

**2008 ANNUAL
WATER QUALITY MONITORING REPORT
IN SUPPORT OF THE DEVELOPMENT AT
KA LAE MANO, NORTH KONA**

Prepared For:

WB Kukio Resorts, LLC
P.O. Box 5349
Kailua-Kona, Hawaii 96745

By:

Richard Brock, Ph.D.
Environmental Assessment, LLC
1232 Lunalilo Home Road
Honolulu, Hawaii 96825

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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 biota 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 and 24 October 2008. This document presents the results of the latter four (2008) during construction water quality monitoring surveys.

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 Hawaii coast thus compliance of these waters to state water quality standards may be affected.

There have been twenty-one water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last fifteen 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 seventeen surveys (20 September 2004 through 24 October 2008). 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. These conditions reduced mixing, hence increasing the sampling of effluxing groundwater which resulted in a higher rate of noncompliance. 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 and 65% in 2008 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 four-year during construction noncompliance rate is calculated as an overall mean, the rate of noncompliance among the parameters falls to 42% 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 be high in 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 since the commencement of construction?" and found that the means for nitrate nitrogen, total nitrogen, orthophosphorous, silica, turbidity 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 were not significant. The ammonia nitrogen means are not particularly elevated (preconstruction mean = 1.67 ug/l; during construction mean = 2.36 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 159-month period of this study?" The Kruskal-Wallis ANOVA found statistical differences among the twenty-one sample dates for all water quality parameters. The greatest mean concentrations are found in the preconstruction (baseline) period for all parameters except ammonia nitrogen in October 2008, salinity in November 2007, chlorophyll-*a* in October 2007, percent saturation of dissolved oxygen in December 2005, temperature in September 2004 and pH in July 2007. 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.

Other than ammonia nitrogen in the during construction period, there is no evidence of a trend of increasing concentrations with time; indeed, the during construction means (2005, 2006, 2007 and 2008)

are spread with no order through the range of most parameters. In the case of ammonia nitrogen, the statistically greater mean concentrations found in recent during construction sample periods are 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. As of February 2008, only 0.07 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. 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 sixteen during construction (2005-2008) surveys show them to be typical of well-flushed, West Hawaii sites. The 2005-2008 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 Hawaii regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealahou 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 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. This document reports on the findings of the 2008 quarterly monitoring program.

METHODS

1. Sample Site Locations

The Department of Health had developed regional water quality standards for the marine waters of the West Hawaii 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 resistance 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, 2006, 2007 and 2008 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.

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. 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 Hawaii coastal waters. The criteria include ammonia nitrogen (NH_4), nitrate + nitrite nitrogen ($\text{NO}_3 + \text{NO}_2$, 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.

Surface water samples are collected by opening 500 ml polyethylene bottles at the desired depth. Samples collected at depth are done so using a Niskin bottle. 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. Analyses for ammonia nitrogen, orthophosphate 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 similarly analyzed following digestion using unfiltered sample water (Standard Methods 1999).

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 Nephelometer 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 thoroughly 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; filters are frozen until laboratory analyses are carried out. Laboratory procedures follow Standard Methods (1999) and pigments are extracted and determined fluorometrically. Salinity samples are collected in 125 ml polyethylene bottles in the field, filled completely and capped tightly until measurement by AGE salinometer in the laboratory. In the field oxygen is measured using an YSI Model 58 meter, pH is determined using a Hanna

millivolt meter and temperature is measured using a laboratory grade thermometer.

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 (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 and all data from these three years are presented in their entirety in Brock (2006, 2007a, 2008). The 2008 quarterly surveys were carried out on 13 March, 8 May, 26 August and 24 October 2008 and these data are presented below in Appendices 1 - 4 and the data are summarized in Table 5. 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 6 as means by survey date. The 2008 well data are given in their entirety in Appendices 1 - 4. Finally the single anchialine pool present at Ka Lae Mano is sampled during the quarterly surveys and these data are summarized in Table 7.

1. Compliance with Department of Health Criteria

The Hawaii 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" (Hawaii Administrative Rules, Chapter 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 Hawaii 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 8 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 8). 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 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 8. In Table 1 the "not to exceed" criteria (as given in Table 8) 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 and 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/noncompliance 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 noncompliance, 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 9). 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 9).

B. "During Construction" Compliance

"During construction" surveys have been carried out quarterly since the commencement of site grading in early 2005, thus there have been 16 surveys. Data for the four 2005 surveys are summarized as geometric means in Table 2 and Table 3 presents the geometric mean summaries for 2006 and the geometric mean summaries for 2007 are given in Table 4. The data from the four 2008 surveys are given in Appendices 1 - 4 and are summarized as geometric means by transect in Table 5. In no cases during any of the sixteen during construction surveys completed to date 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 8 apply to these data.

The 2005 data are summarized in Table 2 as geometric means for each of the five transects sampled on each of the four dates. Geometric means that exceed the regional standards are underlined. Referring to Table 2, nitrate nitrogen was out of compliance on transect A in March

2005, total nitrogen did not meet state standards on transects A and B in March, A, B, and C in September and A, B, C, and E in the December 2005 survey. The geometric means for orthophosphorous did not meet state standards on transects A and C in March 2005 and turbidity was noncompliant on transect A in March and July, on A, B, C and D in September and on transects A, B and D in the December 2005 survey. Finally, chlorophyll-*a* geometric means did not meet state regional standards on transects A, C and D in July 2005. These data can be summarized: there are seven parameters sampled on each of five transects on four dates resulting in 140 opportunities of noncompliance in these during construction data and 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. Summarizing the noncompliance in the 2006 data, nitrate nitrogen did not meet state standards on transect A in March and August as well as transects C, D and E in August. Ammonia nitrogen was out of compliance on Transect A in August. Total nitrogen was out of compliance on all transects in August and November and on transects B, C, D and E in March, orthophosphorous was out of compliance on transects A, B and C in March, and transect A in November. In August orthophosphorous and total phosphorus were out of compliance at all transects, turbidity was out of compliance at all transects in March and again at transect A on the other three dates and did not meet the standards in November at transect B. Finally chlorophyll-*a* was out of compliance at transect A on March, June and August and was out of compliance on transects C and D in June 2006. Summarizing these data, there were 49 instances (out of a possible total of 140 or 35%) where a parameter was out of compliance in 2006. Overall compliance of parameters with state standards is greater in the during construction period than in the baseline period.

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. Underlined geometric means are those out of compliance with state regional standards. Referring to Table 4 nitrate was out of compliance on eight occasions, ammonia nitrogen on 7 occasions, total nitrogen on 20 occasions (on every transect during every survey), orthophosphorous on ten occasions, total phosphorus on 8 occasions, turbidity on eleven occasions and chlorophyll-*a* on six occasions resulting in 70 instances where a parameter was out of compliance with state regional standards. This results in a $70/140 = 50\%$ rate of noncompliance which is equal to the rate of non-compliance in the baseline data set.

Finally, 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 Hawaii regional standards. In 2008 nitrate was out of compliance on fifteen occasions, ammonia nitrogen on eight occasions, total nitrogen on every quarterly survey (i.e., 20 instances), orthophosphorous on fifteen occasions, total phosphorus on 14 instances, turbidity on seventeen instances and chlorophyll-*a* on two instances. This results in an overall noncompliance of $91/140 = 65\%$ rate of noncompliance.

Inspection of the grand geometric means derived for each sample period and transect in the baseline period (Table 1) to the same data from the 2005 (Table 2), 2006 (Table 3), 2007 (Table 4) and 2008 (Table 5) during construction period finds that the survey period grand means are greater in the baseline period for all parameters except chlorophyll-*a* (greatest baseline=0.384 ug/l, greatest during construction=0.440 ug/l), salinity (greatest baseline=34.859 ppt, greatest during construction=35.002 ppt), percent dissolved oxygen concentration (greatest baseline=100%, greatest during construction=102%), pH (greatest baseline=8.24 units, greatest during construction=8.27 units) and ammonia nitrogen (greatest baseline= 4.18 ug/l, greatest during construction=5.66 ug/l). These data support the contention that the grading and landscaping activities occurring on the Ka Lae Mano project site are not having an impact on the quality of the marine waters fronting the project site.

