	500	0.14	0.00	113.96	3.72	8.99	100.52	113.82	5.27	35.036	0.07	0.276	26.1	100	8.12
KL-D	31-S	0	4.62	1.68	143.92	4.96	8.99	882.84	137.62	4.03	34.947	0.10	0.320	24.5	99	8.09
	32-S	10	2.94	1.12	106.96	4.03	6.82	132.16	102.90	2.79	34.981	0.09	0.219	24.6	99	8.09
	33-B	10	3.36	1.54	133.14	4.96	6.82	128.24	128.24	1.86	34.994	0.10	0.210	24.7	98	8.09
	34-S	50	4.34	0.84	118.44	4.65	7.44	159.04	113.26	2.79	34.954	0.10	0.201	25.2	99	8.09
	35-B	50	1.82	0.56	115.22	4.34	7.44	101.92	112.84	3.10	35.037	0.09	0.230	24.7	99	8.10
	36-S	100	1.54	0.28	112.00	4.03	7.44	88.76	110.18	3.41	35.031	0.08	0.225	25.0	100	8.11
	37-B	100	0.00	0.00	115.22	3.72	7.44	84.84	115.22	3.72	35.054	0.07	0.239	25.4	99	8.12
	38-S	200	1.96	0.42	112.70	4.03	7.44	110.88	110.32	3.41	35.009	0.06	0.233	25.3	100	8.12
	39-S	300	3.08	0.56	127.40	4.03	7.75	169.12	123.76	3.72	34.960	0.09	0.234	25.3	100	8.12
	40-S	500	0.00	0.00	111.44	4.03	7.75	165.20	111.44	3.72	35.036	0.09	0.302	25.1	100	8.13
KL-E	41-S	0	6.02	1.68	137.62	4.96	7.75	189.00	129.92	2.79	34.897	0.10	0.274	25.0	99	8.09
	42-S	10	3.78	0.70	113.40	4.65	8.06	116.20	108.92	3.41	34.996	0.11	0.211	24.9	99	8.09
	43-B	10	2.38	0.56	126.84	4.65	7.75	96.04	123.90	3.10	35.033	0.10	0.229	24.7	99	8.10
	44-S	50	3.92	0.98	119.14	5.27	7.44	112.84	114.24	2.17	34.983	0.10	0.180	24.9	99	8.10
	45-B	50	1.82	0.42	121.66	4.96	6.82	95.20	119.42	1.86	35.034	0.08	0.222	24.9	99	8.11
	46-S	100	2.24	0.28	99.40	4.65	6.51	89.04	96.88	1.86	35.027	0.10	0.246	24.5	100	8.12
	47-B	100	0.70	0.28	112.14	1.86	7.75	82.88	111.16	5.89	35.057	0.10	0.262	24.6	99	8.13
	48-S	200	3.22	0.56	113.40	2.17	7.75	140.84	109.62	5.58	34.964	0.11	0.244	24.6	100	8.13
	49-S	300	1.54	0.00	126.28	2.48	8.06	118.72	124.74	5.58	35.006	0.11	0.265	25.0	100	8.13
	50-S	500	0.70	0.00	114.10	1.55	8.06	96.60	113.40	6.51	35.030	0.10	0.279	25.6	100	8.14
Geometric Means			3.67	0.77	132.42	4.69	9.54	213.19	119.99	4.51	34.796	0.10	0.227	25.2	100	8.09
Anchialine Pool and Well Samples																
Well 1	W		2304.82	0.98	3727.36	178.56	373.86	17005.52	1421.56	195.30	2.899	2.20	*	23.8	55	7.38
Well 2	W		2634.80	0.98	4100.18	161.82	244.90	20784.40	1464.40	83.08	2.877	0.23	*	23.6	59	7.63
Well 3	W		2555.84	0.56	4003.16	180.73	272.18	20233.92	1446.76	91.45	2.883	0.54	*	23.4	60	7.82
Well 4	W		2509.50	1.26	3936.94	187.55	281.48	21652.68	1426.18	93.93	1.909	0.40	*	23.3	60	7.86
Well 5	W		2239.44	6.30	3543.82	185.69	281.79	20829.48	1298.08	96.10	2.431	0.25	*	23.7	60	7.88
Pond 1	A		1317.96	16.10	2212.28	147.87	230.02	17364.20	878.22	82.15	3.240	0.47	0.014	24.9	71	7.60