However the question may be raised, "What about the increase in the annual rate of noncompliance among the parameters through the during construction period?" As noted above, the rate of noncompliance in the eleven year baseline period was 50%, then declining to 17% in the first year (2005) of the during construction period, increasing to 35% in 2006, jumping to 50% in 2007 and most recently increasing to 65% in 2008. These data may suggest that there could be materials leaching from the minimal landscaping present on the Ka Lae Mano project site reaching the ocean. If this were the case, the expected increases over time should be with the parameters that are measured and are used in fertilizers, namely, nitrate nitrogen, total nitrogen, orthophosphorous and total phosphorus. However, the highest geometric means for these parameters are found in the baseline data (Table 1), i.e., nitrate nitrogen=86.28 ug/l, total nitrogen=264.30 ug/l, orthophosphorous=12.06 ug/l and total phosphorus=21.52 ug/l which are well above any of the during construction means (Tables 2, 3, 4 and 5). Furthermore, the baseline dataset spans an eleven-year period (1993 through September 2004) while the during construction period only covers a four year period. The baseline rate of noncompliance is a mean (here 50%) spread over eleven years but the during construction rate of noncompliance is calculated annually above. If the during construction rate of noncompliance were calculated for the four year period, the mean rate is 42% which is still less than the 50% obtained in the baseline period.

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 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 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 6 for wells and Table 7 for the anchialine pool. The well data are presented as means for each parameter by survey date. The 2008 well and anchialine pool data are given in their entirety in Appendices 1 - 4. 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).

3. 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 10 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 10 (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 10) where nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells in the during construction period. However, orthophosphorous is 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 parameter concentrations between mauka to makai wells?" we find the same result as just above; namely, orthophosphorous is significantly greater in the mauka wells over the makai wells, nitrate nitrogen, total nitrogen and salinity are significantly greater in the makai wells over the mauka wells (Table 10, 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 10, 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 10, 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 10, Part A) probably because of the small sample size (only one sample period with two mauka and three makai wells). The during construction period analysis comparing mauka to makai wells (Table 10, Part B) finds greater orthophosphorous in mauka wells over makai wells; 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. However, significantly greater nitrate nitrogen and total nitrogen in the makai wells over the mauka wells suggests an input of nitrogen to the groundwater is occurring somewhere on the project site. The source is not from the limited landscaping present at Ka Lae Mano because if it were, orthophosphorous should likewise be greater in the makai wells over the concentrations found in the mauka wells and it is not. (Note that both nitrate nitrogen and orthophosphorous are used in fertilizing landscaping). 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 is for dust control (where only enough is spread on the surface to prevent airborne dust) and limited irrigation. 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.

The results from Part C (Table 10) follow those of directly above (Part B) simply because the during construction data set is significantly greater (n=99) 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 natural 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.

4. 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 and again in March, May, August and October 2008. 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 11 where the means for nitrate nitrogen, total nitrogen, orthophosphorous, silica, turbidity 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*, percent saturation of dissolved oxygen and temperature. 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 is 2.662 ppt and the mean salinity in these wells since the start of construction is 2.694 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 170-

month period of this study encompassing five baseline field surveys and sixteen 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 12. The Kruskal-Wallis ANOVA found statistical differences among the twenty-one sample dates for all parameters. The SNK test also found significant differences among the twenty-one surveys for all parameters. The greatest means are found in the preconstruction (baseline) period for all parameters except ammonia nitrogen in October 2008, salinity in November 2007, chlorophyll-*a* in October 2007, percent saturation of dissolved oxygen in December 2005, temperature in September 2004 and pH in July 2007. It should be noted that for many of the parameters having their greatest mean concentrations occurring in the during construction period, have mean concentrations that 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.

Other than ammonia nitrogen in the during construction period, there is no evidence of a trend of increasing concentrations with time; indeed the during construction means (2005, 2006, 2007 and 2008) 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 most recent (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 Lanai Island (Brock 2007b)

The data do not support the contention that the ongoing grading and landscaping 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 preconstruction means for all parameters in the marine waters fronting this project site over time supports the contention that variability in these water quality parameters is the norm and this variability 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 construction 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. As of late February 2008, landscaping completed is comprised of 143 trees planted and 32,714 square feet of planted shrubs and grasses. Putting this landscaped area into the context of the entire project site (1,071 acres) it covers 0.07 percent of the total area or 0.09 percent of the area that could be developed (i.e., 876.6 acres). Thus at this juncture, preliminary grading of raw lava makes up the majority of the ongoing activities. The landscaping that has been planted is comprised 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 has been largely 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 is being 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. 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. However, the usual mechanism to transport materials to the groundwater table is sufficient water leaching 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. 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 Hawaii 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-one water quality surveys carried out in the marine environment fronting Ka Lae Mano over the last fifteen 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 seventeen surveys (20 September 2004 through 24 October 2008). 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.

Despite little salinity depression along the shoreline in many of the surveys, groundwater is effluxing along the Ka Lae Mano coastline because it is the sole source of the often elevated measured nutrient concentrations. It is surmised that when mixing is high in the coastal waters as occurs during period of surf, winds and in particular rising tides, the effluxing groundwater is rapidly mixed and 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 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 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 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 Hawaii. 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, 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 = 2.36 ug/l) and the presence of well-developed fish communities (i.e., 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 170-month period of this study?” The Kruskal-Wallis ANOVA found statistical differences among the twenty-one sample dates for all water quality parameters. The greatest mean concentrations are found in the preconstruction (baseline) period for all parameters except ammonia nitrogen in October 2008, salinity in November 2007, chlorophyll-*a* in October 2007, percent saturation of dissolved oxygen in December 2005, temperature in September 2004 and pH in July 2007. 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.