APPENDIX 3. Summary of the water quality parameters as measured at 55 sites for the KaLaeMano project on 12 November 2010. One sample is from an anchialine pool, six from a mauka wells, and 50 from the adjacent ocean. For ocean samples the underlined geometric mean exceed the regional Kona coast Department of Health water quality standards applied to nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorphyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No	DFS [m]	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	CHL-a	Temp. [`C]	Oxygen [%]	pH
KL-A	1-S	0	15.82	4.90	108.22	5.27	11.47	391.44	87.50	6.20	34.675	0.61	0.311	27.1	98	8.02
	2-S	10	7.28	4.20	89.46	3.72	9.92	221.76	77.98	6.20	34.868	0.34	0.213	25.8	99	8.02
	3-B	10	4.20	2.80	116.76	3.10	9.30	139.72	109.76	6.20	34.971	0.28	0.213	25.6	97	8.00
	4-S	50	4.20	2.94	137.90	2.79	10.85	133.28	130.76	8.06	34.977	0.26	0.177	25.3	99	8.03
	5-B	50	5.46	2.80	94.92	3.41	9.61	195.72	86.66	6.20	34.907	0.19	0.213	25.2	99	8.03
	6-S	100	1.26	1.54	71.40	2.17	8.68	70.00	68.60	6.51	35.065	0.13	0.123	25.4	100	8.07
	7-B	100	1.12	1.54	73.22	2.17	9.30	61.32	70.56	7.13	35.063	0.10	0.121	25.7	99	8.09
	8-S	200	1.26	1.68	79.24	2.48	9.30	59.08	76.30	6.82	35.060	0.10	0.182	25.2	100	8.10
	9-S	300	1.26	1.12	79.24	1.86	8.68	54.60	76.86	6.82	35.060	0.12	0.143	25.2	100	8.10
	10-S	500	3.08	2.94	91.28	2.79	10.54	52.36	85.26	7.75	35.066	0.11	0.160	25.5	101	8.10
KL-B	11-S	0	4.34	4.76	125.16	3.41	9.61	173.32	116.06	6.20	34.931	0.29	0.233	25.2	99	8.09
	12-S	10	2.38	2.66	91.28	2.48	9.30	85.40	86.24	6.82	35.043	0.16	0.209	25.4	99	8.10
	13-B	10	2.38	3.08	85.82	2.79	8.68	89.32	80.36	5.89	35.025	0.13	0.197	25.3	98	8.10
	14-S	50	1.12	1.40	79.80	1.86	8.37	59.92	77.28	6.51	35.062	0.14	0.126	25.3	99	8.12
	15-B	50	0.56	1.54	79.24	2.17	8.68	53.20	77.14	6.51	35.063	0.13	0.131	24.8	98	8.13
	16-S	100	0.00	1.26	81.06	1.86	8.37	49.00	79.80	6.51	35.065	0.16	0.128	25.8	100	8.12
	17-B	100	0.00	1.96	102.20	2.17	8.99	48.72	100.24	6.82	35.067	0.14	0.140	25.6	99	8.14
	18-S	200	1.26	1.40	84.00	1.86	8.68	48.44	81.34	6.82	35.064	0.22	0.142	25.4	100	8.14
	19-S	300	0.56	1.26	108.22	1.86	8.68	46.20	106.40	6.82	35.063	0.15	0.112	26.2	100	8.14
	20-S	500	0.00	1.82	84.70	2.17	8.37	45.92	82.88	6.20	35.068	0.13	0.128	26.3	100	8.14
KL-C	21-S	0	1.12	4.76	94.92	3.10	8.99	87.08	89.04	5.89	35.013	0.17	0.233	25.1	99	8.11
	22-S	10	1.26	4.06	84.00	3.10	8.99	91.00	78.68	5.89	34.994	0.18	0.198	25.6	99	8.10
	23-B	10	1.26	3.08	91.98	3.10	9.92	88.48	87.64	6.82	35.003	0.18	0.348	25.2	99	8.10
	24-S	50	0.00	1.68	82.88	1.86	8.68	52.92	81.20	6.82	35.063	0.10	0.126	25.4	100	8.12
	25-B	50	0.14	1.82	86.52	2.17	8.68	48.44	84.56	6.51	35.062	0.10	0.140	25.2	99	8.15
	26-S	100	0.00	1.54	125.86	2.17	8.68	46.20	124.32	6.51	35.068	0.11	0.118	25.2	100	8.15
	27-B	100	0.00	1.54	96.74	2.17	8.68	45.92	95.20	6.51	35.069	0.08	0.111	25.0	99	8.15
	28-S	200	0.00	1.68	94.36	2.17	9.92	45.92	92.68	7.75	35.077	0.10	0.143	25.4	100	8.15