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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. As of February 2008, only 0.07 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. 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 sixteen (2005-2008) 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 Hawaii regional water quality standards is not unexpected in light of the lack of compliance noted at many other undeveloped (Kealahou 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	Ammonia	Ortho	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	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	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	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	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	34.859	0.23	0.264	24.9		
KL-B	7.56	2.92	89.39	6.31	11.43	199.89	77.01	34.760	0.28	0.286	24.8		
KL-C	2.85	1.79	83.71	4.70	9.81	100.91	78.84	34.840	0.22	0.196	24.9		
KL-D	2.63	1.12	80.61	3.89	9.34	73.15	76.76	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	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	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	33.682	0.10	0.305	24.8		8.17
KL-D	44.12	0.61	201.91	8.02	21.52	739.24	136.93	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	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	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	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	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	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	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	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	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	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	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	<u>9.17</u>	0.21	<u>122.55</u>	<u>5.55</u>	11.93	137.02	97.81	4.99	34.336	<u>0.13</u>	0.101	25.2	101	8.13
KL-B	2.64	0.25	<u>114.52</u>	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	<u>98.43</u>	<u>5.05</u>	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	<u>92.22</u>	<u>4.46</u>	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	<u>104.01</u>	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	<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 Mean	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
27-Sep-05														
KL-A	2.65	1.29	<u>115.36</u>	4.36	9.36	125.62	104.15	4.26	34.764	<u>0.12</u>	0.205	26.5	101	8.08
KL-B	1.18	1.07	<u>117.21</u>	3.34	9.24	106.37	111.89	5.74	34.824	<u>0.12</u>	0.174	27.0	102	8.09
KL-C	0.91	1.34	<u>117.27</u>	3.21	9.07	98.86	111.66	5.65	34.826	<u>0.12</u>	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	<u>0.10</u>	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	<u>104.79</u>	3.45	8.88	103.82	98.59	5.10	34.823	<u>0.10</u>	0.197	26.9	102	8.10
06-Dec-05														
KL-A	3.61	0.84	<u>110.74</u>	4.31	7.69	145.89	103.14	1.27	34.846	<u>0.22</u>	0.260	24.7	102	8.06
KL-B	3.42	0.67	<u>113.56</u>	3.61	8.23	116.51	107.61	4.36	34.862	<u>0.14</u>	0.187	24.6	102	8.09
KL-C	2.57	0.39	<u>147.46</u>	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	<u>93.37</u>	3.37	6.43	88.59	88.45	2.75	34.860	<u>0.11</u>	0.230	24.0	102	8.09
KL-E	1.78	0.57	<u>100.31</u>	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	<u>111.67</u>	3.52	7.62	100.83	106.32	3.06	34.866	<u>0.12</u>	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	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	<u>88.89</u>	<u>6.35</u>	11.20	458.09	56.47	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	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	34.466	<u>0.13</u>	0.228	25.8	101	8.20
KL-D	0.53	0.73	<u>112.11</u>	<u>4.32</u>	9.41	161.81	110.31	34.825	<u>0.10</u>	0.187	25.8	101	8.20
KL-E	0.89	0.91	<u>126.29</u>	<u>4.37</u>	8.69	171.04	121.78	34.781	<u>0.11</u>	0.233	25.5	101	8.19
Geometric Mean	2.14	1.28	<u>110.96</u>	<u>5.16</u>	10.35	244.93	94.26	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	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	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	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	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	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	34.625	0.08	<u>0.304</u>	27.8	101	8.21
25-Aug-06													
KL-A	7.06	2.92	<u>153.00</u>	<u>7.80</u>	15.20	241.69	120.40	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>	13.44	122.87	123.22	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>	14.13	191.66	86.84	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>	13.05	89.23	113.94	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>	14.23	97.58	111.49	34.737	0.07	0.188	27.3	100	8.10
Geometric Mean	4.92	1.23	<u>127.39</u>	<u>6.14</u>	13.99	137.73	110.36	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	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	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	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	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	34.817	0.08	0.216	25.9	100	8.18
Geometric Mean	0.68	1.21	<u>123.54</u>	4.51	8.77	132.94	120.34	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	<u>27.27</u>	<u>2.75</u>	<u>184.85</u>	<u>7.14</u>	<u>15.17</u>	<u>443.23</u>	<u>140.94</u>	7.98	34.151	<u>0.12</u>	0.244	26.0	100	8.12
KL-B	<u>13.77</u>	0.87	<u>188.56</u>	<u>5.41</u>	<u>14.18</u>	182.88	162.30	8.38	34.490	0.07	0.199	26.0	100	8.13
KL-C	<u>21.19</u>	1.49	<u>191.69</u>	<u>6.97</u>	<u>15.20</u>	223.82	154.57	8.20	34.332	0.07	0.221	25.4	100	8.10
KL-D	<u>10.66</u>	1.18	<u>169.25</u>	<u>6.76</u>	<u>13.83</u>	173.37	155.09	7.03	34.560	0.06	0.173	25.1	100	8.08
KL-E	<u>9.31</u>	1.16	<u>155.99</u>	<u>6.52</u>	<u>12.25</u>	146.28	145.02	5.71	34.621	0.06	0.162	25.0	100	8.10
Geometric Mean	<u>15.12</u>	1.37	<u>177.54</u>	<u>6.53</u>	<u>14.08</u>	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	<u>151.64</u>	<u>5.87</u>	<u>12.73</u>	257.06	122.01	6.81	34.511	<u>0.11</u>	<u>0.303</u>	27.1	100	8.26
KL-B	2.14	2.55	<u>158.70</u>	4.97	11.92	161.40	134.76	6.83	34.637	0.10	<u>0.306</u>	26.8	100	8.27
KL-C	2.96	<u>2.76</u>	<u>171.05</u>	<u>5.87</u>	<u>13.72</u>	249.56	138.93	7.71	34.514	0.10	<u>0.340</u>	26.8	100	8.24
KL-D	0.76	1.31	<u>130.72</u>	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	<u>136.03</u>	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	<u>148.90</u>	4.95	11.95	171.82	128.53	6.88	34.651	<u>0.10</u>	0.279	26.7	100	8.24
25-Oct-07														
KL-A	<u>5.65</u>	2.03	<u>136.47</u>	<u>6.86</u>	<u>16.27</u>	243.17	99.93	9.11	34.376	<u>0.28</u>	<u>0.440</u>	26.4	99	8.08
KL-B	1.96	1.28	<u>129.06</u>	<u>5.05</u>	<u>13.52</u>	113.15	114.17	8.28	34.819	0.15	<u>0.322</u>	27.0	100	8.12
KL-C	0.31	0.86	<u>136.95</u>	4.08	12.40	75.41	130.13	8.31	34.924	<u>0.12</u>	<u>0.332</u>	26.6	100	8.12
KL-D	0.14	0.97	<u>123.32</u>	3.58	10.96	77.64	121.30	7.28	35.002	<u>0.13</u>	0.270	27.0	100	8.11
KL-E	0.27	1.07	<u>112.03</u>	3.98	10.15	116.64	109.78	6.16	34.997	<u>0.10</u>	0.198	27.0	100	8.14
Geometric Mean	0.66	1.18	<u>127.22</u>	4.58	12.48	113.45	114.61	7.76	34.823	<u>0.15</u>	<u>0.302</u>	26.8	100	8.11
13-Nov-07														
KL-A	<u>6.60</u>	3.97	<u>113.62</u>	<u>5.02</u>	11.61	123.51	95.55	6.55	34.819	<u>0.18</u>	0.165	26.7	99	8.16
KL-B	3.69	2.18	<u>113.34</u>	4.08	11.15	81.76	103.36	7.00	34.904	<u>0.12</u>	0.142	26.1	100	8.12
KL-C	1.67	<u>2.51</u>	<u>114.92</u>	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	<u>106.96</u>	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	<u>2.73</u>	<u>113.27</u>	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	<u>112.39</u>	3.98	11.18	72.03	103.63	7.11	34.918	<u>0.11</u>	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>	<u>352.73</u>	<u>113.53</u>	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>	<u>291.10</u>	<u>102.16</u>	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>	<u>338.30</u>	<u>92.76</u>	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>	<u>219.37</u>	<u>92.58</u>	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>	<u>271.98</u>	<u>93.52</u>	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>	<u>280.90</u>	<u>107.20</u>	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>	<u>193.22</u>	<u>110.49</u>	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>	<u>224.37</u>	<u>111.52</u>	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>	<u>210.14</u>	<u>116.99</u>	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>	<u>222.71</u>	<u>128.62</u>	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>	<u>182.85</u>	<u>138.21</u>	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>	<u>141.13</u>	<u>130.77</u>	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>	<u>159.49</u>	<u>114.76</u>	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. 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 - 2008 quarterly surveys. Note that a dust control well (Well 6) was developed at the start of construction but was not sampled in December 2005 (pump off). These data are included in the means below. All values in ug/l unless otherwise noted.

DATE	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	SILICA	SALINITY	TURBIDITY	TEMP	OXYGEN	pH
							[ppt]	[NTU]	[°C]	[%]	
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	2757.41	4.49	4020.80	250.35	362.39	25154.32	2.148	0.32	23.4	66	7.87
08-May-08	2585.78	0.89	3297.85	213.78	275.81	26281.22	2.344	0.65	24.4	74	7.90
26-Aug-08	2659.28	1.17	3834.15	207.82	248.96	26692.34	2.498	0.69	24.1	76	7.97
24-Oct-08	2519.30	9.99	5074.46	208.42	276.86	21834.78	2.493	1.25	25.0	71	8.20

TABLE 7. 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	TURBIDITY	TEMP	OXYGEN	CHL-a	pH
							[ppt]	[NTU]	[°C]	[%]		
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	0.4	0.232	26.2	81	7.77

TABLE 8. 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 and 2008 surveys were all above 32 ppt, so no regression analysis was required to determine compliance with the regional water quality standards.

TABLE 9. 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	<u>31.13</u>	<u>9.08</u>	<u>147.99</u>	<u>7.77</u>	<u>16.31</u>	<u>592.05</u>	70.02	7.42
4	17	<u>9.98</u>	<u>3.67</u>	92.06	4.04	12.01	195.05	70.32	7.79
5	17	<u>6.55</u>	<u>3.92</u>	98.68	3.70	12.24	182.42	84.15	8.36
6	17	4.25	<u>3.71</u>	93.39	3.64	10.66	108.82	82.34	6.84
14	35	<u>68.23</u>	<u>12.69</u>	<u>170.11</u>	<u>8.46</u>	<u>14.50</u>	1214.79	84.76	5.67
15	34	<u>19.27</u>	<u>7.36</u>	<u>114.40</u>	<u>5.61</u>	12.09	395.32	77.50	6.02
16	20	<u>8.05</u>	<u>5.53</u>	<u>101.32</u>	4.11	11.23	211.43	77.80	6.48
17	17	3.86	<u>3.69</u>	86.75	3.31	10.70	127.38	76.15	6.96
18	17	<u>236.11</u>	<u>25.49</u>	<u>399.33</u>	<u>15.47</u>	<u>22.57</u>	3254.21	77.29	4.76
19	11	<u>66.50</u>	<u>11.36</u>	<u>223.43</u>	<u>7.45</u>	<u>15.51</u>	959.04	104.22	7.07
Grand Geometric Means		<u>17.14</u>	<u>7.03</u>	<u>132.68</u>	<u>5.32</u>	<u>14.18</u>	372.39	79.15	7.38

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

TABLE 10. 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.

Analyte	Mauka Wells Means (n)	Makai Wells Means (n)	Significantly Different?
A. Preconstruction Period: Are there significant differences between mauka and makai wells?			
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: Are there significant differences between mauka and makai wells?			
Nitrate-N	2248.60 (32)	2490.56 (62)	YES (P>0.0001)
Interpretation: Nitrate is significantly greater in makai wells.			
Ammonia-N	10.53	10.75	No
Total-N	3910.93	4271.17	YES (P>0.02)
Interpretation: Total nitrogen is significantly greater in makai wells.			
Ortho-P	195.81	182.48	YES (P>0.003)
Interpretation: Ortho-P is significantly greater in mauka wells.			
Total-P	292.55	290.07	No
Silica	26611.40	25444.40	No
Salinity	2.460	2.839	YES (P>0.0001)
Interpretation: Salinity is significantly greater in makai wells.			
C. All Dates: Are there significant differences between mauka to makai wells?			
Nitrate-N	2245.16 (34)	2490.71 (65)	YES (P>0.0001)
Interpretation: Nitrate is significantly greater in makai wells.			
Ammonia-N	10.01	10.58	No
Total-N	3968.41	4343.27	YES (P>0.03)
Interpretation: Total nitrogen is significantly greater in makai wells.			
Ortho-P	196.55	183.09	YES (P>0.002)
Interpretation: Ortho-P is significantly greater in mauka wells.			
Total-P	289.40	288.03	No
Silica	26641.78	25493.15	No
Salinity	2.440	2.847	YES (P>0.0001)
Interpretation: Salinity is significantly greater in the makai wells.			

TABLE 10. Continued.

Analyte	Preconstruction Means (n)	During Construction Means (n)	Significantly Different?
D. Mauka Wells: Are there significant differences between preconstruction to during construction means?			
Nitrate-N	2190.02 (2)	2248.60 (32)	No
Ammonia-N	1.66	10.53	No
Total-N	4888.03	3910.93	No
Ortho-P	208.49	195.81	No
Total-P	239.01	292.55	No
Silica	27127.93	26611.40	No
Salinity	2.131	2.460	No
E. Makai Wells: Are there significant differences between preconstruction to during construction means?			
Nitrate-N	2493.82 (3)	2490.56 (62)	No
Ammonia-N	7.02	10.75	No
Total-N	5833.19	4271.17	YES (P>0.02)
Interpretation: Preconstruction mean is significantly greater.			
Ortho-P	195.91	182.48	No
Total-P	245.93	290.07	No
Silica	26500.65	25444.40	No
Salinity	3.017	2.839	No

TABLE 11. Results of the Wilcoxon 2-Sample Test applied to the means of parameters from the pre-construction (n= 215 samples) and during construction (n= 600 samples) period at 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	10.16	YES	P > 0.0001
	Preconstruction mean significantly greater			
Ammonia N	1.67	2.36	YES	P > 0.0002
	During construction is significantly greater			
Total N	142.36	124.98	YES	P > 0.02
	Preconstruction mean significantly greater			
Ortho P	4.91	4.95	YES	P > 0.003
	Preconstruction mean significantly greater			
Total P	12.59	11.41	NO	
Silica	425.45	204.22	YES	P > 0.001
	Preconstruction mean significantly greater			
Salinity (o/oo)	34.299	34.711	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	0.231	NO	
Temp (°C)	26.4	26.0	NO	
Oxygen (% Sat)	99.9	100.2	NO	
pH (Units)	8.17	8.14	YES	P > 0.0001
	Preconstruction mean significantly greater			

TABLE 12. 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 arithmetic 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	14.508	B C
Aug-06	13.28	B C
Oct-07	12.06	B C
Oct-08	10.343	B C
Mar-06	10.07	B C
Mar-08	8.36	B C
Mar-05	7.18	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

Interpretation: Mean nitrate 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-93	2.46	F C D E
Jan-94	2.39	F D E
Jul-05	1.92	F G E
Aug-08	1.88	F G H E
Aug-06	1.88	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 I E
Oct-07	1.64	F G H I E
Mar-06	1.57	F G H I E
Dec-05	1.19	F 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-02	162.54	B C
Oct-08	150.58	C D
Jul-07	148.30	C D
Sep-04	137.27	D E
Oct-07	134.23	F D E
Aug-08	133.98	F D E
Aug-93	131.06	F D E
Aug-06	130.58	F D E
Nov-06	126.40	F G E
Mar-08	118.50	F G E
May-08	115.85	F G E
Dec-05	115.68	F G E
Mar-06	115.18	F G E
Nov-07	115.12	F G E
Jun-06	112.69	F G
Sep-05	107.80	G H
Mar-05	107.36	G H
Jul-05	92.85	H I
Jan-94	84.69	I

Interpretation: TN has no relationship to development; significantly greater concentration was found in one preconstruction period.

Orthophosphorus ($P > 0.0001$)

Date	Mean	
Apr-02	7.10	A
Apr-07	6.51	A B
Aug-06	6.28	A B C
Oct-08	6.21	A B C D
May-08	5.97	A B C D
Apr-98	5.85	B C D E
Aug-08	5.59	B C D E
Mar-06	5.26	F C D E
Aug-93	5.25	F C D E
Jul-07	5.16	F C D E
Mar-05	5.02	F C D E
Oct-07	4.93	F G D E
Jan-94	4.60	F G E
Jun-06	4.59	F G E
Nov-06	4.56	F G E
Mar-08	4.5286	F G E
Nov-07	4.12	F G H
Dec-05	3.72	G H
Sep-05	3.69	G H
Jul-05	3.13	H
Sep-04	1.55	I

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

TABLE 12. Continued.

Total Phosphorus ($P > 0.0001$)

Date	Mean	
Apr-98	18.93	A
Aug-06	14.11	B
Oct-08	13.86	B
Apr-07	13.74	B C
Aug-08	13.65	B C
Apr-02	12.94	B C D
May-08	12.92	B C D
Oct-07	12.80	B C D
Aug-93	12.54	B C D
Mar-08	12.41	B C D
Jul-07	11.88	C D E
Mar-05	11.57	D E
Nov-07	11.20	F G D E
Mar-06	10.46	F G H E
Jul-05	10.11	F G H I
Jan-94	9.61	G H I
Sep-04	9.19	H I J
Sep-05	8.92	H I J
Nov-06	8.66	I J
Jun-06	8.57	I J
Dec-05	7.78	J

Interpretation: Greatest mean concentration in baseline period. 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	285.2	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
Oct-08	176.52	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

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

Salinity ($P > 0.0001$)

Date	Mean	
Nov-07	34.931	A
Jan-94	34.909	A B
Dec-05	34.872	A B
Oct-07	34.867	A B
Sep-05	34.839	A B C
Mar-08	34.834	A B C
Nov-06	34.792	A B C D
Oct-08	34.773	A B C D
Jul-07	34.714	A B C D E
Sep-04	34.708	A B C D E
Aug-08	34.698	A B C D E
Mar-06	34.673	B C D E
Jul-05	34.631	C D E
Aug-06	34.626	C D E
May-08	34.586	D E
Jun-06	34.523	E
Mar-05	34.517	E
Apr-07	34.502	E
Apr-98	34.106	F
Apr-02	33.922	G
Aug-93	33.894	G

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 C
Dec-05	0.17	B C
May-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	C D E
Sep-05	0.12	C D E
Nov-06	0.11	D E
Jul-07	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
Apr-07	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 12. 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	
Apr-02	0.259	A	B	C	
Nov-06	0.250	A	B	C	
Jan-94	0.246	A	B	C	
Aug-06	0.245	A	B	C	
Aug-08	0.245	A	B	C	
Mar-06	0.239	A	B	C	D
Dec-05	0.23		B	C	D
Oct-08	0.215			C	D E
Jun-06	0.212			C	D E
Apr-07	0.207			C	D E
May-08	0.204			C	D E
Sep-05	0.201			C	D E
Sep-04	0.169	F			D E
Nov-07	0.148	F	G		E
Aug-93	0.128	F	G		
Mar-05	0.107		G		