	29-S	300	0.00	1.54	145.60	1.86	11.16	43.40	144.06	9.30	35.063	0.07	0.154	25.4	100	8.15
	30-S	500	0.00	1.26	141.82	2.17	11.16	41.16	140.56	8.99	35.078	0.18	0.269	25.2	100	8.16
KL-D	31-S	0	1.12	3.36	107.52	3.10	10.54	88.76	103.04	7.44	35.011	0.13	0.166	25.1	99	8.12
	32-S	10	0.56	3.08	114.52	3.10	10.54	63.56	110.88	7.44	35.041	0.16	0.131	25.0	100	8.11
	33-B	10	0.56	3.36	146.16	3.72	14.88	59.36	142.24	11.16	35.054	0.15	1.019	25.1	99	8.13
	34-S	50	0.14	2.10	128.38	2.17	10.23	48.72	126.14	8.06	35.067	0.13	0.125	25.1	100	8.15
	35-B	50	0.14	2.38	117.60	2.48	9.92	44.24	115.08	7.44	35.069	0.14	0.155	25.0	99	8.15
	36-S	100	0.14	1.82	94.22	1.86	8.99	42.00	92.26	7.13	35.069	0.08	0.111	25.1	100	8.16
	37-B	100	0.14	1.68	113.12	1.86	9.92	39.76	111.30	8.06	35.068	0.07	0.103	25.2	99	8.16
	38-S	200	0.00	1.54	100.52	1.86	8.99	37.52	98.98	7.13	35.067	0.07	0.100	24.8	100	8.17
	39-S	300	0.00	1.68	80.78	1.86	9.30	33.04	79.10	7.44	35.070	0.11	0.097	25.0	100	8.17
	40-S	500	0.00	1.82	87.08	2.17	8.99	36.96	85.26	6.82	35.070	0.06	0.114	24.9	101	8.17
KL-E	41-S	0	1.12	4.06	111.72	3.72	9.61	84.56	106.54	5.89	35.014	0.12	0.192	25.0	99	8.13
	42-S	10	1.26	3.64	143.36	3.72	10.54	86.24	138.46	6.82	35.015	0.11	0.154	25.0	99	8.11
	43-B	10	1.82	3.64	265.58	3.72	10.54	84.00	260.12	6.82	35.023	0.13	0.198	24.9	98	8.11
	44-S	50	2.38	3.50	104.72	3.72	8.68	79.52	98.84	4.96	35.033	0.09	0.136	24.9	100	8.10
	45-B	50	1.82	3.36	138.32	4.03	11.16	62.72	133.14	7.13	35.049	0.12	0.255	24.8	99	8.11
	46-S	100	0.14	2.10	132.58	2.48	10.23	42.00	130.34	7.75	35.067	0.07	0.115	25.0	100	8.15
	47-B	100	0.14	2.10	138.88	2.48	10.23	39.48	136.64	7.75	35.069	0.11	0.118	25.9	99	8.16
	48-S	200	0.14	2.10	131.88	2.48	10.23	37.24	129.64	7.75	35.068	0.09	0.136	24.8	100	8.16
	49-S	300	0.14	2.10	134.40	2.48	10.54	36.96	132.16	8.06	35.067	0.10	0.161	24.7	101	8.17
	50-S	500	0.14	2.24	138.88	2.17	10.23	38.92	136.50	8.06	35.068	0.07	0.122	24.9	101	8.17
Geometric Means			0.77	2.21	103.09	2.47	9.56	62.38	99.02	6.98	35.033	0.13	0.150	25.3	100	8.12
Anchialine Pool and Well Samples																
Well 1	W		2732.94	93.94	3388.14	134.23	197.47	26916.40	561.26	63.24	3.655	0.93	*	23.0	66	8.10
Well 2	W		2832.62	93.66	3381.70	150.97	223.51	27294.68	455.42	72.54	2.878	0.33	*	23.2	78	8.19
Well 3	W		2581.60	92.54	3223.22	161.82	235.29	26104.12	549.08	73.47	2.686	0.55	*	23.0	75	8.19
Well 4	W		2553.88	92.96	3305.26	181.97	244.90	28369.32	658.42	62.93	1.893	0.19	*	22.8	62	8.10
Well 5	W		2074.38	94.22	2741.76	177.63	244.59	27383.44	573.16	66.96	2.440	0.20	*	23.1	71	8.02
Well 6	W		2657.48	94.78	3285.94	163.68	229.09	28124.88	533.68	65.41	2.510	0.10	*	23.2	73	8.06
Pond 1	A		209.30	307.16	1664.18	438.34	510.26	29219.40	1147.72	71.92	3.197	1.55	2.209	23.6	65	7.45