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	D
Mar-06	100.5			C	D
Jul-05	100.2				D E
Mar-08	100.1		F		D E
Aug-08	100.1		F		D E
Aug-06	100.0		F		E
Jul-07	99.9		F		E
Apr-07	99.9		F		E
Jun-06	99.9		F		E
Sep-04	99.9		F	G	E
May-08	99.8		F	G	E
Nov-06	99.8		F	G	E
Nov-07	99.7		F	G	
Oct-07	99.4			G	

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 ($^{\circ}\text{C}$) $P > 0.0001$

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		
Apr-02	26.0		G		
Jun-06	25.7			H	
Mar-06	25.7			H	
Apr-07	25.5				I
May-08	25.5				I
Oct-08	25.3				I
Mar-08	25.1				J
Mar-05	24.9	K			
Jan-94	24.8	K			
Apr-98	24.8	K			
Dec-05	24.2		L		

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

pH (units) $P > 0.0001$

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

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

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, chlorophyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Anchialine Pool and Well Samples

Well 2	W	3044.82	2.74	4256.00	210.95	316.20	24704.92	1208.44	105.25	2.313	*	23.9	57	7.83	
Well 3	W	3374.70	2.35	4601.52	375.09	491.35	23302.10	1274.47	116.26	2.304	0.26	*	23.3	61	7.87
Well 4	W	2585.62	6.43	3752.14	224.01	341.93	-28201.70	1160.08	117.92	1.920	0.63	*	22.9	79	7.87
Well 5	W	2074.51	6.42	3473.34	191.36	300.08	24408.58	1392.61	108.72	2.053	0.20	*	23.4	65	7.89
Well 6	W	2589.62	3.81	3739.54	198.21	311.24	27564.99	1146.11	113.03	2.417	0.10	*	23.2	71	7.89
Pond 1	A	628.75	108.68	1664.46	300.65	421.29	26764.68	1277.03	120.64	3.049	0.30	0.117	24.1	76	7.53

APPENDIX 2. Summary of the water quality parameters as measured at 56 sites for the KaLaemano project on 8 May 2008. 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, chlorophyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transect	Site No.	DFS	Nitrate N	Ammonia N	Ortho P	TP	Si	TON	TOP	Salinity [‰]	Turbidity [NTU]	CHL-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	58.27	3.06	160.30	25.11	841.26	98.97	15.84	34.044	0.24	0.320	26.1	98	8.01
	2-S	10	95.47	3.34	190.82	35.34	1187.24	92.01	24.62	33.676	0.16	0.218	25.9	99	8.02
	3-B	10	8.79	1.79	111.58	10.54	267.11	101.00	4.37	34.690	0.19	0.274	25.8	99	8.03
	4-S	50	76.99	3.08	171.64	14.26	983.89	91.56	4.75	33.888	0.12	0.211	25.9	99	8.04
	5-B	50	5.09	1.40	103.32	5.18	9.92	212.60	96.83	34.745	0.11	0.194	25.9	99	8.05
	6-S	100	14.41	1.13	112.28	5.96	10.85	335.68	96.74	34.616	0.11	0.191	25.7	100	8.05
	7-B	100	3.25	1.00	98.42	4.96	9.61	225.27	94.17	34.761	0.22	0.205	25.7	99	8.07
	8-S	200	2.01	0.06	90.44	4.07	8.99	120.76	88.36	34.813	0.10	0.192	25.8	100	8.09
	9-S	300	1.40	0.20	90.16	4.07	8.99	113.38	88.55	34.811	0.12	0.191	25.6	100	8.10
	10-S	500	1.41	0.28	95.34	4.07	9.61	110.97	88.55	34.810	0.14	0.207	25.9	100	8.10
KL-B	11-S	0	58.69	3.74	161.84	8.53	44.33	729.24	99.42	34.133	0.13	0.279	25.1	100	8.05
	12-S	10	36.93	2.39	136.22	7.20	25.11	480.14	96.90	34.383	0.17	0.247	25.0	100	8.07
	13-B	10	13.90	2.74	119.00	6.30	11.78	268.34	102.37	34.654	0.15	0.253	25.0	99	8.07
	14-S	50	29.50	1.93	122.78	6.35	11.78	420.63	91.35	34.442	0.21	0.220	25.5	100	8.07
	15-B	50	7.69	1.66	106.82	5.30	10.54	186.25	97.47	34.717	0.11	0.220	25.5	99	8.08
	16-S	100	2.08	1.81	97.58	4.63	10.54	143.92	93.69	34.804	0.13	0.202	25.4	100	8.10
	17-B	100	2.09	0.46	92.82	4.18	9.61	101.58	90.27	34.803	0.11	0.170	25.5	100	8.11
	18-S	200	2.10	0.46	90.72	4.18	9.30	101.66	88.16	34.809	0.10	0.199	25.6	100	8.11
	19-S	300	2.11	1.22	97.02	5.42	12.40	114.23	93.70	34.806	0.16	0.286	25.4	100	8.09
	20-S	500	2.11	0.61	88.34	4.30	9.61	99.32	85.61	34.806	0.16	0.190	25.4	100	8.11
KL-C	21-S	0	140.50	3.94	233.38	23.56	1318.82	88.94	10.50	33.345	0.17	0.316	25.5	100	8.08
	22-S	10	53.50	3.34	153.16	13.02	591.87	96.32	4.45	34.206	0.11	0.218	25.3	100	8.08
	23-B	10	5.90	1.45	100.66	5.31	10.23	149.57	93.31	34.741	0.09	0.201	25.4	100	8.10
	24-S	50	39.78	2.67	137.06	8.24	13.02	497.25	94.61	34.322	0.09	0.206	25.8	100	8.07
	25-B	50	3.41	1.05	104.16	4.97	9.92	137.25	99.70	34.775	0.13	0.200	26.0	99	8.11
	26-S	100	6.56	1.26	104.72	5.20	10.23	182.38	96.90	34.736	0.07	0.189	25.6	100	8.09
	27-B	100	4.06	1.13	99.26	4.98	9.61	137.43	94.07	34.776	0.07	0.202	25.6	100	8.10
	28-S	200	6.58	1.82	101.78	5.20	9.92	167.56	93.38	34.741	0.10	0.213	25.8	100	8.09
	29-S	300	2.19	0.26	94.36	4.07	9.30	95.05	91.91	34.814	0.07	0.181	26.1	101	8.11
	30-S	500	2.20	0.47	95.48	4.19	15.19	97.64	92.81	34.808	0.07	0.194	25.6	101	8.12
KL-D	31-S	0	5.99	2.65	97.30	5.77	9.92	150.32	88.66	34.725	0.11	0.200	25.6	100	8.08
	32-S	10	19.23	3.88	131.88	7.13	11.47	325.80	108.77	34.513	0.12	0.220	25.2	100	8.07
	33-B	10	6.01	1.99	113.40	6.00	10.23	158.03	105.41	34.727	0.09	0.202	25.3	100	8.08
	34-S	50	10.43	2.60	112.56	6.34	10.85	220.79	99.52	34.631	0.10	0.181	25.5	100	8.07
	35-B	50	5.40	1.73	112.98	5.21	10.54	145.69	105.86	34.727	0.11	0.211	25.7	99	8.08
	36-S	100	2.25	0.51	92.54	4.19	9.61	100.64	89.78	34.777	0.08	0.152	25.2	100	8.10
	37-B	100	2.26	1.13	115.22	4.76	9.92	98.21	111.83	34.778	0.13	0.152	25.1	100	8.11
	38-S	200	3.53	1.34	98.14	5.10	9.61	125.89	93.27	34.759	0.13	0.169	25.4	100	8.11
	39-S	300	2.91	0.60	95.90	4.64	9.30	115.94	92.39	34.771	0.08	0.158	25.8	100	8.11
	40-S	500	2.28	0.60	97.16	4.30	15.19	95.94	94.27	34.793	0.08	0.143	25.7	100	8.12
KL-E	41-S	0	28.90	4.62	156.52	8.75	13.64	470.17	123.00	34.307	0.10	0.233	25.3	100	8.09
	42-S	10	34.62	3.20	146.44	8.52	13.64	545.69	108.62	34.210	0.12	0.242	25.9	100	8.08
	43-B	10	4.21	1.91	116.20	6.02	10.85	138.90	110.07	34.736	0.14	0.164	25.4	100	8.11
	44-S	50	21.99	2.06	123.20	7.50	13.02	422.94	99.15	34.422	0.08	0.226	25.1	99	8.08
	45-B	50	3.60	1.32	110.60	5.79	10.85	136.57	105.69	34.745	0.15	0.190	25.0	99	8.11
	46-S	100	4.88	0.98	109.76	5.33	10.85	176.88	103.90	34.057	0.10	0.153	24.9	100	8.11
	47-B	100	2.98	0.78	103.18	5.22	9.61	116.63	99.42	34.763	0.12	0.178	24.6	100	8.13
	48-S	200	2.99	1.27	103.60	4.99	9.30	114.20	99.34	34.768	0.15	0.165	24.7	100	8.13
	49-S	300	2.36	0.39	93.66	4.31	9.30	90.91	4.99	34.792	0.12	0.155	24.8	100	8.14
	50-S	500	3.01	0.80	100.66	4.31	16.12	86.69	11.81	34.804	0.08	0.134	24.8	101	8.14
Geometric Means															
			8.45	1.22	115.68	5.89	12.79	228.47	6.49	34.516	0.11	0.201	25.5	100	8.09
Anchialine Pool and Well Samples															
Well 1	W	2969.42	14.53	3791.90	153.34	209.87	28056.14	807.95	56.53	3.439	2.20	*	24.3	67	7.85
Well 2	W	1970.78	1.09	2219.01	242.80	285.20	22933.51	247.14	42.40	1.938	0.92	*	25.2	71	8.00
Well 3	W	3164.08	0.00	4043.76	272.33	319.30	25414.75	879.68	46.97	2.513	0.83	*	24.4	75	7.94
Well 4	W	2903.87	0.00	3492.30	239.24	306.90	28481.33	588.43	67.66	1.901	0.91	*	24.1	77	7.94
Well 5	W	2118.89	0.00	3091.34	204.82	262.57	25122.27	972.45	57.75	2.122	0.43	*	24.3	77	7.84
Well 6	W	2623.65	0.00	3502.10	192.12	285.82	28162.42	878.45	93.70	2.452	0.11	*	24.2	79	7.86
Pond 1	A	846.61	53.17	1835.54	191.38	240.87	28290.51	935.76	49.49	3.194	0.41	0.429	25.3	81	7.48

APPENDIX 3. Summary of the water quality parameters as measured at 56 sites for the KaLaMaMo project on 26 August 2008. 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, chlorophyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transsect	Site No.	DFS	Nitrate	Ammonia	TDN	Ortho P	TDP	Si	TON	TOP	Salinity	Turbidity	CHL-a	Temp.	Oxygen	pH
			[m]	N							[‰]	[NTU]		[°C]	[%]	
KL-A	1-S	0	17.33	3.47	131.32	5.72	12.71	240.18	110.52	6.99	34.653	0.27	0.355	26.4	99	8.05
	2-S	10	38.29	2.99	148.68	6.27	13.64	477.50	107.40	7.37	34.389	0.31	0.261	26.5	100	8.09
	3-B	10	13.73	3.06	147.28	4.98	12.40	203.49	130.49	7.42	34.745	0.20	0.271	26.5	100	8.11
	4-S	50	31.75	2.46	133.98	5.77	13.33	440.55	99.77	7.56	34.485	0.15	0.238	26.4	100	8.11
	5-B	50	9.17	1.75	122.08	4.14	12.09	117.55	111.16	7.95	34.802	0.14	0.330	26.5	100	8.12
	6-S	100	21.80	2.29	138.04	5.04	12.71	268.09	113.95	7.67	34.617	0.12	0.239	26.5	100	8.11
	7-B	100	6.61	0.57	103.46	3.76	11.47	90.77	96.28	7.71	34.824	0.17	0.155	26.7	100	8.13
	8-S	200	24.12	1.76	130.06	5.01	13.02	288.01	104.18	8.01	34.603	0.12	0.225	26.6	100	8.12
	9-S	300	16.74	2.90	128.80	4.88	13.64	214.23	109.16	8.76	34.690	0.12	0.246	26.6	100	8.12
	10-S	500	8.88	0.64	115.50	3.83	12.40	165.12	105.98	8.57	34.785	0.14	0.215	26.7	101	8.13
KL-B	11-S	0	47.82	4.03	166.74	6.67	14.88	487.60	114.89	8.21	34.335	0.16	0.416	26.7	100	8.13
	12-S	10	30.70	4.09	137.48	5.40	13.33	337.58	102.69	7.93	34.512	0.15	0.261	26.5	100	8.13
	13-B	10	6.77	2.31	118.16	4.13	12.71	91.79	109.08	8.38	34.841	0.22	0.275	26.4	100	8.13
	14-S	50	25.21	3.32	138.18	2.86	13.33	288.91	109.64	10.47	34.601	0.12	0.237	26.5	100	8.13
	15-B	50	6.17	1.13	122.22	2.73	12.40	82.30	114.92	9.67	34.831	0.11	0.209	26.5	100	8.14
	16-S	100	10.49	1.13	121.52	3.62	12.09	143.87	109.89	8.47	34.745	0.13	0.220	26.8	100	8.14
	17-B	100	3.14	0.37	162.82	3.15	12.71	77.74	159.32	9.56	34.835	0.08	0.142	26.5	100	8.15
	18-S	200	10.38	1.02	122.22	3.36	12.71	146.62	110.82	9.35	34.743	0.08	0.221	26.9	101	8.14
	19-S	300	10.32	1.80	130.20	3.81	17.98	146.77	118.08	14.17	34.755	0.13	0.247	26.8	101	8.14
	20-S	500	3.46	0.08	111.58	3.45	13.02	73.36	108.04	9.57	34.833	0.15	0.221	26.6	101	8.16
KL-C	21-S	0	61.66	4.58	175.56	8.22	17.36	671.55	109.32	9.14	34.110	0.13	0.320	26.4	100	8.14
	22-S	10	30.01	2.87	136.22	6.83	14.26	318.81	103.34	7.43	34.525	0.12	0.218	26.4	99	8.12
	23-B	10	5.18	0.51	108.22	4.87	12.40	74.06	102.53	7.53	34.833	0.10	0.198	26.2	99	8.15
	24-S	50	15.81	2.40	143.64	6.00	13.33	221.08	125.43	7.33	34.692	0.07	0.228	26.4	100	8.13
	25-B	50	water sample lost													
	26-S	100	20.12	2.64	148.96	6.90	16.74	341.07	126.20	9.84	34.656	0.10	0.223	26.6	100	8.13
	27-B	100	5.50	0.58	114.38	4.94	13.02	99.04	108.30	8.08	34.817	0.08	0.161	26.4	100	8.15
	28-S	200	15.63	0.82	122.36	6.41	13.33	194.54	105.90	6.92	34.699	0.09	0.188	26.4	101	8.14
	29-S	300	5.39	0.36	114.38	5.25	13.33	121.37	108.63	8.08	34.804	0.09	0.210	26.4	101	8.15
	30-S	500	3.39	0.01	107.66	4.89	12.09	75.11	104.26	7.20	34.829	0.06	0.172	26.5	101	8.16
KL-D	31-S	0	10.13	3.95	128.38	6.14	13.95	136.33	114.31	7.81	34.777	0.15	0.203	26.2	100	8.12
	32-S	10	12.49	3.48	174.44	6.81	13.64	165.77	158.47	6.83	34.735	0.10	0.192	26.4	99	8.10
	33-B	10	6.14	1.84	123.06	6.22	13.33	90.27	115.08	7.11	34.820	0.10	0.245	26.6	99	8.12
	34-S	50	9.96	1.90	114.38	6.43	13.02	131.90	102.52	6.59	34.766	0.14	0.206	27.3	99	8.12
	35-B	50	4.09	0.55	108.36	5.62	13.02	71.11	103.72	7.40	34.839	0.07	0.161	27.1	100	8.14
	36-S	100	10.33	1.26	115.78	6.29	13.33	171.20	104.19	7.04	34.720	0.09	0.273	26.7	100	8.15
	37-B	100	4.46	0.62	169.12	5.70	13.33	98.25	164.04	7.63	34.822	0.13	0.207	26.6	100	8.16
	38-S	200	9.25	1.09	116.48	6.14	13.33	147.12	106.14	7.19	34.757	0.09	0.265	26.8	100	8.15
	39-S	300	10.16	1.33	127.82	6.70	14.57	342.00	116.33	7.87	34.723	0.09	0.273	27.0	101	8.14
	40-S	500	8.65	1.63	135.80	6.69	15.81	704.63	125.52	9.12	34.759	0.12	0.268	27.3	101	8.14
KL-E	41-S	0	9.56	4.26	149.80	6.90	13.64	193.77	135.98	6.74	34.722	0.13	0.287	26.2	100	8.13
	42-S	10	27.88	3.56	262.50	8.49	16.74	376.25	231.07	8.25	34.443	0.13	0.276	26.1	100	8.13
	43-B	10	5.58	1.23	133.84	6.64	13.64	111.39	127.03	7.00	34.798	0.12	0.312	26.0	99	8.15
	44-S	50	22.92	2.39	142.52	8.23	15.81	337.49	117.20	7.58	34.506	0.10	0.285	26.0	100	8.14
	45-B	50	4.99	1.35	123.90	6.61	13.64	102.00	117.56	7.03	34.813	0.11	0.352	26.2	99	8.15
	46-S	100	18.94	1.76	145.88	7.40	14.57	293.94	125.18	7.17	34.569	0.10	0.298	26.0	100	8.14
	47-B	100	4.40	1.30	138.60	6.00	13.64	107.18	132.90	7.64	34.810	0.11	0.208	26.1	100	8.15
	48-S	200	11.58	0.95	117.32	6.10	13.95	197.09	104.79	7.85	34.683	0.09	0.277	26.1	100	8.14
	49-S	300	9.11	0.96	114.66	6.09	13.64	155.99	104.59	7.55	34.740	0.11	0.303	26.0	101	8.14
	50-S	500	4.72	0.73	120.68	5.84	13.64	122.20	115.24	7.80	34.790	0.10	0.304	26.2	101	8.08
Geometric Means			14.25	1.49	134.16	5.66	13.90	224.47	114.72	8.03	34.650	0.12	0.249	26.5	100	8.13

Anchialine Pool and Well Samples

Well 1	W	2826.20	2.06	3926.58	172.80	209.56	26713.40	1098.32	36.76	3.417	9.80	*	24.1	72	7.93
Well 2	W	2905.02	0.00	4079.88	197.21	234.05	25389.73	1174.86	36.84	2.620	1.33	*	24.7	70	8.00
Well 3	W	2861.59	0.00	4013.24	242.27	287.68	25241.59	1151.65	45.41	2.615	1.42	*	24.0	79	8.01
Well 4	W	2617.94	0.00	3799.88	215.26	254.51	27754.10	1181.94	39.25	1.897	0.30	*	23.9	80	8.02
Well 5	W	2157.68	40.19	3386.60	226.90	272.49	28107.82	1188.73	45.59	2.248	0.22	*	24.0	77	7.96
Well 6	W	2664.86	0.00	3839.92	199.80	243.35	27080.80	1175.06	43.55	2.433	0.09	*	23.8	78	7.93
Pond 1	A	437.94	46.54	3060.12	228.46	524.21	13201.29	2575.64	295.75	3.095	0.31	1.690	25.2	80	7.65

APPENDIX 4. Summary of the water quality parameters as measured at 56 sites for the Kalaheo project on 24 October 2008. 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, chlorophyll-a and turbidity for surface samples. All values are in ug/l unless indicated; ND = below limits of detection.

Transsect	Site No.	DFS	Nitrate N	Ammonia N	TDN	Ortho P	TDP	Si	TON	TOP	Salinity [‰]	Turbidity [NTU]	Chl-a	Temp. [°C]	Oxygen [%]	pH
KL-A	1-S	0	62.47	13.21	222.74	10.85	17.22	898.24	147.06	8.37	34.020	0.63	0.542	25.4	100	8.03
	2-S	10	56.76	6.16	208.46	10.95	19.98	815.41	145.54	7.03	34.082	0.24	0.408	25.5	100	8.06
	3-B	10	33.95	8.47	169.96	9.50	16.74	466.56	127.54	7.24	34.412	0.18	0.468	25.6	100	8.07
	4-S	50	43.08	6.91	208.32	9.84	17.98	565.33	158.34	8.14	34.302	0.33	0.266	25.3	100	8.08
	5-B	50	10.61	4.97	165.06	7.55	14.57	166.12	149.48	7.02	34.774	0.14	0.241	25.5	100	8.10
	6-S	100	4.39	10.21	172.62	5.72	15.50	93.19	158.02	9.78	34.853	0.08	0.167	25.8	101	8.12
	7-B	100	3.83	5.09	137.06	5.95	13.33	80.91	128.13	7.38	34.857	0.14	0.185	25.8	100	8.13
	8-S	200	1.03	2.28	123.48	5.57	12.71	53.97	120.17	7.14	34.872	0.06	0.150	25.5	100	8.15
	9-S	300	2.75	2.59	131.04	5.56	13.02	58.60	125.70	7.46	34.869	0.07	0.155	25.6	101	8.15
	10-S	500	1.64	5.53	126.28	5.53	13.33	56.00	119.12	7.78	34.873	0.06	0.195	25.4	102	8.15
KL-B	11-S	0	21.52	5.59	154.56	8.65	16.43	349.69	127.45	7.78	34.574	0.28	0.563	25.7	101	8.14
	12-S	10	20.97	9.46	149.66	7.92	15.19	322.89	119.23	7.27	34.597	0.21	0.302	25.5	100	8.12
	13-B	10	11.34	8.34	143.08	6.71	14.88	199.83	123.41	8.17	34.734	0.17	0.277	25.4	100	8.12
	14-S	50	11.92	6.59	143.08	6.82	14.26	199.58	124.57	7.44	34.725	0.12	0.189	25.5	100	8.11
	15-B	50	5.13	8.21	140.56	6.33	14.26	98.32	127.21	7.93	34.846	0.08	0.180	26.0	100	8.13
	16-S	100	3.45	9.46	136.36	5.36	13.64	98.11	123.45	8.28	34.889	0.08	0.176	25.9	101	8.14
	17-B	100	2.34	4.77	165.90	5.23	14.26	71.47	158.79	9.03	34.874	0.07	0.164	25.8	100	8.15
	18-S	200	2.36	1.89	142.10	5.34	13.02	95.28	137.85	7.68	34.888	0.06	0.153	25.7	101	8.16
	19-S	300	2.38	0.70	142.10	5.45	12.71	51.86	139.02	7.26	34.872	0.05	0.145	26.1	101	8.16
	20-S	500	2.40	1.20	149.66	5.20	13.02	102.07	146.06	7.82	34.877	0.05	0.113	25.8	102	8.16
KL-C	21-S	0	57.24	22.04	135.38	9.00	13.95	674.73	56.09	4.95	34.103	0.14	0.446	24.9	100	8.15
	22-S	10	10.36	14.03	148.82	5.41	14.26	118.21	124.43	8.85	34.802	0.16	0.229	25.4	100	8.15
	23-B	10	7.57	5.14	160.58	6.46	13.95	110.59	147.87	7.49	34.808	0.17	0.252	25.3	100	8.16
	24-S	50	5.33	2.13	148.68	6.33	13.64	91.61	141.22	7.31	34.842	0.19	0.195	25.1	100	8.16
	25-B	50	4.78	0.00	133.28	6.20	13.02	69.48	128.50	6.82	34.869	0.06	0.174	25.1	100	8.16
	26-S	100	3.11	6.14	136.08	5.11	13.02	69.28	126.83	7.91	34.874	0.06	0.171	25.3	100	8.17
	27-B	100	3.13	2.50	143.08	5.46	13.02	71.47	137.45	7.56	34.876	0.07	0.170	25.2	100	8.17
	28-S	200	2.58	1.50	123.48	5.21	12.40	59.32	119.40	7.19	34.875	0.06	0.183	25.1	101	8.17
	29-S	300	3.73	1.62	141.12	6.86	16.12	926.26	135.77	9.26	34.882	0.06	0.201	25.2	101	8.17
	30-S	500	3.18	0.87	133.42	5.43	12.71	92.37	129.37	7.28	34.882	0.07	0.185	25.3	101	8.17
KL-D	31-S	0	6.58	12.15	154.00	5.30	13.33	89.77	135.27	8.03	34.851	0.12	0.167	25.5	101	8.14
	32-S	10	6.59	4.32	146.30	6.36	13.64	139.67	135.39	7.28	34.834	0.19	0.152	25.0	100	8.13
	33-B	10	6.61	3.50	136.78	6.46	12.71	89.36	126.67	6.25	34.840	0.16	0.205	25.5	100	8.13
	34-S	50	4.94	4.44	133.70	6.10	13.33	91.54	124.32	7.23	34.851	0.12	0.145	25.2	100	8.13
	35-B	50	4.96	11.90	164.92	5.49	13.02	67.50	148.06	7.53	34.860	0.12	0.136	25.4	100	8.14
	36-S	100	3.29	3.94	147.14	5.01	12.40	53.01	139.91	7.19	34.869	0.08	0.157	25.4	101	8.16
	37-B	100	3.31	2.99	128.66	5.23	12.40	59.97	122.35	7.17	34.873	0.16	0.165	25.3	100	8.17
	38-S	200	3.89	2.12	138.20	5.11	13.02	66.91	132.19	7.91	34.868	0.07	0.176	25.5	101	8.16
	39-S	300	2.79	0.86	135.10	5.21	12.40	57.20	131.45	7.19	34.873	0.07	0.157	25.2	101	8.17
	40-S	500	2.25	2.55	141.54	5.08	13.33	52.25	136.74	8.25	34.878	0.08	0.170	25.1	102	8.18
KL-E	41-S	0	10.67	6.69	179.90	6.49	14.26	128.12	162.54	7.77	34.795	0.23	0.236	24.8	100	8.14
	42-S	10	14.04	6.94	136.64	7.31	13.95	180.16	115.65	6.64	34.723	0.2	0.253	24.8	100	8.13
	43-B	10	10.70	6.25	155.72	6.23	13.64	122.92	136.77	7.41	34.815	0.11	0.182	24.8	100	8.13
	44-S	50	5.12	11.28	154.84	4.81	13.33	68.11	138.44	8.32	34.868	0.14	0.150	24.8	100	8.15
	45-B	50	5.14	12.97	167.16	5.03	13.33	67.91	149.05	8.30	34.884	0.15	0.153	25.0	100	8.16
	46-S	100	4.04	3.17	170.52	5.14	12.40	65.35	163.31	7.26	34.870	0.16	0.184	25.2	101	8.16
	47-B	100	4.05	8.20	170.52	4.30	12.71	67.52	158.27	8.41	34.891	0.12	0.186	24.9	100	8.17
	48-S	200	4.63	13.73	170.38	4.41	13.95	91.02	152.02	9.54	34.873	0.11	0.193	25.0	101	8.17
	49-S	300	4.65	3.99	127.12	5.11	12.09	81.34	118.48	6.98	34.873	0.09	0.187	24.9	102	8.17
	50-S	500	3.55	1.98	115.92	4.98	11.78	57.46	110.39	6.80	34.869	0.05	0.150	25.0	102	8.17
Geometric Means			5.90	4.20	148.24	6.06	13.83	122.03	130.83	7.63	34.755	0.11	0.200	25.3	101	8.14
Well Samples	Well 1	W	3055.75	5.78	5322.66	157.32	214.52	25569.17	2261.13	57.20	3.251	2.0	*	24.7	75	8.18
	Well 2	W	2987.76	12.57	5292.28	185.41	233.74	25826.60	2291.95	48.33	2.677	0.25	*	25.2	77	8.19
	Well 3	W	2973.24	9.54	5439.28	223.34	288.61	25715.40	2456.50	65.27	2.685	0.31	*	24.8	75	8.18
	Well 4	W	2755.17	6.14	4918.20	218.97	288.30	27941.24	2156.90	69.33	1.895	10.7	*	24.4	73	8.12
	Well 5	W	2100.45	5.37	4473.98	213.90	269.70	26087.85	2168.16	55.80	2.300	0.42	*	25.0	69	8.05
	Well 6	W	1486.02	43.50	5064.36	268.66	400.21	8754.50	3334.84	131.55	2.356	5.5	*	26.1	60	8.46
Pond 1	A		335.88	52.20	2817.36	264.18	312.79	27580.09	2429.28	48.61	2.992	0.35	0.232	26.2	81	7.77

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).

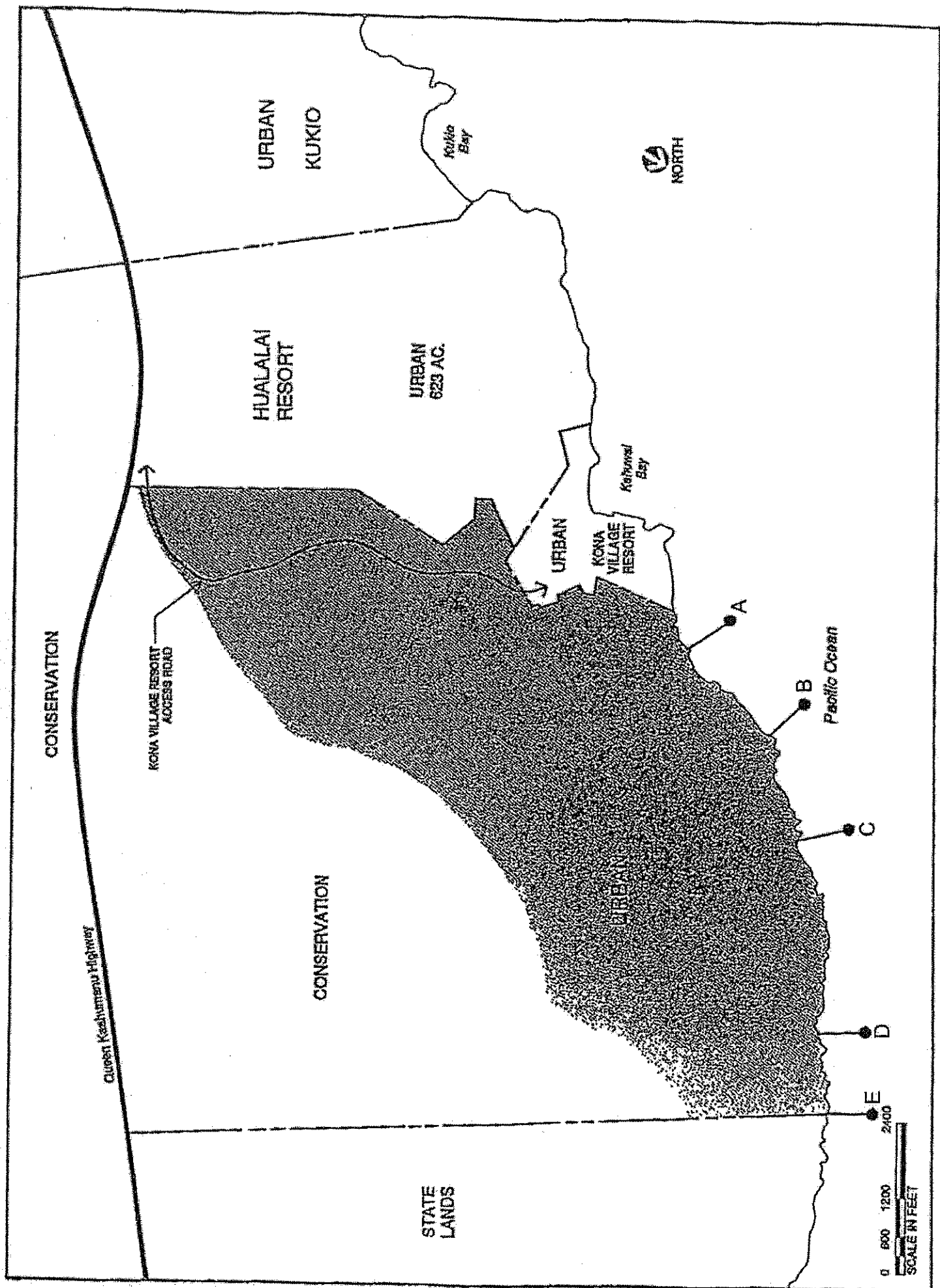


FIGURE 2. Map showing the first phase of the development at Ka Lae Mano with roads and residential lots (under construction). Also shown are the five coastal monitoring wells (1 through 5) along with a dust control well (site 6) and anchialine pool. Map courtesy of W.B. Kukio, LLC.

